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Powering Africa by Empowering its People

An Action Research study at a Zambian Microgrid company building local capacity to reach large scale viability

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Approved 2019-06-06	Examiner Niklas Arvidsson	Supervisor Daniel Berlin
	Commissioner Standard Microgrid	Contact person Brian Somers

Abstract

Despite recent advances in the global electrification rates, increasing from 76% in 1990 to 85% in 2012, the United Nations goal of universal access to electricity by 2030 is still far from achieved, with an estimated 1.1 billion people still without access to electricity. Over half of these live in Sub-Saharan Africa, with a majority in rural areas and extreme poverty. Major challenges are inert with the current electrification path of centralized grid extension, leaving these people without power in decades to come. Microgrids, a decentralized power system consisting of solar power generation, energy storage and distribution technology, has been hailed as the only option to provide life improving and productivity inducing power for rural communities in Africa.

However, despite recent hype and development in the sector, the diffusion of microgrids is still incremental due to a lack of viable large-scale operation, required for profitability. This is explained by targeting customers in remote rural areas with low ability to pay, and the task of delivering expensive technology and complex operations needed to manage and operate the grids. No industry blueprint or research on how to operate microgrids at scale or profitably exists. This thesis explores one blueprint, with the promise to increase profitability and allow for a more sustainable scaling. Local Capacity building is a decentralized approach by developing capacity directly in the local communities, through recruiting, skills development and training of people to be employed to operate and manage their local microgrids.

The results consist of a framework outlining what local capacity building is, through research propositions that define the key components capturing the complete system of local capacity building is for scaling a microgrid business, along with the challenges and opportunities associated with scaling a business using local capacity building. It has been developed iteratively by application of an action research approach conducted on a small-scale Zambian Microgrid company facing radical growth. The researcher was immersed in the context, at the heart of this change, and in a participatory and interventionist fashion turning every stone to explore what local capacity building is, resulting in a robust study anchored in the field. Because of the contextually embedded nature of the data, this also means that the results are local. It is up to the reader to assess the applicability of the results in another context.

The extensive results span multiple areas of the business, capturing the complexity of local capacity building, and contribute to knowledge on a holistic level on what local capacity building is. This blueprint was deemed viable to further develop in the small-scale Zambian microgrid company, specifically because of its potential to lower operating expenses and offer a more sustainable way to scale, and in extension diffuse microgrids in Africa.

Keywords: Microgrids, Off-grid power system, Rural Electrification, Sub-Saharan Africa, solar power, local capacity building, commercial microgrid business, sustainable development, diffusion, training of rural populations, organizational change, Action Research

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2019-06-06	Niklas Arvidsson	Daniel Berlin
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Sammanfattning

Trots en positiv utveckling i tillgång till el globalt, ökandes från 76% år 1990, till 85% år 2012, så är Förenta Nationernas mål om universell tillgång till el till år 2030, långt ifrån att bli uppfyllt. 1.1 miljarder människor estimeras vara utan tillgång till el globalt, där över hälften av dessa bor i Sub-Saharanska Afrika, med majoriteten levandes på landsbygden och i extrem fattigdom. Stora utmaningar finns med innevarande elektrifierings strategin, som handlar om centraliserad elproduktion och distribution genom ett centralt elnät, detta kommer att lämna dessa människor utan el under lång tid framöver. Mikronät, ett decentraliserat energisystem, som kan producera och distribuera el, har lyfts fram som det bästa alternativet för att försörja livsförbättrande och produktivitetsökande elektricitet för samhällen på landsbygden i Afrika.

Dock, trots nylig hype och utveckling i mikronät sektorn, så är spridningen av mikronät fortfarande inkrementell, beroende av en brist på genomförbarheten av att driva mikronät verksamheten i stor skala, vilket krävs för lönsamhet. Detta förklaras av den fundamentala utmaningen i att inrikta sig mot kunder i avlägsna områden, med en låg förmåga att betala, kombinerat med leveransen av dyr teknologi, och de komplex operativa strukturerna som krävs. Det finns ingen forskning eller blåkopia i industrin som visar hur man skulle kunna bedriva mikronäts verksamhets i stor skala, eller på ett lönsamt vis. Denna forskning undersöker en möjlig sådan blåkopia, med löftet att öka lönsamheten och möjliggöra en mer hållbar spridning. Utveckling av lokal kapacitet, är ett decentraliserat tillvägagångssätt för att utveckla kapacitet direkt i dessa avlägsna samhällen, genom rekrytering, färdighetsutveckling och utbildning av människor för att bli anställda för att sköta deras lokala mikronät.

Resultaten i studien består av ett ramverk som visar vad utveckling av lokal kapacitet innebär, genom forskningsförslag som definierar vilka nyckelkomponenter som krävs för att skala upp en mikronäts verksamhet, tillsammans med utmaningar och möjligheter för att göra detta. Ramverket har utvecklats iterativt genom applicering av Action Research, utförd i ett småskaligt mikronät företag i Zambia som står inför en radikal expansion. Forskaren var fördjupad i företagskontexten, i hjärtat av förändringen, och på ett ingripande och deltagande sätt vänt på varenda sten för att utforska vad utveckling av lokal kapacitet är. Detta resulterade i en robust studie, förankrad i verkligheten. På grund av den kontextuellt inbäddade naturen av datan, så betyder detta även att resultaten är lokala. Det är upp till läsaren att bedöma till vilken grad resultaten kan appliceras i en annan kontext.

De omfattande resultaten spänner över många olika områden i företaget, och lyckas fånga komplexiteten i vad utveckling av lokal kapacitet är. Blåkopian som utvecklades, bedömdes värdefull att utveckla vidare i företaget där studien gjorde, specifikt för dess potential att minska de operativa kostnaderna och erbjuda ett mer hållbart sätt att skala verksamheten, och i förlängningen, erbjuda ett mer hållbart sätt att sprida tillgång till el i Afrika.

Nyckelord: Mikronät, fristående energisystem, landsbygds elektrifiering, Sub-Sahara Afrika, Solkraft, Lokal kapacitets utveckling, kommersiellt mikronäts företag, hållbar utveckling, Utbildning av lokalbefolkning, organisatorisk förändring, Action Research

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Thanks to my grandfather Väinö Ala-Mutka (1906 - 1987), a shop owner with no formal education, descending from a family of farmers, for showing that nothing is impossible. Through his demonstration of the power of knowledge and agency, by in the end of 1940s in rural Finland, turning a world war airplane engine into an off-grid hydropower plant, construct and draw out a reticulation system, and become the first to supply electricity in remote village 'Leppälänkylä'. The system had a 200-meter-long wire from the river to the house to control the dam hatchets, and in addition a giant light bulb on top of the house to burn off excess power. At the time, this must have been a peculiar sight, seeing this pulsating beacon of light, in the midst of darkness, with no nearby waters or seafarers. Special thanks to my father, Pekka Ala-Mutka, for instilling the values of altruism, social justice and for throughout his life showing resilience in challenging circumstances and keep fighting for the world that you believe in. These have been the guiding light of my life and choices, and lead to my involvement in energy access in Africa.

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By the end of the research period, the researcher was hired as the 'Country Manager' at the company, to lead the company expansion in Zambia through Local capacity building.

Contents

Abbreviations and explanation of common terms

Microgrid – a technological concept consisting of a small-scale power system (5-100 kW capacity) with power generation and distribution to end users, the system can autonomously generate and provide power for consumption for e.g. a village in rural Africa.
Large scale viability – To succeed with microgrids, they need to be operated as a sustainable business, i.e. profitability. In order to achieve profitability, the business needs to be scaled by adding more microgrid units or systems to scale the business, this is what 'scaling' implies in this thesis.
Local Capacity Building (LCB) – the act of building capacity at the company to train local people, as well as building the capacity of local people through education, training and skills development.
LC – Local capacity – the people living in local communities where the microgrids are built that are invested into to be able to work for the company running the microgrids, they become 'local capacity'
MM – Microgrid Manager – the first of two key roles that are trained to become local capacity, they will work with selling power to customers from the microgrid and provide customer service.
RT – Regional technician- the second of the two key roles that are trained to become local capacity, they work with the technical side of the power system and reticulation, conduct maintenance and repairs to ensure the system runs effectively.
AR – Action research – The methodology used to conduct this thesis.
SSA – Sub-Saharan Africa – the geographic delimitation, means Africa south of the Saharan desert, and typically consists of all countries of Africa except Egypt, Libya, Algeria, Morocco and Tunisia.
ARPU – Average Revenue per user – a key industry metric for microgrids
ACPU – Average cost per user - a key industry metric for microgrids
CAPEX – Capital Expense – used to judge the upfront capital needed for investment, such as hardware of a power system
OPEX – Operating expense – used to judge the on-going costs, such as those of running an already setup power system
SOP – Standard Operating procedure
QC – Quality Control
QA – Quality assurance

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Chapter 1

Introduction

558 million people are without access to electricity in Sub-Saharan Africa (SSA) today. This number is projected to even increase by 2040 due to population growth, with a majority of these people living in rural areas and extreme poverty (Birol, et al., 2014). Electricity access is key to drive development and get these millions out of poverty, with numerous studies showing a strong correlation between electricity consumption of just a few kWh above zero and Human Development Index (Birol, et al., 2014).

Major challenges are inert with the current electrification path through extending the national grids, the upfront capital and grid extension costs to remote and dispersed customers in rural areas with lower ability to pay than those in urban areas, is not economically feasible (Birol, et al., 2014),explaining why for instance rural Zambia only has 4% electricity access, in stark contrast to urban areas of 67% access. Because of the staggeringly slow electrification rate, a majority of people living in rural Sub-Saharan Africa have to spend a large share of their disposable income (and time) on alternative low quality energy sources such as kerosene, charcoal and fuelwood with negative effects for health, environment and social progress (Birol, et al., 2014). Instead, some of this disposable income spent on electricity, would deliver a large consumer surplus, in terms of paying less for energy needs, whilst getting higher utility (Taylor, 2016). Microgrid is the concept of any small scale (less than 100 kW) off-grid power system consisting of power generation and distribution technology. It can autonomously generate and distribute power to an entire community in a more cost-efficient way than through grid extension (Birol, et al., 2014).

While microgrids have been around for a long time, it's the decreasing costs of solar photovoltaics that are triggering a new dynamic in the sector. In the developing world, energy access projects for lower-income people has seen an increase in commercial microgrid operators (operating microgrids in the span of 5-100kW generation capacity and a potential for 25-500 household connections), growing from a dozen to hundred businesses in the past 10 years (Lepicard, et al., 2017). It has been hailed as the only short-term option for life improving or productivity inducing equipment in most rural villages across SSA (Lepicard, et al., 2017). It seems to be the answer to deliver the long held developmental promise and climate change impact in rural SSA.

Even though recent development and hype in the sector, today microgrids are installed at a meagre rate of around 100 per year worldwide, with a total of 1869 microgrids installed worldwide (Paul, 2018), far lower than what is needed to reach United Nations target of universal access to electricity by 2030. The key reason to this slow diffusion is profitability. A majority of these installations are either pilot projects or small scale microgrid businesses (up to 10 microgrid units), these struggle to cover their overhead costs and achieve a sustainable business model that can pay back the huge upfront investment costs of the power system, pay investor returns and deliver profits. There is consensus in the industry, that in order to achieve profitability, microgrids need to be operated at a larger scale, with the target scale required to reach profitability quoted everywhere from 50-300 microgrid units by the microgrid players, a far bigger scale than operated at today (Lepicard, et al., 2017). Still an industry-wide challenge remains in finding a way to scale the microgrid business, a requirement for diffusion and profitability, assuming that economies of scale could be leveraged, such as spreading the overhead costs over a larger number of systems. The same development has historically helped accelerate diffusion of technology such as with the industrialization of automobiles and the conventional power system of the modern world through large-scale centralized power generation such as nuclear power plants. So why do microgrid operators struggle to scale? There are several barriers for scaling a microgrid business, and an operational performance report of microgrid players, by International Finance Corporation (2017) highlights 6 major barriers; 1) access to finance, 2) Capex, 3) Lack or proven operations and scaling models, 4) too high on-going costs, profitability 5) Finding skilled people, 6) regulatory environment). These are further elaborated in the background section 2.2.6.

Explained by above barriers, there are very few businesses in practice that are operating microgrids at scale today (e.g. Husk, Powergen, Powerhive, Mera Gao Power and OMC power), and even fewer have reached profitability unless relying on unique and highly specific conditions, such as governmental subsidies or through partnerships. These scaling paths are not applicable to reach the majority of the millions living in SSA. With the variation amongst players still experimenting and the challenges in finding a sustainable and profitable way to scale and large scale model for microgrids, there doesn't seem to be a blueprint for microgrids at scale yet, the area is still in its infancy. At the same time, the players in the industry operate in silos, with little on their operations models shared with the outside world (Lepicard, et al., 2017), and next to no research on the field of microgrid operations and feasibility of microgrids at scale.

There is thus a clear gap between the potential of microgrid technology and what is done in practice as well as research. This is a critical problem as no other viable alternatives have emerged for rural electrification as of today, leaving, with the current electrification path of grid extension, hundreds of millions in sub-Saharan Africa behind in poverty for the coming decades.

As operations and operating expense are not only key to the company specific context and the ability to scale the business in a successful way, the area is also highly connected to the viability and business case of scaling up. For microgrids, revenue can be considered constant per each new microgrid, however, if operating expense or overhead costs can be lowered per each additional system the profitability of the business increases as it scales. The central problem of understanding the viability of microgrids at scale is therefore highly connected to understanding the operations and the associated operating expense and overhead costs.

This study aims to bridge the gap in research and practice by inquiring into the viability of microgrids at scale, by conducting an Action Research study at a small-scale Zambian microgrid company (operating 3 microgrid systems at the start of the research), that is facing radical growth, aiming to build an additional 150 systems, supported by secured investments. For this expansion, the company shares the industry-wide challenge of exploring and finding a feasible operative structure that is profitable at large scale. This context makes this company a perfect case to investigate a viable operations model.

1.1 Local Capacity Building as an operative intervention to scale a microgrid business

With many different strategies and operational structures on how to scale a business, or specifically a microgrid business, yet with no proof of concept, or blueprint of a profitable large scale microgrid player. Players are still experimenting with different business models, strategies and different operative structures (e.g. centralization vs decentralization), with no dominant design or blueprint emerging on how to profitably operate microgrids at scale.

By mapping and analysing possible scaling strategies, the company and the researcher together selected Local Capacity Building as the operative intervention to scale the business and to study for research. Local Capacity Building is defined in this thesis as the holistic system required for developing local capacity, by recruiting, training and investing in local community members that live where the microgrids are deployed, employed to operate and manage the microgrids in their respective communities. LCB is not an established concept, but rather used as a way to effectively communicate the project and research, as will be later shown, this research is explicitly tasked with exploring *what* Local Capacity building for a microgrid business is.

The intervention was interesting both from a business perspective, but also held strong synergies in terms of sustainability and social development. For the microgrid business, it holds the potential to solve two of the main barrier to scaling a microgrid business, the use of local labour potentially resulting in lower operating expenses (due to site proximity with microgrids specifically targeting remote rural areas, and increased operational efficiency), and the act of investing and training this labour in-house, side-stepping the challenge of finding highly-skilled people. The rationale for this selection was also due to the company having some previous experience using this approach at a limited extent. It was also aligned with the researcher and company's shared value of finding, if possible, a sustainable scaling path, and building local capacity as the engine for growth, means local jobs would be created, with people in the communities empowered through education, skills development and employment. The selection process of which operative intervention to develop and implement, along with rationale is further elaborated upon in section 4.1.

The strategy of local capacity building is not without challenges, the reason why the strategy hasn't been leveraged by any known microgrid players in their attempts to reach scale, is the challenge of training complex engineering skills to low-skilled labour, in some cases illiterate and without education in the rural communities targeted. Outsourcing the management of microgrids, an expensive hardware asset, with a lifetime of decades, needing to operate in an optimal way to pay itself of and start delivering profits, to this newly developed labour is a risky strategy. There is also the classical trade-off associated with the concept of outsourcing, using local capacity, how can the company keep control of operating practices to continuously improve the operational efficiency? And how does the company maintain control of customer relationships to be able to understand its customers and improve the value proposition over time? And how can the company ensure that safety standards are met, crucial in any power system with live voltages and expensive technology, as well as conduct quality assurance and quality control? There is also the initial challenge of standardizing operations, over a limited time frame typically, to convert these into trainable content and putting resources to conduct training. All these are resource intensive tasks, competing with other company objectives, as in any business growing. These questions will be amongst many to be explored further on in this thesis.

1.2 Purpose, Research goal and Research Questions

The company was faced with the need to change, its current operative structure of highly centralized personnel and resources, wouldn't be sustainable nor profitable at a larger scale. This need to change necessitated the analysis and selection of one scaling strategy (also mentioned here as operative intervention) to transform its operations to allow for radical growth, and set the foundation for operational viability at a larger scale in the future. Because of this timing, it was deemed more valuable to focus on being part of developing and implementing this strategy, rather than conduct research on comparing multiple possible scaling strategies. It is also argued that its more valuable in terms of research that this focus allows to develop a more rich, in-depth understanding of what is required to scale a microgrid business, and how this happens, from the point of view of Local Capacity Building. With this area being unexplored in literature and (known) practice, an inductive approach is used to build new theory on what is required to build local capacity.

The purpose of this research is to provide one industry blueprint on what is required to scale a microgrid business, specifically using Local Capacity Building. Specifically, this is done by the Action Research methodology, where the researcher is participating in the real-world organizational change project of Local Capacity Building at the company. By being involved in developing and implementing this strategy, the reflection upon choices and best practices, allows the development of a qualitative and holistic understanding of the factors that affect this process in the business. This allows to the delivery of the thesis goal, to build theory by developing actionable guidelines on what local capacity building entails, from a holistic perspective, and specifically how it is used in the context of scaling a microgrid business in a viable and sustainable way.

This goal addresses the wider problem of the feasibility of scaling microgrids, and particularly doing so in a profitable way, as well as the specific problem of a lack of an operative blueprint on how to scale a microgrid business in research and (known) practice, by selecting and focusing on one particular scaling strategy. The two research questions help guide the research and materialize and concretize this thesis goal.

RQ1:" What are the main challenges and opportunities to a local capacity building strategy for a microgrid business?"

RQ2:" What are the key components to scaling a microgrid business using local capacity building?"

The two research questions are both on a qualitative level, directly connected to the scaling strategy of Local Capacity Building. They are studied on the company level, specifically on the operations side of the business as the level of analysis, at the specific small-scale Zambian microgrid business. Further, they are studied in the context of the phenomena of scaling, the research questions are directly affected by the company's need to scale, and the project of Local Capacity building has the purpose in the business to facilitate scaling and doing so in a profitable and sustainable way, this means the Research questions are inquired upon specifically in the light of how they facilitate this scaling.

The research questions main function is to break down the thesis goal, by providing a structure to categorize inquiry and empirical findings. They are also selected as the process of implementing and developing local capacity building is new to the company, this means there is a strong likelihood to face challenges and opportunities along the way (RQ1) and reflect upon these, how they were managed and deliver these best practices. The second research question helps build a more holistic framework, throughout the implementation and development of local capacity building, by identifying components that are required to build local capacity and conduct the strategy.

This research will contribute to knowledge through the two RQs, that help build theory mainly on what Local Capacity Building is, but also provide an example on how to scale a microgrid business using a specific scaling strategy. It will contribute to theory by exploring a possible operations and scaling model through the creation and use of local capacity and aiming to solve the profitability dilemma of the microgrid sector. With the strong connection between profitability and diffusion of technology, which in turn could be key to deliver power and bring the millions of people living without electricity and in extreme poverty in rural sub-Saharan Africa today. Zooming out, in an energy access sector in SSA consisting of an unsustainable 80% western expatriates, empowering and employing local labour would be a fundamental piece of a more *sustainable* diffusion of microgrids,

1.3Thesis Delimitations

The subject and problem of this thesis is both wide and complex, spanning several disciplines. Here the delimitations are specified and justified, so that the reader can appreciate why certain things are left out of the scope and others are included, why the final path has emerged at every major junction.

Firstly, the geographical delimitation to Sub-Saharan Africa is justified by the magnitude and severity of the problem, along with the researchers' experience, values and interest of working with energy access in Africa. Rural SSA is chosen since this is where the energy access problem is most severe, along with the challenge of providing electricity to these areas through the current option of a centralized grid.

Secondly, Microgrids are the best option to provide energy access to rural areas in SSA, that also can also utilize renewable energy, and thus have a positive climate change impact.

Thirdly, the reason why microgrids struggle to take is rooted in many aspects as outlined, scaling of microgrid businesses is critical for diffusion, and the key issue is the lack of a proven profitable large scale microgrid business.

Fourthly, there is some research on revenue and demand stimulation, and the other business and commercial aspects of microgrids – yet it's the operations side that is the least explored, especially at a larger scale, whilst lowering operating expenses is fundamental to a profitable business at scale.

Finally the delimitation to focus on one specific operative intervention, or scaling strategy, is motivated by its ability to provide more in-depth results, and outline guidelines for how one way to scale a microgrid business can look like, and what is required to do so – provide one operative blueprint. The specific focus on Local capacity building as this one operative intervention is justified by the fit with the company's goals, challenges and previous experience with building local capacity- and now exploring If this can be the operative blueprint and leverage this as the mechanism for scaling.

Of course, there were other initially considered, highly relevant and connected areas to this thesis topic. The dynamics of diffusion of microgrids, to theoretically try to derive and explain this development is interesting, however, the key reasons have already been identified, and a theory is not going to help accelerate diffusion, solving the problems on the ground is what is needed.

Since the main issue is profitability, taking a quantitative approach to understand profitability and operating expenses would make sense, however, this would be too passive, and not develop enough insight. 1) the operating expenses and granular data required for such study is confidential, and also limited (industry-challenge of limited track record, and not a practice of gathering this) 2) it has already been shown that the lack of profitability is due to too high overhead costs over too few systems and scaling is needed, the real problem is finding how to scale. 3) such result would be highly contextual, where operating expense and overhead costs vary significantly between microgrid businesses, and not valuable to other practitioners. The issue is not understanding operating expense, this any business can do from their own accounts, it's finding a way (Strategy, operative intervention, scaling) to lower operating expense that is the bottleneck.

The focus on operations and operating expense, rather than looking at the business model, revenue stimulation etc, was simply chosen because of a lack of research on the operations side, the importance of lowering operating expense, and the lack of a successful large scale microgrid company – reflected in the lack of an operative blueprint.

There were other challenges outlined, such as access to finance, high Capex and regulatory environment, that are not addressed by the specific focus on operations and local capacity building. The first two are connected to the lack of a proof of concept of microgrids in general in the industry, which is why it's so important to find a way to scale microgrids and create a profitable large-scale business, if there is a promise of returns once a certain scale is reached, finance will become cheaper and more accessible. Capex will always be quite constant, and it's an issue in a high initial investment, delivering low returns and requiring time – this is though also connected to an operative structure that is sustainable, capable to deliver power to customers and thus revenue over a long time. The regulatory environment is an issue, but one that is improving in many countries across SSA, as microgrids get more attention as an option for rural electrification, it is also not valuable to focus on for accelerating diffusion of microgrids, since the regulatory environment can vary a lot in different countries of SSA. Thus the focus on exploring a possible scaling mechanism in building local capacity, and build actionable knowledge on the unexplored field of operations and microgrids at scale was the best option to help accelerate diffusion of microgrids.

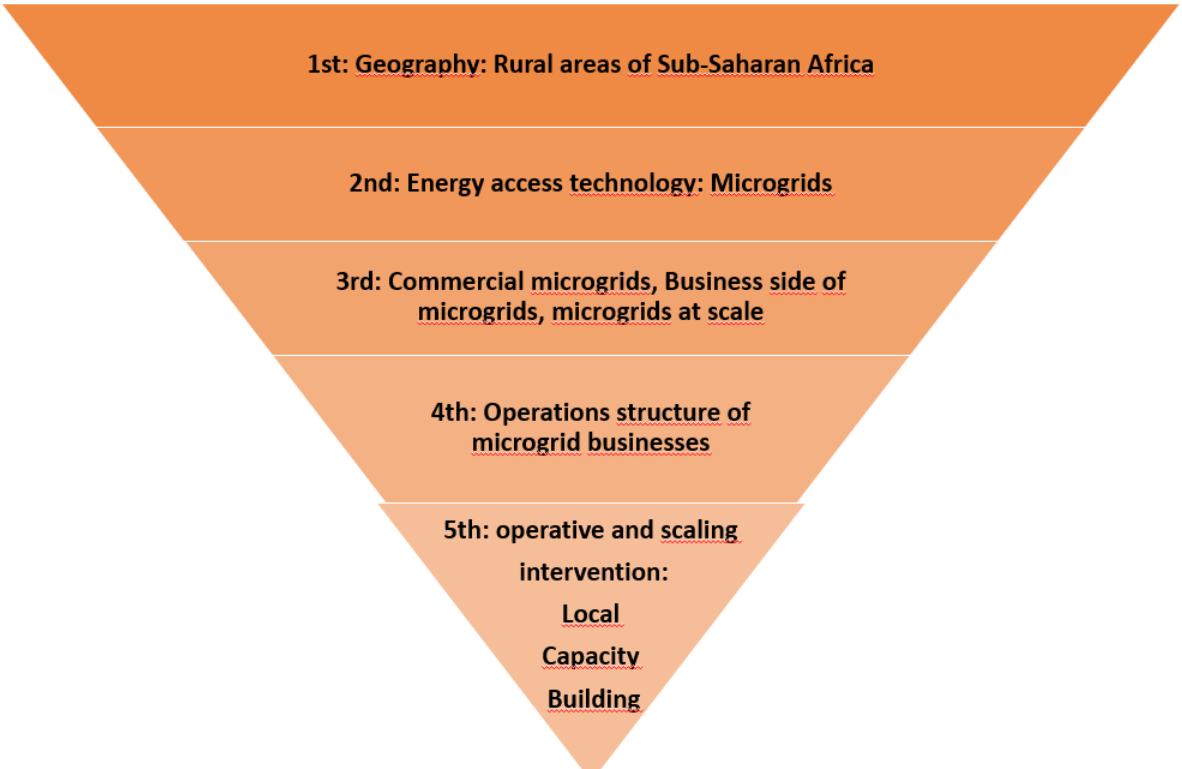

Figure 1: Thesis delimitations

1.4 Thesis disposition

This thesis is divided into seven chapters. In the first chapter, the problem is framed through a funnel approach and the research purpose, goal and research questions to help solve this problem are formulated. The second chapter gives the reader background to understand the issues of rural electrification in SSA and describes the technology central to this thesis, Microgrids. The third chapter explains the methodological choices, and how the collection of empirical data and analysis are divided into three phases. The Fourth chapter presents the empirical findings. The fifth chapter is divided into two sections, starting by showing how the empirical data is analysed to formulate the results, to then present the results of this research. In the sixth chapter a discussion is held with regards to the results, their generalizability and validity, along with a discussion on methodological choices and how they affect research quality. The concluding seventh chapter summarizes the results of this research.

Chapter 2

Background

The purpose of this chapter is to give the reader the background knowledge necessary to understand the research conducted. This chapter is divided into four sections. The first section gives an overview and framing of electricity in Africa, the alternative energy access options, consequences of these and why microgrids are the best option for rural electrification. The second section aims to give a robust knowledge on microgrids. The third section defines what is meant by local capacity building in this thesis. The fourth and final section is a literature review on the Action Research methodology.

2.1 Africa Energy Outlook

This section gives the reader a background understanding on the energy outlook of Sub-Saharan Africa (SSA). It helps frame the general problem of electrification in SSA and allows the reader to appreciate the choices and delimitations made for this thesis.

Despite advances in the overall global electrification rates, increasing from 76% in 1990 to 85% in 2012, and the huge efforts that have been made by practitioners in the last years, the UN goal of universal access to electricity by 2030 is still far from achieved, with an estimated 1.1 billion people are still without access to electricity. Over half of this population (588 million) live south of the Saharan desert, in Sub-Saharan Africa (Cozzi, 2017). With 1360 million people living in SSA, this equates there are 43% without access to electricity. Out of these, a majority live in rural areas and extreme poverty (Cozzi, 2017). On a continent with the highest population growth rate in the world, the additional number of people in Africa will by far outpace the number of people granted access to electricity in the next decades, leaving IEA (2017) with a prediction of 602 million without access in 2043.

There are major challenges inert with the current electrification path of extending the centralized grids across SSA countries. This path relies on building large-scale power plants by leveraging economies of scale, such as nuclear power, gas turbines or hydropower plants (sizes of 1MW and upwards). The total installed capacity in SSA is 68GW, compared to 1063 GW in USA, both of these mainly consist of this large-scale centralized capacity (Cozzi, 2017). The other key to this strategy lies in connecting a large number of customers, households and businesses, to all share in the cost of building and maintaining a centralized grid. This centralized way, relying on these two mechanisms, has been the way that all developed countries have reach high electrification rates. Figure 1 shows these differences.

