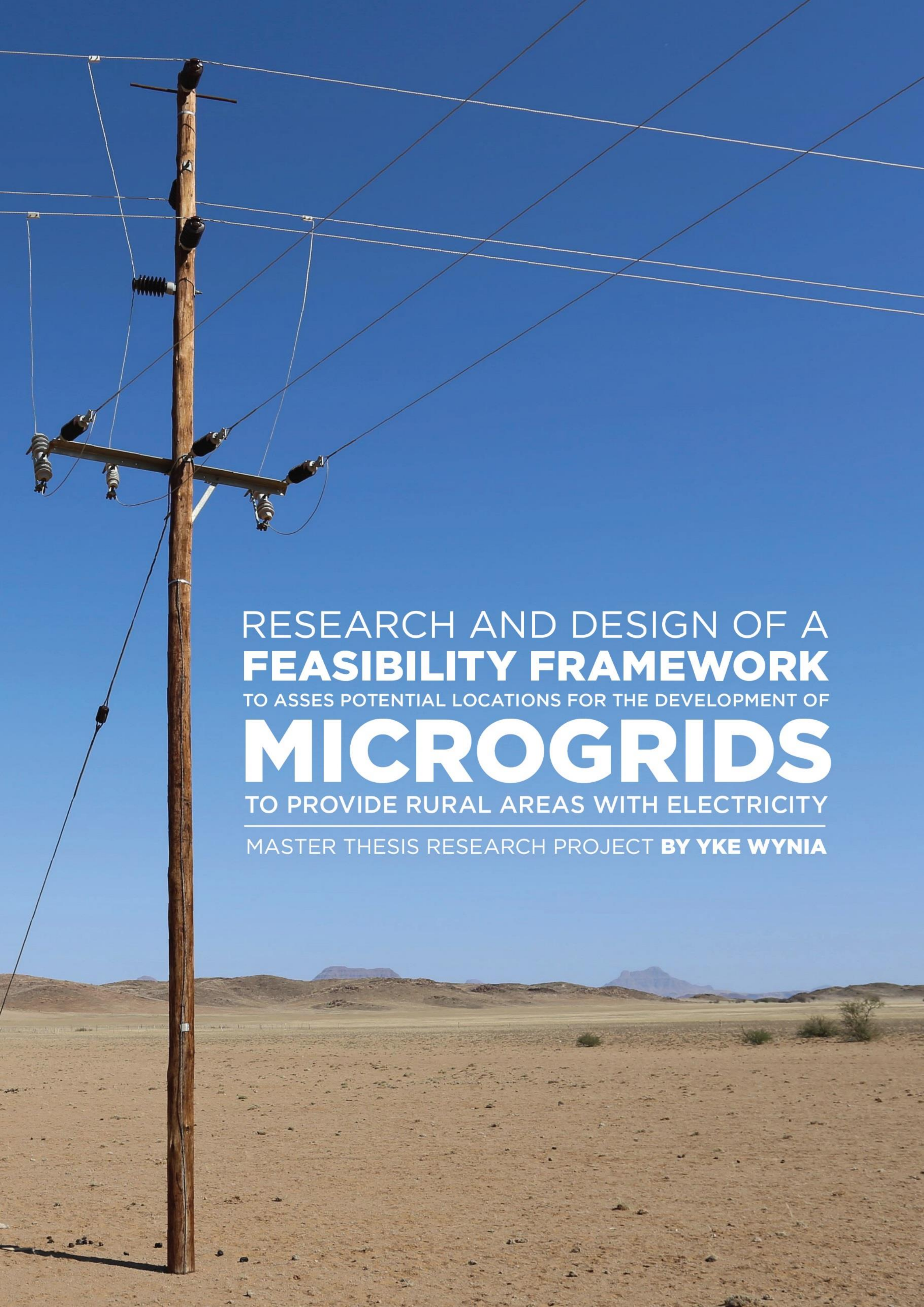

RESEARCH AND DESIGN OF A **FEASIBILITY FRAMEWORK** TO ASSES POTENTIAL LOCATIONS FOR THE DEVELOPMENT OF **MICROGRIDS** TO PROVIDE RURAL AREAS WITH ELECTRICITY

MASTER THESIS RESEARCH PROJECT **BY YKE WYNIA**

Research and design of a feasibility framework to assess potential locations for the development of microgrids to provide rural areas with electricity

In partial fulfilment of the requirements for the degree of
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in Systems Engineering, Policy Analysis and Management

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PREFACE AND ACKNOWLEDGEMENTS

This master thesis research project is the final piece of my academic career. With this project I will finish my Master in Systems Engineering, Policy Analysis and Management at the Delft University of Technology. I am very proud of the report that you are about to read. I believe a lot of the knowledge and skills that I have learned over the course of my time at the Faculty of Technology, Policy and Management has come together in this research project. When reading my final masterpiece, I hope you will be able to find all the energy I have put into it.

Although there is a lot of me in this thesis, I could not have completed it without the help of quite a few people, whom I would like to thank.

I would like to thank Stephen Cook for giving me the opportunity to perform my research as part of the Energy, Cities and Climate Change Consulting team of Arup, London. I would like to thank Maria Brucoli, my supervisor at Arup, for her advice on my research and for getting me in contact with the right people. And I want to thank all my colleagues at Arup for assisting me wherever they could and for the regular stress-relieving Friday afternoon drinks.

I would like to thank my graduation committee, consisting of Paulien Herder, Geerten van de Kaa and Émile Chappin, for their valuable feedback and for their flexibility regarding my London-situation. I especially want to thank my first supervisor Émile for the time he took to have frequent Skype-meetings with me, for his attention to detail and for his words of encouragement whenever I was stuck and did not know what to do.

I would like to thank my boyfriend Niels for not getting tired of my stories about rural electrification and microgrids, for cheering me on whenever I needed it and for his designer-eye in the shaping of my report. I would like to thank my friends for giving me advice, as most of them went through this same experience already. And I would like to thank my mother, father, sister and brother for being there for me and giving me positive energy.

Finally, I would like to dedicate this final piece of my academic career to my grandparents, who will be there when I graduate, either in person or in thought.

Yke Wynia
London, June 2016

SUMMARY

Today 19% of the global population has no access to electricity. Most of these people live in rural areas. These 1,4 billion people would benefit from electricity access for five reasons: their health, education, local economy, sense of safety and communication will benefit.

This thesis focuses on off-grid microgrids, with no extension to a main grid. It targets areas where there is no access to electricity yet and that are so remote that a grid extension is at this point not considered viable. Therefore an off-grid solution like a microgrid will be a good solution. We will look to expand the currently available sources of energy with electricity from renewable sources.

Public and private parties that want to realize rural electrification want to make an informed decision about where to start their electrification efforts. They want to know what location is feasible for the development of a microgrid. Such a public-private partnership wants to be able to assess the feasibility of a possible microgrid location before it starts development.

Therefore the main research question we want to answer is: **How can public and private parties, which aim for the electrification of rural areas, assess the feasibility of a location for the development of a microgrid?** To answer this main research question we will find the answers to three research questions.

1. Which subject areas are dominant and which concepts are most frequent in studies on rural electrification?
It can be concluded from the content analysis that the scientific publishing on rural electrification has increased significantly. Over the last 26 years, since rural electrification was first mentioned in a journal, 434 academic papers have been written about the subject. Just a bit less than half of those were published in the last 4 years, between 2012 and 2015. Because many of these papers cover case studies, it is concluded that rural electrification has gained interest in the real world too.

The subject areas that are dominant in studies on rural electrification are, in order of importance: technology, institutional, user-centric and viability. To which we have added two emerging categories: environmental and frugal. The environmental category is added as we focus on renewable technologies. The frugal category is added because frugal innovation links technology with local circumstances and cultures of people in low-income communities, who often live in rural areas.

An overview of 125 concepts that are most frequent in studies on rural electrification is obtained, divided over the six categories. Both the key concepts found in the word-frequency count and the two additional categories, will be taken forward in answering the next two research questions.

2. Which factors play a role in the development of rural electrification projects?
The deepening and broadening literature research has been a fruitful exercise in finding factors that play a role in the development of rural electrification projects. The 99 factors that are found will give us new and different ways of looking at microgrid feasibility. This in addition to the 58 criteria that were formulated based on the concepts recovered with the content analysis.

There are also steps made in making the criteria useful in the assessment of potential microgrid developments. It should be said that measuring criteria is not always a straightforward process, in the way that there are often more than one way of looking at a criterion. In the case of the factor-based criteria, we have always used the original source of the factor as input for assigning a unit or question to evaluate that criterion.

In conclusion we can say that the deepening and broadening literature research has brought additional insights to rural electrification. And it has helped in getting the criteria ready for their assessment in search for the most feasible microgrid locations. This research step has built a solid foundation to answer the final research question.

3. How can we measure the feasibility of a location for the development of a microgrid?
After evaluating the input of the experts, 15 criteria were selected as having the most effect on the feasibility of a potential microgrid development. It was noticed that financial criteria play an important role in the assessment of feasibility. It was also made clear that a low score on a few of the 15 criteria does not mean that rural electrification through microgrids is unattainable. No, the project partners should use that result to improve the location where this is necessary. Or, when they are uncertain about the feasibility of the targeted location, they could perform a second check to gain more certainty. For this the project partners can use an additional 13 and 50 criteria, that were judged to be of slightly less importance, but were still scored relatively high by the experts.

The two test cases helped us to answer the third research question. We were able to evaluate and improve the feasibility framework, whilst demonstrating the way of measuring the criteria and interpreting the effects.

After a content analysis, a word-frequency count analysis, a broadening and deepening literature research, an expert review and two test cases, we are able to answer the main research question with: by using the feasibility framework. Where this framework is build up out of the following 15 criteria:

- Availability of sunlight
- Length of extension needed when connected to existing electricity grid
- Availability of subsidies for electrification projects
- Long term demand for the project
- Political support
- Willingness to pay for electricity
- Number of potential users in potential microgrid location
- Consumer's ability to pay for electricity
- Appropriate payment opportunities offered to consumers
- Operation and maintenance cost of rural electrification project
- Adequate business models
- Understanding the customers' needs
- Willingness of private party to invest in rural electrification project
- Capital cost of rural electrification project
- Willingness of public party to invest in rural electrification project

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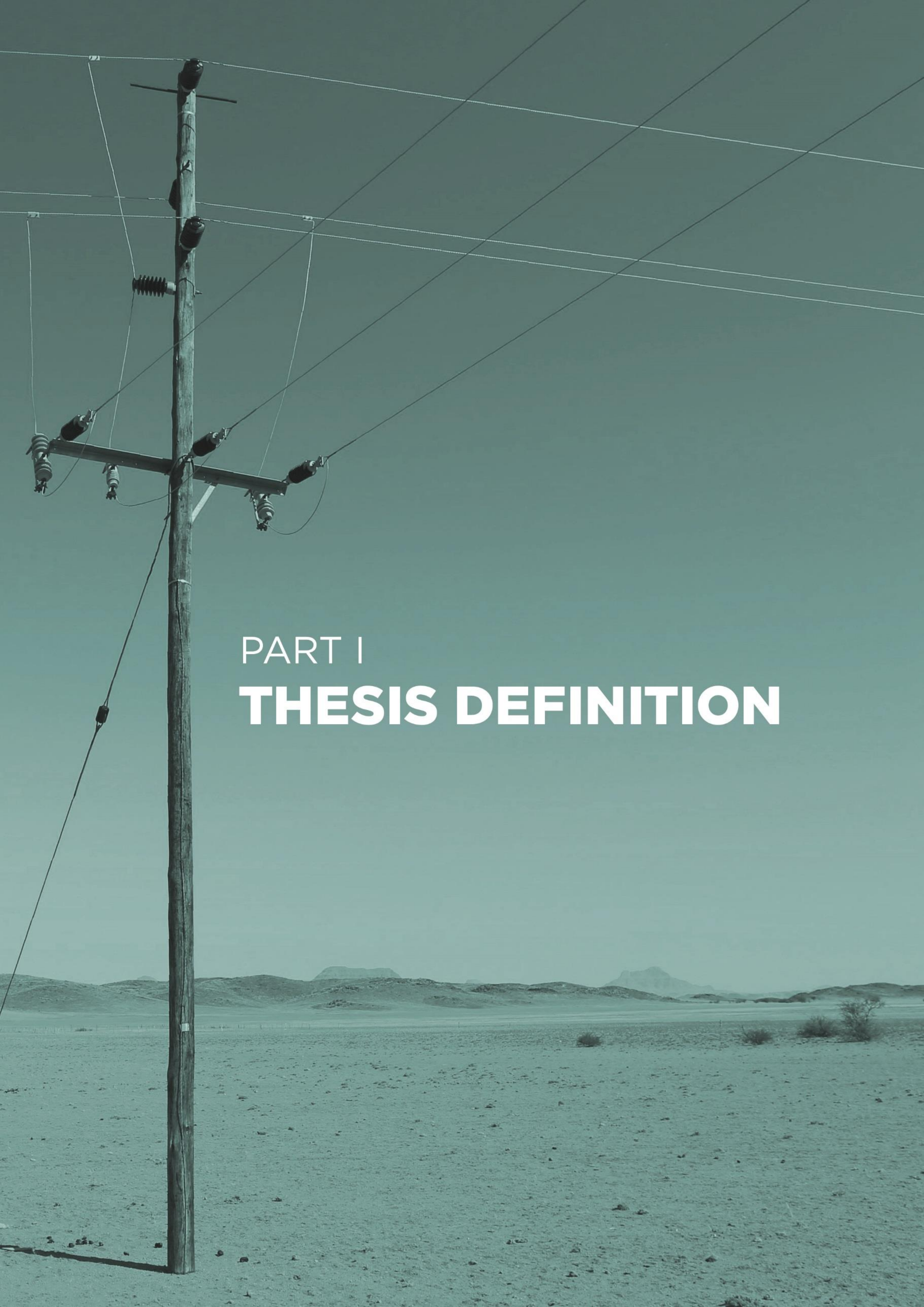
LIST OF ABBREVIATIONS

BOO	build-own-operate
BOP	bottom of the pyramid
BOT	build-operate-transfer
(B)REP	(Bangladesh) Rural Electrification Program
DESCO	Dhaka Electric Supply Company
EGCB	Electricity Generation Company of Bangladesh Ltd.
EIA	Energy Information Administration (of the United States)
ESCOM	Electricity Supply Commission of Malawi
FSA	Financial Services Authority
GENI	Global Energy Network Institute
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development (specialized agency of the UN)
IISD	International Institute for Sustainable Development
IMF	International Monetary Fund
LCOE	levelized cost of energy
LED	light-emitting diode
MAREP	Malawi Rural Electrification Project
MEGA	Mulanje Electricity Generation Agency
MK	Malawian Kwacha (currency of Malawi)
MNC	Multinational Corporation
MOEM	Ministry of Energy and Mining
NGO	non-governmental organisation
NO_x	all binary compounds of nitrogen and oxygen
OECD	Organisation for Economic Co-operation and Development
PPP	public-private partnership
PSRB	Power Sector Reforms in Bangladesh
PV	photovoltaic
R&D	research and development
RERED	Rural Electrification and Renewable Energy Development
RVG	renewable energy based village grid
SHP	small hydropower
SHS	solar home system
SME	small and medium-sized enterprises
TOT	transfer-operate-transfer
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency of International Development
WHO	World Health Organisation



PART I
THESIS DEFINITION

1. INTRODUCTION

This chapter explains the potential benefits of bringing electricity to rural areas. Next, the advantages of using a renewables based, off-grid microgrid in rural electrification will be explained. Fourthly, the efforts of governmental parties considering rural electrification will be illustrated. The potential and challenges of public and private parties working together on microgrid projects are discussed. Finally, the structure of the thesis report will be set out.

1.1 Benefits of electrifying rural areas

Today 19% of the global population has no access to electricity. The majority of this part of the population lives in rural areas of non-OECD countries (Schmidt et al., 2013). If those 1.4 billion people would have access to electricity, it would benefit them in five ways (Hopper, 2011):

- Their health will benefit. Today kerosene is the most used carrier of energy, which causes indoor air pollution and is a fire hazard. Access to electricity would change this.
- Education will benefit. With access to electricity people would be able to light their homes. Currently it is hard to study after the sun sets if you have no lighting.
- The local economy will benefit in three ways. People would not have to buy kerosene, candles and batteries anymore. This will save people money, as lighting from electricity if more efficient (King, 2013). For Nigeria it is estimated that using solar energy instead of kerosene and candles could save households US$66 a year (UNEP & en.lighten, 2013). Second, working hours can be extended when communities will be able to light their workspaces. Third, building and maintaining an electricity grid creates new jobs. Access to electricity will also give the opportunity of automating processes.
- The sense of safety will grow. As lighting would not only be used inside, but could also be used to light the streets. By doing so people will feel more save outside.
- Communication will benefit. People will have access to power to charge their mobile phones. And they will be able to listen to the radio, which is often their main source of information.

The direct and indirect effects of access to electricity, with their resulting benefits, are visualised in Figure 1. In that figure the benefits are linked to the associated UN Millennium Development Goals (UN, 2015): electrification of rural areas will help reach five of the eight goals.

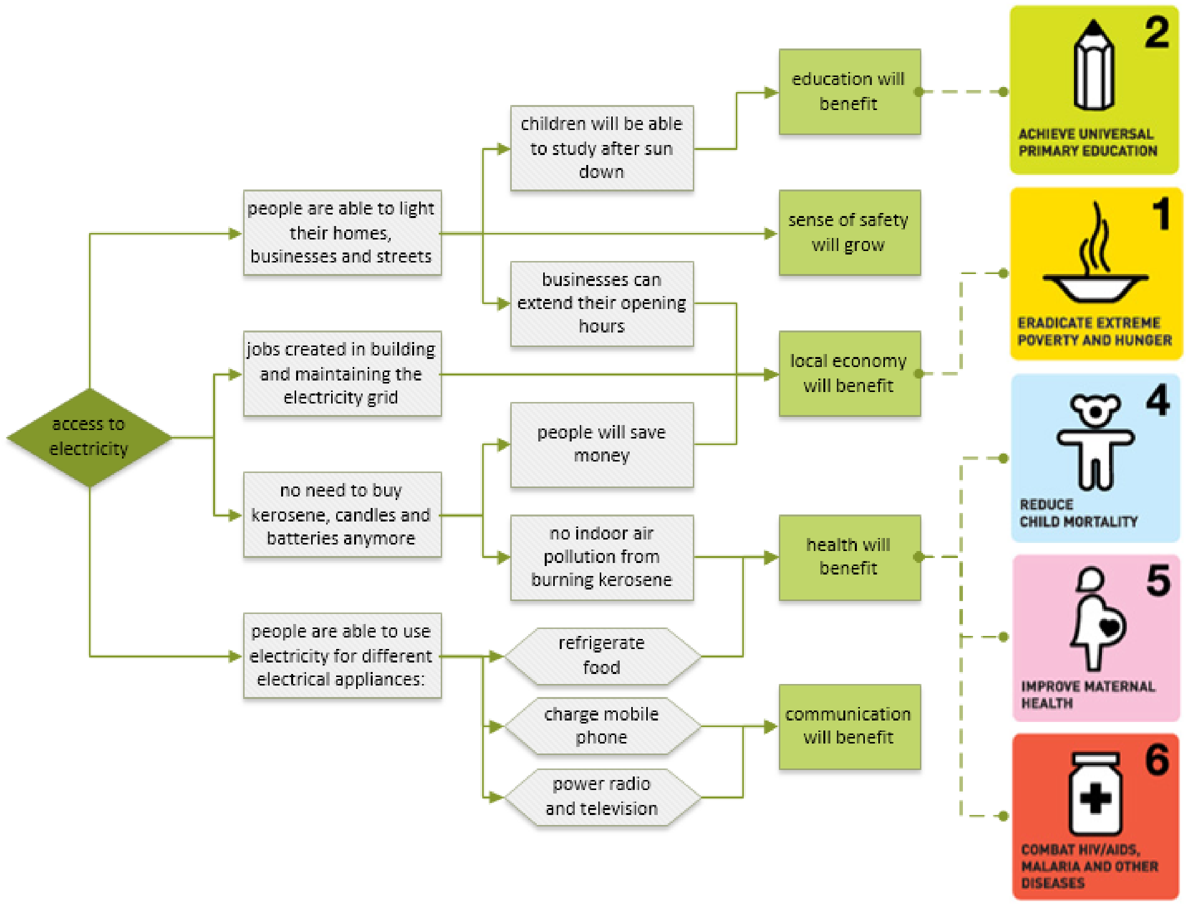


Figure 1 Benefits of access to electricity for rural areas, linked to the UN Millennium Development Goals

1.2 Electrification through off-grid microgrids

This thesis targets areas where there is no access to electricity yet and that are so remote that a grid extension is at this point not considered viable. It therefore focuses on off-grid microgrids, with no extension to a main grid. A grid extension is often not feasible or too expensive in the case of remote areas (Schmidt et al., 2013). “In many countries, the reach of the electricity grid is extremely limited and almost exclusively serves urban areas” (Williams et al., 2015). Therefore an off-grid solution like a microgrid will be a good solution.

Microgrids are defined as “small electrical networks heterogeneously composed of distributed generation units, loads and energy storage systems” (Sadabadi et al., 2015). The microgrid “acts as a single controllable entity and in a synchronized way with the conventional utility grid, but can be disconnected and independently operated according to physical and/or economic conditions” (Hossain et al., 2014). “Being capable of autonomous control, protection, and management, a microgrid can operate either in parallel with the main grid or in an intentional islanded mode” (Fusheng et al., 2016). This islanded mode of the microgrid is the appropriate mode for the areas targeted in this thesis.

In addition to their right fit with remote areas, microgrids can be a good solution for the electrification of rural areas for five more reasons:

- Microgrids have an efficient infrastructure (Hossain et al., 2014): the electricity is used right where it is produced. Electricity transport losses are lower (Fusheng et al., 2016).
- They are resilient in the sense that a rolling blackout would not occur in case of a (natural) disaster when you would have several distributed microgrids instead of one large centralized grid. Therefore the local reliability is higher (Fusheng et al., 2016).

- Related to the previous point: as microgrids consist of several autonomously power-generating sources, it has a flexible infrastructure (Fusheng et al., 2016; Hossain et al., 2014). This flexibility can mainly be gained in the control of the grid.
- Off-grid renewable energy technologies in general “are increasingly becoming the cheapest solutions for sustainable energy access in a range of locations” (Glemarec, 2012).
- They create regional equity by electrifying rural areas, where before mainly the urban areas had access to electricity (Williams et al., 2015).

Figure 2 Indian children studying by candle light (Reuters, 2012)
Figure 3 Children next to a solar panel used by their school in the Philippines (Winrock International, 2013)

1.3 Electrification with the use of renewables

“Fossil-fuel generation technologies have been the most common choice for supply of electricity in these remote grids. However, with the demonstrated technical and economic feasibility of greener generation technologies based on wind, solar, hydrogen and hydro power, integrating these technologies has become a priority in microgrids” (Olivares et al., 2014). Therefore, in addition to focusing on off-grid microgrids, this thesis will look to expand the currently available sources of energy with electricity from renewable sources.

Renewables are a point of focus, because climate change needs to be addressed, as it is a major threat to especially the poorest countries (Schmidt et al., 2013). Resisting this threat can be done by using renewable sources of energy: sun, wind and water. Besides the fact that it helps to mitigate or prevent carbon emissions, the production of electricity from renewable sources has four other good qualities:

- Next to mitigating or preventing carbon emissions, these renewable sources are also cleaner in the sense that they do not produce particulate matter or NO_x.
- With the use of renewable sources, one becomes (or stays) independent from oil producing countries that often have unstable regimes. As in many cases, the sustainable electricity will replace energy from diesel generators. Although one now becomes dependent on solar panel, wind and water turbine producers and therefore dependent on the availability of rare earth metals.
- By definition renewable sources are non-ending sources of energy, so they have the advantage of being future prove. Developing an energy system that is designed for the use of these renewable sources will prepare countries for a future without fossil fuels.
- Another property of renewable sources of energy is that they are available on a decentralized level, so electricity can be produced locally. This means that these sources are also available in remote, rural areas. And thus they can be well-combined with off-grid microgrids.

1.4 Governmental electrification efforts

It can be concluded that an off-grid microgrid that produces electricity from renewable sources has several benefits for communities in rural areas:

- Electrification is a key driver for social and economic welfare;
- Microgrids fit well with remote, rural areas that are hard to connect and;
- They take on issues related to climate change by focusing on renewables.

This is why governments initiate actions on the electrification of their communities and villages (Singh, 2015). If not from an intrinsic need, then because they are pushed by international organisations. For one, the UN (supported by the World Bank) is striving for universal access to modern energy services by 2030 (UN Foundation, 2013). There is a lot of work to do to reach that goal: in 2012 there were 43 countries of which less than half of the population had access to electricity. And in 2012 there were 124 countries of which not the full population had access to electricity (World Bank, 2012). This is visualised in Figure 4, where it is made visible that African and South Asian countries have low levels of access to electricity. The list of countries of which not the full population has access to electricity is given in Appendix B.

Figure 4 Access to electricity (% of population) in the year 2012 (World Bank, 2012)

Despite governments' good initiatives, they face problems: "limited public funds have proven insufficient to meet the aggressive access goals that governments and international organizations have set [and] publicly-owned utility companies have also been known to suffer from inefficiency and poor technical performance" (Williams et al., 2015). This is why governments look to collaborate with other parties.

1.5 Public-private partnerships

Financial help can come from NGO's, development organisations like the World Bank and the United Nations or private parties. Private parties can also provide governments with skills on the development of a microgrid. In trying to establish this collaboration it is key for the government body to convince these potential collaborating parties of the feasibility of a microgrid project in their community. Following several papers on the subject (Glemarec, 2012; Schmidt et al., 2013; Williams et al., 2015), there is a not enough capital available from public and donor sources. Based on that observation these papers conclude investments from the private sector are essential.

Suma Chakrabarti, the president of the European Bank for Reconstruction and Development, agrees with that: he thinks that new partnerships are needed between the private sector and the state in delivering the Sustainable Development Goals set by the UN (the successors of the Millennium Development Goals). In his lecture at the London School for Economics he also gives examples of private sector parties in renewable energy: "local industries, large industries with foreign strategic sponsors, SMEs [(small and medium-sized enterprises)], commercial banks, equity funds, project developers, utilities, individual home owners through residential energy efficiency lines" (Chakrabarti, 2015).

It is difficult to convince these private parties to collaborate on electrification projects; there are various challenges "that must be overcome to create an enabling environment for private sector participation in microgrid electrification" (Williams et al., 2015). "Expanding electricity access to rural areas in developing countries is often motivated by social concern, but as with any investment opportunity, the private sector will measure the attractiveness of a project by its expected financial return and its associated risks" (Williams et al., 2015).

Examples of such risks are:

- The risk that centralized grid options arrive within the repayment period of the off-grid solution (Glemarec, 2012).
- The risk that governments will stop financial support for clean energy technologies (Glemarec, 2012).
- The risk that sub-standard performance of clean energy devices causes the demand for clean energy systems to decrease (Glemarec, 2012).
- And the uncertainty of electricity demand in general is seen as a risk (Williams et al., 2015). As households that did not have electricity access before are now being connected to the grid, it is hard to predict how their energy consumption behaviour will change.

What if public and private parties decide to work together? What if they want to spread the risks of developing a microgrid in rural areas? They would want to know where to invest. They would want to make an informed decision about where to start their electrification efforts. They would want to know what location is feasible for the development of a microgrid. This public-private partnership would want to assess the feasibility of a possible microgrid location before it starts development. Exactly that problem will be solved with this research project.

1.6 Structure of thesis report

This thesis report exists of three main parts: thesis definition, research & design and interpretation. Currently you are reading the first part, that also includes the next chapter in which the research questions will be introduced and the methods of answering those. In the second part the three research questions will be answered, they will each get their own chapter to do so. The third and final part brings everything together and draws conclusions based on the gained insights.

2. RESEARCH DEFINITION

This chapter is aimed to give a sharper delineation of the problem addressed. First, the problem will be further explored and the main deliverable of the project will be introduced. The problem will be defined in the form of a problem statement and a research approach. Finally, the scientific and societal relevance of the proposed research project will be explained.

2.1 Problem exploration: looking beyond the financial aspects

It is found that it can be a problem for parties, who want to electrify rural areas, that they see investing in rural electrification as a risky business. They can be helped by making an assessment of the feasibility of a targeted microgrid location, before investing in that microgrid. Here, the choice of the word 'feasibility' instead of the likely expected 'viability' in the context of investments is a deliberate one. This research does not aim to focus on just the financial aspects of microgrid development; it aims to include all relevant factors affecting rural electrification efforts. A first introduction to such relevant factors will be given in this problem exploration.

Social and cultural challenges

It is already established that public funds are proven insufficient to independently provide in the financial needs for rural electrification. Therefore investments need to come from elsewhere, they can come from countries, companies and organisations outside of the rural area in need of electricity access. As a result, cultural differences come into play when developing microgrids. Specifically these challenges, in the social and cultural context of rural electrification, were studied by García and Bartolomé (2010). They concluded that "electrification projects based on a sustainable technology can introduce substantial changes in rural communities. The success of such projects is threatened by a lack of understanding of the life and habits of the community members, and some projects fail." They saw that failures are often explained from a technology perspective, while they believe "exploring social habits, cultural attitudes, and the networks of social relationships and behaviours" (García & Bartolomé, 2010) will help in understanding why a system is not accepted and gives a more precise explanation of the problems. The trans-disciplinary process of integrating technical and social aspects is seen by the researchers as a necessary process for renewable energy electrification projects to succeed.

Local circumstances and needs

Related to these social-cultural challenges is the concept of frugal innovation. This concept too, has a focus on the linking of technology with local circumstances. Frugal innovation is "a relatively new concept of innovation focused on the development of high-quality, affordable products for emerging markets". " Such innovations need to fit local circumstances and cultures" (Centre for Frugal Innovation in Africa, 2016). Not much has been written on frugal innovation in the field of rural electrification yet. One of the few scientific papers on these combined concepts sees the potential of engineering to "accelerate the development of low-income communities by integrating insights from the social sciences along the entire arc of technological innovation, from idea to manufacture at scale" (Nilsson et al., 2014). Again, it is found that the integration of insights from different fields is seen as an important step.

Taking into account the novelty of the combination of these two concepts, it is not surprising that Nilsson et al. (2014) mainly address challenges and opportunities; as the central challenge they see "designers' limited understanding of the needs and preferences of technology users in low-income countries". Several reasons for this limited understanding are given, as are related challenges and risks, but fortunately they also present a practical way of dealing with these challenges: "incorporating social and economic research throughout the innovation process". The writers see this linking of technology design to the demands of the poor as a new field of development engineering. One that builds upon "techniques from engineering and the natural sciences, as well as economics, business, information science, design, and sociology. It also incorporates insights and practices from development professionals in government, the private sector, and the social sector" (Nilsson et al., 2014).

The writers believe this linking of learnings from different areas has the promise of transforming the innovation ecosystem, they feel the academic world can help in addressing the challenges of poverty.

In this research on the feasibility of rural microgrids, this same trans-disciplinary, integrative process will be followed. The search for feasibility factors will take us further than just the financial risks, even though the perspective of investment barriers is a great starting point, that fact is not diminished.

2.2 Knowledge gap and the main deliverable

One of the insights that can be taken away from the previous chapter is that public-private partnerships are a good way for governments to get access to more funds and technical knowledge and it is a good opportunity to spread the risks of the development of a microgrid. If such a public-private partnership is formed and they decide to develop a rural electrification project, the partners want to be smart about where to start their first development. Because risks can be spread, but not completely avoided. The partnership wants to know what location is most feasible for the development of a microgrid.

But what are the factors that determine the feasibility of the electrification of a certain location? What criteria need to be met before starting the development of a microgrid?

Schillebeeckx et al. (2012) have made a start at defining these factors. They performed a content analysis of 232 articles on the topic of 'rural electrification'. These papers were written between 1990 and 2011, so there is a gap in the knowledge from 2012 to 2015. Another 202 papers are found on the topic of rural electrification, published during those years, which were not yet analysed in a way that is useful in the assessment of the feasibility of a microgrid location.

In this research, feasibility factors will be collected in a way similar to Schillebeeckx et al. (2012). However, their research will be expanded by diving deeper into the topic of rural electrification and broadening the search for feasibility factors (with this a start was made in the previous paragraph) by using different, but related theories. When bringing this all together, the main deliverable of this thesis will be created: a feasibility framework that can be used to assess a potential microgrid location, before investing in and developing this microgrid. The design of this feasibility framework will be explained in more detail in paragraph 2.4.

2.3 Problem statement: definition and delineation of the project

The project will be further defined and delineated by explaining the 'who, what, where, when and why' of the problem that will be solved by performing this thesis research.

Who? Governments of countries where a large part of the population does not have access to electricity. These can be local, regional or national governments, depending on the question who has the power to implement energy policies. The governments will work together with local or international private parties that are interested in investing their money, knowledge and/or skills in the development of microgrids.

What? Design a feasibility framework that can be used by governments that want to facilitate the electrification of their rural areas and by the private sector that wants to invest in electrification projects. After putting in some local data on the potential microgrid location, the framework presents the score of that location. If the location scores low on certain criteria, the government can develop policies to improve these scores. In a way, these criteria are a checklist for the government: have we ticked all the boxes? Is our location ready for the development of a microgrid? After having checked the score and implemented improvements, the governments can approach potential investors or find ways of collaborating with the private sector parties that were mentioned earlier by Chakrabarti (2015). With their potential microgrid location now having a high score on microgrid feasibility, they can present that to prospective collaborative parties and show them that they are ready for the development of a microgrid. Or the feasibility framework is used by investors that independently find good business opportunities in un-electrified areas. Therefore the feasibility framework should become useful for all three potential users: governments, investors and public-private partnerships.

Where? All over the world, with a focus on countries that contain remote, rural areas that have no access to electricity.

When? Microgrids are a relatively new development in the energy sector with still a lot of unexploited potential. Now is the time we can learn from previous (pilot) projects and use that knowledge to further develop the microgrid design in the broadest sense. As this feasibility framework is designed in collaboration with engineering consultancy Arup, they will then be able to use the framework in their work of microgrid development. Arup's clients include both public and private parties. If these parties are interested in the electrification of rural areas, Arup can advise them to use the framework to assess the feasibility of the location that they are interested in.

Why? Because the development of microgrids poses a lot of challenges which this thesis research will help public and private parties overcome. For example, governments are of course aware of the improved living standard they can provide their communities with by giving them access to electricity. But they might not be aware of what conditions are the right conditions for investors to partner up with them in developing a microgrid. And if they are aware, they might not have had the ability to learn from microgrids projects in other countries. As the to-be-developed feasibility framework will include learnings from projects in different countries, this will make them able to indirectly learn from those experiences.

2.4 Research approach: the research questions

Following the description of the research problem, the main research question that will be answered is:

How can public and private parties, which aim for the electrification of rural areas, assess the feasibility of a location for the development of a microgrid?

To answer this main research question, answers will be found to three research questions. A first introduction to these questions and the methods for answering them will be given in this chapter. Part II of this report will discuss and answer the three research questions more comprehensively.

1. Which subject areas are dominant and which concepts are most frequent in studies on rural electrification?

Schillebeeckx et al. (2012) have developed an integrated framework for rural electrification. They performed a content analysis to examine the relevance and trends underlying the four lenses that they chose: technology, institutional, viability and user-centric. They performed their content analysis on 232 papers published between 1990 and 2011. This thesis research will add to that analysis by performing a content analysis on the 202 papers published between 2012 and 2015 (applying the same selection criteria as Schillebeeckx et al. used).

The content analysis exists of two main steps. First, all papers are assigned to one dominant lens, and between zero and three secondary lenses. Second, the important and meaningful words are counted, where some words are grouped together if they have a similar meaning. We will allow for any emerging categories to be added to the initial four. Also there is searched for relationships between the most frequent concepts, in order to understand and describe the lenses even better.

The combined analysis of 434 papers will give a comprehensive overview of concepts that are commonly used in studies on rural electrification. This will be the starting point of the design of the feasibility framework.

2. Which factors play a role in the development of rural electrification projects?

In answering this question, the categories will be examined further. The content analysis, that will be used to answer the first research question, will enable us to describe the categories with the use of frequently used words. But these are just the broad strokes, the answers to this second question will make it possible to colour those in. With a deepening and broadening literature research factors that play a role in rural electrification will be searched for both with a more in-depth investigation of this concepts of rural electrification, as with learnings from other theories. Because it was learned in the first paragraph of this chapter, that opportunities lie in the linking and integration of different fields. The specific choices made in terms of the literature used to uncover feasibility factors from a wider spectrum, will be explained in paragraph 4.1.

The selected papers for this literature research will be examined for factors that might affect microgrid feasibility. The factors that will be identified in each of the categories, will together fill a certain number of long lists of factors for the feasibility framework. These factors will be added to the frequently used concepts from the first research question. Both the concepts and the factors will be transformed into criteria by making them measurable and by determining if they effect the feasibility of a microgrid in a positive or negative way.

3. How can we measure the feasibility of a location for the development of a microgrid?

To come to a short list of the most important criteria, a group of experts will be asked to evaluate and rank the criteria on the long lists. The criteria that everyone labels as important will make the shortlist. I will put together this group of experts with the help of my external supervisor dr. Maria Brucoli, who has been working on microgrid projects for years and therefore knows many people who work in this field. In addition, I will ask people from the Faculty of Technology, Policy and Management to apply their expertise in evaluating the criteria.

These short-listed criteria form the core of the feasibility framework. How this works, is illustrated with a make-believe example: the government of Indonesia has the goal to provide even the smallest islands of their republic with electricity. There are five islands that have made it clear they want to have access to electricity. The national government of Indonesia wants to know which island has the best conditions for them to develop a microgrid together with a private party that is interested to invest. This public-private partnership will test the five different locations with the help of the feasibility framework. The framework will score each criterion for each location. If one location scores high on all (or almost all) criteria, the Indonesian partnership will know on which island to develop the first microgrid. In the meantime it can work on improving the scores of the other four locations to make those feasible locations too.

The design of the feasibility framework will have a multi criteria analysis as a decision structure. This will make it possible for the user of the framework to weigh the criteria, dependent on which of the categories of criteria he finds most important. If he finds them all equally important, every criterion will be taken into account with the same factor of importance.

To be able to score the criteria, local data of the potential microgrid location needs to be available. This is one of the requirements for the feasibility framework. The workings of the framework are tested by applying it to real locations. Based on these test, the framework can be improved concerning the availability of data: if it appears to be hard to obtain data to score a certain criterion, this criterion may need to be adjusted in the design of the framework.

2.5 The scientific and societal relevance

The relevance of the design of a feasibility framework can be explained on two levels:

Scientific relevance

This research project will bring existing scientific knowledge together and use it to create something new. In other words: papers on the topic of the electrification of rural, remote areas and papers on related topics will be used to design a feasibility framework. By doing so we will answer to the call for more research on the topic of electrification investments: “several scholars have pointed out the need for greater academic work exploring barriers and solutions unlocking private sector investment in electrification activities” (Williams et al., 2015). And we will answer to the current shortcomings of scientific research, as “until now, there has been a lack of systematic evaluation of experience with decentralized electricity systems in different cultural and geographic contexts and the transfer of this experience” (Schäfer et al., 2011).

Societal relevance

This research and design aims to be help in the electrification of rural areas. This is relevant as people who live in rural communities will greatly benefit from having access to electricity, as was explained by providing five benefits in paragraph 1.1. To explain it in one sentence: this research and design will contribute to a better living standard for potentially millions of people, as there are still such large numbers of people without access to electricity.

PART II
RESEARCH & DESIGN

3. FREQUENTLY USED CONCEPTS IN STUDIES ON RURAL ELECTRIFICATION

To get a first idea of the state of the art around the topic of rural electrification, an answer will be found to the first research question:

Which subject areas are dominant and which concepts are most frequent in studies on rural electrification?

The method used to find the dominant subject areas and most frequent concepts is content analysis. This method will be explained in the first paragraph. The second paragraph introduces the papers that were used in the content analysis. The third paragraph will give an answer to the first part of the research question. In the following paragraph the second part of the research question will be answered. Finally, in the fifth paragraph, the key concepts will be used to describe the lenses in more detail.

3.1 The steps of the content analysis

Content analysis is a term that is used to describe a family of analytic approaches, used to interpret text data, either in a qualitative or quantitative way (Hsieh & Shannon, 2005). Content analysis is a technique to compress "many words of text into fewer content categories, based on explicit rules of coding" (Stemler, 2001). "Content analysis is also useful for examining trends and patterns in documents" (Stemler, 2001), which is exactly the reason why it is applied in this research.

The complete description of the executed analysis steps is given in Appendix C; the following is a summary of the content analysis performed.

The 202 papers that are analysed are all papers published between 2012 and 2015 on the topic of rural electrification. More information on the selected papers will be given in paragraph 3.2.

The abstracts of all papers are read and based on those, each paper is categorized in one of the four lenses used by Schillebeeckx et al. (2012): technology, institutional, viability and user-centric. In doing so, Figure 5 is used as a handhold as it illustrates which keywords are associated with which lens.

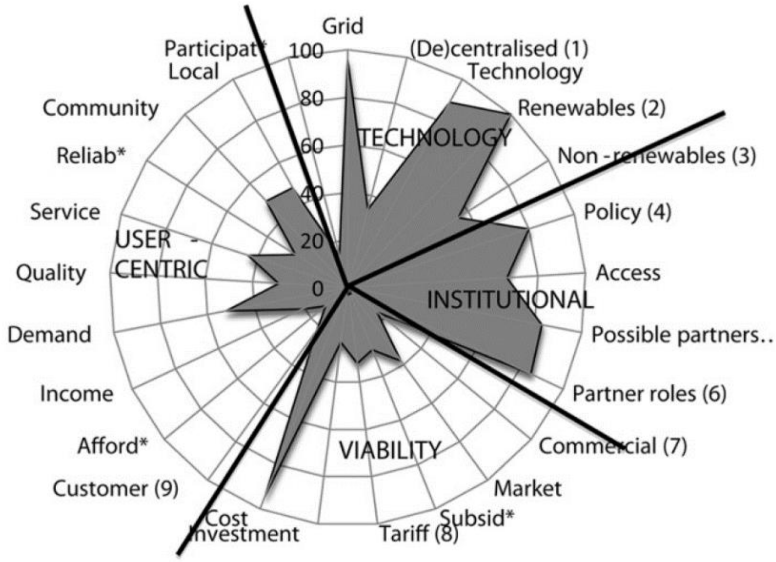


Figure 5 First order words for the four lenses (Schillebeeckx et al., 2012)

If one lens is not enough to capture the full content of the paper, one or more secondary lenses are chosen. Combining the four lenses in all ways possible, gives 32 possible lens-categories that are listed in Appendix D. All 202 papers selected for content analysis are assigned one of these lens-categories on the basis of their abstract, which resulted in the table in Appendix E. The most frequently chosen lenses, also referred to as the dominant subject areas, will be discussed in paragraph 3.3.

In the next step of the content analysis a method called 'word-frequency count' is applied. With the use of a computer script, the words most frequently used in the four dominant lenses are found. This method is explained in more detail in Appendix F. The results of the word-frequency count analysis are discussed in paragraph 3.4.

Finally the categories will be described with the use of the most frequent concepts, this is done in paragraph 3.5.

3.2 The selected papers

A specific search for papers in the scientific database ScienceDirect resulted in 202 papers found on the topic of rural electrification. These papers were published between 2012 and 2015. By analysing these papers, this research is a continuation of the work of Schillebeeckx et al. (2012), who analysed papers on the subject of rural electrification that were published between 1990 and 2011.

An overview of the papers selected for content analysis by Schillebeeckx et al. (2012) and myself is presented in Table 1. The selected papers are also listed in a separate part of the Literature list.

Table 1 Overview of number of papers per journal, Schillebeeckx et al. (2012) and Wynia combined

Journal Title	Count Wynia	Count Schillebeeckx	Total count
Energy Policy	24	60	84
Renewable Energy	20	62	82
Renewable and Sustainable Energy Reviews	47	24	71
Energy for Sustainable Development	35	29	64
Energy Procedia	26	2	28
Energy	15	10	25
Applied Energy	7	6	13
Solar Energy	2	9	11
Biomass and Bioenergy	2	3	5
Energy Conversion and Management	1	3	4
International Journal of Hydrogen Energy	1	3	4
Journal of Cleaner Production	1	3	4
World Development	1	3	4
Solar Energy Materials and Solar Cells	0	4	4
Procedia Engineering	3	0	3
Sustainable Energy Technologies and Assessments	3	0	3
International Journal of Electrical Power & Energy Systems	1	2	3
Energy Research & Social Science	2	0	2
Sustainable Energy, Grids and Networks	2	0	2
Desalination	0	2	2
Electric Power Systems Research	1	0	1
Energy Strategy Reviews	1	0	1
European Journal of Operational Research	1	0	1
Journal of Development Economics	1	0	1
Procedia – Social and Behavioural Sciences	1	0	1
Renewable Energy Focus	1	0	1
Socio-Economic Planning Sciences	1	0	1
Technological Forecasting and Social Change	1	0	1
The Social Science Journal	1	0	1
Computers and Industrial Engineering	0	1	1
Current Opinion in Environmental Sustainability	0	1	1
Energy Economics	0	1	1
Futures	0	1	1
International Transactions in Operational Research	0	1	1
Journal of Power Sources	0	1	1
Journal of Rural Studies	0	1	1
Technology in Society	0	1	1
Utilities Policy	0	1	1
Total Papers	**202**	**234***	**436**
Total Journals	**27**	**25**	**38**

** Minus two from 2012 that were excluded from analysis makes 232 that were used for content analysis*

It is remarkable that in the four years this research is exploring, almost the same number of papers on rural electrification is published as in the 22 years that Schillebeeckx et al. (2012) have analysed. While the number of journals that these papers where published in is nearly the same. From this, one can draw the conclusion that the topic of rural electrification has grown in interest amongst researchers. Even if it is assumed that scientific publications in general have grown over the last 26 years, an increase of 40 publications on average each year is a steep growth. And as a large part of the papers mention pilot projects or case studies, the conclusion can be drawn that rural electrification has gained interest in the real world too. Apart from this being a confirmation of the societal relevance of this research, it also underpins the solid base of information this research is grounded on.

It is also interesting to see that the largest part of the papers on rural electrification were published in just eight of the in total 38 journals. The eight journals that published the most papers on the topic of rural electrification all focus on papers related to the energy field, this is no surprise. Remarkable, however, is the fact that three of the eight journals focus on renewable energy, which is not necessarily an essential point of focus when writing about rural electrification (as earlier stated: the most common choice for electricity generation in remote grids have been fossil-fuel technologies), but it is a perspective that was chosen to apply in this research. It can therefore be concluded that this choice of focussing on renewables is justified.

In addition to the renewables perspective, a focus on developing countries is recognized. This point of focus is also chosen in papers published by the fourth journal in the list 'Energy for Sustainable Development' and the journal 'World Development'. Again, not a surprising perspective, as rural electrification is about bringing electricity to areas that have no access to electricity yet. The fast majority of these areas is located in developing countries.

A third and final recurring subject in the represented journals that needs to be addressed is the social aspect of rural electrification. Five of the journals focus on social science, societal change or cultural dynamics and have published papers on rural electrification, which are thus related concepts. This is probably related to the increase of papers that are categorized in the user-centric lens, as we will see in the next paragraph.

3.3 Dominant subject areas

In the first part of the research question this chapter is answering, there is looked for the dominant subject areas in the field of rural electrification. To find these, I have categorized all 202 papers based on their abstract. To be able to, again, compare these results with those of Schillebeeckx et al. (2012), the same four lenses are applied.

Every paper was assigned one dominant lens, choosing from technology, institutional, user-centric and viability. If the paper were to cover more than one of these overarching fields, it was assigned one or more secondary lenses.

An overview of the prevalence of the four lenses, combining Schillebeeckx' results with mine, is given in Table 2.

Table 2 Prevalence of four lenses, both selected as dominant and secondary lens (number of papers in each category)

	Technology	Institutional	User-centric	Viability
Dominant				
1990-2011	120	69	20	23
% of total papers	52%	29.5%	8.5%	10%
2012-2015	103	39	37	23
% of total papers	51%	19%	18%	11%
1990-2015	223	108	57	46
% of total papers	51%	25%	13%	11%
Secondary				
1990-2011	37	24	31	31
Relative to other lenses	30%	20%	25%	25%
2012-2015	52	53	68	100
Relative to other lenses	19%	19%	25%	37%

The first thing to notice is that the convincing majority of the papers is about the technology of rural electrification. This fact has not changed over the last few years. Viability as a dominant lens also stayed approximately of the same importance for rural electrification.

But a shift happened between the user-centric and institutional lenses: what the user-centric approach gained in share, was lost at the part of institutional papers. So applying the user-centric lens when researching rural electrification has been given more attention over the last few years. This is a trend that started in 2006, when the first paper with a user-centric approach was published.

What does it mean that more papers are written with a user-centric perspective and less from the institutional point of focus? Could we conclude that this shift means that on the highest levels the plans and programs around rural electrification are clear and more attention needs to be given to the local communities? Or could it mean that we have shifted from a top-down to a bottom-up approach? This would make sense, as microgrids are ideally suited for a bottom-up approach because of their decentralized nature. Another explanation could be that before there were mainly plans and programs made to promote rural electrification and that over the last years actual microgrids have been developed. So these papers discuss the recent developments with the use of case studies, like the successes and problems with Solar Home Systems. This suspicion is strengthened by the fact that six of the 37 recent papers on rural electrification with the user-centric lens deal with the topic of SHS and another 16 are based on other case studies.

What can be learned if this same logic is applied when analysing the fact that the technology lens has continued to be the most dominant lens? Why has a technological perspective remained of interest to the scientific community? If we assume researchers write about topics that receive the same attention in the real world, it can be concluded that there still (after 26 years of writing about the technology aspects of rural electrification) is no consensus about the most suitable technology for rural electrification. Apparently there are still technological issues that need to be studied. Based on the titles of the 103 technology papers, it can be seen that only in a few cases the researchers seem to know that one technology is most fitting as they focussed on 'optimization', 'optimal design' and 'optimal operational strategy'. These concepts are found in the titles of seven technology papers. But more often researchers are trying to find the most suitable technology, with titles that contain words as 'comparing' (6), 'assessment' (6), 'evaluation' (5), 'options' (5), 'reviewing' (4) and 'overview' (2). Even including three additional papers on the 'sizing' and 'minimizing' of specific technologies, more often than optimizing one selected technology, the researchers are comparing different technologies to find the best one. This can be a comparison of one technology with another, or the evaluation of one technology in different locations, or the reviewing of different options for one country. Based on these observations, it appears to be hard to find a technology most suited for rural electrification. Could it even be concluded that there is not one best technology, that each situation is different? That a multitude of factors come into play when deciding on the energy generation technology? This insight will be taken forward in answering the second research question in the next chapter.

