2020

Management Barriers in Bringing the Digital Age to Rural Nicaragua

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Walden University
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Abstract

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MBA, University of Illinois at Chicago, 1986

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Applied Management Decision Sciences

Walden University

August 2020

Abstract

Living without access to a steady and reliable source of electricity is one form of energy poverty, and living without access to the Internet is one definition of the digital divide. In many rural and remote areas around the world, residents struggle with energy poverty and the digital divide. However, off-grid renewable energy electricity systems are being installed in these areas to provide electricity. Thus, the purpose of this study was to identify management barriers that affect the maintenance of these off-grid systems and the possibility of using them to provide Internet connectivity. This was a qualitative phenomenological study with semi-structured interviews of key informants, who were individuals who had experienced the phenomenon of an off-grid renewable energy system installation. Thematic analysis was used to discover emergent themes. Emergent themes that provided best practices for a successfully maintained off-grid system included adequate and cohesive maintenance procedures, thorough requirements analysis and system design, use of a village-centered model, and robust communication among all key stakeholders throughout the process. Emerging themes identified for successfully using the off-grid system for Internet connectivity included procuring the required technologies, finding a reliable source of Internet signal, recognizing that each site has specific issues concerning connectivity, managing the affordability of Internet-ready devices and technologies and data usage, and having community acceptance and adoption of new technologies. The positive social implications of access to the information on the Internet include economic growth, increased education, and a general improvement in the quality of life for people living in rural and remote areas.

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Dedication

This dissertation is dedicated to my late parents, Harold and Norine Hicks, who raised me with the belief that I could do anything and be anybody that I wanted to be. Their love, encouragement, and support were instrumental in the belief that I could complete this long journey. This dissertation is also dedicated to my beloved daughter, Meghan. I was striving to provide her with a good example of a successful scholar, but she provided much needed moral and emotional support throughout the entire process.

Acknowledgments

I want to thank all the people who assisted me with this academic endeavor. During the preliminary stages of deciding my dissertation topic, I attended a very motivating plenary speech given by Craig Kielburger and Marc Kielburger at a Walden University residency. I found myself at a fork in the road, and it was their *spark plus gift equals a better world* equation that sparked my interest in renewable energy. Thank you, Craig and Marc, for lighting the best path. My committee chair, Dr. Anthony Lolas, constantly encouraged me with his enthusiasm, wisdom, and leadership. The second committee member, Dr. John Kitoko, and the URR, Dr. Roger Wells, provided invaluable insight and guidance. All were instrumental in the completion of this degree. I am grateful for my fellow Walden colleagues, who provided daily motivation to keep going throughout the program. Dr. Dodie Norton, you are an earth angel. I am forever grateful.

"The things you do for yourself are gone when you are gone, but the things you do for others remain and become your legacy" (Kalu N. Kalu in Kakabadse, Kakabadse, & Kalu, 2009). I hope to add to the body of knowledge and leave behind a legacy, however modest it may be.

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Chapter 1: Introduction to the Study

In some rural areas of Nicaragua, residents not only live without widespread access to the Internet, but they also live without a steady source of electricity. As of 2015, approximately 22% of Nicaraguan residents lacked access to electricity, which is a requirement for computer information technologies and Internet connectivity (Ranaboldo et al., 2015). To have a connection to the Internet, there must be a reliable source of electricity to power the devices or charge the batteries within the devices. Thus, the lack of electricity must be addressed before addressing the lack of access to the Internet.

Residents take electricity for granted in many developed countries. Despite the expansive growth of the global economy, there is still a large portion of the overall population that lacks access to this valuable commodity. Approximately 1.1 billion of the world's population lacks a reliable and affordable source of electricity (United Nations Foundation, 2013a). Without electricity, many of these individuals will lack the opportunity to improve their lives (Pollmann, Podruzsik, & Feher, 2014; Rahman, Paatero, & Lahdelma, 2013, United Nations Foundation, 2013b). This social problem is energy poverty, and it continues to be a popular topic with growing attention among researchers and innovators along with the search for solutions for alleviating energy poverty. Alleviating energy poverty by providing a reliable source of electricity can provide Internet access for global citizens that could lead to a significant improvement in the lives of those who lack this capability (Peters & Sievert, 2016).

This chapter includes the background of the study, the problem statement, the purpose of the study, research questions, conceptual framework for the study, and the nature of the study. This chapter also includes definitions, assumptions, scope and delimitations, limitations, the significance of the study, and a summary that links to the next chapter.

Background

Access to the Internet is a commodity that is used daily by many people in developed countries. As of March 31, 2017, approximately 286.9 million members of the U.S. population were Internet users. With a total population level of 326 million, this translates into a rate of almost 88% in comparison to 49.63% for the entire global population (Pandita, 2017). This statistic indicates a phenomenon known as the digital divide.

The *digital divide* is a phrase that has gained increased attention since the 1990s. It traditionally meant a lack of computer technologies. The term was also defined as the gap in access for new information technology (Van Dijk, 2006, pp. 221-222). Researchers referred to the digital divide as the part of the population lacking information and communication technologies and access to the Internet. Access to computers at some location, either at home, school, the library, or an Internet café, place an individual on one side of the digital divide. On the other side of the digital divide are those who have no access at all to information and communication technologies or no Internet access (Venkatesh & Sykes, 2013). This gulf between the two is continually shifting as information, needs, and technologies change daily.

As information and communication technologies have evolved, the definition of the digital divide has evolved as well. Researchers originally used this term to refer to cases where computers were available to some but not to all the population due to financial constraints, which has now been more distinctly described as the socioeconomic digital divide (Philip, Cottrill, Farrington, Williams, & Ashmore, 2017), with the underlying causation factor being viewed mainly as an economic barrier because not everyone can afford computer information technology. This divide has been changing as well as the definition of the digital divide itself.

Access to the Internet and Internet skills have become the most recent deciding factor in the newest digital divide definition (Van Deursen & Van Dijk, 2010, 2014). Historically, not everyone had access to the devices needed to access the Internet. In recent years, less expensive computer technologies such as tablets, laptops, and smartphones have become more readily affordable to a more significant segment of the global population, including children. These new devices provide easy and relatively inexpensive computer and technological functions and connections to the vast array of information on the Internet. In response, the definition of the digital divide has narrowed to mean the gulf between those who have Internet access and those who do not have access.

Though technological innovation has helped bridge the digital divide (Park & Lee, 2015), there are still many reasons why such a large part of the global population lacks Internet connectivity. Many barriers have hindered the spread of the digital age throughout developing countries and rural and remote areas of developed countries. In addition to individual financial restrictions, these factors include (a) affordability and cost considerations for both the infrastructure components, the connection devices, and the

Internet service provider fees; (b) readiness and educational issues regarding the Internet including skills, awareness, and cultural acceptance; (c) relevance of Internet content in terms of original language content that is meaningful and useful; and (d) availability and physical access to connectivity in terms of the actual infrastructure itself that allows connectivity (El-Darwiche, Herzog, & Samad, 2016; El-Darwiche, Herzog, Samad, Singh, et al., 2016; Miazi, Erasmus, Razzaque, Zennaro, & Bagula, 2016). The presence of one or more of these barriers restricts access to the Internet.

In light of the barriers that restrict access, a newly defined branch of the digital divide is referred to as *digital exclusion*. Those living too far away from the conventional infrastructure components lack any stable and reliable connection to the Internet; therefore, that part of the population is viewed as excluded from the digital age. Frequently, the main reason for no access to the Internet, or digital exclusion, is a lack of the informational infrastructure or inequalities in technological infrastructures (Philip et al., 2017; Raman & Chebrolu, 2007; Williams, Philip, Farrington, & Fairhurst, 2016). There are many reasons why an area lacks the necessary physical infrastructure, but one of the main reasons the Internet infrastructure is not in place in the area is because the electricity infrastructure has not yet arrived (Ranaboldo et al., 2015). Electricity is a requirement for computer and communication technologies (Samantar, 2012). Without a steady and reliable electricity source, people cannot power or recharge batteries for any of the Internet-ready electronic devices that are available today. Some form of electrical infrastructure or some source of electricity must be in place first.

Despite the need for electrical infrastructure, there is still part of the global population that lives without electricity. Globally, as of 2016, approximately 1.1 billion people do not have access to electricity (International Energy Agency, 2017). In October 2018, this statistic fell below 1 billion (Cozzi, Chen, Daly, & Koh, 2018). Without either the informational infrastructure or the electrical infrastructure, connectivity is virtually impossible. In Nicaragua, as of 2016, only 19.4% of the population of 6.1 million people have access to the Internet (Internet Live Stats, 2018). Lack of a constant and reliable source of electricity is one form of energy poverty.

This social problem called energy poverty is defined as energy consumption that cannot meet basic needs (Gonzalez-Eguino, 2015, p. 379). Energy poverty has also been referred to as lacking "access to clean and reliable energy" (Day, Walker, & Simcock, p. 257). This term encompasses many forms of energy, including electricity, natural gas, and biomass. However, narrowing the scope of energy poverty, researchers like Szabo, Bodis, Huld, and Moner-Girona (2013) have focused on electrification as the focal point of energy poverty.

Worldwide, energy poverty occurs mainly in developing countries and in some rural, remote, or traditionally poverty-stricken areas of first world countries (Ezeanya & Kennedy, 2016). The underlying problem is that many rural villages, especially in Nicaragua and other developing countries, are located too far from the traditional central electricity infrastructure for a standard, affordable, and reliable electricity connection (Rahman, Khan, Ullah, Zhang, & Kumar, 2016; Tijani, Tan, & Bashir, 2014). Connection to the traditional grid is usually costly due to the lack of proximity to the existing infrastructure or terrain issues that stand in the way of a straightforward and affordable extension (Chauhan & Saini, 2013). The more remote a village is, the higher the likelihood that there are barriers to growth (Chen, 2016).

Solutions to energy poverty issues must typically come from outside the village itself because the village members individually cannot afford costly solutions, but local governing bodies may lack the resources necessary for traditional infrastructure extension. In developed countries, it has traditionally been viewed as a governmental responsibility to provide an affordable and reliable electricity source to the residents (Bradshaw, 2017). However, on the macro level, national governmental support and expenditure are not always feasible, especially in developing countries and very remote rural areas (Nathan, 2014). Extension of the traditional infrastructure for hard to reach areas might be costly (Chen et al., 2017). Governmental funds may not be available for infrastructure projects, or these funds might be severely limited. Governmental policies might dictate that other programs and projects have a higher fiscal priority at present, and without the national government's fiscal support, expanding the traditional infrastructure is nearly impossible in many situations. Further, in rural areas of underdeveloped countries, there is not necessarily a local government entity that provides for the energy needs of the residents. In Nicaragua, some rural villages have informal village managers as opposed to formally elected officials. These village managers have informally taken on many of the responsibilities of managing the energy needs of the residents.

In addition to a lack of government support, the residents of these rural villages typically lack funds to pay privately for an expensive connection to the main infrastructure. Thus, many of these residents have been raised and continue to live without the luxury of electricity for their daily needs. Having visited rural Nicaragua twice, first in 2013 and again in 2014, I observed that many rural Nicaraguan village members obtain water from wells, use sunshine as their light for daily activities, use flashlights for any evening or pre-dawn activities, and eat a simple diet of rice, beans, garden vegetables and fruits, and meat from farm animals. Cooking is usually done indoors over an open fire burning wood from trees. Rural village residents spend most of their time acquiring the necessities of life. Although they survive by other means, living without a source of electricity in modern times continues to be a significant hardship, which limits their opportunities for social and economic advancement. As Kartikeya Singh (2016) noted, "those who need electricity the most may be the ones with the most limited technology options" (p. 1). This lifestyle leaves little time for other activities that could promote their social and intellectual growth. Without electricity, the social issue of energy poverty persists. Finding an affordable and reliable way to provide the electricity infrastructure has been an ongoing challenge in many areas in Nicaragua and many developing countries worldwide.

Using off-grid renewable energy as a source of electricity could be one option for alleviating energy poverty (Zhao & Liu, 2009). Off-grid systems refer to the electrical infrastructures that are not part of the main traditional national electrical infrastructure. They are self-contained, stand-alone systems and do not need the extension of the traditional electricity infrastructure. These systems are ideal for remote areas, offering high reliability with low servicing needs (Nkwetta et al., 2010, p. 10).

Though solutions like off-grid energy exist, there is not much literature that addresses the management challenges with off-grid renewable energy electricity systems. Multiple studies contain descriptions of some business models used for off-grid systems (Akpan, Isihak, & Udoakah, 2013; Aris & Shabani, 2015; Baky, Rahman, & Islam, 2017; Bhattacharyya, 2015; Biswas, Bryce, & Diesendorf, 2001; Chmiel & Bhattacharyya, 2015; Descoqs & Bhattacharyya, 2018; Feron, 2016; Feron, Heinrichs, & Cordero, 2016a; Hong & Abe, 2013; Kim, Park, & Kim, 2017; Kobayakawa & Kandpal, 2014; Lillo, Ferrer-Marti, Boni, & Fernandez-Baldor, 2015; Palit, 2013; Palit & Chaurey, 2011; Ranaboldo et al., 2015; Shyu, 2013; Shi, Liu, & Yao, 2016; Tongsopit, Moungchareon, Aksornkij, & Potisat, 2016; Urpelainen, 2014, 2016; Urpelainen & Yoon, 2015). However, when it comes to describing management barriers with renewable energy off-grid systems, I found few available studies (Eleftheriadis & Anagnostopoulou, 2015; Katsaprakakis & Christakis, 2016; Rahman, Paatero, Poudyal, & Lahdelma, 2013; Sen & Ganguly, 2017). When combining off-grid systems, the corresponding management issues of these systems, and utilizing these systems to provide Internet connectivity, the literature gap becomes apparent. This study can provide a link between the concepts of using off-grid renewable energy electricity systems and providing Internet access from the off-grid system.

Problem Statement

Rural electrification is critical for the advancement of rural residents (Rahman, Paatero, Poudyal, & Lahdelma, 2013; Schiffer, 2016; Standal & Winther, 2016). But using off-grid renewable energy electricity systems to provide rural electrification has challenges (Marquardt, 2014; Sen & Ganguly, 2017; Ulsrud, Winter, Palit, Rohracher, & Sandgren, 2011). Identifying these barriers is critical to providing a steady and reliable source of electricity (Ahlborg & Hammar, 2014; Chauhan & Saini, 2015; Eleftheriadis & Anagnostopoulou, 2015; Islam, Islam, & Islam, 2017; Kenfack, Lewetchou, Bossou, & Tchaptchet, 2017; Lee, 2015) and subsequent Internet connectivity. The general management problem addressed was that non-governmental organization (NGO) managers, project managers, and experienced volunteer project coordinators have encountered management challenges that prevent implementation and maintenance of off-grid electricity systems and its subsequent use for providing Internet connectivity. The specific management problem was that these challenges have caused management obstacles that interfered with a smooth flow or an easy transition of resources for easily accessible and affordable Internet connectivity for rural village residents using the off-grid solar electricity installation.

Lack of Internet access has many drawbacks that can affect students, workers, medical patients, and those at risk of natural disaster. Without the Internet, students might be unaware of the knowledge available, which can put them at a disadvantage compared to their peers with Internet access. Workers seeking new knowledge and skills for a possible job change can also suffer from a lack of Internet access. Remote learning can provide new job skills, and the Internet can provide information about job opportunities. Without Internet access, these workers have to rely on other means of communication to acquire skills and learn about possible opportunities.

Additionally, some remote medical patients might suffer from a lack of reliable information transfer from their doctor when receiving treatment and care instructions from their medical personnel on a timely basis can assist in a quicker or easier recovery time. Without the Internet, the medical instructions might not be transferred promptly or at all. People at risk for natural disasters can also suffer from the lack of Internet access because dissemination is important for disaster risk reduction (Leidig & Teeuw, 2015, p. 2). Without up-to-date technologies and access to weather conditions and patterns, global citizens living with risk of natural disasters lack timely data that could be critical for saving lives. Access to the Internet can help prevent widespread loss of lives in tsunamis, floods, tornadoes, hurricanes, typhoons, and other natural disasters.

The benefits of alleviating energy poverty and closing the digital divide in remote areas include economic growth, increased education, and an improvement to the quality of life such as health (Department for International Development, n.d.). Installing off-grid renewable energy can also improve employment in developing economies (Acey & Culhane, 2013, p. 1046). Agricultural benefits from photovoltaic systems also include electricity for greenhouses, wastewater purification, and water pumping (Xue, 2017). Further, universal Internet access can help sustain economic prosperity (Trossen, Sathiaseelan, & Ott, 2016, p. 44). There is a correlation between access to information and technology and wealth (Howard, Busch, & Sheets, 2010, p. 110). Additionally, the benefits of off-grid energy appliances include “business opportunity, elimination of labour intensive tasks, preservation of health, protection from people posing a threat” (Hirmer & Guthrie, 2017, p. 924). Standard of living can also be raised by having access to further knowledge (Mchombu, 2007). An extensive list of the benefits of using information and communication technologies to connect to the Internet is shown in Table 1.

Table 1

Facilitation of Rural Development Efforts

Education	Improved educational services and distance education: providing access for teachers and students to a broad menu of educational materials and even educational programming.
Business	Access to information for economic development, such as small business accounting, weather trends and farming best practices, and timely access to market information regarding where to sell products and at what prices.
Healthcare	Improved health care, through remote consultation, diagnosis, and treatment; relevant medical training for remote providers; improved disease prevention and epidemic response capabilities; and dissemination of public health messages.
Government	Local empowerment and democratic preservation.
Cultural/Historical	Cultural and indigenous knowledge preservation.
Disaster Relief	Improved disaster mitigation and response capabilities, through improved communications.
Access	Access to Worldwide markets via the Internet for specialty products such as indigenous music and crafts.