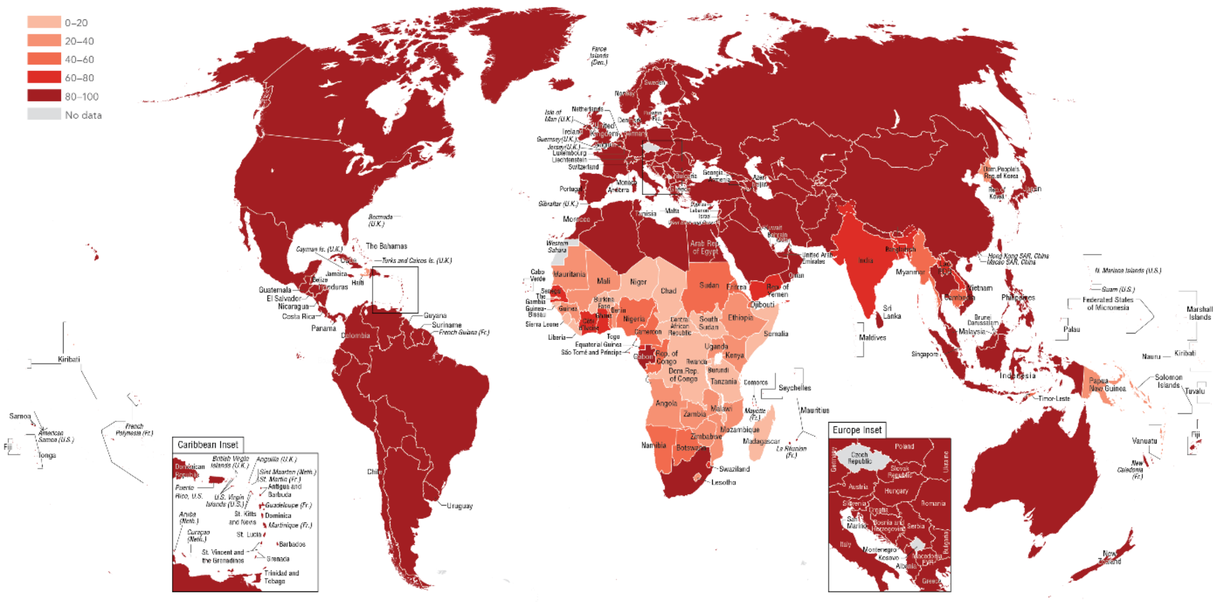

Figure 2: Electricity access rate across the world (Anon., 2017)

The issues in SSA is the lack of capital, required to build large scale power plants and the lack of connected customers with high ability to pay and concentrated demand, giving too low revenues to build and maintain the transmission and distribution grid. Another issue lies in the lack of incentive for monopolized national power utility companies in many SSA countries, to have a cost-efficient business. These are challenges already when electrifying dense urban areas in SSA – and these become even magnified when trying this same strategy of large-scale centralized power production, to electrify rural areas.

Rural areas in SSA are especially challenging for this strategy, and this is reflected in only 25% having access to electricity (Cozzi, 2017). Countries of SSA are characterized by large areas, comparatively, Zambia, is two times the size of Sweden, or similar in size to France or Turkey. And the entire area of SSA, is equal in size too USA, China and India. With a far higher rural connection cost of 4 times higher than the urban connection cost (Birol, et al., 2014)– and a much lower ability to pay – the fundamental market forces of capitalism help explain the current state, and also why there is need for radical change, to change this outlook in the next century.

At the same time, energy and electricity is essential to life and development. Ever since humankind learned to master fire 125,000 years ago, energy has been essential. In the same fashion, the people living in rural SSA that are without access to electricity uses what energy they can get their hands on. The main source used in rural SSA is still biomass, which consists mainly of firewood or charcoal (anaerobically burned firewood), used for cooking, lightning and heating. There are several consequences of direct or indirect use of firewood (Birol, et al., 2014); 1) Because of a demand that exceeds supply (forest stock), it is harvested unsustainably, leading to deforestation, e.g. in Nigeria, 50% of the forest cover has been reduced since 1990 due to overharvesting for firewood (Birol, et al., 2014). 2) the loss of forests, that has the ability to absorb CO_2, along with the burning process to create charcoal and burn of the final fuel, releases pollutants, that lead to global warming, 3) It is often women, that have to spend hours daily, to walk long distances to gather fuelwood or charcoal, this is time that could potentially be freed to study or work. 4) The cost of the fuels are very high, taking up a large chunk of households disposable income on inefficient fuels in terms of efficiency compared to electricity (Taylor, 2016). 5) The fuels are dangerous to health, every year approximately 250,000 die of deaths from pollutants from these fuels in SSA (Birol, et al., 2014), whilst another hundreds of thousands suffer disease and health issues such as burns, respiratory issues etc. 6) the fuels cannot provide higher quality energy uses (see figure 2). Other sources used are e.g. kerosene (lanterns for lightning), candles (for lightning) – these sources hold equally negative consequences (Birol, et al., 2014).

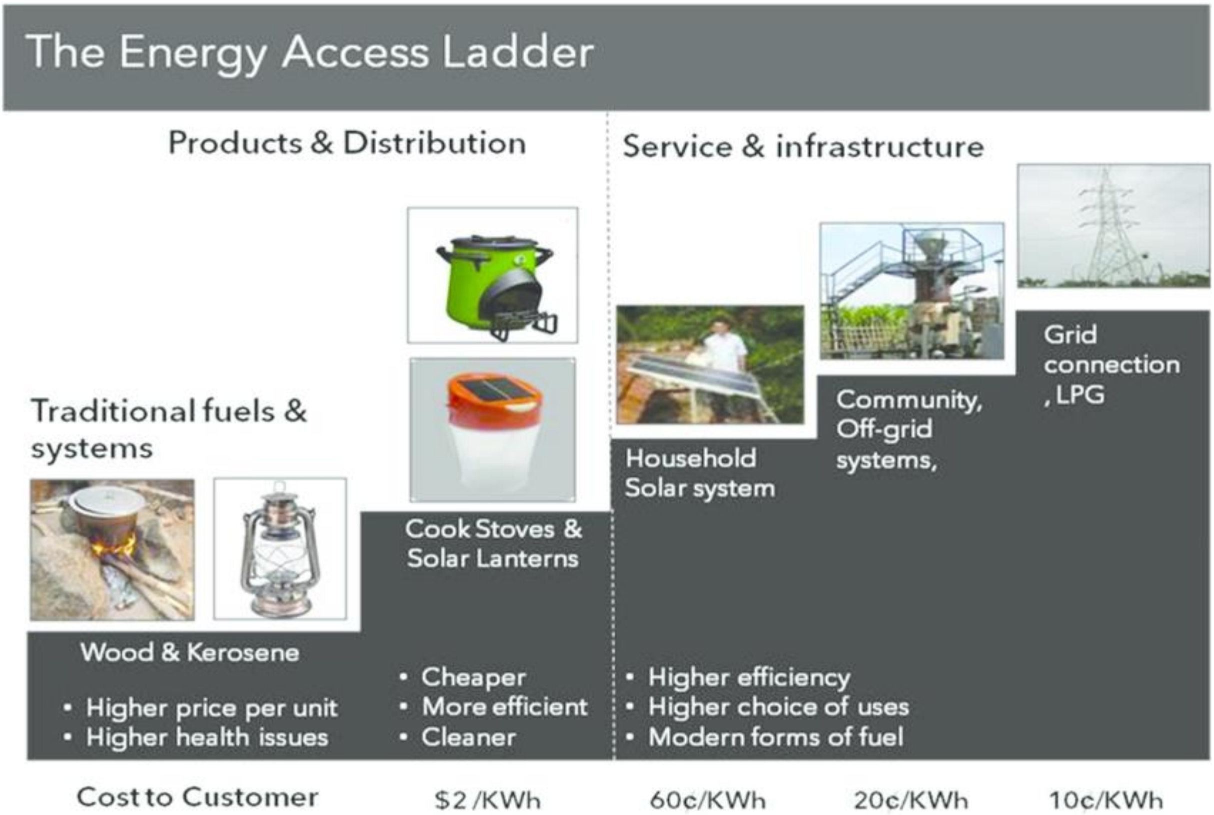

Figure 3: The energy access ladder, showing the different energy options in terms of cost and service level (Carvallo, 2014)

Above reflects why electricity is so fundamental to human development. As has been shown in numerous studies by United Nations (Steinberger, 2016), the electricity consumption (i.e. access) of just a few kWhs above zero shows a strong increase in HDI, Human Development Index, which is an aggregate of educational outcomes, life expectancy and income (see figure 3). The access to electricity, does not only replace and remove the dangers of the alternative energy sources – but it also provides new opportunities – access to a higher quality energy (as shown in figure 2). Studies have shown correlation between educational outcomes and access to high quality LED light, compared to light from kerosene (Birol, et al., 2014). Electricity can also grant access to appliances, such as computers and refrigerators – granted theses can be purchased. In fact, electricity access is so important to development, that UN has set a goal of universal access to 2030. It is also recognized in the global development agenda, the Sustainable

Development Goals (SDGs), set in 2017, where goal 7, access to renewable energy, can act as a multiplier for all other 16 SDGs.

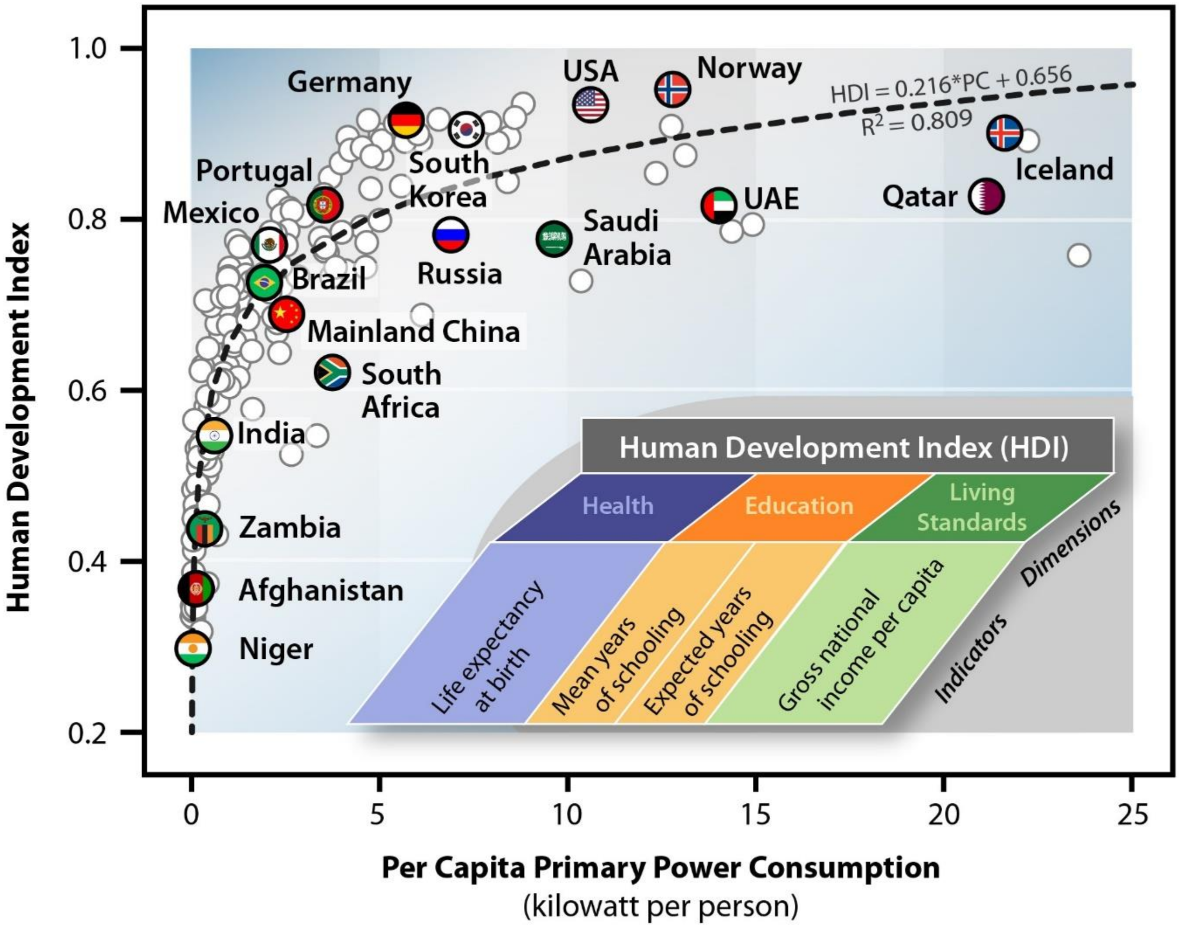

Figure 4: The correlation between Human Development Index (HDI) and power consumption (Steinberger, 2016)

SSA also faces other major issues that are unprecedented in history. There is a huge inequality between urban and rural areas – a generalization is that people in rural areas live without access to electricity, development and in poverty – whereas people in urban areas enjoy access to electricity, the benefits of development, and are on average wealthier – this is not far from reality – and explains why SSA countries has amongst the highest urbanization rates in the world currently.

To connect to this, electricity not only leads to social development, but also to economic development, with discussions regards to whether electricity access can trigger economic development, take the case of an agricultural field in rural SSA, electricity could help power machinery and irrigation, water pumps – extending the harvesting season from 3 months a year to 12 months a year – a fourfold increase in productive time, and one study quotes up to 10 times total increase in output (due to increased agricultural productivity). Stores and entrepreneurs could expand their businesses, by using more efficient machinery, generate more income, and employ more people. This economic growth leads to a surplus, and exports from the rural community, whilst access to electricity leads to ability to use computers, access to knowledge, markets and opportunities. There are also scholars that argue that it's the other way around, that there needs to development, such as businesses and industries that demand electricity, to trigger electricity access, explaining why much businesses and industries in urban areas have helped drive electricity demand and the grid extension to these areas. Nevertheless, the two are correlated, development cannot exist without electricity.

So, if electricity is paramount to social and economic development, and the grid extension strategy is not viable for the millions living in rural areas of SSA – what is the solution?

The answer, as to any complex problem, is not straight forward. Currently the best short term option for life improving and productivity inducing equipment are microgrids (Lepicard, et al., 2017). But that doesn't mean it's a solution that can solve all problems. To elaborate, for instance, one of the biggest issues lies in 'clean cooking', to get rid of the use of firewood. However, microgrids struggle to supply power for cooking, because any heating requires very high amounts of power, an average induction cook stove takes 2000W of power, whereas a LED light, takes 20W, this hundredfold increase is difficult to justify in terms of business of a microgrid, and the peak of power consumption is also challenging to manage technologically for a small microgrid. This is part reason why rural electricity and clean cooking are separated as two markets by development agencies such e.g. UNDP are categorized as separate solutions, electricity access and clean cooking respectively (Lepicard, et al., 2017).

In terms of providing power in rural SSA, there are some alternative solutions today – the first has already been covered, the one of grid extension, which is unviable to large extent. The second solution are solar home systems, which are basically a solar panel and battery, bundled with appliances such as cell phone charger and lights, that are typically installed for an individual household. The benefit of solar home system are that they are far less complex than microgrids, they require significantly less capital (they are usually provided to households with little upfront capital, and then paid off over a couple of years) and can provide the basic electricity needs. The downside is that the average cost of electricity through this solution are still a lot higher than through microgrids or grids. Another downside is the limits in the system size, they cannot provide productive use of electricity, nor higher tiers of electricity usage (see figure 5 for tiers of electricity usage). Thus, SHS provides an immediate alternative, but not a long-term solution.

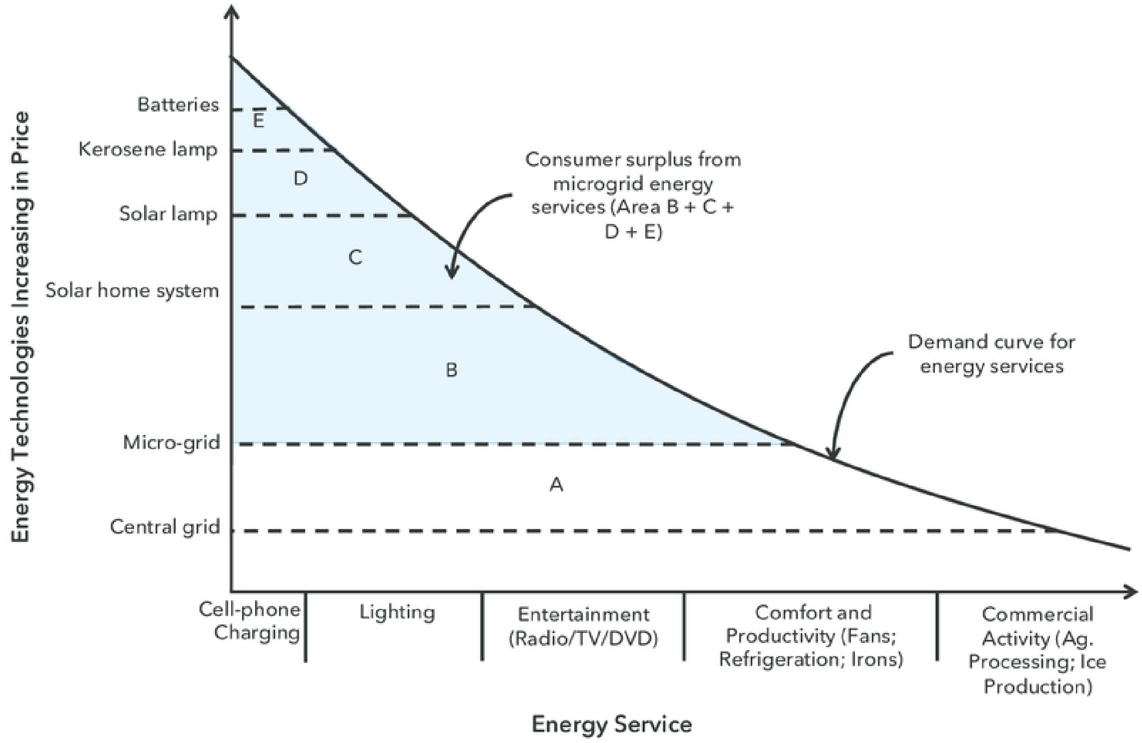

Figure 5: The economics of energy access, showing the various consumer surplus with increased level of energy service (Carvallo, 2014)

Figure 6 shows a comparison of alternative solutions and the roles they play in energy access. The next section focuses on the third solution, that of Microgrids, and explains why this is the best option for most people living in rural areas in terms of electrification.

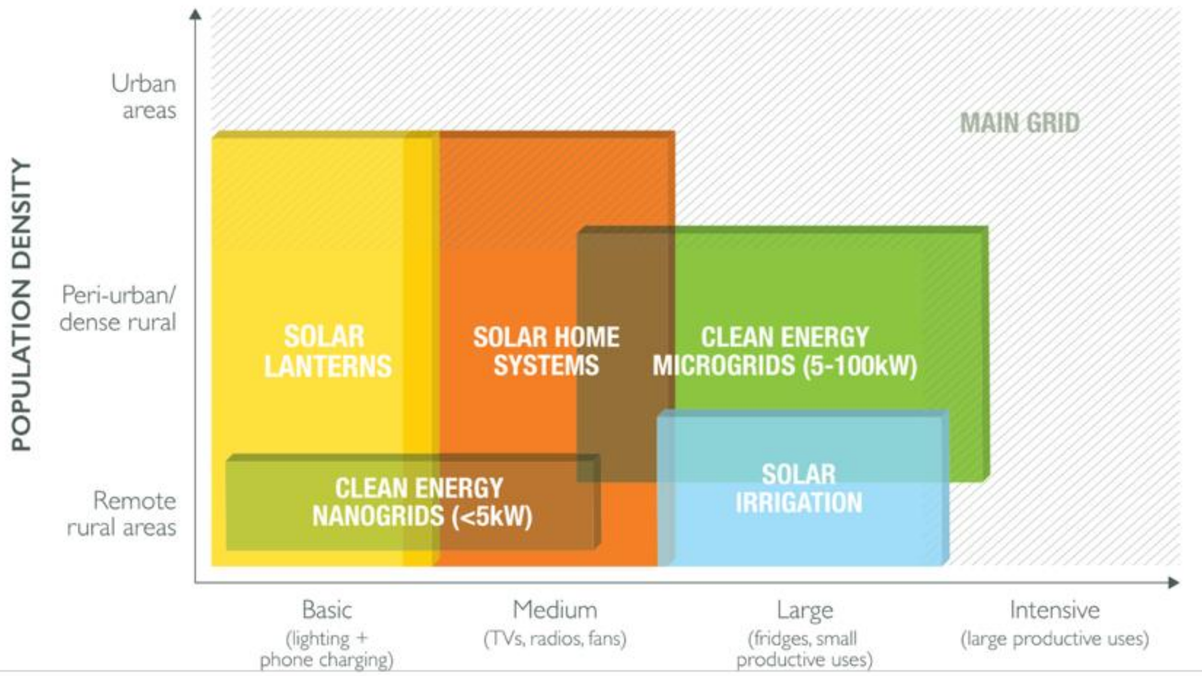

Figure 6: Segmentation of energy access solutions based on energy intensity and population density (Lepicard, et al., 2017)

2.2 Microgrids

In this section, the background on Microgrids, the technology in focus for this research, are provided. What microgrids are, their origins, the research space and technological characteristics are covered and contrasted with those of the company where the research is conducted. The business aspects of the microgrids market, the business case and known challenges are also covered.

2.2.1 The story of Microgrids

The Manhattan Pearl station was built in 1882 and the first commercial electricity power plant in USA. It was also essentially the world's first microgrid, invented by Thomas Edison. This coal fired station initially served 82 customers and powered 400 lamps and later expanded to two years later serve 508 customers and 10,164 lamps (LO3 Energy, 2018). This invention was a small version of what grew to become the traditional energy grid design, a centralized power source serving a large number of customers. This started the revolution, through which this centralized design has become the dominant design of all countries.

The modern definition of microgrid, means a 'small-scale' decentralized power system, capable of generating and distributing power. In the context of most electricity in the world being provided through large-scale centralized grids, microgrids are mainly deployed in remote locations, where it hasn't been feasible or technologically possible to extend the grids historically, such as on islands.

Even though microgrids have been around for a long time, it's not only until recently that development has picked up pace. This is largely thanks to the price drop of solar PV and batteries, but also due to the resilience of microgrids in the context of extreme weather, better flexibility of microgrids and increased independence and control of power generation (LO3 Energy, 2018). In 2012, there were 480 modern-style microgrids worldwide, whereas six years later (in 2018), there were 1,869 projects (Paul, 2018). Today microgrids are still slow in terms of diffusion, with only 100 or so deployed a year worldwide.

Another characteristic is that most microgrids installed are for very specific uses (such as backup power for a critical facility such as hospital or military), for a remote island, or as an aid project in Africa. Thus, most are single unit microgrids, purely hardware solutions, with very few commercial microgrid operators in the world.

In developing countries, microgrids have been hailed as the only short-term option for rural electrification. But to provide the hundreds of millions without access to electricity in these areas, hundreds of thousands of microgrids are needed – several orders of magnitude more than what exist today, and a rate of change required that is exponentially higher. This remainder of this section inquiries into the reasons for the slow diffusion of microgrids, explains the challenges holding microgrids back, and explores potential solutions that could leverage opportunities. The rest of this thesis takes action on these potential solutions.

2.2.2 The research space of microgrids (literature review)

A literature review on Web of Science was conducted by the researcher to get a sense of the research space in terms of published papers. This literature review was conducted in December 2018 and the main search string is shown on top of figure 7. How this literature review was conducted is presented in appendix I.

The research space of microgrids are still in its infancy – focused on solving the many challenges with microgrid systems and its technological components. This is reflected in the research space, with a strong technological focus (figure 7), the numerous challenges are associated with remote control of the systems, and also as in any power system, to manage and optimize power production and power consumption.

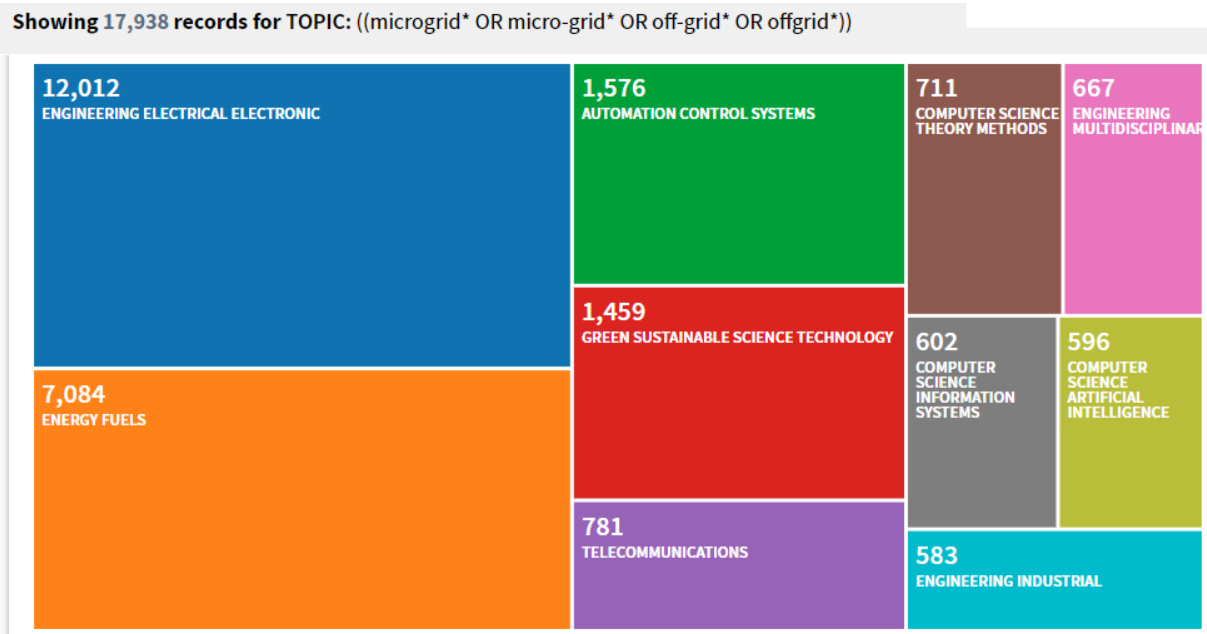

Figure 7: The research space of microgrids, categorized by discipline

An overview of the number of research hits on ‘microgrids’ reflect the increase in interest in micrograds (figure 8) where years 2018 and 2019 was not yet fully saturated by the time the literature review was conducted.

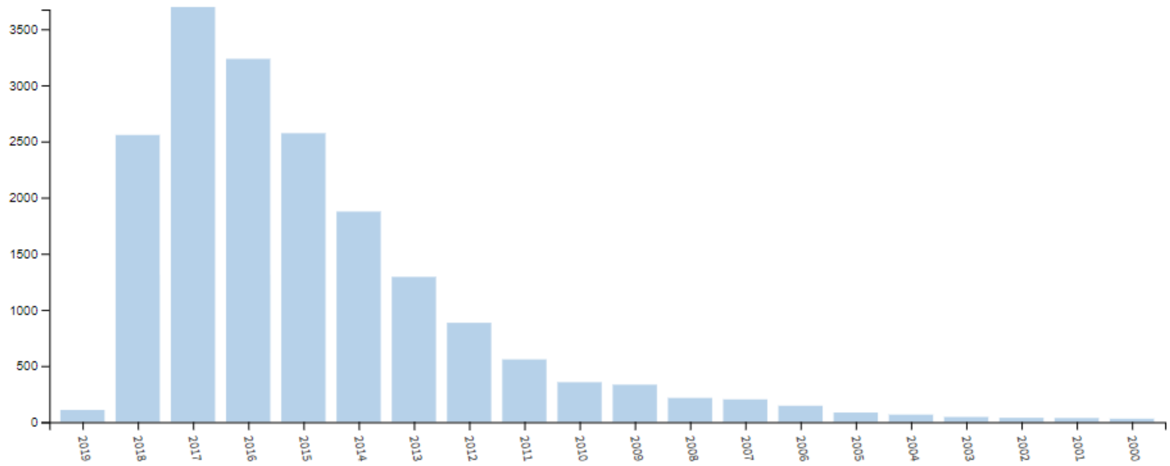

Figure 8: The number of research articles for microgrids on Web of Science (conducted by researcher in 2018)

Even though the interest is increasing, there remain a great gap in the research space in terms of the business and commercial side of microgrids (shown in table 1). Part explanation for this is that most microgrids today are deployed for specific niche uses, as single unit systems – the commercialization of microgrids has not yet happened, and it's not until recently that it's seen as a key cornerstone in reaching universal electricity access in Africa. The lack of commercialization of microgrids, also extends to a lack of studying microgrids at scale (meaning deployment and operation of several microgrids units) – why would one be interested in studying large scale viability, if the most common utilization is deploying a single microgrid? Since microgrids are deployed as one-off, single unit projects, this also means they are pure hardware solutions – and that there is no interest in researching the operations side, of how to run a microgrid business of multiple microgrids.