The trends of all lenses over the years is made visible in Figure 6. And the relative incidence of the four lenses is shown in Figure 7.

Both over the last four years as over the total period from 1990-2015, the order of importance of the subject areas is:

1. Technology (51% on average of total papers published between 1990 and 2015)
2. Institutional (25% on average of total papers published between 1990 and 2015)
3. User-centric (13% on average of total papers published between 1990 and 2015)
4. Viability (11% on average of total papers published between 1990 and 2015)

Even though viability was chosen least as a dominant lens, over the last four years it was assigned most as a secondary lens. When writing about rural electrification, apparently, concepts that are associated with the viability lens (like cost, investment and subsidy) are often used. Could it be that the researchers recognize the same problem as described in paragraph 1.5? There may be many available technologies, well-intentioned policies and community initiatives to realize rural electrification, but if the risks keep getting in the way, no investments will be made.

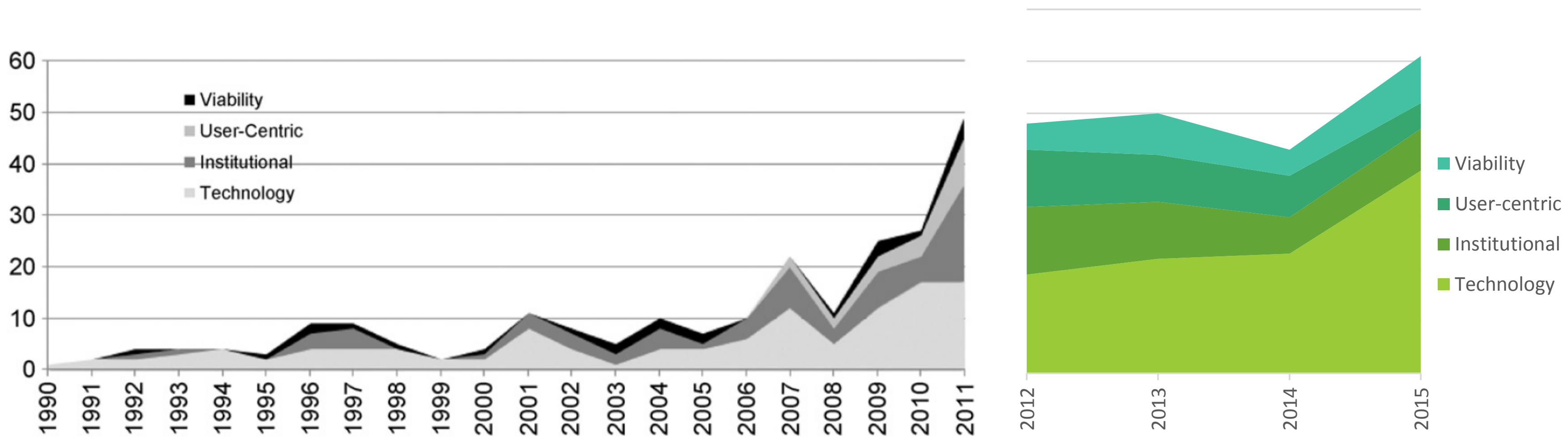


Figure 6 Number of publications per dominant lens from 1990-2011 (Schillebeeckx et al., 2012) and from 2012-2015

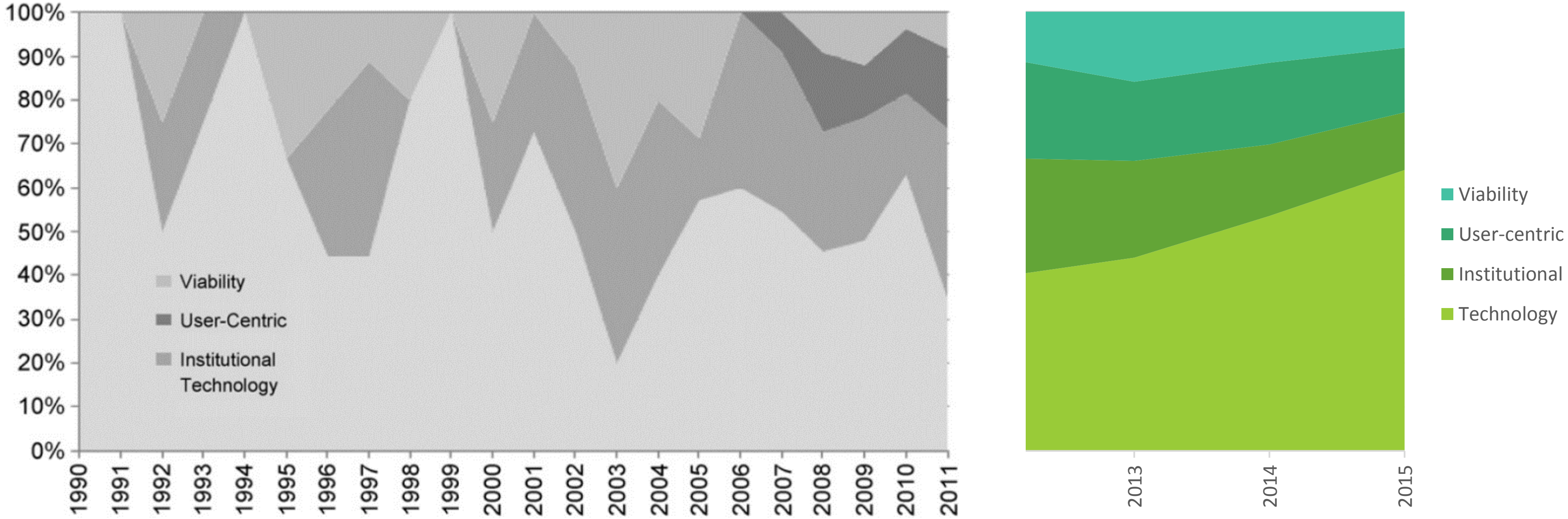


Figure 7 Relative incidence of the four lenses from 1990-2011 (Schillebeeckx et al., 2012) and from 2012-2015

3.4 Most frequent concepts

Now the most dominant subject areas are identified, the research will be continued to find the most frequent concepts used in papers on rural electrification. In performing this search, the subject areas (or lenses) are used to categorize the papers. For every category the most frequent concepts are analysed by performing a word-frequency count analysis. Thus, a word-frequency count analysis is performed four times, using four subsets of papers. For every subset the words are counted and the most frequent and relevant words are grouped and listed. The result of this are the key concepts in Table 3.

When looking at this table, one will immediately see that there are not four, but six categories used in finding the most frequent concepts. Because, as Schillebeeckx et al. (2012) already described, the individual word analysis will facilitate the discovery of key concepts and emerging categories. When the most frequent words were studied, there were some words that did not fit any of the four previously defined categories. Or, better said, that would fit other categories better. Therefore two new categories are constructed that are named 'environmental' and 'frugal'.

As this research has a focus on the potential of the use of renewables in microgrids, a category related to sustainability and the environment could not be absent. Also, in quite a few of the selected papers the environmental perspective was used in writing about rural electrification. Therefore the environmental category is added as a fifth perspective of looking at microgrid feasibility.

The sixth category is called the frugal category, named after the concept of frugal innovation which was addressed in the problem exploration of paragraph 2.1. There the aspect of the linking of technology with local circumstances and cultures was emphasized, but an additional aspect of frugal innovation is the complete focus on emerging markets. This category is an interesting addition, because this research targets remote, rural areas, where the people have no access to electricity. And as a frugal innovation is defined to be cheap, easy to use and develop with minimal amounts of raw materials (Rao, 2013). And as it is a new innovation mind-set that tries to help overcome the challenges of resource constraints while serving and profiting from underserved consumers (Bhatti et al., 2013). Thus this category is a well-fitting and needed addition to the existing categories.

A choice was made to name this category 'frugal', but it also could have been labelled 'inclusive', as the field we want to capture is also very much related to the theory of inclusive growth. George et al. (2012) define inclusive growth as "improvements in the social and economic wellbeing of communities that have structurally been denied access to resources, capabilities, and opportunities. Inclusive growth can be viewed as a desired outcome of innovative initiatives that target individuals in disenfranchised sectors of society as well as, at the same time, a characteristic of the processes by which such innovative initiatives occur".

The listed key concepts give a good picture of the field of rural electrification, while at the same time further defining the six subject areas recognized in this field. This picture will be sharpened even more in the next chapter.

Table 3 Key concepts per category based on the word-frequency count method

Technology		Institutional		User-centric		Viability		Environmental		Frugal	
count	*key concept*	*count*	*key concept*	*count*	*key concept*	*count*	*key concept*	*count*	*key concept*	*count*	*key concept*
9391	energy	1154	program	2006	households	2011	cost	5850	sustainable	8930	rural
5179	electrification	1061	policy	892	village	614	investment	1190	renewable	3592	area
4422	power	785	countries	820	consumption	407	subsidies	950	environmental	2699	access
3850	generators	772	government	631	poverty	374	price	369	emissions	2325	available
3569	hydropower	541	national	553	people	337	loan	217	climate	2267	resources
3204	solar	533	world	486	users	275	market	117	carbon	1842	sources
2576	wind	449	institutional	474	community	275	private			1803	services
2501	batteries	336	subsidy	388	local	260	bank			1342	operation
2423	microgrid	298	international	347	urban	232	economic			1165	remote
1926	turbines	261	implementation	285	social	228	capital			977	management
1813	technologies	213	public	204	cooking	221	financing			936	maintenance
1628	hybrid	200	process	176	education	203	risks			909	control
1321	diesel	164	role	173	women	183	business			785	performance
1156	supply	147	framework	169	health	174	financial			742	equipment
1119	plants	141	ministry	138	school	163	tariff			724	location
1027	capacity	129	actors	137	willingness	149	revenue			661	quality
981	lighting	124	decision	125	satisfaction	146	LCOE			486	reliability
944	biomass	123	initiatives	117	migration	140	income			472	installation
713	fuel	117	strategy			107	contract			449	isolated
665	distribution	115	agency							383	engineering
641	storage	113	political							353	training
401	off-grid	110	promote							242	knowledge
397	biogas	105	regulatory							232	planning
385	engine	100	partnerships							103	productive
348	oil										
341	extension										
296	rice										
287	gas										
268	conversion										
267	temperature										
229	jatropha										
215	fossil										
210	thermal										
210	transmission										

3.5 Interpretation of key concepts and categories

Now we know which concepts are key in studies on rural electrification, we would like to look at these key concepts a bit more. We should remember that the key concepts are the result of the grouping of the most frequent concepts and these frequently used concepts originate from our selection of meaningful words in each of the categories.

We will use the key concepts to describe the six categories in more detail. What do they tell us about the categories they are grouped under? There is searched for relationships between the key concepts, in order to understand the six categories even better. In addition, we will give more context to any of the key concepts that stand out from the overall picture of the category.

Interpretation of technology category

Two types of concepts characterize this category, the first are concepts that describe a physical microgrid: engine, supply, transmission, distribution, storage, etc. These are all parts and processes related to the generation of electricity. The second type of concepts are sources of energy, thus, for example all well-known ways of producing renewable energy are listed: solar, wind, hydro, biomass and (geo)thermal. The fact that an electricity grid is a complex system and the fact that there exist a lot of different ways to provide the grid with electricity, might explain why this category has the longest list of key concepts.

Two sources of renewable energy that might need some more explaining are rice and jatropha, as we think these are less obvious and clear concepts for anyone who has not been introduced to the topic of rural electrification before.

Figure 8 Rice husk (Cymonspace, 2010)
Figure 9 Jatropha (Arnis, 2013)

Rice husk can be used as biomass to produce electricity, which is done in Cambodia: “Rice husk is locally abundant at almost no cost, with a production over 9.3 million tons paddy rice in 2014 for a total population of about 15 million people. The conversion of rice husk into electricity through gasification or thermally generated electricity is a well-known technology. Rice husk can contribute in a sustainable manner to grant access to electricity to Cambodian rural population and is more reliable and competitive with reference to other renewable energy sources of electricity” (Pode et al., 2015). So the sole fact that rice husk is available in large quantities makes for a feasible way of producing electricity. There is a silent prerequisite, though: an energy demand that is not too high. Which is casually mentioned by Pode et al. (2015): “Since the energy requirement of rural population is not very high, rural electrification in many villages realized with a small scale gasifier is providing a sustainable solution to improve the access to energy and, at the same time, to guarantee a cheap kWh.” So rice husk can be an alternative source of energy in rural areas, if the availability of rice husk matches the demand for energy.

"*Jatropha curcas* L. is a small tree that yields oil-bearing seeds. Once extracted the high quality oil can be used directly or converted into biodiesel, either being suitable for use in engines of automobiles or electrical power generation" (Almeida et al., 2014). In the production of bio oil or biodiesel from jatropha the main factors to take into account are availability of jatropha, the yield (Almeida et al., 2014) and willingness to work of the local population, as jatropha is a labour intensive crop (Grimsby et al., 2012). Unfortunately the yield is hard to influence, as it depends on things like rainfall and annual average temperature (Bouffaron et al., 2012). It can however have large implications: "We found that the global warming potential of Jatropha-based electrification can be 13% higher to 20% lower than fossil diesel, depending on the yield. In terms of energy use and fossil fuel depletion, jatropha is more favourable than fossil-based electricity" (Almeida et al., 2014). Like rice husk, jatropha can be used as an alternative source of renewable energy. Although the production of bio oil or -diesel is dependent on the jatropha yield which is hard to influence.

Interpretation of institutional category

The institutional category is mainly made up of intangible concepts like governmental instruments (policy, subsidy) and governmental bodies (ministry, agency). We are aware of the potential of a proactive role taken by influential stakeholders and thus include concepts like initiatives and actors. We also look beyond national borders and include concepts like international and partnerships. This is done to illustrate that rural electrification is not a problem that only can be solved by local or national institutions.

Interpretation of user-centric category

Under the user-centric category fall concepts that define the human side of this category: people, households, community and village. Is also includes concepts that describe the challenges these people have in living without electricity access; getting access would help them with activities as cooking, going to school and would increase their health.

We want to explain why 'women' is an often-used word in papers on rural electrification. To do this, an example from the paper of Grogan and Sadanand (2013) is used: they studied rural electrification in Nicaragua and "found that household electrification causes rural women to be about 23% more likely to work outside the home, but that there are no such effects for men". Women gain this time, because they "spent much less time cooking in electrified than in unelectrified households […] and also less time getting water and firewood". "The provision of electric light to households appears to make it more likely that households become monetized, in the sense of both having women earning money outside the home and buying, rather than gathering, cooking fuel. Electricity, even if not accompanied by vacuum cleaners, dishwashers, and washing machines, impacts intrahousehold resource allocation in ways that are positive for female employment" (Grogan & Sadanand, 2013).

These Nicaraguan examples of the positive effects of rural electrification for women also give insight in how all user-centric concepts are interrelated, because this is certainly the case. Even between categories relations become apparent, as we see the technological concept of lighting and the viability concept of income are connected with concepts in the user-centric category.

Interpretation of viability category

Both the consumer side and the investor side are represented in the viability category. The consumer will mainly be concerned with the tariff or price for electricity and whether their income is high enough to pay that price. The investor will be concerned with the investment it needs to make, so capital costs, a viable business plan, the project revenues and the risks involved with a microgrid development need to be considered. In addition, the financial arrangements between parties involved in rural electrification need to be considered: the types of contracts, the ability for different parties to get a loan and the general status of the financial and energy markets are of interest.

Interpretation of environmental category

The first thing to notice is that the environmental category contains the shortest list of key concepts. This could either be because, in contrast to the technology category, one does not need many different words to explain the environmental field. Or the analysed papers do not use words related to the environmental field often enough to have made the selection of most frequently used concepts.

Either way, the six key concepts tell a clear story. One needs to produce electricity in a sustainable manner from renewable sources, so the emissions of polluting and greenhouse gasses is kept to a minimum and climate change is controlled.

Interpretation of frugal category

The frugal category includes concepts related to frugal innovation and inclusive growth. It contains concepts that describe the circumstances of the location of interest, which is often located in isolated, remote and rural areas. This has consequences for the community's access to resources, both of the human and material kind. Because of this, extra attention needs to be given to the building and operation of potential future microgrids. The level of knowledge and training under the local population in the field of electrification is probably low, because of its remote location and disadvantaged people. This is also why the frugal and institutional categories are related, as public policy will be needed to promote the education of local communities.

These insights can be illustrated with two excerpts from papers on the topic of rural electrification in Africa:

"This paper has reviewed the development of the Kenyan small wind turbine sector" [in which] "there remain pertinent barriers within the regime and the landscape, which include the low government participation, high poverty levels and scepticism towards new technologies. Among the direct influences, we conclude that several material infrastructure and socio-cultural factors inhibit sector growth: Kenya's under developed infrastructure, lack of raw materials, Dependency Syndrome, negative image of self-employment, low quality manufacturing culture, corruption and years of resistance to knowledge sharing" (Kamp & Vanheule, 2015).

"In Tsumkwe local service providers were unprepared to take charge of operations and maintenance after completion of the project and users have difficulties paying for the services. Too strong focus on technology and insufficient efforts made to involve local institutions and beneficiaries throughout the project are main causes. The promotion of local entrepreneurship in Sekhutlane has resulted in 17 local businesses being established, likely to strengthen the cash economy and improved ability to pay for services, and thereby contributing financial resources towards operation and maintenance of systems" (Klintenberg et al., 2014).

3.6 Conclusions

It can be concluded from the content analysis that the scientific publishing on rural electrification has increased significantly. Over the last 26 years, since rural electrification was first mentioned in a journal, 434 academic papers have been written about the subject. Just a bit less than half of those were published in the last 4 years, between 2012 and 2015. Because many of these papers cover case studies, it is concluded that rural electrification has gained interest in the real world too.

The perspective that is used most, in writing about rural electrification, is that of technology. Based on the content analysis and the paper of Schillebeeckx et al. (2012) it can be concluded that 51% of the papers have 'technology' as the dominant lens. The most assigned secondary lens, for the papers published between 2012 and 2015, is 'viability'. Thus rural electrification is mainly studied with the technological options for electrification in the leading role, with viability aspects in the supporting role. Apparently, after 26 years of studying this topic, there are still new and developing technologies to consider and investigate. It appears to be hard to find a technology most suited for rural electrification.

When the papers published in the last four years are compared with the papers published before that, it becomes clear that the user-centric lens has gained in interest what the institutional lens has lost. It seems like Schillebeeckx et al. (2012) had a predictive view, as they mainly focussed on the user-centric lens, whilst this was the lens with the lowest prevalence in their research. They explain this by saying: "The user-centric lens is developed in greater detail than the other three because we believe a better understanding of the underlying 'user' needs is fundamental to increasing the economic success rate of [rural electrification] projects. Yet, such an approach has, until recently, been largely absent from the literature on [rural electrification]" (Schillebeeckx et al., 2012).

Could it be that the two categories added in this research (environmental and frugal) will develop in a similar way in the future? Would environmental concerns and concepts associated with frugal innovation and inclusive growth get more attention over the coming years in writing about rural electrification? It will be very interesting to see how the perspectives of researching rural electrification will develop and change in the future. What events and insights will affect the way of looking at microgrid development? We sure hope there is a role set aside for the environmental and frugal aspects of bringing electricity to rural areas. Hopefully this will inspire other researchers to use them as a different way of looking at rural electrification. At the least it will be very useful and constructive to integrate these views with the four established perspectives of looking at rural electrification.

In the previous paragraph on the interpretation of key concepts and categories, it came forward a few times that the key concepts and thus their categories are related. Even though the six categories are handled as separated entities in this research, it is recognized that these are not six isolated perspectives. It is even acknowledged (see paragraph 2.1) that the integration of insights and learnings from different fields is a necessary process and brings new opportunities. This integration of perspectives will also mean you are bringing different parties together to get answer to questions in the different fields related to rural electrification. As a result partnerships could arise.

With this content analysis we have found an answer to the first part of the research question that we aimed to answer in this chapter. The subject areas that are dominant in studies on rural electrification are: technology, institutional, user-centric and viability. To which two emerging categories are added: environmental and frugal.

In answering the second part of the research question, we have to look back to Table 3. This table gives us a perfect overview of the concepts that are most frequent in studies on rural electrification. Both the key concepts found in the word-frequency count and the two additional categories, will be taken forward in answering the next two research questions. We will continue this research (and not start building the framework now), because we need more context. The identified key concepts are a very good start, but they are only one-word-strong. We will have to deepen and broaden our research to fully understand rural electrification and microgrid feasibility.

4. FACTORS THAT PLAY A ROLE IN RURAL ELECTRIFICATION PROJECTS

The previous chapter has given us an overview of the most important fields in rural electrification. It also provided us with a list of concepts that are frequently used in papers on the topic. In this chapter we will build on this knowledge, as the intention is to find factors that play a role in the development of rural electrification projects.

Thus, this chapter aims to find an answer to the second research question:

Which factors play a role in the development of rural electrification projects?

This distinction between 'concepts' in the first and 'factors' in the second research question is made only in the sense that factors are better defined, more concrete and therefore often consist of more than one word. Also, in applying this distinction, the difference between the methods used to determine these concepts and factors is made clear.

Both the concepts and factors are used to build the feasibility framework. In the second, third and fourth paragraph it will be explained how they both are transformed into measurable criteria. But before we get to that, an explanation will be given about how the factors are found in the first paragraph. The found factors are presented in the second paragraph. A comparison is made between the concept-based and the factor-based criteria, conclusions are drawn from this.

4.1 Deepening and broadening literature research

In the search for factors that play a role in the development of rural electrification projects, both deepening and broadening literature is used. Factors are searched in each of the six categories and for each category a decision is made regarding the literature choice.

When literature is labelled as being deepening, this means it is literature on the topic of rural electrification that is researching one specific category more thoroughly. This deepening literature research is performed for two categories: financial and environmental.

As the deepening financial literature three papers are used that were also part of the selection of 202 papers for the content analysis. The way of selecting these three papers will be explained in the next section of this paragraph. The three papers base their research on "selected papers from academic databases, online reports and conference proceedings from the largest industry conference focussing on [photovoltaic hybrid mini-grid systems]" (Hazelton et al., 2014); field trips and literature (Schmidt et al., 2013); and a review of literature on private sector investment barriers in microgrid-based rural electrification in developing countries (Williams et al., 2015). In their search for benefits, risks, return aspects and barriers, the researchers solely base their work on rural-electrification-specific sources and literature. Their lead is followed in this research project, by not broadening the financial category, but only looking deeper into literature related to this category. So now these papers are not just scanned for the most frequently used words, but are thoroughly researched for factors that play a role in the development of rural electrification projects.

Also in the case of the environmental category the decision is made not to use broadening literature. Because if we would look beyond the scope of rural electrification, it is expected that irrelevant factors will be found. A quick search for environmental criteria resulted in, for example, the environmental health criteria of the World Health Organisation. This list (WHO, 2016) includes criteria like chemicals, toxins, asbestos, ultrasound and dozens more. Most of which would definitely not come forward as important factors in developing microgrids.

So for this category too, we will look deeper into three papers that were part of the selection of 202 papers used in the previous chapter. And again, the selection of these three papers is explained in the next section of this paragraph.

In the case of the other four categories, broadening research is performed. This research is looking beyond the borders of rural electrification. Why does such a broadening literature research need to be performed? Because we want to look further than just the literature that writes about rural electrification directly. Thereby insights will be added based on other theories and in doing so we hope to broaden our look on rural electrification. In all four cases, the direction in which the category is broadened, has already been identified. Four related theories have already been discussed in the previous three chapters. Let us discuss those topics in this context here:

- **Technology dominance theory in relation to the technological category**
  In paragraph 3.3 it was observed that selecting a technology most suited for rural electrification is a difficult decision. We came to realize that a multitude of factors come into play when deciding on the energy generation technology. This is why the theory on technology selection, or technology dominance theory, is used to broaden the technological category.
- **Public-private partnerships in relation to the institutional category**
  In paragraph 1.5 the potential of public-private partnership was already described. Where public and donor funds fall short, private party investments can fill the gap. Additionally, risks can be shared amongst the partners in the partnership. 'Partnerships' is also one of the key concepts that was found in the content analysis. Therefore the broadening of the institutional theory is concentrated around the concept of public-private partnerships.
- **Cultural differences in relation to the social category**
  In paragraph 2.1 we learned that electrification projects often fail because not enough attention is given to understanding the life and habits of the community members. Ignoring the fact that cultural differences exist threatens the successful development of sustainable technology. As ignorance is not an option, this perspective of looking at rural electrification will be added to the social category.
- **Low-income communities** (or the world's poor, or the bottom of the pyramid, or emerging markets, or disenfranchised sectors of society) **in relation to the frugal category**
  In paragraph 2.1 also low-income communities were addressed, as opportunities would arise from the integration of social sciences with technological innovation to develop these communities. And in paragraph 3.2 the 'development perspective' was recognized as an important view, when looking at the journals the 202 analysed papers were published in. Therefore the frugal category will be broadened with literature that focusses around the development of low-income communities. Although in this case, the broadening of the category is a bit less extensive compared to the other three categories. As low-income communities often live in rural areas, the broadening will only be effectively broadening with regards to the electrification part.

The choice of the specific papers that will be used to broaden these four categories will be explained in the following section of this paragraph.

Literature chosen for each of the categories

The technological category is broadened with the use of three papers related to technology dominance theory. In the technological category several options to produce energy are listed, most of them could be deployed in various locations. So why was one technology chosen in the first location and another in the second? Or as Schilling (1998) puts it: "in markets that are in the process of selecting a dominant design, a firm may be technologically locked out because the technology standard it supports is rejected in favour of a competing standard". We hope to get factors that influence this choice by researching papers on technology dominance theory.
On the advice of my supervisor dr. Geerten van de Kaa, who has studied the technology dominance theory topic himself, three papers on this topic are reviewed:

- 'Technological lockout: an integrative model of the economic and strategic factors driving technology success and failure' by Schilling (1998),
- 'Battles for technological dominance: integrative framework' by F. F. Suarez (2003) and
- 'Factors for winning interface format battles: a review and synthesis of the literature' by van de Kaa et al. (2011).

The institutional category will be broadened with learnings from public-private partnerships. A very useful paper is found that reviewed studies on the critical success factors for public-private partnership written by Osei-Kyei and Chan (2015). This paper is considered useful as it presents a comprehensive review of relevant papers and it covers publications done in almost exactly the same time period as is studied in this research. “From the initial search results, a total number of 72 publications on the [critical success factors] for [public-private partnership] projects were identified with 52 different journals from 1990 to 2013 (years inclusive)” (Osei-Kyei & Chan, 2015). The researchers found 57 critical success factors that were mentioned in at least two different papers. We will see that 30 of those are considered to have added value for this thesis.

The concepts in the social category will be expanded with theory on cultural differences. The concepts that currently represent the social category are believed to focus mainly on the social implications of energy poverty, which is really focussing on the current situation with no or poor access to energy. But what would change if electricity access would be realized, when a microgrid project would be developed? To find this out, the exemplary work of Geert Hofstede will be used. Two publications are found to be relevant: ‘Cultural dimensions for project management’ (Hofstede, 1983) and ‘Organising for cultural diversity’ (Hofstede, 1989).

The financial category will be deepened with learnings from papers on investment barriers for electrification projects. We will specifically look at rural electrification, as investing in such projects comes with specific barriers. Four papers are found on the subject, searching ScienceDirect with the terms ‘rural electrification’, ‘investment’ and ‘barriers’ in abstract, title and keywords. Three of those have delivered useful factors:

- ‘Attracting private investments into rural electrification — A case study on renewable energy based village grids in Indonesia’ by Schmidt et al. (2013),
- ‘Enabling private sector investment in microgrid-based rural electrification in developing countries: A review’ by Williams et al. (2015) and
- ‘A review of the potential benefits and risks of photovoltaic hybrid mini-grid systems’ by Hazelton et al. (2014). They looked at technical, financial, social, environmental, organisational and safety risks and benefits and have thereby also provided factors for a few of the other categories.

In looking for environmental factors that play a role in developing microgrid projects, specifically papers on rural electrification are reviewed. ScienceDirect is used to search for papers on the subject, using the search terms ‘rural electrification’, ‘environmental’ and ‘criteria’ in abstract, title and keywords. This resulted in four relevant articles, three of which provided us with useful factors. They all deal with the multi-criteria analysis of rural electrification and have a specific section on environmental criteria:

- ‘Rural electrification options in the Brazilian Amazon - A multi-criteria analysis’ by Fuso Nerini et al. (2014),
- ‘Evaluation of choices for sustainable rural electrification in developing countries: A multicriteria approach’ by Rahman et al. (2013a) and
- ‘Application of multicriteria decision methods for electric supply planning in rural and remote areas’ by Rojas-Zerpa and Yusta (2015).

Finally, we will search for frugal factors, where ‘frugal’ is derived from frugal innovation. As frugal innovation “involves innovating at one of the intersections of technological, institutional and social innovation”, factors found in this category probably will be very much related to these other categories. But as this concept provides such a different way of looking at electrification projects, it is discussed as a separate category. To find the most relevant papers on the topic, I asked prof. dr. Cees van Beers for advice, as he is very knowledgeable on this subject. He provided me with papers on improving the lives of people at the bottom of the economic pyramid, whilst making a profit by Prahalad (2002), on innovation for inclusive growth by George et al. (2012) and on frugal innovation in emerging markets by Zeschky et al. (2011).

Everything described in this paragraph is summarized in Table 4.

Table 4 Categories to apply on factors related to rural electrification projects

Categories	Technological	Institutional	Social	Financial	Environmental	Frugal
Original lenses	Technology	Institutional	User-centric	Viability	-	-
Deepening or broadening view	Technology dominance theory	Public-private partnerships	Cultural differences	Investment barriers	Environmental criteria	Frugal innovation

4.2 Feasibility factors per category

As a result of the before described process a total of 99 factors is found in the six categories. These factors, including their source and some additional context from the paper it was taken from, are presented in Appendix H.

In the selection of these factors the general rule was applied, that if a similar factor came forward in the same or a different category multiple times, it is only listed once, in the category most fitting. Also, a few factors needed to be rearranged. One of the papers that was used to find deepening factors in the financial field, also brought forward factors in the technological, social and frugal categories. Those factors were moved to the right category in Appendix I.

In some cases, the factors taken from the broadening literature require some rewording to make them better fitted to the subject of rural electrification. With this rewording the factors are placed in the context of rural electrification. It is always considered if a reformulation is necessary, never are factors from the broadening literature simply taken over from their original paper. By performing this rewording, the factor is transformed into a criterion. This distinction between 'factor' and 'criterion' is used to be clear about the fact that factors are taken directly from the literature and criteria are subjected to my interpretation. These criteria are added to Appendix I and they are displayed in Table 6.

An example will be given of how factors can be defined differently than criteria. Table 5 shows how one of the technological factors is presented in Appendix H.

Table 5 Selected factor from Appendix H

Factor	Explanation	Source
Big fish	"A big fish is a player (other than the group of format supporters) that can exercise a lot of influence by either promoting or financially supporting a format or by exercising buying power that is so great that this will tip the balance for the format to become dominant in the market [(F. Suarez & Utterback, 1995)]."	(van de Kaa et al., 2011)

To fit the context of rural electrification better, 'big fish' is now defined as 'existence of anchor load'. To determine if this criterion is met, this question will be answered: 'is there a potential client that has a high demand for electricity?'.

It is noteworthy that (again, as with the word-frequency count) the environmental criteria are lowest in number. Apparently, there are just not a lot of different ways to factor in environmental concerns, at least with respect to rural electrification. Even though three papers are reviewed, which is true for most of the other categories too.

The social criteria are quite low in number too. This can be explained by the fact that Hofstede (1983, 1989) has merged several factors under one denominator. The factors of 'recognition' include a spectrum of factors: individualism versus collectivism, large versus small power distance, strong versus weak uncertainty avoidance, masculinity versus femininity. Also the 'awareness' factor is built up of a spectrum of factors: process-oriented versus results-oriented, job-oriented versus employee-oriented, professionally versus parochially oriented, open versus closed systems, tight versus loose internal control, a pragmatic versus a normative. So in a way the factors based on the work of Hofstede (1983, 1989) are umbrella factors, which may explain why the social list is shorter than the other ones.

Table 6 Overview of criteria based on factors from deepening and broadening literature research

Technological	Institutional	Social	Financial	Environmental	Frugal
Efforts of the project partners to invest in learning	Appropriate risk allocation and sharing	Recognition of national culture	Adequate business models	Land requirement for power generation technology	Level of corruption in the country
Base load demand for electricity	Structure and compatibility of the project partnership	Recognition of (the uniting power of) organizational culture	Appropriate payment opportunities offered to consumers	Stress on the ecosystem (caused by the power generation technology)	Level of illiteracy under the local population
Right timing of market entry	Political support	Awareness of business culture differences	Understanding the customers' needs	Lifecycle GHG emissions of power generation technology	Quality of the infrastructure
The project partners' technological knowledge	Community support	Recognition of regional culture	Quality of decentralized operation, maintenance and administration	Local environmental impact	Frequency of currency fluctuations
The project partners' manufacturing capabilities	Transparent procurement	Integration of the project partners with the community	Availability of local human resources	Emissions of CO_2	Level of bureaucratic red tape
The project partners' credibility	Favourable legal framework		Availability of local financial resources	Emissions of SO_2	Level of training received by the project partners on the challenges of bottom of the pyramid markets
Timing of R&D activities	Stable macroeconomic condition		Availability of standards and knowledge transfer on best practices	Emissions of NO_x	Access to advice, technical help and business support services for entrepreneurs
Pricing strategy	Competitive procurement		Availability of information and data		Rural electricity price compared to the urban electricity price
Managing customer's expectations	Strong commitment by all project partners		Availability of national energy technology supplier network		Activity of venture groups and internal investment funds in rural electrification projects
Level of regulation of energy technology by government	Clarity of roles and responsibilities among project partners		Availability of national financial resources (debt and equity)		Existence of a business development task force

Level of regulation of energy technology by private institutions	Financial capabilities of the project partners		Availability of international financial resources (debt, equity, carbon)		Autonomy from central R&D headquarters
Network effects	Level of technology innovation		Negative externalities caused by international donors		Having a team consisting almost exclusively of local engineers
Switching costs for customer (from current source of energy to new electricity provider)	Good feasibility studies		Revenue security		Local human capital
Ability of the project partners to profit from their innovation	Open and constant communication				Existence of partnerships and networks that connect individuals and create opportunities
Characteristics of the energy field	Detailed project planning				Safety of operators
Financial strength of the project partners	Government providing guarantees				Safety of end users
The project partners' reputation	Trust between project partners				
Production capacity	Long term demand for the project				
Compatibility with existing power products	Clear project brief and design development				
Pre-emption of scarce assets	Political stability				
Existence of anchor load	Mature and available financial market				
Effectiveness of the development process	Acceptable level of tariff				
Network of stakeholders	Compatibility skills of the project partners				
Bandwagon effect	Good leadership and entrepreneurship skills				

Competition in the same location	Good governance				
Predictability of future electricity demand	Clear goals and objectives				
Quality of equipment	Employment of professional advisors				
Ability to supply/store continuously	Financial accountability of the project partners				
	Consistent monitoring				
	Reliable power delivery				

4.3 Concepts transformed into criteria

In addition to the somewhat rearranged and reworded factors, Appendix I also contains the concepts from the word-frequency count. As with the factors, I covered them with a layer of my own interpretation. Using the insights gained during the extensive literature research and looking back at the original papers for context, the concepts are transformed into criteria. Based on the 125 concepts found in chapter 3, a number of 58 criteria is constructed that is presented in Table 9.

I have looked at the criteria that are based on the factors, before translating the concepts into criteria. This could be a reason why a certain number of concepts does not mean the same number of criteria are made, as similar criteria were already on the long list. This is made transparent in Table 7.

Table 7 Number of concepts that are used in their transformation into criteria

	Technological	Institutional	Social	Financial	Environmental	Frugal
Concepts	34	24	18	19	5	24
Criteria	12	11	14	12	1	8
# concepts that went into 1 criterion (on average)	2.8	2.2	1.3	1.6	5	3

Let me illustrate the process of constructing criteria based on concepts, with two examples:

Table 8 Selection of concepts from Appendix I

	Concept	Criterion	Question	Unit
3	Jatropha, oil	Availability of bio-oil (jatropha)	Are non-food biodiesel crops available in the area?	
7	Fossil, fuel, hybrid, diesel, gas	Availability of fossil fuels (for hybrid systems)		Length of journey of vil-lager to get diesel, gas or kerosene in km

You will remember the first concepts from the 'interpretation of key concepts and categories' of paragraph 3.5. As already emerged from that paragraph, is 'availability' one of the factors that influences the production of bio oil or bio diesel. That is why these concepts are brought together to define this criterion. In formulating the second criterion quite a few related concepts are brought together. This criterion is given as an example to show that not every single concept is used to create a related criterion, they have been mixed and matched together.

Table 9 Overview of criteria based on concepts from word-frequency count

Technological	Institutional	Social	Financial	Environmental	Frugal
Need for energy storage capacity	Existence of international program(s) that promote rural electrification	Number of households in potential microgrid location	Capital cost of rural electrification project	Extent to which climate change is observed	Availability of material resources in the area
Availability of biogas	Existence of governmental program(s) that promote rural electrification	Number of villages in potential microgrid location	Operation and maintenance cost of rural electrification project		Local knowledge on the operation of the energy generating technology
Availability of bio-oil (jatropha)	Existence of national policy that supports rural electrification (long-term)	Consumer's ability to pay for electricity	Willingness of private party to invest in rural electrification project		Remoteness of the rural area
Availability of biomass (rice straw, rice husk)	Availability of subsidies for electrification projects	Number of people in potential microgrid location	Willingness of public party to invest in rural electrification project		Local knowledge on the management of energy systems
Availability of sources for hydropower (SHP (small hydropower), pico (turbines smaller than 10kW))	Existence of regulatory agency for the power sector	Number of potential users in potential microgrid location	Ability of investing party to get a loan		Local knowledge on the maintenance and control of the electricity network
Availability of sunlight (PV, SHS (solar home system))	Existence of partnerships between the government and private energy companies	Strength of community	Existence of an electricity market for trade		Availability of technical equipment
Availability of fossil fuels (for hybrid systems)	Complexity of decision making process around electrification project	Fuel used for cooking	Activity of banking sector		Local knowledge on the engineering, planning and installation work of the electricity network
Availability of wind	Existence of (governmental) decision making strategy concerning electrification projects	Level of basic education in the community	Oil price		Availability of training in the power field
Availability of geothermal heat	Number of rural electrification initiatives in the country	Influence of women in the community	Size of business sector		
Size of microgrid needed	Level of political will/commitment	Health of the average community member	Revenues for the project partners		
Length of extension needed when connected to existing electricity grid	Level of public participation	Presence of schools in the area	Levelized cost of electricity (LCOE)		

Fuel used for lighting		Willingness to pay for electricity	Income of consumer		
		Level of satisfaction with the current energy supply options			
		Level of migration from areas without access to electricity to areas with access to electricity			

4.4 Criteria made measurable

When both the concepts and the factors are translated into criteria, this results in 157 criteria, which is visualized in Figure 10. These 157 are spread over the six categories with the following distribution: 40 technological, 41 institutional, 19 social, 25 financial, 8 environmental and 24 frugal criteria.

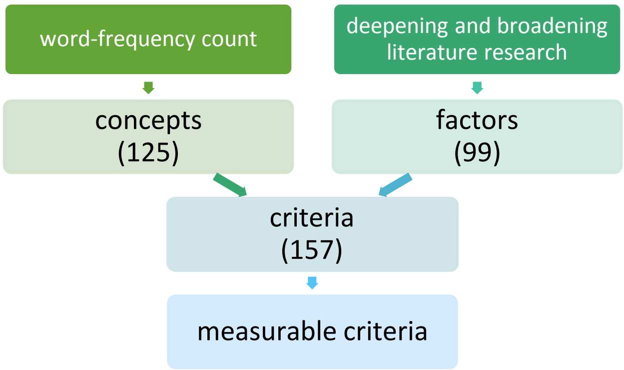


Figure 10 The process of finding criteria

At this point we want to look forward to the final goal of this research: designing a feasibility framework that can be used to assess a potential microgrid location. When we say 'assess' we actually want to be able to score the feasibility level. We want to be able to say that one location scores better on certain criteria than another location. To be able to this, the criteria need to be measurable. So each of them is provided with a way of measuring, this can be with a quantifiable unit or with a yes/no question. It will also be determined if the criteria effect the feasibility of a microgrid in a positive or negative sense. We will elaborate on these effects in chapter 5.Both ways of measuring the criteria are added to the overview tables in Appendix I.

4.5 Two types of criteria compared

The deepening and broadening literature research has been a fruitful exercise in finding factors that play a role in the development of rural electrification projects. The 99 factors that are found give us new and different ways of looking at microgrid feasibility. This in addition to the 58 criteria that were formulated based on the concepts recovered with the content analysis. But how do both types of criteria compare? What are those new ways of looking at microgrid feasibility? Some first conclusions are drawn in this penultimate paragraph.

Technological criteria from concepts and factors compared

The criteria that are based on the concepts, mainly focus on the availability of energy sources needed to produce electricity with the different generation technologies. As a result of the broadening literature research, criteria with a wider perspective are found. The project partners' capabilities in different fields are added as criteria; issues as strategy, competition and collaboration as part of the energy market dynamics are introduced; and on a more technical level the balancing of supply and demand will be added to the long list of criteria. It should also be noted that interrelations with other categories are present: an institutional topic like regulation is part of the technological criteria, as is the social perspective with criteria focussing on customer's expectations and customer costs (this one is also related to the financial category). Although these factor-based criteria are formulated from a technological perspective, it is again observed how the categories are often interrelated. But the main conclusion to draw from this comparison, is that the broadening literature research has provided us with new ways of looking at microgrid feasibility from the technological viewpoint.

Institutional criteria from concepts and factors compared

The concept-based and factor-based criteria are often along the same line of institutional issues: related to governmental support and political conditions. This is a good sign; it means the broadening literature ties in well with the initial rural electrification literature. The broadening literature research also gave us some more lower-level criteria: on the level of the project partners instead of on the national or international level. Therewith it helped to increase the long list to almost four times its size.

Social criteria from concepts and factors compared

For the social category the broadening exercise was the least fruitful, in a quantitate sense anyway, as just five additional criteria were found. Although, as was pointed out in paragraph 4.2, three of the factors on which those criteria are based, should be seen as 'umbrella factors'. Which also explains why these factor-based criteria are on a higher and more abstract level than the concept-based ones. It is believed that this is an example of the need for the knowledge of experts on social and cultural issues. Where I was only able to come up with the more obvious and concrete criteria based on the content analysis, the years of experience of Hofstede (in this case) provided us with a very well-established view on these social and cultural issues. So in that respect the broadening literature research definitely brought something new to the table.

Frugal criteria from concepts and factors compared

For the frugal category, the broadening literature research was a well-needed addition to the content analysis. Here the same applies as for the social category: learning from the experience of established researchers, is a good addition to the first list of concept-based criteria. With the literature on frugal innovation and inclusive growth, the long list of criteria is really taken to the next level. Where the concept-based criteria are mainly focussed around local knowledge and availability of resources, the factor-based criteria offer a wider variety of topics relevant to microgrid feasibility.

Financial and environmental criteria from concepts and factors compared

Finally, the deepening literature research for the financial and environmental categories is reviewed. The two types of criteria are basically interchangeable when looking at the financial category. Some of them are even very much related, like 'revenues for the project partners' and 'revenue security'. This is what we expected, as the deepening literature research put a magnifying glass over the content analysis: we see the same, but with more clarity. For the environmental category the deepening literature research was such a success, that we were only able to define one concept-based criterion: all the other concepts were already covered in the factor-based criteria.

4.6 Conclusions

In conclusion we can say that the deepening and broadening literature research has brought additional insights to rural electrification. The broadening literature has added value in the way that this literature had a wider perspective, included a wider variety of topics and has helped to find factors on a lower level or a higher, more abstract level.

In paragraph 3.4 we stated that we aimed to sharpen the picture of the field of rural electrification, that was created based on the content analysis. It can be concluded that this goal is achieved: the literature research has learned us more about rural-electrification-related topics and theories. It also helped us to understand and define the six categories better, as the technological, institutional, social and frugal categories were linked with related theories. But at the same time the seemingly separate categories have again shown overlap and made clear that integration of the six subject areas is an inevitable process.

A second lesson that can be learned from the broadening literature research, is that rural electrification is not a stand-alone phenomenon. It does not provide challenges that are specific to just the topic of rural electrification, instead it can take learning from other fields and theories. Vice versa, the results from this thesis research might be able to provide the related theories with insights; this will be discussed in paragraph 7.2.

The research performed to answer the second research question also helped in getting the criteria ready for assessment. Steps were made in making the criteria useful to assess potential microgrid developments. It should be said that measuring criteria is not always a straightforward process, in the way that there is often more than one way of looking at a criterion. In the case of the factor-based criteria, the original source of the factor is always used as input for assigning a unit or question to evaluate that criterion. In defining the concept-based criteria, it became clear that many of the concepts taken from the content analysis are related, as several concepts were combined together to make one criterion. With a resulting 99 factors and 157 measurable criteria, this research step has built a solid foundation to answer the final research question.

5. MEASURING THE FEASIBILITY OF A POTENTIAL MICROGRID LOCATION

In the previous chapter we already took a step in the direction of the actual design of the framework that can be used to measure the feasibility of a potential microgrid location. In this chapter we will take the final steps, whilst answering the third research question:

How can we measure the feasibility of a location for the development of a microgrid?

In order to be able to measure the feasibility we will look at two aspects: the weight and effect of the criteria. To determine which criteria have a stronger effect on the feasibility, we will ask a team of experts to evaluate all the criteria. This will also enable us to see which criterion weighs heavier than the other does in the assessment of microgrid potential. Paragraph 5.1 will presents the results of the expert review.

Based on the input of the experts, we will be able to build the feasibility framework in paragraph 5.2. This framework will be applied on two test cases in paragraph 5.3. Where there is learned more about the way of measuring the selected criteria. In testing the feasibility framework, it will also become clear how the weights and effects should be interpreted.

5.1 Criteria selected based on expert review

As 157 criteria is not a workable number for governments, investors or public-private partnerships to apply on a day-to-day basis, we will find a way to select the most important criteria. I have asked a team of 20 experts (Appendix J) to evaluate the criteria on the six long lists. Amongst these 20 experts are people who work at Arup, who are colleagues of my external supervisor dr. Maria Brucoli, who work at Delft University of Technology and is also dr. Simon Schillebeeckx, the writer of the paper that greatly inspired my research.

To let these experts evaluate the long lists with criteria, a survey was sent out, a copy of which is presented in Appendix K. As is explained in the first page of the survey, the team of experts is asked for their help in identifying the most important criteria in assessing the feasibility of a potential microgrid location. The following was stated: "I will use your input to select the most important criteria. The selected criteria will form the basis of the feasibility framework. Keep this in mind when evaluating the criteria: would they be decisive in the assessment of a potential microgrid location?". How the experts evaluated the criteria is shown in Appendix L.

Based on the input of the experts, the relative importance of the criteria will be determined. This concept of relative importance needs to be put into perspective with the following explanation. Some of the same criteria, or factors as they were called at that stage of the research, have been evaluated before on the basis of other cases, they have had a different application. For instance, the technology dominance factors have been reviewed with regards to their importance for the cases of automation systems (van de Kaa et al., 2014a), standard battles (van de Kaa et al., 2014c) and photovoltaic technology selection (van de Kaa et al., 2014b). So if the reader is interested to see how similar factors are evaluated in different cases, he can consult these papers. Or if he is curious to see how the factors on public-private partnerships are ranked, he can use Osei-Kyei and Chan (2015) as a source.

After the experts scored the criteria (which is explained in Appendix M), a short list of criteria is found. This short list is displayed in Table 10 and exists of the 28 criteria with the strongest effect on microgrid feasibility, according to the team of experts. These 28 criteria are, in the eyes of the experts, the most important in comparison with the other 129 criteria; where each criterion is compared to the other criteria in the same category. The criteria of which at least 50% of the experts said they had a 'very strong effect' are selected. This would mean that if a party wants to develop a microgrid in a certain location, it should check these criteria first.

Because if one of these 28 criteria is not met, it has a much stronger impact on the feasibility of that microgrid than the other 129 would have.

Table 10 Short list of criteria based on the condition that 50% of the experts voted 'very strong effect'

Survey answer options	very strong effect	strong effect	weak effect	very weak effect		% of experts that selected 'very strong effect'
Criterion	**# answers**				**total # answers**	
Technological						
Availability of sunlight (PV, SHS)	15	2	1	0	18	**83%**
Length of extension needed when connected to existing electricity grid	12	4	0	1	17	**71%**
Base load demand for electricity	10	4	1	2	17	**59%**
Availability of sources for hydropower (SHP, pico)	9	7	1	1	18	**50%**
Institutional						
Availability of subsidies for electrification projects	11	2	0	1	14	**79%**
Political support	10	2	1	1	14	**71%**
Long term demand for the project	8	4	1	0	13	**62%**
Community support	8	5	0	1	14	**57%**
Political stability	8	3	3	0	14	**57%**
Strong commitment by all project partners	7	5	1	1	14	**50%**
Acceptable level of tariff	7	4	2	1	14	**50%**
Social						
Willingness to pay for electricity	11	4	0	0	15	**73%**
Number of potential users in potential microgrid location	10	5	0	0	15	**67%**
Consumer's ability to pay for electricity	10	5	0	0	15	**67%**
Level of satisfaction with the current energy supply options	8	4	2	0	14	**57%**
Financial						
Appropriate payment opportunities offered to consumers	11	2	0	0	13	**85%**
Operation and maintenance cost of rural electrification project	11	3	0	0	14	**79%**
Adequate business models	11	3	0	1	15	**73%**
Understanding the customers' needs	10	4	0	0	14	**71%**
Willingness of private party to invest in rural electrification project	10	4	0	1	15	**67%**
Capital cost of rural electrification project	9	4	0	1	14	**64%**
Levelized cost of electricity (LCOE)	9	3	1	1	14	**64%**
Quality of decentralized operation, maintenance and administration	8	4	1	1	14	**57%**
Willingness of public party to invest in rural electrification project	8	6	1	0	15	**53%**
Ability of investing party to get a loan	8	5	2	0	15	**53%**
Availability of local financial resources	8	3	3	1	15	**53%**
Availability of national financial resources (debt and equity)	7	2	4	1	14	**50%**
Environmental						
Land requirement for power generation technology	9	5	3	1	18	**50%**

When looking at the short list of criteria with the strongest effect on microgrid feasibility, is seems that money is an important factor. As 12 of the 28 criteria originate from the financial category. In addition, a few of the institutional and social criteria have a financial accent too. We will come back to this observation at the end of this paragraph.