Note. Source of data: Hanley et al., 2003, p. 1.

Given the benefits of Internet access, combined with the drawbacks of lack of Internet access, closing the digital divide is an important goal.

Purpose of the Study

The purpose of this qualitative phenomenological study was to investigate the lived experiences and knowledge of NGO managers, project managers, and the experienced volunteer project coordinators about their experiences of off-grid installations in undeveloped countries. For this study, I used phenomenology to reveal patterns and themes highlighting the barriers and obstacles that prevent successful installations and ongoing maintenance as well as to explore ways for NGO managers and project managers to address these barriers and obstacles and to expand the off-grid solar electricity to allow for Internet connectivity.

The phenomenon in this study was how to implement off-grid systems to provide Internet connectivity for rural or hard-to-reach residents. In this phenomenological study, I approached the research questions from the viewpoints and perspectives of key informants: the NGO managers, the off-grid installation project managers, and the experienced volunteer project coordinators. As a researcher, I investigated these key informants who have participated in the installation of off-grid renewable energy electricity systems in rural villages of Nicaragua and other underdeveloped countries, constituting an original contribution to the field of knowledge. Although there are studies about using off-grid installations to provide electricity, and there are studies about providing Internet connectivity for hard-to-reach and rural areas in underdeveloped countries, I connected the two concepts in this study. This study may add to the existing body of knowledge of renewable energy and offer insight into the experiences of those who have participated in the off-grid electricity installations in rural areas in underdeveloped countries.

Research Questions

The general research question was as follows: What are the internal and external forces that impinge on the ability of NGO managers, the project managers, and the experienced volunteer project coordinators to bring the digital age and Internet connectivity to the rural villages in Nicaragua using off-grid electricity systems? The following are the sub-research questions.

Sub-research Question 1: How can the NGO top project managers, the installation project managers, and the experienced volunteer project coordinators overcome the challenges, barriers, and obstacles encountered with the maintenance of the off-grid electricity systems in rural Nicaragua?

Sub-research Question 2: How can these key managers of the off-grid systems successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity?

Conceptual Framework

The conceptual framework of this qualitative phenomenological study included three theories: the systems theory (Checkland, 1994; Jackson, 2003), the technology acceptance model (Davis, 1986, 1989), and the diffusion of innovation theory (Rogers, 1962, 2003). I chose systems theory because the installation of the off-grid electricity system directly affects many parts of the village system while performing as a system (Mandelli et al., 2016). I observed the multi-dimension systems effect during my two off-grid installations in Nicaragua in 2013 and 2014. Additionally, researchers have applied systems theory to management issues, noting the "focus specifically on knowledge, value, quality, environment, relationships, adaptation, and complexity" (Mele, Pels, & Polese, p. 130). These constructs informed the systems theory framework as the data were collected and analyzed.

The tenets from the technology acceptance model (Davis, 1986, 1989) were used to frame the research concerning how the village members improve their lives and alleviate energy poverty using the free electricity system. Specifically, I explored the acceptance of the off-grid renewable energy technology and its determinants (Hammami, Chtourou, & Triki, 2016). Technology access is a process, not a static set moment in time (Van Dijk, 2006). First, there is the introduction of the innovation, and then later, the enhancement of using the innovation that evolves as the process. This process was captured and explored in this study.

I also used Rogers's (2003) diffusion of innovation theory to frame this study because it directly addresses the process of introducing an innovation and the subsequent steps that evolved following the initial stage (Bergek & Mignon, 2017). The innovation of the off-grid electricity systems and resulting Internet connectivity could impact many aspects of the lives of the residents of these rural villages (Choragudi, 2013; Lacerda & Van Den Bergh, 2016; Urmee & Md, 2016). The goal was a strategic framework for identifying an integrated system needed to bring the digital age and Internet connectivity to the rural villages in Nicaragua using off-grid electricity systems.

Nature of Study

The nature of this study was a qualitative methodology with a phenomenological focus (Moustakas, 1994; Van Manen, 2014, 2017). The phenomenon for this study was an off-grid renewable energy electricity system. Qualitative research was consistent with discovering themes concerning management barriers and obstacles that the NGO managers, the project managers, and the knowledgeable volunteers encountered during the installation. These barriers affect the ongoing management of the daily maintenance of the off-grid system. Users of the system might encounter these same management obstacles when extending the electricity system to provide an Internet connection.

First, I conducted semi-structured interviews with the key informants. Then I used purposive sampling to find more participants to interview. At this point, I anticipated having difficulty getting participants, so I performed a LinkedIn search of key informants to expand the search beyond the initial group. I also searched the professional group, the Institute for Electronic and Electrical Engineers Collabratec (IEEE Collabratec), for key informants as another source of participants. Second, I implemented a search of the literature of current off-grid installations that provide Internet access to determine existing off-grid renewable energy sites and their best practices. Third, I conducted a careful analysis to identify common themes within the key informants' knowledge base. The resulting knowledge from all three sources provided common themes that highlight the management barriers and obstacles and how they could be addressed to provide best practices of successful system maintenance and system integration for Internet connectivity within these rural villages.

A quantitative or mixed-method study was not applicable because the focus was not to quantify the problem or experiences of off-grid electricity installation, maintenance, and Internet connectivity. Additionally, there are a limited number of off-grid solar installations that are available for observation, study, and analysis. The location of many of these installations are globally widespread and typically in hard to reach and very remote areas. A sufficient sample for quantitative analysis would have been costly and time-consuming. Discovering in-depth information from the meanings and themes through a phenomenological study was a more logical choice, given the widespread geographical constraints of the phenomenon.

Definitions

The following definitions are terms used in this dissertation.

Alternative energy: A source of energy that does not use fossil fuels (Ciolkosz, 2017).

Digital divide: Historically, a gap between people who have access to information and communications technology (ICT) and, more recently, a gap between those that have Internet access and those that lack Internet access (Van Dijk, 2017).

Digital exclusion: A branch of the digital divide where there is a lack of Internet connectivity due to lack of conventional infrastructure components (Philip et al., 2017).

Energy poverty: For the purposes of this dissertation, the narrow definition is that part of the population that lacks access to a steady, reliable, and affordable source of electricity. In a broader definition, it is the part of the population who lack access to clean and reliable energy in general (Day, Walker, & Simcock, 2016).

Fuel poverty: A situation that occurs when the amount spent on fuel expenditures for a household exceeds 10% of the household income (Moore, 2012).

Information and communications technology (ICT): A group of electronic tools that provide access to information and computerized data (techterms.com).

Microgrid system: A self-contained electricity-producing system, with the ability to connect or disconnect to the traditional electricity infrastructure. It is also referred to as a “small electric power system integrated with onsite distributed energy resources (DERs) for serving local loads; it is connected to the local utility grid” (Alabdulwahab & Shahidehpour, 2016)

Off-grid system: A self-contained electricity-producing system that cannot be connected to the traditional electricity infrastructure (Energy.gov, 2017). These renewable and sustainable energy systems have only recently been referred to as *off-grid* because of their inability to connect to the conventional electric grid infrastructure.

Personal social responsibility: An individual makes personal decisions within the framework of what will benefit society as a whole (Foller-Carroll & Charlebois, 2016)

Renewable energy: The energy that is derived from naturally occurring and non-depleting sources such as sunlight, wind, or geothermal (Ciolkosz, 2017).

Socioeconomic digital divide: A narrow definition of the digital divide where the causation factor is an economic barrier between those who can afford ICT technologies and those who cannot (Harris, Straker, & Pollock, 2017; Philip et al., 2017).

Smart grid system: “An electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators” (Nordman, 2016). Additionally, it is the traditional electricity grid with an overlaying information and communications grid that provides for continuous monitoring and self-contained solutions (smartgrid.gov, n.d.).

Voluntourism: A form of travel where the travelers participate in a charitable volunteer experience. A “trip that might involve aiding or alleviating the material poverty of some groups in society” (Hasanova, 2017).

Assumptions

This dissertation was founded on four underlying assumptions. One assumption of this study was that the village members desire to have electricity. Modern society relies on electricity, yet it is possible to live a meaningful life without this utility. To address this assumption, the NGO ensured that most village members desired a steady and reliable source of electricity because they must apply for and request an off-grid installation. They must also demonstrate their need and their ability to keep the system sustainable after the initial installation.

The second assumption of this study was that the village members desire to have Internet connectivity. Not everyone desires or exhibits a need for Internet connectivity. Some possible reasons for this might include that individuals do not find meaningful content on the Internet. Alternatively, they might encounter a language barrier that prohibits them from finding content in their particular language or dialect. It is also possible that some individuals have their basic information needs met in other modes of communication, so they do not desire to use the Internet. Therefore, this was an underlying assumption of the study.

The third assumption of this study was that both access to electricity and access to Internet connectivity will improve the living conditions of the residents. Whether progress in technology moves humanity forward is a huge debate that is beyond the scope of this dissertation. In this study, I operated on the assumption that access to electricity and Internet connectivity could improve the lives of the village members (Hanley et al., 2003).

A fourth and final assumption was that the phenomenological method was the best framework for use in this study. Because many of these installations were unique to their locations, the use of phenomenological practices was crucial in identifying themes from the perspective of the participants' lived experiences. Phenomenology framed the study, providing a framework for identifying the collection of patterns and themes and assisting in the development of recommendations for future installations.

Scope and Delimitations

For the interviews, the scope of the study was the participants' perceptions, perspectives, experiences, and knowledge with the installations of the off-grid renewable energy installations. Three factors defined the parameters of the study. First, there are many other possible reasons that the residents did not have Internet access such as cost, governmental policies, personal bias toward not having it, literacy issues, not having computer skills, and lack of physical access. I focused this study on the barriers of physical access to Internet connectivity.

Second, the focus of this study was on renewable off-grid systems. There are other ways to provide Internet access for hard to reach areas, although many are expensive. Chapter 2 contains a brief discussion of the other ways to provide Internet access for geographically hard to reach areas. I focused this study on alleviating energy poverty by providing Internet access using off-grid electricity systems.

Third, the focal point of this study was on the geographical areas of expertise among the participants who are being interviewed. This limits the scope of the study and the possible generalizability because there are possibly many more off-grid remote installations globally. I focused the scope on the installations that the study participants experienced. Finding all off-grid installations and including them in the study would be extremely cost prohibited and time-consuming. The study was limited to the two NGOs from the two trips to Nicaragua taken in 2013 and 2014 as well as the resulting participants obtained from using the purposive sampling technique. The goal of adequate coverage of possible themes was kept in mind when considering the saturation of data collection.

Limitations

The first limitation of this study was the choice of purposive sampling. Starting with the NGO managers, I intended to build the sample base with the top managers from the two trips in 2013 and 2014. The first NGO has one founder/manager and two project managers. The second NGO has two founders/managers, and both were potential study candidates. Additionally, some of the volunteers from the two trips fit this study's requirements, and these knowledgeable volunteers also were candidates for this study. Through purposive sampling, I utilized these candidates to lead to others in the field. Nevertheless, there is a global community of people who could provide relevant content for this study that would allow for generalization across many geographic and cultural boundaries. By limiting the choice to known individuals and their acquaintances and colleagues, I made this study a focused, feasible, and affordable effort.

The second limitation is the chosen data collection method. Semi-structured interviews from participants using self-reported data could be hard to verify due to possible personal bias or selective memory issues. Participants may choose to answer the interview questions to show their NGO or other organizations in the best possible light. This would be counterproductive to the study because the goal was to identify obstacles and barriers encountered within the off-grid installations and maintenance and the possible expansion of the projects to include Internet connectivity. As a researcher, this limitation was countered with multiple sources and triangulation of data to ensure unbiased data collection.

The third limitation was the conceptual framework. There were a few other possible choices for applicable theories that I could have added to the framework for this study. However, adding too many theories in the framework could have been unwieldy. Though I chose to leave some of those theories and constructs for further future research, this choice did not negatively affect the data collection methods or the depth of the study.

Significance to Practice

There are many possible levels of significance for this study. For instance, off-grid renewable energy systems are a solution to energy poverty (Kolhe, Ranaweera, & Gunawardana, 2015). Inexpensive electricity provided by these systems might help alleviate many of the burdens associated with living in energy poverty (Grogan & Sadanand, 2012). Residents can read, study, and engage in other activities now that they have light available after sunset. The medical clinics would also benefit from the electricity because the doctors and nurses would have adequate lighting for nighttime medical procedures. Vaccines and insulin could be stored onsite in a refrigerator that would have electricity for continuous operation. Further, residents could utilize the electricity to provide new revenue streams for the village residents. This revenue stream could provide the necessary income for distilled water needed for the electricity system's batteries and any repairs required for the solar off-grid system. Alleviating energy poverty could ultimately and positively affect many of the residents of these rural village communities globally.

Significance to Social Change

Effecting social change within the rural villages can result from providing a relatively inexpensive source of renewable energy electricity. The electricity system can help provide Internet connectivity for the village residents, leading to a range of benefits from information for better farming methods and access to new entrepreneurial activities (Hanley et al., 2003). Resident usage of the off-grid system could narrow the digital divide, and the off-grid systems could bring the rural communities into the digital age (Erdiaw-Kwasie & Alam, 2016). Increased communications among relatives and increased educational levels of the village residents could be possible social change results from the installation of the off-grid electricity system and Internet connectivity.

Significance to Theory

By discovering how these systems can provide Internet connectivity and how they enable village residents, specifically in Central America, I addressed an under-researched area. Though rural communities need improved connectivity through technology, they remain the least connected (Salemink, Strijker, & Bosworth, 2015). Insights from this research may help potential small business owners and sole proprietors, off-grid system designers and developers, the NGOs that fund these projects, and other major policymakers and stakeholders interested in off-grid rural electrification projects. Future grounded theory studies and descriptive case studies might be useful for developing theories about the nature of this phenomenon.

Summary

Alleviating energy poverty, providing a reliable source of electricity, and providing Internet connectivity are all worthwhile goals for charitable and philanthropic nonprofit groups. As the cost of renewable energy technologies continues to decline, their use as a solution for energy poverty alleviation will increase. Providing a reliable and sustainable electricity infrastructure is critical for introducing computer information technologies in any environment. Using a phenomenological paradigm to reveal patterns and themes provided solutions to the management barriers with the off-grid renewable energy electricity systems, and the corresponding extension of these systems to provide Internet connectivity throughout many underdeveloped and hard to reach areas of the world.

Chapter 2: Literature Review

Introduction

This study was focused on the off-grid solar electricity system and the possible extension of this electricity system to provide Internet connectivity in rural areas. Using off-grid electricity systems could address two social problems: energy poverty (i.e., lack of electricity) and the digital divide (i.e., lack of Internet access and ICT access). In this study, the general management problem was that NGO managers, project managers, and experienced volunteer project coordinators encountered management challenges that affected the implementation and maintenance of these off-grid electricity systems and its subsequent use for providing Internet connectivity. These challenges have interfered with a smooth flow or an easy transition of resources for easily accessible and affordable Internet connectivity for rural village residents using the off-grid solar electricity installation. The purpose of this qualitative phenomenological study was to investigate the lived experiences and knowledge of NGO managers, installation project managers, and experienced volunteer coordinators about the off-grid installations in undeveloped countries.

This chapter contains a discussion of the current literature that establishes the relevance of the problem. The current literature on energy poverty, renewable energy solutions, and the digital divide is included. This literature review contains four main sections. The first section includes a discussion of the conceptual framework using systems thinking (Checkland, 1994), the diffusion of innovation theory (Rogers, 2003), and the technology acceptance model (Davis, 1989). Moving forward from there, I outline and discuss literature related to the constructs of energy poverty and the digital divide. After that, I describe, analyze, and synthesize studies that relate to the phenomenon under study: off-grid electricity systems for rural areas. The final section contains an explanation of current research supporting the choice of the research problem and the research questions that form the basis of this study.

Literature Search Strategy

I initiated the literature review with a search for existing and current (a) peer-reviewed renewable and alternative energy research, (b) peer-reviewed Internet access research, and (c) peer-reviewed research that is related to the research questions and corresponding sub-questions. Online university libraries that were available and used included: Walden University and the university libraries of my alma mater (the University of Illinois at Chicago), a former employer (for a limited period), and current employer. Other sources included Google scholar and Open Access databases and journals such as the Public Library of Science (PLOS) not found within the university libraries. I utilized multiple libraries and sources because the peer-reviewed journal availability varied within the universities and sources.

Databases used included ABI/INFORM Complete, Academic Search Complete, Business Source Complete, Computers and Applied Science Complete, Directory of Open Access Journals, Emerald Insight, IEEE Xplore Digital Library, ProQuest Central, Science Direct, Taylor & Francis Group, Walden's Dissertations and Theses, and Expanded Academic ASAP. This database was unique because it contained peer-reviewed technological advancements relevant to the research problem and research questions. The literature searches began at Walden and continued throughout the other sources listed.

The initial broad searches for *renewable energy* or *alternative energy* provided a vast amount of research, but not all of it was directly applicable to this study. I used this approach to obtain a broad overview of the topic and an understanding of the development and evolution of the field of renewable energy. However, due to the vast number of unrelated articles in the search results, a narrower search focus was necessary. Additionally, it became evident that the search term *alternative energy* was not a fitting term because it was not interchangeable with *renewable energy*. Based on its broader definition, I removed that search term from the list of search terms. I retained *renewable energy* as a search term.

Using two search terms instead of one was a strategy used to narrow the results with the goal of more relevant sources. I searched the databases with the terms *renewable energy* and *Internet access,* which provided mostly results related to Smart Cities and the Internet of Things. But neither of these topics was pertinent to the focus of this study because there is the underlying implication that the electricity source is from the traditional electrical infrastructure.