A Web of Science literature review on the microgrid research space	
Category	**Number of papers on Web of Science**
Microgrid or Off-grid technology	17,938 results
Field of management, operations research and economics	270 results
Business case, economics of microgrid	10 results
Operations, operating expense of microgrid	0 results
Micrograds at scale	0 results
Local capacity building for microgrids	0 results

Table 1: The microgrid research space, a literature review conducted on Web of Science by the researcher

The research space thus shows clear gaps in terms of research and literature on the commercial side, operations and scaling of microgrids. Specifically, on the topic of this thesis, local capacity building for microgrids, no literature was found (see table 1). This also meant the background on microgrids is composed of sources beyond scientific databases such as Web of Science. In developmental agency reports and consultancy reports, some literature was found on the commercial side of microgrids, microgrids at scale, and a little on operations of microgrids. These kinds of sources constitute the background of the next sections. Thus, the remaining section should by no means be seen as a complete picture of microgrids, but only as a means to understand the context for this thesis, and why it is important.

2.2.3 What is a microgrid?

There are many definitions of a 'microgrid'. Some view it as a 'technology', whereas others view it as a concept, or a system of components. There are also different sizes to 'microgrids', which give it different names.

In this thesis, the definition used in the 'Reaching scale in energy access' report by Lepicard (2017) is used to define a microgrid; a small-scale power system that can produce and distribute power to several users, and is sized in the range of 5-100 kW generating capacity.

However, even within this definition, there are still a myriad of parameters and characteristics that can vary in terms of microgrids. These variations are listed below, with origin in the report by Lepicard (2017), to give the reader an understanding of the flexibility of microgrids;

1) **Size:** As already discussed, sizes of microgrids vary, and the 'size' of a microgrid is in terms of generation capacity, in kW or kWp (kilowatt peak, the maximum generation capacity under ideal conditions, such as wind turbine under maximum wind or solar system when the solar irradiance is the highest), thus how much power the system can maximally generate. Size is also connected in many cases connected to the name, 'nanogrid' (<5kW), Microgrid (5-100 kW). Picogrids and minigrids are also used inter exchange ably with the two. For perspective, a 12-kW system can under ideal conditions power 150 households at 80W power each, this could be a small TV, a couple of lights and cell-phone charging.

2) **Power Generation source:** Size means the capacity of the system, but this capacity can be generated from different power sources. Solar, hydropower, Windpower and diesel generators are all common sources, but it can be any source, such as biomass or geothermal. The choice of source depends on what 'potential' is available, e.g. in terms of wind currents, rivers, solar irradiance or geothermal activity.

3) **Components:** A microgrid doesn't necessarily need to have batteries. Neither does it need to have diesel-generators as backup generation option. It can still be defined as a microgrid. There is large variety in terms of the 'setup' of a microgrid, which components and technology that goes into it.

4) **Design and layout of system:** A microgrid can be under the definition of a system that generates and distributes power for consumption a system that serves only one customer, or that serves 1000 customers. This difference affects the layout of the system

in terms of reticulation. A single customer is a much simpler system, whereas a system that has many customers requires a great deal of design, costs and work on the reticulation system (the distribution wiring to connect all customers to the power system)

5) **Customers:** As above, if a system has 1 or 1000 customers affects the business, 1000 customers' needs more customer service, sales ability and likely technical staff that can maintain all the 1000 connections. The customers can also be residential, commercial or a mix of both. The service offering of these setups are also likely different and thus the whole operations side of the business will differ – this shows how far ranging the flexibility of microgrids are – it can be two entirely different businesses, different business models, different operative structures and different technology.

6) **Operations model:** There are many other aspects that have flexibility that are less connected to the technology side, such as business model (selling a commodity, power, kWh versus selling a service, lights for 2 hours), operations model (centralized, skilled staff in central headquarters, versus decentralization, local staff at sites), - this variety shows the power of flexibility, how players in the industry are trying to leverage various aspects of the microgrid flexibility – but also shows that no dominant design, business model or operative model has emerged as an 'industry blueprint'.

7) **Business scope and ownership**: This is another key aspect, who owns the system? Here many options exist, such as a company that only manufactures and designs the microgrids, a company that deploys and installs microgrids or a company that operates and manages the microgrids. Some companies to all of these or a combination of these activities. This aspect is also connected to ownership. If a company manufactures and deploys a microgrid, who then owns the system? Or if a company also operates and manages the microgrid, who owns the system? Does the system owner pay the company to operate and manage the microgrid? And *who* is the owner, is it a commercial company? Is It the national government or national utility company? Or is it the village and the community? How do these stakeholders interact over issues such as payments (how is the system paid, upfront or over time?, security of the system (who is responsible for the system to last over 20 years, and in a legal matter if someone gets hurt or property is damaged, who is liable?), distribution of power of the system (who gets power and to what price?), and who operates and maintains the system? These are all important questions and there are examples of many of these different models of ownership and business scope, with their own pros and cons. This thesis will discuss a bit about this as is connected to the concept of local capacity building, in training people in the local community of the microgrid to run and maintain the system.

Above shows that it isn't easy to define a universal or 'typical' microgrid, and that it's rather a concept that entails plenty of options even under the definition used in this thesis of Lepicard (2017). This large amount of flexibility is two-faced; a microgrid can be aligned with a community and their needs and conditions, to fit perfectly to leverage available generation potential, tailored to the community electricity needs in terms of loads (power consumption sources, appliances, machinery, infrastructure), size of loads (customers, business), distribution (number of connections) to mention a few. However, a challenge in this lies in the very strength of microgrids, in their ability to deliver power to areas that doesn't have power, how does one predict how the electricity needs of a community will develop, that has no historical power consumption data? Another challenge closely related to this thesis lies in the classical operations issue of flexibility versus standardization. To tailor and design systems for each new community is not cost-effective, and to dimension and Built a variety of different systems, different setups, different components is difficult to leverage economies of scale – it requires many subcontractors etc. Whereas standardization may neglect some of the benefits of flexibility, it could offer radically lower costs. This is part of the debate of scaling versus one-off installations to diffuse microgrids. One-off installations can be perfectly adapted, and leverages the very strength of microgrids, there is also in terms of sustainability 'less waste' in this optimized fitting process, but it can rarely be cost-effective or profitable – which is key to disseminate the technology, On the other hand standardization goes away from the very strength of flexibility of microgrids – to find a 'one-fit-all' design that favours cost-effectiveness and could allow to commercialize microgrids.

To give another perspective on the dimensioning. The most common uses of electricity in rural SSA are lightning, cell-phone charging and TV (Taylor, 2016). A system that can produce 12 kW power, can power 150 households of 3x10 Watt lightbulbs, 10 Watt for cell phone charging (multiple phones fully charged) and a 40W TV (total of 80W x 150 households = 12000W). However, to deliver this power in the night-time (when demand is typically the highest for e.g. lightning) the system would need to have battery capacity that can store all the power needed for use when it's dark (and the solar system cannot produce any power). For example, a battery capacity of 60 kWh, can provide the 12 kW of power for 5 hours.

A key stakeholder is the customer – how does their demand look like? What appliances do they want to use? For instance, a cooking stove uses 2000 Watts for a short period of time. Are they using a majority of power in the day or the night? (affecting battery capacity) Are the customers businesses that use a lot of power in the day, for a single appliance? Or fragmented over many low-usage customers? It's also an operational challenge to manage and balance the supply and demand on the system, to optimize for system longevity, such as to ensure that batteries are charged and discharged at an optimal rate which greatly affect their lifetime.

These show the challenges in dimensioning the systems –and together with the technological and financial equations in terms of the sizing of all the components (this also affects the inverter size, which will affect how much power the system can actually deliver at a time, and also the reticulation system, what capacities it is designed to allow to single users) depending on the total system cost (CAPEX) and to optimize it technologically to align the output with what the customers demand (deliver as much value as possible).

2.2.4 The Microgrid market

While the 588 million of people without access to electricity in SSA is a developmental tragedy, it's also the world's largest untapped power market. A market where the customers currently rely on poor substitutes and have a strong willingness and ability to pay for electricity, if only someone would provide it (Taylor, 2016). As shown earlier, there are several options to provide energy, with different pros and cons, making certain technologies and solutions a better fit for certain segments – but for the majority of rural populations in SSA, the microgrids are the best solution currently.

This microgrid market dynamics have changed recently, with a development in businesses going beyond single microgrid systems to the advent of DESCOs (distributed energy service companies), which are a definition of a company that aims to deliver distributed energy services, mainly through microgrids (Lepicard, et al., 2017). Figure 9 shows the inception of key players, reflecting the market space being in its infancy, but with a radical increase in the number of DESCOs in Africa in 2010. As previously explained, this increase is due to the price drop of solar PV and batteries – making clean microgrids more viable than before. This trend is also reinforced by governments in African countries formulating regulations and conditions that make it more viable for these players to conduct business in Africa (Birol, et al., 2014). There are also a number of other aspects of the microgrid market, and why players are located where they are, such as a large concentration in northern India initially and eastern Africa more recently, of political and regulatory reasons (Lepicard, et al., 2017).

INCEPTION			
	Before 2010	**2010-2014**	**Since 2014**
Nanogrids (<5kW)		Devergy (TZ)Mera Gao (IN) Husk DC (IN) MeshPower (RW) NatureTechInfra (IN) Mrida (IN) Steamaco	+ *multiple pilots*
Microgrids (5-100kW)	Husk Power Sys (IN) IBEKA (Asia) DESI (Global) Arnergy (NG)	PowerGen (KN) PowerHive (KN) GramPower (IN) Gham Power (NP) Rafiki (TZ) GVE (NG) Boond (IN) Enèji Pwòp (HT) Minda (IN)	OMC Power (IN) Jumeme (TZ) Power:On (BN) + *multiple pilots*
Large minigrids (>100kW)	AzurePower (IN) FRES (Africa) SPUG (PH)	Redavia (Africa)	Ausar (SN, CI)
Key trends	First clean energy microgrids: mostly hydro, biomass, and wind	Strong improvement in solar techno: boom in number of micro and nanogrids players	- Consolidation of business models - Emergence of regulation (e.g. UP, TZ, NG) - First debt finance but still mostly equity and grants

Figure 9: Sample of key microgrid players, by inception date (Lepicard, et al., 2017)

Figure 10 shows the correlation between maturity and number of connections – as can be seen, even though the key players of the industry, it's leaders, have 5 years of activity, they only serve a couple of thousand connections. However, a couple of exceptions exist to this trend, however these rely on other scaling mechanisms such as expanding with telecom towers, specific governmental subsidies and both Mera Gao Power and Husk are mainly operative outside of SSA. For players that cannot rely on these kind of scaling mechanisms and conditions, this indicates challenges still remain to scale microgrid businesses, and thus implies challenges still remain to diffuse microgrids in general.

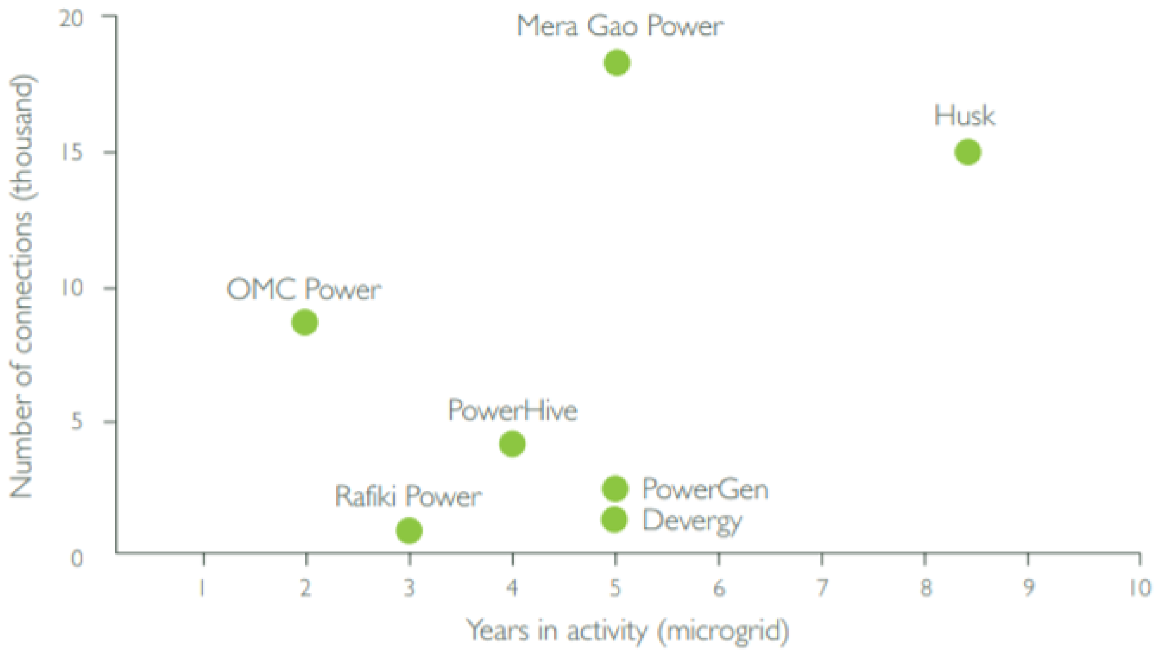

Figure 10: Years in activity and scale of key microgrid players (Lepicard, et al., 2017)

2.2.5 The Challenges of microgrids

There are still numerous challenges facing microgrid businesses, that help explain the slow diffusion – in context of a big untapped market of rural customers in SSA. These have already been briefly mentioned in the introduction, and the challenges below are a summary of the challenges presented in the International Finance Corporations report Operational and financial performance of minigrid DESCOs (2017). They were complemented by the report 'reaching scale in energy access' by Lepicard et. al (2016).

- **Access and cost of finance.** Because small-scale operators have a limited track record, and in most cases not yet reached profitability, it's difficult to access concessional finance for a high-risk, long-term investment, required to expand by deploying more microgrids, to reach profitability - It's a catch 22 situation. At a smaller scale when on-going and overhead costs eat up most or more than the revenue produced by a few microgrid systems – and with the only option to achieve expensive capital, the margins become even thinner, hampers growth, the overall profitability, and in some cases become devastating to businesses.

- **High Capex**. The cost of the power system is a high, and the system is a long-term investment that requires several years of efficient operation to payback itself. Deployed in a remote rural community, with implicit demand, represents a high risk in terms of recovering the investment. The high capex also requires tight controls on assets, technical optimization and maintenance and repairs to ensure it can last the lifetime of 20 years in some cases.

- **Policy, legal and Regulatory**. The role of microgrid businesses are not formalized in most regulations and legislations across SSA. This means that the businesses are not officially recognized as part of electrifying the countries of operation, which in turn can mean that the national utility could extend the grid to the specific areas where microgrids are built. In the context of this the compensation mechanisms for the stranded microgrid assets are unclear, which gives a high risk. Governments also wield the power of subsidies and regulations, that could help microgrids, but also hamper them in the context of a competitive situation with the microgrid businesses.

- **Finding skilled people**. There is a lack of relevant commercial and technical skills to scale microgrids. This is due to the few people that can afford and graduate education higher than upper secondary school. In terms of power engineers or people attending electrical trade school, the labour pools are very limited. The issue is also aggravated by high illiteracy levels, proficiency in English, and lack of computer use. Talent also leaves to find other opportunities in developed countries, a phenomenon called ‘brain drain’.

- **Lack of proven operations model**. There are fundamental operational challenges connected to serving remote and low-income markets, such as accessibility, payments and maintenance. There aren’t cases of general industry success stories of microgrid companies having reached scale, excluding a few companies that have done so, relying on highly unique and limited conditions and environments. There is a very high degree of variation amongst companies operating microgrids, experimenting with different business models, operative structures and financial models. No dominant design has emerged, and these experiments still struggle with viability at larger scale and profitability. This is compounded by a lack of collaboration between players, that are to a large degree operating in silos.

- **Profitability.** As the Capex is very high for microgrids (compared to e.g. solar home systems), profits are required to be able to pay off this initial investment. However, profits are very low, defined by low revenues and high on-going costs, leaving thin margins.

  The on-going costs of a complex infrastructure, requiring customer service and sales to formulate customer relationships and sell power, as well as maintain the power system (for 20 years longevity) is costly. The fact that operating expenses and over-head is too high, is one of the key reasons microgrids struggle to reach profitability and scale. Typical operating expenses and overhead include wages and logistics expenses, such as cars, fuel and material and tools required to operate the system, these are high due to systems placed in remote rural areas (not yet electrified). Other than this, the complex systems need to be managed to some degree centrally, running analytics on technical performance data of the system components, as well as optimizing the system power production and consumption.

This is also due to implicit demand, defined as low or unpredictable demand of power in rural areas. Coupled with a lack of market intelligence, in terms of transparent and reliable data to select rural areas for grid deployments, such as demography, ability to pay, urbanization rates, this makes it more challenging.

2.2.6 Case company: The small-scale Zambian microgrid company

In this section context is given on the microgrids that are designed, deployed and operated by the company where the research is conducted. Their systems consist of solar PV power generation (Solar panels) at the generation capacity of 12 kW. The systems also have inverters (to convert solar DC power to AC power for productive uses and appliances) as well as battery storage for night-time power use. There is some flexibility to the system dimensioning, in terms of system size, battery capacity, and the reticulation system – but the technology and design is optimized and standardized. The systems typically connect up to 150 customers (a mix of residential and commercial customers) and the main uses of power are for lightning, cell-phone charging, tv, radio, refrigeration and small businesses such as shops, hair salons and video arcades. The customers targeted are rural or peri-urban communities in Zambia, with 5 microgrid systems deployed today, and investment for another 150 systems. The goal of these 150 systems is to provide power to 135,000 people in Zambia (over 150 systems, 150 connections per system, and on average 6 people per connection).

2.3 Local Capacity Building

In this section the initial definition of Local Capacity building (LCB), the scaling strategy or operative intervention studied in this thesis, is given. Local Capacity Building (LCB) is not an established concept or theory and this section is only to provide an idea of what was thought of LCB. It is used in this thesis as a collection of concepts and line of inquiry to give a limited and clear focus area for this thesis. Thus, there is no fundament in literature. This thesis is tasked explicitly with exploring and answering what Local Capacity Building for a microgrid business is.

To understand Local Capacity Building, one must start at Capacity Building – which is not simply defined and associated with numerous definitions. In a simplified sense it means that new capabilities (capacity) are developed (Building). This can happen in different contexts, anything from a company implementing the Toyota engines car manufacturing model of no waste, called 'lean management'. In order to do so, the company develops capabilities, i.e. builds capacity. This process and capacity can take different forms, such as through acquiring knowledge, skills, training of personnel, new technology that facilitates the use of the new 'lean' concept etc through different phases of understanding, implementing and operating using lean. Another context that capacity building is strongly associated with is development and aid practices, where there are advocates for building capacity, i.e. transferring knowledge, empowering local populations by developing their skills, providing training, and opportunities for growth – rather than just providing aid money, or a finished solution such as a power system. Thus, Capacity building can be associated in many contexts, such as commercial and business interest, or aid and development – and can also mean training, education, providing tools and machinery and creation of systems.

What is meant in this thesis by 'Local capacity building' is simply capacity building done in two senses. Local meaning building local capacity in the communities that are served by the company, through investing in training and skills development of local community members to help operate and manage the microgrids. To do so successfully, *the company,* also needs to build internal capacity, amongst its employees, systems and processes, to be able to conduct local capacity building. The development and implementation of these capabilities, both internally at a company level, and externally at the local community or individual level – are the main field of enquiry for this thesis (reflected in the research questions, of looking at what components are required to conduct a local capacity building strategy (RQ2) and what the main challenges and opportunities are in doing so (RQ1).

The motivation for this perspective is both as mentioned earlier that they address and offer potential solutions to some of the main challenges facing microgrid players, but also in their shared nature of business opportunity and social development. And on a higher level, beyond that of the individual business, and for the whole energy access industry in Africa - offer a more sustainable diffusion of microgrids, where the diffusion is driven by local community members, empowered and employed to run the microgrids in their own communities. It is worth reiterating that on this topic, of local capacity building for microgrids or energy access there were no examples in practice or literature found. In the context of this, an inductive study and qualitative research paradigm was the most appropriate methodological choice, which will be outlined and justified in the next section.

2.4 Action Research

In this section Action Research is literature reviewed. The origins of AR are described, what AR is, how it is used, and how its quality is judged. This section is necessitated by the fact that AR is not as established as e.g. the case study and its paradigm is in many cases directly opposite to that of traditional paradigm of positivist science.

What is Action Research?

Originally a method by Kurt Lewin in 1940s, Action Research was used to solve social problems that were complex in nature where there is strong rationale for action (Coughlan & Coghlan, 2002). In the last 20 years it has emerged as a strong approach for Operations Research, that builds theory high in relevance in the operations research field with many published papers in scientific journals (Coughlan & Coghlan, 2002). In this field, AR is particularly useful for studying organizational change, and for the development of effective guidelines.

Many different definitions exist for AR, and it can be applied in many ways. Because of this there is a low incidence of conscious application of AR, which leads to the potential of unnecessary threats to validity of the research findings. These threats are reduced by conscious application of AR, recognition of the demands of the AR approach, and conscious adoption of appropriate strategies to maintain rigor (Coughlan & Coghlan, 2002). There are a few broad stroke characteristics that define AR, shown in 13 different methodological papers (Coughlan & Coghlan, 2002);

- Research in Action, rather than research about action
- Participative
- Concurrent with action
- A sequence of events and an approach to problem solving

Firstly, AR is research in action, with the central idea is that AR uses a scientific approach to study how organizations solve problems. AR works through a cyclical approach where action is incorporated of four steps; planning, taking action, evaluating the action, leading to further planning and so forth. Secondly the participative nature of AR is unique, where the researcher is participating and intervening in helping the company solve problems. This contrasts with traditional research where the members of the system studied are objects of the study. Thirdly the concurrent nature of AR means research is concurrent with action, the goal is to make action more effective while simultaneously building up a body of scientific knowledge. Fourthly, as a sequence of events, AR comprises iterative cycles of gathering data, analysing the data, planning action and taking action. As an approach to problem solving, AR is the application of the scientific method of fact finding and experimentation to practical problems that require action solutions. The desired outcomes of the AR approach is not just solutions to the immediate problems in the organization studied, but also important learning from outcomes both intended and unintended, and as such a contribution to scientific knowledge and theory.

How does Action Research work?

Action Research proceeds through iterative cycles of 4 steps: data collection, feeding this data back to those concerned in the organization, analysing the data together, planning action, taking action and evaluating the action – leading to further data and new cycles moving the company project forwards, (Coughlan & Coghlan, 2002) shown in figure 11. In addition to these steps, the researcher engages in reflection upon all steps of the AR cycles. This reflective step is what links the relevance in action moving the real world organizational change project forwards with the research part of generating a body of scientific knowledge (Coughlan & Coghlan, 2002). These AR cycles can vary in time and scope, and with multiple cycles conducted in parallel.

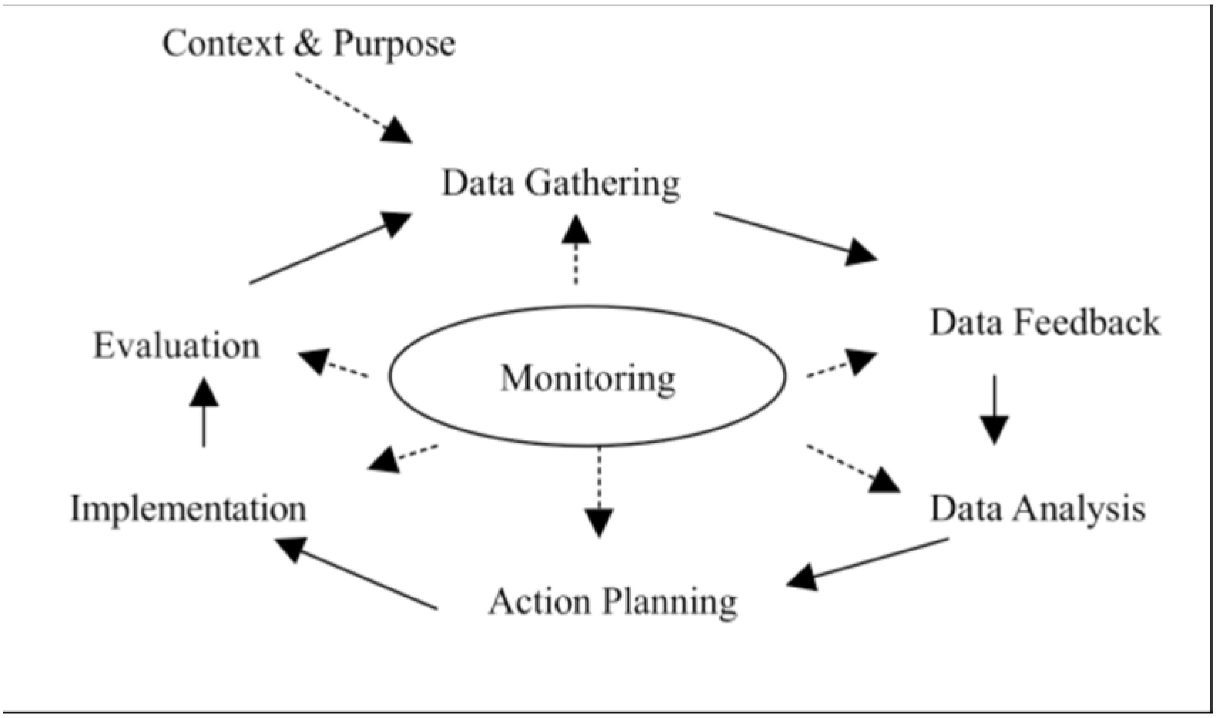

Figure 11: Overview of the Action Research cycles (Coughlan & Coghlan, 2002)

The participatory nature is one of the main criticisms against AR, labelling it as ‘consulting masquerading as research’ (Coughlan & Coghlan, 2002). However, the cyclical approach of Action research, with significant phases of analysis and reflection between action is a vital difference between AR and consulting, and the researcher prioritized taking notes and engaged in reflection frequently as the project proceeded. Consulting is also linear, where the consultant engages, analyses, acts and disengages, whereas AR is cyclical and iterative to build change and knowledge over time.

Quality in Action Research

Action research is full of choices in how it is applied, such as the collaborative nature or the enactment of the iterative cycles, and to what extent these are adhered to in practice, varies (Reason, 2006). The most important thing to maintain quality and validity in the context of these choices of application, is to show awareness and transparency of the choices made at each stage of inquiry (Reason, 2006).

One of the most important features of AR, and its ability to produce results of high relevance, provide new perspectives, and build new theory, is that it is an entirely different research paradigm from that of traditional positivist science (Reason & Bradbury, 2001).

In positivist science Logic and measurement is valued, along with consistency in prediction and control – what this means is that in positivist science, replicability is key. The researcher needs to outline each step of the research, so that another researcher can follow those steps to conduct the study and consistently get the same results. In Action research the key to judge validity is not the same – it’s experiential, meaning knowledge through experience, this means if the person is not there, in situ, they wouldn’t be able to come up with the same insights as if being at arm's length or more. This manifests the immersed role of the researcher and contextually embedded nature of data in AR.

These differences are further explained by the different aims of the two paradigms. Positivist science looks to build universal knowledge, where theory is built and tested – the researcher takes measures to detach from the environment, be neutral, and systematically conduct the research to be able to build universal knowledge, free from the context. Action Research is the opposite, it doesn't aim for empirical or contextual generalizability, but the data is contextually embedded and interpreted. The researcher's relationship to the setting is of an immersed nature, where the researcher's role is an agent of change, participatory and interventionist. This leads to a situational type of knowledge, dependent on the context, with lower generalizability than positivist science. Figure 13 outlines and contrasts these differences.