Robustness of the selected criteria

Before the final feasibility framework is established, the robustness of the 28 selected criteria needs to be checked. Because, what if the criteria with the most effect on microgrid feasibility were selected in a different way? What if we had not only looked at the criteria with a 'very strong effect', but we also included the other answers in the scoring of the criteria? Such a quantitative method is not allowed to apply to the ordinal scale of the answer options presented to the experts. It cannot be assumed that 'very strong effect' has the same distance to 'strong effect' as 'strong effect' to 'weak effect' has. But in this robustness test, this assumption is made, with the consequence that this way of scoring the criteria should be interpreted with caution. This quantitative way of analysing the survey results, is only applied to find those criteria that truly have the most impact on microgrid feasibility. The aim is to find a selection of criteria that is not too large, so the resulting feasibility framework will consist of a manageable amount of criteria.

For the sake of this test, all possible answer options are scored with the following logic. If a respondent selected 'very weak effect', they found that this criterion was not decisive in the assessment of the feasibility of a microgrid. This answer is therefore scored with the lowest score of 1 point. When an expert chose the option 'very strong effect', they found this criterion effected the feasibility of a microgrid very much, compared to the other criteria in that category. This answer is scored with the maximum of 4 points. The answer options in between these two extremes are scored with 2 points for 'weak effect' and 3 point for 'strong effect'. Hence, we have assumed the 'distance' between the answer options is evenly distributed: the difference in effect between 'very weak' and 'weak' is equally large as the difference in effect between 'weak' and 'strong'.

Based on this scoring of answer options the mean is calculated. For every answer option the score is multiplied with the number of respondents that chose that answer. This total score is divided by the total number of people that selected one of the four answers (the 'don't know' option is excluded).

In addition to calculating the mean, it is common to determine the median and mode to analyse data. The mode is the most often selected answer. Which in this case will give no new information, as the 28 criteria are selected on the basis that 'very strong effect' was the most selected answer. Therefore just the mean and median will be determined. These two measures will be interpreted to re-evaluate the previous selected 28 criteria. Let us look at Table 11 to see if we need to adjust this selection.

The criteria with a mean of 3.5 or higher have on average quite a strong to a very strong effect on the feasibility. It can be seen that these criteria also have a median of 4, which means the answer 'very strong effect' is the middle value when listing the answers in order. The median value only changes to 3.5 when 50% of the given answers was 'very strong effect' and an even number of experts assessed this criterion, which resulted in the answer options 3 and 4 both being in the middle of the list of answers.

The aim of analysing the mean and the median is to check the robustness of the initial 28 criteria. Based on the assumption that criteria with a median of 3.5 do not convincingly hold their label of *most important* criteria, those five criteria should be removed from the short list. In addition, criteria with a mean below 3.5 are not considered to have the strongest effect either. If the average answer the experts gave is closer to 'strong effect' than 'very strong effect' they are not considered to be *most important*.

This leaves a robust selection of 15 criteria that have the strongest effect on microgrid feasibility, which are highlighted with thicker, dark-green edges around their cells in Table 11. The fact that this way of analysing the survey results provides us with a smaller selection can be explained: when only looking at the percentage of answers given, the 'very strong effect' labelled criteria are not levelled out with the votes for 'weak effect' and 'very weak effect'. When calculating the mean, these answers are included. This means that if too many experts found the criterion to have a weak effect, it is not included in the final selection. As a result the criteria over which there was disagreement between experts did not make the list, which makes for a robust selection of criteria. It can be seen that the 13 criteria that did not make the final selection, often have a higher summed percentage of experts that selected 'weak effect' and 'very weak effect', compared to the 15 criteria that were selected.

Table 11 Selected criteria checked for robustness with median, mean and percentages of experts that selected different answer options

Criterion	median	mean	% of experts that selected 'very strong effect'	summed % of 'weak effect' and 'very weak effect'
Technological				
Availability of sunlight (PV, SHS)	4	3.8	83%	6%
Length of extension needed when connected to existing electricity grid	4	3.6	71%	6%
Base load demand for electricity	4	3.3	59%	18%
Availability of sources for hydropower (SHP, pico)	3.5	3.3	50%	11%
Institutional				
Availability of subsidies for electrification projects	4	3.6	79%	7%
Political support	4	3.5	71%	14%
Long term demand for the project	4	3.5	62%	8%
Community support	4	3.4	57%	7%
Political stability	4	3.4	57%	21%
Strong commitment by all project partners	3.5	3.3	50%	14%
Acceptable level of tariff	3.5	3.2	50%	21%
Social				
Willingness to pay for electricity	4	3.7	73%	0%
Number of potential users in potential microgrid location	4	3.7	67%	0%
Consumer's ability to pay for electricity	4	3.7	67%	0%
Level of satisfaction with the current energy supply options	4	3.4	57%	14%
Financial				
Appropriate payment opportunities offered to consumers	4	3.8	85%	0%
Operation and maintenance cost of rural electrification project	4	3.8	79%	0%
Adequate business models	4	3.6	73%	7%
Understanding the customers' needs	4	3.7	71%	0%
Willingness of private party to invest in rural electrification project	4	3.5	67%	7%
Capital cost of rural electrification project	4	3.5	64%	7%
Levelized cost of electricity (LCOE)	4	3.4	64%	14%
Quality of decentralized operation, maintenance and administration	4	3.4	57%	14%
Willingness of public party to invest in rural electrification project	4	3.5	53%	7%
Ability of investing party to get a loan	4	3.4	53%	13%
Availability of local financial resources	4	3.2	53%	27%
Availability of national financial resources (debt and equity)	3.5	3.1	50%	36%
Environmental				
Land requirement for power generation technology	3.5	3.2	50%	22%

Overall average score of the categories

It is also interesting to use the calculated means of the criteria to look at the overall average score per category. This score can be used to say something about the relative importance of that category compared to the other categories. Because if the criteria in a category are often labelled to have a very strong effect, these criteria and thus the category in which they are in are important. This is shown in Table 12, where the categories are both ranked based on the survey and on the content analysis results.

Table 12 Average score of all criteria per category based on survey and results from content analysis – to compare

Ranking based on survey	Minimum score	Maximum score	Average score		Ranking based on content analysis	% of papers published
Financial	2.1	3.8	3.2		Technology	51%
Social	2.2	3.7	3.1		Institutional	25%
Institutional	2.2	3.6	3.0		User-centric	13%
Technological	1.8	3.8	2.9		Viability	11%
Frugal	1.9	3.3	2.7			
Environmental	1.9	3.2	2.3			

It is apparent that the top four of categories from the survey does not include the two categories that were added based on the results of the content analysis. This explains why no environmental nor frugal criteria made the short list: not only their overall average score was low, but also none of the criterion's average scores went over the 3.5 limit.

For the environmental category two of experts motivated their choices. Schillebeeckx (2016) commented in the survey: "Problem here is that from an ecological standpoint all these things should matter and a government should take them into consideration, but I fear practically they hardly do". And Brosz (2016) agreed: "Environmental concerns can be (and should be) drivers for microgrid feasibility and adoption. However, from what I've seen, it isn't a huge driver".

There is no concrete evidence as to why the frugal criteria score comparatively low. It might be that I should have given this category a better introduction, as this category is less self-explanatory than the others are. Also, two of the experts suggested a different title for the field (Anonymous, 2016; Van Beers, 2016) and one stated that "answering these questions is hard, because they are tightly linked to institutional criteria" (Van der Voort, 2016). Could this confusion have interfered with the way the experts evaluated the frugal criteria? Or did they just consider these criteria to be less important?

Another interesting thing to notice is the fact that the top four of categories is inverted compared to the ranking of the lenses from the content analysis. For example, viability was lowest on the list of dominant lenses in the content analysis, but is ranked highest based on the view of the experts. This is not surprising, as the viability lens was used most often as a secondary lens. And, as was explained in paragraph 1.4 and 1.5, financial risks are often the main reason why rural electrification is not realized yet. So I strongly agree with the experts that financial criteria should weigh heavily in the assessment of the feasibility of a microgrid development.

5.2 The preliminary feasibility framework

To finalize the feasibility framework, the percentage 'very strong effect' and the effects from Appendix I are put in the overview of Table 13.

The 'very strong effect' percentage each criterion can be used in determining the weight of that criterion in the assessment of a potential microgrid location. Governments, investors and public-private partnerships can choose to use this measure of relative importance in determining a score for the development site they are investigating in. Or the user of the feasibility framework can apply their own weights, potentially in consultation with their project partners.

In some of the papers that were used to formulate the factor-based criteria, weights have been determined for the original factors. These can be used by the project partners to determine their own weights. Therefore it would be good to investigate which of the final 15 criteria are concept-based and which are factor-based. For clarity, an extra column is added to Table 13 with the origin of the criteria. It can be seen that one third of the criteria originate from the deepening and broadening literature research, which has clearly contributed significantly to the design of the feasibility framework.

Table 13 The preliminary feasibility framework with percentages, effects and origin of criteria

Criterion	Percentage	Effect*	Concept- or factor-based
Technological			
Availability of sunlight (PV, SHS)	83%	+	Concept
Length of extension needed when connected to existing electricity grid	71%	+	Concept
Institutional			
Availability of subsidies for electrification projects	79%	~	Concept
Political support	71%	~	Factor
Long term demand for the project	62%	~	Factor
Social			
Willingness to pay for electricity	73%	+	Concept
Number of potential users in potential microgrid location	67%	+	Concept
Consumer's ability to pay for electricity	67%	+	Concept
Financial			
Appropriate payment opportunities offered to consumers	85%	~	Factor
Operation and maintenance cost of rural electrification project	79%	-	Concept
Adequate business models	73%	~	Factor
Understanding the customers' needs	71%	~	Factor
Willingness of private party to invest in rural electrification project	67%	~	Concept
Capital cost of rural electrification project	64%	-	Concept
Willingness of public party to invest in rural electrification project	53%	~	Concept

*
Criterion is labelled + if a high score means high feasibility of the potential microgrid location
Criterion is labelled – if a high score means low feasibility of the potential microgrid location
Criterion is labelled ~ if this is a yes/no criterion: yes is the favourable answer, no is the undesired answer

These 15 criteria have the strongest impact on the feasibility of a microgrid. So what happens if one of the criteria is not met? Does this mean that developing a microgrid in the assessed location is a definite no go? That depends, if all criteria have a negative effect on the feasibility, it will be hard to recover from that. Of course it will be good input for a local or national government: they will know what areas to improve before rural electrification can be realized. If just a few criteria score badly, this might be a good reason to do a more detailed assessment.

For example, if the first criterion of the framework (availability of sunlight) scores badly, that does not mean all renewable sources of energy would not work in the potential microgrid location. It would be too quick to cancel the whole microgrid. You might want to look at some of the other criteria first.

The first step could be to evaluate the additional 13 criteria that were found in the very-strong-effect-method of selecting criteria. And if the project partners wanted to do an even more detailed investigation of the location, they could use the criteria of which between 33% and 50% of the experts found they had a very strong effect. This would give us (in addition to the initial 28) an extra 50 criteria to assess the feasibility. These are listed in Figure 11, with the number of criteria given for every category and with the criteria ranked from strongest to weakest effect.

Technological (14): Availability of fossil fuels (for hybrid systems), Switching costs for customer (from current source of energy to new electricity provider), Availability of wind, Pricing strategy, Size of microgrid needed, Quality of equipment, Ability to supply/store continuously, Ability of the project partners to profit from their innovation, Level of regulation of energy technology by government, Need for energy storage capacity, Managing customer's expectations, Right timing of market entry, Availability of geothermal heat, Effectiveness of the development process.

Institutional (17): Trust between project partners, Appropriate risk allocation and sharing, Existence of governmental program(s) that promote rural electrification, Level of political will/commitment, Existence of national policy that supports rural electrification (long-term), Reliable power delivery, Existence of partnerships between the government and private energy companies, Favourable legal framework, Complexity of decision making process around electrification project, Structure and compatibility of the project partnership, Compatibility skills of the project partners, Good governance, Level of public participation, Good feasibility studies, Consistent monitoring, Level of technology innovation, Open and constant communication.

Social (7): Number of households in potential microgrid location, Number of people in potential microgrid location, Integration of the project partners with the community, Awareness of business culture differences, Number of villages in potential microgrid location, Recognition of national culture, Fuel used for cooking.

Financial (8): Income of consumer, Revenues for the project partners, Revenue security, Availability of national energy technology supplier network, Availability of international financial resources (debt, equity, carbon), Oil price, Availability of local human resources, Negative externalities caused by international donors.

Frugal (4): Remoteness of the rural area, Availability of technical equipment, Local knowledge on the maintenance and control of the electricity network, Availability of training in the power field.

Figure 11 The 50 criteria with a score between 33% and 50% based on the expert review

5.3 The feasibility framework applied

We already started thinking about the application of the framework to assess the feasibility of a location. But before we proceed with this thought experiment, let us be clear about the potential users of the framework. It was established that the feasibility framework should be useful for governments, investors and public-private partnerships. These parties could become project partners in the development of a microgrid. This collective term will be used in this paragraph, so to be clear: the project partners are the public and/or private parties that want to develop a microgrid. They can be the owner, investor, builder and/or operator of the to-be-developed microgrid.

So how would the application of the feasibility framework work in practice? To illustrate this, the framework will be applied on two example cases. Two locations are selected based on the level of access to electricity presented in Appendix B and based on the most frequently mentioned countries from the word-frequency count. The combined results of all four word-frequency analyses is listed in Table 14, these are the countries, areas and continents that were mentioned most often. The percentage of the population in those countries is added in the right column.

Table 14 Locations most used in papers on rural electrification with access to electricity percentages

Word count	Location	% of population with access to electricity
1003	India	78.7%
931	Africa	-
741	China	100%
577	Nepal	76.3%
318	Brazil	99.5%
291	Bangladesh	59,6%
235	Malawi	9.8%
230	Amazon	-
203	Indonesia	96.0%
154	Nigeria	55.6%
149	Malaysia	100%
106	Tanzania	15.3%

We aim to choose a test case that is both written about in scientific articles on rural electrification and has a low percentage of access to electricity. The first will mean there (presumably) is data available, the second that this location is in a target country. Because we also want to test the framework on different continents, Malawi and Bangladesh are chosen as test cases.

These two locations will be discussed criterion per criterion, not case by case. In doing so, we will be able to evaluate the criteria by comparing the two ratings. Thus it is possible to define what a high score and what a low score is for each of the criteria in the framework. It will also provide insights with regards to the way of measuring is suitable: is the posed question the right question to ask, is the unit of measuring fitting? If needed, the framework will be adjusted based on these insights.

In some cases it will be impossible to assess the criterion with a desk research. For example, criterion 12 will need a market research to be conducted to evaluate the criterion (see Table 15). In case we are unable to measure a criterion, we will provide the project partners with advice on how they would be able to assess the criterion.

For the purpose of the test we will look at two randomly chosen areas in the two countries. In both cases we will focus on the most north-western part of the country: in Malawi this area is the Chitipa District and in Bangladesh this is the Panchagarh District (Figure 12).

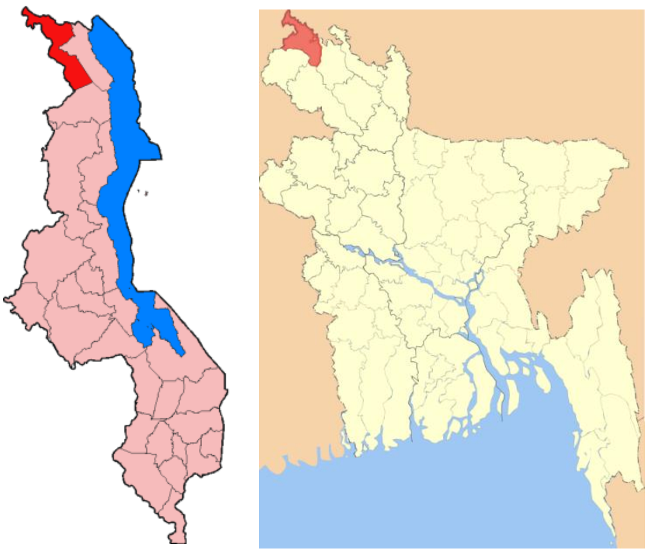


Figure 12 The Chitipa District in Malawi (Acntx, 2006) and the Panchagarh District in Bangladesh (Nafsadh, 2014)

Table 15 Feasibility framework with way of measuring and effects

	Criterion	Question/unit	Effect*
Technological			
1	Availability of sunlight (PV, SHS)	Average daily solar radiation in kWh/m^2/day	+
2	Length of extension needed when connected to existing electricity grid	km	+
Institutional			
3	Availability of subsidies for electrification projects	Are subsidies available for electrification projects?	~
4	Political support	Is there political approval to spend public money on rural electrification projects?	~
5	Long term demand for the project	Is the community there to stay for the long term (they do not lead a nomadic existence)?	~
Social			
6	Willingness to pay for electricity	% of income that people want to spend on electricity	+
7	Number of potential users in potential microgrid location	% of people that want to use electricity from the total population	+
8	Consumer's ability to pay for electricity	Daily income in $/day/household	+
Financial			
9	Appropriate payment opportunities offered to consumers	Is the electricity price adjusted for the ability of consumers to pay?	~
10	Operation and maintenance cost of rural electrification project	Recurring costs for operation and maintenance in $/year	-
11	Adequate business models	Is information shared about pilot projects?	~
12	Understanding the customers' needs	Is market research conducted to understand the location specifics? Do the project partners have a customer service?	~
13	Willingness of private party to invest in rural electrification project	Is a private party willing to invest in the project?	~
14	Capital cost of rural electrification project	Total costs of one-time expenses in $	-
15	Willingness of public party to invest in rural electrification project	Is a public party willing to invest in the project?	~

*
Criterion is labelled + if a high score means high feasibility of the potential microgrid location
Criterion is labelled – if a high score means low feasibility of the potential microgrid location
Criterion is labelled ~ if this is a yes/no criterion: yes is the favourable answer, no is the undesired answer

1. Availability of sunlight

[Average daily solar radiation in kWh/m^2/day]

To measure the availability of sunlight, the global horizontal irradiation will be assessed as this "is the most important parameter for evaluation of solar energy potential of a particular region and the most basic value for PV simulations" (GeoModel Solar, 2016). The free downloadable information on solar radiation from GeoModel Solar (2016) is used to assess this first criterion, see maps in Appendix N.

- The Chitipa District in Malawi has an average annual sum of global horizontal irradiation of between 1900 and 2300 kWh/m^2 (based on the period 1994-2014)
- The Panchagarh District in Bangladesh has an average annual sum of global horizontal irradiation of between 1500 and 1700 kWh/m^2 (based on the period 1999-2011)

To compare: for the biggest part of the Netherlands this number lies between 1025 and 1050 kWh/m^2 (average annual sum, period 1994-2010). And for the whole world this number varies between 800 and 2800 kWh/m^2 (long term average of annual sum).

The first conclusion to draw is that the solar radiation, with the use of this source, is not a daily but an annual average. With 1800 kWh/m^2 being in the middle of the range of world irradiation levels, we can say Bangladesh scores relatively low on this criterion and Malawi high. If we wanted to compare these locations, or any two location for that matter, we can use the average level of global horizontal irradiation directly.

2. Length of extension needed when connected to existing electricity grid

[km]

The length of extension needed to connect an area to the existing grid, tells us something about the feasibility of a microgrid for that area. When the area is very remote, hard to reach because of geographic characteristics or just simply far away from the existing grid, this will mean an extension will not be feasible or viable. Thus an off-grid option, like the microgrid, will be a good fit for that area.

In Appendix O the existing national power grids of Malawi and Bangladesh are displayed. Based on those maps we will say something about the length of extension needed to connect the target areas:

- "The [Malawian] national grid almost exclusively serves urban and peri-urban areas – around 25% of urban households have electricity, compared to 1% of rural households. As such, the 85% of Malawians that live in rural areas are not served by grid-connected electricity and the great majority of the rural population is unlikely to be grid-connected in the near future, even with national grid extension programmes such as The Malawi Rural Electrification Project (MAREP)" (Reegle, 2012).
  This is immediately proven when looking at the map of the national grid. The Malawian transmission grid reaches up to Rumphi, which is the city at the most northern transmission substation. This city is located approximately 50 km away from the south of the Chitipa District and 200 km away from the north border of the District.
  So it is not surprising that companies as MEGA (Mulanje Electricity Generation Agency) started focussing on the development of off-grid solutions in Malawi. Or how they put it themselves: "With a national grid that is simply too expensive to extend to rural regions […] MEGA's model, if successful, is seen to be a positive and impactful solution to the challenge of electrification which can […] effectively complement the existing national grid system" (McKinnon, 2013).
- "The Padma-Jamuna-Meghna river system divides Bangladesh into two zones, East and West. The East contains nearly all of the country's electric generating capacity, while the West, with almost no natural resources, must import power from the East. Electricity interconnection from the East to the West was accomplished in 1982 by a new, 230-kilovolt (kV) power transmission line" (GENI, 2014).
  This interconnection is now extended to reach Thakurgaon, which is a city in the northwest of Bangladesh, in the District directly south of the Panchagarh District. On the map in Appendix O it can also be seen that there are plans made to connect Panchagarh to the national grid. It can thus be concluded that the extension needed to connect the looked at area, is virtually zero.

Based on this test, it is believed the distance to the existing grid a good measure with regards to microgrid feasibility. It can also be concluded that Malawi score higher than Bangladesh on this criterion, which is illustrated by the fact that there are off-grid initiatives in the country.

3. Availability of subsidies for electrification projects

[Are subsidies available for electrification projects?]

- In the Rural Electrification Act of 2004 it is stated that grants and subsidies are given out to agreed concession areas, with money from the Malawi Rural Electrification Fund (Parliament of Malawi, 2004). So the question asked in assessing this criterion is 'yes'.
  Although a note needs to be placed, as the World Bank is very critical of this subsidy: "The heavily subsidized price of electricity—to the degree that electricity is the cheapest cooking fuel in the country—has exacerbated these problems by encouraging an explosion of demand among those that have an electricity connection. The government's justification for subsidizing electricity is to make it affordable to the poor for lighting, but as the great majority of the poor do not have electricity supply the greater part of the benefits from the subsidy go to middle- and upper-income consumers" (Girdis, 2005).
- The Bangladesh Institute of Development Studies, together with the International Institute for Sustainable Development's Global Subsidies Initiative, has written 'A citizen's guide to energy subsidies in Bangladesh'. So yes, subsidies are available for electrification projects.

Although these institutes too place a critical note to this subsidy: “A strong rationale for subsidizing energy is to support access to energy for the poor. While there is some degree of truth to this argument, energy subsidies often benefit wealthier segments of society is proportionately, given that they use more energy. This is true in Bangladesh, where the poor are mostly dependent on traditional biomass and have little access to electricity and other public utilities. Energy subsidies also divert public funds from social programs and welfare schemes that may be of greater benefit to the poor. Nonetheless, an increase in energy costs can have a disproportionate impact on poorer citizens if adequate social safety nets are not in place” (IISD, 2012).

For this test we can learn that asking if subsidies are available is in principle the right question to ask, although the project partners should also be questioning if the subsidies are beneficial for the rural population.

4. Political support

[Is there political approval to spend public money on rural electrification projects?]

We realize this criterion is strongly related with the question if subsidies are available for electrification projects. There are just two subtle differences: this criterion uses the word ‘rural’ where the other does not; and the subsidies mentioned in the other criterion do not necessarily have to come from the national government, whilst political support does. With this in mind, let us look at the two areas:

- After seven previous phases since the start of the before-mentioned MAREP project in the 1980s, “the government of Malawi has allocated to MAREP Phase 8 an estimate of MK12.1 Billion to run the project.” “Minister of Natural Resources, Energy and Mining Bright Msaka says government is expected to reach out to at least 81 [Trading] Centres from each of districts of the country when phase eight of the rural electrification program starts this year” (Zobo, 2015). Thus Chitipa will get three electrified trading centres. If this is supporting rural electrification, is a different question. We are leaning towards ‘no’, strengthened by the report of the World Bank: “The government has expressed its intention to promote rural electrification, and a new framework of institutional arrangement has been drawn up under which responsibility for rural electrification has been given to the Ministry of Energy and Mining (MOEM). There is, however, no practical policy on rural electrification. The existing regulations are unclear with regard to whether ESCOM [(Electricity Supply Commission of Malawi)] or the MOEM is ultimately responsible for rural electrification” (Girdis, 2005).
- Commissioned by the United States Agency of International Development (USAID), a report was written analysing the integrity in Bangladesh’s rural electrification. Because at they say: “Electric power distribution is important for economic development and governance and a frequent target of USAID intervention, but corruption frequently undermines its sustainability” (Nathan Associates Inc., 2006). This report concludes that “the Bangladesh Rural Electrification Program (BREP) has been able to maintain a high level of integrity in an environment where other power distribution networks have not”(Nathan Associates Inc., 2006).
  In addition to this finding, insights are given by Taniguchi and Kaneko (2009): “Despite the country’s political, social, and economic instability, the REP in Bangladesh has achieved a certain level of results in terms of good system design, low system loss, and high bill collection rate. It has been admired as a best practice. Nevertheless, the recent program is said to be a “politically biased program””. With this the authors mean that “the program is often under strong political pressures that demand construction of new electric lines in areas of interest to politicians with disregard to predetermined master plans” (Taniguchi & Kaneko, 2009).

It can be concluded from these test cases that this criterion is hard to assess. Because for both cases it is through that rural electrification officially gets political support. But it is debatable whether the governments live up to their promises. We therefore think it will be hard to assign this criterion with a clear ‘yes’ or ‘no’.

5. Long term demand for the project

[Is the community there to stay for the long term (they do not lead a nomadic existence)?]

- There exist no nomadic communities in Malawi. As far as we are able to assess, the people in Chitipa are there to stay.
- There exists one nomadic group in Bangladesh: “the one-million-strong river-gypsy community of Bangladesh, also known as Bede” (B. Das, 2013). But, as far as we are able to assess, the people who live on the ‘mainland’ of Panchagarh are there to stay.

Based on an online search the question for both areas will be answered with ‘yes’. Although if these were real potential location, the project partners would contact the local population to ask them this question themselves.

6. Willingness to pay for electricity

[% of income that people want to spend on electricity]

We are unable to assess this criterion with just a desk research, the project partners would have to perform a survey under the local population.

But we can say that project partners should be aware of the common misperception about developing markets: that the goods sold there are incredibly cheap. “In fact, throughout the developing world, urban slum dwellers pay, for instance, between four and 100 times as much for drinking water as middle- and upper-class families” (Prahalad, 2002). From this is can be taken that people in rural areas might be willing to pay a larger part of their income to get access to electricity as someone might have thought.

Urpelainen and Yoon (2015) have researched the willingness to pay for a SHS in rural India, they have found that for example the level of education increases the willingness to pay. This paper might be useful for the project partners when making an assessment of the willingness to pay for electricity amongst the population in their target location.

7. Number of potential users in potential microgrid location

[% of people that want to use electricity from the total population]

We are unable to assess this criterion with just a desk research, the project partners would have to perform a survey under the local population. Asking the potential users to pay a participation fee is a possibility; we will come back to this when assessing the 9th criterion.

8. Consumer’s ability to pay for electricity

[Daily income in $/day/household]

The International Fund for Agricultural Development (IFAD) of the United Nations gives a good idea of the status of the rural population of Malawi and Bangladesh:

- “Malawi is one of the world’s poorest countries, ranking 160th out of 182 countries on the Human Development Index. Progress towards reaching the Millennium Development Goal of eradicating extreme poverty has been limited. According to the United Nations Development Programme’s Human Development Report for 2009, about 74 per cent of the population still lives below the income poverty line of US$1.25 a day and 90 per cent below the US$2 a day threshold. The proportion of poor and ultra-poor is highest in rural areas of the southern and northern parts of the country” (IFAD, 2009b).
- “Since gaining independence in 1971, Bangladesh has increased its real per capita income by more than 130 per cent and cut poverty by more than half. It is now well positioned to achieve most of its Millennium Development Goals, but it remains a low-income country with substantial poverty, inequality and deprivation. At least 45 million people in Bangladesh, almost one third of the population, live below the poverty line, and a significant proportion of them live in extreme poverty. The poverty rate is highest in rural areas, at 36 per cent, compared with 28 per cent in urban centres” (IFAD, 2009a).

It appeared hard to find exact numbers on the daily income of the people living in Malawi and Bangladesh. So the unit of measurement will be changed to percentage of the population that lives below the income poverty line. (Because of this change, the effect of the criterion needs to be changed from a positive effect in a negative effect: the more people are unable to pay for electricity, the less likely it is that a microgrid will be viable.) The World Bank has numbers on the percentage of the population that has to live of less than $1.90 a day (World Bank, 2016a). For Malawi this was 70.9% in 2010 and in Bangladesh lived 43.7% below the poverty line in the same year. In both countries is the poverty rate highest in the rural areas, so it might even be the case that these percentages lie higher in Chitipa and Panchagarh. We can at least say that the people in Chitipa will have a hard time paying for electricity, if they would get access to it.

9. Appropriate payment opportunities offered to consumers

[Is the electricity price adjusted for the ability of consumers to pay?]

This is fully dependent on the plans of the project partners, multiple factors will probably be taken into account. “Rural customers are usually poor, typically requiring subsidies to access energy. It can be challenging to set a price that is both sufficiently high to give the investor a return and low enough to make it affordable to the consumer” (Hazelton et al., 2014).

One should also think about the ways offered to the consumer to pay the energy bill: will they pay a standard daily, weekly or monthly amount? Or will they be charged on a pay-as-you-go basis? Hong et al. (2015) also wrote about the option of charging a participation fee, to sort out those who were indeed willing and determined to make use of a microgrid. “The challenge, however, lies in properly defining users' capacity and willingness. There are difficulties in interpreting information about the users and communities amidst the limited time and budget constraints of most development projects. There are perceived merits in determining how limited information about users can be used to characterize their capacities and enable developers to effectively assess and foresee sustainability” (Hong et al., 2015).

We are thus unable to assess this criterion at this point. But we do want to add ‘an appropriate payment scheme’ to the way of measuring this criterion.

10. Operation and maintenance cost of rural electrification project

[Recurring costs for operation and maintenance in $/year]

The costs for operation and maintenance will dependent on the chosen energy source and generation technology. This choice needs to be made by the project partners, dependent on the energy source most appropriate in the target location. Therefore this criterion is strongly related to the first one. And to the criteria that scored above 33% in the expert review, that deal with other sources of energy.

If the project partners have experience in the development of microgrids, they will be able to use the previously completed projects to make an estimation of these costs. They also might be able to model the expected costs for a microgrid development. Otherwise, they should use their network in learning from similar projects.

11. Adequate business models

[Is information shared about pilot projects?]

From the paper of Hazelton et al. (2014), who reviewed potential benefits and risks of photovoltaic hybrid mini-grid systems, we learned that having an effective business model is required to increase the deployment of mini-grids. They refer to Van Leeuwen (2013) who suggests that information sharing about pilot projects can assist in the development of adequate business models. Therefore this as a way of measuring this criterion is chosen.

We believe for the two test cases, this question will be answered with ‘yes’. As one of the reasons for me to choose Malawi and Bangladesh as a test, is the fact that they were mentioned frequently in papers on rural electrification. So we predict there will be enough information available to build an effective business model.

If the project partners also will find information on previously developed projects in their target locations, is hard to say. There might be a lot of information openly available, as we have experienced so far, but if they wanted to get more detailed information, they would have to ask other parties for help. Which in our eyes will only contribute to getting a better understanding of the looked-at location. Although they might be limited because competition could become an issue.

12. Understanding the customers' needs

[Is market research conducted to understand the location specifics? Do the project partners have a customer service?]

We are unable to assess this criterion with just a desk research, the project partners would have to perform a market research under the local population. But we do want to say a bit more about the possible steps that can be taken by the project partners in understanding their customers’ needs.

This criterion originates from the paper written by Schmidt et al. (2013) which is based on a case study performed in Indonesia. From the interviews they conducted it became apparent that renewable energy based village grids “projects often suffer from understanding the needs of their customers” (Schmidt et al., 2013). Challenges that are often faced by investors are: “an “electricity is for free” mind-set, difficulties in collecting electricity fees, avoiding electricity theft, and sensitively handling their position as monopolists” (Schmidt et al., 2013).

This is why the researchers advised to conduct market research as a first step and to introduce a customer service as a second step. “Market research tools which are recommended for rural contexts are home stays, fieldtrips, contacts with competitors and cooperation with local organizations” (Schmidt et al., 2013). Customer “service consists of proper maintenance services including product performance guarantees and warranties as well as regular visits in the villages in order to collect feedback” (Schmidt et al., 2013). As a final advice the researchers state that community involvement can support in carrying out these activities.

13. Willingness of private party to invest in rural electrification project

[Is a private party willing to invest in the project?]

To assess this criterion it will be explored if private parties have invested in rural electrification in Malawi and Bangladesh before.

- The situation in Malawi did not seem optimistic: “The current electricity power supply in Malawi is quite unreliable and according to recent estimates, Malawi loses about USD 16 million annually due to power outages. Investing by the private sector in electricity generation remains a challenge due to the government subsidy provided to ESCOM in electricity generation, which gives unfair advantage to ESCOM over any would be investors, hence ESCOM has remained the sole electricity generation company to date” (Gamula, 2013). But the situation has changed in the last few years: “Following the reforms in the electricity sector, ESCOM Ltd was commercialized and mandated to operate as a commercial entity. ESCOM Ltd could then not continue implementing MAREP since most MAREP projects were deemed not economically viable” (Odziwa, 2015). So the government took over responsibility of MAREP. But at the same time, companies like MEGA (which was mentioned in discussing the second criterion) have taken it upon themselves to commercialize rural electrification. In the case of MEGA, this is done with micro-hydro power in the most densely populated district of Malawi: Mulanje (Practical Action, 2016).
  So we would answer the question with ‘yes’, but it is not a convincing one.
- A period of economic growth in Bangladesh was the trigger for the government to restructure the power sector: “With the economy performing very well during 1992-95, the demand for electricity grew substantially. Constrained by the paucity of its resources, the Government decided to allow private sector participation in the power sector. However, it was quickly realized that private capital, whether domestic or foreign, would not come into a sector, which was not financially viable and was not technically, organizationally and legally structured in a way conducive to attract it. Faced with a grim possibility of serious electricity shortages during the next few years and to enable the sector to be financially self-sustaining and also attract private capital, the cabinet approved in principle, the inter-ministerial committee report named "Power Sector Reforms in Bangladesh (PSRB)", in September 1994” (DESCO, 2016). As a result of the reforms the transmission is in hands of a private company and for the distribution company the plan is to sell shares of the company to the private sector. It has also led to a number of Independent Power Producers (IPP) to enter the market (EGCB, 2016).
  So like Malawi, Bangladesh is slowly having more private parties invest in their energy sector.

We have based this assessment on available information online, but the project partners will probably have a potential investor in their network, or they might even have a private party invest in the project as one of the partners. So the assessment of this criterion might go differently from our efforts above.

14. Capital cost of rural electrification project

[Total costs of one-time expenses in $]

The capital cost of developing a microgrid is very much dependent on the chosen energy generation technology. Actually, everything we wrote on operation and maintenance costs under criterion 10 is true for this criterion too, so we would like to refer to that.

15. Willingness of public party to invest in rural electrification project

[Is a public party willing to invest in the project?]

Like with criterion 13, previously made investments by public parties in rural electrification projects in Malawi and Bangladesh will be explored.

- We have already seen that the Malawian government invests in rural electrification under the heading of MAREP. The World Bank also invested in Malawi's electricity supply system (World Bank, 2011).
- We have already seen that with the BREP the Bangladeshi government invests in rural electrification. They are also supported by the World Bank, which invested in the Rural Electrification and Renewable Energy Development (RERED) project for the second time (World Bank, 2016b).

As public parties have invested in rural electrification in the past, it is excepted that they will do so in the future. Unless the locations are developed to such an extent that no investments are needed anymore, but we have certainly not reached that point yet. So the answer for both countries is 'yes'.

5.4 The feasibility framework improved

We have now assessed all 15 most important criteria. Based on these two test cases, a few adjustments need to made to the feasibility framework. Therefore the framework is displayed again in Table 16, with the improvements shown in **bold**.

To complete the assessment of the test cases, a conclusion will be drawn from the evaluation of the two areas in Malawi and Bangladesh. The seven criteria that we were unable to evaluate with a desk research will not be included in this. (Note: in real life, the project partners would be more likely to be able to assess the criteria, as they will be able to do more than just a desk research.) Then, it is clear that the two rural location have similar results on five of the remaining nine criteria. Therefore we will focus on the three criteria that gave different results for the two areas, these criteria are 1, 2 and 8. It is remarkable that all three criteria have a metric measurement level, instead of a dichotomous yes or no way of assessing the criterion. This can be explained with the fact that if you have just two ways of assessing a criterion, chances are it is reviewed the same. This is less likely with a metric measurement level.

When evaluating the scores on the three criteria with a different result, we see the following:

- On criterion 1 Malawi scores higher on feasibility, with a higher level of solar radiation.
- On criterion 2 Malawi scores better, as the distance to the existing electricity grid is longer, so the feasibility of a microgrid increases.
- On criterion 8 Bangladesh scores better, because a high score on this criterion means the feasibility of a microgrid is lower: the consumer is less able to pay for electricity.

It can be concluded that Chitipa and Panchagarh have a similar feasibility level, but Chitipa in Malawi scores higher on one criterion. So one could say that Chitipa is the preferred location for the development of a microgrid. But one out of 15 (or eight, or three) criteria is not a convincing victory for Malawi. Therefore this is a situation where the weights of the criteria can be used, if the project partners wanted to make a choice between these two locations. The project partners can use the percentages from the expert review in determining the weights for the criteria. Or they can decide to assign their own weights to the criteria. Dependent on the type of parties involved in the partnership, different interests might play a role, which might affect their opinion on the relative importance of one criterion compared to the other.

Table 16 The improved feasibility framework with way of measuring, effects and the evaluation results for Malawi and Bangladesh

	Criterion	Question/unit	Effect*	Malawi	Bangladesh
Technological					
1	Availability of sunlight (PV, SHS)	Average **annual** solar radiation in kWh/m^2	+	1900-2300	1500-1700
2	Length of extension needed when connected to existing electricity grid	km	+	50-200	0
Institutional					
3	Availability of subsidies for electrification projects	Are subsidies available for electrification projects? **(If yes, are they beneficial for the rural population?)**	~	Yes	Yes
4	Political support	Is there political approval to spend public money on rural electrification projects?	~	Unable to assess	Unable to assess
5	Long term demand for the project	Is the community there to stay for the long term (they do not lead a nomadic existence)?	~	Yes	Yes
Social					
6	Willingness to pay for electricity	% of income that people want to spend on electricity	+	Unable to assess	Unable to assess
7	Number of potential users in potential microgrid location	% of people that want to use electricity from the total population	+	Unable to assess	Unable to assess
8	Consumer's ability to pay for electricity	**% of the population that lives below the income poverty line**	**-**	70.9	43.7
Financial					
9	Appropriate payment opportunities offered to consumers	Is the electricity price adjusted for the ability of consumers to pay? **Is there an appropriated payment scheme for the consumers to pay?**	~	Unable to assess	Unable to assess
10	Operation and maintenance cost of rural electrification project	Recurring costs for operation and maintenance in $/year	-	Unable to assess	Unable to assess
11	Adequate business models	Is information shared about pilot projects?	~	Yes	Yes
12	Understanding the customers' needs	Is market research conducted to understand the location specifics? Do the project partners have a customer service?	~	Unable to assess	Unable to assess
13	Willingness of private party to invest in rural electrification project	Is a private party willing to invest in the project?	~	Unconvinced yes	Unconvinced yes
14	Capital cost of rural electrification project	Total costs of one-time expenses in $	-	Unable to assess	Unable to assess
15	Willingness of public party to invest in rural electrification project	Is a public party willing to invest in the project?	~	Yes	Yes

* Criterion is labelled + if a high score means high feasibility of the potential microgrid location
Criterion is labelled – if a high score means low feasibility of the potential microgrid location
Criterion is labelled ~ if this is a yes/no criterion: yes is the favourable answer, no is the undesired answer

5.5 Conclusions

In this chapter the feasibility framework was brought to its final stage with the use of an expert review and two test cases.

By scoring the input of the experts, 15 criteria were selected as having the most effect on the feasibility of a potential microgrid development. It was noticed that financial criteria play an important role in the assessment of feasibility. This has become a recurring theme throughout this research. It started with the observation in paragraphs 1.4 and 1.5 that financial risks are often the main reason why electrification projects do not get realized. In paragraph 2.1 it was stated that investment barriers are a useful starting point of researching microgrid feasibility. And in paragraph 3.3 it was learned, on the basis of the content analysis, that the viability lens was assigned most as a secondary lens. So even though the dominant lens, the main perspective, of a paper was technology, institutional or user-centric, still financial concepts were abundantly present. Apparently, all of the perspectives of looking at rural electrification are supported and compatible with the financial perspective. This will explain why the criteria of the financial category are so well-represented in the feasibility framework.

It was also made clear that a low score on a few of the 15 criteria does not mean that rural electrification through microgrids is unattainable. No, the project partners should use that result to improve the location where this is necessary. Or, when they started having doubts about the feasibility of the targeted location, they could perform a second check to gain more certainty. For this the project partners can use the other 13 criteria that scored above 50% and the 50 criteria that scored between 33% and 50% in the expert review.

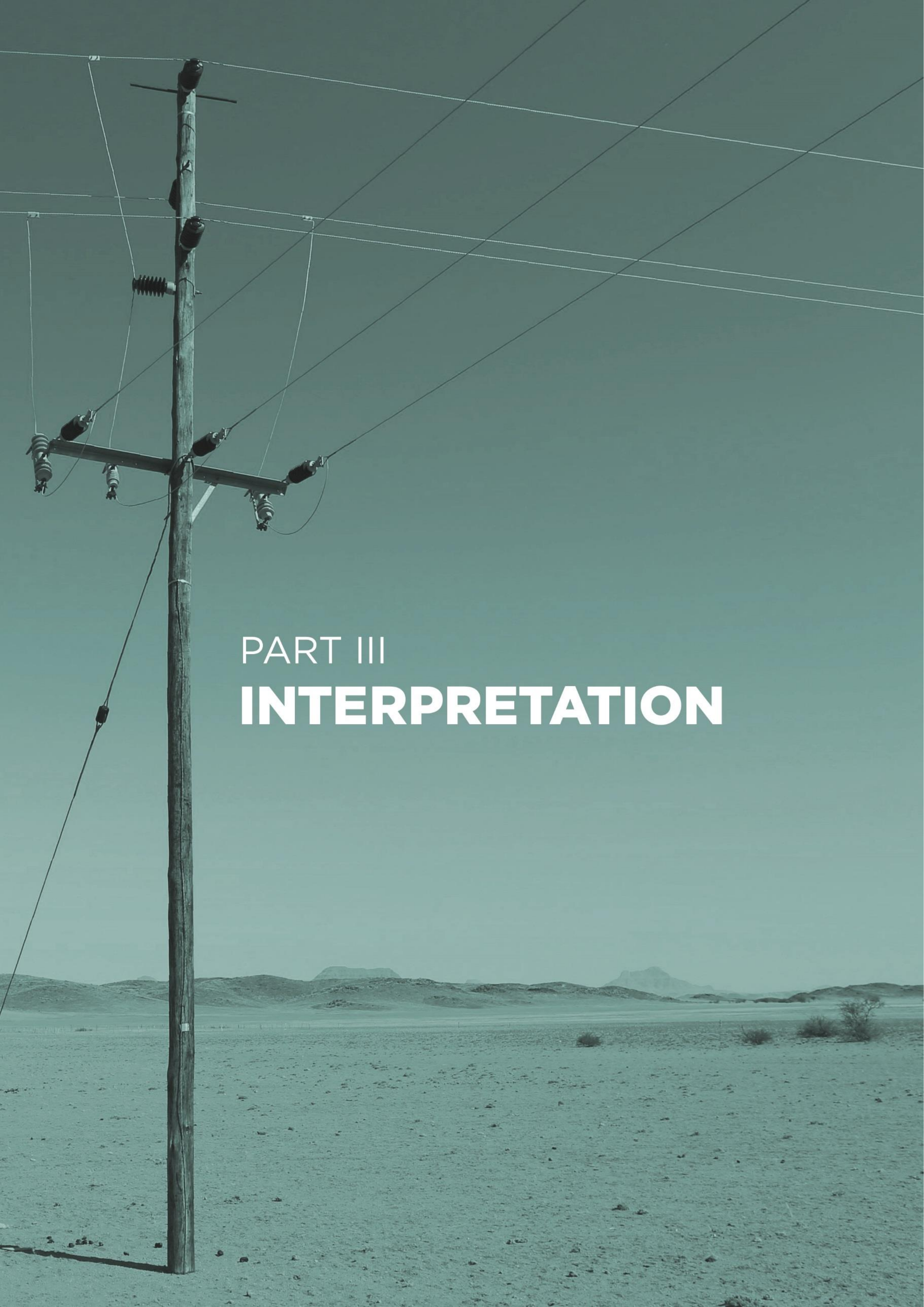
The two test cases helped us to answer the third research question: How can we measure the feasibility of a location for the development of a microgrid? We were able to evaluate and improve the feasibility framework, whilst demonstrating the way of measuring the criteria and interpreting the effects.

Whilst evaluating the framework, it became apparent that there exist links between the 15 criteria. This is what we would have expected, as at various places in this report it became clear that interrelations between categories exist and should be brought to good use. In applying the framework to the test cases, we saw clear links between five couples of criteria:

- 1 & 10: availability of sunlight & operation and maintenance cost → technological and financial
- 3 & 4: availability of subsidies & political support → 2x institutional
- 7 & 9: number of potential users & appropriate payment opportunities → social and financial
- 10 & 14: operation and maintenance cost & capital cost → 2x financial
- 13 & 15: willingness of private party & willingness of public party to invest → 2x financial

Links between criteria of one category are not that surprising, but it is good to see that there also exist clear links in the way of measuring criteria from different categories. This makes that the framework can and should be seen as an integrated whole.

Coming back to the way of measuring the criteria: it was found that the test cases only had different scores on three criteria measured on a metric measurement level. To make the difference between different locations become more apparent, we could try to give the eight dichotomous criteria a metric measurement level too. For example, we could not only ask *if* subsidies for electrification projects are available, but also ask *how much* subsidy is available. This type of unit could also be applied to criterion 13 and 15. But for the other five dichotomous criteria such a transformation is harder to realize. Also, the question should be asked if a metric way of measuring should be a goal in itself; does this not give false clearness? As the differences between locations might not be that simple and clear. Knowing how much a party is willing to invest, does not say a lot; in one location a smaller, cheaper microgrid might be the best fit, where in a different location the development costs might be a lot higher. Solely basing one's investment decision on the score of the feasibility framework would be a mistake. The framework should be seen as a part of a bigger process of collaboration and deliberation between project partners. Scoring different locations and comparing them to each other is very informative and useful for potential investors and project partners. But in the case two locations have a similar score on feasibility, this does not mean the application of the framework has been useless. Because the collaborating parties have learned a lot about the targeted locations and about each other.



PART III
INTERPRETATION

6. CONCLUSIONS

In this chapter the research outcomes will be presented by answering the three research question and the overarching main research question. In answering the main research question a 'user manual' for the feasibility framework will be given.

6.1 Research outcomes

The answers to the three research questions are:

Which subject areas are dominant and which concepts are most frequent in studies on rural electrification?
The subject areas that are dominant in studies on rural electrification are: technology, institutional, user-centric and viability. Of which the technological category is most often used in papers on rural electrification. This observation resulted in the thought that it is hard to find one best technology suitable for rural electrification. It was also seen that the user-centric lens has gained in interest over the last four years. From which we take away that electrification projects actually have been carried out, as researchers write about the successes and challenges of the projects with a focus on the users. And it was seen that the financial category is often used as a secondary lens, as financial concerns are intertwined with the other subject areas.

To these four subject areas two emerging categories are added: environmental and frugal. The environmental category is added as we focus on renewable technologies. The frugal category is added because frugal innovation links technology with local circumstances and cultures of people in low-income communities, who often live in rural areas.

In the six categories, there are 125 concepts found that are most frequent in studies on rural electrification (an overview of those is given in Table 3).

Which factors play a role in the development of rural electrification projects?
Divided over the six categories, a number of 99 factors is found that play a role in rural electrification projects. The research performed to answer the second research question also helped in getting the criteria ready for assessment. Steps were made in making the criteria useful to assess potential microgrid developments.

In the search for these 99 factors, a deepening and broadening literature research was performed. From that we learned that broadening literature can provide us with a wider perspective, included a wider variety of topics and has helped to find factors on a lower level or a higher, more abstract level.

Linking the technological, institutional, social and frugal categories with related theories helped us to understand and define the six categories better. But at the same time the seemingly separate categories have again shown overlap and made clear that integration of the six subject areas is an inevitable process.

How can we measure the feasibility of a location for the development of a microgrid?
With the use of the results of the expert review, 15 criteria were selected as having the most effect on the feasibility of a potential microgrid development. As seven of the 15 criteria are from the financial category, financial concerns appear to be seen as the most important criteria when assessing for microgrid feasibility.

The 15 criteria were applied on two test cases to establish the best way of measuring their effect of the feasibility of a potential microgrid location. For a more detailed assessment of a location, an additional 13 and 50 criteria are selected based on the expert review. The next paragraph will explain how the feasibility framework should be applied.

6.2 How to use the feasibility framework

The main research question that was posed in chapter 2, was: **How can public and private parties, which aim for the electrification of rural areas, assess the feasibility of a location for the development of a microgrid?** After a content analysis, a word-frequency count analysis, a broadening and deepening literature research, an expert review and two test cases, we are able to answer this question with: by using the feasibility framework. The final feasibility framework is presented in two ways: in Table 17 with the questions and units included and in Figure 13 where it is visualized in a way that gives public and private parties the ability to score the criteria. In addition to those presentations of the feasibility framework, a 'user manual' will be given to complete the answer to the main research question.