Initially, searching for *off-grid* and *Internet access* yielded no results from the libraries and the databases. Part of the issue was that the term *off-grid* was a relatively new term. Although researchers have widely researched renewable energy over the past few decades, the specific term *off-grid* was not frequently used. It became popular with the inception of the term *smart grid*. As mentioned, *smart grid* refers to the evolution of the electricity infrastructure as it now encompasses the overlaying layer of computer and measurement information technology components added on top of the initial physical energy infrastructure. *Off-grid* was a term used to compare a system that was stand-alone versus one that could be connected to this traditional energy infrastructure. Another new term included *micro-grid.* The difference between a micro-grid and an off-grid is the possibility of connecting to the main electricity infrastructure. A micro-grid can connect to the traditional infrastructure, whereas an off-grid system does not have this capability. The off-grid system must remain as an independent system. This fine distinction was subtle to the focus of the literature search.

Given all these search terms, I took a slightly different approach and I searched for off-grid technologies currently used along with the business models executed or researched to provide the electricity systems in marginal communities. Searching for original research of off-grid systems alone initially provided a limited amount of results. Many of the searches provided results that were studies conducted from an engineering and scientific perspective usually found in the Science Direct database. Another area of numerous results were studies focused on the business models used in the implementation of the off-grid or micro-grid systems. Again, these results were somewhat useful because they represented research on one aspect of the current study but not all the multiple elements.

More recent searches were more fruitful. Using the search terms *off-grid* and *Internet access* in the Science Direct database yielded over 8,000 results. I limited this search by narrowing it down to those dated between 2012 to the present. This refinement resulted in 4,658 search results. A careful sorting/searching through these results proved that some sources are for *grid* but not necessarily *off-grid*. Articles on smart grids were inadequate for the research questions. Some results were for *Internet* but not necessarily *Internet access*, which is a slightly different term/concept. I was able to eliminate most of these references.

At this point, I entered a third search term *voluntourism*. To ensure that the searches were on target, I also used a fourth term: management. Using all three search terms of *off-grid*, *Internet access*, and *voluntourism* yielded no results in both Business Source Complete and Academic Search Complete. The search yielded one result in Science Direct (Molz, 2013), which had nothing to do with off-grid electricity systems. Using all four search terms provided no results. This indicated the literature gap that illuminates a connection between using the business model of voluntourism to provide off-grid electricity systems and using these systems to provide Internet connectivity.

Adjusting the approach slightly, I established a base knowledge of existing research about voluntourism (i.e., volunteer tourism). Concerning the connection to the research questions, I initiated a search of just this term by itself. From this, I learned that voluntourism is the newer version of the term ecotourism. Voluntourism is also all-encompassing, because medical volunteering, home and school construction, and other disciplines now were included in this new term. This search strategy yielded some sources worthy of inclusion based on the focus of the research and therefore were included in the literature review synopsis that follows.

During the literature searches, I noticed that some of the Walden library searches provided links to articles unavailable at the library. It was possible to see the citation and the abstract, but not the full text. Usually, this was because of what is called an embargo or black-out period. Some journals make arrangements with libraries to provide past issues of their journals, but not the most recent issues (typically the last 12 months or 18 months). To overcome this problem, I would first save the citation data and then perform a search on Google Scholar to see if there is a free version of the article somewhere on the Internet. Another possible source of finding these embargoed articles is on a website called researchgate.net, which is similar to LinkedIn.com but focuses more on researchers and writers. Authors often share a free copy of their article on this site even when it is unavailable to the general public. I found a few full-text articles this way.

Another search strategy that I utilized included checking the reference list of available articles. This strategy yielded some relevant articles that did not appear using the conventional search strategies listed. I utilized these search strategies to create a comprehensive base of literature concerning the phenomenon of off-grid electricity systems and their possible extension to providing Internet connectivity.

When searching for timely Internet statistics and global Internet connectivity, it was nearly impossible to find current year statistics within peer-reviewed sources. This difficulty was due to the peer-review process' nature that can take months or years before publishers accept a final version of an article for publication. Online publications have somewhat shortened this lengthy process, but timely statistics of necessity came from continuously updated Internet websites that may have oversight but not necessarily a peer-review process. To address the issue of trustworthiness and verifiability, multiple sources were consulted to ensure the accuracy of the statistics. Older peer-reviewed sources were consulted to determine which websites were used by those researchers/authors, thereby lending credibility to the chosen websites. Recent Internet statistics were relevant for discussing the choice of the research questions and the chosen conceptual framework. Whenever possible, I used a combination of peer-reviewed sources and current Internet sources as citations to provide up to date statistics.

Conceptual Framework

Of significance to this study were the concepts within systems theory (Checkland, 1994), the diffusion of innovation theory (Rogers, 2003), and the technology acceptance model (Davis, 1986, 1989). These two theories and one model served as the conceptual framework for this qualitative phenomenological study. For decades, stand-alone off-grid systems have provided electricity to remote areas. Rapidly changing and more affordable technologies have made these systems more attractive and adaptable to a broader set of applications. Using these off-grid systems to provide electricity in remote or hard-to-reach areas has become a viable business model. Residents can also switch from polluting fuels to green alternatives for power (Hart & Christensen, 2002). The key is to effectively and efficiently provide and manage the resources and workforce necessary for a successful installation of this innovation using the voluntourism model (McGehee, 2014). But evaluating the sustainability of these systems is complex (Strantzali & Aravossis, 2016, p. 885).

Systems theory (Checkland, 1994), as a contextual lens, works on many levels. Changing one part of the system will change other parts of the system. Installing and maintaining an off-grid solar electricity system within the village might change how the different parts of the village system operate. These changes might have a direct impact on the management and maintenance of the system. When investigating the phenomenon of the off-grid electricity system and its management, this contextual lens provided various viewpoints for studying the system components and the system as a whole. Residents of rural villages do not necessarily have the same living conditions, needs, and desires as those in developed urban areas. Instead of a homogenous need for grid-connected electricity, there are many reasons, both physically and financially, as to why a grid-connection is not the standard solution for all. Even within the off-grid environment, the system needs are not homogenous. Although a solar photovoltaic system might be the perfect source of electricity for one village, a wind-powered off-grid system may be necessary for a heavily shaded village. In terms of energy efficiency, a hybrid system may be most effective for other communities. Viewing the villages and the off-grid systems through a systems theory contextual lens can illuminate the challenges faced by the managers.

In addition to the systems theory perspective, I included the diffusion of innovation theory in the conceptual framework. Rogers (2003) developed the multi-level diffusion of innovation theory that contained an explanation of the four main elements necessary for the diffusion, and the five stages that an innovation moves through during the diffusion process. He defined an innovation as “an idea, or object perceived as new by an individual or other unit of adoption" (Rogers, 2003, p. 5). The two innovations in this study include (a) off-grid solar electricity installations and (b) Internet access in hard to reach areas. The four main elements in Roger's model that must be present are (a) the innovation, (b) communication channels, (c) passage of time, and (d) a social system (Rogers, 2003). Whether an innovation will be successfully adopted depends on the state and interaction of these four critical elements. The innovation must move through the appropriate communication channels during a desired amount of time and within the desired social system. As an innovation moves through the process, it passes through the five stages of the innovation framework: (a) knowledge/awareness, (b) attitude/interest, (c) evaluation/decision, (d) trial/implementation, and (e) adoption/confirmation (Rogers, 2003).

In this study, the diffusion of innovations related to how the NGO's top managers first become aware of the need for an off-grid solar-powered system by the village request for a system installation. Thus, the village members have already moved through the first three stages of knowledge/awareness, attitude/interest, and evaluation/decision. They have expressed their interest to the NGO and have decided that the off-grid system is the desired innovation. On the NGO end of the decision process, the NGO managers conduct their evaluation of the community to ensure that the basic requirements for the innovation are in place. Some of the requirements include such things as the availability of a building with southern exposure for optimal solar panel placement as well as the availability of village members to form an energy committee with management responsibilities to observe and monitor the installation process and take over the maintenance process after the installation is complete. The installation of the off-grid solar electricity system is the trial/implementation stage of the diffusion, and this stage has its own set of management issues. After the off-grid installation, the village residents and the village energy committee must move the innovation to the adoption/confirmation stage. That stage also has its own set of management barriers and issues.

Within the model that Rogers (2003) created, there are also five categories to the readiness of an individual to adopting an innovation. On one end of the spectrum are the innovators who either introduce the innovation or are among the initial group that accepts the innovation. Moving along the innovation continuum, the middle categories are early adopters, early majority, late majority, and at the far end of the continuum are the laggards (Rogers, 2003). This continuum is relevant to the research problem because the village members might be viewing themselves as laggards, not having electricity and Internet access in their rural and remote locations. In contrast, their peers who are closer to the traditional electricity infrastructure already have a steady source of electricity and most likely the possibility of an Internet connection. Once the innovation, the off-grid electricity system, is in place, the managers determine how it will be used based on the technology acceptance model's constructs. This theory was thus applicable to the study and has also framed previous studies relevant to this study's focus (Bergek, 2017; Eleftheriadis, 2015; Kumar & Agarwala, 2016; Singh, 2016; Riva et al., 2019).

The management of this technology is dependent on the diffusion of it. "Decision making in energy projects requires consideration of technical, economic, environmental, and social impacts and is often complex" (Strantzali & Aravossis, 2016, p. 885). Kumar and Agarwala (2016) stressed the "components of technology, conversion, availability of sources, cost and policy" (p. 1524) as critical components in the framing of an integrated diffusion. Researchers have predicated business models on this goal, with the result being a sustainable stand-alone system. At the same time, the technology itself should be diffused and accepted as viable for the system to be successfully accepted by its users.

Further, the technology acceptance model (Davis, 1986, 1989) was a conceptual fit because it addresses the issues of the off-grid electricity's system ease of use and usefulness. Previous studies have used acceptance of technologies included (Hammami, 2016; Kabanda, 2014; & Van Dijk, 2017). If the village members find the electricity system easy to use, and it provides usefulness to their daily routines, then the innovation will be adopted, accepted, and utilized within their daily lives. Should the village members encounter management issues or barriers with the maintenance and daily use of the system, then there is a chance that the innovation will not be adopted, or it might be ignored and remain unused. Identification of these management issues was part of the focus of this study.

Once the NGO and the volunteer tourists have completed the installation of the off-grid solar electricity system, the team usually leaves the village. At this point in my two trips to Nicaragua, I pondered the possibility of using the off-grid system to provide Internet connectivity for the village residents. Is there a national Wi-Fi system that the village residents could use for Internet connectivity? Would it be relatively easy to find a source of connection to the Internet and some affordable and easy to use computer and information technologies for the village members? Using the technology acceptance model framework, these questions and the possibility of Internet connectivity using the off-grid electricity system were explored within this study.

Literature Review

Energy Poverty

The social issue of energy poverty was at the core of the research problems and research questions. Energy poverty is a term that originated with the concept of *fuel poverty*. Fuel poverty was identified in 1991 by Brenda Boardman in her seminal work. The term included those consumers who spend more than 10% of their income on fuel expenditures (Boardman, 1991; Moore, 2012). Bouzarovski (2018) succinctly described it in a more modern way: “energy poverty occurs when a household is unable to secure a level and quality of domestic energy services—space cooling and heating, cooking, appliances, information technology—sufficient for its social and material needs” (p. 1). Bouzarovski and Petrova (2015) pivoted the definition away from a group of consumers and toward a specific household situation. Because general poverty is more income-oriented, it is a slight but important distinction to say that the energy poverty is more situation dependent. Income may or may not be the deciding factor as to why a specific household or location fails to have access to a necessary level of energy.

As time went on, the definition of the term and its characteristics evolved. Day, Walker, and Simcock (2016) took the meaning even further, postulating that “energy consumption is an essential need or right that should be provided for, and the lack of this as a form of deprivation that should be addressed” (p. 255). Access to energy and individuals’ well-being is a critical relationship requiring further observation and research

(Diaz-Maurin, Chiguvare, & Gope,2018; Kolk & Van Den Buuse, 2012; Mininni, 2017). This relationship complements the United Nation's Millennium Development Goals to eradicate poverty and provide clean energy.

There are still many areas globally where people live without a steady source of energy. Promoting universal energy access for all global citizens is critical to achieving the United Nation's Millennium Development Goals, especially goal (1) no poverty and goal (7) affordable and clean energy (United Nations Foundation, 2015). In an overview of the energy poverty issue, Gonzalez-Eguino (2015) explained that energy poverty is one of three major issues that the global leaders must address within the coming decades, with the other two issues being energy security and climate change. Consequences of energy poverty include a negative impact on health, economy, and the environment (Gonzalez-Equino, 2015; Winiecki & Kumar, 2014).

For healthy development and growth of its residents, an area must have a steady and constant source of reliable and affordable energy (International Energy Agency, 2017; Kumar, 2018; Mainali, Pachauri, Rao, & Silveira, 2014). As noted in the Department for International Development from the United Kingdom report (n.d.), "economic growth is the most powerful instrument for reducing poverty and improving the quality of life in developing countries" (p. 2). Access to energy is critical to ensuring economic growth and sustainability (Bhandari et al., 2017; Kobayakawa & Kandpal, 2014; Kulkarni & Anil, 2015; Winther, Matinga, Ulsrud, & Standal, 2017). In fact, "energy access is the 'golden thread' that weaves together economic growth, human development, and environmental sustainability" (International Energy Access, 2018, para. 1).

Armey and Hosman (2016) noted that electricity is central to any ICT development, whereas Damasen and Uhomoibhi (2012, 2014) examined solar energy for ICT development. Fernandez-Baldor Martinez and colleagues postulated that electrification projects provide "benefits to the communities [such as] reducing air pollution caused by candles and kerosene, improving the access to communication through television and radio, providing the possibility of night study under appropriate light etc.…and an expansion of capabilities… [in areas of] religion, leisure or community participation" (Fernandez-Baldor Martinez et al., 2014, p. 13). Diallo and Moussa found evidence that home electrification provides benefits to the welfare of residents (Diallo & Moussa, 2020). Other researchers agree with this position (Grogan & Sadanand, 2013; Rahman, Paatero, Poudyal, & Lahdelma, 2013).

Inadequate access to a reliable and steady source of energy in many locations could have resulted from numerous governance or political influences. The existence of adequate infrastructure is dependent on the "close relationship between the governance of global economic dynamics, on the one hand, and the political and organizational aspects of infrastructure operation in the energy sector, on the other" (Bouzarovski, Bradshaw, & Wochnik, 2015, p. 219). Sovacool (2013) cited a lack of resources and policy conflicts as possible reasons for the existence of energy poverty. In other words, the national or local government policies most likely would have provided universal access to electricity, yet for whatever reasons, certain areas still lack access. The solution is not a simple one-dimensional approach.

Sovacool, Bazilian, and Toman (2016) indicated that as of 2016, 1.1 billion people globally still lacked electricity. These researchers identified three energy access paradigms as possible solutions: donor support, market creation, and the sustainable energy approach. Each of these paradigms includes unique main actors, emphasis, provision, standardization, capacity building, monitoring and evaluation, and ownership. The researchers suggested a cross-discipline research approach encompassing all stakeholders, including investors, policymakers, energy suppliers, and fund suppliers (Sovacool, Bazilian, & Toman, 2016; Herington, van de Fliert, Smart, & Lant, 2017).

Remote and rural areas far from the conventional electrical infrastructure might lack access to a steady source of electricity due to their isolated location (Atsu, Agyemang, & Tsike, 2016; de Almeida, Moura, & Quaresma, 2020; Mohammed, Mustafa, Bashir, & Ibrahem, 2017). If the traditional stakeholders attempted to extend the electricity infrastructure to these remote locations, it could prove costly and nearly physically impossible (Willcox, Water, Wanjiru, Muzee, & Esendi, 2015). A possible solution to this infrastructure issue is to bypass the extension of the traditional infrastructure and focus on other possible solutions for providing an affordable and reliable source of electricity. Using renewable energy sources is just one solution to alleviating energy poverty and providing affordable and clean energy (Bhide & Monroy, 2011; Heynen, Lant, Sridharan, Smart, & Greig, 2019; Ong, 2015; Vargas et al., 2016). Renewable energy sources are the focus of the next section in this chapter.

Renewable Energy

The initial search for a dissertation topic led to an interest in renewable energy technologies. Saving the environment and conserving natural resources has been a priority for many organizations and individuals. Because of this, I searched for a topic related to this industry. Thus, directly related to the research problem and research questions is the concept of renewable energy. Renewable energy has been a popular topic for a few decades, partly due to rising oil prices and partly due to climate change (Tai & Uhlen, 2014). Using renewable energy as a source of electricity is attractive because of its affordability, sustainability, and accessibility (Kumar & Shekhar, 2015; Pillot, Muselli, Poggi, & Dias, 2019; Rohankar et al., 2016; Tlili, 2015). On the other hand, renewable energy sources are variable and uncertain in supply and location-specific (Kondziella & Bruckner, 2016).

There are many choices for renewable energy technologies. Among these are wind power, hydropower, geothermal, biomass, marine, and solar (Ellabban, Abu-Rub, & Blaabjerg, 2014; Orajaka, 2013; Wesseh & Lin, 2017; Zamfir, 2012). Advances in new technologies continue, driving down the cost of the technologies in most cases. With lower prices and more widespread availability, using renewables as a solution for energy poverty continues to rise.