	Positivist science	Action research
Aim of research	Universal knowledge Theory building and testing	Knowledge in action Theory building and testing in action
Type of knowledge acquired	Universal Covering law	Particular Situational Praxis
Nature of data	Context free	Contextually embedded
Validation	Logic, measurement Consistency of prediction and control	Experiential
Researcher's role	Observer	Actor Agent of change
Researcher's relationship to setting	Detached neutral	Immersed

Figure 9: The difference between positivist science and Action Research (Coughlan & Coghlan, 2002)

Thus if AR produces relevant and new theory using its own paradigm, shown through numerous influential published papers (Coughlan & Coghlan, 2002), it cannot then be judged In terms of research quality by the criteria of another paradigm (such as that of positivist science). The Action Research paradigm thus requires its own quality criteria and as Gummesson (2000) puts it, should *not* be judged the criteria of positivist science, but rather by its own criteria. Reason and Bradbury (2001) outline what they consider choice points and questions to judge quality in Action Research;

1) *Is the AR explicit in reflecting how co-operation between the action researcher and members of the organization?*
2) *Is AR guided by a reflexive concern for practical outcomes? Is the action project governed by constant and iterative reflections as part of the process of organizational change or improvement?*
3) *Does AR include a plurality of knowing, which ensures conceptual-theoretical integrity, extends our way of knowing and has a methodological appropriateness?*
4) *Does AR engage in significant work? The significance of the project is an important quality in action research.*

5) *Does the AR result in new and enduring infrastructures? In other words, does sustainable change come out of the project?*

Chapter 3

Methodology

In this chapter, the chosen methods for conducting the research are presented and argued for. Section 3.1 presents the research design and setting. Section 3.2 specifies how Action Research was applied and justifies its choice. Section 3.3. elaborates on data collection and argues for choices made in this regard. Section 3.4 explains how the data analysis was conducted and section 3.5 explains how the empirical data and the results of the analysis are presented.

3.1 Research design

The goal of this research was to build theory by developing actionable guidelines around local capacity building as a means to scale a microgrid business. In the context of no existing literature on local capacity building for microgrids, an inductive approach was chosen. To deliver the goal, the research was carried out through a qualitative research paradigm because of the interdisciplinary complexity of the research area and the requirement of a deep-contextual understanding to develop actionable guidelines. The Action Research (AR) approach was used to generate data, defined as an participatory problem solving approach where the company and researcher collaborate to solve an organizational problem and to build theory simultaneously (Coughlan & Coghlan, 2002). This approach allows for the gathering of detailed and rich data through a robust study that is anchored in the field. However, this approach comes with a trade-off, as it leverages the local context of the company, the contextual generalizability is low.

The research was conducted over a period of 5 months divided into three phases. The first phase (presented in section 4.1.) was conducted remotely for 2 months, and was concerned with understanding the company context, its rational for change, and the selection of an organizational change project of Local Capacity Building, that is also the Action Research project at which knowledge is built. This phase is called the 'pre-step' in Action Research by Coughlan and Coghlan (2002) and a crucial for finding an Action Research project that has strong rationale for action, as well as research.

The second phase was initiated by the results of the first phase. This is where Action Research was applied in the organization change project of Local Capacity Building, with the researcher at the company premises in Zambia for 2 months. During this phase empirical data was collected by the researcher acting as a participatory and interventionist insider, helping move the action research project forwards, whilst engaging in reflection upon the proceedings – to simultaneously build a body of scientific knowledge. During this period, the company was undergoing transformative change. Having 3 microgrid systems in operation at the start of the research period and deploying and operating another one during the research period, followed by another 6 systems later in 2019, this represents a radical increase in the size of the business. The current operations model was not sufficient for larger scale, both in terms of operational efficiency and profitability – and the company was faced with the same challenges as other microgrid businesses aspiring to transform to larger scale. These findings are presented in section 4.2.

In the third and final phase, the empirical data from the previous phases was analysed. The data analysis is presented in section 5.1. The result of the third and final phase, and result of the research are presented in section 5.2.

3.2 The application of Action Research

Action Research is characteristically full of choices, and its application varies. To maintain quality and validity, the most important thing is to show awareness of the choices for application of AR available at each step of inquiry (Reason, 2006). In this section a recounting on how Action Research was applied in this research is reflected.

The Action research project of Local Capacity Building was launched at the company, as an organizational change project, with the aim to develop an understanding and blueprint for what is required to conduct this strategy. This aim was aligned with the two research questions, which are about developing this blueprint through the key components required for Local Capacity Building, and the opportunities and challenges faced. There is thus a strong synergy between the purpose of the project in the company, and that of research – as actions are taken in the company that move the project forwards, are reflected upon and building the operative blueprint – this also builds a body of scientific knowledge, aligned perfectly to answer the research questions.

The purpose of the AR project for the company was highly affected by the context of the need to scale the business (by deploying more microgrid systems in new communities), necessitating a local resource capacitation to support this expansion. The company goal was to enable an operating structure, using local capacity, that is viable and profitable for larger scale. This is also aligned with the wider problem outlined in this thesis introduction – of the need to find a viable and profitable scaling path for microgrid businesses in general to accelerate diffusion. By the delivery of this project, and reflection upon how the business is impacted by its findings throughout the research period, this research can start building new knowledge in this area.

Since there was no existing blueprint or research on this area, along with no known examples of microgrid businesses building local capacity in practice, a highly inductive and holistic approach was used in the business. The motivation for this was simply that general theoretical frameworks, or best practices from other industries (since nothing was available for the microgrid industry), was highly difficult to utilize because the company context is unique. It's a small-scale start-up, facing radical growth thanks to acquirement of large investments, operating in a developing country in Africa (Zambia specifically) and in a sector that is still in its infancy (microgrids).

This approach meant that every stone was turned, through iterations and experimentation, rather than trying to formulate the operative blueprint immediately deductively. Many different things were tested at smaller scale, through training sessions, various recruitment, exploration of digital platforms etc, thus the operative blueprint of LCB emerged and was built over time. This practical methodology of experimentation and holistic perspective was aligned well with the research, and suitable to develop new theory in the context of an unexplored area.

Action Research always involves two goals, to solve a real world problem and contribute to science (Gummesson, 2000). And through the approach used, as the Action Research project of LCB progressed, driven by real world action, this also generated extensive amounts of data. This AR project is where research is conducted. The implication of this, is that the research is grounded in knowledge and in action, explaining the high relevance AR typically holds (Coughlan & Coghlan, 2002).

The researcher was highly active and participatory in the project of LCB at the company, as outlined in section 2.4, collaboration is a possible element of action research. Collaboration with other employees was strived for as much as possible, but due to resource constraints at the start-up and many competing interests, this was not always possible. There were thus times where the collaborative characteristic of AR had to be abandoned, with the researcher at times driving the project of LCB forwards without any other employees. Because of this the researcher was given lead on the LCB project, and thus the one most involved and contributory to developing it, in the company context. This is a weakness since it limits the collaborative nature, and perspective from other employees, with knowledge of the business. At the same time, it allowed the researcher to deliver the research goal by being at the heart of change, navigating decisions, experiencing what works in the company and what doesn’t work. The researcher kept a journal of all proceedings such as meetings, workshops, training sessions, site deployments and observations. Along with this, the researcher ensured time twice a week to disengage from the project and reflect upon these proceedings. This step of reflection is what links action with research.

Another aspect of AR are the iterative cycles of planning, taking action, evaluating action leading to further action and so forth. The conscious enactment of these AR cycles can improve rigor of the research. However, this structure was impossible to maintain entirely once the researcher entered the field. The reason was that there were many things happening in parallel, at an extreme pace. It was difficult to filter what parts of the business and activities are relevant to the project of LCB. In collaboration with other employees, the AR cycles were simply not always kept, sometimes a decision had to be taken out of necessity, without prior planning, and sometimes there wasn’t time to evaluate an decision that was taken. This, along with the lack of collaborative nature, resulted in a discrepancy between some of the elements of how AR is typically carried through, how the methodology was planned to be applied, and the reality faced once entering the field. The reality of a small-scale start-up, in the middle of a radical scaling, the need to radically transform its operations, and constrained on resources, resulting in a lower level of active participation in research than expected.

The justification of the use of Action Research

The choice to use AR to develop guidelines on what local capacity building is, was in the context of above, still by far the best methodological choice, and was grounded in more than one argument.

Firstly, as in any resource constrained small business, the researcher would likely become highly embedded in the company context and involved through its day-to-day operations. The company also explicitly wanted 'more than facilitation' in this process and were not interested in a study where the researcher would have been a passive observer. Rather than see this as a disadvantage, AR uses this context as a strength, a company operating at a high tempo, making progress in multiple and parallel areas, there is plenty of opportunities for a holistic research on LCB. By the researcher being immersed in the company context, participatory and interventionist in its operations, at the heart of change, this perspective allows to gain valuable insight and from the inside develop effective guidelines. For a similar situation, AR was used successfully in building an actionable framework for measuring supplier performance in collaborative design (Dain, et al., 2010). An often mentioned rationale for doing action research projects is that it gives researchers access to knowledge that is not possible to acquire by means of interviews or surveys or similar data collection methods (Huxham & Eden, 1996) (Gummesson, 2000).

Secondly, AR is particularly good for studying organizational change, and has been applied in this context successfully through numerous published papers ((Johnson, et al., 2014) (Nair, et al., 2011) (Hendry, et al., 2013)). This is because the researchers close engagement and high level of access to the change process by being participative, which generates insights how organizations manage change and how key actors perceive and enact their roles with regard to change (Coghlan, 2003**.** To do action research, therefore also acting as a change agent, it is argued, provides better access to data and management reality and a change process also makes sure that the issues being discussed are at the top of mind of the people involved (Huxham & Eden, 1996).

Thirdly, AR aims at developing holistic understanding during a project, and recognizes complexity (Gummesson, 2000). As outlined already, the AR project of LCB became very complex, interdisciplinary, with many things happening in parallel. There is thus a fit between the company context (of complexity), the project of LCB (embracing this complexity), and the research (to deliver a holistic understanding on LCB, capturing this complexity). Particularly, AR embraces this complexity through understanding, as a member of the business, how and why the action change or improve the working of some aspects of a system and understand the process of change or improvement, in order to learn from it (Coghlan & Brannick, 2001).

These strengths, also comes with threats to the validity of AR. Especially as the researcher is imbedded and engaged in shaping and telling the story, it's important to what extent the story is a valid representation of what has taken place and how it was understood (Coughlan & Coghlan, 2002). Torbert (1995) suggests several ways address this which have been utilized in this thesis to improve validity. 1) Explicitly stating the goal to be achieved, in practice and research (Goal in practice: succeed as well as possible with development and implementation of local capacity building, that allows the business to scale, is feasible at large scale, and is profitable). 2) Telling the concrete story (extensive empirical section) 3) inquiring the participants about their perspectives and views (exit interviews with key employees regarding the results). The main threat to validity for this research is the lack of impartiality on the researcher's side. The researcher was hired to continue to work within Local Capacity Building a permanent position, this means the researcher has a vested interest in protecting the company from any negative results. The researcher also has a strong passion and belief in sustainable diffusion and wants to find answers and succeed in this ambition. The researcher also, by adopting Action Research, is heavily immersed in the context and driving the project forwards.

However as will be argued here, these are turned into strengths, and mitigative actions are taken where necessary. These have all been a driving force that has produced extensive findings and results, coupled with extensive documentation of the processes and work to get to those results. – this means the goal of the thesis, to develop effective guidelines for a company to build local capacity, benefited greatly.

The leading word in the empirical data and company context is transparency, the researcher has not confined from including 'negative' aspects in the context or the process – such as numerously questioning the company's commitment to the project. Secondly, the relationship with the thesis supervisor, provides an external perspective on the research – providing guidance to ensure that an external can understand and follow the process and how the results emerge, without the context the insider researcher has. Thirdly, it's explicitly stated that the goal of Action Research is to the best of the ability of the researcher and the company succeed in the strategy of local capacity building. The fact that the researcher is immersed and actively driving the process of developing LCB is a strength in that it gives another level of access and insight to understanding the process, combined with the explicit goal of finding a successful path, on what is required to succeed, how challenges are navigated and how opportunities are turned into results. The fact that the researcher was hired at full time in the company furthers this statement, in showing the success and value of the research, transparently presented in the empirical findings and results. A mere process of passively evaluating and observing the process of LCB would very likely not have been capable of generating equally extensive results. Further to this, the way the data is presented (elaborated on in section 3.5) helps improve validity.

3.3 Data Collection

Data was collected through the two initial phases. The first phase was concerned with understanding the company context, their challenges, rationale for change. This part of research was conducted remotely. Together with the company the topic for research was selected: Local Capacity building. This process is presented in empirical findings section 4.1. For this phase, company documentation, meetings and e-mail correspondence were the sources of data. The main source of data was the studying of the company's standard operating procedures, a meticulous documentation over hundreds of pages, outlining every process taken to run the business, described step by step. In addition to this meetings with the company and email correspondence furthered the understanding of the company context, discussed the challenges faced in the business, opportunities that exist, and the rationale for organizational change.

The second phase, Action Research in the field, is main phase of research and data collection. Throughout the duration of this phase, the researcher was at the company premises, as the action research project of developing and implementing local capacity building progressed. Most of this data is empirical and soft data. Multiple sources were gathered and used throughout the project. Data took the form of notes taken by the researcher during meetings, emails, etc. In others, meetings were attended, where the researcher took active part in the discussions and engaged in problem solving. Plenty of time was spent by the researcher analysing the business context to develop the Local Capacity building project, by building training systems, preparing training content, assessing training needs, being part of conducting training, evaluating training and inquiring about other areas of the business where LCB could be related to. Several existing microgrid sites were visited, as well as the researcher joining for the deployment of new sites, living with the team of technicians in the field, for the purpose of getting an understanding for the technical aspects of the system, observing training of local capacity, seeing how this capacity performs, and in general seeing the company operations in action, as well as get the opportunity to more informally talk to the deployment team. Along with the active lead in the field, collaboration and through observations, the researcher took consistently took time twice a week in allocated slots for reflection, with the purpose to disengage and distance from the project, and reflect upon all the proceedings (conducted by the researcher or through others work).

At the end of this phase, interviews were held with employees at the company that were key to the project of LCB. The interviews were semi-structured, in which open questions were asked regards to the research questions, further inquiring on new and interesting ideas that emerge, as well as specific questions related to the empirical data found. The purpose of the interviews was to gain the employees perspective in the context to the answers that had emerged regards to LCB, to see if they had other ideas or have them put in their own words what they perceive LCB is about. These interviews complete the empirical data.

All data was stored in the researcher's journal in written form by data type and in a chronological order. The narrative of the empirical findings in chapter 4 is a recollection of this data. The list below gives a further overview of the different type of situations where the researcher collected data along with examples of particular situations.

- Study of company documents (standard operating procedures, training materials to get a sense of the business and what is currently done)
- Problem solving in a collaborative context (work together with company employees to formulate training system, training curriculums and training content)
- Problem solving by the researcher (analysis around the company context and the project of LCB, such as what is required to move it forwards and succeed, or further understanding of a specific element of LCB by focused analysis, such as assessing the training needs for a specific role to be trained based on the company SOPs)
- Creation of processes and content (such as the researcher formulating a training system, training curriculums or training content)
- Surveying of those trained (post-evaluation survey of 3-day microgrid manager training)
- Observation of training (how is the content received by trainees, assessment of knowledge through practical tests)
- Conducting training and observing how training is conducted (observation of trainer pedagogy, structure of training)
- Observation and of trainees (assessment of differing initial skill levels, personalities, attitudes, abilities to learn)
- Helping work to setup new sites (managing subcontractors, inventory management, lend a helping hand where needed)

- Observe company employees in action (experience technicians conducting technical work such as connecting customers, deploying the distribution grid)
- Observe local capacity in action (such as a trained technician conducting work on connecting customers to the grid or a microgrid manager interacting with customers and making sales)
- Maintenance and repair jobs on existing sites (observation of local capacity on-the-job performance, hands-on involvement with practical work to understand nature of the job – such as a battery extension job and wiring at existing site)
- Meetings with technology partners, subcontractors and suppliers (understanding dynamics and flexibility of relationships and how these can integrate into local capacity)
- Interviews with company employees (to triangulate results with their perspectives and views)

3.4 Data analysis

The collected data was analysed at the end of the research, once all empirical data was gathered, in a similar way as to what grounded theorists label "coding" (Charmaz, 2006) and sorted into categories that help answer the research questions, of components, opportunities and challenges essential to local capacity building. This analysis is done by frequency of the categories appearance in the empirical data, and by importance. Frequency of the categories is shown in data analysis tables of section 5.1. And importance is judged by company employees highlighting certain data, or because of their critical role to LCB, the criteria of importance is elaborated directly in the results where applicable.

This process allowed to analyse and categorize the rich empirical data into eight key components required to scale a microgrid business using local capacity building, as well as the main challenges and opportunities of LCB. Only the categories that was deemed essential enough (by having high frequency, or being important) and that thus ended up in the results, are presented in the data analysis tables, for other categories (less essential) the reader is referred to the empirical findings.

The exact definition of what is looked for in terms of the categorization into challenges, opportunities and key components is defined before each respective data analysis table in section 5.1.

3.5 Presentation of data and emergent theory

In practice, the researcher became the vessel of data generation by taking action in the field and observing action. This journey was far from linear, but rather iterative, with many things in the organization experimented with and topics being explored in parallel. The high tempo in the company along with the complexity of LCB and a holistic inquiry, resulted in extensive documentation of several hundred pages of empirical data. This coupled with the multiple different sources of data, created by the researcher taking action, observing action and reflecting upon the two, furthers this complexity.

To navigate the challenges of complex and extensive data, the presentation is structured by reflecting the research from a chronological perspective. This allows the reader to appreciate the origins of the research propositions and how these have emerged through action and reflection in the field. This structure also provides a strong chain of evidence starting from the pieces of empirical data in chapter 4, when they emerged and how they develop over time, connected through the data analysis directly to the final research propositions. Next, this structure is elaborated upon individually for each section of this chain of evidence.

The main part of the empirical findings, section 4.2. are presented in a chronological order divided into weeks. This structure was deemed the best way to reflect the findings as transparently as possible. Because of the immersed nature of the researcher in the context, driving the AR project at times, along with the difficulties of maintaining the AR cyclicality – the mitigation was for the researcher to engage in reflection upon the proceedings and focus on the chronological structure. This chronological presentation of the empirical findings allows the reader to get a sense of the timescale of what was happening, and most importantly when in time certain pieces of data appeared, when they are iterated or not iterated, and how they develop – this narrative is central to understanding of how the AR was applied to generate data, and captures how the research propositions emerge from this process over time. The final exit interviews are not presented as they were very extensive, and not a big part of the empirical findings or Action Research project. They are used in the formulation of the results to some extent, and their use is indicated in the data analysis tables.

Section 5.1, The data analysis, is presented in the form of a simple table showing the final research propositions, and allows the reader to appreciate when in time (in which weeks) data emerged that contributed to these propositions. The analysis was done for many more categories, but only the categories that ended up in the results, as per the process in the previous section are presented. This synthesis was necessary to condense the results from extensive empirical data, and to only capture the essence, as in the research question, 'key components.

Section 5.2, The final results, clearly outline the research propositions, a synthesis of the empirical findings, found through the data analysis. The chain of evidence is shown in section 5.1, the data analysis, that links the empirical findings directly to research propositions in section 5.2.

Chapter 4

Empirical findings: Local Capacity Building at a small-scale Zambian microgrid company

This section contains a summary of the work processes so the reader can easily appreciate the origins of the research propositions around local capacity building. It is also an attempt at 'a confessional tale' (Williander & Styhre, 2006) *to provide further understanding and demystify how action research on local capacity building can be carried out in practice. For the purpose of narration, effort has been put into highlighting important aspects rather than providing long descriptive sections. The qualitative data used during this time was stored in the form of meeting notes, observations, discussions and reflections in a journal kept by the researcher. The section is divided into two sub-sections, or phases. The first phase concerns the selection and rationale for the Action Research project of Local Capacity Building. The second phase is where Action Research is carried out in the field, at the company premises in Zambia. The recounting of events below is the compilation of this material.*

4.1 The selection process and rationale for Local Capacity building

(conducted January – February 2019, Stockholm).

This section gives the reader an understanding of the origins of the organizational change project (and Action Research project) of Local Capacity Building. Firstly, the company context of the small-scale Zambian microgrid company, and its rationale for change is presented. Then the motivation and initial scope of the project is presented.

The small-scale Zambian microgrid company

The company was founded in 2013. The company is engaged throughout the supply chain of procurement, deployment and operation of microgrids throughout the lifecycle of the systems. The company has four 12 kWp microgrids active in rural communities across Zambia today that can support up to 150 connections each. With its four microgrids, the company is relatively small in size, but thanks to the company's proprietary technology and long-term thinking, the company is seen as an industry leader within microgrids, and has attracted plenty of investment to lead the expansion of microgrids in Africa. Initial investment is to expand the business to build an additional 150 microgrids across rural Zambia to bring power to 130,000 people within the next 4 years. This represents a radical increase in scale of the business, putting pressure on the supply chain to deploy 11 grids in 2019 (thus expanding from 3 to 14 grids) and doubling this deployment rate year-over-year in the following years. The increase in number of grids deployed also puts pressure on the operative structure and need for employees to manage and operate the grids, both ensuring the system functionality of each microgrid through operation, maintenance and repairs as well as establishing customer relationships, selling power and providing customer service. For a perspective of this scaling challenge, the company had ambition to deploy 10 grids in 2018, but only managed to deploy 2 due to the challenge of finding the right people needed for the expansion, as well having an operative structure that was not supportive of this increase in scale.

This backdrop provides the context for the research period. The central phenomena being around scaling the business, with four grids deployed during the research period, whilst the company needing to simultaneously develop an operations structure that can support hundreds of microgrids. Key to this new structure will be improved cost-efficiency, mainly by lowering operating expense, something most microgrid players struggle with and something that is crucial to reach profitability at scale. The company also has a vested interest in finding a more sustainable way to scale (than the rest of the industry), mainly by empowering local people in the communities they serve to help manage the microgrids.

The key of operating expense for success when scaling is evident, reflected in the initially proposed research focus, on studying and understanding how operating expense scales in a microgrid business as the business scales. However, this was deemed not a valuable approach because of its passive nature and nor providing value to other practitioners. The focus was instead shifted to identifying and classifying what operational interventions could be done to lower operating expense and expanding the business in a sustainable way (showing the importance of operating expense area still as the focal point).

The rationale for change

This process of choosing a field for operational intervention (in practice) and subsequently the focus of research was done through workshops and meetings, where the company operative challenges were mapped out;

- **Lowering operating expenses:** The main challenge moving forwards was that of operating expense, which is a key issue for all microgrid players, that face thin profitability margins. Examples of these are the cost to conduct maintenance, repairs, customer service or technical issue resolving - since the microgrid systems are in remote rural areas, requiring use of car, fuel, insurance, expensive highly skilled labour to go out to site drive costs.
- **Finding highly skilled people:** The second challenge, was the one that hampered growth of the business in 2018, the challenge of finding highly skilled people in Zambia. The labour pools of engineers and managers are more limited in Zambia, compared to developed countries, due to education being limited, expensive, and ‘brain drain’ – where skilled people emigrate to developed countries for other opportunities.
- **Leverage economies of scale:** Another rationale for change lied in finding an operative structure that can leverage economies of scale as the business expands – being part of the core assumptions of the microgrid industry– that profitability follows scale, and where economies of scale and ‘learning curve’ effects need to be leveraged in order to deliver that profitability.

- **The enigma of large scale operations:** Above was particularly important in the context of a sector without any 'industry blueprint' on how to scale a microgrids business, with what operative structure and operative interventions, and how to achieve profitability. There is also no known research or documentation on the businesses that have failed to scale and why. This void provided few answers on the adoption of traditional means used to scale businesses in other industries and environments– but at the same time presented a blank sheet with plenty of room for innovation.

The selection of Local Capacity Building as the operative intervention in practice, and as the research topic

The main motivation for looking at local capacity building was thanks to the company's long-term thinking by documenting and standardizing all their operating procedures (which is a very extensive job, especially for a time- and resource-constrained start-up) - the importance of this documentation is that there is a track record of how things are done, that can be trained to others -this allowed the company to in the final quarter of 2018 trial using external capacity for technical maintenance and repair jobs to some success in terms of lowering operating expenses (this was using already skilled engineers, contracted for a job to follow the operating procedures, where the company started thinking if this could be taken even further by contracting people in the local communities where the microgrids are). Another aspect was that the company had already recruited 'Microgrid Managers', personnel that sell power in the microgrid communities, which had been successful – this lead to thinking further, if this concept can be leveraged to a greater extent throughout the business, or even as a means to scale the business. Furthermore, the company had identified an opportunity in local labour pools, where at every site there has been local labour available that come and ask for a job or if they can help. If these resources could be leveraged to help manage and operate the grids locally, the operations would be more efficient and hold a lower cost (for instance, instead of sending a company engineer with a car, fuel, insurance, materials from company offices to a remote site – using a locally trained technician, would drastically lower the costs, and also be more efficient). In this sense, the prospects of local capacity building addressed the two main challenges the company faced – the one-off lowering operating expense and the one-off finding skilled people.

It was also a good fit in terms of research, as the researcher had experience and competence in the activity of training and capacity building. Mainly by being heavily involved in designing and conducting training for virtual communications solutions for over four years and more recently through three years of work at the biggest electric utility company in northern Europe, being part of instigating and developing a concept that help build capacity for all citizens of Sweden in terms of the individual environmental impact, and empowering them to take action for sustainability.

The researcher also shared the interest and fundamental values with the company in finding a way to scale the business that is sustainable – fundamentally the business needs to be profitable to be able to grow, and provide electricity at scale - but equally importantly this diffusion of microgrids needs to be socially sustainable through job creation, empowerment and capacity building of local populations. Critical in the context of an energy access industry that is dominated by 80% western expats.

With all these arguments the choice fell on local capacity building as a practical means to scale the business, as well as the research topic.

Local capacity building at Standard Microgrid, initial requirements and scope

The scope of local capacity building, defining roles and training needs were set. There were two roles initially considered for local capacity, that is capacity in the local communities where the microgrid is deployed. Microgrid managers and Regional Technicians. Below the scope of the roles and training needs are defined for both, note that this is not what was done in practice at the time, but rather the envisioned capacity for future deployments and sites.

The microgrid managers (MM), have a central role in their community; selling power to the customers, handling customer relationships, providing customer service and being the company's point of contact in the community. Because of a company policy in empowering young women, the microgrid manager is always selected from young women in the community (typically without any further education than high school or upper secondary school). The company already had 3 microgrid managers at their existing three microgrid sites, already operating without much training though. The microgrid manager needs high skill levels in sales and customer service, as well as social skills to handle difficult customers, such as customers that want more for the money, want to try and pay less or claim they have been tricked. There had been incidents when especially some men in the communities because of cultural bias may feel they can and are justified to manipulate the microgrid manager to get what they want. The microgrid managers also need to learn and understand the company's business model, the service offering, which appliances that can be used and use a mobile app to conduct sales.

The regional technicians (RT) are recruited from local community members where the microgrids are deployed that are to be trained to become technicians in that community. The local labour pools are typically unemployed people without education above high school or upper secondary school, most are computer illiterate and illiteracy is a reality in most cases, and in almost all cases they are without any trade school or vocational training. The RT is tasked with maintaining, conducting repairs on the power system and reticulation system as well as handling ad-hoc technical issues. They could also potentially be involved in deploying microgrid sites in other communities at a later stage. The training needs are to have a high attention to detail, conducting work in a safe way and continuously conduct quality assurance that adhere to industry standards and safety requirements. The RT also need to understand the power system, it's components, how to conduct various work tasks and communicate with the central operations and do quality control on the work done.

4.2 Action Research in the field

(conducted March – April 2019, Zambia)

This section constitutes the empirical findings from conducting Action Research at the company premises in Zambia. This section is structured in a chronological order, so that the reader can appreciate when in time data appeared, and follow how those data are further acted upon, or not acted upon, and how they evolve over the eight weeks. This section is lengthy, diverse and complex, reflecting the reality and environment of the research, specific areas were not carried out in a focused linear fashion in reality, but rather multiple things were done in parallel and sometimes intersecting. Each empirical finding is introduced with a title that captures its essence, such as highlighting a key activity that is happening, or a reflection about a specific category. This structure is selected to give a transparent account of how the research was carried out, concurrent with action, and used in later sections to show how theory emerges from these empirical findings over time.

Each empirical data is denoted with WX.Y, where W is for 'week', X is the week number, and Y is the number of empirical data in that week, this denotation is to refer to these data later in the data analysis.

Week 1, A week of first impressions in Zambia

W1.1 Standard operating procedures

The company has mapped their standard operating procedures, this documentation is very extensive. Plenty of time was spent to understand the business and its operations, to be able to understand what the training requirements are and what content that is to be taught. A key take away from this work was how methodological the standard operating procedures are, for example with the task of erecting an utility pole divided into several steps that need to be followed in a strict order, with stops to conduct quality control to be allowed to continue to the next steps. This was mainly the case with the technical part of the business.

On the other hand, the soft skills, required for microgrid managers didn't have much documentation- pointing to two very different training content, ways of work and training requirements. The regional technicians need to be able to strictly follow the operating procedure, step by step, and conduct quality assurance in-between, without much personal interpretation. The Microgrid managers, need to be trained in soft skills, such as sales and customer service, have a feeling and intuition for the situation, the customer and adapt their behaviour from this.