Table 17 The final feasibility framework

	Criterion	Question/unit	Effect*
Technological			
1	Availability of sunlight	Average annual solar radiation in kWh/m^2	+
2	Length of extension needed when connected to existing electricity grid	km	+
Institutional			
3	Availability of subsidies for electrification projects	Are subsidies available for electrification projects? (If yes, are they beneficial for the rural population?)	~
4	Long term demand for the project	Is the community there to stay for the long term (they do not lead a nomadic existence)?	~
5	Political support	Is there political approval to spend public money on rural electrification projects?	~
Social			
6	Willingness to pay for electricity	% of income that people want to spend on electricity	+
7	Number of potential users in potential microgrid location	% of people that want to use electricity from the total population	+
8	Consumer's ability to pay for electricity	% of the population that lives below the income poverty line	-
Financial			
9	Appropriate payment opportunities offered to consumers	Is the electricity price adjusted for the ability of consumers to pay? Is there an appropriated payment scheme for the consumers to pay?	~
10	Operation and maintenance cost of rural electrification project	Recurring costs for operation and maintenance in $/year	-
11	Adequate business models	Is information shared about pilot projects?	~
12	Understanding the customers' needs	Is market research conducted to understand the location specifics? Do the project partners have a customer service?	~
13	Willingness of private party to invest in rural electrification project	Is a private party willing to invest in the project?	~
14	Capital cost of rural electrification project	Total costs of one-time expenses in $	-
15	Willingness of public party to invest in rural electrification project	Is a public party willing to invest in the project?	~

*
Criterion is labelled + if a high score means high feasibility of the potential microgrid location
Criterion is labelled – if a high score means low feasibility of the potential microgrid location
Criterion is labelled ~ if this is a yes/no criterion: yes is the favourable answer, no is the undesired answer

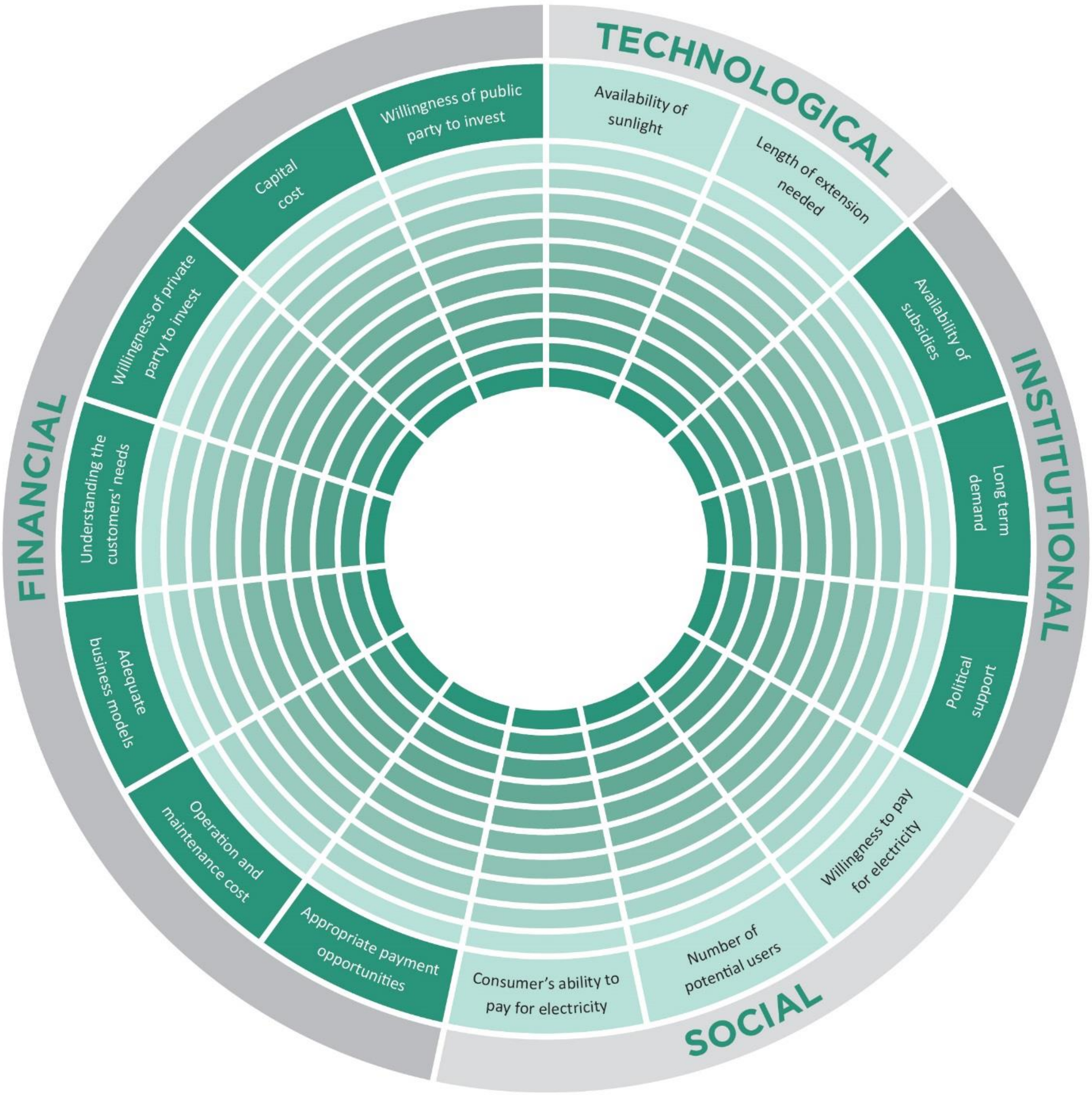


Figure 13 The feasibility framework that can be used to score the criteria

A user manual: how to use the feasibility framework?

In this section the steps in using the feasibility framework will be described. This user manual can be used by governments, investors and public-private partnerships, as these parties could become project partners in the development of a microgrid. These steps already have been discussed in paragraph 2.3 and chapter 5, but will be brought together and summarized here.

1. **Target one or more locations** in rural areas that you want to electrify
2. **Find potential partners** for the development of a microgrid
3. **Score the 15 criteria** of the feasibility framework together with your partner(s). The criteria can be scored in any order. It is likely that some are easier to assess than others, so the advice would be to start with the criteria of which the partners have data within easy reach.

Next, different scenarios can unfold:

4. **Unable to assess** one or more of the criteria?
   Maybe you need to find additional or different partners that can help you with the assessment of those criteria. Otherwise you keep those criteria unassessed.
   If the project partners are unable to assess some of the criteria in the first instance, the framework has still been of use and benefit. As the framework has brought the project partners together and has made them collaborate. The assessment of the criteria in the feasibility framework has provided them with insights into the potential of the targeted microgrid location, the hurdles that still need to be taken and the complementary qualities of the partners.
5. **How do the criteria score** that you were able to assess?
   Do all or most of them have a high score on feasibility? Great! Your location is ready for the development of a microgrid. If you had not yet approached investors as project partners, this is the time to do so.
   Does your targeted location score low on feasibility? Look into the criteria that had a low score and try to improve the score of those criteria. For example, a government could develop policies that benefit rural areas. If you are unable to improve the score of too many of the criteria, it seems this location is not ready for the development of a microgrid.
   If just a few criteria have a low score, this might be a good reason to do a more detailed assessment. For example, if the criterion 'availability of sunlight' scores badly, that does not mean all renewable sources of energy would not work in the potential microgrid location. It would be too quick to cancel the whole microgrid. You might want to look at some of the other criteria first. The first step could be to evaluate the additional 13 criteria that were found in the very-strong-effect-method of selecting criteria. And if the project partners wanted to do an even more detailed investigation of the location, they could use the criteria of which between 33% and 50% of the experts found they had a very strong effect. This would give an extra 50 criteria to assess the feasibility.
6. Did you **compare different potential locations**?
   In that case you could either have a clear winner: one location that scored much better than the other location(s). Or, you would find it hard to decide in which of the locations to invest, as they have similar scores. In the second situation, the project partners would have to decide on which criteria they think should weigh heaviest. The project partners can use the percentages from the expert review in determining the weights for the criteria. Or they can decide to assign their own weights to the criteria. Dependent on the type of parties involved in the partnership, different interests might play a role, which might affect their opinion on the relative importance of one criterion compared to the other.
   In any case, the visualisation of the framework in Figure 13 will come in handy when comparing different locations. As it will give a quick overview of the feasibility of a microgrid in any location. An example of what the framework would look like when the criteria are scored, is given in Figure 14. It can be seen that the dichotomous criteria either have all or none of the boxes coloured in. The criteria with a metric measurement level have a number of the ten boxes coloured in, dependent on their score compared to the other locations. Criteria that the project partners are unable to assess will be coloured grey, by way of saying one should not forget those criteria and score them when data has become available.

Finally, this is a good time to repeat one of the conclusions from chapter 5. Where it was stated that solely basing one's investment decision on the score of the feasibility framework would be a mistake. The framework should be seen as a part of a bigger process of collaboration and deliberation between project partners. Scoring different locations and comparing them to each other is very informative and useful for potential investors and project partners.

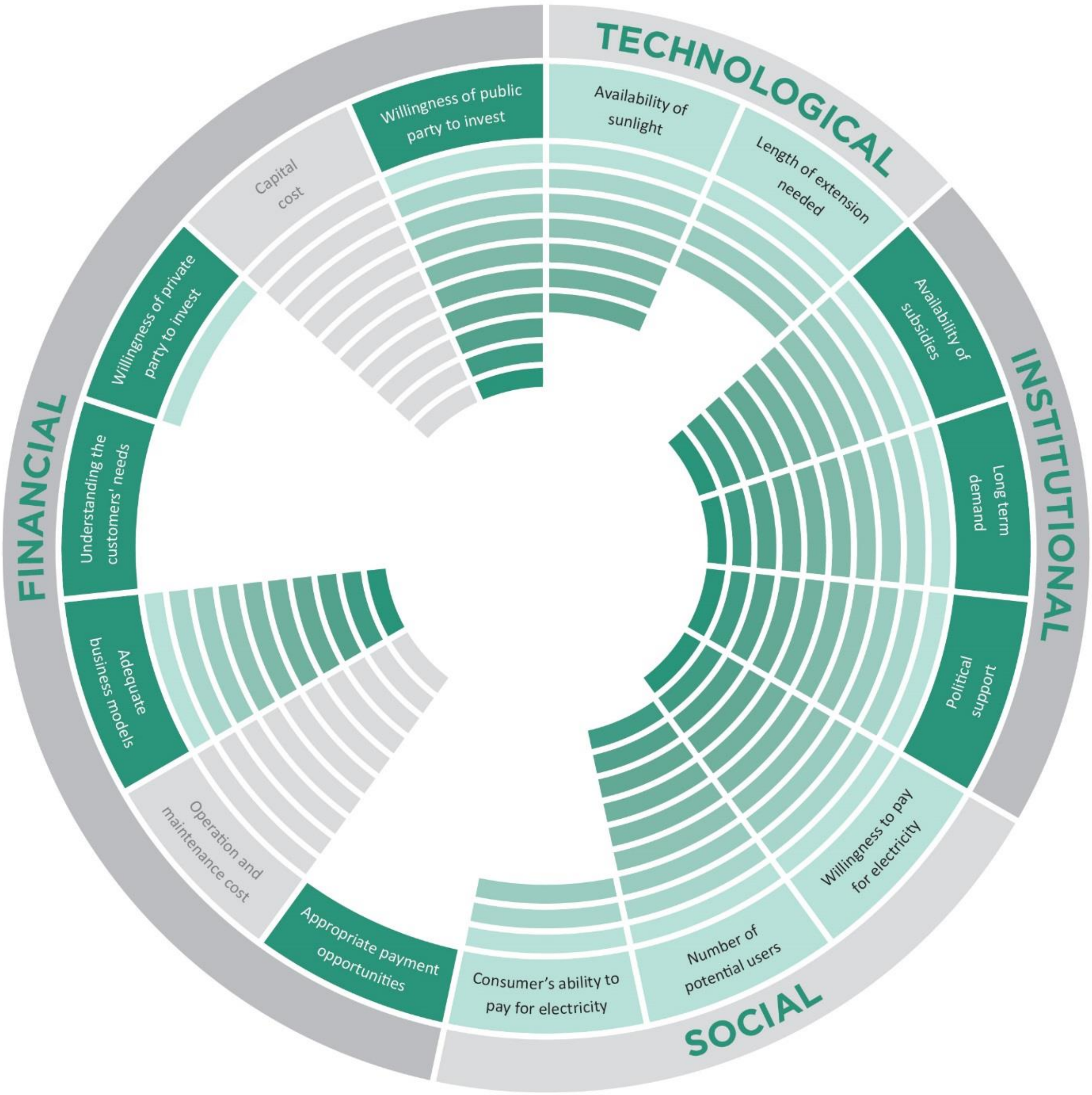


Figure 14 The feasibility framework of which the criteria are scored by way of example

7. REFLECTION

In this final chapter I will look back at my completed research and ask myself if and how my choices affected the research outcomes. What are the limitations of the research that constrain generalization of the outcomes? The possible limitations of each of the used methods are discussed. In the second paragraph I will reflect on the choices I made during the course of the project. In the third and final paragraph I will give recommendations for future research.

7.1 Limitations

For each of the five methods that were used to come to the final feasibility framework, the possible limitations are discussed and it is explained how is dealt with those limitations.

But first, we want to make a general statement. The user of the framework should be aware of the fact that even though a broad spectrum of sources is used to build the framework, with learnings from electrification cases all over the world, every location will raise new and different challenges. It would be too ambitious to aim for the framework to cover all these challenges. The framework is designed to be applicable in any location, so the user should ask himself if the targeted location poses any extreme or extraordinary circumstances, as these might influence the feasibility score.

Limitations of content analysis

When performing a content analysis everything depends on the selected content. The first three of the seven steps executed in the content analysis are dedicated to selecting the right papers. ScienceDirect was used as a database to find the relevant papers, using specific key words. It was checked if the selected papers were published in journals with a high scientific standard. And it is verified is all papers actually write about the topic of rural electrification. By doing this, I believe the potential problem of having selected irrelevant content for analysis is resolved.

A second limitation of content analysis is, on the other hand, not resolved. Content analysis learns us what the dominant subject areas are and what the most frequent concepts in rural electrification are, but it does not tell us why. I had to guess why the user-centric lens gained more interest in the last few years, for example. This is why the content analysis raised some interesting questions, that did not all get a clear answer.

Limitations of word-frequency count analysis

Stemler (2001) has helped me in pointing out the potential limitations the use of a word-frequency count. I would like to single out two of them.

The first is the fact that one word can have multiple meanings. As such, it can be categorized under one category, where it would also have fitted another category. I was aware of this problem while I performed the word-frequency count, so I have excluded these ambivalent words as much as I could. For example, I have excluded the word 'network' from my selection of meaningful words, because it can be used in the context of an electricity network as well as a stakeholders network. Another word I excluded was 'home' because it is used in the context of solar home system, but can also be categorized under the user-centric lens.

A limitation that I was unable to cover for, was the fact that words have synonyms. This has two implications: words with many synonyms might have had a low frequency per version of the concept and did therefore not make the cut of most frequently used words. Another consequence is that words that do not have any synonyms become one of the words with the highest frequency. An example of such a word is jatropha.

Limitations of broadening and deepening literature research

I want to place just one short footnote to my choice of broadening theories. I had my reasons to choose these, which I explained in paragraph 4.1, but someone else might have argued for a different choice of papers. As a result, they probably would have found a different selection of factors. Although I am not sure if this should be called a limitation, I did want to make note of this.

Limitations of expert review

By performing an expert review you are completely reliant on the knowledge, experience and even opinions of the chosen experts. With regards to the knowledge and experience I aimed to select people with an academic background and people who work for a private company. In the end I received input from 11 people working at a university, 6 working for Arup, 1 working for another private company and 1 working for the World Bank. So I was able the get quite a well-mixed group of experts. I am especially very happy that Simon Schillebeeckx (the lead author of the paper that inspired my way of answering the first research question) found the time to complete my survey.

When the experts speak from their experience and interest, why is 'availability of sunlight' seen as having more effect than other sources of renewable energy? I found it remarkable that from all renewable sources of energy just sun is selected, is this because the experts know about the widespread existence of Solar Home Systems? Did they maybe think too much about what is developed already, instead of thinking about future possibilities? If this is true, it could have had a limiting effect on their survey input.

Limitations of test cases

Two limitations came forward in the application of the feasibility framework on the test cases.

One, there are just two test cases used, so it is hard to get a good idea of the possible scores on the criteria. this is precisely why I recommended to perform more test cases in future research.

Two, I was limited by the fact that I had to assess the criteria by performing a desk research, I therefore was unable to review all the criteria in the same manner as would have been done in practice. As a result I was unable to evaluate some of the criteria, which also meant I was unable to fully evaluate whether the way of measuring those criteria would have been effective.

7.2 Reflection

First, I want to reflect on two things: some of the choices I made with regards to the delineation of my research project and some of the comments made by the experts when they filled out the survey. Next, I will reflect on the scientific and societal relevance of this thesis research project.

Because I focussed on locations with no access to electricity, I found I needed to target rural and remote areas. Based on that, I chose to focus on renewables and off-grid microgrids. This helped me find my focus. It helped me visualize the ultimate goal, as rural electrification can still be put in practice in many different ways, but renewables based, off-grid microgrids is a delineation that has helped me focus.

One of the experts made this comment on my survey: “"Feasibility of microgrid" is very broad. There are probably different criteria that matter for 1) starting a microgrid, and 2) maintaining a microgrid (and potentially 3) adoption of electricity). Here they are all thrown together which can confuse some answers where it is unclear which phase of development you (implicitly) refer to” (Schillebeeckx, 2016). In principle I have focussed on the first phase of development, as defined by Schillebeeckx (2016), but I definitely have included a few criteria that relate to the second and third phase too. But I do not believe this should be a problem. In assessing the feasibility of a microgrid, I think one should also consider maintenance and adoption issues: why start a development that will not be successful when it develops further?

Van der Voort (2016) said: “Nice longlist. Of course many criteria are related. I guess the longlist needs a bit of clustering”, as a comment when he was filling out the survey. This is something I considered doing, before sending out the survey, but now I am happy I did not. I suspect I might have grouped some criteria together that now have scored very differently. The fact that I did not group criteria together has provided us a beautifully differentiated list of criteria, which tells us more about the different criteria than if they would have been grouped together.

Finally, another reflective discussion on the criteria: I have not performed an exhaustive search to find all possible factors that might affect the feasibility of a microgrid development. This would be impossible. It is thus unsurprising that the experts came up with a few more suggestions for criteria. I did not include them in my framework, but I do think it is good to be aware of the fact that I am not claiming to have found all factors that might play a role in rural electrification.

Reflection on scientific relevance

In paragraph 2.5 I wrote about the scientific relevance of my research; the goals I set myself.

I wanted to bring existing scientific knowledge together and use it to create something new. I did this by combining the learnings from 202 papers on rural electrification with theoretical knowledge on broader topics, and I used this to build the foundation of my feasibility framework.

I wanted to answer the call for more research on the investment side of rural electrification. This was done in the first place by having ‘financial’ as a category of focus when looking at electrification. But it also became apparent in paragraph 5.1 that a few of the other selected criteria also have a focus on the money side of things. Thirdly, one of the highest goals of this research was to help public and private parties in deciding in which potential microgrid projects to invest. These parties want to make an informed decision about the feasibility of a project, before investing in it.

The third goal is set myself was to help decrease the “lack of systematic evaluation of experience with decentralized electricity systems in different cultural and geographic contexts and the transfer of this experience” (Schäfer et al., 2011). I think I have been very systematic in my content analysis on the topic of rural electrification. In addition, my framework is applicable in different cultural and geographic context, as I demonstrated with my test cases. It therefore can be used to evaluate and transfer knowledge on different locations amongst all parties interested.

In addition to reaching these three goals, I believe this research has scientific value for researchers who are working on the topics of rural electrification and microgrid development. Several insights gained in this thesis research can and should be taken forwards. First, the addition of the frugal and environmental categories were an enrichment of this research and will certainly be of use to other researchers. In the light of the user-centric perspective gaining in interest over the last few years, the frugal category aligns with that evolution, having a social edge as well. Even though the interest in the customers’ needs has grown, the technological perspective remains the dominant perspective in researching rural electrification. It is valuable for researchers to be aware of this fact. I concluded from this that selecting the right generation technology is a difficult choice to make, but there might be more behind this continuous presence of the technological perspective. In all cases, awareness of this fact is of value for researchers. A final valuable addition to the science of rural electrification is this: the integration of insights and learnings from different fields is a necessary process and brings new opportunities. It is clear that the scientific world is not permeated enough of this fact, because only 39 of the 202 papers from the content analysis integrated all four lenses.

This thesis research also has scientific value with regard to research being performed in the fields that were used in the broadening literature research.

In connection to the great attention given to the technological perspective, a potentially interesting meeting of perspectives would be to apply the technology dominance theory on a rural electrification project. Apparently selecting the most successful technology in rural electrification is difficult, so for technology dominance researchers this might be an interesting case study. Possibly, the technology dominance theory can be developed with learnings from this rural electrification case study. As they might be able to uncover critical success factors of energy generation technologies for rural areas, which then can be used in a broader way of selecting dominant technologies. Might we already be able to learn from the two technological criteria in the framework?

These are two concept-based criteria: ‘availability of sunlight’ and ‘length of extension needed when connected to existing electricity grid’. The first can be generalized to ‘availability of resources’, which is related to the technology dominance factor of 'operational supremacy’ (see Appendix H1 for definition). Related, but not synonymous, so there is room to enrich or enlarge the technology dominance factors.

The broadening of this research with the public-private partnerships literature, gave us some more lower-level criteria. So if we would want the public-private partnership researchers to learn from this thesis research, they might be able to take away some insights from the concept-based criteria on a national and international level. As partnerships cross borders, the factors influencing their success do too.

In this research the social category was enriched with learnings on social and cultural differences: both in the problem exploration paragraph and in the broadening literature research. We hope to give these researchers back the encouragement to include rural electrification projects in their research. I noticed this collaboration between the social sciences and engineering creates potential, potential that should be exploited from both sides. We can already see how my research could be integrated with Hofstede’s research (1989): I formulated ‘influence of women in the community’ as a criterion and he uses ‘masculinity versus femininity’ as aspects of national culture. So it would seem we agree on seeing women as a factor in the development of international projects. However, only 15% of my experts found the influence of women to have a very strong effect on microgrid feasibility. Did the experts underestimate the importance of this criterion or do Hofstede’s aspects need an upgrade? Food for thought.

Finally, what scientific value has this research had for researchers in the field of frugal innovation? Realistically, not a lot: I mainly learned from them, so it will be hard to give something back. Thereby, as the only one of four broadening fields of research, rural electrification was mentioned in two of the three studied papers. It seems the frugal innovation and inclusive growth researchers have already recognized the value of integrating rural electrification in their research. So they might be interested to see how I have tried to implement frugal factors in my feasibility framework.

Reflection on societal relevance

As with the theoretical contribution, is set myself a goal with regards to the societal relevance of my research project. I wanted to help bring the electrification of areas without access to electricity closer, as the rural population will benefit greatly from this. I gave five examples of things that will benefit from access to electricity (education, sense of safety, local economy, health and communication) and linked them with the UN Millennium Development Goals. At this point, looking back at my completed research, I want to come back to these millennium goals (Figure 15) and see if I feel my research will help in reaching those.

Figure 15 UN Millennium Development Goals (UN, 2015)

Because I believe my research can help in realizing rural electrification, I also believe that I have brought the realization of the goals numbered with 1, 2, 4, 5 and 6 closer. In addition, since I presented Figure 1 in the first chapter, the link of my research with the other three goals became clear. In paragraph 3.5 I explained how especially women will benefit from electrification (goal 3). In paragraph 1.3 I explained why the use of renewable sources of energy is a good match with the development of microgrids (goal 7). In paragraph 1.5 and chapter 5 it became clear how forming partnerships can help in realizing rural electrification (goal 8). In conclusion, I am happy to see that my research is very relevant for society, in a sense that it can help tackle all of the great global challenges set by the UN.

7.3 Recommendations for future research

In case anyone would want to take this research further, presented next are a few recommendations for things to look into.

In order to get a better sense of the range of possible scores that each criterion could have, one could execute more test cases. This will make it easier to judge whether a location has a high or a low feasibility, as there will be more locations to compare the feasibility score with.

One could take this way of thinking even further by making a map of all the countries with a very low level of access to electricity. Based on a large basis of case studies, it would become possible to map the feasibility of several locations. Such a map could look like the ones in Appendix N with the solar radiation levels: a dashboard could be developed where all possible energy generation technologies are listed and the person looking at the map would be able to select his choices and see the effect on the feasibility of that, for example.

This is also where the research will reach a point where the practical use for Arup becomes very clear. Arup is involved in electrification projects in Africa, including one or two off-grid projects. So they probably have clients that they could advise on their next steps, based on the above described application of my research.

If someone wanted to research more fundamental, theoretical topics, they could ask the question: why is it that environmental factors are very much under-represented in number? Or: why do half of the papers that write about rural electrification focus on the technological aspects of it? And: why do experts see criteria related to frugal innovation and inclusive growth as having a relatively weak effect on microgrid feasibility? I had to make well-argued guesses when discussing these remarkable issues and their associated questions.

Finally, it would be interesting to apply the framework on a location where an actual microgrid is developed. That way the scoring of the framework can be compared to the real outcomes of the microgrid development.

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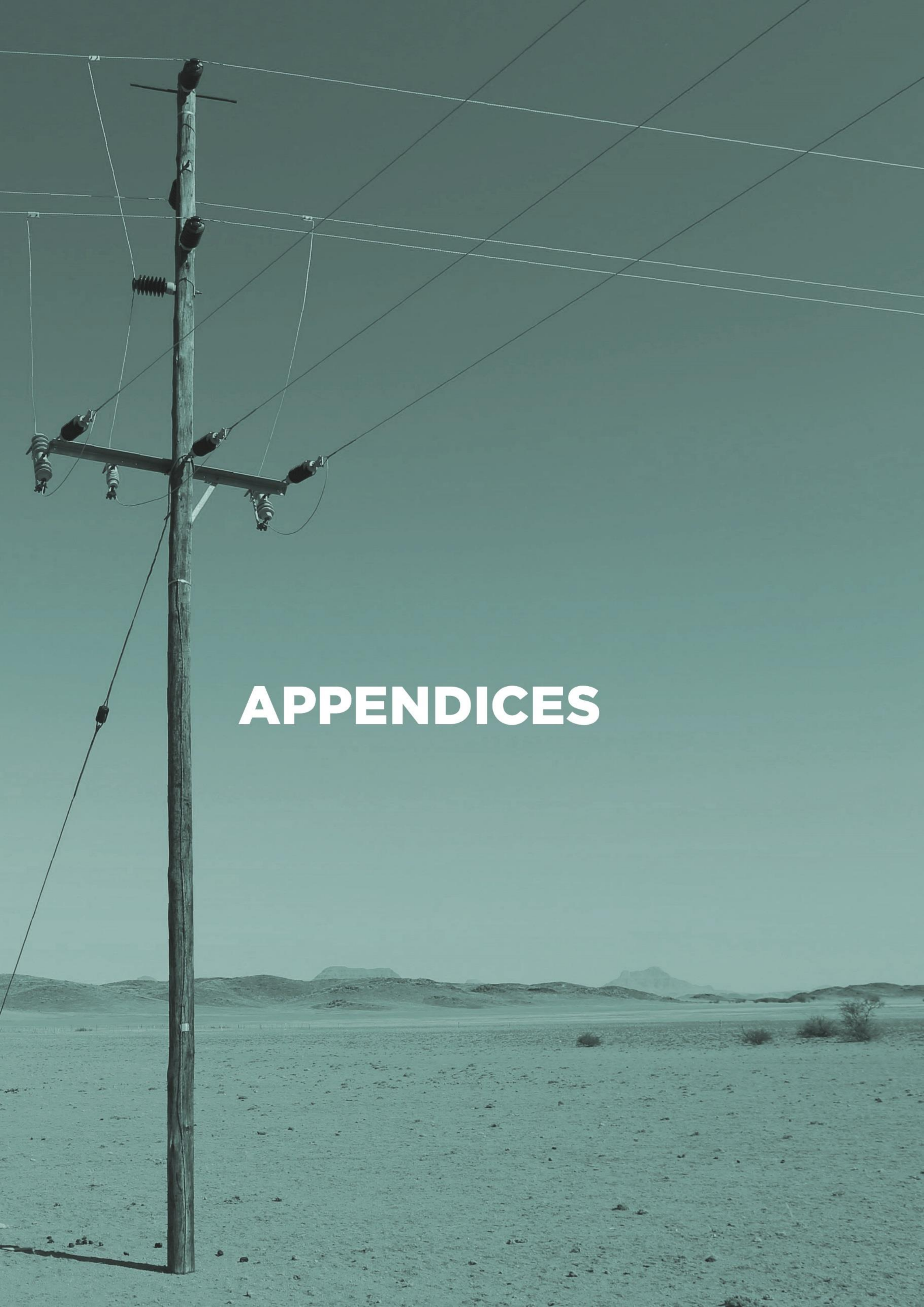

APPENDICES

Appendix A. Scientific article

Dominant subject areas and concepts most frequent in studies on rural electrification

Content and word-frequency count analysis on the topic of rural electrification

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ABSTRACT

Today 19% of the global population has no access to electricity. Most of these people live in rural areas. We found 202 papers on the topic of rural electrification published between 2012 and 2015, which were not yet analysed in a way that is useful in the assessment of the feasibility of a microgrid location. Based on these papers a content and a word-frequency count analysis are performed. As a result the dominant subject areas and concepts most frequent in studies on rural electrification are found. Including two new subject areas, that would be interesting topics of future research.

Contents

1. Introduction

Today 19% of the global population has no access to electricity. Most of these people live in rural areas. These 1.4 billion people would benefit from electricity access for five reasons: their health, education, local economy, sense of safety and communication will benefit.

Public-private partnerships are a good way for governments to get access to more funds and technical knowledge and it is a good opportunity to spread the risks of the development of a microgrid. If such a public-private partnership is formed and they decide to develop a rural electrification project, the partners want to be smart about where to start their first development. The partnership wants to know what location is most feasible for the development of a microgrid. But what are the factors that determine the feasibility of the electrification of a certain location?

Schillebeeckx et al. (2012)have made a start at defining these factors. They performed a content analysis of 232 articles on the topic of 'rural electrification'. These papers were written between 1990 and 2011, so there is a gap in the knowledge from 2012 to 2015. We found another 202 papers on the topic of rural electrification during those years, which were not yet analysed in a way that is useful in the assessment of the feasibility of a microgrid location. These additional papers will be used to answer the research question of this paper: Which subject areas are dominant and which concepts are most frequent in studies on rural electrification?

2. Research method: content analysis

Content analysis is a term that is used to describe a family of analytic approaches, used to interpret text data, either in a qualitative or quantitative way (Hsieh & Shannon, 2005). Content analysis is a technique to compress "many words of text into fewer content categories, based on explicit rules of coding" (Stemler, 2001). "Content analysis is also useful for examining trends and patterns in documents" (Stemler, 2001), which is exactly the reason why it is applied in this research.

The content analysis is executed following seven steps, which were distilled from Schillebeeckx' paper. These steps and their results are presented here.

1. Search for papers with the phrase 'rural electrification' in their abstract, title or keywords of journals from 2012 to present (excluding 2016). Exclude books from the search.

Result: 202 papers were found on 30 November 2015 using the search engine ScienceDirect.

2. Check if any papers are published in 'Fuel and Energy Abstracts', 'Refocus' or 'Photovoltaic Bulletin'. These journals are considered not to be academic in nature. Exclude paper if published in any of these journals.

Result: none of the selected papers was published in one of these journals, so no articles are excluded. I think ScienceDirect agrees with Schillebeeckx et al. (2012) and does not consider these journals to be of a high enough academic standard, therefore no articles published in these journals came up in the search engine.

3. Check if the selected papers actually discuss the topic of 'rural electrification'.

Result: zero papers were excluded after having read all their abstracts. I did find some papers that were focused around a very specific topic or technology. But these papers were not excluded, as possible technology specific jargon would be filtered out with the use of word-frequency count. This will be further explained in step 5.

4. Read abstracts and decide in which a priori category the paper fits. Classify with exactly one dominant and between zero and three secondary lenses. In case of doubt, choose more lenses.

Result: I read all the abstracts and decided which of the four lenses that Schillebeeckx et al. (2012) applied (technology, institutional, viability, user-centric) matched the content of the paper best. I used Figure 1 as a handhold.

I also chose one or more secondary lenses if one lens was not enough to capture the full content of the article.

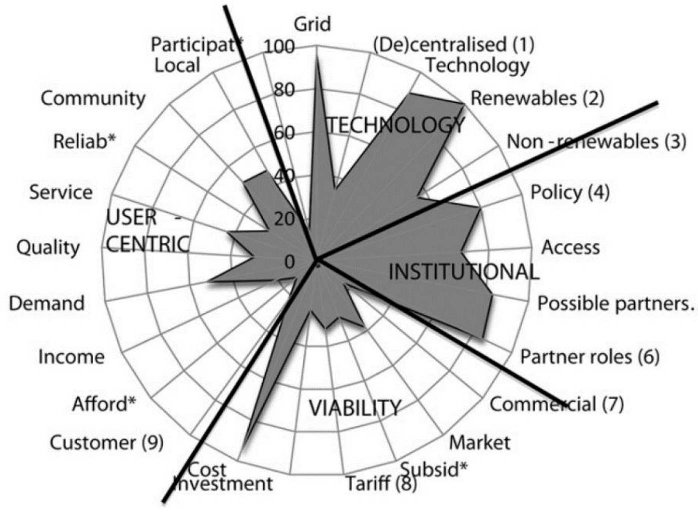

Figure 1 First order words for the four lenses (S. J. D. Schillebeeckx et al., 2012)

Combining the four lenses in all ways possible, gave 32 possible lens-categories. All 202 papers selected for content analysis are assigned one of these lens-categories based on their abstract. Schillebeeckx et al. (2012) described in their paper that they categorized the first 50 papers with an iterative process between the authors. After which Schillebeeckx categorized that remaining papers himself, with just a random sample of 25 papers that was assessed by the other authors as a control. In this content analysis I categorized all the papers myself. The only check I performed was a quick test using my colleagues: I presented them (as a group) with six randomly chosen papers and asked them to assign a dominant lens and (non-mandatory) secondary lenses to those. It appeared that we both chose the same lenses to categorize the paper. But in two of the six cases there was discussion about which of those lenses was the most dominant. There was also disagreement amongst my colleagues. This shows that the categorization of the papers was based on an informed choice, not on facts. However, I can say that whilst reading 202 abstracts, you develop a skill for categorizing papers.

5. Find key concepts and emerging categories using 'word-frequency count'. Group similar words.

Result (key concepts): the most frequent and therefore key concepts per category are found with the use of 'word-frequency count'. The methodology used to count the most frequent words is explained in Appendix A. The meaningful concepts of the most frequently used words per category are summarized in Table 3.

Result (emerging categories): part of the word-frequency count method is defining which of the most frequently used words have a meaning associated with one of the four categories as applied by Schillebeeckx et al. (2012). Sometimes during this process, I would find a meaningful word that I would find hard to link with any of the four categories. An example: ‘climate’ and ‘emissions’, I felt these words (and a few related ones) would work best under the header of ‘environmental’. Also, in quite a few papers this perspective was used in writing about rural electrification, so I believe it makes sense to add this categories as a fifth one. I also found words like ‘installation’, ‘maintenance’, ‘resources’ and ‘knowledge’, which I associated with the concept of frugal innovation.

6. Search for relationships between the first order words. Categorize related words under second order concepts.

Result: this is done as the fourth step of the word-frequency count method.

7. Use second and first order concepts to describe lenses.

Result: greater understanding of relations between concepts and lenses.

3. The selected papers

A specific search for papers in the scientific database ScienceDirect resulted in 202 papers found on the topic of rural electrification. These papers were published between 2012 and 2015. By analysing these papers, my research is a continuation of the work of Schillebeeckx et al. (2012), who analysed papers on the subject of rural electrification that were published between 1990 and 2011.

An overview of the papers selected for content analysis by Schillebeeckx et al. (2012) and myself is presented in Table 1.

It is remarkable that in the four years I am studying, almost the same number of papers on rural electrification is published as in the 22 years that Schillebeeckx et al. (2012) have analysed. While the number of journals that these papers where published in is nearly the same. From this, one can draw the conclusion that the topic of rural electrification has grown in interest amongst researchers. Even if it is assumed that scientific publications in general have grown over the last 26 years, an increase of 40 publications on average each year is a steep growth. And as a large part of the papers mention pilot projects or case studies, the conclusion can be drawn that rural electrification has gained interest in the real world.

Apart from this being a confirmation of the societal relevance of this research, it also underpins the solid base of information this research is grounded on.

It is also interesting to see that the largest part of the papers on rural electrification were published in just eight of the in total 38 journals. The eight journals that published the most papers on the topic of rural electrification all focus on papers related to the energy field, this is no surprise. Remarkable, however, is the fact that three of the eight journals focus on renewable energy, which is not necessarily an essential point of focus when writing about rural electrification (as earlier stated: the most common choice for electricity generation in remote grids have been fossil-fuel technologies), but it is a perspective that I have chosen to apply in my research. I can therefore conclude my choice of focussing on renewables is justified.

Next to the renewables perspective, I recognize a focus on developing countries, as the fourth journal in the list ‘Energy for Sustainable Development’ has. Again, not a surprising point of focus, as we are talking about bringing electricity to areas that have no access to electricity yet. The fast majority of these areas is located in developing countries.

A third and final recurring subject in the represented journals I want to address is the social aspect of rural electrification. Five of the journals focus on social science, societal change or cultural dynamics and have published papers on rural electrification, which are thus related concepts. This is probably related to the increase of papers that are categorized in the user-centric lens.

4. Dominant subject areas

In the first part of the research question this paper is answering, I am looking for the dominant subject areas in the field of rural electrification. To find these, I have categorized all 202 papers based on their abstract. To be able to, again, compare my results with those of Schillebeeckx et al. (2012), I have used the same four lenses they applied.

Every paper was assigned one dominant lens, choosing from technology, institutional, user-centric and viability. If the paper were to cover more than one of these overarching fields, it was assigned one or more secondary lenses.

An overview of the prevalence of the four lenses, combining Schillebeeckx’ results with mine, is given in Table 2.

The first thing to notice is that the convincing majority of the papers is about the technology of rural electrification. This fact has not changed over the last few years. Viability as a dominant lens also stayed approximately of the same importance for rural electrification.

Table 1 Overview of number of papers per journal, Schillebeeckx et al. (2012) and Wynia combined

Journal Title	Count Wynia	Count Schillebeeckx	Total count
Energy Policy	24	60	84
Renewable Energy	20	62	82
Renewable and Sustainable Energy Reviews	47	24	71
Energy for Sustainable Development	35	29	64
Energy Procedia	26	2	28
Energy	15	10	25
Applied Energy	7	6	13
Solar Energy	2	9	11
Biomass and Bioenergy	2	3	5
Energy Conversion and Management	1	3	4
International Journal of Hydrogen Energy	1	3	4
Journal of Cleaner Production	1	3	4
World Development	1	3	4
Solar Energy Materials and Solar Cells	0	4	4
Procedia Engineering	3	0	3
Sustainable Energy Technologies and Assessments	3	0	3
International Journal of Electrical Power & Energy Systems	1	2	3
Energy Research & Social Science	2	0	2
Sustainable Energy, Grids and Networks	2	0	2
Desalination	0	2	2
Electric Power Systems Research	1	0	1
Energy Strategy Reviews	1	0	1
European Journal of Operational Research	1	0	1
Journal of Development Economics	1	0	1
Procedia – Social and Behavioural Sciences	1	0	1
Renewable Energy Focus	1	0	1
Socio-Economic Planning Sciences	1	0	1
Technological Forecasting and Social Change	1	0	1
The Social Science Journal	1	0	1
Computers and Industrial Engineering	0	1	1
Current Opinion in Environmental Sustainability	0	1	1
Energy Economics	0	1	1
Futures	0	1	1
International Transactions in Operational Research	0	1	1
Journal of Power Sources	0	1	1
Journal of Rural Studies	0	1	1
Technology in Society	0	1	1
Utilities Policy	0	1	1
Total Papers	**202**	**234***	**436**
Total Journals	**27**	**25**	**38**

** Minus two from 2012 that were excluded from analysis makes 232 that were used for content analysis*

Table 2 Prevalence of four lenses, both selected as dominant and secondary lens (number of papers in each category)

	Technology	Institutional	User-centric	Viability
Dominant				
1990-2011	**120**	**69**	**20**	**23**
% of total papers	**52%**	**29.5%**	**8.5%**	**10%**
2012-2015	**103**	**39**	**37**	**23**
% of total papers	**51%**	**19%**	**18%**	**11%**
1990-2015	**223**	**108**	**57**	**46**
% of total papers	**51%**	**25%**	**13%**	**11%**
Secondary				
1990-2011	**37**	**24**	**31**	**31**
Relative to other lenses	**30%**	**20%**	**25%**	**25%**
2012-2015	**52**	**53**	**68**	**100**
Relative to other lenses	**19%**	**19%**	**25%**	**37%**

But a shift happened between the user-centric and institutional lenses: what the user-centric approach gained in share, was lost at the part of institutional papers. So using the user-centric lens when researching rural electrification has been given more attention over the last few years. This is a trend that started in 2006, when the first paper with a user-centric approach was published.
What does it mean that more papers are written with a user-centric perspective and less from the institutional point of focus? Could we conclude that this shift means that on the highest levels the plans and programs around rural electrification are clear and more attention needs to be given to the local communities? Or could it mean that we have shifted from a top-down to a bottom-up approach? This would make sense, as microgrids are ideally suited for a bottom-up approach because of their decentralized nature. Another explanation could be that before there were mainly plans and programs made to promote rural electrification and that over the last years actual microgrids have been developed. So these papers discuss the recent developments with the use of case studies, like the successes and problems with Solar Home Systems. This suspicion is strengthened by the fact that six of the 37 recent papers on rural electrification deal with the topic of SHS and another 16 are based on other case studies.
The trends of all lenses over the years is made visible in Figure 2. And the relative incidence of the four lenses is shown in Figure 3.
Both over the last four years as over the total period from 1990-2015, the order of importance of the subject areas is:
1. Technology (51% on average of total papers published between 1990 and 2015)
2. Institutional (25% on average of total papers published between 1990 and 2015)
3. User-centric (13% on average of total papers published between 1990 and 2015)
4. Viability (11% on average of total papers published between 1990 and 2015)
Even though viability was chosen least as a dominant lens, over the last four years it was assigned most as a secondary lens. When writing about rural electrification, apparently, concepts that are associated with the viability lens (like cost, investment and subsidy) are often used. There may be many available technologies, well-intentioned policies and community initiatives to realize rural electrification, but if the risks keep getting in the way, no investments will be made.

5. Most frequent concepts
Now we have identified the most dominant subject area, we are looking to find the most frequent concepts used in papers on rural electrification. In performing this search, the subject areas (or lenses) are used to categorize the papers. For every category the most frequent concepts are analysed by performing a word-frequency count analysis. So a word-frequency count analysis is performed four times, using four subsets of papers. For every subset the words are counted and the most frequent and relevant words are grouped and listed. The result of this are the key concepts in Table 3.
When looking at this table, one will immediately see that there are not four, but six categories used in finding the most frequent concepts. Because, as Schillebeeckx et al. (2012) already described, the individual word analysis will facilitate the discovery of key concepts and emerging categories. When I studied the most frequent words, I discovered frequently used words that did not fit any of the four previously defined categories. There-fore I constructed two new categories that I named ‘environmental’ and ‘frugal’.

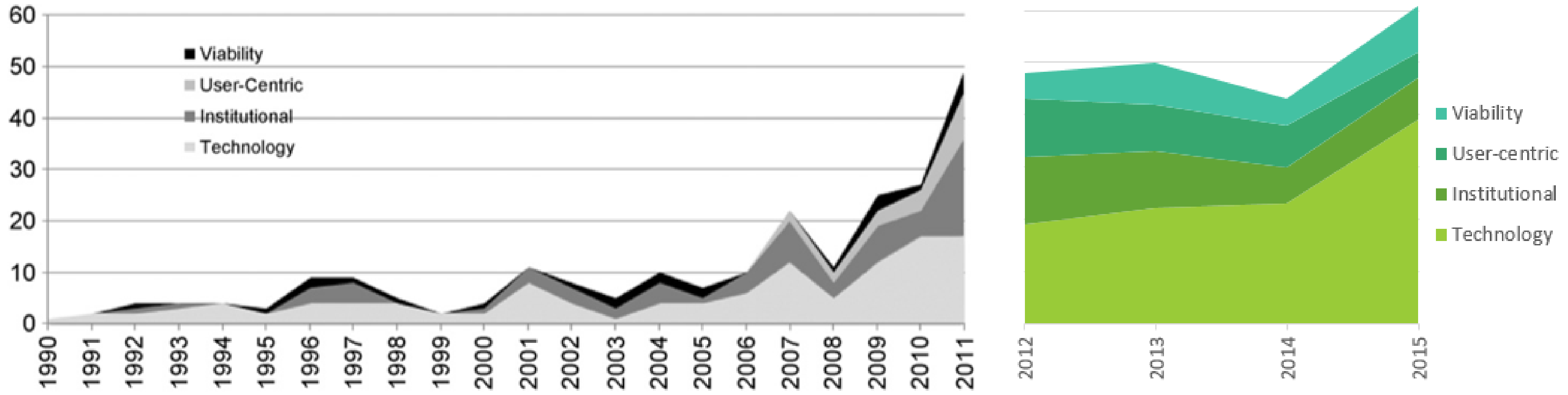

Figure 2 Number of publications per dominant lens from 1990-2011 (Schillebeeckx et al., 2012) and from 2012-2015

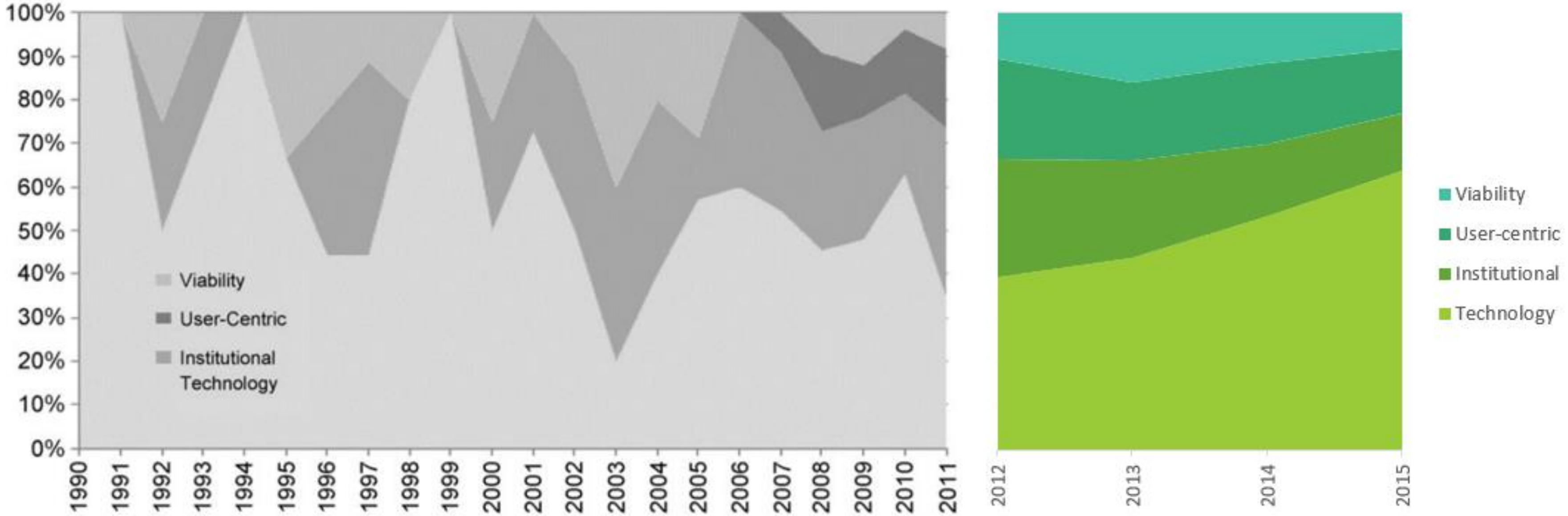

Figure 3 Relative incidence of the four lenses from 1990-2011 (Schillebeeckx et al., 2012) and from 2012-2015

Table 3 Key concepts per category based on the word-frequency count method

Technology		Institutional		User-centric		Viability		Environmental		Frugal	
count	key concept	count	key concept	count	key concept	count	key concept	count	key concept	count	key concept
9391	energy	1154	program	2006	households	2011	cost	5850	sustainable	8930	rural
5179	electrification	1061	policy	892	village	614	investment	1190	renewable	3592	area
4422	power	785	countries	820	consumption	407	subsidies	950	environmental	2699	access
3850	generators	772	government	631	poverty	374	price	369	emissions	2325	available
3569	hydropower	541	national	553	people	337	loan	217	climate	2267	resources
3204	solar	533	world	486	users	275	market	117	carbon	1842	sources
2576	wind	449	institutional	474	community	275	private			1803	services
2501	batteries	336	subsidy	388	local	260	bank			1342	operation
2423	microgrid	298	international	347	urban	232	economic			1165	remote
1926	turbines	261	implementation	285	social	228	capital			977	management
1813	technologies	213	public	204	cooking	221	financing			936	maintenance
1628	hybrid	200	process	176	education	203	risks			909	control
1321	diesel	164	role	173	women	183	business			785	performance
1156	supply	147	framework	169	health	174	financial			742	equipment
1119	plants	141	ministry	138	school	163	tariff			724	location
1027	capacity	129	actors	137	willingness	149	revenue			661	quality
981	lighting	124	decision	125	satisfaction	146	LCOE			486	reliability
944	biomass	123	initiatives	117	migration	140	income			472	installation
713	fuel	117	strategy			107	contract			449	isolated
665	distribution	115	agency							383	engineering
641	storage	113	political							353	training
401	off-grid	110	promote							242	knowledge
397	biogas	105	regulatory							232	planning
385	engine	100	partnerships							103	productive
348	oil										
341	extension										
296	rice										
287	gas										
268	conversion										
267	temperature										
229	jatropha										
215	fossil										
210	thermal										
210	transmission										

As I am focussing on the potential of the use of renewables in microgrids, a category related to sustainability and the environment could not be absent. Also, in quite a few of the selected papers the environmental perspective was used in writing about rural electrification.
The frugal category is mainly interesting as I am looking at remote, rural areas, where the people have no access to electricity. And as a frugal innovation is defined to be cheap, easy to use and develop with minimal amounts of raw materials (Rao, 2013). And as it is a new innovation mind-set that tries to help overcome the challenges of resource constraints while serving and profiting from underserved consumers (Bhatti et al., 2013). I therefore believe this category is a needed addition to the existing categories. I have chosen to name this category 'frugal', but it also could have been labelled 'inclusive', as the field I want to capture is also very much related to the theory of inclusive growth. George et al. (2012) define inclusive growth as "improvements in the social and economic wellbeing of communities that have structurally been denied access to resources, capabilities, and opportunities. Inclusive growth can be viewed as a desired outcome of innovative initiatives that target individuals in disenfranchised sectors of society as well as, at the same time, a characteristic of the processes by which such innovative initiatives occur".
The listed key concepts give a good picture of the field of rural electrification, while at the same time further defining the six subject areas recognized in this field.