Currently, residents of many countries can use renewable energy sources to reduce carbon footprint, help against the progression of climate change, and decrease the expense of obtaining energy. Within the smart grid electricity system, and the traditional electricity infrastructure, renewable sources continue to grow as a viable means of providing inexpensive or free energy while decreasing the carbon footprint of humans (Augustine & McGavisk, 2016; Evens, 2015; Lam & Law, 2016). Providing off-grid renewable energy source could be a viable solution for those rural, remote, or hard to reach geographical areas. Solar is the most commonly used renewable energy source for off-grid installations (Vannini & Taggart, 2015). Recent research contains many examples and business models of off-grid systems, as noted in the following sections.

Off-Grid Systems

Using off-grid solar energy is a subset of the solution to alleviating energy poverty. However, it is a solution that is becoming more attractive as the cost of solar panels decreases, and the knowledge needed to maintain the solar systems becomes less complicated. Corporate social responsibility for some corporations addresses this issue through their philanthropic programs. Schneider Electric's BIPBOP Program (Schneider-electric.com/bipbop) is one example of using micro-grids to provide electricity in those areas that are hard to reach. (BIPBOP is an acronym for Business, Innovation, and People at the Bottom of the Pyramid.) Schneider provides their expertise and a range of products that are suitable for off-grid or micro-grid installations. Using NGOs, entrepreneurs, micro-financing models, and sometimes local authorities or local corporations, the equipment and models can provide off-grid installations for those living in remote or rural areas (Kumar, Shankar, Momaya & Gupte, 2010; Larsen et al., 2014; Smith & Urpelainen, 2014).

Another related possibility is by providing solar-powered mobile lighting devices (Alstone, Lai, Mills, & Jacobson, 2014; Tamulaitis, 2011). Some of these devices contain USB ports for cell phone charging. This solution provides power for only a minimal subset of the possible uses of electricity. One example is a Global Light Projects (globallightprojects.org), a group that offers solar-powered lighting, and the power to run electronic equipment and a water pump.

Another business choice is to use microfinancing for small groups through programs such as Kiva and Grameen Bank. Usually, an NGO or a non-profit organization has set up a plan to provide funding for installing an off-grid or a micro-grid system. These programs are popular with philanthropic organizations as the key is getting the funds directly into the hands of the individuals who have the need.

Lastly, but not exhaustively, there are the NGO/non-profit organization groups who use the voluntourism (volunteer tourist) model to help fund and provide the labor for the installation of off-grid renewable energy electricity systems in remote and rural areas. Although this model is the focus of this study, a literature review of off-grid systems themselves was included in the next section, to provide a more solid foundation of possible business models and best practices for off-grid systems.

Current peer-reviewed literature about off-grid systems. From a geographical viewpoint, off-grid research usually is focused on developing countries. South and Central America were popular choices for the use of off-grid systems because there are many emerging countries in these regions where off-grid electricity systems provide significant benefits to remote rural villages. Lillo, Ferrer-Marti, Boni, and Fernandez-Baldor (2015) focused on systems in Peru. These researchers focused on the use of solar photovoltaic off-grid to alleviate poverty. On the other hand, Hong and Abe (2013) and

Hong, Abe, Baclay, and Arciaga (2015) focused on the Philippines. Numerous studies were conducted in India only, such as Kobayakawa and Kandpal (2014), Kumar, Sundareswaran, and Venkateswaran (2014), and Urpelainen (2016). Several studies focused on both India and Asia. These included Bhattacharyya (2014), Bhattacharyya (2015), Jinayim, Mungkung, and Kasayapanand (2014), Palit (2013), Palit and Chaurey (2011), and Shyu (2013).

Africa is another continent/region where renewable energy is a rapidly growing trend. The researchers Franceschi, Rothkop, and Miller (2014) and Ondraczek (2013) all chose to focus on East Africa for their studies. One group of researchers conducted in Europe in Germany (Schwartz, Denef, Stevens, Ramirez, and Wulf, 2013; Schwartz, Stevens, Ramirez, & Wulf, 2013). The analysis of peer-reviewed research in geographical perspective serves to highlight the limited amount of literature that could be generalized over many areas and populations.

A more relevant framing and analysis of the current literature is a comparison and contrast of the business models used in the off-grid peer-reviewed articles. Many business models were evident in the literature. Some of the management models focused on costs and tariffs, whereas other management models focused on the ownership of the renewable energy system. Some of the business models focused on the supply of the utility itself.

Management models of off-grid and microgrid renewable energy systems vary depending on certain specific characteristics. These characteristics include the installation of the equipment, ownership of the system, level of user participation with the ongoing operational responsibility of the system, and user involvement in the system's ongoing financial responsibility (Lillo, Ferrer-Marti, Boni, & Fernandez-Baldor, 2015).

Within the business model is the identification of the source of capital funding for installing the system. Financing is a critical role (Shi, Liu, & Yao, 2016). Several sources are available for financing and equipment, including the country's government, local municipal government, community resources, private local groups, international Non-Governmental Organizations, or Non-Profit Organizations, and the village residents.

Another aspect of the business model is the ownership of the off-grid electricity system. Ownership can vary from being wholly owned by the national government or the Non-Governmental Organization to being entirely owned by the remote community's residents, or a partnership that falls somewhere in between that broad spectrum. In some cases, ownership remains with the local government. In this situation, the government not only controls who receives the flow of electricity, but it also controls the fees set for the usage of the utility. Another business model is when the village members themselves are given ownership of the system. The problem with this situation is that these residents are typically responsible for the maintenance, ongoing operations, upkeep, and upgrades of the system. The villagers usually elect their managers to oversee these functions. This ownership model can quickly become a burden to the village residents if these systems were installed in remote rural areas where there is a lack of wealth. Time spent on the electricity system maintenance typically means time taken away from daily and necessary activities such as raising children, acquiring drinkable water, tending to any farming chores with animals or crops, searching for fruits, berries, and nuts, preparing and cooking meals, cleaning the small home and farm/garden area.

The level of user participation can vary also. Some models have the residents as strictly customers of the utility, whereas some models have given the residents a more hands-on role. Connected to this is the operational responsibility of the energy system. Some models have no user participation, whereas some of the models have resident/user participation at the 100% level for the ongoing daily functioning operations. The level of ownership of the system directly impacts the financial responsibility for it. Some models reflect governmental responsibility, whereas others have entirely autonomous resident/user responsibility. In the following analysis of the literature, I analyzed each source for the management model present or lack thereof. This analysis was useful for providing new insight into possible best practices of business models of off-grid and micro-grid systems.

In 2014, Bhattacharyya described a business model that he referred to as the Huck power systems model. The system's objective is a "rural electrification business that has combined electrification with rural development by providing access to electricity while ensuring environment protection, the wellbeing of local population and empowerment of local communities" (Bhattacharyya, 2014, p. 45). By securing funds from charitable sources and financial institutions, Huck power systems installs the power plant system after receiving a deposit from the villagers. Consumers pay a connection charge and a flat monthly fee for basic service. The model is called BOOM: Build, Own, Operate, and Maintain. Huck power systems uses smart technologies and rice husk gasification as its technologies for the renewable energy system. Electricity providers use smart meters for billing purposes. To supplement the electricity producing aspect, the byproducts are collected and used by local entrepreneurs as supply materials for incense stick-making.

In 2015, Bhattacharyya studied mini-grid systems in remote rural villages in Bangladesh. The researchers approached the project from a different angle. Instead of studying existing off-grid systems, the researchers studied a non-electrified rural village. They used a software model to determine the optimal technological configuration of an off-grid system given the estimated demand, environmental conditions, any social issues, and regulatory governance that might affect the business case. The installers would provide the village with the renewable energy system, but the residents would have 15 years to repay the project's cost. It also became evident that there were many stakeholders in these cases: investors, consumers, and the government. Although the system would be off-grid, the business model more closely resembled a micro-grid configuration where the residents are provided with the utility yet are still responsible for all of the costs and expenses involved.

Franceschi, Rothkop, and Miller (2014) studied off-grid renewable energy systems in Kenya. These off-grid systems were used for fieldwork for humanitarian projects from emergency communications needs to refugee camp needs. This study's business model was hidden within the product development and market adoption and distribution of existing prepackaged and portable systems. For this reason, and because most of these systems are considered temporary, this article was not informative for identifying permanent or long-term successful business models in remote rural villages.

In 2013, Hong and Abe studied the sustainability of off-grid systems in remote villages in the Philippines. Two cases were studied. For the business model for the Pangan-an case, the Belgian government donated the funds for the development of the projects. Additionally, "the project included the establishment of a community cooperative to operate and maintain the system while being overseen by the Department of Energy of the Philippines" (Hong & Abe, 2013, p. 356). The second case in Alumar had a slightly different technology setup and business model. This case provided solar home systems for fifty residences. The Philippine government worked together with the Japan Internal Cooperation Agency to provide these solar home systems. For a viable business model, in either case, Hong and Abe found that there must be a good match between the technologies used and the user requirements (Hong & Abe, 2013).

In 2015, Hong, Abe, Baclay, and Arciaga studied off-grid systems in the Philippines. As in the article above, the researchers focused this study on the village of Alumar. In this scenario, fifty homes had individual solar home systems. The business model is the same as before but described more accurately and with more details in this subsequent article. The national government's Department of Energy, the local government, and an international agency (the Japan International Cooperation Agency JICA) provided the system. The community cooperative expected the residents to pay a participation fee initially and then a monthly fee to the community cooperative. The community cooperative expected these residents to maintain and inspect their systems to keep it sustainable. Selecting active managers was essential for sustaining the cooperative operation.

Kobayakawa and Kandpal studied off-grid in rural India in 2014. This off-grid system was installed by the West Bengal Renewable Energy Development Agency. The Agency required initial charges as well as a monthly tariff payment. As the researchers noted, “one of the major challenges of the planning and operational process of the micro-grid system is to decide the trade-off between financial viability and affordability in tariff setting for the electricity being supplied” (Kobayakawa & Kandpal, 2014, p. 92). The financial components of this system were of utmost importance to the researchers.

Kumar, Sundareswaran, and Venkateswaran researched a grid-connected solar photovoltaic system in India in 2014. The performance of the renewable energy system was studied. It became evident that the electricity was used to power a boiler manufacturer plant, instead of the village’s homes. The business model was not evident in this article and, therefore, of little use to this study.

Lillo, Ferrer-Marti, Boni, and Fernandez-Baldor (2015) called their management model the “microenterprise management model.” The off-grid electricity systems in this study were implemented with resources from the NGO called Practical Action. Before the implementation, the NGO members studied various factors: “the organizational dimension, capacity strengthening, client relationships, and stakeholder participation were evaluated” (Lillo et al., 2015, p. 18). This approach was one of the crucial success factors of the systems studied by these researchers.

The Practical Action NGO had primary objectives of “efficient financial and technical long-term operation of small isolated power systems…the owners of the systems (generally the district municipality) give responsibility for [the] operation, maintenance, and administration to a local private microenterprise (managed locally by the members of the community)" (Lillo et al., 2015, p. 18). Users pay a monthly tariff. A group of residents comprises the board that oversees the administration of the system. A microenterprise operates and manages the system. Users add to the tariff collection, thereby increasing the reserve fund for maintenance and repairs. This business model could prove useful compared to the business model in this study.

Ondraczek (2013) prepared an extensive literature review of the historical development and current status of solar markets. Ondraczek stated that

> from the early 1980s, the government, international donors and development agencies began to include solar energy in their projects for the provision of electricity for various social users in off-grid environments, such as school lighting, water pumping, and vaccine refrigeration. Their demand for solar power systems fostered the emergence of a national PV supply chain (p. 408).

The domestic private solar power market grew in the next two decades. Systems include residential solar home systems, systems for schools, health centers, missions, and other social institutions, and solar-powered base stations in mobile-phone networks (Ondraczek, 2013). Residents who have the resources to afford them typically purchase Solar Home Systems individually. These systems provide electricity for lighting, to recharge mobile phones, and to power televisions. Ownership remains with the individual residents, and they are responsible for the ongoing maintenance of the systems.

Additionally, there has been some public sector procurement of solar systems. As Ondraczek (2013) noted

> large segments of Tanzania's solar market remain dependent on the funding and active support of the country's government, international donors, and development organisations.…On a smaller scale, national and international non-governmental organisations (NGOs) remain active as buyers of solar power systems and providers of know-how and training (p. 411).

Ondraczek did not detail the business models used for the implementation and ongoing operation of these systems, but noted that the trend was becoming more popular.

In South Asia, Palit (2013) studied solar energy systems in rural areas. Palit stated, "while most of these projects/programs have and continue to be via grants and donor-driven in most countries, a combination of free market and grant based model has also been successfully tested and being scaled-up in Bangladesh, Sri Lanka, and India" (Palit, 2013, p. 271). For the Solar Home Systems, it appeared that individuals purchase this technology in the private market from solar companies, usually with leasing or consumer financing involved. Palit noted that there had been instances where "due to the poor battery performances which in many cases do not function until the end of the loan duration of 3 years, there has been default in loan repayment by the customers" (Palit, 2013, p. 273). For the development of the infrastructure for renewable energy for the industrial market, two types of grants were available: institutional development grant and system buy-down grant. Other types of financing include micro-credit programs and fee-for-service mechanisms such as in Bangladesh, where the Rural Electrification Board uses a business model to install the system and retain ownership but the household pays a monthly bill. Overall, the researchers discussed many business models in this article (Palit, 2013).

Palit and Chaurey (2011) studied off-grid in rural South Asia. One of the new business models in this article included the distribution franchises in India that developers used to “ensure revenue sustainability” (p. 268). These groups were given authority by the government to handle metering, billing, and revenue collection. In another part of the region, in Nepal, community involvement in electrification systems has increased. “Consumer associations, typically in the form of cooperatives, take the responsibility of managing, maintaining, and expanding the rural distribution of electricity. Communities raised 20% of the investment cost for grid extension to their area, and 80% of the cost is borne by the Government of Nepal through the Nepal Electricity Authority” (Palit & Chaurey, 2011, p. 268). Note that this is *grid expansion*, not off-grid systems. Business models can differ widely for grid extension and expansion versus stand-alone off-grid or micro-grid systems.

Regardless of the type of technology used, the researchers claimed that “most off-grid electrification programs in the region have been grant-based and donor-driven and continue to be so in countries such as India, Nepal, and Pakistan” (Palit & Chaurey, 2011, p. 270). These researchers compared the technologies implemented and the business models adopted for the four countries that were studied. See Table 2 for these comparisons.

Table 2

Technologies and Business Models

Country	Major off-grid technologies implemented	Business models adopted
Bangladesh	Solar home system	Consumer financing, leasing
India	Solar home system , solar lanterns, biomass gasifier, micro/mini hydropower	Consumer financing, leasing, fee for service, village energy committee
Nepal	Solar home system, micro/mini hydropower	Consumer financing, village energy committee
Sri Lanka	Solar home system, micro/mini hydropower	Consumer financing, village development committee

Note. Source: Palit and Chaurey, 2011, p. 270.

The business model studied by Shyu (2013) in China reflects the Township Electrification Program launched by the Chinese government in 2002 in an attempt to provide electricity for all. Shyu (2013) stated that

> this program aims to electrify the townships in the 11 western provinces which did not have any electricity access by constructing stand-alone mini-grid solar PV power stations, solar PV/wind hybrid power stations, and small hydropower stations. As the Township Electrification Program is a top-down, centralized national policy initiated by the Chinese government, the program is also a supply-driven rural electrification, focusing mainly on electricity supply (p. 392).

In this business model, developers constructed mini-grids, with as many homes as possible connected to them. The mini-grid included electric meters, and a monthly tariff was due based on usage. This business model resulted in an insufficient amount of electricity supplied, and it also resulted in a lack of the utility when there were periods of no electricity at all. Demand did not match supply, which Shyu (2013) noted was one of the main problems with this supply-driven top-down business model.

One of the business models that Urpelainen (2016) described in his article was a traditional consumer business model in India. Entrepreneurs provided solar home systems to residents in rural areas using a subscriber model. The entrepreneurs retained ownership and management of the systems while providing the rural residents with the technology. Residents paid a monthly subscription to the entrepreneurs. The problem with this model was that not all of these entrepreneurs were honest and ethical business people. Distrust among the rural residents grew to the point where even honest entrepreneurs were not trusted. Additionally, a steady and reliable stream of electricity was not guaranteed, especially at night. Once the batteries were depleted, the residents were without power until the solar panels began receiving sunlight again.

The other issue in this situation was that "part of the problem lies with the lack of financial models" (Urpelainen, 2016, p. 535). To grow and be sustainable, the entrepreneurs needed volume sales, yet the villagers looked for integrity and honesty in their business dealings. Without the expanding customer base, solar could not become mainstream for the entrepreneurs. Because of this, a second business model started to flourish. The other source of these systems was a business model where the government was the micro-grid's technology provider. Rural residents "preferred government leadership in rural electrification" (Urpelainen, 2016, p. 538), even if it was off-grid or microgrid systems because some of these villages were too far from the existing infrastructure to make the connection a viable alternative. The residents valued reliability, a steady stream of electricity, and honesty in their business and financial dealings. Effective management of the system was a crucial part of providing these requirements (Onyeji-Nwogu, Bazilian & Moss, 2017; Bhattacharyya & Palit, 2016). Many of these researchers focused on the business model aspect of the off-grid system, and they provided insight into the best practices used to implement and sustain off-grid and micro-grid rural electrification systems in developing countries.

Current literature on off-grid: Best practices of business models. The previous analysis of the current literature provided many best practices for the use of renewable energy systems in off-grid and micro-grid electrification systems. The conclusions of the researchers were rich in knowledge of these best practices.