W1.2 First day on microgrid site – complexity of operations in action

First day in Zambia was immediately spent in the field on a nearby microgrid site, seeing operations in action, some local capacity already deployed by the company through a microgrid manager at the site, that manage community sales and provide customers with a point of contact. The site visit was together with a couple technicians at the company and its Operations manager (OM). It was quickly apparent that the job was very much hands-on, with ad-hoc problem solving and critical thinking required, the OM encountered a wide range of issues from data science problems, to electrical engineering, troubleshooting skills to soft skills in handling unhappy customers as well as managing the rest of the team and communicating centrally with company. Training someone to fill this more advanced role would be extremely challenging, helping explain the initial focus is on the regional technicians and microgrid managers. It was also clear at this stage the level of different tasks and stakeholders, showing the complexity of the operations. Anyone that represents the company, either a technician, microgrid manager or in some other capacity will face a variety of customers, with technical, sales or service issues and inquiries. They also need to communicate with the rest of the local capacity (in this case only a microgrid manager, but in the future more people, such as RTs), the rest of the central team on site (Such as additional technicians coming to site to do a more advanced or extensive job), the team manager on site and the central operations in Lusaka. People associated with the company need to wield a variety of information to understand who to escalate problems or enquiries to, who to communicate with, what resources are available, on-site as well as centrally to judge what actions to take when confronted by a customer, prospective customer, or some other stakeholder in the community (such as e.g. the local liaison). Some of these things may be intuitive for someone that has spent years working in a business and been exposed to different organizational structures – but for someone that has spent their life working as self-employed shop owner (with no organizational structure to adhere to), or as a farmer (with little customer interaction) these are important aspects of training.

W1.3 Company First Regional Technician Training

Rest of week we started training technicians and regional technicians in setting up the microgrid distribution system. The technicians had electrical education and a high initial skill level (3 in total), whereas two (2) community members from a site were the first 'local capacity building' attempt for Regional Technicians. These had previously been hired to help with non-technical tasks on a previous site that was setup by the company, with the work involving basic tasks such as digging holes and helping erect poles. Training was observed as it was conducted by a more experienced technician that had been with the company for 1 year, helping set up previous microgrid sites. The training was based on both Standard operating procedures developed by the company, and the trainer's personal interpretation and experience. Training was to some part theoretical, but mainly practical.

W1.4 Initial impressions, observations of training in practice

It's clear that a key challenge will lie in teaching complex engineering skills to low-skilled labour without education and who are in some cases illiterate.

It was also clear that as any start-up that is facing rapid growth, there is a very high tempo in the company, with actions being delivery oriented, to get tasks done and move the company forwards. This leaves little time for reflection, or long-term agendas, such as building a training curriculum, creating training material, compiling handouts to trainees, conduct surveys on training etc. Most of the training was improvised and conducted on the spot, rather than prepared. This approach relies heavily on the quality/ability of the trainer and is not scalable.

Another aspect is the challenge of training a diverse group, with different initial experience, skill levels, and personalities. Some participants were more active and engaged, showed willingness to learn, and were rewarded by getting answers to their questions or thoughts and by getting to do many tasks practically, whereas other were more reserved and observed. It's difficult to judge how well the knowledge has been transferred, as no theoretical or practical test was conducted, it's one thing to be able to replicate once immediately after the instructor – than critically assessing a problem four weeks later in the field, and choosing which approach to use and remember what to do from training.

These challenges combined with the interest in looking for a low-cost, efficient and mainly scalable training platform lead to the company starting to look at ways to create training content and have access to this content remotely, such as through video material, accessible from a smart phone, when facing a technical issue on a remote site.

Week 2, Starting to build a training system

W2.1 -Building a training system

There was no current system or framework for training in the company and neither any dedicated resources for training. Some training had occurred sporadically, when necessary and whoever that was available to conduct it, thus, to focus on training was new for the company. The motivation for this was that a stronger commitment to training would improve training outcomes. The researcher was tasked with creating a higher level training system on how practices are transferred to training content, how training is conducted, pedagogy, how training is evaluated and improved and how it's connected to field outcomes (how the local capacity perform). Figure 13 shows an early draft of this training system, created by the researcher, reflecting the extensiveness of this system, and how it spans the whole organization and integrates into operations and feedback loops. The motivation to create this higher-level system was that a more structured approach would improve training outputs and the value of training in the long-term, and also facilitate the development of local capacity. However, the development and mainly *implementation* of this kind of system would also require significant initial resources, especially in terms of time and personnel, that are already very restricted in the start-up.

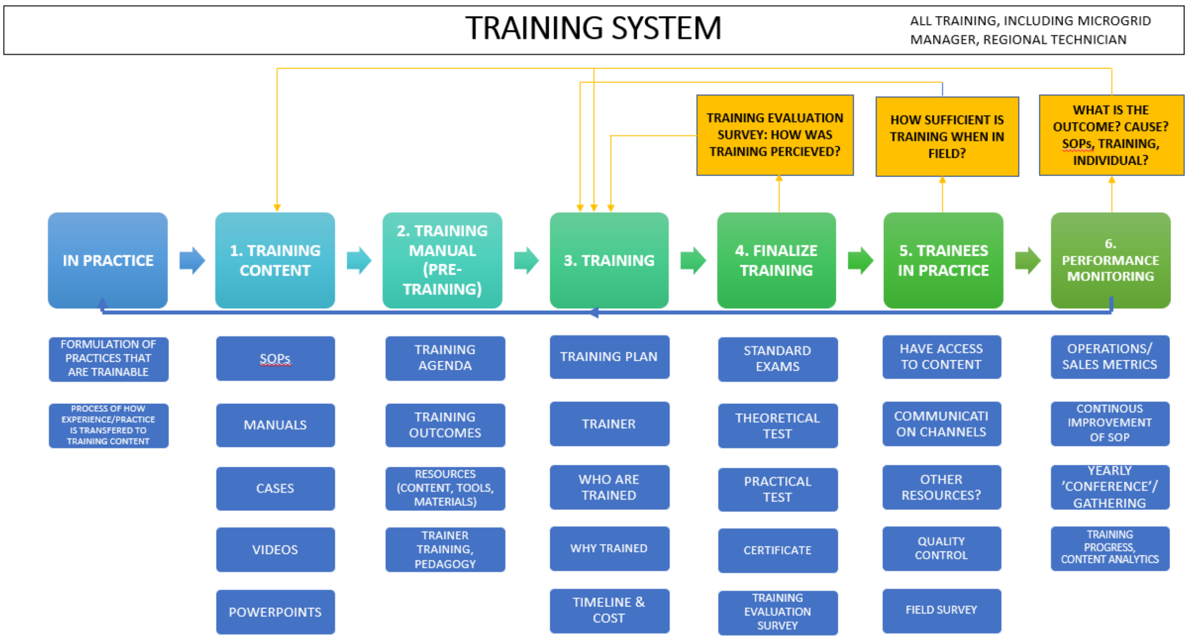

Figure 13: Initial draft for training system, created by the researcher

W2.2. Project Sangam – Digital training

As a reaction to the need for a more scalable training system, a meeting was conducted with a software company that has a community empowerment training platform, used for last-mile training (main difference with other education platforms is the capabilities for offline content and low-bandwidth streaming). On this platform it's possible to create courses and have several kinds of content, such as videos or PowerPoints. It's also easy to enrol new trainees to the courses, evaluate their knowledge through quizzes and exams, as well as through analytics track the progress and how the content is perceived. This sparked the idea to look further into low-cost, cloud-based training/collaboration platforms. This kind of platform would also be less extensive than a training system based around practical/personal training. At this stage though all options were kept open, to try and learn and be open to what, how and where to conduct training best.

W2.3 Operational integration – remote operations

Operational integration was also looked at. This is key for scaling the operation, which is the goal of the company, by having greater access to labour through a network of local workers, and lower operating expense (by not having to use highly skilled staff at the headquarters) there is room to expand the business. But there also comes the challenge of operational integration – How are tasks that need to be done in the field allocated to the local capacity? How to ensure they have appropriate knowledge and skills? Ensure that they follow safety procedures whilst conducting work? That they have the appropriate tools and materials to carry through the task? And most importantly, how does the company remotely conduct quality control and quality assurance on the final work? – Answers to all of these questions need to be found in the midst of scaling the company, meaning more sites, more personnel, more logistical flows, more timelines etc. This brought the discussion around the need for operational measurements, that were limited at the time, which was reasonable given the company only operated three sites.

W2.4 Many components of LCB

More and more components keep emerging around 'local capacity building', moving beyond 'training', and adding operational integration, communication platform and centralized training system. It's clear early on that business and operational scaling using local capacity building is a complex system of several components that are interdependently linked. It's difficult to isolate local capacity building from this operational context, and its value is directly connected to the rest of this system. Some theory that investigates how these components are linked could be valuable to look further into.

Week 3, First Microgrid Manager training and learnings

W3.1 First organized microgrid manager training

A microgrid manager training was scheduled and carried out over the course of three days. Prior to this a training curriculum and training content for the specific training was created by the researcher in collaboration with the operations manager and community engagement specialist. 4 microgrid managers were going to be trained, 3 of them in the job for about 1 month and 1 totally newly recruited. There were also two new recruits with the company that were going to work with the training further on who were part of formulating the training content and conducting the training. For this there was very limited resources both in terms of time and personnel to plan, prepare and conduct the training. Even though this is an area highly prioritized by the company, there are so many other things going on when scaling and expanding the business, especially in the context of planning and preparing logistics to set up 4 new sites (a more than doubling of the company size) within the coming months, as well as attending to investors, whose capital is crucial for the ability to expand.

W3.2 Initial resource requirements

The initial creation of a good training system requires plenty of resources, production of initial content used in training, training of the trainers, planning of the training, defining learning outcomes etc – all these frameworks and contents need to be produced for the first training – where after they can be evaluated and improved, iteratively for each new training conducted.

The issue in the initial creation is the need for resources, both in terms of time, but also in terms of key personnel, affecting what input goes into the trainings; people with the vision on what the trained roles should be able to do, the operations manager in terms of operational integration, as well as people with experience in conducting training, on the pedagogy and structure of the training, the training design would thus benefit from all these different roles, to be built from all these different perspectives. The paradox lies in the purpose - training is developed and conducted to be able to scale the company, whilst the scaling is already happening in parallel. This results in resources being stretched extremely thin, and especially for a task to build a long-term value project, such as a training system, are difficult to find. Once established, the value would lie in low investment cost in terms of resources and time, as well as high output of skilled personnel, and the development of a network of workers at the company's disposal. This trade-off between developing a long-term system enabling expansion and short-term pressure of expansion is interesting. Also the trade-off between training to scale and scaling to train – meaning that the higher scale and volume of the business, the learning curve, experience, and the number of iterations of training – the more the training can be improved.

W3.3 Language barriers

Language is another challenge – the company's operational language is English. All standard operating procedures, company documents, manuals etc are written in English. The executive team only speaks English, whereas for instance in Zambia there are two other main languages, Bemba (spoken by 52% of the population) and Nyanja (by 37%). The Microgrid manager interacts with customers in their local language (usually Bemba or Nyanja), whereas most of the training is held in English, as well as the need for the MM to communicate with the company in English. This language barrier puts additional pressure on the training and learning ability, both in the transfer of knowledge from the company to the trainees, but also in terms of nuances in feedback from the trainees back to the company being lost. This challenge was partly mitigated as parts of the training were held in English (conducted by the researcher and other trainers), but certain parts that were more difficult to grasp were held in Nyanja – making it difficult for the researcher to capture what was happening and contribute with their perspective. This highlights the challenge in that it may be difficult for everyone to collaborate on training. This challenge goes beyond the English Language and is a similar challenge for those in the company working that are from Zambia, where it's common to speak either Nyanja or Bemba only – whereas the trainees (local capacity, i.e. people from different parts of Zambia) either speak Nyanja or Bemba, leading to a mismatch in some cases where someone speaks Nyanja and the other party speaks Bemba. Certain aspects of the training can by advantage be held in

English, such as the context in explaining the organization, business model and technology, as the MM would communicate with the company regarding these and would need to know the English terminology. For soft skills such as sales and customer service, it's important that the Microgrid manager is able to express and use nuances (i.e. in their local language), the difference between two words can make a significant difference in sales, such as 'your investment' versus 'your payment'. Teaching these softer skills in English rather than in Nyanja or Bemba – will likely affect the confidence of the Microgrid Manager and the final outcomes.

W3.4 Different forms of variation

Another learning from the Microgrid Manager training was that there can be a lot of variation between microgrid sites – and that these cannot be generalized to 'rural Zambia' – between geographical areas and villages there are different community dynamics, such as the amount of people with work, what kind of employment, affected by geography for instance, if people are farmers, their income is cyclical to the harvest periods, different demographics, share of women, men, kids, different preferences in terms of household spending etc. Differences are also what kind of customers there are in a village, what expectations they have on power, the service, cost etc. Culturally how the community members perceive a young woman as the microgrid manager, that has final say over the service delivery also varies. The labour pools can also be different, with high differences in the quality of education received and what local jobs they've previously held. All this variation challenges a standardized and central training programme, where a 'one fits all' kind of programme for all microgrid managers might be suboptimal, if not impossible. The standardization approach may be more possible for RTs that work with standardized technology (a core element of the business model) that is the same at all grids and where work is to be conducted through standardized procedures.

Another variance factor is the initial skill level of the trainees, along with the difference in personalities – some might not say if they don't understand something, some might be more active and engaged in training, wanting to do everything practically, some learn better from videos whilst some cannot read from a manual because of illiteracy. All these variations make it difficult to create a central training programme that is standardized, when there is need for flexibility, customization and personalization. It likely comes down to a balance of how much is standardized and taught through e.g. videos or accessible through a written manual – and what parts are held on-site, as vocational training, shadowing another employee or workshops.

W3.5 Conducting a survey, getting feedback

After the Microgrid manager training a post-training evaluation survey was conducted. This was challenging though as the survey was prepared in google forms on a computer in English, which the trainees couldn't use for language and computer illiteracy reasons, as well as no access to individual computers (highlighting some of the resource constraints in lack of organization for planning and organizing training). The survey was then improvised into a group discussion instead, in one of the local languages, Nyanja. A challenge here was that the participants were hesitant to answer any questions in the group at all, especially not with a negative insinuation, and the only answers received were not very nuanced, such as that everything was very good, even though there was a lot of room for improvement in this first, quite improvised, training.

From the survey what was learnt was that all the participants preferred the interactive sessions that were held, over the theoretical one-way lectures, they also appreciated to meet other microgrid managers, with experience in the field, and hear their stories and experiences, as well as customer cases, how to handle difficult customers etc. How to handle difficult customers was the main worry of most microgrid managers.

W3.6 Use of local know-how
What was also learnt during the training was that the knowledge transfer was a balance of how much the company knows, and to what extent this is taught as 'this is the right way to do it', versus the many good ideas and knowledge the microgrid managers held, especially in terms of what works in their specific communities, how they've built customer relationships, etc that go beyond the company's current knowledge. It's interesting to look at how the business could leverage this local know-how, which is invaluable to the business – maybe by creating a network of all microgrid managers, bringing all together, having workshops around best practices etc to capture these ideas and this knowledge – but also ensure that the knowledge is transferred between the microgrid managers themselves as a form of continuous learning.

How this interactive part can be incorporated into the training system needs to be further inquired into, if using e.g. video modules, these are a one-way communication form, and thus teaching of 'how it is' with little room for other ideas or suggestions. These likely need to complement by central trainings and workshops. The ideas and perspectives of the microgrid managers was also challenging to extract, they need to feel very comfortable and empowered to feel that they are allowed to share their ideas.

Possible solution area to look into is how to create this environment and create this *culture* of openness and sharing of ideas. Another area is the creation of incentive systems to incentivize this.

W3.7 Challenge of continuous improvement, creation of feedback loops and the use of data
The training gave a couple of insights. A lot of things are taken for granted in a well-run organization in the developed world. One such thing is the use of surveys, forms, or other means to gather data and feedback as part of any system to improve the procedures. However, in this context, there is limited nuanced data from the field – only power generation, consumption and sales data are available – but this isn't connected to operational measurements or sales metrics, thus it's difficult to capture what actions are taken and what is done successfully in practice and what can be more efficient because of the lack of this causality. One such example that arose in the training evaluation discussion was that all participants said the content, delivery of content and organization of training was rated 'very good'– the reasons for this can be many, such as they don't want to say anything negative – but also likely that they don't have a reference point of a well-organized training, or how a training should be organized optimally -without this information this makes it difficult to assess how the training can be improved. A system that can be improved thus requires different tools and mechanisms than traditional systems - The process of how to identify inefficiencies and how to give feedback need to be taught, what to look for, how to evaluate as well as fostering a culture of feeling empowered to do so. The operating environment is quite unstructured, and more reliant on key personnel and relationships – compared to traditional businesses that rely on structures, frameworks and KPIs.

W3.8 Different structure of organizational learning
As a result of above, knowledge and experience is accumulated at key personnel that are heavily involved – rather than into the organization, through best practices and frameworks – this is a key challenge moving forwards when looking to standardize, scale and continuously improve the operations. This challenge is especially critical as the business is in a start-up phase that is radically growing – there is opportunity to try and learn as more systems are deployed, and

invest in creating a good structure and operating procedures for the coming expansion will be crucial for success.

Week 4, Language and culture

W4.1 Challenge of limited resources

There are limited resources in the business devoted to reflecting, analysing and long-term thinking and creating a structure able to capture inefficiencies, workshops to gain new ideas and perspectives and methods/processes to apply these in the field – all of these are done, but mainly when necessary or when the time allows for it. For instance, so far, the RT and MM trainings have been very spontaneous, unstructured and reliant on a few individuals. There hasn't been much tracking/control on how these trainings were conducted, what was learnt from these trainings and how they could be improved, nor assessment of the trainee's knowledge afterwards. There is likely need for further training for some of the trainees, but it's difficult to know what gaps existed in the training until they turn up as a problem in the field. On the other side it's also difficult to know what further training could be held to improve field outcomes beyond the essentials into adding more value to the business, such as an MM ability to stimulate demand and thus increase revenue. It would also be impossible for a new trainer to conduct the same training, as the current (improvised) training process is not replicable.

Another insight was that of constant change, making it difficult to plan and prepare things, schedules, timings and priorities change. This is more likely because of start-up phenomena, rather than this particular business, with the start-up running at full gear in a period where a lot of things happen at once to expand the business. But also because of the context the impression so far from Zambia has been that a lot of things are delayed, or changing, difficult to attribute to a single factor, but rather a combination of poor communication, subcontractors and logistics, power outages, internet outages, family events such as funerals, cultural holidays, weather conditions (if very hot, cannot work on site, if raining, difficult to work etc). This makes it more challenging to plan a training, and puts additional pressure on the trainer to be able to improvise, change the curriculum, change the use of teaching aids etc (such as use of computer when power is out, or field practice on utility poles when it's raining). Some are also attributed internally, because of the high tempo in the business and lack of processes and structure, materials weren't always in place and tools for conducting the training, which lead to breaks and delays, aggravated as trainers had other duties in parallel and thus unable to focus 100% on the training.

W4.2 – Labour pools of Zambia

In terms of the labour pools of Zambia, As told by a source at ILO (international labour organization) working with assessing training requirements for power sector in Zambia: "Attitude challenges is seem to exist in Zambia [according to companies that have been assessed], companies need people that are willing to work really hard, sometimes long hours , be diligent, attention to detail, follow standards companies set, especially in power sector, where safety is crucial with live wires, working at heights etc – it's difficult for some people to fit into this stringent framework that the companies require, and adhere to standard operating procedures". The way the company has mitigated these challenges has been through hiring people quickly and put them into the field as soon as possible, which shows the attitude, whereas long interview and recruitment processes gives very little information around these potential attitude challenges – hire quickly and then fire quickly if it doesn't work out, need to weed attitude challenges out from the organization to develop a culture that is aligned with the requirements of the industry (power infrastructure). The researcher cannot assess the extensiveness of these challenges, as mainly got to work with already recruited talent that did not showcase these attitude challenges, but this selection is not representative for an assessment of a complete picture of Zambia. This does however bring up an important aspect of local capacity building, 'the input' component - in how talent is identified, assessed and recruited, especially in context of a potential attitude mismatch.

W4.3 Culture

Building a good company culture is key to the success for any business, and 'a good culture' can be defined in many ways. For any start-up, the culture that emerges from the first years that will be key to the success or failure of the company with ambitions to reach larger scale. For a start-up in the power sector, attention to detail is key, adherence to standard operating procedures, safety, quality control – if any accidents happen it would be catastrophic for the business and future ambitions. The researchers experience was that the Zambian culture has British influence (being a former British colony), the culture is one of very strict and clear outlined processes for everything with zero deviation. This has overlaps in compatibility with the industry requirements. Process is prioritized, for instance in every car park in Zambia there is the need to fill in a form, and people take instructions, without knowing why what they are doing is important.

W4.4 Second Digital collaboration platform meeting

The potential use of a digital collaboration platform progressed well, it seems like an resource that can be used for last mile training, rural employees with provisioning of only simple smartphones to access training content. Adapted for offline content and low-bandwidth connectivity. The content would be in form of video modules. Features include creation of training programmes, enrol new trainees on the platform easily, check knowledge through various tests, and track user progress how many videos have watched, how users performed in tests etc. The platform also allows for content analytics, to better understand how content is viewed and received. It's a solution that would be very cheap to run and easy to scale by just adding more content and enrolling more participants, whilst having all training in one system for data analysis. A weakness is that this is a pure training tool, which cannot integrate operations management, such as task allocation, quality control, chat functionality, check lists for materials and tools, safety procedures etc into this – however the training system could be integrated into an operations management platform in the future. Integration options needs to be further explored.

Week 5, The value of local capacity

W5.1 – Building a training framework

Work was done on building a training framework, that consist within the overall 'training system'. The purpose of this framework was to list all tasks that are essential of the training for a role as a microgrid manager or regional technician, and specify which channel is best used to distribute this content (such as use of personal training, theoretical education, on-site shadowing of experienced employees, written form, such as manuals, and video modules). With on-going prospecting of a digital collaboration platform, it was particularly important to understand how much of the content would be suitable for dissemination through video modules, to assess the value a digital collaboration platform would hold. This categorization was challenging to do, as it's difficult to assess which content will be understood by someone watching a video a repeated number of times. Factors such as script and language, use of additional graphics, pedagogy (e.g. body language) of the trainer in the video are all important. As is the recipient, the one getting trained, with how they prefer to receive content and learn in the best possible way, with as already discussed, big variety in a number of ways.

W5.2 Value of training local capacity

The researcher set out to map up the value of the roles that are sought to be trained locally, based on the understanding of standard operating procedures, company documentation and experience in the field so far. The focus was initially on the key tasks that the roles need to be able to perform, for instance for the Microgrid Manager;

Essential qualities:
-understand the company, the power system, the service sold and provide basic customer service around this
-ability to use smartphone app and sell service to customers
-reporting, cash management
-point of contact on the ground, represent the company, being available

Nice to have qualities:
-Ability to stimulate demand, help accelerate customer journey to use more appliances and power
-Ability to stimulate new productive uses, for businesses
-Ability to provide and sell partnership products (beyond the company core offering)
-Ability to spot new opportunities, new productive uses, partnerships, appliances, inefficiencies etc – both by themselves, but also to relay this information from community members effectively.
-Ability to build strong customer relationships, this would not only increase sales, but is crucial for a sustainable long-term business, with system life of 20+ years.

As seen here, the essentials are important for the system to work and deliver value, where the microgrid managers are essentially the last link in the value chain between the whole power system and delivery of service to customers. There is lots of work and investment to get the system to site and get it fully operational and it's also a long-term investment, that should serve the community for 20+ years. The company's profitability is directly linked to the revenue from each microgrid, which is directly linked to the ability of the microgrid manager. This makes a case for investing in the microgrid managers beyond the 'essential' training needs. These skills, under 'nice to have' are more difficult to train and might not be possible to standardize and replicate.

Same goes for the Regional technicians. They are responsible for maintain and operate the system to optimize the asset for 20+ years, the better regional technicians can be at conducting their jobs, spotting inefficiencies and adhering to quality standards, communicate with company central operations, the more efficient the business will run. This will also result in less interruptions, optimized uptime of the system and quicker time until repair – all associated with lowered operating expense and improving the reputation and perception of the company and its service in the community (increasing sales). Together with Microgrid managers who can increase revenue, and the regional technicians, that can lower operating expenses - the two can widen the profitability margin of the business.

W5.3 Value goes beyond essential training

It's clear the training value can go beyond just training essential tasks and can radically improve the function and value of the business. This deserves to be further looked into, inquiries into questions such as, how much is it worth to invest in this local capacity resource? What would cost, how to train these tasks, how do these differ from the fundamental requirements? What would the value be? There also comes risks with this, as the employees become more experienced and trained, they can leave for other jobs.

W5.4 Recap on how the current (in progress) training programmes look

For RT (those without any trade school training or higher than upper secondary education) – 1 week training + on-the job training. For MM it's 3-day training + on-the job training. Technicians (trade school, e.g. electrical) – do 1-month shadowing with existing, experienced technician before working independently. Quality Control technicians (more experienced employees, engineering education) similarly shadowing work.

W5.5 Requirements in terms of people trained

The requirements in terms of a trained workforce can be divided into two categories; employees for deployment and local capacity for on-going operation. For deployment, for every 4 microgrids deployed need 1 QC specialist and 2 technicians – these employee requirements will scale as pace of deployment is ramped up (thanks to inorganic scaling path through grants, investors and aid money). In 2019, 8 grids will be deployed, needing 2 QC specialists + 4 technicians – next year double this growth etc to reach 150 grids in 4 years. In terms of local capacity, for each site want to have 2 microgrid managers and 2 regional technicians. This means 4 people per site (local capacity) leaving 600 people for 150 grids employed to operate and run the grids (excluding the team to deploy the systems).

W5.6 Longevity

A key question in this is also that the system operates for 20+ years. Thus, it's key that customer relationships are built for this timeframe in the community and that structures are created that address this. For instance a system where microgrid managers can work for the company for a couple of years, and then move on to other things – not expecting the microgrid managers to stay at job for 20 years – but maybe part of the incentive system that they can either climb in the company or that the company can help them move on.

Week 6, Deploying a new site

W6.1 Setting up new site in Rural Zambia

A new microgrid site that has been assessed and permitted in rural Zambia was deployed. The team consisted of 3 technicians, of which 1 more experienced, 1 operations manager, 1 QC officer. Additionally, three prospective regional technicians were helping with the deployment, and the newly recruited microgrid manager (that was part of training in week 3) was conducting customer onboarding (together with community engagement specialist).

Over 100 customers were successfully onboarded at deployment (high for the industry). Plenty of work was carried out to setup the reticulation system, switches and customer socket connections. The power system was setup by subcontractor at end of deployment. The reticulation system work took longer than estimated.

W6.2 Technical variation of customer connections

An observation was that every house that power system is connected to looks different, different planks, roof, angles etc, these designs are far from standardized. This requires the technicians to pick the best technical solution for every situation. Consequences of sub-optimal connections are that water comes into customers' homes along the cables or cables grinding against tin roof (which could eventually short circuit the whole grid) and Cable grinding against planks (eventually breaking, meaning the customer loses connection until fixed). There were several solutions used in field: the use of different techniques and materials (pig tail, porcelain shackles, wrap around plank, plastic pipe etc). A challenge in this lies in the difficulty of training this critical thinking. This becomes especially important in the context of the power system longevity, which is supposed to last 20 years, allowing no safety hazards, uninsulated live wires, electrified tin roofs or system short circuits, some of these are dangerous, and some are costly to go out and repair.

W6.3 On-site shadowing: Training vs short-term cost-efficiency

When the team was out in field deploying the new site, they hired 3 locals as future prospective regional technicians. These three worked together with the team in the field, getting to shadow the technicians in their work and learn through observation and practice. However, there is an apparent trade-off between deployment results and training. The faster and better (higher quality) the power system and reticulation is set up, the more cost-efficient the deployment is and the faster customers gets power and the system can start generating revenue. However, this scenario means that the most skilled and best technicians do the work themselves, rather than teach how to do the work, let the new recruits do work, supervise and quality control their work (a more time consuming process). To put into perspective – a new site, such as the one recently deployed, had 130 household connections, this means 130 switches installed, meaning a big overhead reticulation grid to cover the whole community, with poles and wiring, stay wiring etc, drops from the aerial reticulation system to switches and from switches to up to 5 sockets per switch, at up to 650 switches.

W6.4 Viability of microgrids

The microgrid is a costly system (hardware and reticulation), requiring many hours of difficult work to connect many diverse homes (huge number of connections required for break-even, due to generally low ability to pay). On the revenue side, it's a low paying service (due to low ability to pay of customers, inexperience of using electricity, a slow customer journey). There is thus a desperate need to both drive down costs whilst increase quality of operations. A training system for local capacity is likely a possible means to facilitate this.