6. Interpretation of key concepts and categories

Now we know which concepts are key in studies on rural electrification, we would like to look at these key concepts a bit more. We should remember that the key concepts are the result of the grouping of the most frequent concepts and these frequently used concepts originate from my selection of meaningful words in each of the categories.
We will use the key concepts to describe the six categories in more detail. What do they tell us about the categories they are grouped under? There is searched for relationships between the key concepts, in order to understand the six categories even better. In addition, we will give more context to any of the key concepts that stand out from the overall picture of the category.

6.1 Interpretation of technology category

Two types of concepts characterize this category, the first are concepts that describe a physical microgrid: engine, supply, transmission, distribution, storage, etc. These are all parts and processes related to the generation of electricity. The second type of concepts are sources of energy, thus, for example all well-known ways of producing renewable energy are listed: solar, wind, hydro, biomass and (geo)thermal. The fact that an electricity grid is a complex system and the fact that there exist a lot of different ways to provide the grid with electricity, might explain why this category has the longest list of key concepts.
Two sources of renewable energy that might need some more explanation are rice and jatropha, as I think these are less obvious and clear concepts for anyone who has not been introduced to the topic of rural electrification before.
Rice husk can be used as biomass to produce electricity, which is done in Cambodia: "Rice husk is locally abundant at almost no cost, with a production over 9.3 million tons paddy rice in 2014 for a total population of about 15 million people. The conversion of rice husk into electricity through gasification or thermally generated electricity is a well-known technology. Rice husk can contribute in a sustainable manner to grant access to electricity to Cambodian rural population and is more reliable and competitive with reference to other renewable energy sources of electricity" (Pode et al., 2015).
So the sole fact that rice husk is available in large quantities makes for a feasible way of producing electricity. There is a silent prerequisite, though: an energy demand that is not too high. Which is casually mentioned by Pode et al. (2015): "Since the energy requirement of rural population is not very high, rural electrification in many villages realized with a small scale gasifier is providing a sustainable solution to improve the access to energy and, at the same time, to guarantee a cheap kWh." So rice husk can be alternative source of energy in rural areas, if the availability of rice husk matches the demand for energy.
"*Jatropha curcas* L. is a small tree that yields oil-bearing seeds. Once extracted the high quality oil can be used directly or converted into biodiesel, either being suitable for use in engines of automobiles or electrical power generation" (Almeida et al., 2014). In the production of bio oil or biodiesel from jatropha the main factors to take into account are availability of jatropha, the yield (Almeida et al., 2014) and willingness to work of the local population, as jatropha is a labour intensive crop (Grimsby et al., 2012). Unfortunately the yield is hard to influence, as it depends on things like rainfall and annual average temperature (Bouffaron et al., 2012). It can however have large implications: "We found that the global warming potential of Jatropha-based electrification can be 13% higher to 20% lower than fossil diesel, depending on the yield.

In terms of energy use and fossil fuel depletion, Jatropha is more favourable than fossil-based electricity" (Almeida et al., 2014). Like rice husk, jatropha can be used as an alternative source of renewable energy. Although the production of bio oil or –diesel is dependent on the jatropha yield which is hard to influence.

6.2 Interpretation of institutional category

The institutional category is mainly made up of intangible concepts like governmental instruments (policy, subsidy) and governmental bodies (ministry, agency). We are aware of the potential of a proactive role taken by influential stakeholders and thus include concepts like initiatives and actors. We also look beyond national borders and include concepts like international and partnerships. This is done to illustrate that rural electrification is not a problem that only can be solved by local or national institutions.

6.3 Interpretation of user-centric category

Under the user-centric category fall concepts that define the human side of this category: people, households, community and village. Is also includes concepts that describe the challenges these people have in living without electricity access; getting access would help them with activities as cooking, going to school and would increase their health.
I would like to explain why 'women' is an often-used word in papers on rural electrification. I want to use an example from the paper of Grogan and Sadanand (2013), who studied rural electrification in Nicaragua and "found that household electrification causes rural women to be about 23% more likely to work outside the home, but that there are no such effects for men".
Women gain this time, because they "spent much less time cooking in electrified than in unelectrified households […] and also less time getting water and firewood". "The provision of electric light to households appears to make it more likely that households become monetized, in the sense of both having women earning money outside the home and buying, rather than gathering, cooking fuel. Electricity, even if not accompanied by vacuum cleaners, dishwashers, and washing machines, impacts intrahousehold resource allocation in ways that are positive for female employment" (Grogan & Sadanand, 2013).
This example also gives insight in how all user-centric concepts are interrelated, because this is certainly the case. Even between categories relations becomes apparent, as we see the technological concept of lighting and the viability concept of income are connected with concepts in the user-centric category.

6.4 Interpretation of viability category

Both the consumer side and the investor side are represented in the viability category. The consumer will mainly be concerned with the tariff or price for electricity and whether they can pay this with their income. The investor will be concerned with the investment it needs to make, so capital costs, a viable business plan, the project revenues and the risks involved with a microgrid development need to be considered. In addition, the financial arrangements between parties need to be considered: so the types of contracts, the ability for different parties to get a loan and the general status of the financial and energy markets are of interest.

6.5 Interpretation of environmental category

The first thing to notice is that the environmental category contains the shortest list of key concepts. This could either be because, in contrast to the technology category, one does not need many different words to explain the environmental field. Or the analysed papers do not use words related to the environmental field often enough to have made the selection of most frequently used concepts.
Either way, the six key concepts tell a clear story. One needs to produce electricity in a sustainable manner from renewable sources, so the emissions of polluting and greenhouse gasses is kept to a minimum and climate change is controlled.

6.6 Interpretation of frugal category

The frugal category includes concepts related to frugal innovation and inclusive growth. It contains concepts that describe the circumstances of the location of interest, which is often located in isolated, remote and rural areas. This has consequences for the community's access to resources, both of the human and material kind. Because of this, extra attention needs to be given to the building and operation of potential future microgrids. The level of knowledge and training under the local population in the field of electrification is probably low, because of its remote location and disadvantaged people. This is also why the frugal and institutional categories are related, as public policy will be needed to promote the education of local communities.
I would like to illustrate this with two quotes from papers on the topic of rural electrification in Africa: "This paper has reviewed the development of the Kenyan small wind turbine sector" [in which] "there remain pertinent barriers within the regime and the landscape, which include the low government participation, high poverty levels and scepticism towards new technologies.

Among the direct influences, we conclude that several material infrastructure and socio-cultural factors inhibit sector growth: Kenya's under developed infrastructure, lack of raw materials, Dependency Syndrome, negative image of self-employment, low quality manufacturing culture, corruption and years of resistance to knowledge sharing" (Kamp & Vanheule, 2015).
"In Tsumkwe local service providers were unprepared to take charge of operations and maintenance after completion of the project and users have difficulties paying for the services. Too strong focus on technology and insufficient efforts made to involve local institutions and beneficiaries throughout the project are main causes. The promotion of local entrepreneurship in Sekhutlane has resulted in 17 local businesses being established, likely to strengthen the cash economy and improved ability to pay for services, and thereby contributing financial resources towards operation and maintenance of systems" (Klintenberg et al., 2014).

7. Conclusion, discussion and recommendations for future research

It can be concluded from the content analysis that the scientific publishing on rural electrification has increased significantly. Over the last 26 years, since rural electrification was first mentioned in a journal, 434 academic papers have been written about the subject. Just a bit less than half of those were published in the last 4 years, between 2012 and 2015. Because many of these papers cover case studies, it is concluded that rural electrification has gained interest in the real world too.
The perspective that is used most, in writing about rural electrification, is that of technology. Based on my content analysis and the paper of Schillebeeckx et al. (2012) we can say that 51% of the papers have 'technology' as the dominant lens. The most assigned secondary lens, for the papers published between 2012 and 2015, is 'viability'. Thus rural electrification is mainly studied with the technological options for electrification in the leading role, with viability aspects in the supporting role. Apparently, after 26 years of studying this topic, there are still new and developing technologies to consider and investigate.
When we compare the papers published in the last 4 years and compare them with the papers published before that, it becomes clear that the user-centric lens has gained in interest what the institutional lens has lost. It seems like Schillebeeckx et al. (2012) had a predictive view, as they mainly focussed on the user-centric lens, whilst this was the lens with the lowest prevalence in their research.
I wish I could look in the future to see if my additionally defined categories (environmental and frugal) have such an evolution lying ahead for them. Would environmental concerns and concepts associated with frugal innovation and inclusive growth get more attention over the coming years in writing about rural electrification? I at least hope that it will inspire other researchers to use them as a different way of looking at rural electrification. In addition to the other lenses, as it is important to integrate the different views, see where they strengthen or weaken each other. This integration of perspectives will also mean you are bringing different parties together to get answer to questions in the different fields related to rural electrification. As a result partnerships could arise.
With this content analysis we have found an answer to the first part of the research question that we aimed to answer in this paper. The subject areas that are dominant in studies on rural electrification are: technology, institutional, user-centric and viability. To which I have added two emerging categories: environmental and frugal.
In answering the second part of the research question, we have to look back to Table 3. This table gives us a perfect overview of the concepts that are most frequent in studies on rural electrification.

Appendix A

I used a different methodology than Schillebeeckx et al. (2012), but did in essence the same. The biggest difference is that they grouped more words together under one concept than I did. Also, they were purposely looking for specific words, I only included and interpreted the most frequent ones.
I will explain my methodology here:
1. Save papers as plain text in four separate folders.
2. Run computer script four times: once per category. The script runs all words through a code that searches for unique words and counts the occurrence of these words in the inputted text. The output is a list of words with the frequency of those words printed in front of it.
3. Filter out the meaningful words of the most frequent words per category.
All words that are counted 100 times or more are considered to be frequently used. For the papers in the technological category, the limit is set a bit higher at 200 times, as 50% of all papers are categorized with technology as the main lens. If the frequency limit was set at 100 for this category, 892 words would have been selected, instead of the 434 words that are analysed now. For the other categories 421, 305 and 261 words were selected for analysis, applying the frequency limit of 100.

Meaningful is interpreted as words related to the category. So words like 'the', 'have' and 'with' are not considered to be meaningful. When looking for meaningful words in the technology category, words that are related to one of the other five categories are not considered meaningful. So a 'financial' word like 'capital' or an 'environmental' word like 'emissions' will not be found in the list of frequent and meaningful words of the technology category.

4. Group words that are very similar, like the singular and plural of the same word. Also related words are grouped, to give a few examples: batteries & charging or village & township or world & global. When similar words are grouped, their frequencies are added together. This brought a list of 56 technological concepts back to 34 concepts, which makes them much easier to interpret and work with in the second part of this research.

5. Done! The final lists with key concepts per category is found.

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Appendix B. Access to electricity per country

Table 18 List of countries of which not the full population has access to electricity (World Bank, 2012)

#	Country name	% that has access to electricity
1	South Sudan	5.1
2	Chad	6.4
3	Burundi	6.5
4	Liberia	9.8
5	Malawi	9.8
6	Central African Republic	10.8
7	Burkina Faso	13.1
8	Sierra Leone	14.2
9	Niger	14.4
10	Tanzania	15.3
11	Madagascar	15.4
12	Congo, Dem. Rep.	16.4
13	Rwanda	18.0
14	Papua New Guinea	18.1
15	Uganda	18.2
16	Mozambique	20.2
17	Lesotho	20.6
18	Mauritania	21.8
19	Zambia	22.1
20	Solomon Islands	22.8
21	Kenya	23.0
22	Mali	25.6
23	Guinea	26.2
24	Ethiopia	26.6
25	Vanuatu	27.1
26	Korea, Dem. Rep.	29.6
27	Cambodia	31.1
28	Togo	31.5
29	Sudan	32.6
30	Somalia	32.7
31	Gambia, The	34.5
32	Eritrea	36.1
33	Angola	37.0
34	Haiti	37.9
35	Benin	38.4
36	Zimbabwe	40.5
37	Timor-Leste	41.6
38	Congo, Rep.	41.6
39	Swaziland	42.0
40	Afghanistan	43.0
41	Tuvalu	44.6
42	Namibia	47.3
43	Yemen, Rep.	48.4

#	Country name	% that has access to electricity
44	Myanmar	52.4
45	Botswana	53.2
46	Djibouti	53.3
47	Cameroon	53.7
48	Nigeria	55.6
49	Cote d'Ivoire	55.8
50	Senegal	56.5
51	French Polynesia	59.3
52	Palau	59.3
53	Micronesia, Fed. Sts.	59.3
54	Kiribati	59.3
55	American Samoa	59.3
56	Fiji	59.3
57	New Caledonia	59.3
58	Guam	59.3
59	Marshall Islands	59.3
60	Bangladesh	59.6
61	Sao Tome and Principe	60.5
62	Guinea-Bissau	60.6
63	Ghana	64.1
64	Equatorial Guinea	66.0
65	Comoros	69.3
66	Lao PDR	70.0
67	Cabo Verde	70.6
68	Bhutan	75.6
69	St. Vincent and the Grenadines	75.9
70	Brunei Darussalam	76.2
71	Nepal	76.3
72	Nicaragua	77.9
73	Guatemala	78.5
74	India	78.7
75	Guyana	79.5
76	Honduras	82.2
77	South Africa	85.4
78	Philippines	87.5
79	Sri Lanka	88.7
80	Gabon	89.3
81	Mongolia	89.8
82	Bolivia	90.5
83	Macao SAR, China	90.5
84	Barbados	90.9
85	Virgin Islands (U.S.)	90.9
86	St. Martin (French part)	90.9

#	Country name	% that has access to electricity
87	St. Kitts and Nevis	90.9
88	Turks and Caicos Islands	90.9
89	Grenada	90.9
90	Antigua and Barbuda	90.9
91	Panama	90.9
92	St. Lucia	90.9
93	Cayman Islands	90.9
94	Aruba	90.9
95	Puerto Rico	90.9
96	Curacao	90.9
97	Peru	91.2
98	Jamaica	92.6
99	Dominica	92.7
100	Pakistan	93.6
101	El Salvador	93.7
102	Tonga	95.9
103	Indonesia	96.0
104	Syrian Arab Republic	96.3
105	Colombia	97.0
106	Ecuador	97.2
107	Kuwait	97.7
108	West Bank and Gaza	97.7
109	Bahrain	97.7
110	Oman	97.7
111	Saudi Arabia	97.7
112	United Arab Emirates	97.7
113	Qatar	97.7
114	Dominican Republic	98.0
115	Paraguay	98.2
116	Vietnam	99.0
117	Mexico	99.1
118	Brazil	99.5
119	Jordan	99.5
120	Costa Rica	99.5
121	Uruguay	99.5
122	Chile	99.6
123	Argentina	99.8
124	Trinidad and Tobago	99.8

Appendix C. Steps of the content analysis

The content analysis is executed following seven steps, which were distilled from Schillebeeckx' paper. These steps and their results are presented here. A full discussion of the results is presented in chapter 0.

1. Search for papers with the phrase 'rural electrification' in their abstract, title or keywords of journals from 2012 to present (excluding 2016). Exclude books from the search.
   Result: 202 papers were found on 30 November 2015 using the search engine ScienceDirect.
2. Check if any papers are published in 'Fuel and Energy Abstracts', 'Refocus' or 'Photovoltaic Bulletin'. These journals are considered not to be academic in nature. Exclude paper if published in any of these journals.
   Result: none of the selected papers was published in one of these journals, so no articles are excluded. We think ScienceDirect agrees with Schillebeeckx et al. (2012) and does not consider these journals to be of a high enough academic standard, therefore no articles published in these journals came up in the search engine.
3. Check if the selected papers actually discuss the topic of 'rural electrification'.
   Result: zero papers were excluded after having read all their abstracts. We did find some papers that were focused around a very specific topic or technology. But these papers were not excluded, as possible technology specific jargon would be filtered out with the use of word-frequency count. This will be further explained in step 5.
4. Read abstracts and decide in which a priori category the paper fits. Classify with exactly one dominant and between zero and three secondary lenses. In case of doubt, choose more lenses.
   Result: I read all the abstracts and decided which of the four lenses that Schillebeeckx et al. (2012) applied (technology, institutional, viability, user-centric) matched the content of the paper best. Figure 5 was used as a handhold.

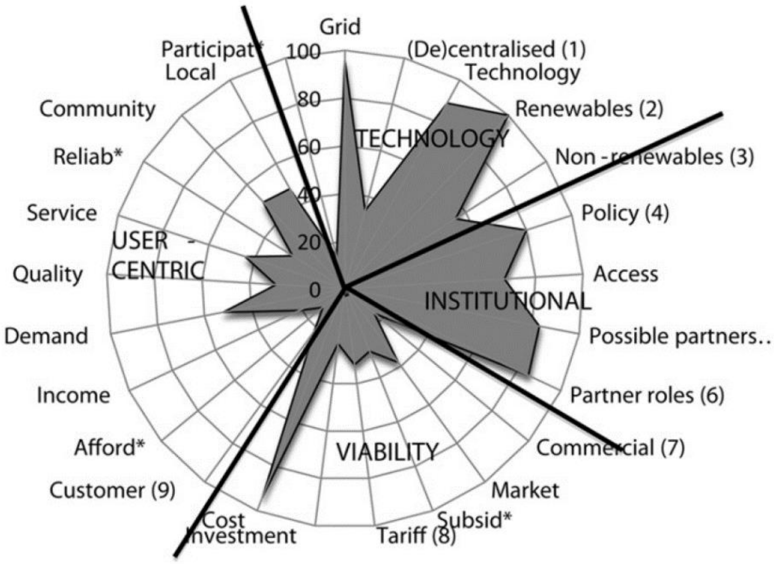

Figure 5 First order words for the four lenses (Schillebeeckx et al., 2012)

I also chose one or more secondary lenses if one lens was not enough to capture the full content of the article. Combining the four lenses in all ways possible, gave 32 possible lens-categories that are listed in Appendix D0. All 202 papers selected for content analysis are assigned one of these lens-categories based on their abstract (see Appendix E).

Schillebeeckx et al. (2012) described in their paper that they categorized the first 50 papers with an iterative process between the authors. After which Schillebeeckx categorized that remaining papers himself, with just a random sample of 25 papers that was assessed by the other authors as a control. In this content analysis I categorized all the papers myself. The only check I performed was a quick test using my colleagues at Arup: I presented them (as a group) with six randomly chosen papers and asked them to assign a dominant lens and (non-mandatory) secondary lenses to those. It appeared that we both chose the same lenses to categorize the paper. But in two of the six cases there was discussion about which of those lenses was the most dominant. There was also disagreement amongst my colleagues. This shows that the categorization of the papers was based on an informed choice, not on facts. However, I can say that whilst reading 202 abstracts, you develop a skill for categorizing papers.

5. Find key concepts and emerging categories using 'word-frequency count'. Group similar words.
   Result (key concepts): the most frequent and therefore key concepts per category are found with the use of 'word-frequency count'. The methodology used to count the most frequent words is explained in Appendix F and the results are given in Appendix G. The meaningful concepts of the most frequently used words per category are summarized in Table 3.
   Result (emerging categories): part of the word-frequency count method is defining which of the most frequently used words have a meaning associated with one of the four categories as applied by Schillebeeckx et al. (2012). Sometimes during this process, I would find a meaningful word that I would find hard to link with any of the four categories. An example: 'climate' and 'emissions', I felt these words (and a few related ones) would work best under the header of 'environmental'. Also, in quite a few papers this perspective was used in writing about rural electrification, so I believe it makes sense to add this categories as a fifth one. I also found words like 'installation', 'maintenance', 'resources' and 'knowledge', which I associated with the concept of frugal innovation. This concept is explained in paragraph 3.4
6. Search for relationships between the first order words. Categorize related words under second order concepts.
   Result: this is done as the fourth step of the word-frequency count method, so see Appendix F and Appendix G for the full results. In these appendices you can see why and how first order concepts are grouped into second order concepts.
7. Use second and first order concepts to describe lenses.
   Result: greater understanding of relations between concepts and lenses.

Appendix D. Possible lens combinations

Table 19 All possible combinations of lenses (as defined by (Schillebeeckx et al., 2012)) used to categorize papers based on their abstract

1.1	**Technology**			
1.2	**Technology**	Institutional		
1.3	**Technology**	Viability		
1.4	**Technology**	User-centric		
1.5	**Technology**	Institutional	Viability	
1.6	**Technology**	Institutional	User-centric	
1.7	**Technology**	Viability	User-centric	
1.8	**Technology**	Institutional	Viability	User-centric
2.1	**Institutional**			
2.2	**Institutional**	Technology		
2.3	**Institutional**	Viability		
2.4	**Institutional**	User-centric		
2.5	**Institutional**	Technology	Viability	
2.6	**Institutional**	Technology	User-centric	
2.7	**Institutional**	Viability	User-centric	
2.8	**Institutional**	Technology	Viability	User-centric
3.1	**Viability**			
3.2	**Viability**	Technology		
3.3	**Viability**	Institutional		
3.4	**Viability**	User-centric		
3.5	**Viability**	Technology	Institutional	
3.6	**Viability**	Technology	User-centric	
3.7	**Viability**	Institutional	User-centric	
3.8	**Viability**	Technology	Institutional	User-centric
4.1	**User-centric**			
4.2	**User-centric**	Technology		
4.3	**User-centric**	Institutional		
4.4	**User-centric**	Viability		
4.5	**User-centric**	Technology	Institutional	
4.6	**User-centric**	Technology	Viability	
4.7	**User-centric**	Institutional	Viability	
4.8	**User-centric**	Technology	Institutional	Viability

These lens combinations are used to categorize the papers selected for content analysis. The first number is the number of the dominant lens, the second is a way of categorizing the other, secondary lenses. This numbering from 1.1 to 4.8 is used in Appendix E.

Appendix E. Lenses applied to papers

Table 20 Lenses applied to the papers selected for content analysis (use Appendix D to understand numbering)

Lenses		1	Technology							2	Institutional							3	Viability							4	User-centric						
First author	Year	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Abdullah	2012																															X	
Adebayo	2013																X																
Agarwal	2013	X																															
Ahammed	2013							X																									
Ahlborg	2014																X																
Ahlborg	2015															X																	
Akikur	2013	X																															
Akpan	2013																					X											
Akpan	2015																		X														
Alex	2014	X																															
Almeida	2014	X																															
Arashnia	2015	X																															
Asrari	2012			X																													
Astolfi	2015			X																													
Azimoh	2014																														X		
Azimoh	2015																														X		
Banerjee	2012																	X															
Bassett	2015	X																															
Bazmi	2015			X																													
Bekele	2012	X																															
Belouda	2013	X																															
Bensch	2012									X																							
Bergh	2014																X																
Bertheau	2014			X																													
Bhattacharyya	2012																X																
Blum	2013																					X											
Blum	2015										X																						

Lenses		1	Technology							2	Institutional							3	Viability							4	User-centric						
First author	**Year**	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Boait	**2015**				X																												
Bogno	**2014**			X																													
Bogno	**2015**			X																													
Borah	**2014**								X																								
Borhanazad	**2013**															X																	
Bouffaron	**2012**			X																													
Bridge	**2015**																									X							
Brooks	**2014**																									X							
Buitenhuis	**2012**	X																															
Camocardi	**2012**	X																															
Carrasco	**2013**																	X															
Carrasco	**2014**							X																									
Castellanos	**2015**	X																															
Chand	**2013**										X																						
Chauhan	**2015**								X																								
Chaurey	**2012**																X																
Cheng	**2014**																													X			
Cheng	**2015**	X																															
Chica	**2013**	X																															
Cobb	**2013**	X																															
Dada	**2014**							X																									
Damirchi	**2015**	X																															
Das	**2012**		X																														
Dekker	**2012**			X																													
Dia	**2014**																														X		
Dinkelman	**2015**																											X					
Diouf	**2013**																										X						
Diouf	**2013**																									X							
Domenech	**2015**							X																									
Domenech	**2015**				X																												
Dorji	**2012**								X																								
Dornan	**2014**									X																							
Eder	**2015**																														X		

Lenses		1	Technology							2	Institutional							3	Viability							4	User-centric						
First author	Year	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Eziyi	2014				X																												
Fadaeenejad	2014	X																															
Ferrer-Marti	2012								X																								
Ferrer-Marti	2013							X																									
Fuso Nerini	2014								X																								
Gago Calderon	2015	X																															
Ghaem Sigarchian	2014	X																															
Ghaem Sigarchian	2015			X																													
Ghasemi	2013			X																													
Ghezloun	2012									X																							
Ghezloun	2012									X																							
Gomez	2012															X																	
Gomez	2015															X																	
Gomez	2015																X																
Grimsby	2012							X																									
Grogan	2013																									X							
Gurung	2012																X																
Harish	2013																																X
Harish	2013								X																								
Harish	2014																								X								
Hassiba	2013			X																													
Hazelton	2014																								X								
Hirmer	2014																									X							
Holtmeyer	2013			X																													
Hong	2012								X																								
Hong	2012																														X		
Hong	2015																														X		
Hoque	2013							X																									
Ismail	2015																			X													
Javadi	2013										X																						
Kamp	2015						X																										
Karakaya	2015						X																										
Kaunda	2013					X																											

Lenses		1	Technology							2	Institutional							3	Viability							4	User-centric						
First author	Year	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Khan	2015	X																															
Khan	2015							X																									
Khandker	2012																											X					
Khatiwada	2012		X																														
Klintenberg	2014						X																										
Kobayakawa	2014																				X												
Kobayakawa	2014																										X						
Kobayakawa	2015																										X						
Kocaman	2012	X																															
Koko	2015	X																															
Kolhe	2015			X																													
Komatsu	2013																									X							
Kong	2015	X																															
Kruckenberg	2015									X																							
Kusakana	2013	X																															
Kusakana	2014			X																													
Kusakana	2014			X																													
Kusakana	2014			X																													
Kusakana	2015			X																													
Laghari	2013			X																													
Lahimer	2013								X																								
Leary	2012																X																
Levin	2014																	X															
Lillo	2015																														X		
Luo	2013											X																					
Mahama	2012													X																			
Mahapatra	2012																		X														
Mainali	2012																			X													
Mainali	2013								X																								
Mainali	2015					X																											
Maltsoglou	2015								X																								
Manchester	2013																										X						
Mandelli	2015					X																											

Lenses		1	Technology							2	Institutional							3	Viability							4	User-centric						
First author	**Year**	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Manning	**2015**																												X				
Martin	**2014**								X																								
Matsika	**2013**																											X					
Mawhood	**2014**											X																					
Millinger	**2012**																										X						
Morales	**2015**					X																											
Muggenburg	**2012**																										X						
Muller	**2014**	X																															
Murni	**2012**																													X			
Murni	**2013**																												X				
Narula	**2012**																		X														
Norta	**2015**	X																															
Nurlaila	**2015**												X																				
Obermaier	**2012**																											X					
Okot	**2013**			X																													
Olatomiwa	**2015**			X																													
Onyeji	**2012**															X																	
Opiyo	**2015**	X																															
Ouedraogo	**2015**																		X														
Paleta	**2012**																														X		
Palit	**2013**													X																			
Perera	**2013**																					X											
Pinheiro	**2012**								X																								
Pode	**2013**																						X										
Pode	**2015**								X																								
Pode	**2015**								X																								
Portugal-Pereira	**2015**	X																															
Poudel	**2013**											X																					
Proietti	**2015**	X																															
Rahman	**2013**																X																
Rahman	**2013**																X																
Ranaboldo	**2013**							X																									
Ranaboldo	**2014**				X																												

Lenses		1	Technology							2	Institutional							3	Viability							4	User-centric						
First author	Year	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Ranaboldo	2014			X																													
Ranaboldo	2015				X																												
Rogers	2013								X																								
Rojas-Zerpa	2014																X																
Rojas-Zerpa	2015																X																
Sachdev	2015					X																											
Sanchez	2015								X																								
Sarraf	2013											X																					
Schillebeeckx	2012																																X
Schmidt	2013																			X													
Seraphim	2014	X																															
Shaaban	2014																X																
Sharif	2013																								X								
Shyu	2012																X																
Shyu	2013																										X						
Silva Herran	2012				X																												
Sivakumar	2012	X																															
Slough	2015															X																	
Smith	2015							X																									
Sovacool	2012																									X							
Sovacool	2012																																X
Sovacool	2013															X																	
Sowe	2014			X																													
Sriwannawit	2014																				X												
Susanto	2012				X																												
Szabo	2013																					X											
Taele	2012									X																							
Tan	2014	X																															
Tebibel	2013	X																															
Urpelainen	2014													X																			
Urpelainen	2015																															X	
Vadirajacharya	2012			X																													
Valer	2014																									X							

Lenses		1	Technology							2	Institutional							3	Viability							4	User-centric						
First author	**Year**	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Van Els	**2012**															X																	
Van Els	**2015**	X																															
Van Gevelt	**2014**																											X					
Van Ruijven	**2012**																								X								
Vermaak	**2014**					X																											
Wiemann	**2013**								X																								
Williams	**2015**																			X													
Williamson	**2015**	X																															
Ximei	**2015**																			X													
Yadoo	**2012**								X																								

Appendix F. Word-frequency count methodology

We used a different methodology than Schillebeeckx et al. (2012), but did in essence the same. The biggest difference is that they grouped more words together under one concept than we did. Also, they were purposely looking for specific words, we only included and interpreted the most frequent ones.

We will explain our methodology here:

1. Save papers as plain text in four separate folders.
2. Run computer script four times: once per category. The script runs all words through a code that searches for unique words and counts the occurrence of these words in the inputted text. The output is a list of words with the frequency of those words printed in front of it.
3. Filter out the meaningful words of the most frequent words per category.
   All words that are counted 100 times or more are considered to be frequently used. For the papers in the technological category, the limit is set a bit higher at 200 times, as 50% of all papers are categorized with technology as the main lens. If the frequency limit was set at 100 for this category, 892 words would have been selected, instead of the 434 words that are analysed now. For the other categories 421, 305 and 261 words were selected for analysis, applying the frequency limit of 100.
   A full overview of the most frequent words per category is given in Appendix G.
   Meaningful is interpreted as words related to the category. So words like 'the', 'have' and 'with' are not considered to be meaningful. When looking for meaningful words in the technology category, words that are related to one of the other five categories are not considered meaningful. So a 'financial' word like 'capital' or an 'environmental' word like 'emissions' will not be found in the list of frequent and meaningful words of the technology category.
4. Group words that are very similar, like the singular and plural of the same word. Also related words are grouped, to give a few examples: batteries & charging or village & township or world & global. When similar words are grouped, their frequencies are added together. This brought a list of 56 technological concepts back to 34 concepts, which makes them much easier to interpret and work with in the second part of this research.
5. Done! The final lists with key concepts per category are given in Table 3.

Appendix G. Word-frequency count results

The results of the word-frequency count are presented in six sub-appendices, one per category. In those appendices the full results are ‘coded’ in the following way:

- The meaningless words are given in *italic*
- The meaningful words are given in **bold**
- The meaningful words that are not specific for the looked-at category are underlined

Appendix G1. Word-frequency count results – Technology

Table 21 Full results of the word-frequency count analysis of the technology category, all words with a frequency above 200

44427 the	*1072 using*	*696 two*
21508 and	**1048 water**	*691 only*
9578 for	*1036 all*	*690 there*
9391 energy	*1029 based*	*687 projects*
4709 are	**1027 capacity**	<u>686 policy</u>
4422 power	*1023 model*	*672 time*
4389 with	*1020 potential*	*668 where*
4347 system	*1012 analysis*	<u>653 control</u>
3517 that	**1007 technology**	*652 when*
3341 this	<u>1006 costs</u>	**651 SHP**
3038 from	*992 study*	<u>648 access</u>
<u>2769 rural</u>	*973 design*	**641 storage**
<u>2750 renewable</u>	*962 table*	*640 however*
2719 electricity	*950 total*	*636 some*
<u>2676 cost</u>	**944 biomass**	<u>631 resource</u>
2576 wind	*925 different*	<u>626 area</u>
2448 systems	*923 other*	**624 batteries**
2315 solar	*917 high*	*624 000*
2300 can	*914 use*	<u>620 countries</u>
1818 has	*903 their*	*616 considered*
1803 generation	*900 one*	*610 through*
1676 have	*884 were*	*604 installed*
1637 fig	*868 low*	*598 but*
1628 hybrid	*864 most*	<u>596 voltage</u>
1533 grid	*854 each*	<u>596 remote</u>
1517 electrification	*848 such*	<u>593 operation</u>
1512 which	*848 project*	**587 plants**
1507 not	*820 production*	*585 speed*
1496 was	**806 technologies**	*582 into*
<u>1362 load</u>	<u>792 resources</u>	*574 point*
1331 development	*791 data*	<u>561 community</u>
1321 diesel	*790 number*	*552 during*
1318 battery	**784 hydropower**	*551 technical*
<u>1308 demand</u>	*781 case*	*551 about*
1295 used	*778 results*	*547 new*
1277 been	*772 between*	<u>547 national</u>
1251 small	*751 will*	<u>541 efficiency</u>
1202 turbine	*733 its*	*536 current*
1192 these	**733 hydro**	*534 they*
<u>1191 areas</u>	*731 per*	**532 plant**
1156 supply	**724 turbines**	*526 research*
1132 than	<u>721 sources</u>	<u>526 performance</u>
<u>1131 sustainable</u>	**713 fuel**	*525 value*
1128 also	*709 due*	*525 output*
1117 generator	<u>707 local</u>	<u>525 households</u>
1114 more	<u>706 economic</u>	*518 both*
<u>1079 available</u>	*703 average*	*517 level*

512 over	392 capital	**339 LED**
510 while	*389 well*	*338 without*
509 shown	*389 size*	*338 possible*
509 maximum	*388 lower*	*338 less*
508 may	*388 2014*	338 bank
504 consumption	386 government	*336 simulation*
501 higher	385 maintenance	*334 renew*
499 electric	**385 engine**	*333 impact*
497 reviews	383 optimal	**332 charge**
494 generators	*383 2012*	*330 same*
483 years	*381 shows*	330 investment
483 would	*380 because*	*329 range*
478 environmental	*378 site*	*329 important*
473 points	*377 values*	325 global
473 optimization	377 price	*323 obtained*
470 year	*375 developed*	322 Africa
469 compared	*374 given*	318 quality
468 order	371 region	*315 home*
463 solution	371 process	314 villages
461 distribution	*371 network*	*314 solutions*
460 under	370 sustainability	314 household
456 world	369 emissions	*313 respectively*
456 therefore	*369 components*	*313 day*
453 India	*368 proposed*	310 isolated
453 developing	**367 photovoltaic**	*309 homer*
449 source	365 market	*309 considering*
448 management	*363 life*	*309 2009*
448 large	*363 connected*	308 installation
448 could	*362 thus*	308 equipment
445 rate	*360 provide*	*307 selected*
444 electrical	359 china	*307 need*
439 2011	*358 section*	*302 according*
436 three	358 population	*301 scale*
436 generated	*358 annual*	*300 in:*
427 many	*357 set*	*300 daily*
423 flow	**356 lighting**	299 Nepal
422 sector	*355 (2015)*	*298 several*
416 very	**353 hydrokinetic**	*297 part*
415 country	**352 microgrid**	**297 microgrids**
414 assessment	*352 2010*	297 location
412 state	*351 increase*	297 availability
411 village	*350 tion*	**296 rice**
411 users	*350 100*	*295 estimated*
410 international	*349 presented*	*294 review*
409 should	*348 required*	*294 needs*
409 option	*348 out*	*293 south*
409 2013	**348 oil**	*292 various*
404 paper	*347 main*	*292 unit*
402 options	*345 since*	291 sustain
401 off-grid	*342 conditions*	290 social
398 communities	*341 within*	*290 scenario*
397 biogas	**341 extension**	290 initial
396 type	*340 then*	*290 change*
396 present	*339 period*	**287 gas**

287 amount	*245 minimum*	*217 although*
286 lamps	*245 even*	*217 500*
285 studies	**241 micro**	*216 NPC*
284 support	*241 any*	*216 factors*
284 applied	*240 individual*	215 located
282 around	*239 monthly*	215 income
280 produced	*236 head*	**215 fossil**
279 must	*236 assumed*	*214 terms*
278 found	235 Malawi	*214 first*
278 alternative	*235 including*	214 environment
278 2015	*234 IEEE*	*214 2008*
274 people	*234 heat*	*213 sensitivity*
274 engineering	232 peak	*213 component*
273 indicators	*232 ltd*	212 locations
273 Elsevier	*232 among*	211 sizing
272 radiation	*231 overall*	**210 transmission**
270 university	*231 module*	**210 thermal**
268 conversion	*231 models*	210 industry
267 temperature	*229 rev*	*209 reduction*
266 method	**229 jatropha**	*209 designed*
266 comparison	*229 conference*	*209 (2013)*
266 best	*228 input*	*208 problem*
264 cycle	228 frequency	*207 report*
263 kwh	*227 increasing*	*207 line*
263 being	**227 charging**	*207 impacts*
261 reliability	*227 able*	*206 them*
261 operating	*226 inverter*	*206 similar*
260 net	*225 still*	*206 made*
259 parameters	225 reliable	*206 calculated*
259 example	*225 limited*	*205 result*
256 controller	225 business	205 loads
255 sites	*225 algorithm*	*205 (2012)*
255 single	*224 benefits*	*204 taken*
255 information	*222 raps*	*204 suitable*
255 following	*222 evaluation*	**204 distributed**
254 work	221 services	*203 software*
250 specific	221 service	*203 characteristics*
250 panels	*221 ratio*	*202 increased*
250 further	*221 lack*	*202 conventional*
250 factor	*220 future*	*201 those*
249 approach	*218 program*	201 financial
249 applications	*218 like*	*200 open*
247 application	*217 meet*	*200 configuration*
247 after	217 climate	

Table 22 Selection of meaningful technology words and meaningful words grouped together

#	Grouped words	Also include:			
9391	**energy**				
5179	**electrification**	electricity	electric	electrical	
4422	**power**				
3850	**generators**				
3569	**hydropower**	water	hydro	SHP	hydrokinetic
3204	**solar**	solar	radiation	panels	
2576	**wind**				
2501	**batteries**	battery	charge	charging	
2423	**microgrid**	grid	microgrids	micro	
1926	**turbines**	turbine			
1813	**technologies**	technology			
1628	**hybrid**				
1321	**diesel**				
1156	**supply**				
1119	**plants**	plant			
1027	**capacity**				
981	**lighting**	led	lamps		
944	**biomass**				
713	**fuel**				
665	**distribution**	distributed			
641	**storage**				
401	**off-grid**				
397	**biogas**				
385	**engine**				
348	**oil**				
341	**extension**				
296	**rice**				
287	**gas**				
268	**conversion**				
267	**temperature**				
229	**jatropha**				
215	**fossil**				
210	**thermal**				
210	**transmission**				

Appendix G2. Word-frequency count results – Institutional

Table 23 Full results of the word-frequency count analysis of the institutional category, all words with a frequency above 100

20261 the	*513 its*	*311 number*
10841 and	496 households	*311 about*
4569 for	483 wind	307 community
4042 energy	*483 new*	*306 table*
2868 rural	*478 sector*	305 service
2300 electricity	472 technology	304 electrification
2249 that	*470 based*	*303 technical*
2042 are	*468 all*	**303 institutional**
2019 with	*467 than*	301 remote
1707 electrification	463 generation	300 village
1496 from	*437 they*	300 extension
1439 this	*429 through*	**298 international**
1341 power	424 resources	293 social
1311 development	422 economic	293 bank
1159 has	*421 will*	*290 total*
1139 renewable	*420 between*	*288 model*
1099 have	416 capacity	*287 000*
994 not	*416 but*	*285 research*
976 solar	*407 there*	281 distribution
972 access	*400 one*	278 Nepal
957 grid	*391 level*	*276 provide*
893 local	**390 world**	276 management
868 system	*390 only*	*275 into*
863 was	*388 use*	*275 analysis*
830 policy	*375 most*	*272 using*
804 systems	*373 developing*	271 sources
800 which	357 technologies	*270 2012*
800 areas	357 private	268 people
771 can	357 costs	267 china
749 also	*356 some*	*265 2011*
714 been	349 communities	**261 implementation**
698 project	*348 used*	*260 under*
658 government	*347 small*	*259 impact*
639 cost	*342 per*	259 demand
608 their	*342 high*	258 investment
591 these	*340 however*	*256 both*
583 other	*335 low*	*249 state*
583 more	*334 case*	247 hydropower
581 supply	*333 2010*	*246 well*
578 off-grid	331 available	*244 may*
557 projects	*327 potential*	*243 many*
556 were	326 services	*243 could*
553 countries	322 support	*243 area*
541 national	*320 fig*	242 knowledge
537 sustainable	*318 study*	*241 two*
519 such	318 population	*241 should*
516 program	*318 different*	241 maintenance

240 operation	182 Africa	*154 how*
237 where	*181 since*	154 biomass
236 rate	*181 example*	*153 pacific*
234 2009	181 companies	*152 information*
233 had	**179 subsidy**	*152 higher*
232 planning	*178 very*	151 users
232 country	*177 because*	*151 studies*
232 approach	*176 evaluation*	*150 providing*
231 policies	*176 after*	*150 criteria*
231 million	*175 issues*	*149 them*
231 important	*174 reviews*	149 Malaysia
230 region	174 decentralized	149 business
230 amazon	*173 without*	148 quality
227 electric	173 infrastructure	148 price
225 while	*172 challenges*	148 customers
225 lighting	172 central	147 urban
224 poor	*171 among*	**147 framework**
222 over	*170 when*	147 Bangladesh
220 time	*169 order*	*146 terms*
219 lack	169 income	*146 part*
219 household	**168 programme**	**146 institutions**
218 consumption	**166 programs**	*145 less*
217 year	**166 plan**	*143 those*
216 data	*166 our*	**143 global**
216 average	*165 main*	143 funding
213 results	*164 solutions*	*143 even*
213 public	**164 role**	*143 2012)*
211 provided	164 installation	*142 2010)*
211 due	*163 problems*	141 township
203 each	*163 out*	**141 ministry**
201 financial	*162 who*	*141 developed*
200 process	162 market	*140 same*
200 during	*162 large*	139 water
199 villages	162 hydro	*139 period*
195 tion	161 tariffs	139 isolated
195 fuel	*161 first*	**138 scheme**
195 Brazilian	161 load	*138 models*
194 years	*160 section*	*138 major*
194 installed	*160 alternative*	138 India
194 capital	*160 2013*	*137 increased*
193 would	*159 within*	*137 further*
192 levels	*158 required*	*137 annual*
191 three	*158 factors*	*136 therefore*
191 needs	**157 subsidies**	*136 review*
191 increase	*157 being*	136 plants
190 need	*157 (2012)*	*136 implemented*
189 hybrid	*157 2007*	*136 best*
188 poverty	156 SHS	*135 growth*
188 2000	*156 considered*	*135 2006*
187 paper	155 electrical	*135 100*
187 diesel	*155 change*	134 environment
187 design	*155 activities*	*133 still*
184 according	*155 2008*	*133 found*
183 production	154 Nigeria	133 connection
183 2011)	*154 line*	*132 any*

130 significant	*118 2012;*	*109 selected*
130 pay	**117 strategy**	*109 provision*
130 consumers	*117 related*	*109 productive*
130 barriers	*117 rates*	*109 literature*
129 successful	117 oil	*109 expected*
129 resource	*117 key*	*109 established*
129 effective	117 expansion	108 photovoltaic
129 actors	*116 made*	*108 improved*
127 utilities	*116 initiative*	*108 around*
127 including	*116 assessment*	*107 value*
126 training	*116 2005*	*107 universal*
126 set	*115 what*	107 tariff
126 result	*115 then*	*107 success*
126 ment	*115 percent*	107 equipment
126 limited	*115 existing*	*107 2004*
124 sustainability	**115 agency**	106 Tanzania
124 environmental	*115 (2013)*	*106 meet*
124 decision	114 regional	*106 although*
123 scale	**114 governments**	**105 regulatory**
123 often	*114 context*	*105 LPT*
123 initiatives	*114 building*	*104 means*
123 estimated	*113 university*	*104 lower*
123 brazil	**113 political**	*103 various*
122 long	113 performance	103 utility
121 south	*113 focus*	*103 present*
121 connections	*112 reform*	*103 appropriate*
120 work	*112 improve*	*102 several*
120 technological	112 distributed	102 off-grid
120 problem	*112 2003*	*102 especially*
120 given	*112 2002*	*102 ensure*
120 company	*111 united*	*102 (2015)*
119 report	*111 following*	101 source
119 future	111 enterprises	101 plant
119 funds	**110 promote**	*101 addition*
119 form	*110 options*	*101 2014*
118 network	*110 making*	**100 partnerships**
118 mainly	*110 make*	*100 include*
118 home	*110 impacts*	
118 current	*109 states*	

Table 24 Selection of meaningful institutional words and meaningful words grouped together

#	Grouped words	Also include:			
1154	**program**	programme	programs	scheme	plan
1061	**policy**	policies			
785	**countries**	country			
772	**government**	governments			
541	**national**				
533	**world**	global			
449	**institutional**	institutions			
336	**subsidy**	subsidies			
298	**international**				
261	**implementation**				
213	**public**				
200	**process**				
164	**role**				
147	**framework**				
141	**ministry**				
129	**actors**				
124	**decision**				
123	**initiatives**				
117	**strategy**				
115	**agency**				
113	**political**				
110	**promote**				
105	**regulatory**				
100	**partnerships**				

Appendix G3. Word-frequency count results – User-centric

Table 25 Full results of the word-frequency count analysis of the user-centric category, all words with a frequency above 100

15887 the	*387 there*	*267 land*
7827 and	*387 all*	*266 south*
3689 for	*383 number*	*265 level*
2830 energy	381 lighting	*265 however*
2159 that	**380 poverty**	**262 population**
1909 rural	*378 one*	*262 new*
1768 electricity	*370 only*	261 fuel
1597 with	*364 fig*	260 kerosene
1554 are	**358 village**	*259 home*
1400 this	*355 used*	*258 results*
1209 from	*353 project*	258 India
1115 households	351 renewable	*258 because*
942 not	*349 been*	*257 high*
891 household	**347 urban**	257 capacity
849 was	*346 between*	256 technology
824 electrification	*338 both*	**251 poor**
814 development	*334 but*	249 fuelwood
811 solar	*328 may*	245 available
795 have	**326 villages**	*244 each*
737 were	*323 they*	*242 2010*
720 system	317 world	241 Africa
702 use	*317 using*	*240 total*
681 systems	*315 analysis*	240 grid
654 more	*313 data*	*239 average*
651 power	*310 our*	*235 based*
612 which	306 sustainable	*234 while*
600 their	*306 most*	*232 technical*
586 can	**306 community**	232 bank
585 income	*302 would*	227 training
580 has	*301 two*	*225 value*
568 access	**300 users**	*224 impact*
530 SHS	*298 projects*	**224 demand**
513 per	*298 about*	*223 research*
508 these	*296 case*	*221 low*
486 than	*294 when*	220 services
483 also	*292 some*	216 costs
473 cost	**291 people**	*215 different*
470 areas	289 supply	214 price
454 consumption	286 program	*211 will*
443 such	**285 social**	*210 over*
425 study	*285 developing*	210 market
417 policy	281 countries	208 pay
403 time	279 economic	*208 many*
403 table	*278 through*	*207 approach*
397 other	*277 survey*	*206 higher*
388 model	275 battery	204 service
388 local	*271 monthly*	204 government

204 cooking	151 management	*120 likely*
202 who	*151 example*	*120 given*
202 had	*150 studies*	*120 according*
201 increase	150 financial	*119 what*
200 well	*150 factors*	119 LPG
200 important	149 infrastructure	*119 design*
199 where	149 fuels	*118 output*
199 should	*148 years*	*117 sample*
195 quality	148 programs	*117 same*
195 effects	*148 MHS*	*117 period*
194 into	148 business	**117 migration**
194 found	*148 Buduk*	*116 size*
194 could	*148 2012*	*116 following*
193 benefits	*147 among*	*116 daily*
192 needs	146 performance	*116 although*
189 during	*143 lower*	*115 result*
188 welfare	*143 after*	115 charging
188 provide	*143 activities*	114 technologies
188 area	*142 under*	*113 very*
186 user	142 sources	*113 terms*
184 due	*142 potential*	*113 further*
183 less	**142 load**	*111 often*
183 its	142 electrification	*111 much*
180 how	*141 year*	*111 hours*
176 education	140 national	*111 being*
175 light	**138 school**	*109 current*
174 paper	**137 willingness**	*108 mean*
173 women	*136 effect*	*108 individual*
173 information	*134 respondents*	*108 having*
172 tion	*133 work*	107 operation
171 without	133 water	**106 township**
169 small	*132 significant*	*106 shown*
169 life	*132 change*	*106 show*
169 installed	*131 therefore*	106 distribution
169 health	*129 impacts*	106 appliances
168 expenditure	*128 shows*	*106 any*
168 communities	126 remote	105 standard
167 thus	*126 order*	*105 characteristics*
167 even	*126 levels*	*105 able*
164 does	*126 day*	*105 2007*
162 variables	*126 000*	104 process
161 lack	**125 satisfaction**	*104 main*
157 connection	*124 improve*	104 batteries
156 need	124 electric	*103 models*
156 modern	*124 (2012)*	*103 estimated*
156 maintenance	123 resources	**102 villagers**
156 international	*123 provided*	*102 then*
156 charge	*122 within*	*102 stacking*
155 sustainability	*122 rate*	*102 possible*
155 2011	*122 large*	*102 key*
153 out	122 lamps	*101 estimate*
153 biomass	121 sustain	*100 united*
152 three	*121 state*	100 plant
152 those	*121 2005*	*100 means*
152 since	*120 them*	

Table 26 Selection of meaningful user-centric words and meaningful words grouped together

#	Grouped words	Also include:		
2006	**households**	household		
892	**village**	villages	townships	villagers
820	**consumption**	demand	load	
631	**poverty**	poor		
553	**people**	population		
486	**users**	user		
474	**community**	communities		
388	**local**			
347	**urban**			
285	**social**			
204	**cooking**			
176	**education**			
173	**women**			
169	**health**			
138	**school**			
137	**willingness**			
125	**satisfaction**			
117	**migration**			

Appendix G4. Word-frequency count results – Viability

Table 27 Full results of the word-frequency count analysis of the viability category, all words with a frequency above 100

12089 the	*315 was*	224 load
5982 and	*310 analysis*	*223 potential*
3184 for	*299 such*	*222 through*
2441 energy	295 world	*222 case*
1539 electricity	*294 than*	**221 financing**
1384 rural	293 village	*220 when*
1381 are	293 households	*220 most*
1367 cost	*290 their*	**218 subsidies**
1219 that	*289 table*	*213 only*
1061 solar	*285 used*	210 battery
1055 from	285 government	*207 while*
1036 with	281 technology	*207 number*
915 this	*281 other*	*206 000*
793 grid	281 fuel	*205 about*
733 power	280 population	*204 new*
692 system	277 local	*203 were*
692 renewable	**275 private**	203 Indonesia
672 systems	**275 market**	*197 2011*
644 costs	275 capacity	*195 each*
640 electrification	267 lighting	*195 developing*
616 demand	*265 option*	194 photovoltaic
609 development	*265 high*	193 biomass
596 have	262 countries	*191 years*
541 has	**260 bank**	190 consumption
537 can	*257 use*	**189 subsidy**
521 which	*255 project*	*189 due*
511 access	*254 rate*	*189 between*
465 not	254 available	*188 options*
428 policy	*251 study*	*187 where*
424 fig	250 technologies	*187 may*
421 small	*249 all*	186 Africa
410 also	*247 total*	*183 results*
380 will	*247 projects*	*183 into*
376 diesel	*243 different*	**183 business**
370 more	*237 using*	*181 there*
369 investment	**236 price**	*178 year*
356 these	234 national	*175 they*
356 SHS	**232 economic**	*174 some*
356 hydropower	*231 sector*	**174 financial**
353 per	*231 however*	*172 increase*
350 generation	*231 2012*	171 extension
349 been	229 household	*169 two*
347 sustainable	*229 data*	169 program
344 based	**228 capital**	*169 one*
335 model	*226 low*	168 resources
328 supply	**225 loan**	*168 average*
317 areas	*225 level*	167 poor

167 2010	*132 section*	*111 production*
163 tariff	132 hydro	110 sustain
163 hybrid	130 decentralized	*110 levels*
160 over	*129 paper*	*110 both*
159 under	129 off-grid	109 installation
159 but	*128 impact*	*109 considered*
158 time	128 distribution	108 social
158 sources	128 country	*108 lack*
158 installed	*127 support*	*108 during*
158 home	127 public	*107 result*
157 services	127 people	*107 hours*
157 could	*127 many*	**107 contract**
156 its	126 consumers	*106 often*
156 higher	126 communities	*106 literature*
155 would	*126 benefits*	*105 size*
155 international	125 electrification	*105 network*
154 maintenance	*124 very*	*105 change*
154 India	*124 shows*	104 villages
152 provide	*123 annual*	*104 provided*
152 global	*121 shown*	*104 nodes*
151 million	*120 well*	*104 needs*
149 service	120 agency	104 infrastructure
149 revenue	*119 estimated*	104 customers
146 LCOE	119 availability	*104 additional*
145 investors	*117 monthly*	*104 2009*
144 Bangladesh	117 carbon	103 productive
143 reviews	*116 out*	*102 various*
142 remote	115 water	*102 value*
142 2013	*115 period*	**102 risks**
141 operation	*115 our*	102 region
140 income	*115 lower*	*102 reduction*
138 prices	*115 important*	102 management
137 wind	115 china	**101 risk**
136 therefore	*113 technical*	101 programme
136 research	*113 (2013)*	*101 models*
136 providing	*112 present*	*101 growth*
135 SHSs	112 interest	101 efficiency
134 required	*112 existing*	*101 2008*
132 unit	*112 design*	100 policies
132 should	**112 credit**	**100 investments**

Table 28 Selection of meaningful viability words and meaningful words grouped together

#	Grouped words	Also include:	
2011	**cost**	costs	
614	**investment**	investors	investments
407	**subsidies**	subsidy	
374	**price**	prices	
337	**loan**	credit	
275	**market**		
275	**private**		
260	**bank**		
232	**economic**		
228	**capital**		
221	**financing**		
203	**risks**	risk	
183	**business**		
174	**financial**		
163	**tariff**		
149	**revenue**		
146	**LCOE**		
140	**income**		
107	**contract**		

Appendix G5. Word-frequency count results – Environmental

Table 29 Meaningful environmental words selected per category of papers and meaningful words grouped together and summed

Technology		Institutional		User-centric		Viability		Total	
2750	renewable	1139	renewable	351	renewable	692	renewable	**5850**	**sustainable**
1131	sustainable	537	sustainable	306	sustainable	347	sustainable	**1190**	**renewable**
478	environmental	134	environment	155	sustainability	117	carbon	**950**	**environmental**
370	sustainability	124	sustainability					**369**	**emissions**
369	emissions	124	environmental					**217**	**climate**
217	climate							**117**	**carbon**
214	environment								

Appendix G6. Word-frequency count results – Frugal

Table 30 Meaningful frugal words selected per category of papers and meaningful words grouped together and summed

Technology		Institutional		User-centric		Viability		Total	
2769	rural	2868	rural	1909	rural	1384	rural	**8930**	**rural**
1191	areas	972	access	568	access	511	access	**3592**	**area**
1079	available	800	areas	470	areas	317	areas	**2699**	**access**
792	resources	424	resources	245	available	254	available	**2325**	**available**
721	sources	331	available	227	training	168	resources	**2267**	**resources**
653	control	326	services	220	services	158	sources	**1842**	**sources**
648	access	305	service	204	service	158	installed	**1803**	**services**
631	resource	301	remote	195	quality	157	services	**1342**	**operation**
626	area	276	manage-ment	188	area	154	mainte-nance	**1165**	**remote**
596	remote	271	sources	169	installed	149	service	**977**	**manage-ment**
593	operation	242	knowledge	156	mainte-nance	142	remote	**936**	**mainte-nance**
526	perfor-mance	241	mainte-nance	151	manage-ment	141	operation	**909**	**control**
449	source	240	operation	146	perfor-mance	119	availability	**785**	**perfor-mance**
448	manage-ment	232	planning	142	sources	109	installation	**742**	**equipment**
385	mainte-nance	164	installation	126	remote	103	productive	**724**	**location**
383	optimal	148	quality	123	resources	102	manage-ment	**661**	**quality**
318	quality	139	isolated	107	operation			**486**	**reliability**
310	isolated	129	resource					**472**	**installa-tion**
308	installation	126	training					**449**	**isolated**
308	equipment	113	perfor-mance					**383**	**engineer-ing**
297	location	107	equipment					**353**	**training**
297	availability	101	source					**242**	**knowledge**
274	engineer-ing							**232**	**planning**
261	reliability							**103**	**productive**
261	operating								
256	controller								
225	reliable								
221	services								
221	service								
215	located								
212	locations								

Appendix H. Factors from deepening and broadening literature research

Factors are only listed once: if a similar factor comes forward in the same or a different category multiple times, it is only listed once, in the category most fitting.