Hong and Abe (2013) explained, “the users were found to have varying levels of incomes and livelihood opportunities which resulted to varying electricity usage and financial capacities” (p. 356). These researchers concluded that one of the key success factors for off-grid rural systems in these cases included a good match between the system’s users and their needs and the system’s technological requirements. Further confirmation of this came from Shyu (2013), who noted that many renewable energy rural electrification installations in China instilled a “supply-driven paradigm” instead of a needs-based end-user perspective. The use of a needs-based pre-system analysis and configuration will ensure that the proper system will be installed based on the needs and requirements of the residents at each location.

Hong and Abe (2013) also noted that the residents’ ability to maintain the system physically and financially is a crucial success factor. Residents must have the time, knowledge, and resources available to keep the system components working. The solar panels must be free of debris or other interference. The wiring system must be kept in good working order. The batteries required distilled water on a timely basis. The success of the system is dependent on all of these functions, and Laufer and Schafer (2011) agreed by noting that “robust technologies, adequate maintenance and financing strategies” (p. 330) are critical to sustainable systems.

Kumar, Sundareswaran, and Venkateswaran (2014) concluded that off-grid solar systems are lagging implementation due to a “vagueness associated with the economics of the system” (p. 301), whereas the other main economic barrier included the initial cost of the system. For these systems to become viable solutions to energy poverty, best practices must consist of education for the residents concerning the financial and economic benefits and costs of these systems. With more knowledge, the residents can make better choices regarding their time management for system upkeep and their choices for the most effective and efficient use of this valuable resource.

In 2011, Palit and Chaurey concluded that the micro-lending model needed some innovation, and the electricity supply needed enhancement by continuing the tariffs into the future. Other improvements that these researchers recommended included more organized access to credit and financial arrangements. Later, in 2013, Palit concluded that for India, Bangladesh, Sri Lanka, and Nepal, the systems’ success factors were “improved access to capital, development of effective after-sales service, customer-centric market development, and regular stakeholder involvement assisted in scale-up” (p. 277). Other critical success factors were robust financial innovation systems and private sector involvement. Future recommendations included the removal of "barriers to supply, demand, and scalability and at the same time [adoption] of standard process and metrics" (p. 278). Ultimately, Palit and Chaurey (2011) concluded that "the underlying principle for choice of a particular mode is adopting the least cost technology options and with minimum maintenance requirements as far as possible" (p. 269).

In the final analysis, it was the integrity that was necessary for the success of most business models. Urpelainen (2016) concluded that the "findings highlight the importance of quality certification, awareness raising, and excellent service. Unless solar entrepreneurs can convince rural villagers that they are honest and conduct business with integrity, it will be hard for them to penetrate the rural markets" (Urpelainen, 2016, p. 538).

Giwa, Alabi, Yusuf, and Olukan (2017) prepared a comprehensive review of renewable energy within Nigeria. They concluded that "the techno-economic feasibility and environmental significance of solar power and bioenergy for Nigeria's sustainable development is site-specific and subject to factors such as incentives and financing, research and development, public enlightenment, government's policies, and private investments" (Giwa et al., 2017). In conclusion, all the aspects of the business model must be addressed on a case-by-case basis for each location because these business models are quite diverse (Gomez & Silveira, 2012; Gomez, Tellez, & Silveira, 2015).

Energy innovation can occur when there is a transnational technology transfer (Wieczorek, Raven, & Berkhout, 2015). Key factors highlighted included substantial funding for building and implementing the system, increased knowledge among residents for the ability to maintain the system, a robust ongoing business model to keep the resident engaged in the use and maintenance of the system, and a sustainable plan for the future use and development. Orajaka (2013) stressed that "the success of the project lies with the collaboration of the project team with the community locals from the earliest phases of the implementation cycles" (p. 6). Kerr, Johnson, and Weir (2017) noted that "local involvement in the development stage allows for a form of community control over the environment that can result in greater acceptance" (p. 204). Although not directly mentioned by the authors, the effectiveness of the management of the system was also an essential criterion for the successful operation of the system.

With some knowledge of the best practices and the issues and barriers of off-grid systems, I now pivot to focus on the current literature for the business model for this dissertation: voluntourism. Could this model provide a successful off-grid electricity system for village members in rural and remote regions of developing countries and an extension of Internet connectivity? A review of the existing literature concerning voluntourism provided more insight into the viability of this business model.

Volunteer Tourism or Voluntourism

Current research on voluntourism. Researchers defined voluntourism (volunteer tourism) as "the combination of travel and volunteering, typically in social or economic development or conversation oriented projects" (Sin, Oakes, & Mostafanezhad, 2015, p. 119). Researchers based the voluntourism model on an earlier ecotourism model, with ecotourism defined as "responsible travel that conserves the natural environment and improves the well-being of local people" (Singh, Dash, & Vashko, 2016, p. 237). In the ecotourist model, the "tourist is not given central priority but becomes an equal part of the system" (Wearing & McDonald, 2010, p. 191).

In the 1980s, ecotourism was originally for volunteers who desired to help protect the environment and globally conserve natural resources. It was a model that expanded to be used not only for environmental issues but also for medical purposes (Doctors without Borders), home building (Habitat for Humanity), disaster relief and cleanup (All Hands and Hearts), and poverty alleviation (The Hunger Project). Sin, Oakes, and Mostafanezhad (2015) noted that voluntourism could include working in orphanages or farms.

Volunteer tourism also stemmed from the original concept of overseas volunteering that included those individuals who went outside their home country for volunteer opportunities such as the Peace Corps (Sharpley, 2018). In contrast to overseas volunteering, voluntourism usually involved a shorter trip to a foreign country, typically one to two weeks. Participants in volunteer tourism were called "volunteer tourists [and] are those individuals who travel to host communities both domestically and internationally to volunteer their vacation time to work on a wide range of humanitarian or environment-related projects" (Lyons, Wearing, & Benson, 2009, p. 269). Usually, a large part of the trip was devoted to predetermined volunteer activities performed by the hosts and the volunteers, whereas part of the trip was related to experiencing the culture of the area. Given that it is a form of travel with participation by the tourists, voluntourism could also be described as *participatory experience tourism* (De Bruin & Jelincic, 2016).

Until the last ten years, researchers had claimed that there was a lack of systematic academic research about the specific topic of voluntourism (Lyons, Wearing, & Benson, 2009, and Romero-Brito, Buckley, & Byrne, 2016). Now it is a topic that is quickly growing in popularity. More recently, other researchers stated that research on voluntourism has evolved as the phenomenon itself has become more popular because this industry has experienced “explosive growth” (Wearing & McGehee, 2013, p. 120). This is evident by the growing volume of recent (last three years) literature available about this phenomenon as well as the many tangents of the research subtopics that were studied by the authors.

Volunteer tourism is directly connected to the concept of global citizenship (Butcher, 2017). Stoner and colleagues claimed that “global citizens understand the interdependency of the world and its inhabitants, and the connective links that exist between all living things” (Stoner et al., 2014, p. 152). Phi, Whitford, Dredge, and Reid (2017) noted that global citizens share a belief that all global residents are interconnected, which results in the ability to “foster an awareness that their tourism activities can create a better world” (p. 235). Global citizens, therefore, are potentially active agents of social change.

On the other hand, Sharpley (2018) noted that “volunteer tourism is a confusing and, perhaps, contradictory term,” (p. 98), or an oxymoron. The individual is either a tourist (a leisure activity) or a volunteer (a labor-intensive activity). There are also criticisms that the volunteer tourists could be viewed as being globally cosmopolitan individuals, although conversely, the activity itself is neo-colonial based on western superiority and western privilege (Judge, 2017; McLennan, 2014). Discussions of this dichotomy were evident throughout some of the literature, where Burrai and Hannam (2018) postulated that "responsible volunteer tourism remains integral to neoliberalism which emphasizes market-based economics as the solution to poverty at the expense of broader state interventions into the social inequalities that responsible volunteer tourists engage with" (pp. 90-91). As a multi-faceted business model, the topic of volunteer tourism "is a theme that can be examined from many perspectives…It also has implications for business: its operation, marketing, and also its ethical basis" (Butcher, 2017, p. 128).

One focus of the current research on voluntourism concerned the motivations and experiences of volunteer tourists. Within the themes identified, there are motivations for the participant "to gain personal development and growth and to gain new experiences" (Proyrungroj, 2017, p. 560). Gossling (2018) postulated that "learning is often a central element of tourism" (p. 292), whereas Wearing, Young, and Everingham (2017) noted that transformative learning is a benefit for volunteers. McGehee (2014) indicated that voluntourists have motivations that sometimes are altruistic, whereas others have self-improvement goals. Additionally, there can be a desire for "giving back to the host community, participating in community and international development, and improving cultural understanding" (McGehee, 2014, p. 848). Wilson (2015) echoed these findings with her statement that voluntourism "enriches the local community at the same time as offering the opportunity for a more profound travel experience" (p. 201). Caissie and

Halpenny (2003) noted volunteer motives that included “leaving a legacy” and “altruism” (p. 38).

Other researchers offered more motives for volunteer tourists. Dillette, Douglas, Martin, and O’Neil (2017) found that the highest motivating factor for voluntourist participation was community involvement. Proyrungroj (2017) postulated that learning about the local culture and making new friends were significant motivations for participants who had volunteered in philanthropic tourism activities. However, another group of researchers noted that there is a mainstream trend in that travelers are searching for “authentic and unique experiences” (Santos, Veiga, & Aquas, 2016, p. 655) and tourists are “seeking more sustainable and responsible tourism experiences” (Wearing, Young, & Everingham, p. 512). Foller-Carroll and Charlebois (2016) noted that some individuals now display *personal social responsibility*, that is, an individual desire to assist others. Butcher (2017) noted that these voluntourist projects are “projects of ethical selfhood: the forging of an ethical sense of self” (p. 127).

Individual volunteer motivations are significant to the research questions identified herein because these motivations can directly affect the success and the financial viability of the management of the business model and project at hand. From the NGO’s viewpoint, the business model of voluntourism includes providing a steady stream of short-term volunteers. These volunteers can work side-by-side with the NGO’s in-country project managers (Lyons, Wearing, & Benson, 2009; Coghlan, 2018). To determine the projects’ success, managers must view the results with both the participants/voluntourists and the village residents in mind. The salient outcome is the success of the off-grid solar electricity installation project. From the village viewpoint, the projects would be considered successful, given the fulfillment of the precursor objectives of the projects as agreed by the NGO and the Village Energy Committee. However, Wearing, Young, and Everingham (2017) noted that voluntourism is not a homogenous product, making it harder to determine the success of the phenomenon itself. In light of this, there are existing barriers, obstacles, and limitations encountered during the implementation of these voluntourism projects.

There were many problems with the volunteer tourists identified in the literature. Sin, Oakes, and Mostafanezhad (2015) found that "as development work, volunteer tourism has clearly been found wanting" possibly due to "short-term presence, poor skills, and relative disorganization of [volunteer] tourists" (p. 123). Guttentag (2009) agreed, citing a possible "completion of unsatisfactory work" as well as "hindering of work progress" (p. 537). Additionally, in support of this stance, McGehee (2014) noted that volunteers occasionally performed poorly. Jakubiak and Iordache-Bryant (2017) stated that there could be "a significant language barrier, limited professional or technical expertise, and a lack of knowledge of the service context" (p. 212). Burrai and Hannam (2018) suggested that volunteers could unknowingly exacerbate existing local problems within the hosting communities. Additionally, "the idealist and educational expectations of the volunteers often clash with the practical short-term goals of the community: there are also cultural and experiential differences between the parties" (Prince, 2017, p. 1617). "The economic goals of hosts are not always compatible with the personal goals of the volunteers" (Prince, 2017, p. 1621).

There were many problems with the projects themselves identified in the literature. For some projects, some of the issues with this business model include "poorly planned volunteer projects that do little to benefit a community" (Lyons, Wearing, & Benson, 2009, p. 270). Singh (2014) asserted that there could be a misunderstanding of the impact of these projects on the community. Wilson (2015) noted that projects failed to meet adequate standards due to lack of regulation, lack of adequately trained staff, and limited resources. McGeehee (2014) found the mismanagement of resources within the projects. Singh (2014) identified misusing the local resources as an issue. Phelan (2015) noted that projects might leave volunteers wondering about the impact of their service.

Problems with the project managing organizations, the NGO/non-profit organization, were also identified. Prince (2017) identified a possible mismatch of goals and culture clashes between the NGO/non-profit organization and the hosting communities. Guttentag (2009) noted neglect of local's desires, disruption of local economies, and poverty rationalizations. McGehee (2014) found that there could also be an "exploitation of host communities, the volunteers, and the environment, dependency, and continued neo-colonialism of at-risk populations…and lack of communication among the various stakeholders" (p. 848). For project evaluations, Steele, Dredge, and Scherrer (2017) found that there exists "a lack of time and resources as barriers to monitoring an evaluation" (p. 1674). In most of these situations, the lack of effective management was apparent.

Although many researchers focused on the problems and issues with this business model, other researchers focused on best practices to resolve or avoid some of the problems. Klaver (2015) noted that "it is crucial for volunteer tourists to address the needs of the host community, for the volunteer organizer to offer projects wherein people are in need and for researchers, media, and NGO watchers to generate more transparency of the volunteer organizations" (p. 189). Rozier, Lasker, and Compton (2017) agreed by noting that organizers and host communities must be aligned. Brookes, Altinay, and Ringham (2014) and Sujarittanonta (2014) noted that it is essential to have cooperation among all stakeholders. Loh, Valdman, and Dacso (2016) and Foller-Carroll and Charlebois (2016) stressed that it is equally important to include all stakeholders and ensure alignment of efforts and goals to ensure that short-term volunteer experience does not interfere with long term goals for the host communities. Lupoli (2013) produced the same finding in his doctoral dissertation: include all stakeholders, encourage collaboration, and "address mutual goals and needs" (p. ii). Nino et al. (2017) agreed.

Other possible solutions to the concerns of voluntourism include the push for greater accountability, the development of a code of conduct, and encouraging volunteers to consider their choice of projects and groups (Coghlan, 2018). Wilson (2015) provided recommendations for sharing information, improving communications, and setting minimum standards. Monitoring and maintaining quality experiences for both the volunteers and the village residents is another critical success factor (McGehee, 2014; Steele, Dredge, & Scherrer, 2017). Better management of the resources and communication structures could result in a higher success rate for the projects.

Both Wearing and McDonald (2010) and Wearing, Young, and Everingham (2017) proposed a shift in view of volunteer tourist projects. Wearing and McDonald

(2010) postulated that "conservation and development are not about choosing between two mutually exclusive modes of practice—tradition or modernity. Rather it is concerned with finding a new balance in a changing time and enabling people to communicate their priorities to outside influences" (p. 199). Wearing, Young, and Everingham (2017) noted that "how we evaluate 'making a difference' if often confined within an outdated development aid model…what volunteer tourism should be about, that is, volunteers and local communities coming together, either through conservation projects or community-oriented projects to interact in mutually beneficial cultural exchanges" (p. 518).

Having identified the problems, issues, and barriers with the business model of Voluntourism within the current literature, the next step is to review the current literature of the digital divide, specifically in developing countries or rural and remote areas where Internet access is not yet readily available.

Digital Divide

Current research on the digital divide. When reviewing the current literature on the digital divide, Van Dijk (2006) historically postulated there is nothing new "about the inequality of access to and use of information and communication technology as compared to other scarce materials and immaterial resources in society" (p. 223). Adamson (2016) noted that "half of the world's population does not access the Internet" (para. 2). As with other resources such as water, fuel, and electricity, researchers have studied the benefits of Internet connectivity as a utility. Information and communication technologies provide many benefits, including the possibility of using the Internet's information and other resources and platforms to pull oneself out of energy poverty (Malecki, 2003).

One of the benefits of Internet connectivity includes knowledge about medical and mental health issues. Wang, Bennett, and Probst (2011) postulated that rural residents could overcome obstacles to healthcare needs through the use of the Internet. Burmeister and Marks (2015) agreed that access to the Internet could assist in mental health recovery, precisely “the challenges of distance, access to healthcare and the ease of isolating oneself are best overcome through a combination of technology and communal social responsibility” (p. 170). Leung (2015) noted that “self-monitoring and management of chronic diseases via telehealth technology may seem beneficial to both the patient and healthcare provider” (p. 324). Dobransky and Hargittai (2006) postulated that access to the Internet could increase opportunities for people with disabilities. As noted in chapter one earlier, the benefits of Internet connectivity are many and varied, and the existence of a digital divide limits access to those who could benefit most from access to it (Wijers, 2010). Roberts, Anderson, Skerratt, and Farrington (2016) postulated that Internet connectivity could result in “increased resilience of individuals and communities” (p. 1.)

Developing countries are especially vulnerable to a broader digital divide (see Park, 2015). Chang, Wong, and Park (2014) noted that the digital divide “places developing countries in a disadvantaged position economically, politically, and socially that in turn affects the life and social well-being of the citizens” (p. 1). Although some researchers (Li & Ranieri, 2013, Mequanint & Lemma, 2015; Scoda, 2014) stressed the importance of providing ICT for student development, others noted that the reason for the digital divide in rural or remote areas is the lack of physical access and technology availability (Freeman & Park, 2015; Sparks, 2013; Yu, Lin, & Liao, 2017). Blackman (2002) reiterated that "unreliable infrastructure and high costs of Internet services" contribute to the digital divide. Sujarwoto and Tampubolon (2016) postulated that the Internet divide expanded, partly due to the urban-rural divide.