W6.5 Training whilst expanding – setting up new site with new recruits

When a new site is setup, the current and new company practice of hiring regional technicians to help out for the deployment, who can observe and participate is synergistic because help of these locals increase legitimacy in the community, the system can be deployed faster (more labour) and they get trained whilst doing this. However, there was no formal agenda, curriculum or material for this practice in the company.

W6.6 Design a training system for local capacity in iterations, not a complete training system from the outset

It's difficult to predict how this kind of system would work, thus the best is to create some module or some specific training and test it in the field, learn from it and adapt, much like lean 'start-up methodology' (of getting something to field quickly and receiving feedback and developing the product/service in iterations). This view gets reinforced as it was very challenging in earlier phases to judge how to use various formats, content, how to teach and how trainees learn best. Another argument for not creating an extensive training system that's 'perfect', is because the experience that everything will changes. The current procedure of testing in small batches, like first MM training, first RT training , second RT training on-site etc, however this is more due to a lack of concentrated resources than a deliberate choice. Success with this 'iterative' approach depends though on having some dedicated resources, responsible for a central training system, where goals and learning outcomes are defined. This holistic system also needs to have processes to design, implement, test and evaluate training, as well as information on these from the iterations performed. This way this system can be aligned with performance metrics from the field and together with feedback be used to improve trainings. It's thus more about processes and a framework to systematically conduct trainings within this framework rather than development of a full training curriculum and all of the content at once. As the company learns more about the business and training needs, they can feed into this system.

Another perspective on this came from discussion with the founder of a logistics start-up in Zambia. He meant that one needs to find more creative ways to train in Africa. Holding a traditional workshop won't have the same effect in the developed world and will need a lot of work to succeed and is thus inefficient. He meant that to succeed in Africa, one needs to go beyond the traditional training methods, maybe through a dance or a soap opera, the latter which was successful in mending the wounds between Hutus and Tutsis in Rwanda after the genocide through a radio broadcasted soap opera. This furthers the idea of iterating different ways and concepts of training to find what works, rather than go all out on a big 'traditional' training programme.

W6.7 Resources and commitment

The experience is that there are little resources to conduct training, even less so to conduct training in a focused manner (usually other things done in parallel), and even less resources to think of improving training, getting feedback, etc. Thus, there are littles resources to train with a purpose, especially long-term purpose. As part of the above system, where one needs to use a more holistic approach, gather feedback on the training process, and try and document how training was conducted. There is thus some discrepancy between the technical timeline of 20+ years per microgrid system, and the business operative way of short-term in setting up systems and connecting customers.

Solutions: 1) make training high priority in business, devote resources, set goals, e.g. 3 RTs per site with list of knowledge they should possess. Show commitment from the management that this is a business priority. 2) design efficient training system, processes to conduct, evaluate and improve training. This also becomes a database where information on how training was actually conducted, feedback from surveys or post-training evaluations, and eventually correlation with various performance metrics (to evaluate the effect of training in the field) 3) have a champion that is responsible for enforcing the training system, working with developing it, ensuring training is documented, post-training feedback is gathered – and evaluating the quality of training and creating new iterations of training modules to test. This person is responsible for disseminating latest information, latest training modules, and training others on how to use the system for training. This may sound extensive, but without a champion, or a dedicated single point of accountability it's a high risk that long-term agenda such as training will always be secondary priority. 4) alignment of training priority with business resources, since there are many different types of training formats and ways to train, this can be aligned with the business operations, when a site is deployed, it's excellent opportunity for shadow training, when things are calmer (in the rainy season) centralized trainings, evaluation sessions and creative workshops can be held.

W6.8 Training others while on job to setup system

Issue with using technicians, is that they can be very good at their job, but not versed in pedagogy, this could mean they just do the work, without e.g. a conscious knowledge transfer, such as explaining why do certain way, motivation of choices made etc. Because of their skill, they can also tend to do most/all work themselves, leaving little opportunity for a prospective RT to practice. Part of these observations were also because the company hadn't formalized on-site training, that's not in the technician job description, KPIs, incentives or expectations. This needs to be integrated to improve on-site training.

W6.9 Training of trainers

This is connected to above points. It may be valuable to give technicians training on how to train others. The issue with this can be though that it's challenging to find experienced technicians, thus most technicians are also quite new to the job, and not that comfortable/skilled to train others yet.

W6.10 Integrate training and R&D

An idea also occurred in connecting R&D and training. In terms of R&D and procurement for materials, components and tools, there are many aspects to consider, with tight margins, cost-efficiency is crucial. Other aspects would be to consider having components that are easy to install, and especially easy to train RTs and MMs to maintain, troubleshoot and interact with, such as the switches which is the point at which sockets are connected, where the MM interacts to upload new power programmes for the sockets and where consumption data is gathered. The easier components are to train to maintain and use, the easier it will be to have local capacity.

W6.11 Learning curve

As for any start-up, most of the operating procedures, local capacity building, is relatively new for the company, and the speed at which the company learns, improves will detrimental in future success and survival. This phenomenon is also known as 'the learning curve' and is about how the business improves over time as it accumulates more knowledge. In the microgrid industry, the fact that there is little of industry blueprint or best practices for scaling, coupled with enormous pressure to scale to reach profitability, this has resulted in many businesses not learning fast enough and going out of business. This makes the case of local capacity building more important – as it's the practice about understanding how the business operates, breaking down and formulating this into its best practices (standard operating procedures) and the very understanding of how to disseminate this knowledge throughout the business (also into local capacity) and translating it into action. It is thus the very definition of the 'learning curve' phenomena and to take the time to reflect and put resources and thinking into this process is a very good investment. In the process of learning to explain and teach the processes of the business, the business is forced to take time to reflect and learn more about these. Especially valuable in the context of training is that by putting the processes out there to trainees, and in this case, with the diversity of people trained, there is a good chance of capturing many different perspectives and ideas. In this marriage of operational excellence and training, feedback is key to a successful scaling and leveraging of the synergies– if on the other hand this is done in a one-way dissemination without feedback and discussion – there is chance of a sub-optimal blueprint and way of working is replicated and scaled, whilst trained to local capacity who follow this blueprint.

As an anonymous source with the experience of running a successful business in an extremely challenging environment for over 30 years said "there are limited resources in any start-up, and it's paramount to commit resources financially and in terms of time to get the workforce trained well, the business needs to learn and do so fast to succeed". It's also especially crucial for a business that has received financing to scale up to 150 microgrid systems in the coming years (representing 170% growth per year), errors and inefficiencies will quickly replicate and be costly if spread to 150 microgrids sites. And with thin margins, these could threaten profitability and thus the viability of the business.

It is obvious that any business would benefit from putting resources into long-term thinking, reflecting and optimizing its processes. However, the difference why it's relevant in this case is because it's all part of local capacity building umbrella, and where local capacity building holds other benefits (such as a means for the business to expand, that is also viable through improved profitability), and thus there are strong synergies with the two.

W6.12 The QC officer role in the business could be important for training and data collection

This role or team member is part of site deployment and serve a key function to act as an external perspective, provide another set of eyes upon work conducted. The worker cannot QC their own work. As part of this, the QC can observe from distance, and literary in their job description is to ensure work has been done to standard. This role could be a link in assessing training, and transfer of knowledge – as a way of data collection, was the quality-controlled work done by an experienced technician or a recruit (prospective Regional Technician)? Which aspects of work succeeded/failed in terms of quality assurance? They could feed these aspects back to the training system to capture and improve next training. This is however also a trade-off though between the key role of QC being only focused on QC work, who with this focus and great knowledge of QC protocol and operating procedures, can act as second set of eyes to spot mistakes. In any training system though, it will be about finding roles that can execute the system processes, who will conduct training in the field? The already busy technicians without pedagogical training? And who will take the time to assess how the training is received, inefficiencies and room for improvement in the way training is conducted? Also, the technicians? And who will evaluate how training was carried out, how it was received and connect it with how the trainee has performed in the field? These make a case for extending the QC officer duties to also 'QC' training.

W6.13 Company commitment

So far, most of the work has been the researcher doing a research project on local capacity building, and put thinking into this, there is little to no incentive for anyone to focus, devote resources, thinking etc on this, it may seem as it's not seen as a key area moving forwards.

W6.14 Create culture of idea sharing

To leverage more perspectives, local RT, MM have ideas, other perspectives, know what works in their communities- however they may culturally not be comfortable sharing ideas, questioning things etc. It's reiterated from before that it would be beneficial to create and foster a culture where everyone feels they can contribute, openness is valued, also incentivized to spot inefficiencies, and do things beyond the essentials. The company has efforts to do this already, but it's especially challenging in the cultural context of Zambia, and maybe more resources or other ways to do it need to be explored – it's valuable for local capacity building, but this does go however a bit beyond this thesis scope.

W6.15 Local labour pools, how are candidates selected for local capacity building?

This is crucial for the success of local capacity building, the better candidates that are selected, the more likelihood for success, however it's also the question of to what extent Local capacity is built for the purpose of social development. Some successful regional technicians have been village electricians, which is a promising labour pool, they can get up to speed quickly, but they already have a job. Another is influential community members, such as the neighbourhood watch, their influence helps the deployment and legitimacy, and they have already likely gone through a vetting process by other parties – however, they also already have a job. Even though the business can further develop their skills and capabilities, and provide them with more income – it would perhaps be in terms of social development more impactful to develop the skills and capabilities of someone that is uneducated and unemployed. At the same time, the business must start somewhere, and starting with too grand a challenge, may diminish the faith in the local capacity building strategy and it may not be adopted for as extensive uses as if successful. A perspective on this is also the selection and choice of the local microgrid manager. The company has a policy of helping empower young women, and thus the microgrid manager is always selected from young women that apply for the role. It would likely have been easier and more profitable to choose an influential man in the community, to run the microgrid and make sales – as there is cultural inertia and bias towards (young) women providing such a valuable service in many communities. At the same time these women have earned respect of their community members, and started to reshape the cultural bias, they have the ultimate say over who gets power, if they are not treated with the equal respect they deserve, the customer simply won't get to buy power. This is once again a trade-off between short-term profitability and success of the local capacity strategy and that of social development. In the long-term, the company has the opportunity to radically help social development by changing perceptions in terms of women inequality and by investing and providing jobs to local community members.

Week 7, A local capacity building framework starts to emerge

W7.1 A Local capacity building model

From all the empirical data, it's clear that local capacity building is a complex phenomenon, thus here the notes of how these constitute the components at this time are presented.

1) Training – initial training assessment, follow-up, extra training, beyond essentials etc
2) HR – contract, hiring, incentives, incentives, perks, conditions, recruitment process – climb ladder, bonus etc, identification of labour
3) Operations – communication, logistics, QC, QA, task allocation
4) Resources – training database, smart phone, tools, escalation path, support centre
5) Business – cost, time, resources, value/benefit
6) Social development aspect – empowerment, equality

W7.2 Synergy: Opportunity to train RTs when deploying system

It was fairly successful to test training RTs when deploying a system, they could be trained passively, by just being part of the deployment and observing, and also help out (more labour to accelerate the deployment), and help provide more legitimacy in the community, know-how of all community members and general the layout of the community, homes and facilities. However, this also took time and the process would benefit from being formalized and streamlined. Looking forwards, there is through a huge opportunity for training, as the business is rapidly expanding, with many sites deployed. Instead of having regional technicians transported to Lusaka for centralized training, they can be trained whilst doing something productive (setting up a new site), thus a strong synergy. With the main challenge of local capacity building being resources constrained for expanding the business, the ability to build and use local capacity in the very act of expanding is highly synergetic.

W7.3 The initial skill level and ability to learn of RT and MM will vary a lot

This was apparent throughout the research period, where new RTs and MMs where recruited. Some had very high initial skill levels and some learned very quickly from training. The attitude and willingness to learn also differed between candidates. This will be a challenge to adapt training around.

One possible mitigation or synergy of this phenomena is to use local capacity that learns very fast and becomes successful in their new roles as trainers of other local capacity. It can be psychologically powerful for someone recruited for the MM role, to be trained and see the journey another MM has done, it's easier to relate to them and their journey – rather than be trained by a highly skilled worker, with years of working experience form the company headquarters. Thus, they can feel they can also learn the job. Also in the process of teaching others, the local capacity will likely also improve, and get another perspective on their role and the processes they perform every day at work, this perspective can lead in a similar fashion to ideas for improvement and refinement (as discussed already could be beneficial to have for the company when formulating the initial training content). By observing the training of one local capacity to another, the company also learns, what the MM for instance puts emphasis on when explaining and training another MM, and which aspects they are hesitant to explain or that may be challenging. This experience and data can be fed into the holistic training system for further optimization. This kinsman ship of training and helping each other can be elaborated into a network, community amongst the local capacity, as a means for supporting each other but also finding friends (this would be part of the incentive systems).

W7.4 The value of a training system extends beyond local capacity to train the entire workforce

In advanced meetings with deployment of the digital collaboration platform, starting to plan and design courses and create roles, it was immediately very clear that this can be extended beyond local capacity. It's very easy to use this system to create other categories, training modules and enrol users (other employees). It's a realization that this is a very good way to disseminate important information and knowledge in the company – especially in a start-up, where a lot of things are done manually, knowledge spread through verbal communication/training, spontaneous/ad-hoc employee on-boarding , training/knowledge transfer connected to certain personnel. Instead in a centralized training system, all employees can contribute to what knowledge gets disseminated when designing training modules – and then these can be easily assigned to employees. Thus, it's possible to create a standardized on-boarding programme, safety programme etc – and also track the knowledge level of the employees through analytics. Another benefit with this kind of system, is that no time is required to 'train', only the time to create the initial videos – thus strong economies of scale exist when distributing to tens or hundreds of employees. The use of videos also allows for automatic standardization – if someone, or even different people are conducting training – it will always vary – whereas a video is always the same. This could be particularly useful for RTs that require highly standardized training, and for the 80% of MM training that could be standardized. By having a training curriculum/programme – can also ensure that everything is there, whereas a spontaneous training, might miss certain stuff. There is also the bigger picture of how information is stored and disseminated in the company, how far could this be taken? An Interesting interaction is between the written SOPs (current way to store and disseminate knowledge in the company) and Video modules that could replace or reinforce these. Could potentially be used as a knowledge database for all information in the company.

W7.5 Is it really local capacity building?

A thought that occurred, was that there is such emphasis on optimizing the training of the local capacity to deliver as much value as possible in their new role, value for the company. The company still possess the central knowledge in-house, learn from those that are trained, and train for very specific company purposes. Do they really become empowered or locked-in to work for the organization which perfectly aligns with their developed capabilities and skills? Is it then really a matter in developmental terms of capacity building? Which is defined as developing the skills and capabilities of people so that they are empowered and can get new opportunities? Is the training done for their best, or the company best, or a mix of the two? This of course all depends on how capacity building is defined, which as outlined in the literature review, and at its best is an ambiguity between company capacity and social development.

Week 8, A week of final reflections

W8.1 Granular field Data from operations to improve/evaluate training – powerful feedback loop system

An important aspect to evaluate or improve a training system is to know how the local capacity is performing. Currently, as in any start-up, most data collection/performance measurements from operations and sales are collected through technology or manually. Such as sales metrics in terms of customers, their power consumption, revenue, appliances are all very detailed – but these could be improved, as these only paint part of the picture in relation to what the MMs are trained on. Sales and customers service skills are vital part of the envisioned training, and these would suffer if only evaluated through part of the picture, the final result in terms of revenue. A more nuanced picture would be to understand how many customers in their community they visit a day, number of interactions they have etc – to fully understand their sales process, how this sales process correlates with how the training is designed and also how this correlates with the final sales numbers.

A possible feedback system could have the following components;

a) The training, how, when, where, what content is disseminated to the MMs
b) The actions of the microgrid manager, number of interactions, proactive or reactive (going to households or having customers come to them) – what packages/offer given to customers initially etc (nuanced field data)
c) Incentives – to control the MM in certain ways, perform certain tasks etc – performance measurement systems KPIs etc
d) The actual outcome, final revenue metrics, revenue ramp rates, churn, retention rates

This is a powerful system of feedback loops, to understand how training correlates with the actions of the microgrid manager, and in extension how this correlates with the final outcome (revenue). This system can be used not only to improve and optimize training, but together with incentives control the actions of the MM. In this way – the outcome and process can be used to evaluate and improve the training system – and changes to the training system can be traced in the outcome – both reinforcing each other.

For Regional technicians, a similar system could be formulated;

a) The training – how, when, where, what content is disseminated to the RTs
b) The actions of RT – how they work in the field, Qc, how identify problems, how solved the problems etc
c) Incentives
d) Actual outcome – like ‘system is working’ or how long until system issue and thus a very long-term thing – It could be without issue for 15 years, or just 1 month without an issue– it could be a minor issue, like a customer that could be without power if not resolved, or a more sever, like the whole grid is down for a long time. Because of these differences it’s very important to understand that the process has been followed, safety adhered to – to be able to evaluate if the actions/work has been performed correctly.

W8.2 Creation of the McDonalds of microgrids

By learning to train and build local capacity in RT and MM, and working with an extensive training system for doing so, a business that has a proven track record, is replicable and highly scalable and low cost to run, is a vital part of a potential franchise model. One of the most complex aspects of operating microgrids are the operations. If two of the key operative functions (technical function and customer function) can be easily trained (through RTs and MMs), by also mitigating the challenge of finding skilled people – with additional benefits of local community legitimacy, social development in local job creation and women empowerment, as well as better profitability margins – the prospect for a 'business in a box' is much more attractive. Especially in the context of no industry blueprint for operations in microgrids and challenges for many players to scale their microgrid businesses - a Local capacity building recipe, is a key piece for the prospects of franchising, and diffusing microgrids in the future. The potential of franchising is one that is powerful and could accelerate rural electrification rates across SSA and also do so in a sustainable way by being built upon local capacity as a corner stone and the creation of local entrepreneurs in local markets as the franchisees.

W8.3 Digital collaboration platform for rural capacity building

The microgrid company partnered with the software developer to use their rural development platform. This is a digital platform for capacity building. Training programmes can be created, content uploaded such as videos and PowerPoints, and quizzes. New users can easily be enrolled to the classes created, their knowledge assessed and given certificates upon completion. Analytics feature allows to track users training progress and results. The platform is highly scalable. The platform has successfully been used to help clean up the cities of India, in a project called 'Swachh Bharat Mission', a collaboration between the Indian Ministry of housing and urban affairs– The results are astonishing; with 110,000 municipal functionaries trained in over 4000 cities, to disseminate information and best practices on waste management.

W8.4 – Partnership synergy

There is a potential synergy for partnerships beyond the core offering through the development of LCB. In general in rural SSA there are many companies that are trying to provide various services and products to rural communities, but they all work in silos, independently and there isn't a lot of collaboration going on. This means every company has their own costs and processes for assessing sites, recruiting personnel, training a workforce, to establish distribution channels, provide customer service etc. This is what is driving overhead costs and making its so expensive to provide these products and services to remote areas. With the microgrid company building local capacity, having a grid in the community and establishing customer relationship and community know-how already, this network of remote sites can be used to distribute valuable products and services for other companies as well, such as cooking stoves or selling electric appliances (that also hold synergies for the microgrid business revenue). Through this collaboration economies of scale and scope are leveraged, as costs to establish this infrastructure (of local capacity) are shared over more products and services.

This becomes especially powerful with the development of a digital training platform. Such platform is highly scalable, the cost of enrolling additional trainees or add additional training programmes is very cost-effective, such as that of a new training programme for new product or processes of a new partner. The digital training platform, which has been designed as part of LCB to be optimal to disseminate knowledge and develop new capabilities of the local microgrid manager of the community, can add the additional courses from the partner company and thus build capacity at the microgrid manager to sell their products or services too, they can thus offer a more valuable service to their customers (offering a variety of different services) and earn more money themselves (from commission on multiple products or services).

Exit interviews
At the end of the two months, interviews were held with company employees key to the LCB project. These interviews were semi-structured where employees were inquired about how they would answer the research questions, such as the main challenges and opportunities to LCB, and what they perceive as the key components. Interesting topics that emerge were further elaborated upon. The interviews also inquired about specific empirical findings from the eight weeks above. In the next section, interview findings, where applicable are linked to the individual resulting research propositions. In the presentation of the results, it is noted where the interview findings contribute. The employees interviewed were the CEO, a community engagement specialist, the operations manager, an experience technician and a newly hired technician. The findings from these interviews are not presented here due to their limited role in the research coupled with their extensive nature.

Chapter 5

Results

In this chapter the results of the research will be clearly outlined and described. The empirical data from the previous chapter was sorted and classified into categories deemed critical to the development, implementation and running of local capacity building, this data analysis is outlined in the first section. In the second section the results to the research questions are presented.

5.1 Data analysis

The data analysis was guided by the two research questions, looking to categorize the empirical findings of chapter 4 into key components, opportunities and challenges. The results of the data analysis are presented here, the process used to conduct the data analysis is explained I section 3.4.

Presentation of the data analysis

The tables 2, 3 and 4 below present the data analysis for the research questions. Three parts of data was used in the analysis. Data from section 4.1 is denoted by a simple X in the table. Data from section 4.2 is denoted by WX.Y, specifying the week and number of data in that week. The interview contributions to the results are denoted, ET, TE1, CEO, CES, OM.

<u>Interview denotations:</u>
CEO: Chief Executive officer, since 2013
ET: Experience Technician, 1 year in company
TE1: Technician 1, newly recruited
CES: Community Engagement Specialist, newly recruited
OM: Operations Manager, 1 year in company

RQ1 data analysis

This data analysis was guided by the first research question.

"What are the main challenges and opportunities to a local capacity building strategy for a microgrid business?"

The challenges and opportunities were faced when conducting the AR to develop and implement LCB. They were also born out the researchers' reflections and observations on the future of LCB. The two tables below outline the categories of challenges and opportunities, and their origin in the empirical data.

Table 2: Data analysis of empirical data to identify the challenges of LCB

Research Question 1a: Challenges of Local Capacity Building					
Empirical source	**1: Having the resources**	**2: Language**	**3: Huge variety**	**4: Complexity**	**5: Certification**
Phase I					
Week 1	W1.4	W1.4	W1.1, W1.4	W1.2	
Week 2				W2.1, W2.4	
Week 3	W3.1	W3.3	W3.4	W3.8	
Week 4	W4.1		W4.1		
Week 5					
Week 6	W6.7, W6.13		W6.2		
Week 7			W7.3	W7.1	
Week 8					
Interviews	ET, TE1, CEO, CES	CEO, CES, OM, ET	CES, ET		OM, ET, TE1

Table 3: Data analysis of empirical data to identify opportunities of LCB

Research Question 1b: Opportunities of Local Capacity Building					
Empirical source	**1: Increased profitability**	**2: Sustainable development**	**3: A community of local capacity**	**4: Synergies within the company**	**5: Synergies beyond the company**
Phase I	X	X			
Week 1					
Week 2					
Week 3			W3.6		
Week 4					
Week 5	W5.2, W5.3				
Week 6	W6.4		W6.14	W6.3, W6.5, W6.8, W6.11	
Week 7	W7.4			W7.2	
Week 8					W8.2, W8.3
Interviews	CEO, OM, TE1	CEO	CES		

RQ2 data analysis

This data analysis was guided by the second research question

"What are the key components to scaling a microgrid business using local capacity building?"

The key components are defined as any component that is critical to either *develop, implement* or *run* local capacity building as an operative intervention to scale a microgrid business. The component can be some physical system, process, philosophical perspective, or resources. There were many more components than mentioned here and this is a synthesis of the most frequently occurring and critical ones. The table below outline the categories of components, and their origin in and relation to the empirical data.

Table 4: Data analysis of empirical data to identify the key components of LCB

Research Question 2: Key components of Local Capacity Building								
Empirical source	**1: Resources & commitment**	**2: Labour pools**	**3: Standard Operating Procedures**	**4: Design of Training system**	**5: Operational Integration**	**6: Feedback Loops**	**7: Incentives & Motivation**	**8: Digital Collaboration Platform**
Phase I		X	X		X			
Week 1	W1.4		W1.1			W1.4		W1.4
Week 2				W2.1	W2.3			W2.2
Week 3	W3.2			W3.4		W3.5, W3.7, W3.8		
Week 4		W4.2						W4.4
Week 5	W5.5			W5.1				
Week 6	W6.7	W6.15		W6.3, W6.6, W6.9		W6.12		
Week 7								
Week 8						W8.1		W8.3
Interviews	ET, TE1, CEO, CES, OM	ET, TE1, OM		CES, OM, ET	OM	CEO, CES, OM	CEO, CES	CEO, ET

5.2 Answers to the Research Questions

In this section the results to the research questions are presented. The results are a synthesis of the empirical data, as shown in the previous data analysis section. For the interested reader the data analysis tables (section 5.1) show the origin in the empirical data of each research proposition for further reading.

RQ1: Five Challenges and five Opportunities to a local capacity building strategy

Answer to research question 1: The challenges and opportunities to a local capacity building strategy	
Challenges	**Opportunities**
1: Having the initial resources	1: Improved profitability
2: Language	2: Sustainable development
3: Many forms of variety	3: A community of local capacity
4: Complexity	4: Synergies within the company
5: Certification	5: Synergies beyond the company

Challenges

1. **Having the initial resources**. This challenge was apparent throughout the research period, the company showed strong commitment to the idea of LCB, but in execution it was difficult to find the necessary resources (mainly the time and attention of key personnel), even in the context of very promising early signs for LCB. The start-up was also characterized by a very high tempo, making it difficult to plan things far ahead, and ensure the proper resources in place. This impacted the LCB project, training was often not prepared for, and rather improvised and conducted on the spot. Without the researcher devoting time to study and reflect upon training and other tasks, this analytical thinking, would likely not exist naturally in the context of the other things going on. LCB is also a long-term strategy, requiring plenty initial resources to develop a training system, training content, conduct and evaluate trainings, to get to a standardized blueprint that then brings the promise of lower operating expense, these initial resources to accelerate or even succeed with the project are a challenge to acquire and it's easy to underestimate the amount of work and focused thinking required. This challenge is especially evident in the context where LCB is in its infancy, and the success is yet to be evaluated and validated over the long-term. With little resources to train with a purpose, especially long-term purpose, this challenge of not having enough resources may impact early results of LCB, and thus the motivation to carry through the strategy. In a wider sense, this makes it risky to devote resources, until some microgrid player has proven the viability of the LCB strategy. The CEO (CEO) reiterated this challenge of prioritizing LCB as an important and non-urgent task, in context of several important and urgent tasks happening. Several other employees said this was a challenge. It was also clear from interviews that when resources for LCB and training are lacking, employees become insecure of the company commitment, and to what extent they should engage in the strategy.

2. **Language**. It emerged during the first microgrid manage training that the trainees preferred to learn soft skills (how they interact) with customers and have discussions around this in their local language (Nyanja in this case). Whereas the company language is English, with the language for communication, all correspondence, and documents written in English. Locally in Zambia there are three main languages (Bemba, Tonga and Nyanja), where most people speak only one of them. This led to challenges for collaboration and communication during training and in terms of content preparation. This also brings up the question of which language is the most effective to train in? If a MM communicates with their customers in Bemba, it is an extra step to learn and comprehend things in English, and then having to interpret that in Bemba, with already training and transferring knowledge being a challenge, this added step of interpretation may be unfeasible. In terms of language, there is also the issue of illiteracy, which is widespread in rural communities where the microgrids are typically built. The issue of illiteracy is also apparent in terms of 'computer illiteracy' or 'smartphone illiteracy', where most are not used to operate this technology. The consequence of this is that certain content cannot be disseminated through written manuals or powerpoints, but rather through training videos or practically. These issues become even more nuanced when considering the specific vernacular for the power sector, which takes time to get used to for someone not used to dealing with electrical equipment, there are also specific bespoke terms in the business – a consistent vocabulary is key, and for someone not used to communicating in English, using these terms, there is chance for misunderstanding, communicating effectively is very difficult as the CEO points out in the interviews. With the level of and attention to detail required to succeed in the industry, small misunderstandings can cause huge issues. With the issues of vernacular, and technological illiteracy, along with few speaking English as their main language, there is a lot of overhead to small issues trying to decode what is meant.

   In addition to this, there is a skill gap in training complex engineering to low skilled labour. Most local capacity recruited don't have education beyond upper secondary school, specifically no trade school training, such as electrical training. Neither are they used to working with electrical equipment, due to no electricity access in their local communities. As the Experienced Technician interviewed put It, training someone without prior knowledge in electrical is a huge challenge by itself. This skill gap adds to the challenge of training as iterated by the trainers in the company.

3. **Many forms of variety.** This was the most frequently occurring challenge, where variation was experience in different ways throughout the research period. This is a big challenge because part of the assumptions that goes into LCB is that things can be standardized, replicated and trained at scale. Variation challenges those assumptions.
   -The initial skill level of the trainees varied, some picked up the job in hours and could do work with next to zero supervision, whereas for some it took longer.
   -The trainees also have different personalities, in terms of personality, some are proactive and engaged during training, they are not shy to ask questions and want to try things practically, whereas others are more shy and reserved.
   -Different abilities to learn, both in terms of illiteracy, where some cannot learn from a written manual, but also the general ability to learn, some pick up concepts faster, and others take more time.
   -There are also different community dynamics, this means that the content, or work processes in how to best perform the job varies from community to community.