Appendix H1. Technological factors

Under 'source' the paper is referred that the explanation is quoted from. It is also the 'source' of the factor, but when following that logic, several factors should have had multiple 'sources'. As Suarez was inspired by Schilling and Van de Kaa used both Suarez and Schilling as a reference. For clarity, we have chosen to give the first paper that mentioned the factor and built the list by studying the three papers in chronological order, adding new factors to the list that were not described in the previous paper(s).

Table 31 Technological factors based on in-depth literature research

Factor	Explanation	Source
Invest in learning	"The resource-based view of the firm and the literature on organizational learning and renewal reveal that, through investment in technology development and its associated learning, firms both expand their knowledge and skill base (or core capabilities) and improve their ability to assimilate and utilize future information (their absorptive capacity)."	(Schilling, 1998)
Sufficient complementary goods	"A firm producing a technology for which there is a lack of complementary goods is likely to find its technology rejected."	(Schilling, 1998)
Right timing of market entry	"In an industry where pressures encouraging adoption of a dominant design exist, the timing of a firm's investment in new technology development may be critical to its likelihood of success."	(Schilling, 1998)
Firm's technological superiority	"Other things being equal, the better a technology performs with respect to competing technologies, the higher the likelihood that it will become dominant."	(F. F. Suarez, 2003)
Firm's complementary assets	Manufacturing capabilities	(F. F. Suarez, 2003)
Firm's credibility	Experience and reputation	(F. F. Suarez, 2003)
Timing of systemic R&D activities	Related to the 'right timing of market entry' factor	(F. F. Suarez, 2003)
Pricing strategy	"Early aggressive pricing in the presence of network effects can lead to a larger installed base that in turn makes it more likely a firm's technology will become dominant [(Katz & Shapiro, 1985)]."	(F. F. Suarez, 2003)
Managing customer's expectations	The form and intensity of a firm's marketing and public relations efforts	(F. F. Suarez, 2003)
Regulation by government	"Sometimes a government will intervene directly to mandate the use of a particular technology."	(F. F. Suarez, 2003)
Regulation by private institutions	"Sometimes, private institutions such as industry associations or standard making bodies [...] can influence which technology enters the industry first or even which technology dominates."	(F. F. Suarez, 2003)
Network effects	"Direct network effects arise from mere fact that when the n^{th} customer joins a network a new network connection is created for all existing customers." "Indirect network effects arise as a result of increased demand for complementary products or services." In other words, the value of the system grows as the number of users increases.	(F. F. Suarez, 2003)
Switching costs	"The higher the switching costs, the more difficult it is for a firm to steal customers away from rivals and the more "loyal" is its own customer base."	(F. F. Suarez, 2003)

Regime of appro-priability	The ability of the project partners to profit from their innovation, by the use of patents, licences, etc.	(F. F. Suarez, 2003)
Characteristics of the technological field	“Within a new technological field, alternative technological trajecto-ries compete for dominance. It follows that the ability of a firm to reach agreement with other actors in the technological field—e.g. pro-ducers of complementary products or services and customers—will depend in part on the structure and dynamics of the technological field itself, i.e. the number and relative power of each actor and the level of cooperation versus competition.”	(F. F. Suarez, 2003)
Financial strength	“Financial strength [(Willard & Cooper, 1985)] is not only the current financial condition of the parent corporation, but also its future pro-spects.”	(van de Kaa et al., 2011)
Brand reputation and credibility	“Past performance in setting dominant formats has a positive impact on the attitude to new proposals [(Axelrod et al., 1995)]. Also, a group of format supporters with a good reputation will find it easier to at-tract other stakeholders to join the group [(Foray, 1994)] resulting in an increase in the format's installed base.”	(van de Kaa et al., 2011)
Operational su-premacy	“When a group of format supporters is composed in such a way that it is able to exploit its resources better than competitors, it has an ad-vantage over them which will positively influence its chances of reach-ing dominance with the format.” “Operational supremacy can be reached, for instance, by the possession of a superior production ca-pacity [(F. Suarez & Lanzolla, 2005)].”	(van de Kaa et al., 2011)
Compatibility	“Compatibility concerns the fitting of interrelated entities to each other in order to enable them to function together [(de Vries, 1999)].”	(van de Kaa et al., 2011)
Pre-emption of scarce assets	“Firms that are able to capture scarce assets at an early stage, thus denying them from other players, are able to create a competitive ad-vantage [(Barney, 1991)].”	(van de Kaa et al., 2011)
Big fish	“A big fish is a player (other than the group of format supporters) that can exercise a lot of influence by either promoting or financially sup-porting a format or by exercising buying power that is so great that this will tip the balance for the format to become dominant in the market [(F. Suarez & Utterback, 1995)].”	(van de Kaa et al., 2011)
Effectiveness of the format devel-opment process	“Interface formats can be developed in different ways, for instance, by a single company, in a consortium of different companies, or in com-mittees of an official standardization organization. Differences in, for instance, decision rules, process management and stakeholder in-volvement impact the effectiveness of the process, for example, in terms of its duration [(de Vries, 1999)] or the quality of the resulting specifications.”	(van de Kaa et al., 2011)
Network of stake-holders	“Several characteristics of the network of stakeholders supporting a format can have a positive influence on the chances that the format will achieve dominance. We emphasize the diversity of the network of stakeholders.”	(van de Kaa et al., 2011)
Bandwagon effect	“When some users have chosen to implement a certain solution to a matching problem, others tend to choose the same solution; often for reasons of availability of information [(de Vries, 1999)].”	(van de Kaa et al., 2011)
Number of options available	“The number of competing interface formats plays a significant role in the potential market share of a format [(Tripsas, 1997)].”	(van de Kaa et al., 2011)

Appendix H2. Institutional factors

All factors are taken from one paper, a review of studies on the critical success factors for public-private partnership (PPP) projects (Osei-Kyei & Chan, 2015). Explanations are mainly taken from the papers that Osei-Kyei and Chan (2015) reviewed, a different source is used when their explanation did not suffice.

Table 32 Institutional factors based on in-depth literature research

Factor	Explanation
Appropriate risk allocation and sharing	"Risk allocation involves identifying risks and appropriately sharing it among parties (public and private sectors) [(Ke et al., 2010a; Ke et al., 2010b)]. During negotiations, risks are clearly defined and allocated to the party that has better mitigation techniques to manage [(Roumboutsos & Anagnostopoulos, 2008)]" (Osei-Kyei & Chan, 2015).
Strong private consortium	"The complex nature of PPP projects makes it very difficult for a single construction company to execute the project hence different companies often come together to form a consortium. However, the structure and compatibility of this entity influences the success of the project. A weak and poorly managed consortium would obviously result in difficulties and eventually a failure to undertake the PPP project successfully. In this regard, consortium must be equipped with strong technical, operational and managerial capacity to be able to undertake PPP projects [(Zhang, 2005)]" (Osei-Kyei & Chan, 2015).
Political support	"It is obvious that PPP as a public policy has a direct relation with the political setting of the host country [(Li et al., 2005)]. Without the necessary political support, an approval for public expenditure on public project and work would not be granted [(Jacobson & Choi, 2008)]." "Moreover, the necessary support from political leaders attracts more investors to a particular economy. In jurisdictions where political backing is not strong, the political risk is considered to be high, which limits competition in the tendering process, as many investors would not like to tender in such environment [(OECD, 2008)]. A notable example of a country that is observed to have an overwhelming political acceptability for PPP is the U.K. [(Li et al., 2005)]" (Osei-Kyei & Chan, 2015).
Public/community support	"The acceptance and understanding by the public community be it the media, trade unions, civil societies and other non-governmental organizations is very important in ensuring the progress of PPP projects" (Osei-Kyei & Chan, 2015).
Transparent procurement	"PPP is a procurement process, therefore there is a need for transparency throughout this process. It must be highlighted that transparency does not only apply to the tendering process but it must be observed throughout the delivery of the PPP project" (Osei-Kyei & Chan, 2015).
Favourable legal framework	"Singapore has enjoyed political stability for a long time, and has a well-knit legal framework that provides a sound architecture for efficient and corruption free public procurement. Hence, the public sector is able to better manage these risk factors at low costs and ensure that PPP projects are in a favourable environment for private sectors" (Hwang et al., 2013). "Legal frameworks comprise a set of documents that include the constitution, legislation, regulations, and contracts" (Natural Resource Governance Institute, 2015).
Stable macroeconomic condition	"There is a continuum of various combinations of levels of key macroeconomic variables that could indicate macroeconomic instability. While it may be relatively easy to identify a country in a state of macroeconomic instability: large current account deficits financed by short-term borrowing, high and rising levels of public debt, double-digit inflation rates, and stagnant or declining GDP. Or stability: current account and fiscal balances consistent with low and declining debt levels, inflation in the low single digits, and rising per capita GDP. There is a substantial "grey area" in between where countries enjoy a degree of stability, but where macroeconomic performance could clearly be improved" (IMF, 2001).

Competitive procurement	"The award of the concession through tendering competition, as opposed to direct negotiation, increases the government's bargaining power in relation to the investor pursuing the project. At the same time, competitive tendering allows the local government to select the most capable investor with adequate investment funding, strong technical strength, enough operation experience, and advanced management skills. This is partly because a normal procurement process in accordance with international practice increases the project's attractiveness and heightens the investors' confidence, partly because many more investors participate in project competition, and partly because fair and transparent competition contributes to the establishment of "the best wins" mechanism and the optimum allocation of various resources" (Meng, 2011).
Strong commitment by both parties	"Commitment is a logical result of monitoring and fine-tuning the unifying specific vision throughout the sometimes challenging processes of planning and construction. In terms of the interorganizational relations theory, every participant is expected to make best commitment to accomplish agreed-specific goals and vision through active participations and involvement in the partnership projects. During the pre-construction visioning process of the PPP, participants noted that commitment became stronger because of the battles all confronted" (Jacobson & Choi, 2008).
Clarity of roles and responsibilities among parties	"Respect can be engendered through understanding each participant's roles, responsibilities and risks. Each key member of the construction group should have clear definition of roles and responsibilities. This needs to be used to help develop mutual goals for the specific vision. Those interviewed regarding the PPP noted that there was respect for the team vision and each other's needs" (Jacobson & Choi, 2008).
Financial capabilities of the private sector	"There is no generally accepted definition of the term 'financial capability'. However, at its core it means: having the knowledge, understanding, skills, motivation and confidence to make financial decisions which are appropriate to one's personal circumstances. The FSA [(Financial Services Authority)] ascribes five components to financial capability: making ends meet; keeping track of your finances; planning ahead; choosing financial products; and staying informed about financial matters" (Mendelson, 2013).
Technology innovation	"The proposal should not be technically too innovative in the country for which it is intended. For instance, a nuclear power station in a less developed country has little chance of proceeding successfully on a BOT [(build-operate-transfer)] basis" (Tiong, 1992).
Good feasibility studies	"Lessons learned, moreover, suggest that PPPs must begin with careful groundwork and preparation, including a comprehensive feasibility study and economic evaluation for each potential partnership project. In this respect, developing country governments need to build their legal and regulatory capacity to effectively foster and participate in PPPs" (Jamali, 2004).
Open and constant communication	"Selecting the right partner is crucial, as is consistent monitoring. Dixon and Cuorato point to transparent and consistent communication between parties as critical to the success of housing PPP. According to Susilawati and Armitage, trust and information have positive associations: without trust the parties do not share information and without further sharing of information, trust cannot increase" (Abdul-Aziz & Jahn Kassim, 2011).
Detailed project planning	"Other important issues include the clear statement of the objectives of the contract and the obligations and rights of the contracting parties, adequacy and clarity of plans and technical specifications, a formal dispute resolution process, and motivation and incentives to the contracting parties" (Zhang, 2005).
Government providing guarantees	"Government loan guarantees eliminate the default risk to the lender by shifting it entirely to the government, enabling the borrower to obtain much more favourable loan rates. Often, without the guarantee, the loan would not have been approved at all. In other cases, the interest rate would have been higher" (Earth Track, 2016).
Trust	"Generally, trust, openness and fairness are basic foundational underpinnings of successful PPPs." "Partners behave toward each other in honorable ways that enhance mutual trust without abusing the information they gain, nor undermining each other." "A key characteristic of a successful PPP project is a trusting relationship between the parties based on a shared vision." (Jamali, 2004)

	"Trust, open communication, and the willingness to compromise or collaborate are intertwined. Open and honest communication mechanisms engender trust when change is necessary; while trust underlies the construction team's ability to compromise or collaborate to attain mutual project objectives" (Jacobson & Choi, 2008).
Long term demand for the project	"Existence of a long-term demand of the services in the community" (Ng et al., 2012).
Clear project brief and design development	"A brief is a formal document produced at the end of the project briefing stage that defines the detailed stakeholder requirements" (Tang et al., 2012). "In theory, design development is the process of integrating an initial design with construction methods. It is a process where architects, consultants and builders further develop the design in order to match it to project constraints, regulations, construction processes and materials. There is the need to further develop the design, but there is also the need to meet practical time and cost project outcomes" (Raisbeck & Tang, 2013).
Political stability	"Political stability is the regularity of the flow of political exchanges. The more regular the flow of political exchanges, the more stability. Alternatively, we might say that there is political stability to the extent that members of society restrict themselves to the behaviour patterns that fall within the limits imposed by political role expectations. Any act that deviates from these limits is an instance of political instability" (Ake, 1975).
Mature and available financial market	"There exists a supportive market where enough debt and equity can be raised" (Ozdoganm & Talat Birgonul, 2000)
Acceptable level of tariff	"Public affordability is also a key test for economic viability. The scope of long-term service charges must be within public budget constraints. If users pay for a service, appropriate toll/ tariff levels should be established, taking into account the users' affordability. Otherwise, strong public opposition may ruin the project" (Zhang, 2005).
Compatibility skills of both parties	"There must be compatibility between the private developer and the public agency, which is not easy as the former seeks to make profit while the latter to fulfil social and electoral responsibilities. Incompatibility has resulted in lengthy negotiations" (Abdul-Aziz & Jahn Kassim, 2011).
Good leadership and entrepreneurship skills	"Strong team of stakeholder [with] leadership from a key entrepreneur or corporation" (Tiong, 1992).
Good governance	Following Chan et al. (2010) the privileges and attractions of PPP are sponsorship, assistance in financing and guarantee from government.
Clear goals and objectives	"Also, the Hong Kong survey found significant implications for industry practitioners in producing briefing guidelines, whereas the Construction Industry Board suggests that a clear and agreed objective and carefully thought-out requirements are critical for the success of the briefing process, with the former requiring an understanding of the values of the organization" (Tang et al., 2012).
Employment of professional advisors	"The local governments usually lack of experience in TOT [(transfer-operate-transfer)] practice. Employment of professionals with relevant expertise is crucial to TOT project success, although they must be paid. Professionals may include investment and financing consultants, legal advisers, and asset appraisal experts." "In fact, employment of professional advisers is not only essential to local governments, but also necessary for investors. By comparison, foreign and domestic private businesses have paid more attention to this important issue." (Meng, 2011)
Financial accountability	"To start with, the government needs to maintain its involvement, whether in its capacity as partner or regulator. This is especially true where accountability is critical, cost-shifting presents problems, the timeframe is long, or societal normative choices are more important than costs." "Hence, while PPPs can bring added value to the public and private sector partners, a sound legal and regulatory framework and complete transparency particularly with regards to financial accountability are essential elements." (Jamali, 2004)

Consistent monitoring	"Apart from technical committees designated to monitor the performance of private developers, one very effective monitoring mechanism was the joint management committee comprising of senior managers from both sides whose view of PPP projects were more strategic than operational" (Abdul-Aziz & Jahn Kassim, 2011).
Reliable service delivery	"The success of a TOT project can be discussed from different perspectives such as consumers, local governments, and foreign or private investors. The primary concern of consumers is better quality services" (Meng, 2011).

Appendix H3. Social factors

Table 33 Social factors based on in-depth literature research

Factor	Explanation	Source
Recognition of national culture	Recognition and awareness are the first step, next the project partners should think of a strategy to deal with any problems cultural differences between cooperating nations might cause. Establishing which four of eight concepts of Hofstede apply, might help with this (individualism versus collectivism, large versus small power distance, strong versus weak uncertainty avoidance, masculinity versus femininity).	(Hofstede, 1983)
Recognition of (the uniting power of) organizational culture	Recognition and awareness are the first step, next the project partners should think of a strategy to deal with any problems organizational differences between cooperating parties might cause. Establishing which four of eight concepts of Hofstede apply, might help with this (individualism versus collectivism, large versus small power distance, strong versus weak uncertainty avoidance, masculinity versus femininity).	(Hofstede, 1983)
Awareness of business culture differences	Business culture difference cut across national borders and are rooted in the occupational and organizational components of culture (process-oriented versus results-oriented, job-oriented versus employee-oriented, professionally versus parochially oriented, open versus closed systems, tight versus loose internal control, a pragmatic versus a normative)	(Hofstede, 1989)

Appendix H4. Financial factors

Table 34 Financial factors based on in-depth literature research

Factor	Explanation	Source
Predictability of future electricity demand	"As with all decentralised electricity supply solutions, poor estimation of load size, growth and schedule creates risk. Lack of knowledge about load conditions can result in oversized systems[,] increased investment & running cost, lower efficiency […] or undersized system[s]."	(Hazelton et al., 2014)
Quality of equipment	"Premature failure of hardware would in many cases cause interruption of service, but could also potentially result in damage to the entire system. […] While many components are covered by warranty or guarantee, enforcing these is challenging for poor isolated communities in areas where markets do not operate effectively and distributors are not well established [(Lena, 2013)]."	(Hazelton et al., 2014)
Ability to supply/store continuously	"Batteries are expensive, have limited life spans and usually the vulnerable component to misuse [(Turcotte et al., 2001)]. Furthermore ageing of batteries has an enormous influence on energy balance and supply, and this reduced capacity may have a kick on effect to operating strategies of the generators [(Díaz et al., 2011)]. Recorded end user experiences in China showed that people were generally dissatisfied with the unpredictable supply [(Shyu, 2013)]."	(Hazelton et al., 2014)
Adequate business models	"Information sharing about pilot projects will assist in the development of adequate business models [(Van Leeuwen, 2013)]."	(Hazelton et al., 2014)
Integration with the community	"Community engagement from the outset and follow up [(Mohns & Stein, 2008)], avoid a top-down development approach [(Jacquin et al., 2011)]."	(Hazelton et al., 2014)
Appropriate payment opportunities offered to consumers	"Rural customers are usually poor, typically requiring subsidies to access energy. It can be challenging to set a price that is both sufficiently high to give the investor a return and low enough to make it affordable to the consumer [(Kimera, 2012)]."	(Hazelton et al., 2014)
Safety of operators	"Mini-grids operate on AC and much higher voltages relative to solar home systems, so risks of harm to operators and users is increased [(Vallve, 2012)]. The dangers of AC electricity may not be known to new users, and extensive wiring throughout communities may present dangers not well understood [(Jacquin et al., 2011)]."	(Hazelton et al., 2014)
Safety of end users	"Mini-grids operate on AC and much higher voltages relative to solar home systems, so risks of harm to operators and users is increased [(Vallve, 2012)]. The dangers of AC electricity may not be known to new users, and extensive wiring throughout communities may present dangers not well understood [(Jacquin et al., 2011)]."	(Hazelton et al., 2014)
Understanding the customers' needs	"In order to assure the sustained success of an RVG [renewable energy based village grid], projects ought to be seen rather as projects improving the livelihood of villagers than as mere energy projects [(Kumar et al., 2009; UNDP, 2011)]." "Doing successful business requires knowing these customers and their needs and designing products and services accordingly." Examples of how to do this are: "conduct market research to understand village specifics, introduce customer service and involve the community".	(Schmidt et al., 2013)

Quality of decentralized operation, maintenance and administration	"Typically Indonesian organizations (including rural electrification organizations) tend to implement centralized structures with headquarters in Jakarta or other major cities. However, this is not the most effective structure in a decentralized, rural context as local presence matters […]. Hence, practitioners are convinced that BOO [(build-own-operate)] investors would benefit from implementing a decentralized organizational structure, referring to small, independent and flexible units [(Schmidt & Dabur, 2014)]. When implementing such structure, assuring a continuous knowledge flow between the sub-units is crucial to distribute learning by doing and using […]. The decentralized structure is strengthened by employing locals, even if skilled labor is scarce […]. Concrete actions are, e.g., the training of own, local staff, subcontracts with local business partners (e.g., franchises) or cooperation with local organizations [(Rickerson et al., 2012; Yadoo & Cruickshank, 2010)]."	(Schmidt et al., 2013)
Availability of local human resources	"While in 2008 the average Indonesian adult illiteracy rate was at 7.8% [(UNESCO, 2009)], this rate is much higher in rural areas where RVGs are implemented. Consequently the lack of skilled (and motivated) local human resources in rural Indonesia to build, operate and manage RVG power plants represents a major barrier […] and BOO investors cope with the challenge of identifying and employing skilled local staff."	(Schmidt et al., 2013)
Availability of local financial resources	"Finally, in rural Indonesia the villagers lack financial resources. On the one hand, villagers have low income levels; on the other hand a banking system providing loans to rural locals is absent [(Monroy & Hernández, 2005)] and as an interviewee from the private sector states "The villagers won't be able to get funding and realize a RVG project on their own. Typically they'd have to turn to some sort of institution." Strategies to deal with this are: "design a locally adapted tariff and payment scheme, foster local productive use and entrepreneurship and provide customers with access to loans".	(Schmidt et al., 2013)
Availability of standards and knowledge transfer on best practices	"Despite the more than 900 RVG projects and pilots across Indonesia, there is still a lack of standards, certification and knowledge transfer on the best practices of management and operation." Measures to deal with a lack of standard and knowledge transfer on best practices: "draw from and advocate for existing best practice examples and standards and conduct pilot projects, then scale up".	(Schmidt et al., 2013)
Availability of information and data	"In Indonesia, as well as in many other non-OECD countries, there is often a lack of reliable data on natural resources (water flow in rivers, wind strengths, irradiation, and rainfall), population and infrastructure in rural areas[…]. BOO investors have to close this information gap by own means in order to be able to e.g., identify villages which could be promising business cases." Possible measures: "collect and share information and data, lack of national network of investors, attend and conduct workshops, seminars and conferences and build strategic partnerships".	(Schmidt et al., 2013)
Availability of national technology supplier network	"This results in a limited local technology supplier network as most suppliers are from outside Indonesia […]. The consequences are not so much higher cost […] but long delivery times for parts for repair or capacity extension. BOO investors face the trade-off of choosing from the limited selection of Indonesian suppliers (if at all available), accepting longer delivery times (and thus potentially longer outages), or having higher stocks which involve fixed capital."	(Schmidt et al., 2013)

Availability of national financial resources (debt and equity)	"Similar to the very scarce financial resources at the local level, there is also a lack of equity sponsors and Indonesian banks that provide capital at reasonable financing cost."	(Schmidt et al., 2013)
Availability of international financial resources (debt, equity, carbon)	"As financial resources on the local and national levels are tight, BOO investors try to tap international resources. However, there is also a lack on the international level which again hits BOO investors in their struggle for funding [...]. It requires keeping up with international standards and involves higher transaction costs as well as currency challenges as equity and debt are usually provided in USD or EUR and not in the Indonesian currency IDR."	(Schmidt et al., 2013)
Severity of negative externalities caused by international donors	"It occurs that Indonesian private and public actors perceive international involvement as disruptive to national and local efforts in rural electrification, especially when it hinders the development of a private market." So one should "strengthen NGOs, governmental agencies and other non-private actors in their understanding of free market mechanisms".	(Schmidt et al., 2013)
Revenue security	"Revenue security risks are amplified due to the capital-intensive nature of electrification, particularly if they include large amounts of renewable energy generation such as wind and photovoltaic systems, though the costs of these technologies are rapidly falling [(EIA, 2014)]. This means that several years may be required for the project to break even and start generating profits, which exposes project owners to long-term risks that could cause a project to fail before the recovery of initial capital investments." Measures can be taken: "long-term PPAs, anchor customers, fixed service based tariffs and financing of appliances".	(Williams et al., 2015)

Appendix H5. Environmental factors

Table 35 Environmental factors based on in-depth literature research

Factor	Explanation	Source
Land requirement for power generation technology	"It is not always easy in rural areas of the Amazon to access big areas without compromising the local ecosystem."	(Fuso Nerini et al., 2014)
Stress on the ecosystem	"Environmental stress refers to physical, chemical, and biological constraints on the productivity of species and on the development of ecosystems. Stressors can be natural environmental factors, or they may result from the activities of humans. Stressors are challenges to the integrity of ecosystems and to the quality of the environment." (Science Encyclopedia, 2016)	(Fuso Nerini et al., 2014)
Lifecycle GHG emissions	"It is the life cycle production quantity of GHG per unit energy production by the system. Options with less GHS emission rates are better for the environment."	(Rahman et al., 2013a)
Local environmental impact	"Any negative impact on the local community can make the system unacceptable. For example, small-hydropower can cause disturbance to the aquatic faunal populations (e.g. fish) thus results their disappearance."	(Rahman et al., 2013a)
Emissions of CO_2	"Measures emissions that cause the greenhouse effect such as carbon dioxide (CO_2), methane (NH_4) and nitrous oxide (N_2O). This indicator is not a measure of environmental pollution but global warming."	(Rojas-Zerpa & Yusta, 2015)
Emissions of SO_2	"Quantifies emissions of sulphur dioxide (SO_2 derived from the combustion) of fossil resources or emissions from the energy used by renewable technologies during its lifecycle. The indicator is a measure of pollution known as acid rain."	(Rojas-Zerpa & Yusta, 2015)
Emissions of NO_x	"Quantifies emissions of nitrogen monoxide (NO) and nitrogen dioxide (NO_2) from the combustion of fossil resources or the energy used in renewable technologies during its lifecycle."	(Rojas-Zerpa & Yusta, 2015)

Appendix H6. Frugal factors

Table 36 Frugal factors based on in-depth literature research

Factor	Explanation	Source
Level of corruption in the country	"[Companies] assume that various barriers to commerce – corruption, illiteracy, inadequate infrastructure, currency fluctuations, bureaucratic red tape – make it impossible to do business profitably in these regions."	(Prahalad, 2002)
Level of illiteracy under the local population	"[Companies] assume that various barriers to commerce – corruption, illiteracy, inadequate infrastructure, currency fluctuations, bureaucratic red tape – make it impossible to do business profitably in these regions."	(Prahalad, 2002)
Quality of the infrastructure	"[Companies] assume that various barriers to commerce – corruption, illiteracy, inadequate infrastructure, currency fluctuations, bureaucratic red tape – make it impossible to do business profitably in these regions."	(Prahalad, 2002)
Frequency of currency fluctuations	"[Companies] assume that various barriers to commerce – corruption, illiteracy, inadequate infrastructure, currency fluctuations, bureaucratic red tape – make it impossible to do business profitably in these regions."	(Prahalad, 2002)
Level of bureaucratic red tape	"[Companies] assume that various barriers to commerce – corruption, illiteracy, inadequate infrastructure, currency fluctuations, bureaucratic red tape – make it impossible to do business profitably in these regions."	(Prahalad, 2002)
Level of training received by executives on the challenges of bottom of the pyramid markets	"The biggest change, though, has to come in the attitudes and practices of executives. Unless CEOs and other business leaders confront their own preconceptions, companies are unlikely to master the challenges of BOP [(bottom of the pyramid)] markets. The traditional workforce is so rigidly conditioned to operate in higher-margin markets that, without formal training, it is unlikely to see the vast potential of the BOP market."	(Prahalad, 2002)
Access to advice, technical help, seed funding and business support services for entrepreneurs	"Entrepreneurs in BOP markets lack access to the advice, technical help, seed funding, and business support services available in the industrial world. So MNCs [(Multinational Corporations)] may need to take on mentoring roles or partner with local business development organizations that can help entrepreneurs create investment and partnering opportunities."	(Prahalad, 2002)
Rural electricity price compared to the urban price	"Consumers at the bottom of the pyramid pay much higher prices for most things than middle-class consumers do, which means that there's a real opportunity for companies, particularly big corporations with economies of scale and efficient supply chains, to capture market share by offering higher quality goods at lower prices while maintaining attractive margins."	(Prahalad, 2002)
Activity of venture groups and internal investment funds	"Companies might also create venture groups and internal investment funds aimed at seeding entrepreneurial efforts in BOP markets."	(Prahalad, 2002)
Existence of a business development task force	"MNCs should also consider creating a business development task force aimed at these markets. Assembling a diverse group of people from across the corporation and empowering it to function as a skunk works team that ignores conventional dogma will likely lead to greater innovation. Companies that have tried this approach have been surprised by the amount of interest such a task force generates. Many employees want to work on projects that have the potential to make a real difference in improving the lives of the poor."	(Prahalad, 2002)

Autonomy from central R&D headquarters	"Autonomy from central R&D headquarters seems to be a necessary but not sufficient condition to enable the local development of frugal innovations. The subsidiary must also be able to understand local needs and translate those into appropriate product solutions."	(Zeschky et al., 2011)
Having a team consisting almost exclusively of local engineers	"Although local cost advantages were a persistent motivation for local development activities, the findings show that understanding the local environment and user behaviour was vital to product success. Managers at Mettler Toledo, GE, Logitech, and Siemens told us that having a team consisting almost exclusively of local engineers guaranteed that they could effectively translate local requirements into final products."	(Zeschky et al., 2011)
Human capital	"Although many constraints on business activity commonly arise in settings of poverty, we highlight four: (i) government regulation; (ii) technology know-how; (iii) attitudes, behaviours, and consumption patterns; and (iv) human capital." "The development of human capital, such as education and skill development, is well known as a strong predictor of social and economic wellbeing as it empowers individuals to seek out new opportunities and create a better livelihood [(Sachs, 2005)]."	(George et al., 2012)
Existence of partnerships and networks that connect individuals and create opportunities	"Bridging access refers to organizational processes that identify, locate, and create access to disenfranchised individuals and communities. In so doing, bridging access involves implementing new forms of partnerships and networks that connect hitherto disconnected individuals with opportunities."	(George et al., 2012)

Appendix I. Measurable criteria

Criterion is labelled + if a high score means high feasibility of the potential microgrid location
Criterion is labelled – if a high score means low feasibility of the potential microgrid location
Criterion is labelled ~ if this is a yes/no criterion: yes is the favourable answer, no is the undesired answer
Criterion is labelled ~~ if this is a yes/no criterion: no is the favourable answer, yes is the undesired answer

Appendix I1. Measurable criteria – Technological

Table 37 Transformation of concepts and factors into measurable criteria, with unit and effect on feasibility – technological

	Concept	Criterion	Question	Unit	Measurement level	+/-/~/~~
1	Storage, capacity	Need for energy storage capacity	Is a large storage capacity needed to store energy?		Dichotomous	~~
2	Biogas	Availability of biogas	Is agricultural or plant waste available in the area?		Dichotomous	~
3	Jatropha, oil	Availability of bio-oil (jatropha)	Are non-food biodiesel crops available in the area?		Dichotomous	~
4	Biomass, rice	Availability of biomass (rice straw, rice husk)	Is biomass available in the area?		Dichotomous	~
5	Hydropower	Availability of sources for hydro-power (SHP (small hydropower), pico (turbines smaller than 10kW))		Number of water reservoirs, rivers and streams in the area	Metric	+
6	Solar	Availability of sunlight (PV, SHS (so-lar home system))		Average daily solar radiation in $kWh/m^2/day$	Metric	+
7	Fossil, fuel, hybrid, diesel, gas	Availability of fossil fuels (for hy-brid systems)		Length of journey of villager to get diesel, gas or kerosene in km	Metric	-
8	Wind	Availability of wind		Average wind speed in km/h	Metric	+
9	Thermal	Availability of geothermal heat		Usability of geothermal reser-voir (dependent on tempera-ture and permeability)	Ordinal	+
10	Microgrid	Size of microgrid needed		Area the microgrid covers in km^2	Metric	-
11	Extension	Length of extension needed when connected to existing electricity grid		km	Metric	+
12	Lighting	Fuel used for lighting	Does the use of fuel for lighting emit fumes and gasses in the home?		Dichotomous	~

	Factor	Criterion	Question	Unit	Measurement level	+/-/~/~~
13	Invest in learning	Efforts of the project partners to invest in learning	Do the project partners invest in technology development and learning?		Dichotomous	~
14	Sufficient complementary goods	Base load demand for electricity	Is there a well-defined base load demand for electricity?		Dichotomous	+
15	Right timing of market entry	Right timing of market entry		Percentage of population that wants to have access to electricity	Metric	+
16	Firm's technological superiority	The project partners' technological knowledge	Is the technological knowledge of the project partners better developed than that of competing technologies?		Dichotomous	~
17	Firm's complementary assets	The project partners' manufacturing capabilities	Are the project partners able to adjust manufacturing to local production needs?		Dichotomous	~
18	Firm's credibility	The project partners' credibility	Do the project partners have experience with the electrification of rural areas?		Dichotomous	~
19	Timing of systemic R&D activities	Timing of R&D activities	Do the project partners regularly invest in the development of their technology?		Dichotomous	~
20	Pricing strategy	Pricing strategy	Are the consumers' willingness and ability to pay taken into account when deciding on the electricity price?		Dichotomous	~
21	Managing customer's expectations	Managing customer's expectations	Do the project partners have a team on marketing and public relations?		Dichotomous	~
22	Regulation by government	Level of regulation of energy technology by government	Is energy technology regulated by the government?		Dichotomous	~
23	Regulation by private institutions	Level of regulation of energy technology by private institutions	Is energy technology regulated by a private regulation body?		Dichotomous	~
24	Network effects	Network effects		% of population that will start using electricity when it becomes available	Metric	+
25	Switching costs	Switching costs for customer (from current source of energy to new electricity provider)		$ it costs to switch	Metric	-

26	Regime of appropri-ability	Ability of the project partners to profit from their innovation	If the project partners use an innovative technology to provide the area with elec-tricity, is it patented or licensed?		Dichotomous	~
27	Characteristics of the technological field	Characteristics of the energy field	Is the level of cooperation higher than the level of competition with other actors in the energy field?		Dichotomous	~
28	Financial strength	Financial strength of the project partners	Are the project partners in good financial health (when looking at their dept-equity ratio, for example)?		Dichotomous	~
29	Brand reputation and credibility	The project partners' reputation	Do the project partners have a good rep-utation in the field of electrification?		Dichotomous	~
30	Operational su-premacy	Production capacity		Number of previously devel-oped electrification projects still operational	Metric	+
31	Compatibility	Compatibility with existing power products	Do voltage, current and frequency of the microgrid match electrical products avail-able for customers?		Dichotomous	~
32	Pre-emption of scarce assets	Pre-emption of scarce assets	Do other parties (want to) make use of the source of energy used to generate power or of the materials to build the grid?		Dichotomous	~~
33	Big fish	Existence of anchor load	Is there a potential client that has a high demand for electricity?		Dichotomous	~
34	Effectiveness of the format develop-ment process	Effectiveness of the development process	Is there a process management strategy in place between project partners?		Dichotomous	~
35	Network of stake-holders	Network of stakeholders	Do the stakeholders form an appropriate mix of backgrounds, sectors, industries, etc.?		Dichotomous	~
36	Bandwagon effect	Bandwagon effect		% of population that started using electrical products be-cause their friends were using them	Metric	+
37	Number of options available	Competition in the same location	Are there parties competing on the de-velopment of an electrification project in the same location?		Dichotomous	~~

	Factor (from financial category)	Criterion	Question	Unit	Measurement level	+/-/~/~~
38	Predictability of future electricity demand	Predictability of future electricity demand	Is there data available on historic and current electricity consumption of other areas in the same country?		Dichotomous	~
39	Quality of equipment	Quality of equipment		# equipment failures/year	Metric	-
40	Ability to supply/store continuously	Ability to supply/store continuously	Can supply be continuous and predictable (by using batteries)?		Dichotomous	~

Appendix I2. Measurable criteria – Institutional

Table 38 Transformation of concepts and factors into measurable criteria, with unit and effect on feasibility – institutional

	Concept	Criterion	Question	Unit	Measure-ment level	+/-/~/~~
1	International, program, promote	Existence of international program(s) that promote rural electrification	Is rural electrification promoted by international programs?		Dichotomous	~
2	Government, program, promote	Existence of governmental program(s) that promote rural electrification	Is rural electrification promoted by governmental programs?		Dichotomous	~
3	National, policy	Existence of national policy that supports rural electrification (long-term)	Is rural electrification supported by national policy?		Dichotomous	~
4	Subsidy	Availability of subsidies for electrification projects	Are subsidies available for electrification projects?		Dichotomous	~
5	Regulatory, agency	Existence of regulatory agency for the power sector	Is there a regulatory agency for the power sector?		Dichotomous	~
6	Partnerships	Existence of partnerships between the government and private energy companies	Are there partnerships between the government and private energy companies?		Dichotomous	~
7	Decision, process	Complexity of decision making process around electrification project	Is there a conflict of interest between the involved stakeholders?		Dichotomous	~~
8	Decision, strategy	Existence of (governmental) decision making strategy concerning electrification projects	Is there a decision making strategy in place concerning electrification projects?		Dichotomous	~
9	Initiatives, country	Number of rural electrification initiatives in the country		# rural electrification initiatives	Metric	+
10	Political	Level of political will/commitment	Do governments set clear and realistically attainable policy goals, with specific targets?		Dichotomous	~
11	Public	Level of public participation	Is local community participation stimulated?		Dichotomous	~

	Factor	Criterion	Question	Unit	Measure-ment level	+/-/~/~~
12	Appropriate risk allocation and sharing	Appropriate risk allocation and sharing	Is there agreement on the allocation or sharing of responsibility for dealing with the consequences of each risk?		Dichotomous	~
13	Strong private consortium	Structure and compatibility of the project partnership	Is the project partnership equipped with strong technical, operational and managerial capacity?		Dichotomous	~
14	Political support	Political support	Is there political approval to spend public money on rural electrification projects?		Dichotomous	~
15	Public/community support	Community support	Is there acceptance and understanding for electrifi-cation projects amongst the community?		Dichotomous	~
16	Transparent pro-curement	Transparent procurement	Do all parties have equal access to all elements of the procurement system?		Dichotomous	~
17	Favourable legal framework	Favourable legal framework	Is the national electricity market liberalized?		Dichotomous	~
18	Stable macroeco-nomic condition	Stable macroeconomic con-dition		National GDP growth (annual %)	Metric	+
19	Competitive pro-curement	Competitive procurement	Is the procurement process in accordance with in-ternational practice?		Dichotomous	~
20	Strong commit-ment by both par-ties	Strong commitment by all project partners	Are all project partners actively participating in the process of coming to an agreement on the project goals and vision?		Dichotomous	~
21	Clarity of roles and responsibili-ties among par-ties	Clarity of roles and responsi-bilities among project part-ners	Do all project partners have a clear definition of roles and responsibilities?		Dichotomous	~
22	Financial capabili-ties of the private sector	Financial capabilities of the project partners	Do the project partners have the knowledge, under-standing, skills, motivation and confidence to make appropriate financial decisions?		Dichotomous	~
23	Technology inno-vation	Level of technology innova-tion	Is the technology not too innovative for the loca-tion?		Dichotomous	~
24	Good feasibility studies	Good feasibility studies	Have the involved parties performed a feasibility study before starting the electrification project?		Dichotomous	~
25	Open and con-stant communica-tion	Open and constant commu-nication	Is there transparent and consistent communication between project partners?		Dichotomous	~

26	Detailed project planning	Detailed project planning	Have the involved parties drafted a detailed project planning?		Dichotomous	~
27	Government providing guarantees	Government providing guarantees	Does the government provide (loan) guarantees to private parties?		Dichotomous	~
28	Trust	Trust between project partners	Do the project partners behave in honourable ways that enhance mutual trust, without abusing gained information, nor undermining each other?		Dichotomous	~
29	Long term demand for the project	Long term demand for the project	Is the community there to stay for the long term (they do not lead a nomadic existence)?		Dichotomous	~
30	Clear project brief and design development	Clear project brief and design development	Is there room for the development/modification of the microgrid design (as stated in the project brief)?		Dichotomous	~
31	Political stability	Political stability	Do citizens express their dissatisfaction with the government through violent or terrorist activities? Are there political coups, revolutions or a civil war happening in the country?		Dichotomous	~~
32	Mature and available financial market	Mature and available financial market	Does the country have a mature financial market where enough debt and equity can be raised?		Dichotomous	~
33	Acceptable level of tariff	Acceptable level of tariff		Electricity price in $/kWh compared to the average price in the country = price in location – average price in country	Metric	-
34	Compatibility skills of both parties	Compatibility skills of the project partners	Do the project partners have knowledge in different, but compatible fields?		Dichotomous	~
35	Good leadership and entrepreneurship skills	Good leadership and entrepreneurship skills	Does the leading project partner have leadership experience?		Dichotomous	~
36	Good governance	Good governance	Does the government sponsor, assist in financing with and give a guarantee to the electrification project?		Dichotomous	~

37	Clear goals and objectives	Clear goals and objectives	Have the partners agreed on objectives and requirement for the project?		Dichotomous	~
38	Employment of professional advisors	Employment of professional advisors	Does the partnership employ professional advisors?		Dichotomous	~
39	Financial accountability	Financial accountability of the project partners	Is there complete transparency concerning the finances of all project partners?		Dichotomous	~
40	Consistent monitoring	Consistent monitoring	Is the project development consistently monitored?		Dichotomous	~
41	Reliable service delivery	Reliable power delivery		# blackouts and/or brownouts per year	Metric	-

Appendix 13. Measurable criteria – Social

Table 39 Transformation of concepts and factors into measurable criteria, with unit and effect on feasibility – social

	Concept	Criterion	Question	Unit	Measurement level	+/-/~/~~
1	Households	Number of households in potential microgrid location		# households in area	Metric	+
2	Villages	Number of villages in potential microgrid location		# villages in area	Metric	-
3	Poverty	Consumer's ability to pay for electricity		Daily income in $/day/household	Metric	+
4	People	Number of people in potential microgrid location		People/m^2	Metric	+
5	Users	Number of potential users in potential microgrid location		% of people that want to use electricity from the total population	Metric	+
6	Community	Strength of community		Number of community activities organized in activities/year	Metric	+
7	Cooking	Fuel used for cooking	Does the use of fuel during cooking emit fumes and gasses in the home?		Dichotomous	~
8	Education	Level of basic education in the community		% of community with basic education	Metric	+
9	Women	Influence of women in the community	Do women in the community have a strong voice?		Dichotomous	~
10	Health	Health of the average community member		Life expectancy of the average community member in years	Metric	-
11	School	Presence of schools in the area		# schools in the area	Metric	+
12	Willingness	Willingness to pay for electricity		% of income that people want to spend on electricity	Metric	+
13	Satisfaction	Level of satisfaction with the current energy supply options	With what grade is the quality of the current energy supply options graded?	X out of 10	Metric	-

14	Migration	Level of migration from areas without access to electricity to areas with access to electricity	Are there country-based examples of people moving to areas where they would have access to electricity?		Dichotomous	~~ *
	Factor	**Criterion**	**Question**	**Unit**	**Measurement level**	**+/-/~/~~**
15	Recognition of national culture	Recognition of national culture	Are the project partners aware of the national culture present in the rural area?		Dichotomous	~
16	Recognition of (the uniting power of) organizational culture	Recognition of (the uniting power of) organizational culture	Are the project partners aware of the organizational culture present in the partnering organizations?		Dichotomous	~
17	Awareness of business culture differences	Awareness of business culture differences	Are the project partners aware of the business culture present in the partnering businesses?		Dichotomous	~
	Inspired by factor 'recognition of national culture'	**Criterion**	**Question**	**Unit**	**Measurement level**	**+/-/~/~~**
18	x	Recognition of regional culture	Are the project partners aware of the regional culture present in the rural area?		Dichotomous	~
	Factor (from financial category)	**Criterion**	**Question**	**Unit**	**Measurement level**	**+/-/~/~~**
19	Integration with the community	Integration of the project partners with the community	Is there a community engagement strategy in place?		Dichotomous	~

*
"Future urbanization and development of rural areas in poor countries are likely to bring migration and related congestion issues to the fore once more" (Dinkelman & Schulhofer-Wohl, 2015).