Townsend, Sathiaseelan, Fairhurst, and Wallace (2013) and Townsend, Wallace, and Fairhurst (2015) noted that the digital divide is growing wider between rural areas and other areas, due to lack of access to the Internet. Their solution is to increase broadband whenever possible. Reed, Haroon, and Ryan (2014) postulated that broadband deployment could be used, eventually shifting to fiber-based networks, for those rural and hard to reach customers. Zander and Mahonen (2013) suggested wireless and mobile Internet access as a possible solution, although not always an affordable one. Unfortunately, this is not always feasible as a solution, especially in remote areas (Pejovic et al., 2012). If the electricity infrastructure has yet to reach the rural or remote area, then the source of electricity for broadband or wireless access is also absent.

Bernadas, Verville, and Burton (2012) asserted that "the majority of research about the digital divide deals with the 'Internet divide' in the USA. It is often seen as a problem of access to technology" (p. 17). Ragnedda and Muschert (2013) agreed with this position. One solution to a lack of ICT is to use smartphones to access the Internet (Park & Lee, 2015; Tsetsi & Rains, 2017). These devices are typically more affordable and readily available. Stork, Calandro, and Gillwald (2012) asserted that "the mobile phone is now the key entry point for Internet usage" (p. 1). However, Pearce and Rice (2013) noted that "mobile Internet is available for those on the wrong side of the digital divide, [but] these users do not engage in many activities, decreasing potential benefits" (p. 721). Vimalkumar, Singh, and Sharma (2020) also stated that mobile phones "serve as the gateway to high-speed internet for large populations in developing economies" (p. 1).

Residents in remote villages in developing countries may have access to mobile phones, but without a way to recharge the phone batteries, they cannot use them to access the Internet. On the one hand, it appeared that access to electricity is the driving force behind the spread of Internet connectivity. However, as a result of the proliferation of cell phones, the demand for phone charging and Internet connectivity might be driving the demand for access to an affordable and reliable source of electricity (Manchester & Swan, 2013). Morley, Widdicks, and Hazas (2018) noted that "Internet-connected digital technologies will play a key role in transitions to a more sustainable and more energy efficient future" (p. 128). Park (2015) noted that "when implementing digital inclusion strategies, both supply (infrastructure) and demand (education levels, industry sector, employment opportunities, socio-demographics) factors must be considered" (p. 1).

Without mobile phone coverage that provides Internet connectivity, there are other possible Internet connectivity options in rural and remote areas of developing countries. These include Google's Project Loon balloons and Facebook's Internet.org project, which provides for highly innovative ways such as connecting with lasers and using unmanned aircraft for delivering Internet coverage for hard to reach areas (Internet.org). This concept aligns with Pandita's (2017) claim, which follows:

> ICT rich countries can help to raise the tangible ICT infrastructure in all such countries be it by providing monetary support, by supplying the equipment itself, providing technical knowhow, training and skill development of their human resources and much more…[the] Internet in itself is turning out to be an agent of change to such an extent, where the rest of the things are following (p. 90).

In summary, closing the digital divide could help to alleviate energy poverty, but as mentioned throughout, a steady and affordable source of electricity must first be in place for this to occur.

Gaps in the Literature

As discussed earlier in this chapter, there were studies about the barriers, challenges, and obstacles from renewable energy and off-grid installations (Ahlborg and Hammar, 2014; Barrios-O'Neill & Schuitema, 2016; Blenkinsopp, Coles, & Kirwan, 2013; Costa, Diniz, & Kazmerski, 2016; Chowdhury & Mourshed, 2016; Eleftheriadis & Anagnostopoulou, 2015; Katsaprakakis & Christakis, 2016; Rahman, Paatero, & Lahdelma, 2013; Roche & Blanchard, 2018; Schafer, Kebir, & Neumann, 2011; Sen & Ganguly, 2017; Urmee & Md, 2016). There was also literature concerning barriers, challenges, and obstacles from using voluntourism as a model (Burrai & Hannam, 2018; Guttentag, 2009; McGehee, 2014; Prince, 2017; and Sin, Oakes, & Mostafanezhad, 2015). Numerous studies included problems with voluntourism projects (Lyons, Wearing, & Benson, 2009; McGehee, 2014; Phelan, 2015; Singh, 2014; and Wilson, 2015) and problems with the project managing organizations (Guttentag, 2009; McGehee, 2014; and Prince, 2017). The first gap in the literature was a combination of these two topics: barriers, challenges, and obstacles from using voluntourism as the business model for the installation and management of off-grid installations and the subsequent extension of the system to provide for Internet connectivity.

The general research question of this study was as follows: What are the internal and external forces that impinge on the ability of the NGO managers, the Project managers, and the experienced volunteer project coordinators to bring the digital age and Internet connectivity to rural villages in Nicaragua using reliable off-grid electricity systems? In this study, I investigated the lived experiences and knowledge of the NGO managers, the Project managers, and the experienced volunteer project coordinators using a qualitative phenomenological study. By focusing on the barriers, challenges, and obstacles that these managers encountered during the installation of the off-grid electricity system, the first gap in the literature was addressed.

Building on this, there was literature about off-grid installation best practices (Chatterjee, Burmester, Brent, & Rayudu, 2019; Hong & Abe, 2013; Laufer & Schafer, 2011; Palit & Chaurey, 2011; and Urpelainen, 2016). There were ample studies about voluntourism best practices (Brookes, Altinay, & Ringham, 2014; Coghlan, 2018; Foller-Carroll & Charlebois, 2016; Klaver, 2015; Loh, Valdman, & Dacso, 2016; Lupoli, 2013; McGehee, 2014; Nino et al., 2017; Rozier, Lasker, & Compton, 2017; Sujarittanonta, 2014; and Wilson, 2015). The second gap in the literature connects the best practices of the management of off-grid systems with the best practices using voluntourism as the business model.

The first sub research question of this study was: how can the NGO top project managers, the installation project managers, and the experienced volunteer project coordinators overcome the challenges, barriers, and obstacles encountered with the maintenance of the off-grid electricity systems in rural Nicaragua? I identified best practices of the management and maintenance of the off-grid systems using semi-structured interviews of the key informants. This result addressed the second gap in the literature that I had identified.

The third gap in the literature was using off-grid to provide Internet connectivity. Lipschultz reported in 2001 that schools outside Durban, South Africa, were supplied with off-grid solar and a satellite uplink, thereby providing students with electricity and Internet access. In a different case, Ley and her colleagues noted the installation of off-grid installations in Honduran schools and community centers, with resulting Internet service through packet radio (Ley et al., 2006). Specifically connecting the management of *off-grid* renewable energy systems with closing the *digital divide* is an under-researched area in peer-reviewed research.

The second sub research question of this study was: how can these key managers of the off-grid systems successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity? I identified themes using the data from the semi-structured interviews. These themes provided best practices for utilizing the off-grid electricity system to provide for Internet connectivity. By addressing the three gaps in the literature, my study adds to the body of knowledge of using off-grid electricity installations to help alleviate energy poverty and provide for Internet connectivity.

Summary and Conclusions

Underlying all of this is the assumption of a source of electricity. "Internet and energy connectivity are intrinsically linked" (McCabe, 2018, p. 32). Combine this with the fact that most of these rural and remote areas in developing countries contain an element of energy poverty, resulting in a more convoluted issue of lack of Internet connectivity. Is the business model of using voluntourism to provide off-grid renewable energy electricity a viable solution? In this study, I will focus on the management barriers and obstacles arising from the off-grid systems and voluntourism and how the managers can overcome the barriers and obstacles and use the electricity system to provide Internet connectivity for the remote and rural areas of developing countries.

Chapter 3: Research Method

Introduction

The purpose of this qualitative phenomenological study was to investigate the experiences and knowledge of NGO managers, the off-grid project managers, and the experienced volunteer project coordinators who have experienced the phenomenon of off-grid installations in undeveloped countries. The focus of this research was on (a) lack of electricity described as energy poverty (Gonzalez-Equino, 2015) and (b) lack of Internet access described as the digital divide (Park, 2015) in rural areas in many undeveloped countries, specifically Nicaragua. NGO managers, project managers, and experienced volunteer project coordinators have encountered challenges that affect the implementation and maintenance of these off-grid electricity systems and its subsequent use for providing Internet connectivity, which affect the transition to resources for available and affordable Internet for rural village residents. For this study, I used phenomenology to reveal patterns and themes highlighting the management challenges that prevent successful ongoing maintenance as well as to explore ways for NGO managers and project managers to address these barriers and obstacles and to expand the off-grid solar electricity to allow for Internet connectivity in rural areas, specifically Nicaragua.

Chapter 3 contains an explanation of the phenomenology research design and rationale for using it. This chapter also includes the researcher's role in collecting data, the data collection procedures, and the analysis procedures used. I also discuss ethical issues, and the approach to addressing issues of trustworthiness is covered in the remaining sections of this chapter.

Research Tradition and Rationale

The central concept of this study was the installation of the off-grid solar electricity system. As previously described, an off-grid system is a self-contained electricity-producing system that cannot connect to the traditional electricity infrastructure (Energy.gov, 2017). In this study, the business model used to install this off-grid solar electricity system was the voluntourist (volunteer tourist) model. I used a qualitative phenomenological study to explore the knowledge and experiences of the NGO managers, the project managers, and the knowledgeable volunteers.

Phenomenological research is rooted in existentialism and can be used to describe experiences. Phenomenology involves collecting and analyzing people's perceptions related to a phenomenon (Dawidowicz, 2016, p. 203), as meanings are given to people's experiences (Guignon, 2012). Phenomenology also relates to people's changing selves and what they think and act (Van Manen, 2007). This aspect of phenomenology applied to how voluntourism can be used to provide electricity to residents of remote or rural villages in developing countries, which transforms them. Thus, the phenomenological approach helped capture the transformation of the relationships between the various stakeholders (the voluntourists, the project managers, and the NGO managers) and the village residents. Phenomenology was appropriate for this study because it provided a framework for examining the perceptions of this study's participants to answer the research questions:

What are the internal and external forces that impinge on the ability of NGO managers, the project managers, and the experienced volunteer project coordinators to bring the digital age and Internet connectivity to the rural villages in Nicaragua using off-grid electricity systems?

Sub-research Question 1: How can the NGO top project managers, the installation project managers, and the experienced volunteer project coordinators overcome the challenges, barriers, and obstacles encountered with the maintenance of the off-grid electricity systems in rural Nicaragua?

Sub-research Question 2: How can these key managers of the off-grid systems successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity?

I followed epoche or bracketing to set aside preexisting beliefs and judgments and view the lived experiences of the participants of the phenomenology in a non-judgmental light (Moustakas, 1994). Bracketing eliminates or reduces the possible bias that the researcher might bring to the study. This helped reveal participants' interpretations and assign meaning to these patterns and themes, which illuminated barriers, best practices for installations, and solutions for extending the off-grid solar electricity system to provide for Internet connectivity.

Role of the Researcher

The fundamental role I had was to collect, organize, and analyze qualitative data that addressed the research questions. I gathered initial background knowledge of the topic in my role as a voluntourist/volunteer tourist in both 2013 and 2014, attending two separate 1-week off-grid solar installations in rural Nicaragua. My current role in fulfilling the requirements for a doctoral degree was to interview the research participants, analyze the qualitative data, and identify themes and patterns that adequately addressed the management problem and the research questions.

On the first off-grid solar installation, I traveled with an American NGO (referred to as NGO#1). We traveled to a remote village in Nicaragua. This village was too far from the traditional electricity infrastructure, prohibiting a traditional utility connection via the existing infrastructure. As a volunteer, I participated in the entire off-grid installation, from installing the solar panels on the roof of the grade school, to bringing the wiring down and into the building, to installing light fixtures, switches, outlets, a converter, a battery system, and a usage meter. We also prepared a small training presentation outlining proper usage and maintenance of the system, which was the final step in our volunteer activities.

I returned to Nicaragua in 2014, traveling with NGO#2. NGO#1 had been absorbed by NGO#2 in the time between the two trips. This time we traveled to a different remote village for a similar installation. This village already had an NGO#1 off-grid installation on the roof of their medical clinic that provided lighting. This trip included adding more panels to the existing medical clinic's installation to provide power for a small refrigerator that would store insulin and vaccines. We also installed another stand-alone off-grid solar installation on the village school roof to provide power for lighting and other uses for the students and teachers of the village. The knowledge obtained from this fieldwork as a volunteer helped to provide insight into choosing the research questions and the interview questions.

As a doctoral student, I performed the steps necessary in a phenomenological study by (a) bracketing my experience and then (b) collecting data for this study (Randolph, 2009). I was an observer and interviewer, gathering data using semi-structured interviews to identify themes and patterns related to the management barriers and issues encountered during off-grid system maintenance. I also collected information that will address the possibility of bringing the digital age to the villages using these off-grid renewable energy systems for Internet connectivity. The participants of this study were key informants that included a selection of the NGO managers, the project managers, and the fellow knowledgeable voluntourists. Although I have kept in digital contact with most of these potential candidates, I have not discussed this study with them. We currently have no mutual supervisory or instructor relationships.

To prohibit any researcher biases, I used the concept of epoche, setting aside biases or preconceived ideas (Moustakas, 1994, p. 84). This helped obtain new knowledge from the study's participants. Whatever thoughts, beliefs, and judgments I may have about the phenomenon were noted in a journal so that I was aware of these potential biases, and I took care to set them aside during interviewing, data collection, and analysis.

During data collection, I also followed the ethical responsibilities outlined by the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research and the guidelines established by Walden University's Institutional

Review Board (IRB). I also addressed possible issues of trustworthiness of the study, paying close attention to credibility, dependability, and confirmability.

Methodology

In this study, I used a qualitative methodology with a phenomenological design that incorporated a conceptual framework built on systems theory (Checkland, 1994, Jackson, 2003), the diffusion of innovation theory (Rogers,2003), and the technology acceptance model (Davis, 1986, 1989). These two theories and one model provided vital concepts of the adoption of new technologies and innovations, and the effect of innovations on the entire system. The constructs from these theories provided the framework and investigative lens, creating a perspective for investigating the phenomenon of off-grid solar electricity systems. Qualitative research was the appropriate methodology because the research questions were formulated to determine how the phenomenon, the off-grid electricity system, can be effectively and efficiently managed to provide a reliable source of electricity and possible Internet connectivity.

Population

The population of this study included individuals globally who have experienced an off-grid renewable energy installation along with a possible extension to adding Internet connectivity. The sample population was the NGO managers, project managers, and experienced volunteer project coordinators who experienced an off-grid renewable energy installation. These same individuals should have a management perspective of the phenomenon. Although I have experienced off-grid installations only in Nicaragua, it is a global solution found in many countries and on many continents. But it would be difficult to quantify how many off-grid installations there are worldwide because most of them are in undeveloped or difficult to reach areas. Further, this phenomenon could occur within the voluntourist business model, or with other possible business models identified in Chapter 2. This study's narrower population included the focus of off-grid installations that alleviate energy poverty and provide Internet connectivity.

Participant Selection and Logic

As a researcher, I focused this study on an innovative solution to energy poverty. Consequently, identifying candidates who have experienced the phenomenon was a critical task. For this study, the criteria on which participant selection included individuals who satisfy the following requirements: (a) have participated in at least one off-grid electricity excursion or similar experience as a knowledgeable voluntourist, a project manager, or an NGO manager; (b) have a basic knowledge of renewable energy systems; and (c) have a basic knowledge of the requirements for Internet access. Additionally, I included individuals who have extensive experience in off-grid installations and the field of Internet access for hard to reach areas using off-grid electricity systems. An additional requirement was knowledge and proficient use of the English language to eliminate the need for language translators.

The starting point for selecting candidates was the manager/founder of NGO#1 and the two managers/founders of NGO#2. These three key informants were the first potential candidates for inclusion in this study. I had also identified candidates for this study from my two trips to Nicaragua (voluntourists and NGO project managers). After receiving IRB approval, I contacted these candidates using e-mail. I also asked these candidates (some became study participants) to share my study invitation to find more candidates for the study. This snowball sampling did not yield a sufficient number of key informants for the study. The next step was a purposive sampling of members of LinkedIn and IEEE's Collabratec. By altering the original recruitment process using this secondary step, the NGO management, project managers, and fellow travelers/voluntourists then become gatekeepers in the recruitment process (Namageyo-Funa et al., 2014).

For those who expressed interest in the study, I determined if any possible participants met all of the above criteria for this study. Using a semi-structured interview protocol, the interview questions contained three questions to ensure that the participants meet the criterion stated above. Because the two participant selection approaches listed above failed to yield sufficient study participants, I used a search of the LinkedIn web site and IEEE's Collabratec web site for possible candidates that met the criterion listed above.

Sampling Strategy, Sample Size, and Saturation

The target sample size for this study was approximately 15-20 participants, based on Dawidowicz's (2016) statement that "the goal should be to obtain enough data appropriate to the study" (p. 207). Leedy and Ormrod (2010) provided a guide of 5-25 individuals based on purposive sampling. Because the goal was to obtain the depth of the participant's experiences with the phenomenon, a larger sample size for this qualitative phenomenological study was unnecessary. A sample of approximately 15-20 NGO managers, project managers, and experienced volunteer project coordinators who have experienced the phenomenon provided adequate depth for the phenomenon under study.

The initial sampling strategy was purposive sampling, as described above. Etikan, Musa, and Alkassim (2015) described purposive sampling as “the deliberate choice of a participant due to the qualities the participant possesses” (p. 2). I did not reach the targeted sample size using the initial purposive sampling, so I then utilized an extended purposive sampling by asking the NGO managers and project managers to share my invitation. Both of those sampling methods did not provide an adequate sample size, so purposive sampling within the website LinkedIn and the website IEEE Collabratec was the next step used to locate key informants. I contacted these candidates via e-mail for recruitment.