However, this variety will be faced by all microgrid companies likely, and LCB is likely a good strategy to address this variety by developing localized capacity, managing and accommodating this variety is still a challenge.

4. **Complexity of LCB.** It was apparent early on that LCB is a complex system, consisting of multiple components (as shown in the answer to the second RQ). Throughout the research many different topics were inquired upon as they were found to be highly relevant to LCB. This complexity extends to several areas of the business, that are interdependent with LCB, such as operational performance data, necessary to evaluate the performance of local capacity, along with logistics to ensure materials and tools are in place for the local capacity to carry through a task. This requires interdisciplinary competencies in the business (such as personnel concerned with training, HR, operations management etc), and also a holistic point of view on LCB, to understand how it works with all affected areas of the rest of the business. This complexity is a challenge to manage, as is apparent in this research, with the need to inquire upon many different areas. Thus, without someone dedicated to working with LCB, having this focused holistic approach to understand and develop LCB, integrate it with the rest of the business, its likely to fail by individual components not properly integrated.

5. **Certification.** The legislative issues of certification needed to offer more advanced work to local capacity (thus offer a possible career path within the business) could prove a challenge. This emerged as a possible challenge through the interviews, that didn't emerge during the field research, since this was iterated independently by several employees interviewed it is considered important to include. This is connected to legislation, in even if RT are trained according to industry and safety standards in Zambia, and follow processes to execute this work and conduct QA and QC – they need to get certified in this process by an official institution. This could become an opportunity though if the training programme is aligned with a certified programme and is approved, they can get certified in the training process at the company. This certificate is valuable to them beyond the company duties and would be a good incentive – it may require some additional training that goes beyond those of the key tasks in the business. However, if not resolved, it could be a risk where the company is liable if an uncertified technician is found doing faulty work.

Opportunities

1. **Improved profitability.** This opportunity was one of the driving factors for instigating the LCB strategy. As many microgrid players struggle with high operating expenses, LCB provides an opportunity for significantly lower operating expenses which would be key to be profitable at larger scale and thus key for a sustainable business expansion. The use of decentralized (and local) capacity also improves operational efficiency, as someone locally can quickly attend to a problem and try and resolve it, this is not only cheaper, but also higher level of service. The alternative is to send someone from central offices, pay for their wages, car insurance, fuel, use of car, and many hours to get out to a remote rural site, potentially an overnight stay and getting back. This is inefficient and costly, yet the main way microgrids operate. The more of the work of operating and maintain the microgrids, selling power and providing customer service that can be done by local capacity, the lower the operating expenses. Several key employees iterated this through the interviews as the main opportunity for LCB. While it holds opportunity to capacitate local resources, the

process of building this capacity is challenging and time consuming, the balance of these costs will thus affect the final profit margin. This value was not quantified in this thesis as the data was not yet available (due to LCB in its infancy and lack of quantitative data).

It emerged that the value of LCB goes beyond training the essential skills required, and by adding more resources and investment into the training system, the business can gain much more back. For instance, if looking at the point of view of cost accumulation throughout the value chain. In exemplific figures, 99% of the investment is put into the system design, power system hardware, deployment of system and installation of reticulation system, connection of customer homes. The final link to extract all value from this investment and remaining 1% of the investment is the microgrid manager who provides customer service and sells the service to the customers. The revenue acceleration as well as amount of revenue is directly proportional to the ability of the microgrid manager in terms of building customer relationships and making sales. There is thus a strong case to invest even more than training the essential skills and develop the microgrid manager. If looking at the system life cycle, of over 20 years, 1% of this time is about site assessment, permitting, deployment, whereas 99% is about operating and running the system. The more efficient this running part is, as well as ensuring that it actually does run for 20 years, which is up to the RTs – maintenance, repairs, spot inefficiencies, system diagnosis etc, the higher profitability of the system and over 20 years, this makes a big difference in returns. There is thus also a case to invest into developing the RTs. This additional investment into the two roles will develop their capabilities and thus the profitability of the business.

2. **Sustainable development.** In a wider sense, the fact that the systems run solely on clean and renewable solar power, replacing charcoal, fuelwood, kerosene, candles and other inefficient and dangerous sources, is good for health, the environment and giving households more benefit for a smaller share of their disposable income. The systems are also built in rural areas with people living in poverty, areas that are neglected by the national grid, and in a country where close to 70% enjoy electricity access in urban areas and only 4% in rural areas, this is important for equality. If LCB helps facilitate the diffusion of microgrids, its already sustainable development.

   In terms of social development the LCB strategy specifically will foster local job creation, gender equality and empowerment of young women (thanks to the company policy of only hiring young women for the MM role, which is changing how they are perceived in their communities). The fact that these aspects also increase the company legitimacy in the local community also shows great synergies to further this strategy. Beyond this, LCB is not only about local job creation, it's also about developing a capability in the company to train, invest and develop the skills of this capacity, people living in their local communities. The whole system of LCB is about optimizing how to train low skilled labour in rural communities of Zambia. This is what Powering Africa by Empowering its people is about. The mechanism for scaling microgrids using local capacity, is directly proportional to investing and development of this capacity by the company.

   This opportunity of sustainable development was not further inquired upon during the thesis, other than factually that there is a positive social development from LCB (and microgrids), and the focus of inquiry was one the business side, to make LCB viable from a business perspective – would increase its utilization, and thus its side-effect of social development.

3. **A community of local capacity.** An interesting idea is to create a community sense amongst the local capacity, where they can bond, this had already been proven powerful between the microgrid managers, who formulated a sense of kinsman ship and feeling of being part of something beyond themselves and their community. It's also valuable to the business that these bonds grow stronger, as well as that they can use the network to support, help and motivate each other. There are plenty of opportunities in creating this community, it can also extend to a higher meaning, in for instance aggregating and showing data on how many people they have together provided electricity to, or create leader boards and competitions to further motivation.

   The local capacity can train each other. This frees up other personnel in the business (the workforce is thus expanded), but primarily it has the potential to create a bond between the trainees, importantly psychologically it can be powerful to facilitate learning as a microgrid manager being taught by another microgrid manager can relate to their journey and feel that they too can learn and master the content. By training others, the local capacity conducting the training is also forced to reflect upon their learnings and what they do, which can lead to insights and improvements.

   By creating a culture of openness and idea sharing, local know-how can be utilized. There are many different ideas and perspectives with the local community members (that are trained to local capacity), that are valuable to extend the knowledge of the business, such as their understanding of their community dynamics or how to best conduct sales to the customers. There is a challenge in creating a culture of openness and idea sharing, but if this is done, there is also plenty of opportunity. If these are fed into the way the business operates, it becomes more of a business of the local community members and their ideas and perspectives, and less of an American start-up in Zambia. This is easier said than done but holds potential.

4. **Synergies within the company.** It was apparent that multiple synergies exist with developing a system and processes to optimize knowledge transfer and skills development.

   The development of a good training system can also be used to train employees beyond local capacity, such as all employees in the microgrid business. The learning from assessing training needs, preparation of content, conduction of training and evaluation of training for the local capacity, can also be used to the benefit to optimize training for other company employees, with likely economies of scale effects.

   The creation of processes and optimization of these is part of LCB, the creation of a training system requires the company to think and reflect upon the operating procedures that the business and its operations are built upon. This is valuable for any business, but the time is not always there for especially start-ups to engage in detailed long-term improvement. The fact that this is forced as part of succeeding with LCB is highly synergetic, as this would likely accelerate the learning curve effect to do this early and systematically, especially in the context of a business that is scaling, the way things are done quickly becomes replicated to a larger scale, where errors can be costly, and efficient practices deliver the economies of scale sought. This is reinforced by integrating feedback, ideas and perspectives from all local capacity trained into this process of improvement.

   On the job training is an effective approach when deploying a new site, new recruits get the chance to observe experienced technicians (taking no time of the existing workforce), and they get to practice and help setup the site (takes some time, but also throughout the deployment, get more time back in terms of additional labour), whilst their use also increases community legitimacy, and their local community know-how can be useful during the deployment. This approach to training was thus highly synergistic with optimizing deployments, and as the business was in the midst of managing the balance of building local capacity, as well as scale and deploy sites at a high pace.

5. **Synergies beyond the core offering.** There were multiple synergies that extend beyond the core offering of the business from developing LCB.

   The first is that of Franchising, which could be an even more powerful way to diffuse microgrids in the future. Due to the industry struggling to find success in scaling a business, with a lack of operative blueprint, having a business with a solid track record at scale, and that is built upon the mechanism of LCB in mapping operations, converting these to trainable content, and train local capacity (with low initial skill levels) to execute the operations of the business. This is a very good fundament to have if entering franchising, which is basically built on the ambition to create and optimize an operative blueprint, which is what local capacity building is about. The current scope captures two of the main roles required to operate and maintain microgrids in in technical and customer capabilities.

   There is a synergy with partnerships and LCB. Many players (general beyond microgrids) are looking to provide products and services (such as clean cook stoves, electric appliances) to rural communities, however, it's costly to establish customer relationships, infrastructures and distribution networks, this overhead makes supply to these communities costly. LCB build local capacity, establishes a relationship between them and the microgrid business, and they in turn have an existing relationship to their local community peers. Additional training on partner products or services can be added to the digital training platform, and the local capacity can learn to provide these to customers in addition to manage the microgrid. This leverages economy of scope and the overhead costs are distributed over a greater number of products, leading to lower prices for the rural customers, and improved profits for the suppliers. The incentive for the local capacity lies in the ability to provide their customers with a greater choice, along with further commissions from selling multiple offerings.

   Another interesting aspect moving forwards would be to create a 'university' on the digital training platform. This is same as the partnership synergy that leverages economies of scope effect. In this sense, the company already has an existing relationship with trainees, an established infrastructure to disseminate knowledge and assess knowledge and possibly also the authority of issuing certifications. The trainees are used to learn from this system – thus adding personal development courses that extend beyond that of the core business skills and capabilities, would further the 'education' and social development aspect – to a low additional cost. This approach would in turn improve the labour pools of Zambia, benefitting the company.

RQ2: Eight Key components on what is required to use local capacity building to scale a microgrid business

Figure 18 shows the eight key components and how they are related to each other. This figure is a simplified model only used to portray visually how the key components capture a holistic view of Local Capacity Building. The first component, Resources and commitment is necessary to develop and implement LCB. Next a value chain of LCB starts with component 2, the labour (resource input), followed by component 3, the Standard Operating procedures (knowledge input), along with component 4, Design of training system (affecting how training of the labour is done). Once the capacity is trained and engages in work, component 5, operational integration is crucial (logistics of material, communication). Component 6 is concerned with evaluating the work conducted by local capacity, and creation of feedback loops to monitor and improve the system of LCB. The 7th component is concerned with the local capacity, in which recruitment, training, work and performance is highly connected to incentives and motivation. The eighth and final component, Digital Collaboration platform, allows to leverage digitalization for the system of LCB. Next these components will be elaborated upon one at a time.

The eight key components of local capacity building to scale a microgrid business

1. Resources and commitment
2. Labour used for local capacity
3. Standard Operating procedures
4. Design of Training system
5. Operational Integration
6. Feedback loops
7. Incentives and Motivation
8. Digital Collaboration Platform

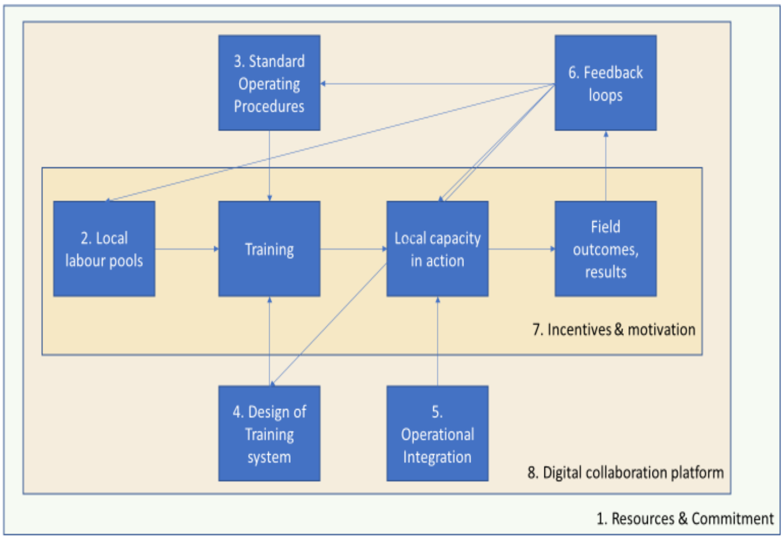

Figure 14: 8 Key components to Local Capacity Building

1. **Resources & commitment** are required to succeed, especially initial resources in terms of time and personnel mainly, e.g. by having initial workshops around the goals of what to achieve with LCB in the company, and a roadmap in how to get there. Resources are needed to create SOPs if these doesn't exist, formulate training programme and processes, as well as creation of initial training content, personnel to conduct training etc. Specifically, there needs to be dedicated resources to have a holistic view of LCB, how it integrates with other areas of the business (such as operations) and manage these interactions. There needs to be resources in the initial development and implementation of LCB, once the initial infrastructures, processes, content and trainings are held, the costs drop.

It is also important that the leadership shows commitment to the strategy of LCB and that this is formalized through processes in how training is prepared, conducted and evaluated. During the research, many employees that were part of training local capacity wasn't sure how much budget, resources or attention they should devote to this. Neither was there any formalized training curriculums, content to use, but rather relied upon them improvising the training. With other main responsibilities, training was often given a low priority, and never throughout the research period conducted with an absolute focus. Without a developed system of LCB, processes to conduct and evaluate training, and gather data from this to improve further trainings, the system is not optimized. This was clear in research as no employees were concerned with reflecting upon how to conduct training, or learnings afterwards, due to a lack of time and incentives to focus upon this. Part of this commitment and formalization is incentivizing processes connected to LCB (such as evaluation of training) and including it in job descriptions. Along with this goes allocating resources to the project and by establishing responsibility and accountability for someone to create the holistic training system. This was also reflected in the interviews, where there was some uncertainty amongst employees regards to the company commitment, incentives or responsibility in terms of preparing and conducting training. Nor was there a cohesive vision of what the goal with LCB was, or how to reach that goal, which can be explained to some extent of this project being in its infancy.

A key intervention that is a good place to focus some resources is to train trainers. This will not only enhance the quality of training, but if they are trained in pedagogy, how to asses knowledge and how to do post-training evaluations, they are able to commit and contribute more to the development of the training system. This also shows commitment from the company side, as the trainers are invested into to, reflecting the importance of LCB and them to carry out training. The same was true for the synergistic on-the-job training setup tested for the first time when deploying a site during the research period. There were many benefits and opportunities with this, but the team deploying the site all felt it was not formalized, and a bit unclear how much time and effort they should commit to this – also without a formal curriculum or processes on how to conduct training (whilst focusing on the actual work of deployment) this proved to be extra burdensome. This lack of formalization is understandable, as the company adopted the experimental and iterative approach to design the training programme, but it needs to be anchored and clearly outlined by the company that this (LCB) is a new priority area in the business.

2. **Labour used for local capacity.** A key component to any strategy looking to build local capacity is how what local labour is hired and trained. With the huge variety already mentioned in challenges in initial skills, personalities, language and ability to learn, this becomes a major difference to the requirements of training. In interviews employees said the two main attributes looked for are social skills (such as the ability to read a situation and interact with customers) and attitude (the willingness to learn and work). Capabilities that could radically facilitate the capacity building were mainly electrical, although these were rare in rural communities. Thinking put into optimizing this input, of which labour is identified by what criteria and how they are recruited can help manage the variation faced. Selecting labour accordingly to the capabilities in terms of LCB in the business, such as e.g. content formats of video training, technical manuals or practical training – all have different value in terms of which labour is recruited (depending on smart phone access, literacy, proximity for practical training).

3. **Standard Operating Procedures (SOPs).** This is a component that was a crucial condition to even start looking at LCB in the first place. SOPs are a blueprint of the way the company operates, carefully documented step-by-step of all the processes the company runs to operate the business, such as sales, customer support, installation manuals, maintenance guides etc. This is extensive work for any business to document the field work and formulate these manuals. The SOPs also need to be tested in the field to be able to evaluate if the operating procedures captures the way operations are handled in practice, and if the end result is satisfactory. They are critical for LCB because it is the input, the content that goes into the training system, in what is that is going to be trained.

4. **Design of training system.** The training system is defined as a holistic system that contains the processes and goals to carry through local capacity building training (see example of a draft created by the researcher in figure 14 (under week 2 in the empirical findings, phase II). This system gathers the training curriculums, the content, the practice, process of training, evaluation of training and how these processes feed into one another to improve the curriculum, content etc. This system is necessary because it establishes a framework with processes for employees to follow, it gives structure and direction in their daily work with local capacity building. This is particularly important in a high pace environment, characterized by complexity and many things happening in parallel, such as a company rapidly expanding. This structure ensures the necessary actions are taken and processes are followed to apply and improve the training of local capacity building.

   It was apparent early that it’s difficult to create this system entirely from the offset, the company needs to learn more by conducting more training (with little prior formalized trainings conducted) to understand what works. There was no blueprint to be found on this system, as LCB for microgrids is unexplored. Additionally, in the context of huge levels of variation (described previously under challenges) faced in terms of skill levels, ability and preferences to learn, and some ambiguity in what content, format is most efficient, it’s a better approach to test different kinds of training setups and evaluate these, to see what is efficient in terms of knowledge transfer, requirement of personnel, resources and cost. This methodology also allows the company to be more open minded to external perspectives and ideas (from e.g. local capacity or various employees) to adopt as the training system is allowed to emerge over time.

   Part of the design lies in understanding the different formats at disposal, content can be disseminated in many different ways, such as through videos, written manuals, personal training, on-site shadowing, group workshops etc. It can also be disseminated in more concentrated efforts and more intense trainings covering all content, or in batches over time, either at a certain given frequency, or when the trainee has time to by themselves engage in the content over time. The iterative design methodology is about testing and learning about these different formats, their pros and cons, how they complement each other, to be able to find a good balance and judge when to use which formats (on-boarding, first training, continuous training, ad-hoc training, personal development) and for what kind of knowledge they are most suitable (e.g. soft skills or technical repeatable tasks). This balance is about optimizing many variables, such as the power to transfer knowledge (which may be very strong in practical one-on-one training) cost-efficiency (where a video or written manual can be disseminated with no extra costs to additional users, whereas a personal training is expensive) or resource requirement (need for personnel to conduct training, on a remote site in the field, centrally at offices, individually or for a group etc). For instance, on-the-job training when deploying a new site was in this company context highly synergistic where local capacity was trained whilst deploying a site (by mere observation), the workforce extended (by capacity training practically) and community legitimacy was increased due to their involvement. Finding and understanding the formats is valuable.

As variety is a challenge to LCB, the ability to handle variation becomes a key aspect in the design of a training system, with many different kinds of variation faced, from different roles and training requirements addressed, different kinds of knowledge from theory to practical tasks, to very different initial skill levels, preferences and abilities to learn (such as illiteracy, computer illiteracy, no smart phone). One way to handle this variation is to have several formats and contents that complement each other. Another is to focus on the most universal ones. The local capacity roles are mainly practical, and not very theoretical, and most seemed to learn very well from practical training. This format could thus be fundamental as it seems universal and aligned with the job requirements and training content. At the same time, practical training is expensive, videos of a trainer showing what they do and explain, could be a potential substitute.

5. **Operational integration.** This has much to do with the fact that the capacity is remote, decentralized and that they need to cooperate with the central operations of the company. Thus, there will be logistical challenges. Who is responsible to spot and escalate errors? How are these errors, or other tasks allocated to local capacity? How do they get the tools, and in situations where needed, the materials to carry through the work? How/who ensures that work follows safety protocol when conducted? Or How/Who ensures that the microgrid manager follows the ethics and represents the company in a good way when interacting with customers and conducting sales? How/who quality controls the work of the technician? Figuring out these questions, here labelled under the umbrella of 'Operational integration' will be fundamental to succeed. One of the main drivers for local capacity is the shift from central resources to decentralized resources– the ability to carry through this approach, and the level of efficiency and value created will be down to how well operational integration is done. This also reflects well that it's not possible to look at training as an isolated component for LCB, it is interdependent on other aspects such as operational integration to work practically, part of LCB and the training will be how to communicate, escalate, conduct QC, get tools and acquire materials. This component was not inquired upon further due to LCB being in its infancy and these problems were yet not faced in practice (with lack of empirical data to support inquiry).

6. **Feedback loops.** Feedback loops are a vital part of the system of LCB. They role are to manage data flows, attribute errors, and continuously allow to improve the system. This is particularly important when conducting work remotely, using local capacity, rather than an experience company employee being on site personally. An error that occurs in the field by a RT can be subject to several factors. 1) It could be that the SOPs, the process that is trained, the raw training material that causes the error, 2) maybe the transformation of the SOP into the training content created the error, 3) possibly the act of training itself, the video, manual or trainer might have left room for uncertainty or interpretation, 4) or the local capacity could be the cause for the error, by e.g. forgetting the procedure or simply not adhering to it.

   The feedback loops thus need to be created on several levels to help attribution. Operational performance data that captures the performance of the local capacity is a starting point to monitor and evaluate the field outcomes and identify inefficiencies or room for

improvement, this can be done in terms of e.g. jobs completed, issues faced, insecure or improper work for the RT, or number of sales, revenue ramp rate, number of customer visits, happiness of customers etc for the MM. This allows not only to identify errors or inefficiencies, but also to holistically monitor the operational performance of the business. With little data for this, much needs to be done manually, such as through manual reporting, customer surveys or dialogue.
A more proactive feedback loop is already when conducting the work, processes need to be in place, such as having the RT take a photo of the work conducted, so that this can be centrally QCed as mentioned as part of the operational integration component.

A feedback loop process on another level is to evaluate training by surveying the trainees and assessing their knowledge. However, an issue that appeared is the challenge of getting feedback from the trainees. As experience by the researcher and mentioned by the CES, the input from training evaluation is limited. The CES explains this is cultural, if the trainee says they don't understand, or express that something can be improved, they may feel they are looked upon differently, that they would be gotten rid of and the company finding another person, thus it's difficult for them to be 100% honest. Another aspect of this lied in the fact that many trainees don't have the point of reference for an ideal training, they are not exposed in the same manner to company workshops and skills development seminars, thus it's difficult to express how content can be delivered more effectively, or how the trainer can improve their pedagogy.

Another important aspect of feedback is assessing the knowledge of the trainees before they are engaging in work. The CEO and Community engagement specialist iterate that the best way to assess knowledge was to conduct practical tests, simulations of practical situations, and see how they perform. This also gives feedback on what needs to be improved in terms of the training, to address specific gaps that appear through the practical tests.

Part of this is also to gather data from the field, since local capacity is used, being the eyes on the ground, its necessary to have dialogue with what problems they face in the field, potential inefficiencies, and in general their experiences. Having a system to identify problems, solve those and follow-up and engage with customers is crucial for the reputation of the business and customer relationships.

This reinforces the need to carefully think through feedback loops on multiple levels to be able to attribute errors and improve the system of LCB and training. Processes needs to be creatively created, such as having dialogue with the MM constantly or conducting practical simulations.

7. **Incentives and motivation**. Several employees said that motivation of the local capacity will be key moving forwards. The training system can be optimized, but if the local capacity is not motivated, it doesn't matter. Also, for a technical system with a lifetime of 20+ years, there needs to be demand of people that operate and manage the system for that time, necessitating a good reputation in terms of work incentives. This was not a particular area that the researcher was looking into as this question would need to be tested and evaluated over a long period of time, to understand loyalty and motivation in the long run.

   It is clear though for the role of MM, who earn a commission on the power sales, that the start is crucial, both for the business and for the income of the MM. If effort is put into connecting and on-boarding customers, and accelerating their spending on power – the MM will quickly earn plenty, and motivated to maintain this level, whereas If the start is slow, there can be a lot of work coupled with an initial low power consumption and thus low income. For the business, the time until the system reaches the equilibrium of starting to generate returns is a crucial metric. It is thus about incentivizing for the early push in the case of MM.

In terms of designing incentives, it's important to acknowledge what the local capacity values. As the CEO puts this, the motivation by money is not that high, compared to status in their community (such as being a leader, or being the one providing the service of electricity to them). Providing the service in their community, also gives a sense of pride, by helping their neighbours. Another incentive mentioned by employees was the value of a personal development programme, training and skills development in general is valuable, but the prospect of these beyond the requirements necessary to work for the microgrid company would increase motivation. Another incentive was shown to be connected to the sense of community, which was highly valued, this can be built by providing business cards, t-shirt, name badge – these also give a visible status within the community. T-shirts are particularly powerful because its clothing they can wear and show association with something that is bigger than themselves.

The topic of motivation is also highly connected to intimidation, for people living in rural communities with no education and that are illiterate, getting the opportunity to be trained to work with managing the microgrids can be motivational, but the process required to learn everything necessary, and especially seeing other employees confident in the content can be intimidating.

8. **Digital training platform.** This will be a key component in the future for LCB, even though it was only prospected and not tested in the field during this research period. Mainly because the platform can encompass much of the local capacity building training. To a great extent it replaces or carries out the processes of the holistic training system, but in a digital system, where everything is traceable and scalable. The benefits of such are to get an overview of all trainees, all courses and material, enrol trainees freely to existing and new courses, as well as follow the trainees progress, evaluate their knowledge through quizzes and exams, as well as issue certificates. There were such benefits and scale effects, that having a digital training platform even if only as a complement to other formats was considered valuable. One potential cost incurred is having to provide smartphones to local capacity, as most people in the rural areas lack these, required to watch videos online. (However, smartphones are also important in other aspects such as taking photos of their work for remote QC purposes and general communication). It is not particularly difficult or costly to setup this kind of platform, and cheap to run (of course depending on which supplier is used). Another benefit lies in the possibility to trace everything, have all data, and run analytics on the progress of trainees, content analytics and how trainees have passed exams. The big potential lies in economies of scale, where each additional training video, additional training course, additional local capacity role and additional trainee (that can access all of this). Key will be to understand how the local capacity perceives and learns from video modules, variations between them – and on the other side adapt in terms of how videos are designed, using teaching aids, graphics, a teacher, complexity, numbers, duration etc. Based on interviews, it seemed the use of video material to disseminate knowledge and train local capacity, was viable.

Chapter 6

Discussion

In this section the results of the research are discussed. First the research propositions presented in chapter 5 are discussed. Next the discussion is extended to the methodology of Action Research, the fit for this research is evaluated in the light of how it was applied. In relation to this the validity and generalizability of the results are discussed, as well as the general quality and replicability of the research conducted. Finally, the implications for practitioners, researchers and wider implications are outlined, with a specific topic discussing sustainable development. Suggestions for future research are given throughout the discussion where appropriate.

Answering the research questions

The ambition of this research was to develop an operative blueprint, which was done by taking a holistic approach of local capacity building, trying to find all necessary components by turning every stone, and the many challenges and opportunities faced when doing so. The research resulted in 18 research propositions, or summarized, guidelines, in the shape of 5 challenges, 5 opportunities and 8 key components for local capacity building.

In general the results answer the research questions very well, because of the holistic approach, extensive amounts of data were gathered, which could be analysed to identify the most important challenges, opportunities and components for local capacity building. The completeness of these also deliver the goal of the thesis, to deliver actionable guidelines on local capacity building. However, if the 18 research propositions are studied individually, they vary in quality, some are more insightful, backed my more empirical data and analysis, whereas others are simply included because a key employee states they are essential, or because they are essential for the viability.

The approach used was synergistic with LCB itself, which is highly complex, an operative intervention interconnected of several areas within the company. The holistic approach allowed to capture this complexity and outline the key components. However, as a deep dive into each of the research propositions was not possible because of time and scoping, some of the results also end up abstract, on a high-level, whereas others are more detailed.

Certain key components suffered particularly from this, such as local labour pools (2^{nd} key component), the standard operating procedures (3^{rd} key component) and operational integration (5^{th} key component). For all of these they were identified early as essential aspects to succeed with LCB, and the focus of inquiry moved onto exploring and finding other components of LCB. The amount of insight in these three results are thus quite low, only noting that they are important, but not much about what to do with them, however, this was not the focus of this thesis. A general challenge for all the results lies synthesizing extensive amounts of empirical data (the data presented in chapter 4 is only a compilation) – between doing this very specifically for the company context and details (that were not always available or inquired upon due to the qualitative nature of the study) and that of trying to find more universal or general insights.

Other components suffered because they were still in their infancy, such as the digital collaboration platform (8^{th} key component), that was not yet launched during the research period, and thus not allowing an evaluation and insights around how to actually use the platform in practice. In challenges the 5^{th} challenge of certification, along with most of the challenges, and the 7^{th} component of incentives and motivation, emerged late or at the very end of the research, limiting the time to inquire further upon these.