Appendix I4. Measurable criteria – Financial

Table 40 Transformation of concepts and factors into measurable criteria, with unit and effect on feasibility – financial

	Concept	Criterion	Question	Unit	Measurement level	+/-/~/~~
1	Capital, cost	Capital cost of rural electrification project		Total costs of one-time expenses in $	Metric	-
2	Cost	Operation and maintenance cost of rural electrification project		Recurring costs for operation and maintenance in $/year	Metric	-
3	Private, investment	Willingness of private party to invest in rural electrification project	Is a private party willing to invest in the project?		Dichotomous	~
4	Investment	Willingness of public party to invest in rural electrification project	Is a public party willing to invest in the project?		Dichotomous	~
5	Loan	Ability of investing party to get a loan	What is the financial health of the investing party?	This is determined with the use of the solvency ratio.	Metric	+
6	Market	Existence of an electricity market for trade	Does the country have a trade market for electricity?		Dichotomous	~
7	Bank	Activity of banking sector		Total bank assets corrected for the GDP in $	Metric	+
8	Price	Oil price		$/barrel	Metric	+
9	Business	Size of business sector		Number of workers employed	Metric	+
10	Revenue	Revenues for the project partners		Projected project revenues	Metric	+
11	LCOE	Levelized cost of electricity (LCOE)		$/kWh	Metric	-
12	Income	Income of consumer		Average income per household in $/year	Metric	+

	Factor	Criterion	Question	Unit	Measurement level	+/-/~/~~
13	Adequate business models	Adequate business models	Is information shared about pilot projects?		Dichotomous	~
14	Appropriate payment opportunities offered to consumers	Appropriate payment opportunities offered to consumers	Is the electricity price adjusted for the ability of consumers to pay?		Dichotomous	~
15	Understanding the customers' needs	Understanding the customers' needs	Is market research conducted to understand the location specifics? Do the project partners have a customer service?		Dichotomous	~
16	Quality of decentralized operation, maintenance and administration	Quality of decentralized operation, maintenance and administration	Is there a decentralized organizational structure implemented?		Dichotomous	~
17	Availability of local human resources	Availability of local human resources		Size of labour force as % of total area population	Metric	+
18	Availability of local financial resources	Availability of local financial resources	Do locals have access to loans?		Dichotomous	~
19	Availability of standards and knowledge transfer on best practices	Availability of standards and knowledge transfer on best practices	Are best practice examples with similar circumstances studied and learned from?		Dichotomous	~
20	Availability of information and data	Availability of information and data	Is information collected and shared through a national network of investors or through other strategic partnerships?		Dichotomous	~
21	Availability of national technology supplier network	Availability of national energy technology supplier network	Are there local suppliers of the energy technology (for example wind turbines or PV panels)?		Dichotomous	~
22	Availability of national financial resources (debt and equity)	Availability of national financial resources (debt and equity)	Are national funds available for energy projects?		Dichotomous	~
23	Availability of international financial resources (debt, equity, carbon)	Availability of international financial resources (debt, equity, carbon)	Are international funds available for energy projects?		Dichotomous	~

24	Severity of negative externalities caused by international donors	Negative externalities caused by international donors	Do international donors hinder the development of a local private market?		Dichotomous	~~
25	Revenue security	Revenue security	Is there a strategy in place to secure revenues from customers?		Dichotomous	~

Appendix I5. Measurable criteria – Environmental

Table 41 Transformation of concepts and factors into measurable criteria, with unit and effect on feasibility – environmental

	Concept	Criterion	Question	Unit	Measurement level	+/-/~/~~
1	Climate	Extent to which climate change is observed (related to environmental stress, see 3)		Frequency of events of flood, heavy weather, drought, scarcity of drinking water in event/year	Metric	+
	Factor	**Criterion**	**Question**	**Unit**	**Measurement level**	**+/-/~/~~**
2	Land requirement for power generation technology	Land requirement for power generation technology		m^2	Metric	-
3	Stress on the ecosystem	Stress on the ecosystem (caused by the power generation technology)	Rapid combustion of biomass, heat released into the environment, toxic pollution: would these stresses occur when power is being generated?		Dichotomous	~~
4	Lifecycle GHG emissions	Lifecycle GHG emissions of power generation technology		$kgCO_2/kWh$	Metric	-
5	Local environmental impact	Local environmental impact	Would a microgrid have a negative impact on the local community (small-hydropower can, for example, affect the fish population)?		Dichotomous	~~
6	Emissions of CO_2	Emissions of CO_2		tons/MWh	Metric	-
7	Emissions of SO_2	Emissions of SO_2		kg/MWh	Metric	-
8	Emissions of NO_x	Emissions of NO_x		kg/MWh	Metric	-

Appendix 16. Measurable criteria – Frugal

Table 42 Transformation of concepts and factors into measurable criteria, with unit and effect on feasibility – frugal

	Concept	Criterion	Question	Unit	Measurement level	+/-/~/~~
1	Available, resource, area	Availability of material resources in the area	Are material resources, which are used in the construction of microgrids, available in the area?		Dichotomous	~
2	Knowledge, operation	Local knowledge on the operation of the energy generating technology		% of working population with experience in the energy operations field	Metric	+
3	Remote, isolated, rural	Remoteness of the rural area		Number of roads leading to the community	Metric	+
4	Knowledge, management	Local knowledge on the management of energy systems		% of working population with experience in the energy management field	Metric	+
5	Knowledge, maintenance, control	Local knowledge on the maintenance and control of the electricity network		% of working population with experience in the energy maintenance and control field	Metric	+
6	Equipment	Availability of technical equipment	Is the necessary equipment available in the area?		Dichotomous	~
7	Knowledge, engineering, planning, installation	Local knowledge on the engineering, planning and installation work of the electricity network		% of working population with experience in the energy engineering, planning and installation field	Metric	+
8	Training	Availability of training in the power field	Are there appropriate training programs available in the area/country?		Dichotomous	~

	Factor	Criterion	Question	Unit	Measurement level	+/-/~/~~
9	Level of corruption in the country	Level of corruption in the country		Score on Corruption Perceptions Index	Metric	-
10	Level of illiteracy under the local population	Level of illiteracy under the local population		% of the population that is illiterate	Metric	-
11	Quality of the infrastructure	Quality of the infrastructure		Score based on numbers of the World Bank	Metric	+
12	Frequency of currency fluctuations	Frequency of currency fluctuations		# fluctuations of over 1% over a period of a quarter of a year	Metric	-
13	Level of bureaucratic red tape	Level of bureaucratic red tape		Score based on survey: the general perception of bureaucratic red tape	Metric	-
14	Level of training received by executives on the challenges of bottom of the pyramid markets	Level of training received by the project partners on the challenges of bottom of the pyramid markets	Did the project partners receive training on the challenges of bottom of the pyramid markets?		Dichotomous	~
15	Access to advice, technical help, seed funding and business support services for entrepreneurs	Access to advice, technical help and business support services for entrepreneurs	Are there local organizations that help entrepreneurs start their business?		Dichotomous	~
16	Rural electricity price compared to the urban price	Rural electricity price compared to the urban electricity price		Rural electricity price – urban electricity price	Metric	-
17	Activity of venture groups and internal investment funds	Activity of venture groups and internal investment funds in rural electrification projects	Are there venture groups or investment funds active in the area?		Dichotomous	~
18	Existence of a business development task force	Existence of a business development task force	Is there a business development task force active in the area?		Dichotomous	~
19	Autonomy from central R&D headquarters	Autonomy from central R&D headquarters	Do the (local) project partners have their own R&D department?		Dichotomous	~
20	Having a team consisting almost exclusively of local engineers	Having a team consisting almost exclusively of local engineers	Do the project partners employ a team that consists almost exclusively of local engineers?		Dichotomous	~

21	Human capital	Local human capital		Score on Human Capital Index 2013 of the World Economic Forum	Metric	+
22	Existence of partnerships and networks that connect individu-als and create opportunities	Existence of partnerships and networks that connect individuals and create opportunities	Are there local partnerships and networks active in the area?		Dichotomous	~
	Factor (from financial category)	**Criterion**	**Question**	**Unit**	**Measurement level**	**+/-/~/~~**
23	Safety of operators	Safety of operators	Have grid operators received appropriate training?		Dichotomous	~
24	Safety of end users	Safety of end users	Is the design and installation in agreement with international standards?		Dichotomous	~

Appendix J. The team of experts – who is who

Table 43 Team of experts – who is who

#	Name		Function	Organisation
1	Linda Kamp	PhD	Assistant professor - Technology Dynamics & Sustainable Development	Delft University of Technology
2	Gunjan Gautam	MSc	Energy and Smart Grid Consultant	World Bank
3	Haiko van der Voort	PhD	Assistant professor – Multi-Actor Systems	Delft University of Technology
4	Cees van Beers	PhD	Professor of Management of Technical Innovations	Delft University of Technology
5	Simon Schillebeeckx	PhD	Post-Doctoral Researcher	Singapore Management University
6	Laurens de Vries	PhD	Associate Professor – Energy & Industry Section	Delft University of Technology
7	Aad Correljé	PhD	Associate Professor – Economics of Infrastructures Section	Delft University of Technology
8	Chris Brosz	BEng	Senior Energy Consultant	Arup
9	Auret Basson	MEng, MEM	Senior Engineer – Energy Projects	Arup
10	Gautham Ram Chandra Mouli	MSc	PhD candidate in Electric Vehicles and Photovoltaic	Delft University of Technology
11	Iwona Bisaga	MSc	PhD candidate – Dept. of Civil, Environmental & Geomatic Engineering	University College London
12	Daniel Adegbie	MEng	Graduate Energy Engineer (worked on African power project before this)	Arup
13	Russell Carr	CEng	Senior Engineer – Electricity storage and microgrids	Arup
14	Aditya Shekhar	MSc	PhD candidate – DC systems, Energy conversion & Storage	Delft University of Technology
15	Anonymous		-	-
16	Geoffrey Morgan	MPhil	Consultant – International Development	Arup
17	Kaveri Iychettira	MSc	PhD candidate – Energy Policy	Delft University of Technology
18	Jaspreet Singh	MPhil	Graduate Engineer (worked on microgrids in India before this)	Arup
19	Jeyakrishna Sridhar	MSc	Graduated on photovoltaic based off-grid systems for rural electrification	Alfen
20	Joseph Mutale	PhD	Reader at the School of Electrical and Electronic Engineering	University of Manchester

Appendix K. Survey questions

The following is a copy of the survey that was send out to my team of experts, accompanied with a personal email for each of the experts. I was able to use the account that Arup has with Bristol Online Survey (BOS) to put together my survey.

Welcome!

Thank you for helping me in building a feasibility framework to assess the feasibility of microgrids in rural areas.

I have asked for your help in identifying the most important criteria in assessing the feasibility of a potential microgrid location. This location is situated in a remote and rural area, where the population has no access to electricity at this moment. Often because the costs for an extension of the existing electricity grid to that location would be too high.

The criteria will be presented in six categories: technological, institutional, social, financial, environmental and frugal. These categories will be explained, one at a time, in the continuation of this survey. After each explanation you will be asked if you feel you have enough knowledge in this field to evaluate the criteria.

I will use your input to select the most important criteria. The selected criteria will form the basis of the feasibility framework. Keep this in mind when evaluating the criteria: would they be decisive in the assessment of a potential microgrid location?

A final note: several criteria mention 'project partners'. These are the public and/or private parties that have the intention to develop a microgrid. They can be the owner, investor, builder and/or operator of the to-be-developed microgrid.

Category 1: Technological

Do you feel you have knowledge and expertise in the technological field? This includes topics like: the availability of energy sources for the chosen technology, the energy demand of the potential customer and the technological capabilities of the project partners. If you are uncertain, select 'yes' and have a look at the criteria, you can always decide to skip the question.

Yes

No

Category 1: Technological criteria

Please evaluate the technological criteria below. Decide for each criterion what effect it has on the feasibility of a microgrid in a rural location (compared to the other criteria). The way of measuring the criteria is given in the column on the right, this can help in understanding the criteria. (Please, don't let the number of criteria discourage you. Only the first two categories have quite a few of them, the other four have less.)

Please don't select more than 1 answer(s) per row.
Having trouble with the format of this question? View in tableless mode

	very strong effect	strong effect	weak effect	very weak effect	don't know	
Availability of biogas						Is agricultural or plant waste available in the area? Y/N
Availability of bio-oil (jatropha)						Are non-food biodiesel crops available in the area? Y/N
Availability of biomass (rice straw, rice husk)						Is biomass available in the area? Y/N
Availability of sources for hydropower (SHP, pico)						Number of water reservoirs, rivers and streams in the area
Availability of sunlight (PV, SHS)						Average daily solar radiation in $kWh/m^2/day$
Availability of fossil fuels (for hybrid systems)						Length of journey of villager to get diesel, gas or kerosene in km
Availability of wind						Average wind speed in km/h
Availability of geothermal heat						Usability of geothermal reservoir (dependent on temperature and permeability)
Level of regulation of energy technology by government						Is energy technology regulated by the government? Y/N

Level of regulation of energy technology by private institutions						Is energy technology regulated by a private regulation body? Y/N
Fuel used for lighting						Does the use of fuel for lighting emit fumes and gasses in the home? Y/N
Base load demand for electricity						Is there a well-defined base load demand for electricity? Y/N
Network effects						% of population that will start using electricity when it becomes available
Switching costs for customer (from current source of energy to new electricity provider)						$ it costs to switch
Existence of anchor load						Is there a potential client that has a high demand for electricity? Y/N
Bandwagon effect						% of population that started using electrical products because their friends were using them
Predictability of future electricity demand						Is there data available on historic and current electricity consumption of other areas in the same country? Y/N
Efforts of the project partners to invest in learning						Do the project partners invest in technology development and learning? Y/N
Right timing of market entry						Percentage of population that wants to have access to electricity
The project partners' technological knowledge						Is the technological knowledge of the project partners better developed than that of competing technologies? Y/N
The project partners' manufacturing capabilities						Are the project partners able to adjust manufacturing to local production needs? Y/N
The project partners' credibility						Do the project partners have experience with the electrification of rural areas? Y/N
Timing of R&D activities						Do the project partners regularly invest in the development of their technology? Y/N

Pricing strategy	☐	☐	☐	☐	☐	Are the consumers' willingness and ability to pay taken into account when deciding on the electricity price? Y/N
Managing customer's expectations	☐	☐	☐	☐	☐	Do the project partners have a team on marketing and public relations? Y/N
Ability of the project partners to profit from their innovation	☐	☐	☐	☐	☐	If the project partners use an innovative technology to provide the area with electricity, is it patented or licensed? Y/N
Characteristics of the energy field	☐	☐	☐	☐	☐	Is the level of cooperation higher than the level of competition with other actors in the energy field?
Financial strength of the project partners	☐	☐	☐	☐	☐	Are the project partners in good financial health (when looking at their dept-equity ratio, for example)? Y/N
The project partners' reputation	☐	☐	☐	☐	☐	Do the project partners have a good reputation in the field of electrification? Y/N
Production capacity	☐	☐	☐	☐	☐	Number of previously developed electrification projects still operational
Pre-emption of scarce assets	☐	☐	☐	☐	☐	Do other parties (want to) make use of the source of energy used to generate power or of the materials to build the grid? Y/N
Effectiveness of the development process	☐	☐	☐	☐	☐	Is there a process management strategy in place between project partners? Y/N
Network of stakeholders	☐	☐	☐	☐	☐	Do the stakeholders form an appropriate mix of backgrounds, sectors, industries, etc.? Y/N
Competition in the same location	☐	☐	☐	☐	☐	Are there parties competing on the development of an electrification project in the same location? Y/N
Need for energy storage capacity	☐	☐	☐	☐	☐	Is a large storage capacity needed to store en-ergy? Y/N
Size of microgrid needed	☐	☐	☐	☐	☐	Area the microgrid covers in km^2

Length of extension needed when connected to existing electricity grid	☐	☐	☐	☐	☐	km
Compatibility with existing power products	☐	☐	☐	☐	☐	Do voltage, current and frequency of the microgrid match electrical products available for customers? Y/N
Quality of equipment	☐	☐	☐	☐	☐	# equipment failures/year
Ability to supply/store continuously	☐	☐	☐	☐	☐	Can supply be continuous and predictable (by using batteries)? Y/N

Do you think any technological criteria are missing from this list? If so, which?

Do you have any other comments?

Category 2: Institutional

Do you feel you have knowledge and expertise in the institutional field? This includes topics like: (inter)national policy, economic circumstances, procurement and project management. If you are uncertain, select 'yes' and have a look at the criteria, you can always decide to skip the question.

Yes

No

Category 2: Institutional criteria

Please evaluate the institutional criteria below. Decide for each criterion what effect it has on the feasibility of a microgrid in a rural location (compared to the other criteria). The way of measuring the criteria is given in the column on the right, this can help in understanding the criteria. (Please, don't let the number of criteria discourage you. Only the first two categories have quite a few of them, the other four have less.)

Please don't select more than 1 answer(s) per row.
Having trouble with the format of this question? View in tableless mode

	very strong effect	strong effect	weak effect	very weak effect	don't know	
Existence of international program(s) that promote rural electrification						Is rural electrification promoted by international programs? Y/N
Existence of governmental program(s) that promote rural electrification						Is rural electrification promoted by governmental programs? Y/N
Existence of national policy that supports rural electrification (long-term)						Is rural electrification supported by national policy? Y/N
Availability of subsidies for electrification projects						Are subsidies available for electrification projects? Y/N
Existence of regulatory agency for the power sector						Is there a regulatory agency for the power sector? Y/N
Existence of partnerships between the government and private energy companies						Are there partnerships between the government and private energy companies? Y/N

Complexity of decision making process around electrification project	☐	☐	☐	☐	☐	Is there a conflict of interest between the involved stakeholders? Y/N
Existence of (governmental) decision making strategy concerning electrification projects	☐	☐	☐	☐	☐	Is there a decision making strategy in place concerning electrification projects? Y/N
Number of rural electrification initiatives in the country	☐	☐	☐	☐	☐	# rural electrification initiatives
Level of political will/commitment	☐	☐	☐	☐	☐	Do governments set clear and realistically attainable policy goals, with specific targets? Y/N
Level of public participation	☐	☐	☐	☐	☐	Is local community participation stimulated? Y/N
Favourable legal framework	☐	☐	☐	☐	☐	Is the national electricity market liberalized? Y/N
Stable macroeconomic condition	☐	☐	☐	☐	☐	National GDP growth (annual %)
Government providing guarantees	☐	☐	☐	☐	☐	Does the government provide (loan) guarantees to private parties? Y/N
Political stability	☐	☐	☐	☐	☐	Do citizens express their dissatisfaction with the government through violent or terrorist activities? Are there political coups, revolutions or a civil war happening in the country? Y/N
Mature and available financial market	☐	☐	☐	☐	☐	Does the country have a mature financial market where enough debt and equity can be raised? Y/N
Good governance	☐	☐	☐	☐	☐	Does the government sponsor, assist in financing with and give a guarantee to the electrification project? Y/N
Appropriate risk allocation and sharing	☐	☐	☐	☐	☐	Is there agreement on the allocation or sharing of responsibility for dealing with the consequences of each risk? Y/N
Structure and compatibility of the project partnership	☐	☐	☐	☐	☐	Is the project partnership equipped with strong technical, operational and managerial capacity? Y/N
Political support	☐	☐	☐	☐	☐	Is there political approval to spend public money on rural electrification projects? Y/N

Community support	☐	☐	☐	☐	☐	Is there acceptance and understanding for electrification projects amongst the community? Y/N
Transparent procurement	☐	☐	☐	☐	☐	Do all parties have equal access to all elements of the procurement system? Y/N
Competitive procurement	☐	☐	☐	☐	☐	Is the procurement process in accordance with international practice? Y/N
Strong commitment by all project partners	☐	☐	☐	☐	☐	Are all project partners actively participating in the process of coming to an agreement on the project goals and vision? Y/N
Clarity of roles and responsibilities among project partners	☐	☐	☐	☐	☐	Do all project partners have a clear definition of roles and responsibilities? Y/N
Financial capabilities of the project partners	☐	☐	☐	☐	☐	Do the project partners have the knowledge, understanding, skills, motivation and confidence to make appropriate financial decisions? Y/N
Level of technology innovation	☐	☐	☐	☐	☐	Is the technology not too innovative for the location? Y/N
Good feasibility studies	☐	☐	☐	☐	☐	Have the involved parties performed a feasibility study before starting the electrification project? Y/N
Open and constant communication	☐	☐	☐	☐	☐	Is there transparent and consistent communication between project partners? Y/N
Detailed project planning	☐	☐	☐	☐	☐	Have the involved parties drafted a detailed project planning? Y/N
Trust between project partners	☐	☐	☐	☐	☐	Do the project partners behave in honourable ways that enhance mutual trust, without abusing gained information, nor undermining each other? Y/N
Long term demand for the project	☐	☐	☐	☐	☐	Is the community there to stay for the long term (they do not lead a nomadic existence)? Y/N
Clear project brief and design development	☐	☐	☐	☐	☐	Is there room for the development/modification of the microgrid design (as stated in the project brief)? Y/N

Acceptable level of tariff	☐	☐	☐	☐	☐	Electricity price in $/kWh compared to the average price in the country = price in location – average price in country
Compatibility skills of the project partners	☐	☐	☐	☐	☐	Do the project partners have knowledge in different, but compatible fields? Y/N
Good leadership and entrepreneurship skills	☐	☐	☐	☐	☐	Does the leading project partner have leadership experience? Y/N
Clear goals and objectives	☐	☐	☐	☐	☐	Have the partners agreed on objectives and requirement for the project? Y/N
Employment of professional advisors	☐	☐	☐	☐	☐	Does the partnership employ professional advisors? Y/N
Financial accountability of the project partners	☐	☐	☐	☐	☐	Is there complete transparency concerning the finances of all project partners? Y/N
Consistent monitoring	☐	☐	☐	☐	☐	Is the project development consistently monitored? Y/N
Reliable power delivery	☐	☐	☐	☐	☐	# blackouts and/or brownouts per year

Do you think any institutional criteria are missing from this list? If so, which?

Do you have any other comments?

Category 3: Social

Do you feel you have knowledge and expertise in the social field? This includes topics like: the development level of the community, the current energy situation in the community and cultural differences. If you are uncertain, select 'yes' and have a look at the criteria, you can always decide to skip the question.

Yes

No

Category 3: Social criteria

Please evaluate the social criteria below. Decide for each criterion what effect it has on the feasibility of a microgrid in a rural location (compared to the other criteria). The way of measuring the criteria is given in the column on the right, this can help in understanding the criteria.

Please don't select more than 1 answer(s) per row.
Having trouble with the format of this question? View in tableless mode

	very strong effect	strong effect	weak effect	very weak effect	don't know	
Number of households in potential microgrid location						# households in area
Number of villages in potential microgrid location						# villages in area
Number of people in potential microgrid location						People/m^2
Number of potential users in potential microgrid location						% of people that want to use electricity from the total population
Strength of community						Number of community activities organized in activities/year
Level of basic education in the community						% of community with basic education
Influence of women in the community						Do women in the community have a strong voice? Y/N
Health of the average community member						Life expectancy of the average community member in years
Presence of schools in the area						# schools in the area

Level of migration from areas without access to electricity to areas with access to electricity	☐	☐	☐	☐	☐	Are there country-based examples of people moving to areas where they would have access to electricity? Y/N
Fuel used for cooking	☐	☐	☐	☐	☐	Does the use of fuel during cooking emit fumes and gasses in the home? Y/N
Consumer's ability to pay for electricity	☐	☐	☐	☐	☐	Daily income in $/day/household
Willingness to pay for electricity	☐	☐	☐	☐	☐	% of income that people want to spend on electricity
Level of satisfaction with the current energy supply options	☐	☐	☐	☐	☐	With what grade is the quality of the current energy supply options graded? X out of 10
Recognition of national culture	☐	☐	☐	☐	☐	Are the project partners aware of the national culture present in the rural area? Y/N
Recognition of regional culture	☐	☐	☐	☐	☐	Are the project partners aware of the regional culture present in the rural area? Y/N
Recognition of (the uniting power of) organizational culture	☐	☐	☐	☐	☐	Are the project partners aware of the organizational culture present in the partnering organizations? Y/N
Awareness of business culture differences	☐	☐	☐	☐	☐	Are the project partners aware of the business culture present in the partnering businesses? Y/N
Integration of the project partners with the community	☐	☐	☐	☐	☐	Is there a community engagement strategy in place? Y/N

Do you think any social criteria are missing from this list? If so, which?

Do you have any other comments?

Category 4: Financial

Do you feel you have knowledge and expertise in the financial field? This includes topics like: the state of the financial sector, the financial abilities of the project partners and the project costs and revenues. If you are uncertain, select 'yes' and have a look at the criteria, you can always decide to skip the question.

Yes

No

Category 4: Financial criteria

Please evaluate the financial criteria below. Decide for each criterion what effect it has on the feasibility of a microgrid in a rural location (compared to the other criteria). The way of measuring the criteria is given in the column on the right, this can help in understanding the criteria.

Please don't select more than 1 answer(s) per row.
Having trouble with the format of this question? View in tableless mode

	very strong effect	strong effect	weak effect	very weak effect	don't know	
Existence of an electricity market for trade						Does the country have a trade market for electricity? Y/N
Activity of banking sector						Total bank assets corrected for the GDP in $
Oil price						$/barrel
Size of business sector						Number of workers employed
Availability of national financial resources (debt and equity)						Are national funds available for energy projects? Y/N
Availability of international financial resources (debt, equity, carbon)						Are international funds available for energy projects? Y/N
Negative externalities caused by international donors						Do international donors hinder the development of a local private market? Y/N
Willingness of private party to invest in rural electrification project						Is a private party willing to invest in the project? Y/N

Willingness of public party to invest in rural electrification project	☐	☐	☐	☐	☐	Is a public party willing to invest in the project? Y/N
Ability of investing party to get a loan	☐	☐	☐	☐	☐	What is the financial health of the investing party? This is determined with the use of the solvency ratio.
Revenues for the project partners	☐	☐	☐	☐	☐	Projected project revenues
Availability of local human resources	☐	☐	☐	☐	☐	Size of labour force as % of total area population
Availability of local financial resources	☐	☐	☐	☐	☐	Do locals have access to loans? Y/N
Availability of standards and knowledge transfer on best practices	☐	☐	☐	☐	☐	Are best practice examples with similar circumstances studied and learned from? Y/N
Availability of information and data	☐	☐	☐	☐	☐	Is information collected and shared through a national network of investors or through other strategic partnerships? Y/N
Capital cost of rural electrification project	☐	☐	☐	☐	☐	Total costs of one-time expenses in $
Operation and maintenance cost of rural electrification project	☐	☐	☐	☐	☐	Recurring costs for operation and maintenance in $/year
Levelized cost of electricity (LCOE)	☐	☐	☐	☐	☐	$/kWh
Income of consumer	☐	☐	☐	☐	☐	Average income per household in $/year
Adequate business models	☐	☐	☐	☐	☐	Is information shared about pilot projects? Y/N
Appropriate payment opportunities offered to consumers	☐	☐	☐	☐	☐	Is the electricity price adjusted for the ability of consumers to pay? Y/N
Understanding the customers' needs	☐	☐	☐	☐	☐	Is market research conducted to understand the location specifics? Do the project partners have a customer service? Y/N
Quality of decentralized operation, maintenance and administration	☐	☐	☐	☐	☐	Is there a decentralized organizational structure implemented? Y/N

Availability of national energy technology supplier network	☐	☐	☐	☐	☐	Are there local suppliers of the energy technology (for example wind turbines or PV panels)? Y/N
Revenue security	☐	☐	☐	☐	☐	Is there a strategy in place to secure revenues from customers? Y/N

Do you think any financial criteria are missing from this list? If so, which?

Do you have any other comments?

Category 5: Environmental

Do you feel you have knowledge and expertise in the environmental field? This includes topics like: climate change, ecosystems and emissions. If you are uncertain, select 'yes' and have a look at the criteria, you can always decide to skip the question.

Yes

No

Category 5: Environmental criteria

Please evaluate the environmental criteria below. Decide for each criterion what effect it has on the feasibility of a microgrid in a rural location (compared to the other criteria). The way of measuring the criteria is given in the column on the right, this can help in understanding the criteria.

Please don't select more than 1 answer(s) per row.
Having trouble with the format of this question? View in tableless mode

	very strong effect	strong effect	weak effect	very weak effect	don't know	
Land requirement for power generation technology						m^2
Extent to which climate change is observed (related to environmental stress, see 3)						Frequency of events of flood, heavy weather, drought, scarcity of drinking water in event/year
Stress on the ecosystem (caused by the power generation technology)						Rapid combustion of biomass, heat released into the environment, toxic pollution: would these stresses occur when power is being generated? Y/N
Local environmental impact						Would a microgrid have a negative impact on the local community (small-hydropower can, for example, affect the fish population)? Y/N
Lifecycle GHG emissions of power generation technology						$kgCO_2/kWh$
Emissions of CO_2						tons/MWh
Emissions of SO_2						kg/MWh
Emissions of NO_x						kg/MWh

Do you think any environmental criteria are missing from this list? If so, which?

Do you have any other comments?

Category 6: Frugal

Do you feel you have knowledge and expertise in the frugal field? This includes topics like: local resources, local knowledge and the ability of the project partners to work in rural areas. If you are uncertain, select 'yes' and have a look at the criteria, you can always decide to skip the question.

Yes

No

Category 6: Frugal criteria

Please evaluate the frugal criteria below. Decide for each criterion what effect it has on the feasibility of a microgrid in a rural location (compared to the other criteria). The way of measuring the criteria is given in the column on the right, this can help in understanding the criteria.

Please don't select more than 1 answer(s) per row.
Having trouble with the format of this question? View in tableless mode

	very strong effect	strong effect	weak effect	very weak effect	don't know	
Availability of material resources in the area						Are material resources, which are used in the construction of microgrids, available in the area? Y/N
Local knowledge on the operation of the energy generating technology						% of working population with experience in the energy operations field
Remoteness of the rural area						Number of roads leading to the community
Local knowledge on the management of energy systems						% of working population with experience in the energy management field
Local knowledge on the maintenance and control of the electricity network						% of working population with experience in the energy maintenance and control field
Availability of technical equipment						Is the necessary equipment available in the area? Y/N
Local knowledge on the engineering, planning and installation work of the electricity network						% of working population with experience in the energy engineering, planning and installation field

Availability of training in the power field						Are there appropriate training programs available in the area/country? Y/N
Level of corruption in the country						Score on Corruption Perceptions Index
Level of illiteracy under the local population						% of the population that is illiterate
Quality of the infrastructure						Score based on numbers of the World Bank
Frequency of currency fluctuations						# fluctuations of over 1% over a period of a quarter of a year
Level of bureaucratic red tape						Score based on survey: the general perception of bureaucratic red tape
Local human capital						Score on Human Capital Index 2013 of the World Economic Forum
Level of training received by the project partners on the challenges of bottom of the pyramid markets						Did the project partners receive training on the challenges of bottom of the pyramid markets? Y/N
Access to advice, technical help and business support services for entrepreneurs						Are there local organizations that help entrepreneurs start their business? Y/N
Rural electricity price compared to the urban electricity price						Rural electricity price – urban electricity price
Activity of venture groups and internal investment funds in rural electrification projects						Are there venture groups or investment funds active in the area? Y/N
Existence of a business development task force						Is there a business development task force active in the area? Y/N
Autonomy from central R&D headquarters						Do the (local) project partners have their own R&D department? Y/N
Having a team consisting almost exclusively of local engineers						Do the project partners employ a team that consists almost exclusively of local engineers? Y/N

Existence of partnerships and networks that connect individuals and create opportunities	☐	☐	☐	☐	☐	Are there local partnerships and networks active in the area? Y/N
Safety of operators	☐	☐	☐	☐	☐	Have grid operators received appropriate training? Y/N
Safety of end users	☐	☐	☐	☐	☐	Is the design and installation in agreement with international standards? Y/N

Do you think any frugal criteria are missing from this list? If so, which?

Do you have any other comments?

Final questions

Did you feel a category of criteria was missing from the six I have used (technological, institutional, social, financial, environmental and frugal)?

Could I contact you if I have any questions or want more information?

Yes

No

What is your email address?

Do you have any final questions or comments?

Thank you!

Thank you for helping me build my feasibility framework for microgrids!

You can contact me on *email address* or *phone number*.

Appendix L. Survey answers

The answers to the following questions, as given by the team of experts, are presented in this appendix:

1. Do you feel you have knowledge and expertise in the technological field?
2. Review of technological criteria (2.1-2.40)
3. Do you think any technological criteria are missing from this list? If so, which?
4. Do you have any other comments?

5. Do you feel you have knowledge and expertise in the institutional field?
6. Review of institutional criteria (6.1-6.41)
7. Do you think any institutional criteria are missing from this list? If so, which?
8. Do you have any other comments?

9. Do you feel you have knowledge and expertise in the social field?
10. Review of social criteria (10.1-10.19)
11. Do you think any social criteria are missing from this list? If so, which?
12. Do you have any other comments?

13. Do you feel you have knowledge and expertise in the financial field?
14. Review of financial criteria (14.1-14.25)
15. Do you think any financial criteria are missing from this list? If so, which?
16. Do you have any other comments?

17. Do you feel you have knowledge and expertise in the environmental field?
18. Review of environmental criteria (18.1-18.8)
19. Do you think any environmental criteria are missing from this list? If so, which?
20. Do you have any other comments?

21. Do you feel you have knowledge and expertise in the frugal field?
22. Review of frugal criteria (22.1-22.24)
23. Do you think any frugal criteria are missing from this list? If so, which?
24. Do you have any other comments?

25. Did you feel a category of criteria was missing from the six I have used (technological, institutional, social, financial, environmental and frugal)?
26. Could I contact you if I have any questions or want more information?
    What is your email address?
27. Do you have any final questions or comments?

The answers to questions 2, 6, 10, 14, 18 and 22 are colour coded:

Table 44 Explanation of colour coding of the survey answers

If the percentage of the respondents that gave this answer is the highest, and the answer is either 'strong effect' or 'very strong effect', this green colour is applied to that percentage.
If the percentage of the respondents that gave this answer is the highest, and the answer is either 'weak effect' or 'very weak effect', this green colour is applied to that percentage.

When the two highest percentages are the same or very close together (meaning the second highest percentage had only one respondent less), both percentages are highlighted.

1. Do you feel you have knowledge and expertise in the **technological** field?

	#	%
Yes	18	90

2. Review of technological criteria

Criterion	Effect	#	%
2.1 Availability of biogas	Very strong effect	1	5.5
	Strong effect	9	50
	Weak effect	5	28
	Very weak effect	2	11
	Don't know	1	5.5
2.2 Availability of bio-oil (jatropha)	Very strong effect	2	11
	Strong effect	6	33
	Weak effect	4	22
	Very weak effect	5	28
	Don't know	1	6
2.3 Availability of bio-mass (rice straw, rice husk)	Very strong effect	2	11
	Strong effect	12	67
	Weak effect	3	17
	Very weak effect	1	5
	Don't know	0	0
2.4 Availability of sources for hydropower (SHP, pico)	Very strong effect	9	50
	Strong effect	7	39
	Weak effect	1	5.5
	Very weak effect	1	5.5
	Don't know	0	0
2.5 Availability of sun-light (PV, SHS)	Very strong effect	15	83
	Strong effect	2	11
	Weak effect	1	6
	Very weak effect	0	0
	Don't know	0	0
2.6 Availability of fossil fuels (for hybrid sys-tems)	Very strong effect	8	44.5
	Strong effect	7	39
	Weak effect	1	5.5
	Very weak effect	1	5.5
	Don't know	1	5.5
2.7 Availability of wind	Very strong effect	8	44
	Strong effect	5	28
	Weak effect	4	22
	Very weak effect	1	6
	Don't know	0	0
2.8 Availability of geo-thermal heat	Very strong effect	6	33.25
	Strong effect	4	22.25
	Weak effect	4	22.25
	Very weak effect	4	22.25
	Don't know	0	0
2.9 Level of regulation of energy technology by government	Very strong effect	7	39
	Strong effect	6	33
	Weak effect	3	17
	Very weak effect	2	11
	Don't know	0	0

2.10 Level of regulation of energy technology by private institutions	Very strong effect	3	18
	Strong effect	6	35
	Weak effect	4	23.5
	Very weak effect	4	23.5
	Don't know	0	0
2.11 Fuel used for lighting	Very strong effect	4	22
	Strong effect	9	50
	Weak effect	3	17
	Very weak effect	1	5.5
	Don't know	1	5.5
2.12 Base load demand for electricity	Very strong effect	10	56
	Strong effect	4	22
	Weak effect	1	5.5
	Very weak effect	2	11
	Don't know	1	5.5
2.13 Network effects	Very strong effect	4	22
	Strong effect	13	72
	Weak effect	1	6
	Very weak effect	0	0
	Don't know	0	0
2.14 Switching costs for customer (from current source of energy to new electricity provider)	Very strong effect	8	44.5
	Strong effect	8	44.5
	Weak effect	2	11
	Very weak effect	0	0
	Don't know	0	0
2.15 Existence of anchor load	Very strong effect	4	22
	Strong effect	11	61
	Weak effect	3	17
	Very weak effect	0	0
	Don't know	0	0
2.16 Bandwagon effect	Very strong effect	4	22
	Strong effect	9	50
	Weak effect	5	28
	Very weak effect	0	0
	Don't know	0	0
2.17 Predictability of future electricity demand	Very strong effect	4	22
	Strong effect	6	33.5
	Weak effect	6	33.5
	Very weak effect	2	11
	Don't know	0	0
2.18 Efforts of the project partners to invest in learning	Very strong effect	5	28
	Strong effect	6	33
	Weak effect	2	11
	Very weak effect	3	17
	Don't know	2	11
2.19 Right timing of market entry	Very strong effect	6	33
	Strong effect	8	44
	Weak effect	3	17
	Very weak effect	1	6
	Don't know	0	0
2.20 The project partners' technological knowledge	Very strong effect	2	11
	Strong effect	7	39
	Weak effect	4	22
	Very weak effect	3	17
	Don't know	2	11

2.21 The project partners' manufacturing capabilities	Very strong effect	2	11
	Strong effect	2	11
	Weak effect	5	28
	Very weak effect	7	39
	Don't know	2	11
2.22 The project partners' credibility	Very strong effect	4	22
	Strong effect	5	28
	Weak effect	6	33
	Very weak effect	1	6
	Don't know	2	11
2.23 Timing of R&D activities	Very strong effect	1	6
	Strong effect	2	11
	Weak effect	6	33
	Very weak effect	7	39
	Don't know	2	11
2.24 Pricing strategy	Very strong effect	7	39
	Strong effect	9	50
	Weak effect	0	0
	Very weak effect	0	0
	Don't know	2	11
2.25 Managing customer's expectations	Very strong effect	6	33
	Strong effect	5	28
	Weak effect	3	16.5
	Very weak effect	3	16.5
	Don't know	1	6
2.26 Ability of the project partners to profit from their innovation	Very strong effect	6	33
	Strong effect	4	22
	Weak effect	3	17
	Very weak effect	2	11
	Don't know	3	17
2.27 Characteristics of the energy field	Very strong effect	3	16.5
	Strong effect	6	33
	Weak effect	5	28
	Very weak effect	1	6
	Don't know	3	16.5
2.28 Financial strength of the project partners	Very strong effect	4	22
	Strong effect	10	56
	Weak effect	2	11
	Very weak effect	0	0
	Don't know	2	11
2.29 The project partners' reputation	Very strong effect	3	17
	Strong effect	7	39
	Weak effect	4	22
	Very weak effect	2	11
	Don't know	2	11
2.30 Production capacity	Very strong effect	4	22
	Strong effect	6	33
	Weak effect	5	28
	Very weak effect	1	6
	Don't know	2	11
2.31 Pre-emption of scarce assets	Very strong effect	4	22.25
	Strong effect	4	22.25
	Weak effect	4	22.25
	Very weak effect	2	11
	Don't know	4	22.25

2.32 Effectiveness of the development process	Very strong effect	5	28
	Strong effect	6	33
	Weak effect	3	16.5
	Very weak effect	1	6
	Don't know	3	16.5
2.33 Network of stake-holders	Very strong effect	4	22
	Strong effect	4	22
	Weak effect	5	28
	Very weak effect	3	17
	Don't know	2	11
2.34 Competition in the same location	Very strong effect	3	16.66
	Strong effect	5	28
	Weak effect	3	16.66
	Very weak effect	4	22
	Don't know	3	16.66
2.35 Need for energy storage capacity	Very strong effect	6	33.5
	Strong effect	6	33.5
	Weak effect	2	11
	Very weak effect	2	11
	Don't know	2	11
2.36 Size of microgrid needed	Very strong effect	7	39
	Strong effect	6	33
	Weak effect	3	17
	Very weak effect	1	5.5
	Don't know	1	5.5
2.37 Length of extension needed when connected to existing electricity grid	Very strong effect	12	67
	Strong effect	4	22
	Weak effect	0	0
	Very weak effect	1	5.5
	Don't know	1	5.5
2.38 Compatibility with existing power products	Very strong effect	5	28
	Strong effect	10	55.5
	Weak effect	3	16.5
	Very weak effect	0	0
	Don't know	0	0
2.39 Quality of equip-ment	Very strong effect	7	39
	Strong effect	6	33
	Weak effect	3	17
	Very weak effect	1	5.5
	Don't know	1	5.5
2.40 Ability to sup-ply/store continuously	Very strong effect	7	39
	Strong effect	6	33
	Weak effect	3	17
	Very weak effect	1	5.5
	Don't know	1	5.5

3. Do you think any technological criteria are missing from this list? If so, which?

Respondent	Answer
Simon Schillebeeckx	"feasibility of microgrid" is very broad. There are probably different criteria that matter for 1) starting a microgrid, and 2) maintaining a microgrid (and potentially 3) adoption of electricity). Here they are all thrown together which can confuse some answers where it is unclear which phase of development you (implicitly) refer to
Aad Correljé	1) Distinguish between projects with large initial capital outlay and low variable cost, and those with continuous substantial variable cost (and less initial investment) 2) The density of consumption (i.e. per km^2) is also important, to justify the construction of a grid; i.e. low density and large distance between users causes high distribution cost per unit of energy supplied.
Gautham Ram Chandra Mouli	Know how of local community in maintenance of products installed on the long run
?	variability of resource
Jaspreet Singh	Resource Management, resource consumption and resource potential
Joseph Mutale	Demand management Smart grid technologies

4. Do you have any other comments?

Respondent	Answer
Simon Schillebeeckx	- Do the project partners invest in technology development and learning? Y/N: Unclear whether it concerns learning within their organizations or teaching locals - Need for energy storage capacity: This will be highly dependent on the energy source - Number of previously developed electrification projects still operational: Where? How does this affect an unelectrified village?
Aad Correljé	I am curious about the results!!!
Auret Basson	The second half of the questions were difficult to answer as I do not have a specific project team to refer to and same of the questions asked for quantitative answers which I found difficult to answer with the available tick box options.
Iwona Bisaga	No
?	Some of these criteria definitions could be confusing.
Kaveri Iychettira	It is difficult to understand the meaning of 'strong effect -weak effect' in the context of Y/N questions! It is also unclear what you mean by comparing with 'other criteria' in your description. Your question on batteries is a matter purely of technical feasibility. And the answer is obviously a Yes! But what does strong or weak effect mean in this context?
Joseph Mutale	he questionnaire was a bit confusing between left and right side descriptions

5. Do you feel you have knowledge and expertise in the **institutional** field?

	#	%
Yes	14	70

6. Review of institutional criteria

Criterion	Effect	#	%
6.1 Existence of international program(s) that promote rural electrification	Very strong effect	4	28.5
	Strong effect	6	43
	Weak effect	5	28.5
	Very weak effect	0	0
	Don't know	0	0
6.2 Existence of governmental program(s) that promote rural electrification	Very strong effect	6	43
	Strong effect	7	50
	Weak effect	1	7
	Very weak effect	0	0
	Don't know	0	0
6.3 Existence of national policy that supports rural electrification (long-term)	Very strong effect	6	43
	Strong effect	6	43
	Weak effect	2	14
	Very weak effect	0	0
	Don't know	0	0
6.4 Availability of subsidies for electrification projects	Very strong effect	11	79
	Strong effect	2	14
	Weak effect	0	0
	Very weak effect	1	7
	Don't know	0	0
6.5 Existence of regulatory agency for the power sector	Very strong effect	4	28.5
	Strong effect	5	36
	Weak effect	4	28.5
	Very weak effect	1	7
	Don't know	0	0
6.6 Existence of partnerships between the government and private energy companies	Very strong effect	6	43
	Strong effect	5	36
	Weak effect	2	14
	Very weak effect	1	7
	Don't know	0	0
6.7 Complexity of decision making process around electrification project	Very strong effect	5	36
	Strong effect	5	36
	Weak effect	2	14
	Very weak effect	0	0
	Don't know	2	14
6.8 Existence of (governmental) decision making strategy concerning electrification projects	Very strong effect	4	29
	Strong effect	6	43
	Weak effect	2	14
	Very weak effect	1	7
	Don't know	1	7
6.9 Number of rural electrification initiatives in the country	Very strong effect	2	14
	Strong effect	6	43
	Weak effect	5	36
	Very weak effect	1	7
	Don't know	0	0

6.10 Level of political will/commitment	Very strong effect	6	43
	Strong effect	7	50
	Weak effect	1	7
	Very weak effect	0	0
	Don't know	0	0
6.11 Level of public participation	Very strong effect	5	36
	Strong effect	6	43
	Weak effect	2	14
	Very weak effect	1	7
	Don't know	0	0
6.12 Favourable legal framework	Very strong effect	6	43
	Strong effect	3	21
	Weak effect	1	7
	Very weak effect	4	29
	Don't know	0	0
6.13 Stable macroeconomic condition	Very strong effect	4	29
	Strong effect	4	29
	Weak effect	3	21
	Very weak effect	2	14
	Don't know	1	7
6.14 Government providing guarantees	Very strong effect	3	21.5
	Strong effect	7	50
	Weak effect	3	21.5
	Very weak effect	0	0
	Don't know	1	7
6.15 Political stability	Very strong effect	8	57
	Strong effect	3	21.5
	Weak effect	3	21.5
	Very weak effect	0	0
	Don't know	0	0
6.16 Mature and available financial market	Very strong effect	2	14
	Strong effect	6	43
	Weak effect	3	21.5
	Very weak effect	3	21.5
	Don't know	0	0
6.17 Good governance	Very strong effect	5	36
	Strong effect	5	36
	Weak effect	3	21
	Very weak effect	0	0
	Don't know	1	7
6.18 Appropriate risk allocation and sharing	Very strong effect	6	43
	Strong effect	3	21.5
	Weak effect	3	21.5
	Very weak effect	1	7
	Don't know	1	7
6.19 Structure and compatibility of the project partnership	Very strong effect	5	38.5
	Strong effect	5	38.5
	Weak effect	1	7.66
	Very weak effect	1	7.66
	Don't know	1	7.66
6.20 Political support	Very strong effect	10	72
	Strong effect	2	14
	Weak effect	1	7
	Very weak effect	1	7
	Don't know	0	0

6.21 Community support	Very strong effect	8	57
	Strong effect	5	36
	Weak effect	0	0
	Very weak effect	1	7
	Don't know	0	0
6.22 Transparent procurement	Very strong effect	3	21.5
	Strong effect	3	21.5
	Weak effect	6	43
	Very weak effect	1	7
	Don't know	1	7
6.23 Competitive procurement	Very strong effect	2	14
	Strong effect	5	36
	Weak effect	3	21.5
	Very weak effect	3	21.5
	Don't know	1	7
6.24 Strong commitment by all project partners	Very strong effect	7	50
	Strong effect	5	36
	Weak effect	1	7
	Very weak effect	1	7
	Don't know	0	0
6.25 Clarity of roles and responsibilities among project partners	Very strong effect	4	29
	Strong effect	6	43
	Weak effect	2	14
	Very weak effect	1	7
	Don't know	1	7
6.26 Financial capabilities of the project partners	Very strong effect	4	29
	Strong effect	8	57
	Weak effect	2	14
	Very weak effect	0	0
	Don't know	0	0
6.27 Level of technology innovation	Very strong effect	4	29
	Strong effect	5	36
	Weak effect	2	14
	Very weak effect	1	7
	Don't know	2	14
6.28 Good feasibility studies	Very strong effect	5	36
	Strong effect	5	36
	Weak effect	2	14
	Very weak effect	2	14
	Don't know	0	0
6.29 Open and constant communication	Very strong effect	4	29
	Strong effect	5	36
	Weak effect	2	14
	Very weak effect	1	7
	Don't know	2	14
6.30 Detailed project planning	Very strong effect	4	29
	Strong effect	4	29
	Weak effect	3	21
	Very weak effect	2	14
	Don't know	1	7
6.31 Trust between project partners	Very strong effect	6	43
	Strong effect	4	29
	Weak effect	3	21
	Very weak effect	0	0
	Don't know	1	7

6.32 Long term demand for the project	Very strong effect	8	57
	Strong effect	4	29
	Weak effect	1	7
	Very weak effect	0	0
	Don't know	1	7
6.33 Clear project brief and design development	Very strong effect	2	14
	Strong effect	7	50
	Weak effect	5	36
	Very weak effect	0	0
	Don't know	0	0
6.34 Acceptable level of tariff	Very strong effect	7	50
	Strong effect	4	29
	Weak effect	2	14
	Very weak effect	1	7
	Don't know	0	0
6.35 Compatibility skills of the project partners	Very strong effect	5	36
	Strong effect	5	36
	Weak effect	2	14
	Very weak effect	0	0
	Don't know	2	14
6.36 Good leadership and entrepreneurship skills	Very strong effect	4	29
	Strong effect	7	50
	Weak effect	2	14
	Very weak effect	0	0
	Don't know	1	7
6.37 Clear goals and objectives	Very strong effect	3	21.5
	Strong effect	7	50
	Weak effect	3	21.5
	Very weak effect	0	0
	Don't know	1	7
6.38 Employment of professional advisors	Very strong effect	1	7
	Strong effect	3	21.5
	Weak effect	6	43
	Very weak effect	3	21.5
	Don't know	1	7
6.39 Financial accountability of the project partners	Very strong effect	3	22
	Strong effect	7	50
	Weak effect	2	14
	Very weak effect	2	14
	Don't know	0	0
6.40 Consistent monitoring	Very strong effect	5	36
	Strong effect	3	21
	Weak effect	4	29
	Very weak effect	2	14
	Don't know	0	0
6.41 Reliable power delivery	Very strong effect	6	43
	Strong effect	6	43
	Weak effect	2	14
	Very weak effect	0	0
	Don't know	0	0

7. Do you think any institutional criteria are missing from this list? If so, which?

Respondent	Answer
Haiko van der Voort	Perceptions of users regarding reliability, safety and costs
Aad Correljé	1) Credible recourse to (local or selected foreign) judicial system: where are conflicts solved 2) Degree of politization of the project; i.e. is it "owned" by a particular political fraction/party (may be a problem)
?	Is the proposed project meeting a measured local need? (Has a needs assessment been completed) Training capability (i.e. by local institutions) for employee turnover Breadth of supply chain for all inputs. (how replaceable are all components (from physical to human capitals, etc), how much would it cost. Level of community buy-in (% of total capital cost) Ownership incentivized and clear (could be a refinement on 'clear roles')
Jaspreet Singh	Technology subsidies offered by the local and national government can be a strong key in deciding the technology needed.