An adequate sample should yield saturation of the data. Mason (2010) noted that “qualitative samples must be large enough to assure that most or all of the perceptions that might be important are uncovered, but at the same time if the sample is too large data becomes repetitive and, eventually, superfluous” (p. 2). Although Fusch and Ness (2015) noted that saturation is not necessarily an easy concept to define, they proposed that “data saturation is reached when there is enough information to replicate the study, when the ability to obtain additional new information has been attained, and when further coding is no longer feasible” (p. 1408). Using this definition of saturation during the interview process, I was able to gauge that after 17 participants, the study’s participants were no longer providing any new data.

Instrumentation Reliability and Validity

In qualitative studies, the main instrument is the researcher. For this qualitative phenomenological study, the primary data collection instrument was the interview of the study's participants (Leedy & Ormrod, 2010). I recorded the interviews and took notes throughout the interviews to record participants' nonverbal cues and (if a Skype interview) body language cues.

The interviews consisted of semi-structured interview questions. I linked the interview questions to the research questions (see Appendix A for researcher produced interview questions). A field test of the interview questions was used to determine content validity; that is, if the interview questions will yield results that will directly and sufficiently answer the research questions and sub-questions. I gave the field test to a group of three people to determine the appropriateness of the interview questions. The interview questions were revised based on the results of this field test.

Leung (2015) defined validity in qualitative research as meaning the appropriateness of the tools, processes, and data. It begins with the choice of methodology, the sampling, and data analysis, as well as the data collection. The use of the field study helped to ensure content validity. Directly connected to validity includes the concept of reliability. Leung (2015) stressed that reliability depends on consistency throughout the study. The same interview techniques and protocol and meticulous record-keeping provided consistency and reliability throughout the interview process.

Data Collection

The semi-structured interviews yielded qualitative data that included "observations that yield detailed, thick description; inquiry in depth; interviews that capture direct quotations about people's personal perspectives and experiences" (Patton, 2002, p. 40). Each study participant was asked the same semi-structured interview questions (see Appendix A), and each interview was to last approximately 20-60 minutes. I recorded the audio of the interviews for later data analysis. I kept a research journal to provide notes during the interviews. All of the above steps were part of the formal data collection protocol.

Once participants completed their interviews, a debriefing immediately followed. The debriefing included an offer to provide a copy of the completed study results if desired by the interviewee. It also included a request to contact the participant for any follow-up questions or interviews, should the need arise.

Data Analysis Plan

Upon completion of the interviews, the data analysis was next. The first step was to transcribe the audio recordings to provide written transcripts of the interviews. I used software entitled Express Scribe for transcription, as well as manually listening to the audio recordings. I used these transcripts, along with the research journal field notes containing the nonverbal clues, to analyze to identify themes and patterns. Both hand-coding of the data and the use of NVivo software were incorporated into the data analysis sequence. Any discrepant cases were handled when encountered during the data analysis stage. I used a data matrix to organize the results.

Trustworthiness

Issues of trustworthiness can occur during the data collection and data analysis processes. "Threats to trustworthiness include too shallow a view of participants' experiences with the phenomenon, bias in interpretation, leading participants; responses, not collecting enough data, or reading into the data rather than letting the data speak for itself" (Dawidowitz, 2016, p. 210). I addressed the concepts of credibility, transferability, dependability, confirmability, and ethical procedures to counteract these possible issues of trustworthiness.

Credibility

Johnson and Rasulova (2016) identified credibility with the question, "How can we be confident about the 'truth' of the findings?" (p. 12). Strategies to achieve credibility included a careful selection of research participants with a clear explanation of why they were chosen, and "sampling of all possible situations relevant to the research" (Johnson & Rasulova, 2016, p. 15). Credibility, or internal validity, was addressed using triangulation methods (Patton, 2002).

Transferability

Transferability, or external validity, was addressed using thick description. Patton (2002) described thick description as "rich, detailed, and concrete descriptions of people and places" (p. 438). The degree of transferability was dependent on the level of similarity between the current setting under study and possible comparative settings. Because the descriptions of the two settings were detailed and closely aligned, transferability will be more successful. The use of purposive sampling "is considered to be more suitable for qualitative research which allows the researcher to have information-rich cases for the study that will provide relevant data to the study question" (Johnson & Rasulova, 2016, p. 15).

Dependability

I used consistent procedures throughout the data collection and data analysis processes to address any issues of dependability of the data. Johnson and Rasulova (2016) suggested audit trails. "Being able to trace resources that the data comes from and about documenting the data, methods, and decisions made during the fieldwork. So consistency in the entire research process is key for achieving dependability" (Johnson & Rasulova, 2016, p. 23). The use of audit trails and triangulation were incorporated to provide dependability.

Confirmability

Confirmability of data, reflexivity, and elimination of researcher bias are keys to address any threats to confirmability (Patton, 2002). "Ensuring that the research process and findings are not biased" (Johnson & Rasulova, 2016, p. 20) is the principle behind confirmability. The confirmability strategies were similar to those for dependability, including audit trails, carefully kept field notes, systematic coding, and ethical procedures during data collection and handling (Johnson & Rasulova, 2016; Johnson & Rasulova, 2017).

Ethical Procedures

The procedures used to recruit participants, collect data, and analyze data, all conformed to the guidelines contained within the IRB process. The necessary IRB documents were filed, and formal IRB approval was received before any steps were taken to recruit study participants or collect data. Following the IRB protocol, I addressed all ethical concerns in connection with candidate recruitment and data collection. Participant refusal to participate or early withdrawal was handled with discretion and according to the IRB guidelines. Participant names will remain confidential. Data will be securely stored for a minimum of five years and then properly disposed of to protect the privacy of those involved.

Summary

In this study, I used a qualitative phenomenological research design to answer the stated research questions. I used semi-structured interview questions while interviewing participants who have participated in the experience of an installation of an off-grid renewable energy system installation and the possibility of Internet connectivity. Using NVivo and hand-coding, I identified themes and patterns within the data that highlight the management barriers and obstacles encountered during participation in the installation. Additionally, I identified themes and patterns for extending the off-grid electricity system to provide Internet access, thereby reducing the Digital Divide.

Chapter 4: Results

The purpose of this qualitative phenomenological study was to investigate the lived experiences and knowledge of NGO managers, project managers, and the experienced volunteer project coordinators about their experience of off-grid installations in undeveloped countries. The participants had a basic understanding of renewable energy systems and Internet usage and its requirements. I utilized interview questions to highlight the barriers that prevented successful installations and ongoing maintenance, and additional interview questions to provide themes to explore ways for NGO managers and project managers to address these barriers and obstacles. Other interview questions helped explore ways to expand the off-grid solar electricity to allow for more stable Internet connectivity. Interview responses were used to help answer the research question related to the factors that affect the ability of NGO managers, project managers, and experienced volunteer project coordinators in improving Internet connectivity with off-grid electricity systems.

The general research question was as follows: What are the internal and external forces that impinge on the ability of NGO managers, the project managers, and the experienced volunteer project coordinators to bring the digital age and Internet connectivity to rural villages in Nicaragua using reliable off-grid electricity systems? The following were the sub-research questions.

Sub-research Question 1: How can the NGO top project managers, the installation project managers, and the experienced volunteer project coordinators overcome the challenges, barriers, and obstacles encountered with the maintenance of the off-grid electricity systems in rural Nicaragua?

Sub-research Question 2: How can these key managers of the off-grid systems successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity?

This chapter includes the results of the field test, details of the study's research setting, data collection and data analysis procedures, and a discussion on evidence of trustworthiness. The chapter also includes the results of the study's research questions and the associated themes that I discovered. The chapter concludes with a brief introduction to Chapter 5.

Field Test

A field test of the interview questions was the first step I conducted to determine content validity (i.e., if the interview questions will yield results that will directly and sufficiently answer the research questions and sub-research questions). I gave the list of interview questions to three people to determine the appropriateness of these questions. One of the participants of the field test was an expert in doctoral qualitative studies. The second participant was an expert in the field of rural studies in developing countries. The third participant was an expert in doctoral phenomenological studies. All three field test participants reviewed the interview questions after being sent a copy of them via e-mail (see Appendix B).

Field Test Participant 1 stated that they looked for "bias language (none noted), ambiguous or obscure questions (none noted), leading questions (none noted), or questions that are unclear (none noted). Pilot study participants should also look for the order of the questions—looks great to me." Field Test Participant 2 suggested that Interview Question 2 be changed from "What key factors influenced the management of the outcome?" to "What key factors influenced the management of the outcome of the off-grid installation?" for clarity. Field Test Participant 3 found the interview questions appropriate and valid for the given research question and sub-research questions. Hence, one of the original interview questions was revised based on the results of this field test, and the remaining interview questions were kept intact.

Research Setting

The research setting for this study consisted of either telephone or e-mail interviews. Due to their schedules or traveling conflicts, 4 participants were not available for a scheduled voice interview, so they agreed to answer the interview questions via e-mail. Fifteen participants agreed to voice interviews. For the voice interviews, I conducted one using Skype, I conducted one using an app called FreeConferenceCall.com, and the remaining 13 were phone interviews.

I scheduled the voice interviews for appointment times that were convenient for the participants. Each voice interview took place in a setting that was private for me, ensuring solitude and privacy for the study participant. I instructed each study participant to be at a safe and private location ensuring their safety and privacy. I informed each participant that the interview would be recorded. The audio of the voice interviews was recorded using a digital recorder. I ensured each participant that they could opt-out of any interview question or opt-out of the interview itself at any time for any reason. This study had no known trauma involved for the participants. This study also had no known budgetary constraints.

Demographics

The participants of this study had experienced the phenomenon of an off-grid electricity installation system (although some of them referred to it as a microgrid). They also were familiar with the use of the Internet and its basic requirements. They were from various countries around the globe, yet they had experienced the phenomenon of off-grid installations in Nicaragua, Zambia, Tanzania, Myanmar, Pakistan, India, or the United States. The participants included 6 women and 13 men. The participants had various occupations, but I did not collect any specific demographic details such as age, race, or level of education because it was not pertinent to this study.

Data Collection

Before collecting any data, I sought and obtained IRB approval on June 7, 2019 (IRB Approval No. 06-07-19-0168741). Upon receiving IRB approval, I sent e-mail invitations to the three managers/founders of NGO#1 and NGO#2. There was no response from any of these possible key informants. Next, I had identified 21 candidates for this study from my two trips to Central America (experienced volunteer coordinators and NGO project managers). I contacted these candidates using the same e-mail invitation. Of the 21 invitations sent, 12 agreed to participate, though one later decided to not participate. From the 11 that participated, I asked each to share my study's e-mail invitation. This provided 3 additional referred participants. The next step was a purposive sampling of members of LinkedIn and IEEE's Collabratec using my approved social media invitation. I posted my social media invitation on my LinkedIn profile and sent it to candidates who might meet the study requirements, which resulted in five additional study participants. I received 20 consent forms from those who agreed to participate, and a total of 19 people participated in this study.

As each consent form arrived via e-mail, I set up an appointment for the interview that was convenient for each participant. Four participants preferred e-mail interviews, so I e-mailed the list of interview questions (see Appendix B), and their responses were returned via e-mail. Fifteen participants agreed to voice interviews. I conducted one via Skype, one via FreeConferenceCall.com, and the remainder I conducted via telephone interviews.

I began each interview with the study introduction. Next, I reminded the participants that they could opt-out of any of the questions or opt-out of the study itself if they wanted to at any time. I reminded them that the interview was being recorded and that I would be taking notes. Voice interviews were recorded using a digital audio recording device that I had purchased for the sole purpose of recording these interviews. I asked each interviewee the same interview questions. The interview times ranged from 20 minutes to 71 minutes. At the end of the interview, I provided a short debriefing explaining the next steps of the data collection process.

I transcribed the interviews using Express Scribe Pro version 8.20 software. After the transcriptions were complete, each transcript was returned to the participant via e-mail for a quick review. Each e-mail interview was also returned to the corresponding study participant for a quick review. At this point, the participants could provide any corrections, clarifications, or additional information if they so desired. One e-mail address was no longer accepting e-mail, so that participant did not receive a copy of their transcript. Seven participants did not raise any concerns to the follow-up e-mail. The remainder of the 11 study participants returned the transcripts with minor changes or corrections or additional information.

After the participant review of the transcripts, I anonymized the interviews. Four of the interviews were e-mail interviews, and I coded these participants as PE1, PE2, PE3, and PE4. Fifteen of the interviews were voice interviews and I coded these participants as PV1-PV15. Any other identifying characteristics were removed from the interviews to protect the privacy of individuals or organizations.

Bracketing

Having participated in two off-grid solar installations in Central America, I had direct experience with this study's phenomenon. As a researcher, I put aside my thoughts and bias from these experiences. From my perspective, I had witnessed what I would describe as management obstacles during the two installations. For example, I remember the weather-related challenges that were encountered. But I had put these thoughts and preconceived ideas aside to be open to insight and understanding of what the participants viewed as management barriers.

The use of bracketing was critical to ensure my objectivity while conducting my data collection. By bracketing my thoughts and opinions, I was able to prevent my bias from influencing the data collection and data analysis stages (see Van Manen, 2014). Controlling my judgments and notions helped to raise my self-awareness and separate myself from the participants' responses. The result was not to understand the phenomenon from my perception but to arrive at an objective understanding of the essence of the phenomenon from the study participants' perceptions.

Data Saturation

Optimal sample size can be a challenge for qualitative studies. Research such as Saumure and Given (2012) have suggested a sample size of 15-20 participants. Given this desired sample size, the next step was determining when I reached actual saturation, which is when no new information emerges (Saumure & Given, 2012). I aimed for a sample size of 20 but ended up with 19 participants. However, after the 17th interview, it became apparent that no new concepts or themes were collected. Therefore, I reached data saturation before conducting the 19th interview.

Data Analysis

The purpose of this qualitative phenomenological study was to investigate the lived experiences and knowledge of NGO managers, project managers, and the experienced volunteer project coordinators about their experiences and knowledge of off-grid installations in undeveloped countries. For this study, I used phenomenology to reveal patterns and themes related to barriers that prevent successful installations and ongoing maintenance as well as to explore ways for NGO managers and project managers to address these obstacles and to expand the off-grid solar electricity to allow for Internet connectivity.

For the coding process, I used both inductive and deductive coding. Inductive analysis involves observing patterns (Patton, 2002). As the codes and themes became apparent during the data analysis stage, the focus shifted to a deductive approach, verifying the patterns that were emerging (Patton, 2002). I used Attride-Stirling's (2001) tool for developing thematic networks, which included (a) coding material, (b) identifying themes, (c) constructing thematic networks, (d) describing and exploring thematic networks, and (e) summarizing thematic networks.

The interview process resulted in 19 interviews containing 228 pages. The transcribed documents were uploaded into NVivo 12 software to assist in coding the material. The first step was to code the material by devising a coding framework (Attride-Stirling, 2001). I initially used the interview questions to serve as an initial coding framework. The next task was to "dissect text using the coding framework" (Attride-Stirling, 2001, p. 391). Each document was processed line by line both manually and using NVivo 12 software to provide identifying categories and coding subcategories for organizing the dissected text. At this stage, I refined the categories, reorganized them, and eliminated some of them. Two of the interview questions, Question 2 and Question 3, were subdivided into (a) key factors and (b) barriers and obstacles. Each of the main themes was subdivided into coding subcategories within each interview question and entitled: (a) human factors, (b) process factors, and (c) technology factors. All the categories were then sorted into these subcategories to develop the thematic networks. Each interview document was counted once within each node. There were no obvious discrepant cases. Table 3 provides a sample of the identifying themes from the second interview question.

Table 3

Results for Interview Question 2

Interview questions	Documents (19)	% of 19
Q2a: Installation Key Factors	19	100
Human Factors		
Community Acceptance, Involvement, Buy-in	9	47
Experienced Team Members	7	37
Ownership of Completed System	2	11
Skilled Contractors/Subcontractors	6	32
Team and Community Communication	3	16
Training of Team Members	7	37
Process Factors		
Contingency Planning	2	11
Location and Land	7	37
Logistics	4	21
Planning and Organization	6	32
Pre-process and Needs Analysis	11	58
Safety Factors	1	5
Technology Factors		
Logistical Practices	2	11
Tools and Equipment and Supplies	6	32

Note. *N* = 19. Subcategories are listed in alphabetical order.

The next step in the data analysis was to deduce global themes for the main subcategories. I used global themes to "summarize the main claim, proposition, argument, assertion or assumption that the organizing themes are about" (Attride-Stirling, 2001, p. 393). The global themes should capture the essence of the organizing themes about the associated interview question as it is related to the underlying research question or questions. Global themes were derived from the nodes and subcategories and are listed in the Themes section later in this chapter.

Evidence of Trustworthiness

Credibility

Credibility, or internal validity, of the qualitative findings, was achieved in numerous ways. First, I selected candidates with a clear explanation of why they were chosen for the study (Johnson & Rasulova, 2016). I asked only those who closely satisfied the selection criteria to participate in the study. Additionally, after participating, I sent the participants a transcription of their interviews so that they could make any corrections, clarifications, or add any information to it for completeness. When transcripts were returned with changes, these copies were used for the data analysis. This review by the inquiry participants is a form of triangulation (Patton, 2002). Member checking and using quotes in the writing process were two additional strategies used to increase credibility (Johnson & Rasulova, 2016).

Transferability

Transferability, or external validity, was addressed using purposive sampling as well as thick description. Transferability was increased by “search[ing] for as many different cases as possible until new themes stop emerging” (Johnson & Rasulova, 2016, p. 25). Through purposive sampling, by the 17th interview, no new themes were emerging, and it was clear that data saturation was reached by the 19th interview. This purposive sampling allowed for more information-rich cases to be recorded, thereby increasing the likelihood of transferability from the current setting to other settings (Patton, 2002).