A more targeted inquiry looking to understand each research proposition at a deeper level would of course generate further insights on the specific component, however that would also mean that the system perspective on LCB would likely be lost in the details of a few components, failing to identify all key components and likely resulting in generating fewer general challenges and opportunities. The inquiry was instead to turn every stone and understand what is and what is not important and formulate these as key components, along with challenges and opportunities that help address areas that were not deeper explored during the research, but that can be important in the future. In this ambition, to capture the entirety of LCB, and synthesizing this into actionable guidelines, the research succeeded.

The holistic approach can also be argued to be more valuable in context of the research space of LCB, which is entirely unexplored for microgrid businesses. This approach builds a wide foundation on what LCB is, rather than focusing on a particular area (such as a specific component or part of the business), where it is argued in the context of the research results, that LCB must be understood on a holistic level to succeed. The results will help future research in the area of LCB, giving this research a good foundation to understand what *LCB* can be, and in the context of this choose methods of inquiry and scoping.

The specific study context and research process also outlines the journey on the project's development and implementation in a small-scale microgrid business expanding rapidly. This process also holds the value of understanding organizational change in a small-scale business growing rapidly as reflected in the opportunities and challenges. The 'What' of LCB shows how each aspect of the organization needs to be integrated for such a transformative organizational change project to succeed. Action Research does not strive for generalizability, but rather for contextually dependent contributions to reality. The development of generalizable results, free of context, would thus fail to deliver this goal of AR. The results may be applied in other contexts, but to what extent this is possible is left to the reader to assess.

Is it valuable to engage in Local capacity building?

This is a key question for practitioners and future research. And while this research has not been specifically designed to look at the quantitative value of local capacity building, but rather as argued for deliberately focused on qualitative questions in how to engage in local capacity building, it was impossible to do this study without being exposed to this question continuously, as the researcher and business constantly asks this question and tries to evaluate this by understanding the opportunities and challenges associated with local capacity building. Understanding the potential value of local capacity building, is what drives decisions for what steps, and what stones are turned next. An issue in a quantification such as the operating expenses previously versus those of utilizing local capacity is difficult, since LCB is in its infancy and such quantification would be highly speculative before knowing the extensiveness of LCB, what is required for LCB (which was the purpose of this study), the cost of running such system and how the future operating expenses for local capacity look like. Along with these a certain time horizon practicing LCB would be needed to give a fair prediction of its value and viability. This quantification of LCB, and understanding its value from a quantitative perspective, is a future research area, that could further the understanding of LCB from a monetary sense, and further the interest to undertake such strategy for practitioners if it turns out to be able to deliver strong value.

For an indication of the value of LCB, one implication was that the researcher was hired as the new 'Country Manager', responsible for the business in Zambia, it's current and coming expansion, and specifically by further developing Local capacity building as a means to expand. This reflects the business continued interest in LCB and affirms that LCB holds potential value.

There were plenty of opportunities, and likely many more to be found

An interesting aspect occurs from studying the data analysis table (section 5.1). It appears that all challenges emerge quite early in the research, whereas the opportunities appear in the last few weeks (other than the two initial opportunities of the project of LCB, in increased profitability and sustainable development). In terms of the components their emergence holds no significant pattern. It is likely that the challenges emerged early because of the researcher getting immersed immediately in the high-pace, resource low, environment, and the project of LCB instantly became much more complex than initially predicted. The challenges of these facts thus became apparent early. In terms of the opportunities, first what LCB is, and the main components that constitute it need to emerge, and from this understanding, it was possible to understand what possible synergies the project of LCB, and its specific components, holds within and beyond the business.

Overall, there are many positive effects that come with the focus on LCB that have huge opportunities beyond the work carried out by the local capacity in their new roles. Synergies with other partners, education, with organizational learning, and potential future franchising and sustainable development. This also makes an assessment of the value of LCB difficult, with its many externalities and spill over effects, difficult to quantify. Especially as noted, all opportunities (other than the initial driving ones), emerged at the end of the study, meaning the likelihood when diving deeper into LCB and exploring what it can be, would result in more opportunities found.

Sustainable development

This topic has not been that much in focus of this thesis, much because a business needs to first and foremost be profitable, deliver returns, to acquire capital needed to expand, to be able to diffuse microgrids. If the strategy used to achieve that profitability relies on recruiting, training, developing and hiring people in the local communities where the systems are built, which is what local capacity building is about, there is a highly positive side effect for sustainable development, and specifically social development.

Specifically in terms of social development, the synergies through LCB could have far wider reaching consequences for rural development than just job creation and capacity development, as the system of LCB can leverage economies of scope and scale to disseminate products, services, and educate people.

Social development – is it really capacity building?

One of the unquantifiable benefits of the LCB strategy is that of social development. As mentioned in the introduction, there are numerous benefits with building microgrids for health, social progress and the environment (renewable power replacing non-renewable energy). Specifically with LCB at the very core lies local job creation, this is what LCB is about, but it's not only about creating a job, LCB takes it further by investing in training the individual to thrive in their new role (mutually beneficial for the business). The question though in 'is it really capacity building?' lies in the perspective and the ambiguous definition. In development terms, capacity building is characterized by building the skills and capabilities of an individual, such that they can access and leverage new opportunities – it is thus highly connected with empowerment. In business terms, it's about developing the skills and capabilities of the business, so that they can improve (such as implementing lean in an organization). Why this is a question lies in the fact that why are the local community members trained, for what purposes, and with what content? The training is optimized for them to excel in their new role within the business, they are not trained so that they are empowered to find other opportunities beyond the business. Thus, it is not entirely capacity building from a development perspective, whereas from a business perspective it is. The important thing to note lies in the difference between investing and training these individuals, giving them a job, versus managing the job by bringing in someone already trained from outside the community – speaking for the positives of social development of LCB.

Above is particularly important for a microgrid, that becomes a key resource in a community, that did not have access to power before. The community becomes highly dependent and invested in the microgrid and it's operation, and with a LCB strategy, the company becomes dependent and invested in the community members operating the microgrid and the community in paying for the continuous delivery of the power service. This helps balance the power dynamic between the company and the community and forms a more symbiotic relationship. This is a unique relation, where as a contrast in Sweden, very few think or care about the power system infrastructure, we can easily change power providers, and power is taken for granted. In the long term, LCB is also important for the sustainability of the business and the relationship with the community, as the system lifetime is over 20 years with small profitability margins, this sustainability is crucial to deliver returns. Another aspect that is part of this power dynamic between the community and the company, lies in the company police to work for gender equality. This is executed by only hiring young women as the microgrid manager role, operating the microgrid and conducting sales. This gives these women power to deny customers for any reason (such as cultural bias towards young women in such a crucial role) the service of power. This was seen help radically change the perception that these women could handle the role and take this position in their community. Thus, the LCB strategy benefits for development can have far ranging implications that go beyond of the business, into having the power to accelerate gender equality.

Many challenges emerged and were not addressed in the research

Through the research, many challenges also emerged, that were in different disciplines (legislative and institutional through certification requirements, language, culture, variation, resources and training). This shows the complexity of the field of LCB, and there was simply not time to dive deeper into these and address all of them. Many of them could deserve an own research by themselves, such as how to handle variety in an organization looking to standardize. In general, the challenges can be summarized under one umbrella, which is also typical for energy access in Africa, where organizations try and generalize issues and conditions to one context in Sub-Saharan Africa. This challenge is about variety, in addressing remote rural communities, and by building local capacity by training local people living in these communities, there is bound to be variation. Variation in terms of languages, cultural variation, personalities, skill levels, levels of development, literacy, different community dynamics. This is the constant struggle, between the company that needs to standardize its technology and operations to reach efficiency at scale, with this local variation, requiring flexibility and an adopted approach. This is why the strategy of centralization to scale a microgrid business is so difficult, in having to address all this variety, and where a decentralized approach, even though this variety is a challenge, can provide a far better, localized outcome. Another aspect to these challenges with local capacity building lies in, does the company have any choice? Electrical engineers don't grow on trees anywhere in the world, and especially in Zambia, with few educated engineers graduating each year, this labour pool is very limited, is there any other choice than for the company to train and build this capacity in order to be able to expand? (reflected also in the industry wide problem outlined in the introduction of finding skilled people). In an industry that struggles with profitability, what other options are there to reach large scale viability, than adopt a strategy that holds the potential to lower operating expenses and increase revenues?

The use of Action Research

Two things are particularly important in terms of the methodological choices, the first was that of the extreme pace in the business once the researcher entered the field, and as outlined multiple times, the lack of resources, leading to the researcher having to conduct parts of the research (Action) himself. The second aspect lies in the fact that Action Research as a methodology, was more resource intensive, and demanding than the researcher predicted. These two together, simply meaning that the research required more resources than predicted (additionally burdened by the extensiveness of LCB) with less resources at disposal, lead to the main methodological tweaks, or adaptions that had to be taken in order to carry through the research.

There are many possible ways to conduct AR, the most important thing for validity is to show awareness of the choices made, transparently reflect those choices (Reason, 2006). The collaborative nature of AR, along with the conscious enactment of AR cycles was not always possible to realize in the company environment, as discussed above. These choices, along with how AR was applied in practice are presented and justified in chapter four. Further the choices in terms of how data is presented and analysed are also transparently accounted for. In this regard, the validity of the results is high.

There were many learnings gained from entering a new environment of a start-up operating at high pace, facing big organizational changes, and in the midst of a radical business expansion, along with the fact of living and conducting research in the field in Zambia, also a new environment. The use of Action Research for the first time, and the uncertainty and instability associated with using AR, which doesn't rely on much planning as it proceeds through iterations and allows theory and important concepts to emerge inductively, was experienced first-hand. The combination of the company environment, and the first time use of AR is highly challenging and placed very high demands on the researcher to maintain structure of the research, whilst simultaneously often taking the lead to move the organizational change project of LCB forwards. There wasn't the alignment necessary between the company's commitment before the project started, and how reality turned out – this was largely due to the company attending to important investors, as well as being in the midst of a radical growth, together requiring all available resources. Things don't always turn out as planned, the researcher tried to navigate this fact to the best of his abilities, and instead tried to leverage the context of a time and resource constrained company, operating at high pace, to develop and implement an organizational change project in the midst of this. The ability to adapt AR to fit the research context and conditions is a strength of the methodology. Another methodology such as the case study, would have failed to generate hardly anything on LCB, as most the data was generated by the researcher taking action in the company context. Perhaps this is the greatest lesson from this research, of the challenges and opportunities in the results of attempting to navigate this environment – which any practitioner and fellow researcher likely can associate with – the reality of compromise, and of things not always going the way as planned. Hopefully the reader will feel the awareness of the choices made, and transparency in reflecting the ups and downs of these choices, makes up for this, and can provide the lessons learned by this journey.

These lessons gained from using AR in this highly special context contributes to literature on how to conduct AR, along with its challenges and strengths.

To summarize this section, the choice to use AR was extremely demanding and difficult for a researcher being used to the positivist science paradigm. The researcher was faced with many choices along the way in terms of methodology and scoping of the research topic, as well as to what extent to engage in the project. In the end these choices, and how AR was applied lead to extensive results, providing a very high yield even though a lot of time and energy was put into the research. These results are also high in relevance, both because of the large amount of empirical data, allowing for a synthesis of only the most essential results, and data produced through a study anchored in the field and with the researcher immersed at the heart of change to produce valuable insights. In this regard, the methodological choice to use AR, was in the end, highly successful.

What is the research quality?

It’s important to discuss the quality of the research of any study, but it’s especially for an Action Research study since it is often judged by the wrong quality criteria. This is because Action Research has a research paradigm of its own, and directly opposite to the traditional research paradigm of positivist science. The use of the paradigm of AR has the ability to provide results of new perspectives (than those of positivist studies) and that are high in relevance, thanks to the immersed nature of the researcher, and the production of knowledge through action and in action. This allows AR to produce new theory as shown in numerous published papers.

Thus if AR produces relevant and new theory using its own paradigm, shown through numerous published papers (Coughlan & Coghlan, 2002), it cannot then be judged In terms of research quality by the criteria of another paradigm (such as that of positivist science). The Action Research paradigm thus requires its own quality criteria and as Gummesson (2000) puts it, should *not* be judged the criteria of positivist science, but rather by its own criteria. Reason and Bradbury (2001) outline what they consider choice points and questions to judge quality in Action Research;

1) *Is the AR explicit in reflecting how co-operation between the action researcher and members of the organization?*
2) *Is AR guided by a reflexive concern for practical outcomes? Is the action project governed by constant and iterative reflections as part of the process of organizational change or improvement?*
3) *Does AR include a plurality of knowing, which ensures conceptual-theoretical integrity, extends our way of knowing and has a methodological appropriateness?*
4) *Does AR engage in significant work? The significance of the project is an important quality in action research.*
5) *Does the AR result in new and enduring infrastructures? In other words, does sustainable change come out of the project?*

Fulfilling the first criteria comes from explicitly stating that there wasn’t much co-operation, and mentioning instances where there was described in the empirical data, such as if a training is held together with other employees etc.

The second criteria were delivered by the goal to create actionable guidelines, and thus highly practical outcomes. Additionally, the researcher constantly took time to reflect upon proceedings through twice a week allocated time slots.

The third criteria mean that AR develops knowledge on different levels, practical, experiential and propositional. In this regard, it is highly clear the research fulfils the criterion, through the development of practical guidelines in shape of research propositions, developed through experiential knowledge. The levels of knowledge also extends beyond these conceptual levels, to the research results in the context of organizational change, learning from the used methodology to generate the results and doing so in the reality of a small-scale start-up facing radical growth.

The fourth criteria was ensured through the enactment of the ‘pre-step’ presented in section 4.1, in the selection process of the AR project, and its rationale, to be relevant for action, as well as business. The significance is also reflected as the researcher was hired to continue develop the results of this research, in a full-time position at the company.

The fifth criteria is what the project of LCB was all about. To develop and implement LCB in the organization, was the ‘action’ part of the action research. This infrastructure has a specific connection to sustainability, to be sustainable at large scale operation, along with the social development in employing and training local people in doing so.

The fulfilment of all five criteria reflects a research of high quality. This also reflects the conscious conduction, design and motivation of choices, of the research in line with the propositions for quality in Action Research by Reason and Bradbury (2001).

Another aspect to judge quality that is important to mention, due to positivist science being the more mainstream one, is the key criterion to judge positivist science research, replicability. As positivist science values logic and measurement, along with consistency in prediction and control, the researcher (conducting positivist research) needs to outline each step of the research, so that another researcher can follow those steps and consistently get the same results. This stems from the positivism researcher’s role of contextually detached, the researcher’s neutrality, and the goal to develop empirical and contextually generalizable results, universal law. Action research is diametrically opposed, the researcher is immersed in the context and an agent of change, allowing the researcher to develop knowledge through action and experience (observation & reflection) – thus the key criterion for validity in AR is experiential, this means how knowledge is developed through experience, and means that if the person is not there, in situ, they wouldn’t be able to come up with the same insights.

Implications

The research searched for an actionable operative blueprint on Local Capacity building to scale a microgrid business. The extensiveness of topics covered paint a broad picture of the complexity and the key components presented capture what local capacity building is about in a holistic sense. This holistic perspective gives an idea on what Local capacity building is as an operative blueprint. At the same time, this leaves a broad and somewhat superficial understanding on local capacity building, without much deeper analysis of the individual research propositions.

The challenges and opportunities presented are embedded in the context of the researcher being immersed, taking action in reality and thus reflect what action research is really about, knowledge in action.

Further the research presented in the empirical findings and results is full of insights around microgrid businesses, scaling a microgrid business and local capacity building.

It is important to note that these results are developed in a highly specific context, and furthered by the researcher being immersed in this context, and taking action in relation to this context – the *empirical and contextual* generalizability is low. AR strives to develop contextually dependent contributions to reality. It is left to the reader to assess to what extent the results presented here can be applied in other contexts.

In general, thanks to the extensive results, the practitioner is very likely to find some of the propositions, along with the lessons learned through the challenges and opportunities, relevant. Especially for a microgrid business, this research gives an understanding on what is required to conduct an organizational change project of the nature of LCB.

The most important implication, and that was the fundamental enquiry for this research, in can local capacity building be a viable way for the Zambian microgrid business to scale? To this question the answer seems to be yes, as the company has showed further commitment to the project through the hiring of the researcher as the Country manager, to build a team and lead the expansion of the small-scale microgrid business in Zambia, with the specific focus in doing so using local capacity.

Local capacity building thus seems to hold the promise to provide a means to scale a microgrid business, to increase profitability and provide a sustainable way to diffuse microgrids.

Chapter 7

Conclusions

Local capacity building is a complex, intra-organizational long-term strategic commitment, that requires plenty of initial resources, especially in times of involvement and time of key personnel. The eight key components presented in this research capture this complexity and answer what local capacity building is on a high level. Together they create actionable guidelines on what components are essential to local capacity building, which is a key finding, in the context of an unexplored research space. The challenges and opportunities presented here reflect the application of AR, turning every stone to explore what LCB is, and the challenges and opportunities faced along the way. LCB can hold many opportunities and synergies for a business that is growing, especially through forcing to take time and reflect upon operating procedures, how these can be improved, and how they are taught. In contrast to the results capturing what LCB is on a holistic level, a weakness of the results is the lack of deep analysis around the individual research propositions. These are an interesting area for future research, along with trying to quantify the value of LCB.

With the researcher immersed in the development and implementation of local capacity building, and at times leading this process, these results are generated through a robust study anchored in the field. For the specific small-scale Zambian microgrid business studied, LCB seems to be a viable way to scale the business, reinforcing this is the fact that the researcher was hired as the Country Manager, tasked to lead the expansion in Zambia, and specifically using LCB to do so.

However, this also means that the research propositions are highly embedded in the specific company context, the local conditions, opportunities, challenges, operative environment of Zambia and so forth. The implication of this is that generalizability of the results is, in theory, low. Thus, the reader is encouraged to assess themselves to what extent the results can be used for a microgrid business looking to expand or give ideas around microgrid operations.

Action Research was a challenging methodology to apply, demanding plenty from the researcher in terms of active participation, as well as reflecting and analysing that action. It also requires plenty of resources of the company and its employees where the research is conducted. This was especially challenging at the company that was a small-scale start-up, expanding rapidly, characterized by a very high pace, and many important and urgent tasks to attend to. These circumstances were instead leveraged by adapting the methodology, to use the high pace to focus on turning every stone and attending multiple things in parallel, which together with the pace in the business generated hundreds of pages of empirical data. Together with the researcher taking mitigative actions to disengage and reflect upon the proceedings, this allowed to synthesize actionable guidelines, derived from extensive empirical data, that captured the complexity from a holistic perspective of what LCB is. In this regard, the use of AR was highly successful in delivering the research goal and generating new theory. How AR was applied for this research was presented in the methodology chapter, along with the empirical findings and results that resulted from this, and the learnings presented in the previous discussion, give a holistic understanding on what is required to undertake AR, and what kind of results it can produce, is another key contribution of this research.

For the Microgrid industry that lacks an operational blueprint, scaling through local capacity building could be a future focus for these businesses to explore, and in a wider sense it offers a scaling path to diffuse microgrids across Sub-Saharan Africa that is sustainable.

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Appendix I: A literature review on the microgrid research space

A systematic literature review was conducted on web of science to get an understanding on the research space of microgrids. There were two aims to this. First to get a broad understanding of what is researched and to what extent, to assess the state-of-art of the technology. Secondly to find and review research connected to the research questions, connected to the business side of microgrids, specifically at the level of analysis in the management field in operations and operating expenses and the phenomena of scaling and operating microgrids at scale.

A Web of Science literature review on the microgrid research space	
Category	**Number of papers on Web of Science**
Microgrid or Off-grid technology	17,938 results
Field of management, operations research and economics	270 results
Business case, economics of microgrid	10 results
Operations, operating expense of microgrid	0 results
Microgrids at scale	0 results
Local capacity building for microgrids	0 results

Step 1: **Search for keywords on web of science**

The first step was to try and find all research connected to microgrids. In the search string the wider term off-grid was also added as microgrid is an off-grid energy technology to give an as extensive research body as possible.

Search string used: *Microgrid* OR micro-grid* OR off-grid* OR offgrid**

This search yielded 17,938 results (note that by only searching for microgrid 15,881 results were found, showing how closely connected and overlapping off-grid and microgrid concepts are).

An analysis of the results shows that the majority of these are concerning the technical aspects of the microgrid system (shown in figure 1). There is a large degree of flexibility in this kind of power system, which can be designed to fit a community needs utilizing different power generation sources (wind, hydro, solar, diesel) and use different components such as energy storage, backup generation, distribution wiring and various control units. The operation of the system also yields many different options, it can be operated autonomously in 'island mode' in an off-grid fashion and it can also be integrated into the grid. All this flexibility comes with many technical considerations that are covered extensively in research, for instance the area of automation control systems is important to control the microgrids performance and optimize its lifetime and utility, especially if controlled remotely, computer science algorithms can match supply and demand, predict maintenance, provide simulations etc.

As seen in figure 2, the technology and research field are relatively new, emerging around year 2000 and increasing exponentially - this could be part explanation why so much focus is still on technical improvement and optimization, and how to operate the microgrid, rather than around the business side. With most of the research seemingly regarding microgrids in developed countries, the exponential increase in the number of search results also reflect the trend of decentralization and Distributed energy resource (DER) technology facing the developed world's energy systems.

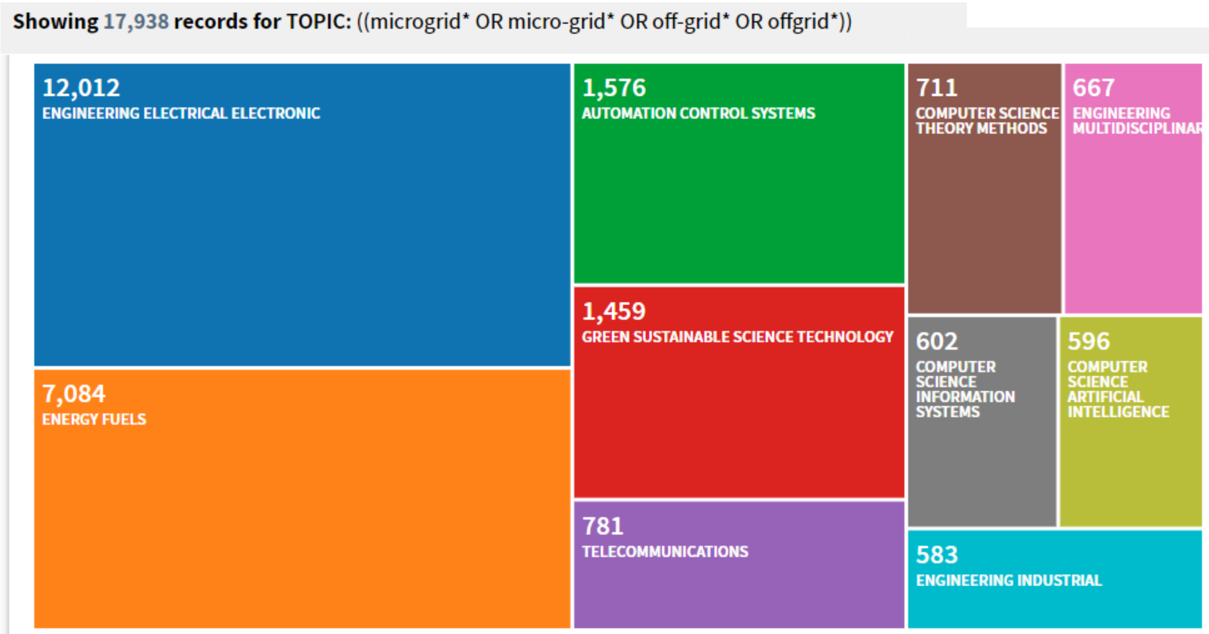

Figure 1: Step 1 search results by Web of Science category (Web of Science)

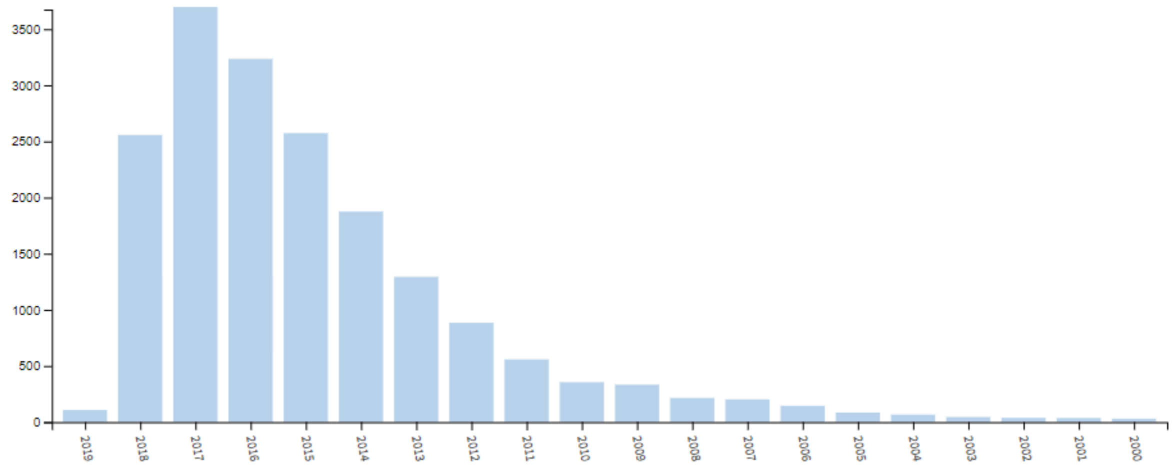

Figure 2: Step 1 search results by publication year (Web of Science)

Step 2: Refinement by category.

In the second step the results were filtered to find results connected to the business side and economics of microgrids, rather than the technology. This was done by selecting all categories that was a good fit for this purpose, listed below.

Categories selected: *Operations research management science (163), Economics (95), Management (18), Business (13)*

This process left 270 results which show how little of the research space that is concerning the business aspect of microgrids. The 270 out of 17,938 results equals roughly 1.5%.

Synthesis of results: By looking at the paper titles a majority of these 270 results were concerning the actual operation of the system in a technical sense, not the operation of the business. This is partly explained because practice and research both concern single unit microgrids, pilot projects and are purely hardware solutions. Another explanation is because of the high degree of flexibility in the microgrid design and operation, with numerous variables to be optimized.

In terms of deployment of a microgrid, the dimensioning of the system in terms of power generation capacity, source, storage capacity, need for backup generation etc are all crucial for the business to fit community needs both in terms of performance (delivery and usage of power) as well as revenue (a too small system foregoes potential revenue, a too large system won't be able to cover its costs). Numerous papers regarding mathematical modelling, simulation to test and predict microgrid demand and supply were found, as well as analysis of the selection of different technological components for the system. In terms of the actual operation of the microgrid it needs to be optimized in terms of reliability, availability, revenue, quality of service and system longevity to name a few aspects. Think of how much work goes into the management of a traditional power system and it's easy to see why this is a big topic in microgrids too, which is a small-scale power system that operates on its own. Energy management becomes important, how to generate power, when to generate power, how to supply power, to what extent and how to control the power system to make these choices in an optimal way.

In cases where a plural or network of microgrids was mentioned this was regarding the operation of several *interconnected* microgrids, or regarding *integration* of the microgrid to the grid, not the business side of operating several isolated microgrids at scale.

Step 3: Manual sort

Because of the over-representation of technical papers after the filtering, the 270 papers were filtered manually by looking at papers that are concerning the business aspect of microgrids, especially around operations or operating expense side and microgrids at scale.

Specifically, the categories looked for are listed below (with the number of papers found in each). These categories were created based on the scope of the literature review and research question alignment. The sorting process was done by briefly looking at abstracts of the 270 papers found.

1) *The business case, financing, policy design, economics (10)*
2) *Operations or operating expense (0)*
3) *Microgrids at scale (0)*

On a higher-level concerning business and economics only 10 papers were found. These results were concerning financing of microgrids, revenue stimulation, ability- and willingness-to-pay of customers, socio economic analyses of community impact, public acceptance of microgrids, community engagement strategies as well as policy design. These results won't be further elaborated as they are both too few and not that relevant for this thesis scope.

In terms of operations, operating expense, or cost of business no results were found. Papers concerning the business side or business case of microgrids at scale were not found. Note that until this stage, not even the geographical context of Sub-saharan Africa has been included (which would further reduce the number of results). In terms of local capacity building, using multiple different ways to search and categorize, no results were found.

Step 4: The gap and thesis research area

There is thus a clear gap in literature, with the research heavily focusing on the technology side of microgrids and the optimization of single microgrids, rather than microgrids at scale – with little to none research on the business case of microgrids, the viability of large scale microgrid business and no results on the operations and operating expense side of a microgrids business. There could be three reasons for this gap.