8. Do you have any other comments?

Respondent	Answer
Haiko van der Voort	Nice longlist. Of course many criteria are related. I guess the longlist needs a bit of clustering.
Iwona Bisaga	No
?	Should be noted that the level of effect of criteria is linked to the existence of other criteria. Are we to assume that each criteria is be considered alone, or with a specific set (and level of development) of institutions which I assume? This makes it difficult to answer this.
Kaveri Iychettira	1)Political Stability: Do citizens express their dissatisfaction with the government through violent or terrorist activities? Are there political coups, revolutions or a civil war happening in the country? Y/N You call this 'political stability', while the description refers to political instability! How is this to be interpreted? Is the project partnership equipped with strong technical, operational and managerial capacity? Y/N: your use of the term 'the project partnership' needs clarification. Assuming you mean a hypothetical entity that wants to set up a microgrid, I have answers the question. Do all project partners have a clear definition of roles and responsibilities? Y/N Isn't such a question extremely context dependent? The regulatory and technical environments differ widely from state to state, and it is difficult to give a generic response to such questions.

9. Do you feel you have knowledge and expertise in the **social** field?

	#	%
Yes	15	75

10. Review of social criteria

Criterion	Effect	#	%
10.1 Number of households in potential microgrid location	Very strong effect	7	47
	Strong effect	8	53
	Weak effect	0	0
	Very weak effect	0	0
	Don't know	0	0
10.2 Number of villages in potential microgrid location	Very strong effect	5	33
	Strong effect	6	40
	Weak effect	2	13.5
	Very weak effect	0	0
	Don't know	2	13.5
10.3 Number of people in potential microgrid location	Very strong effect	6	40
	Strong effect	9	60
	Weak effect	0	0
	Very weak effect	0	0
	Don't know	0	0
10.4 Number of potential users in potential microgrid location	Very strong effect	10	67
	Strong effect	5	33
	Weak effect	0	0
	Very weak effect	0	0
	Don't know	0	0
10.5 Strength of community	Very strong effect	3	20
	Strong effect	6	40
	Weak effect	3	20
	Very weak effect	2	13
	Don't know	1	7
10.6 Level of basic education in the community	Very strong effect	4	27
	Strong effect	8	53
	Weak effect	3	20
	Very weak effect	0	0
	Don't know	0	0
10.7 Influence of women in the community	Very strong effect	2	13.33
	Strong effect	6	40
	Weak effect	3	20
	Very weak effect	2	13.33
	Don't know	2	13.33
10.8 Health of the average community member	Very strong effect	1	7
	Strong effect	3	20
	Weak effect	5	33
	Very weak effect	3	20
	Don't know	3	20
10.9 Presence of schools in the area	Very strong effect	3	20
	Strong effect	8	53
	Weak effect	2	13
	Very weak effect	1	7
	Don't know	1	7

10.10 Level of migration from areas without access to electricity to areas with access to electricity	Very strong effect	2	13
	Strong effect	3	20
	Weak effect	4	27
	Very weak effect	3	20
	Don't know	3	20
10.11 Fuel used for cooking	Very strong effect	5	33.33
	Strong effect	6	40
	Weak effect	2	13.33
	Very weak effect	2	13.33
	Don't know	0	0
10.12 Consumer's ability to pay for electricity	Very strong effect	10	67
	Strong effect	5	33
	Weak effect	0	0
	Very weak effect	0	0
	Don't know	0	0
10.13 Willingness to pay for electricity	Very strong effect	11	73
	Strong effect	4	27
	Weak effect	0	0
	Very weak effect	0	0
	Don't know	0	0
10.14 Level of satisfaction with the current energy supply options	Very strong effect	8	53
	Strong effect	4	27
	Weak effect	2	13
	Very weak effect	0	0
	Don't know	1	7
10.15 Recognition of national culture	Very strong effect	5	33
	Strong effect	3	20
	Weak effect	3	20
	Very weak effect	3	20
	Don't know	1	7
10.16 Recognition of regional culture	Very strong effect	4	26.66
	Strong effect	7	46.66
	Weak effect	3	20
	Very weak effect	0	0
	Don't know	1	6.66
10.17 Recognition of (the uniting power of) organizational culture	Very strong effect	2	14.5
	Strong effect	7	50
	Weak effect	3	21.5
	Very weak effect	1	7
	Don't know	1	7
10.18 Awareness of business culture differences	Very strong effect	6	40
	Strong effect	4	26.66
	Weak effect	4	26.66
	Very weak effect	1	6.66
	Don't know	0	0
10.19 Integration of the project partners with the community	Very strong effect	6	40
	Strong effect	7	46.66
	Weak effect	1	6.66
	Very weak effect	1	6.66
	Don't know	0	0

11. Do you think any social criteria are missing from this list? If so, which?

Respondent	Answer
Linda Kamp	number of years the local population has been in school, on average
Aad Correljé	1) good/bad experience with earlier attempts (of a similar nature - not necessarily energy). 2) "involvement" of the local community with the system; i.e. is it "their" system
Jaspreet Singh	Understanding the socio-political behaviour

12. Do you have any other comments?

Respondent	Answer
Linda Kamp	on the previous page (institutional factors) I miss suitable business model
Simon Schillebeeckx	- Number of community activities organized in activities/year: Don't think this measure adequately captures community strength - Difference between business and organizational culture is unclear
Iwona Bisaga	No

13. Do you feel you have knowledge and expertise in the **financial** field?

	#	%
Yes	15	75

14. Review of financial criteria

Criterion	Effect	#	%
14.1 Existence of an electricity market for trade	Very strong effect	3	20
	Strong effect	3	20
	Weak effect	3	20
	Very weak effect	6	40
	Don't know	0	0
14.2 Activity of banking sector	Very strong effect	4	26.66
	Strong effect	3	20
	Weak effect	4	26.66
	Very weak effect	4	26.66
	Don't know	0	0
14.3 Oil price	Very strong effect	5	33
	Strong effect	3	20
	Weak effect	3	20
	Very weak effect	3	20
	Don't know	1	7
14.4 Size of business sector	Very strong effect	2	13
	Strong effect	2	13
	Weak effect	6	40
	Very weak effect	4	27
	Don't know	1	7
14.5 Availability of national financial resources (debt and equity)	Very strong effect	7	47
	Strong effect	2	13
	Weak effect	4	26.66
	Very weak effect	1	6.66
	Don't know	1	6.66
14.6 Availability of international financial resources (debt, equity, carbon)	Very strong effect	5	33
	Strong effect	4	27
	Weak effect	5	33
	Very weak effect	0	0
	Don't know	1	7
14.7 Negative externalities caused by international donors	Very strong effect	4	26.66
	Strong effect	6	40
	Weak effect	1	6.66
	Very weak effect	1	6.66
	Don't know	3	20
14.8 Willingness of private party to invest in rural electrification project	Very strong effect	10	66.66
	Strong effect	4	26.66
	Weak effect	0	0
	Very weak effect	1	6.66
	Don't know	0	0
14.9 Willingness of public party to invest in rural electrification project	Very strong effect	8	53
	Strong effect	6	40
	Weak effect	1	7
	Very weak effect	0	0
	Don't know	0	0

14.10 Ability of investing party to get a loan	Very strong effect	8	53.33
	Strong effect	5	33.33
	Weak effect	2	13.33
	Very weak effect	0	0
	Don't know	0	0
14.11 Revenues for the project partners	Very strong effect	6	40
	Strong effect	7	46.66
	Weak effect	1	6.66
	Very weak effect	0	0
	Don't know	1	6.66
14.12 Availability of local human resources	Very strong effect	5	33.33
	Strong effect	5	33.33
	Weak effect	3	20
	Very weak effect	2	13.33
	Don't know	0	0
14.13 Availability of local financial resources	Very strong effect	8	53
	Strong effect	3	20
	Weak effect	3	20
	Very weak effect	1	7
	Don't know	0	0
14.14 Availability of standards and knowledge transfer on best practices	Very strong effect	4	27
	Strong effect	8	53
	Weak effect	2	13
	Very weak effect	1	7
	Don't know	0	0
14.15 Availability of information and data	Very strong effect	4	29
	Strong effect	7	50
	Weak effect	2	14
	Very weak effect	1	7
	Don't know	0	0
14.16 Capital cost of rural electrification project	Very strong effect	9	60
	Strong effect	4	26.66
	Weak effect	0	0
	Very weak effect	1	6.66
	Don't know	1	6.66
14.17 Operation and maintenance cost of rural electrification project	Very strong effect	11	73
	Strong effect	3	20
	Weak effect	0	0
	Very weak effect	0	0
	Don't know	1	7
14.18 Levelized cost of electricity (LCOE)	Very strong effect	9	60
	Strong effect	3	20
	Weak effect	1	6.66
	Very weak effect	1	6.66
	Don't know	1	6.66
14.19 Income of consumer	Very strong effect	7	46.66
	Strong effect	6	40
	Weak effect	1	6.66
	Very weak effect	1	6.66
	Don't know	0	0
14.20 Adequate business models	Very strong effect	11	73
	Strong effect	3	20
	Weak effect	0	0
	Very weak effect	1	7
	Don't know	0	0

14.21 Appropriate payment opportunities offered to consumers	Very strong effect	11	73.33
	Strong effect	2	13.33
	Weak effect	0	0
	Very weak effect	0	0
	Don’t know	2	13.33
14.22 Understanding the customers' needs	Very strong effect	10	66.66
	Strong effect	4	26.66
	Weak effect	0	0
	Very weak effect	0	0
	Don’t know	1	6.66
14.23 Quality of decentralized operation, maintenance and administration	Very strong effect	8	53
	Strong effect	4	26
	Weak effect	1	6.33
	Very weak effect	1	6.33
	Don’t know	1	6.33
14.24 Availability of national energy technology supplier network	Very strong effect	6	40
	Strong effect	5	33
	Weak effect	1	7
	Very weak effect	2	13
	Don’t know	1	7
14.25 Revenue security	Very strong effect	6	40
	Strong effect	7	46.66
	Weak effect	0	0
	Very weak effect	1	6.66
	Don’t know	1	6.66

15. Do you think any financial criteria are missing from this list? If so, which?

Respondent	Answer
Aad Correlje	1) Impact of (local) taxes and costs of permits
Jaspreet Singh	Willingness to pay by the rural population

16. Do you have any other comments?

Respondent	Answer
Simon Schillebeeckx	- Projected project revenues: different ~ public or private I think 'adequate business models' does not related to "Is information shared about pilot projects? Y/N". I replied (as always) thinking about the measure, not the construct
Iwona Bisaga	No
?	Some of these again are difficult to interpret: CAPEX, OPEX, and LCOE are all important to know, but vary significantly. Are you asking for the availability of these values, or having them low or what? The explanation on how to define the criteria offer no help...

17. Do you feel you have knowledge and expertise in the **environmental** field?

	#	%
Yes	18	90

18. Review of environmental criteria

Criterion	Effect	#	%
18.1 Land requirement for power generation technology	Very strong effect	9	50
	Strong effect	5	28
	Weak effect	3	16.5
	Very weak effect	1	5.5
	Don't know	0	0
18.2 Extent to which climate change is observed (related to environmental stress, see 3)	Very strong effect	3	17
	Strong effect	3	17
	Weak effect	6	33
	Very weak effect	4	22
	Don't know	2	11
18.3 Stress on the ecosystem (caused by the power generation technology)	Very strong effect	3	17
	Strong effect	7	39
	Weak effect	6	33
	Very weak effect	2	11
	Don't know	0	0
18.4 Local environmental impact	Very strong effect	5	28
	Strong effect	8	44
	Weak effect	3	17
	Very weak effect	2	11
	Don't know	0	0
18.5 Lifecycle GHG emissions of power generation technology	Very strong effect	0	0
	Strong effect	6	33
	Weak effect	3	17
	Very weak effect	8	44
	Don't know	1	6
18.6 Emissions of CO_2	Very strong effect	1	6
	Strong effect	5	28
	Weak effect	4	22
	Very weak effect	8	44
	Don't know	0	0
18.7 Emissions of SO_2	Very strong effect	1	6
	Strong effect	5	28
	Weak effect	4	22
	Very weak effect	8	44
	Don't know	0	0
18.8 Emissions of NO_x	Very strong effect	1	5.5
	Strong effect	5	28
	Weak effect	3	16.5
	Very weak effect	9	50
	Don't know	0	0

19. Do you think any environmental criteria are missing from this list? If so, which?

Respondent	Answer
Aad Correljé	Dust and smog?
Gautham Ram Chandra Mouli	Battery disposal and recycling, maintenance issues of equipment.

20. Do you have any other comments?

Respondent	Answer
Simon Schillebeeckx	Problem here is that from an ecological standpoint all these things should matter and a government should take them into consideration, but I fear practically they hardly do
Chris Brosz	environmental concerns can be (and should be) drivers for microgrid feasibility and adoption. however, from what I've seen, it isn't a huge driver.
Jaspreet Singh	It might be hard to judge the environment impact for small projects. Might have to be satisfied with ones own observations and stakeholders responses.

21. Do you feel you have knowledge and expertise in the **frugal** field?

	#	%
Yes	15	75

22. Review of frugal criteria

Criterion	Effect	#	%
22.1 Availability of material resources in the area	Very strong effect	3	21
	Strong effect	7	50
	Weak effect	4	29
	Very weak effect	0	0
	Don't know	0	0
22.2 Local knowledge on the operation of the energy generating technology	Very strong effect	2	14
	Strong effect	8	57
	Weak effect	4	29
	Very weak effect	0	0
	Don't know	0	0
22.3 Remoteness of the rural area	Very strong effect	6	43
	Strong effect	5	36
	Weak effect	3	21
	Very weak effect	0	0
	Don't know	0	0
22.4 Local knowledge on the management of energy systems	Very strong effect	2	14
	Strong effect	7	50
	Weak effect	4	29
	Very weak effect	1	7
	Don't know	0	0
22.5 Local knowledge on the maintenance and control of the electricity network	Very strong effect	5	36
	Strong effect	8	57
	Weak effect	1	7
	Very weak effect	0	0
	Don't know	0	0
22.6 Availability of technical equipment	Very strong effect	6	43
	Strong effect	5	36
	Weak effect	1	7
	Very weak effect	2	14
	Don't know	0	0
22.7 Local knowledge on the engineering, planning and installation work of the electricity network	Very strong effect	3	21.33
	Strong effect	7	50
	Weak effect	2	14.33
	Very weak effect	2	14.33
	Don't know	0	0
22.8 Availability of training in the power field	Very strong effect	5	36
	Strong effect	6	43
	Weak effect	3	21
	Very weak effect	0	0
	Don't know	0	0
22.9 Level of corruption in the country	Very strong effect	3	21
	Strong effect	7	50
	Weak effect	4	29
	Very weak effect	0	0
	Don't know	0	0

22.10 Level of illiteracy under the local population	Very strong effect	3	21
	Strong effect	4	29
	Weak effect	7	50
	Very weak effect	0	0
	Don't know	0	0
22.11 Quality of the infrastructure	Very strong effect	3	21.5
	Strong effect	7	50
	Weak effect	3	21.5
	Very weak effect	0	0
	Don't know	1	7
22.12 Frequency of currency fluctuations	Very strong effect	1	7
	Strong effect	4	29
	Weak effect	3	21
	Very weak effect	4	29
	Don't know	2	14
22.13 Level of bureaucratic red tape	Very strong effect	4	29
	Strong effect	8	57
	Weak effect	2	14
	Very weak effect	0	0
	Don't know	0	0
22.14 Local human capital	Very strong effect	4	28.5
	Strong effect	5	36
	Weak effect	4	28.5
	Very weak effect	1	7
	Don't know	0	0
22.15 Level of training received by the project partners on the challenges of bottom of the pyramid markets	Very strong effect	3	21.5
	Strong effect	5	36
	Weak effect	3	21.5
	Very weak effect	2	14
	Don't know	1	7
22.16 Access to advice, technical help and business support services for entrepreneurs	Very strong effect	3	21.5
	Strong effect	6	43
	Weak effect	2	14
	Very weak effect	3	21.5
	Don't know	0	0
22.17 Rural electricity price compared to the urban electricity price	Very strong effect	1	7
	Strong effect	5	36
	Weak effect	6	43
	Very weak effect	2	14
	Don't know	0	0
22.18 Activity of venture groups and internal investment funds in rural electrification projects	Very strong effect	2	14
	Strong effect	3	21.5
	Weak effect	4	29
	Very weak effect	3	21.5
	Don't know	2	14
22.19 Existence of a business development task force	Very strong effect	0	0
	Strong effect	3	21
	Weak effect	5	36
	Very weak effect	4	29
	Don't know	2	14
22.20 Autonomy from central R&D headquarters	Very strong effect	1	7
	Strong effect	0	0
	Weak effect	7	50
	Very weak effect	3	21.5
	Don't know	3	21.5

22.21 Having a team consisting almost exclusively of local engineers	Very strong effect	0	0
	Strong effect	7	50
	Weak effect	6	43
	Very weak effect	1	7
	Don't know	0	0
22.22 Existence of partnerships and networks that connect individuals and create opportunities	Very strong effect	3	21.5
	Strong effect	6	43
	Weak effect	3	21.5
	Very weak effect	2	14
	Don't know	0	0
22.23 Safety of operators	Very strong effect	2	14
	Strong effect	7	50
	Weak effect	4	29
	Very weak effect	1	7
	Don't know	0	0
22.24 Safety of end users	Very strong effect	4	29
	Strong effect	5	36
	Weak effect	2	14
	Very weak effect	3	21
	Don't know	0	0

23. Do you think any frugal criteria are missing from this list? If so, which?

Respondent	Answer
-	-

24. Do you have any other comments?

Respondent	Answer
Haiko van der Voort	Answering these questions is hard, because they are tightly linked to institutional criteria. What should I assume here? Are they in a developing or developed country? What trust in institutions is in place? What basic knowledge on electricity one can assume here? F.i. "local knowledge" is not critical in developed countries with good infrastructure and robust institutions. It is essential where these features are scarce.
Simon Schillebeeckx	- Quality of the infrastructure: I expect that if this is high, likelihood of decentralized grid goes down
?	This is a very strange definition and title for the 'field'. 'Local Resources' may have been a better title?

25. Did you feel a category of criteria was missing from the six I have used (technological, institutional, social, financial, environmental and frugal)?

Respondent	Answer
Linda Kamp	no
Cees van Beers	No!
Aad Correljé	Looks fairly complete…
Iwona Bisaga	No
Joseph Mutale	Capacity building Local cultural issues

26. Could I contact you if I have any questions or want more information?
What is your email address?

I will not share this information.

27. Do you have any final questions or comments?

Respondent	Answer
Linda Kamp	no
Haiko van der Voort	Good luck!
Cees van Beers	I noticed that when you want to measure "frugal" criteria you actually mean "inclusive" criteria.
Aad Correljé	No
Auret Basson	Please note that I have completed the questionnaire from an African perspective with reference to the 7+ hybrid energy supply projects we have looked at in the region over the last 18 months
Gautham Ram Chandra Mouli	All the best !
Iwona Bisaga	No
Joseph Mutale	No

Appendix M. Selection of criteria

As was explained in the first page of the survey, the team of experts was asked for their help in identifying the most important criteria in assessing the feasibility of a potential microgrid location. I told them: “I will use your input to select the most important criteria. The selected criteria will form the basis of the feasibility framework. Keep this in mind when evaluating the criteria: would they be decisive in the assessment of a potential microgrid location?”.

That is what we will do now: selecting the most important criteria. In doing so, all criteria are colour-coded with the logic explained in Table 45.

Table 45 Explanation of colour coding of the criterions average score

50%-100%	At least 50% of the experts chose this criterion to have a very strong effect: these criteria are seen as essential and decisive in the assessment of a potential microgrid location.
33%-49%	At least one third of the experts were of the opinion that this criterion had a very strong effect, but the majority labelled it as having a different kind of effect.
15%-32%	Two third of the experts selected an answer different from ‘very strong effect’.
0%-14%	Just one or two of the experts found this criterion to have a very strong effect. Any criterion that is scored below 15% is seen as non-essential in the assessment of potential microgrid locations.

Appendix M1. Selection of technological criteria

Table 46 Scoring of technological criteria based on survey answers

Survey answer options	very strong effect	strong effect	weak effect	very weak effect		
Criterion	# answers				total # answers	% 'very strong effect'
2.5 Availability of sun light (PV, SHS)	15	2	1	0	18	**83%**
2.37 Length of extension needed when connected to existing electricity grid	12	4	0	1	17	**71%**
2.12 Base load demand for electricity	10	4	1	2	17	**59%**
2.4 Availability of sources for hydropower (SHP, pico)	9	7	1	1	18	**50%**
2.6 Availability of fossil fuels (for hybrid systems)	8	7	1	1	17	**47%**
2.14 Switching costs for customer (from current source of energy to new electricity provider)	8	8	2	0	18	**44%**
2.7 Availability of wind	8	5	4	1	18	**44%**
2.24 Pricing strategy	7	9	0	0	16	**44%**
2.36 Size of microgrid needed	7	6	3	1	17	**41%**
2.39 Quality of equipment	7	6	3	1	17	**41%**
2.40 Ability to supply/store continuously	7	6	3	1	17	**41%**
2.26 Ability of the project partners to profit from their innovation	6	4	3	2	15	**40%**
2.9 Level of regulation of energy technology by government	7	6	3	2	18	**39%**
2.35 Need for energy storage capacity	6	6	2	2	16	**38%**
2.25 Managing customer's expectations	6	5	3	3	17	**35%**
2.19 Right timing of market entry	6	8	3	1	18	**33%**
2.8 Availability of geothermal heat	6	4	4	4	18	**33%**
2.32 Effectiveness of the development process	5	6	3	1	15	**33%**
2.18 Efforts of the project partners to invest in learning	5	6	2	3	16	**31%**
2.31 Pre-emption of scarce assets	4	4	4	2	14	**29%**
2.38 Compatibility with existing power products	5	10	3	0	18	**28%**
2.28 Financial strength of the project partners	4	10	2	0	16	**25%**
2.30 Production capacity	4	6	5	1	16	**25%**
2.22 The project partners' credibility	4	5	6	1	16	**25%**
2.33 Network of stakeholders	4	4	5	3	16	**25%**
2.11 Fuel used for lighting	4	9	3	1	17	**24%**
2.13 Network effects	4	13	1	0	18	**22%**
2.15 Existence of anchor load	4	11	3	0	18	**22%**
2.16 Bandwagon effect	4	9	5	0	18	**22%**

2.17 Predictability of future electricity demand	4	6	6	2	18	**22%**
2.27 Characteristics of the energy field	3	6	5	1	15	**20%**
2.34 Competition in the same location	3	5	3	4	15	**20%**
2.29 The project partners' reputation	3	7	4	2	16	**19%**
2.10 Level of regulation of energy technology by private institutions	3	6	4	4	17	**18%**
2.20 The project partners' technological knowledge	2	7	4	3	16	**13%**
2.21 The project partners' manufacturing capabilities	2	2	5	7	16	**13%**
2.2 Availability of bio-oil (jatropha)	2	6	4	5	17	**12%**
2.3 Availability of biomass (rice straw, rice husk)	2	12	3	1	18	**11%**
2.23 Timing of R&D activities	1	2	6	7	16	**6%**
2.1 Availability of biogas	1	9	5	2	17	**6%**

Appendix M2. Selection of institutional criteria

Table 47 Scoring of institutional criteria based on survey answers

Survey answer options	very strong effect	strong effect	weak effect	very weak effect		
Criterion	# answers				total # answers	% 'very strong effect'
6.4 Availability of subsidies for electrification projects	11	2	0	1	14	**79%**
6.20 Political support	10	2	1	1	14	**71%**
6.32 Long term demand for the project	8	4	1	0	13	**62%**
6.21 Community support	8	5	0	1	14	**57%**
6.15 Political stability	8	3	3	0	14	**57%**
6.24 Strong commitment by all project partners	7	5	1	1	14	**50%**
6.34 Acceptable level of tariff	7	4	2	1	14	**50%**
6.31 Trust between project partners	6	4	3	0	13	**46%**
6.18 Appropriate risk allocation and sharing	6	3	3	1	13	**46%**
6.2 Existence of governmental program(s) that promote rural electrification	6	7	1	0	14	**43%**
6.10 Level of political will/commitment	6	7	1	0	14	**43%**
6.3 Existence of national policy that supports rural electrification (long-term)	6	6	2	0	14	**43%**
6.41 Reliable power delivery	6	6	2	0	14	**43%**
6.6 Existence of partnerships between the government and private energy companies	6	5	2	1	14	**43%**
6.12 Favourable legal framework	6	3	1	4	14	**43%**
6.7 Complexity of decision making process around electrification project	5	5	2	0	12	**42%**
6.19 Structure and compatibility of the project partnership	5	5	1	1	12	**42%**
6.35 Compatibility skills of the project partners	5	5	2	0	12	**42%**
6.17 Good governance	5	5	3	0	13	**38%**
6.11 Level of public participation	5	6	2	1	14	**36%**
6.28 Good feasibility studies	5	5	2	2	14	**36%**
6.40 Consistent monitoring	5	3	4	2	14	**36%**
6.27 Level of technology innovation	4	5	2	1	12	**33%**
6.29 Open and constant communication	4	5	2	1	12	**33%**
6.36 Good leadership and entrepreneurship skills	4	7	2	0	13	**31%**
6.8 Existence of (governmental) decision making strategy concerning electrification projects	4	6	2	1	13	**31%**
6.25 Clarity of roles and responsibilities among project partners	4	6	2	1	13	**31%**
6.13 Stable macroeconomic condition	4	4	3	2	13	**31%**

6.30 Detailed project planning	4	4	3	2	13	**31%**
6.26 Financial capabilities of the project partners	4	8	2	0	14	**29%**
6.1 Existence of international program(s) that promote rural electrification	4	6	4	0	14	**29%**
6.5 Existence of regulatory agency for the power sector	4	5	4	1	14	**29%**
6.14 Government providing guarantees	3	7	3	0	13	**23%**
6.37 Clear goals and objectives	3	7	3	0	13	**23%**
6.22 Transparent procurement	3	3	6	1	13	**23%**
6.39 Financial accountability of the project partners	3	7	2	2	14	**21%**
6.23 Competitive procurement	2	5	3	3	13	**15%**
6.33 Clear project brief and design development	2	7	5	0	14	**14%**
6.9 Number of rural electrification initiatives in the country	2	6	5	1	14	**14%**
6.16 Mature and available financial market	2	6	3	3	14	**14%**
6.38 Employment of professional advisors	1	3	6	3	13	**8%**

Appendix M3. Selection of social criteria

Table 48 Scoring of social criteria based on survey answers

Survey answer options	very strong effect	strong effect	weak effect	very weak effect		
Criterion	**# answers**				**total # answers**	**% 'very strong effect'**
10.13 Willingness to pay for electricity	11	4	0	0	15	**73%**
10.4 Number of potential users in potential microgrid location	10	5	0	0	15	**67%**
10.12 Consumer's ability to pay for electricity	10	5	0	0	15	**67%**
10.14 Level of satisfaction with the current energy supply options	8	4	2	0	14	**57%**
10.1 Number of households in potential microgrid location	7	8	0	0	15	**47%**
10.3 Number of people in potential microgrid location	6	9	0	0	15	**40%**
10.19 Integration of the project partners with the community	6	7	1	1	15	**40%**
10.18 Awareness of business culture differences	6	4	4	1	15	**40%**
10.2 Number of villages in potential microgrid location	5	6	2	0	13	**38%**
10.15 Recognition of national culture	5	3	3	3	14	**36%**
10.11 Fuel used for cooking	5	6	2	2	15	**33%**
10.16 Recognition of regional culture	4	7	3	0	14	**29%**
10.6 Level of basic education in the community	4	8	3	0	15	**27%**
10.9 Presence of schools in the area	3	8	2	1	14	**21%**
10.5 Strength of community	3	6	3	2	14	**21%**
10.10 Level of migration from areas without access to electricity to areas with access to electricity	2	3	4	3	12	**17%**
10.17 Recognition of (the uniting power of) organizational culture	2	7	3	1	13	**15%**
10.7 Influence of women in the community	2	6	3	2	13	**15%**
10.8 Health of the average community member	1	3	5	3	12	**8%**

Appendix M4. Selection of financial criteria

Table 49 Scoring of financial criteria based on survey answers

Survey answer options	very strong effect	strong effect	weak effect	very weak effect		
Criterion	# answers				total # answers	% 'very strong effect'
14.21 Appropriate payment opportunities offered to consumers	11	2	0	0	13	**85%**
14.17 Operation and maintenance cost of rural electrification project	11	3	0	0	14	**79%**
14.20 Adequate business models	11	3	0	1	15	**73%**
14.22 Understanding the customers' needs	10	4	0	0	14	**71%**
14.8 Willingness of private party to invest in rural electrification project	10	4	0	1	15	**67%**
14.16 Capital cost of rural electrification project	9	4	0	1	14	**64%**
14.18 Levelized cost of electricity (LCOE)	9	3	1	1	14	**64%**
14.23 Quality of decentralized operation, maintenance and administration	8	4	1	1	14	**57%**
14.9 Willingness of public party to invest in rural electrification project	8	6	1	0	15	**53%**
14.10 Ability of investing party to get a loan	8	5	2	0	15	**53%**
14.13 Availability of local financial resources	8	3	3	1	15	**53%**
14.5 Availability of national financial resources (debt and equity)	7	2	4	1	14	**50%**
14.19 Income of consumer	7	6	1	1	15	**47%**
14.11 Revenues for the project partners	6	7	1	0	14	**43%**
14.25 Revenue security	6	7	0	1	14	**43%**
14.24 Availability of national energy technology supplier network	6	5	1	2	14	**43%**
14.6 Availability of international financial resources (debt, equity, carbon)	5	4	5	0	14	**36%**
14.3 Oil price	5	3	3	3	14	**36%**
14.12 Availability of local human resources	5	5	3	2	15	**33%**
14.7 Negative externalities caused by international donors	4	6	1	1	12	**33%**
14.15 Availability of information and data	4	7	2	1	14	**29%**
14.14 Availability of standards and knowledge transfer on best practices	4	8	2	1	15	**27%**
14.2 Activity of banking sector	4	3	4	4	15	**27%**
14.1 Existence of an electricity market for trade	3	3	3	6	15	**20%**
14.4 Size of business sector	2	2	6	4	14	**14%**

Appendix M5. Selection of environmental criteria

Table 50 Scoring of environmental criteria based on survey answers

Survey answer options	very strong effect	strong effect	weak effect	very weak effect		
Criterion	**# answers**				**total # answers**	**% 'very strong effect'**
18.1 Land requirement for power generation technology	9	5	3	1	18	**50%**
18.4 Local environmental impact	5	8	3	2	18	**28%**
18.2 Extent to which climate change is observed (related to environmental stress, see 3)	3	3	6	4	16	**19%**
18.3 Stress on the ecosystem (caused by the power generation technology)	3	7	6	2	18	**17%**
18.6 Emissions of CO_2	1	5	4	8	18	**6%**
18.7 Emissions of SO_2	1	5	4	8	18	**6%**
18.8 Emissions of NO_x	1	5	3	9	18	**6%**
18.5 Lifecycle GHG emissions of power generation technology	0	6	3	8	17	**0%**

Appendix M6. Selection of frugal criteria

Table 51 Scoring of frugal criteria based on survey answers

Survey answer options	very strong effect	strong effect	weak effect	very weak effect		
Criterion	# answers				total # answers	% 'very strong effect'
22.3 Remoteness of the rural area	6	5	3	0	14	**43%**
22.6 Availability of technical equipment	6	5	1	2	14	**43%**
22.5 Local knowledge on the maintenance and control of the electricity network	5	8	1	0	14	**36%**
22.8 Availability of training in the power field	5	6	3	0	14	**36%**
22.13 Level of bureaucratic red tape	4	8	2	0	14	**29%**
22.14 Local human capital	4	5	4	1	14	**29%**
22.24 Safety of end users	4	5	2	3	14	**29%**
22.11 Quality of the infrastructure	3	7	3	0	13	**23%**
22.15 Level of training received by the project partners on the challenges of bottom of the pyramid markets	3	5	3	2	13	**23%**
22.1 Availability of material resources in the area	3	7	4	0	14	**21%**
22.7 Local knowledge on the engineering, planning and installation work of the electricity network	3	7	2	2	14	**21%**
22.9 Level of corruption in the country	3	7	4	0	14	**21%**
22.16 Access to advice, technical help and business support services for entrepreneurs	3	6	2	3	14	**21%**
22.22 Existence of partnerships and networks that connect individuals and create opportunities	3	6	3	2	14	**21%**
22.10 Level of illiteracy under the local population	3	4	7	0	14	**21%**
22.18 Activity of venture groups and internal investment funds in rural electrification projects	2	3	4	3	12	**17%**
22.2 Local knowledge on the operation of the energy generating technology	2	8	4	0	14	**14%**
22.4 Local knowledge on the management of energy systems	2	7	4	1	14	**14%**
22.23 Safety of operators	2	7	4	1	14	**14%**
22.20 Autonomy from central R&D headquarters	1	0	7	3	11	**9%**
22.12 Frequency of currency fluctuations	1	4	3	4	12	**8%**
22.17 Rural electricity price compared to the urban electricity price	1	5	6	2	14	**7%**
22.21 Having a team consisting almost exclusively of local engineers	0	7	6	1	14	**0%**
22.19 Existence of a business development task force	0	3	5	4	12	**0%**

Appendix N. Solar radiation maps

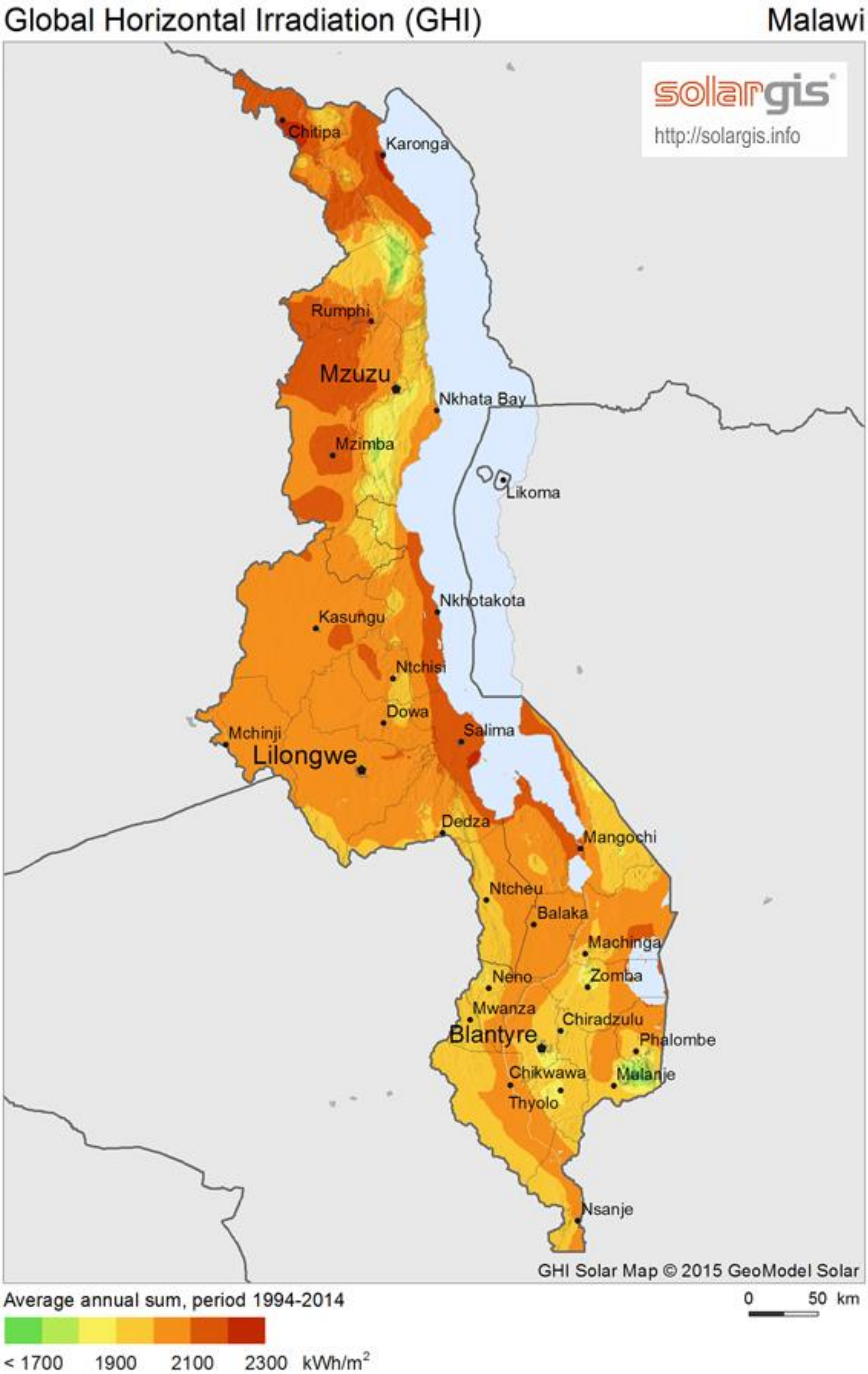

Figure 16 Global Horizontal Irradiation of Malawi (GeoModel Solar, 2016)

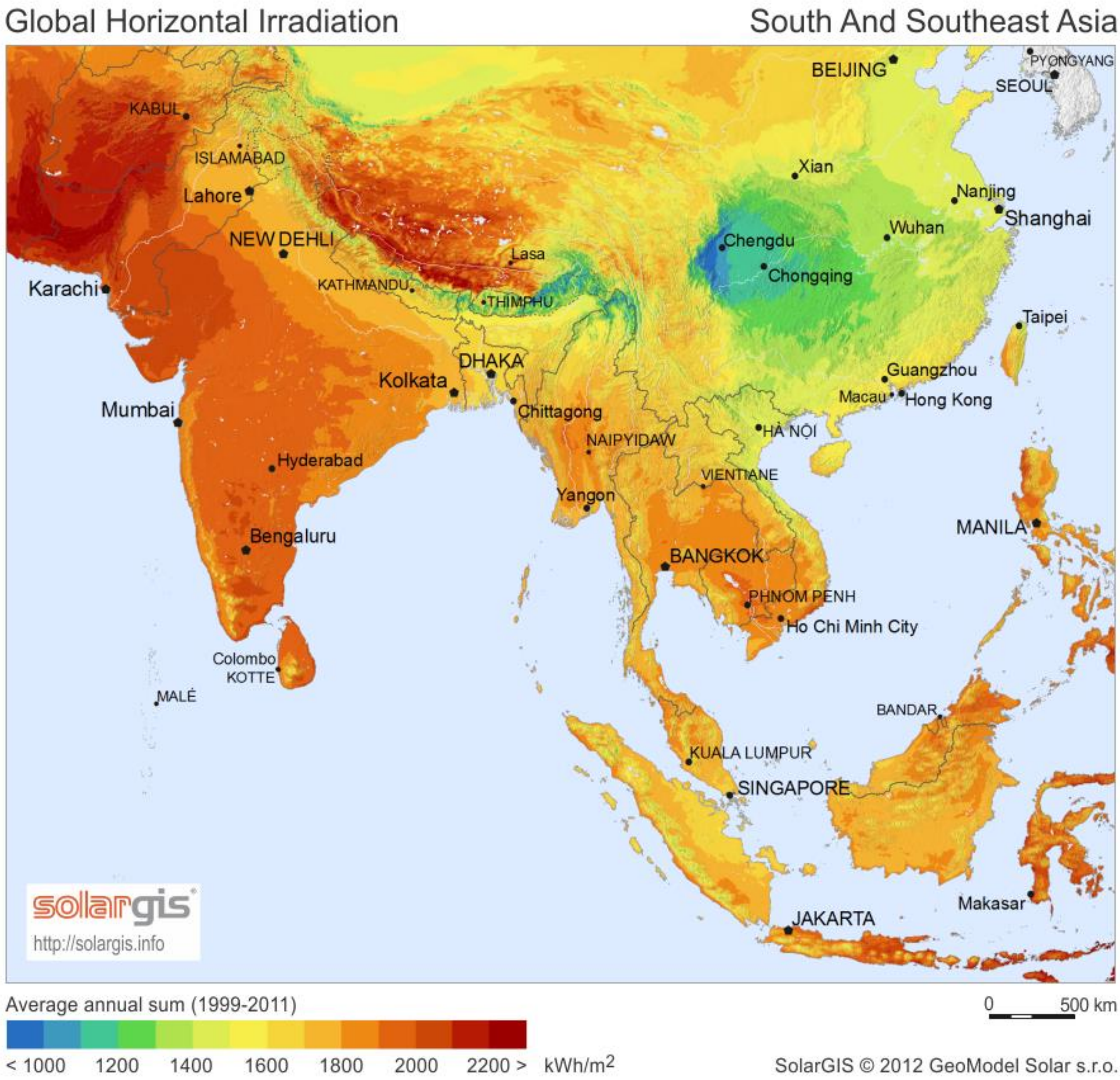

Figure 17 Global Horizontal Irradiation of South and Southeast Asia (GeoModel Solar, 2016)

Appendix O. Maps of national power grids

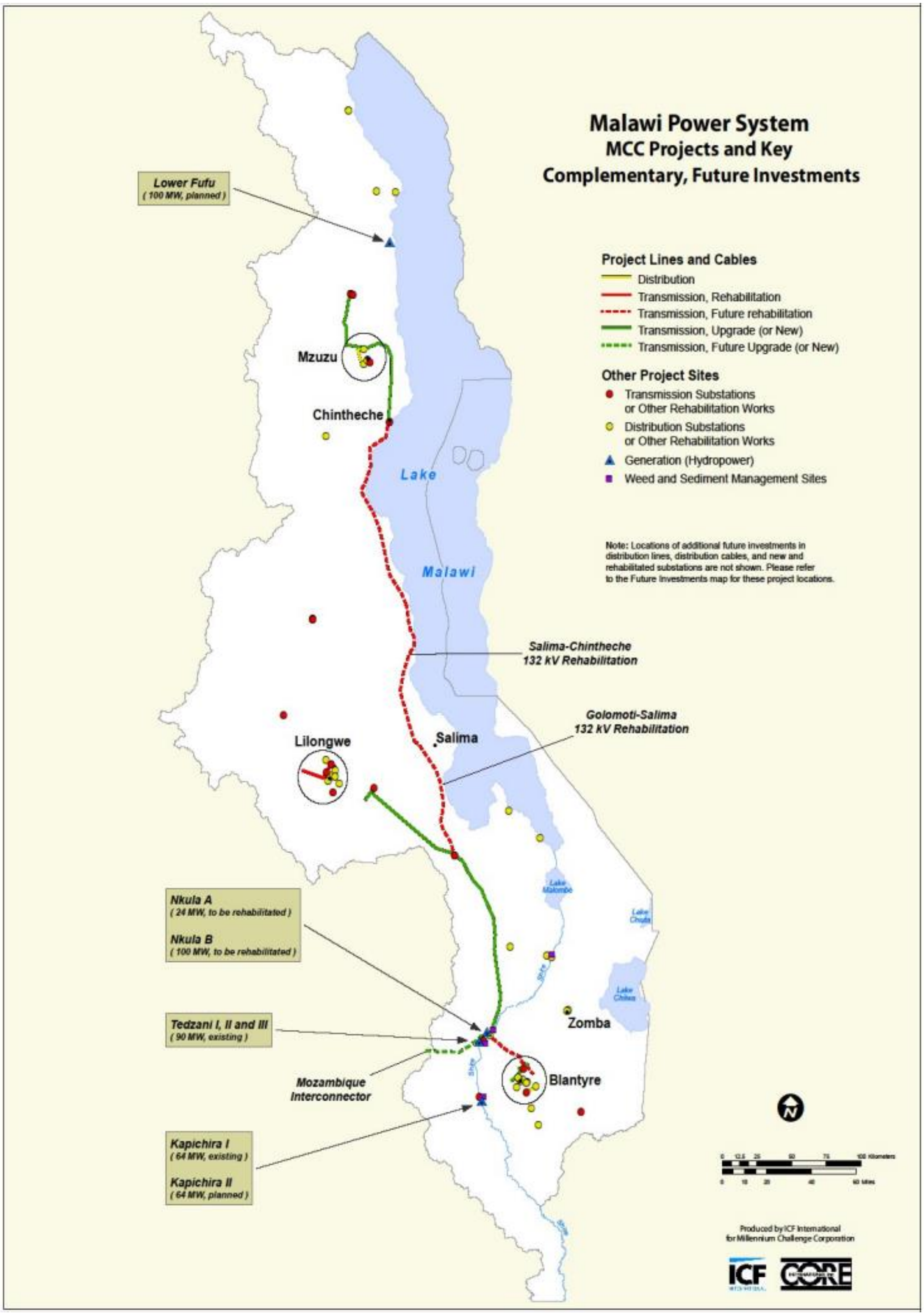

Figure 18 Malawi national power grid, including future connections (Government of Malawi, 2014)

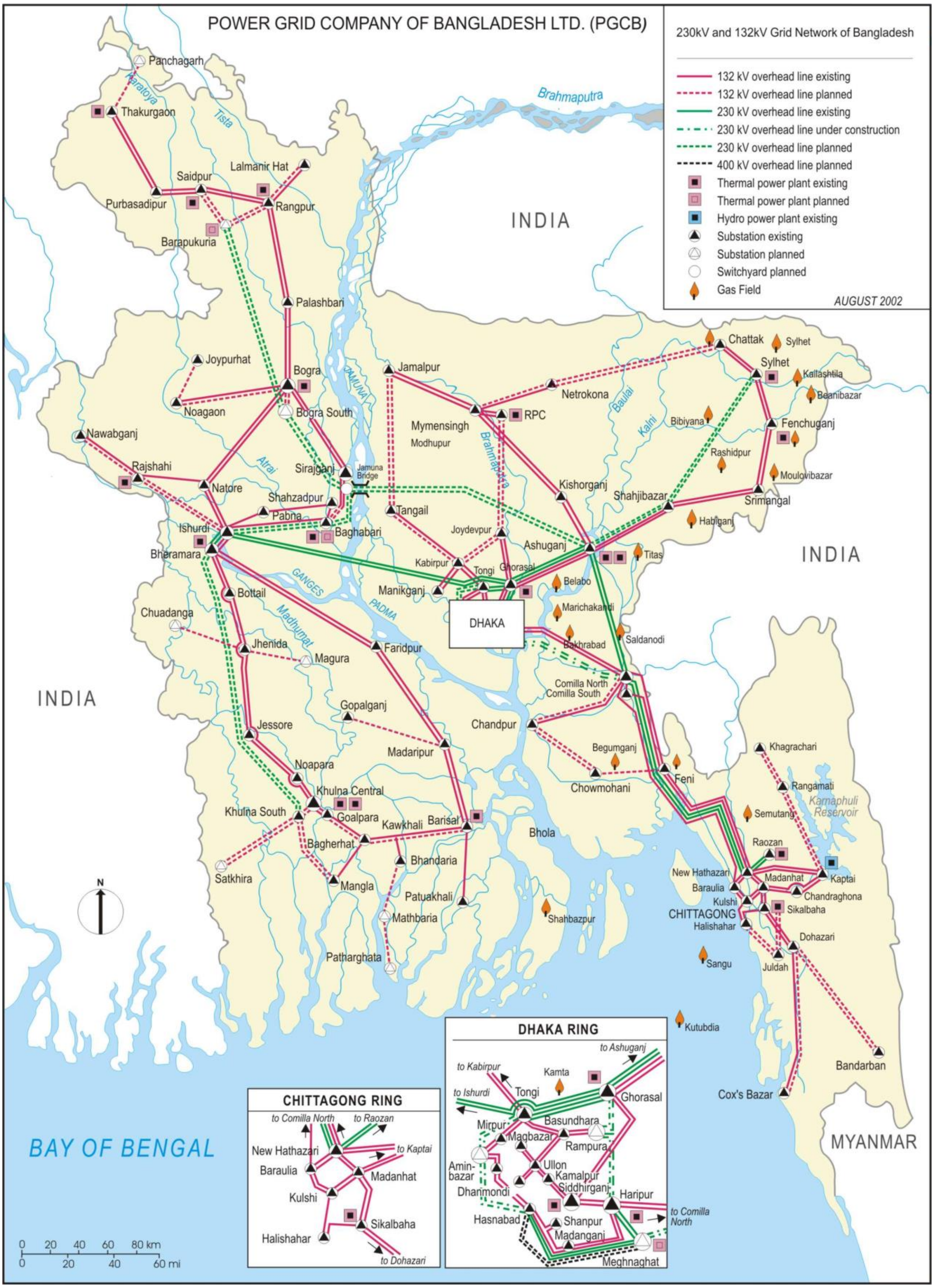

Figure 19 Bangladesh national power grid, including future connections (GENI, 2014)