Dependability

To increase the study's dependability, I used consistent procedures throughout the data collection and data analysis processes. I employed audit trails throughout the data collection phase (Patton, 2002). Keeping detailed and cohesive documentation of the participant responses increased dependability. I utilized journaling and field notes for additional study consistency. These provided the ability to efficiently "trace resources that data comes from" (Johnson & Rasulova, 2016, p. 23). Additionally, coding by hand and recoding using NVivo 12 software provided dependability of the data analysis stage.

Confirmability

As mentioned in chapter three, confirmability of data, reflexivity, and elimination of researcher bias are keys to addressing any threats to confirmability (Patton, 2002). Strategies used for confirmability were similar to those for dependability, including audit trails, carefully kept field notes, systematic coding, and ethical procedures during data collection and handling (Johnson & Rasulova, 2016 & 2017). Additionally, I set aside researcher bias by using bracketing to handle the interview process and the data analysis steps objectively.

Study Results

I transcribed and coded the 19 interviews. Initially, I began with a coding framework using the interview questions as categories. I subdivided the categories into subcategories labeled *Human Factors*, *Process Factors*, and *Technology Factors* during the coding process. These subcategories resulted in 104 coded raw themes. Table 4 illustrates the categories and subcategories from which I developed the emerging themes.

Table 4

Nodes and Subcategories

Interview questions	Documents (19)	% of 19
Q1: Experience with phenomenon	19	100
Q2a: Installation Key Factors	19	100
Human factors		
Community Acceptance, Involvement, Buy-in	9	47
Experienced Team Members	7	37
Ownership of Completed System	2	11
Skilled Contractors/Subcontractors	6	32
Team and Community Communication	3	16
Training of Team Members	7	37
Process factors		
Contingency Planning	2	11
Location and Land	7	37
Logistics	4	21
Planning and Organization	6	32
Pre-process and Needs Analysis	11	58
Safety Factors	1	5
Technology factors		
Logistical Practices	2	11
Tools and Equipment and Supplies	6	32
Q2b: Installation Barriers and Obstacles	19	100
Human factors		
Communication Issues	2	11
Community Issues	5	26
Health of Volunteers	1	5
Lack of Trained People	7	37
Language and Cultural Barriers	8	42
Ownership Issues	1	5
Team Member Tensions	2	11
Unclear Instructions	3	16
Process factors		
Governmental and Regulation Barriers	1	5
Ignoring Risk Management	1	5
Inadequate Needs Analysis	2	11
Lack of Adequate Planning	1	5
Lack of Collection of Feedback Information	1	5
Location and Land Issues	9	47
Logistics Challenges	11	58
Political Unrest	1	5
Safety Issues	3	16
Scheduling and Time Management Issues	2	11
Weather Challenges	6	32
Technology factors		
Cheap Parts Used	1	5
Cost and Budget Factors	6	32
Customs and Border Issues	3	16
Equipment and Tools Issues	5	26

(table continues)

Interview questions	Documents (19)	% of 19
Q3a: System Maintenance Barriers and Issues	17	89
Human Factors		
Communication Issues	6	32
Community Power Struggles	2	11
Fear or Distrust of System	2	11
Theft of Electricity	4	21
Training Issues	3	16
Process Factors		
Lack of Knowledge Among Users	5	26
Lack of Planning	3	16
Lack of Resources	2	11
Safety Issues	2	11
Technology Factors		
Cost and Budget for Maintenance	5	26
Cost of System Repair	2	11
Distance to Travel to Repair	3	16
Lack of Parts and Supplies	5	26
Lack of Repair Technicians	1	5
System Becomes Obsolete	4	21
System Malfunctioning or Inoperable	8	42
Theft of Panels or Components	2	11
Weather and Environmental Issues	7	37
Q3b: System Maintenance Key Factors	16	84
Human Factors		
Community Education and Training	9	47
Community Involvement and Ownership	7	37
In-country Support	8	42
Inspection and Monitoring of System	3	16
Process Factors		
Adequate and Cohesive Maintenance Procedures	12	63
Adequate Documentation	3	16
Contingency Planning	3	16
Contractor Maintenance Agreements	2	11
Technology Factors		
Adequate Maintenance Budget	3	16
Appropriate Technology for Environment	3	16
Available Repair Technicians	2	11
Quick Response	3	16
Safety	2	11
Q4: Experience with Relevant Internet Connectivity	16	43
Q5: Internet Connectivity Key Factors	18	95
Human Factors		
Affordability	4	21
Awareness of Benefits	5	26
Community Embraced Technology	4	21
Educational and Training Aspect	3	16
Long Term Support	1	5

(table continues)

Interview questions	Documents (19)	% of 19
Process Factors		
Cost and Benefit Analysis and ROI	2	11
Power Needs Analysis	5	26
Technology Factors		
Devices and Equipment to Connect	15	79
Maintain Electricity Source First	3	16
Protect Electricity Source First	2	11
Source of Electricity First	6	32
Source of Internet Signal	10	53
Technology Advancements	1	5
Q6: Internet Connectivity Barriers and Obstacles	15	79
Human Factors		
Cultural Shock	1	5
Entrenched in Tradition	1	5
Help or Harm	3	16
Lack of Education About Internet	4	21
Lack of Skill Set	1	5
No Recognized Need to Connect	2	11
Priorities of Electricity	4	21
Unwise or Unintended Use	3	16
Process Factors		
Content Availability in Local Language	1	5
Demand Not Matching Supply of Off-Grid System	1	5
Disadvantages of Internet Connectivity	1	5
Governmental Regulations	3	16
Political Dimension	3	16
Technology Factors		
Availability of Devices	6	32
Connectivity Versus Access	3	16
Cost of Data	1	5
Cost of Devices and Equipment	7	37
Cybersecurity Issues	2	11
Location Too Remote for Signal	3	16
Poor Maintenance of Equipment	1	5
Priorities of Devices	2	11
Unavailable ISP	1	5
Unreliable Source of Signal	5	26

Note. Subcategories appear alphabetically. Percentages rounded to nearest whole number.

Themes

The general research question was as follows: What are the internal and external forces that impinge on the ability of NGO managers, the project managers, and the experienced volunteer project coordinators to bring the digital age and Internet connectivity to the rural villages in Nicaragua using off-grid electricity systems? I discovered themes that answer this research question, and these themes are presented in Table 5.

Table 5

Themes Addressing the General Research Question

Themes and Subcategories	*N* = 19
1. Location and Land Issues	9
2. Off-grid System Malfunctioning or Obsolete	8
3. Language and Cultural Barriers	8
4. Cost of Devices & Equipment	7
Availability of Devices & Equipment	6
5. Unreliable Source of Signal	5

Note. Themes 1-5 listed here. Next table continues with numeration of Themes 6 through 9.

Theme 1: Location and land issues. Some of the issues that participants encountered with bringing electricity and Internet connectivity to rural areas included location and land issues. Nine of the 19 study participants (47%) mentioned that the location of these remote villages was a major issue. PE3 stated that “the location of the villages needing the systems are remote, hence the reason they don’t have grid-tied electricity. This lends to difficulty getting to the installation location.” PV11 agreed that one of the barriers “was of course the remoteness and I guess that’s what you are obviously going to encounter with places that would benefit from an off-grid system.”

Traveling to these remote locations was a challenge. Some locations were accessible by motor vehicles. Some locations were accessible by hiking or horseback. PV11 stated that the location of their installation "was really only accessible by boat. It was the sort of village where you really depend on the tides. If the tide is out, you can't get to the village at all." PV3 agreed that "just to get there was just a hassle." PV8 shared that an obstacle was to "get to and from the location." PV9 noted that an obstacle "could be that the road could be broken and it would take us more time to get to the community." PV14 shared that "its inaccessible by any sort of road or trail so we had to have a boat.". Not only the remote location, but also the travel conditions of the roads or paths were a challenge. "I believe there was a significant rainfall perhaps more than the previous season. Which made travel to the village a little bit more challenging…So we had to travel by foot" (PV2).

Land ownership issues could also be a barrier. Determining the actual property owners was not always an easy task, as noted by PV5 and PV12. Determining where to install the system raised issues of "who owns the land on which it will be installed? Is there an actual deed? Are there traditional land rights, etc., that are being followed? So that is certainly a risk" (PV5). The structures that some residents lived in could be an additional barrier as noted by PV12: "these people are very poor, you know. Their houses are made of mud. You know, there are no proper houses. They are sort of make-shift houses." Therefore, location and land were obvious barriers for the off-grid electricity installation as well as extending the system to provide for Internet connectivity.

Theme 2: Off-grid system malfunctioning or obsolete. Another force that impinges on bringing the digital age to remote and rural villages included having an off-grid electricity system that malfunctioned or was inoperable. Keeping a steady source of electricity is critical for a sustainable Internet connection. Participants discussed a wide range of problems that would affect the viability and sustainability of the off-grid electricity system.

Eight of the 19 participants (42%) brought up issues with the electricity system malfunctioning or not functioning. These issues included broken panels (PE4), batteries draining too quickly (PV11), batteries needing to be replaced (PV7, PV12, PV15), charge controller getting burned out (PV11), inverter malfunctioning or not functioning (PV4, PV15), and breakers needing replacement (PV9).

Weather and environmental issues affected the operation of the off-grid system too. Foreign items on the solar panels interfered with the operability of the panels. These items might include dirt, dust, and pollen (PE4, PV5, PV6), or bird droppings (PV6, PV15). Additionally, there is the possibility of a lightning strike to the panels or the inverter box, thereby causing damage to the system (PE1, PV4).

In addition, it is crucial to make sure the components of the system are protected from wildlife. Spider webs need to be kept out of the system (PV5). PV4 described a problem with the inverter box:

> It decides to crawl inside the inverter box, and shorts out the wires…and they open it up and here is a carcass of a mouse in there…It's obvious what happened because of the chew marks on the wires.

Participant PV9 described problems with wildlife entering the e-panel:

> We open the e-panel and we find bees nests because they go inside because they like the warmth and sometimes we have seen snake skins because [they] also like to go inside even if we close all the ports in the e-panel, but they find a way to go inside…So the risk could be a charred circuit.

Therefore, keeping wildlife out of the off-grid electricity system is an obvious challenge for the management of the off-grid electricity systems and using it for Internet connectivity.

In addition to the challenges that occur during regular operation, there are also challenges to the off-grid system that could render it inoperable or obsolete. One of the common obstacles that might occur is the theft of the parts of the system, such as the batteries or solar panels. PE1 mentioned the theft of the system's batteries, rendering the storage aspect no longer possible. PE4 mentioned the theft of the solar panels. Each component of the system is critical, so the theft of a component could render the system useless.

Another possible obstacle could be the inability of village residents to obtain distilled water for the lead-acid batteries. Three study participants noted that this was an issue that they experienced (PV5, PV6, and PV9). Without the proper water, which was also called "battery water," the batteries would dry up and lose their useful life earlier than expected. If the residents used water other than distilled was used, it could damage the batteries. Without the necessary resources, the system became obsolete to the village residents once it stopped working properly. With no electricity source, there would be no way to provide power to the devices and equipment needed for Internet connectivity.

Theme 3: Language and cultural barriers. Other issues that impinged on bringing the information age to developing countries included both language barriers and cultural barriers. Eight out of 19 study participants (42%) noted language and cultural barriers. If the language of the remote and rural community was different from the language of the NGO managers and project managers, this could result in ineffective or lack of communication. PE1 stated that "language differences can make communication difficult" whereas PE3 stated that "there were a handful of bilingual people, but it was still difficult to spread them among each working group." PV2 described this as "the communication barrier with respect to our command of the [local] language."

The study participants also discussed cultural barriers. One issue of the cultural barriers included the difference between village resident living conditions versus the daily living conditions of the NGO managers, project managers, and experienced volunteer project coordinators. PE1 stated the conditions that were encountered included "heat, humidity, and exhaustion as you were staying in homes that offered only a floor or hard surface to sleep on and not everyone can adapt to food and environment of a rural village." PV8 described it as "living conditions that we weren't used to, right? That were pretty rural and without a lot of amenities that we are used to." These amenities that people in the developed countries are "used to" included running water, sanitary toilets, air conditioning, and comfortable sleeping conditions.

Another aspect of the cultural barriers encountered related to the technology itself. This cultural component had to do with what the village residents were accustomed to and how electricity and possible Internet access would require adjustments to their traditional way of life. PV11 stated that "there were also a couple of sort of cultural issues that I noticed. One was just unfamiliarity with electricity and its potential dangers." PV9 stated that "we tell the community that they cannot open the e-panel because there are too many cables inside, and it could be a little risky for them if they don't know which cable is hot." PV3 described it as "they [local residents] were a little bit unsure and the reason why is because…they had never seen that type of technology or you know they never felt like they are going to have power coming from the sun…They had never seen the lights during the night except for the flashlight or the little candles they have. Now they are going to have light." PV6 stated that "everybody needs to really understand that it [the off-grid system] is one big fragile machine, not just a couple of wires that you can tap into." Unfamiliarity with the technology and not recognizing the risks involved with using it was clearly a crucial barrier to technology acceptance and the management of its safe use.

Theme 4: Cost and availability of devices and equipment. Bringing the digital age to developing countries would require new devices and equipment. This concept would include the equipment needed to provide the Internet signal and devices used to connect to the Internet. Devices could be computers, laptops, tablets, or smartphones. The cost involved with this hardware was an obstacle because many remote and rural villages were already living below or near the poverty line.

Cost was a barrier that was discussed by 7 of the 19 participants (37%). PE1 stated that “the rural communities that I did my installations in were not affluent enough to have computers.” PV15 stated that it “won’t be affordable for people living in that poverty level in undeveloped countries…It’s just not affordable.” PV6 claimed that “the people living in the villages don’t have financial resources in order to connect.” And PV9 said that “a computer is more expensive, so people, there is no way that people are going to buy a computer.”

The cost of the necessary traditional Internet infrastructure might also be an obstacle. PE3 stated that “these locations may not be able to pull a powerful enough signal to supply reliable connections without excessive cost.” PV15 stated that “I don’t see people being able to afford a $200 receiver from an ISP.” PV3 agreed that “most of the barriers that arise are, first of all, the initial capital.” Using a traditional Internet infrastructure appeared to be a significant financial obstacle for the management of Internet connectivity.

The cost of devices needed for Internet connectivity is a management barrier, and the availability of those necessary devices is also a management barrier. Six participants (32%) stated that there was an issue with the availability of devices. PV1 stated that “I’m not even sure if there are computers.” PV5 stated, “you know, although phones are widely available in rural areas, smartphones aren’t. And tablets aren’t. And laptops aren’t widely available and you would need to have some way of making those, getting that equipment in people’s hands.” The procurement and the management of the necessary devices are obstacles for having Internet connectivity in these rural and remote areas of developing countries.

Theme 5: Unreliable source of signal. Another obstacle related to the above themes includes the inability to secure a reliable source of signal for Internet connectivity. Five of the 19 participants (26%) reported that the signal was unavailable, unreliable, or not strong enough. PE1 stated that "in most of those communities, they were located in valleys and did not have access to WiFi or even satellites." PE3 mentioned that "these locations may not be able to pull a powerful enough signal to supply reliable connection," and PV4 agreed, stating that "is that going to be reliable? Probably not." PV4 noted that when they were in the rural and remote villages, they "won't get even totally pure Internet connectivity. Sometimes it gives out or it's slow." PV9 reported that "sometimes at school, there is no cell phone signal. There is no cell phone or Internet signal." The inability to obtain a reliable and constant source of Internet signal impinges on the ability to stay connected to the Internet. Managing that aspect of Internet connectivity, together with addressing the other barriers and obstacles listed above, is discussed in the next two sections that cover the themes arising from the two sub research questions.

The following was the first sub research question: How can the NGO top project managers, the installation project managers, and the experienced volunteer project coordinators overcome the challenges, barriers, and obstacles encountered with the maintenance of the off-grid electricity systems in rural Nicaragua?

Table 6

Themes Addressing the First Sub-research Question

Themes and subcategories	*N* = 19
6. Adequate and Cohesive Maintenance Procedures	12
7. Requirements Analysis & Logistics Planning	
Pre-process & Needs Analysis	11
Logistics Challenges	11
8. Village Centered Model	
Community Acceptance, Involvement	9
Community Involvement, Ownership	7
9. Community Education & Training &	9
Robust Communication Among Stakeholders	6

Note. Themes 6-9 listed here. Next table continues with numeration of Themes 10 through 15.

Theme 6: Adequate and cohesive maintenance procedures. Twelve of the 19 study participants (63%) stated that a maintenance plan was a key factor in the off-grid system's success. For a solar off-grid system, cleaning the solar panels was deemed a vital part of that regular maintenance plan (PE4, PV3, PV4, PV5, PV6, PV7, PV8, PV11, PV15). PV15 stated that "once in a while I will walk by my panels and notice they are dirty and I'll just take the hose and wash them off." PV11 stated that "people were willing to clean the panels. Not that we saw there was any huge build-up of dust or anything, but they were willing to clean it." PV6 explained that not every location had an adequate supply of water to clean the solar panels, so one could use "rollers like micro fiber cloths on them that don't necessarily need water to wipe off the dust...These are some differences depending on locality."

The batteries need maintenance plans for the successful management of the off-grid electricity system. PV15 starts their maintenance plan by "checking battery water once a month" and then moving on to brushing all the battery terminals. PV3 agreed with this: “you have to clean your solar panels…you have to clean the batteries…make sure the connections are clean.” PV5 added that “you might need to add distilled water to the battery to fill the lead acid battery.” Pv9 agreed, stating that “mainly the batteries need a lot of maintenance…fill them with water.” PV7 stated that “you have to make sure that your battery connections are not corroded and kept clean.” Participants noted that using sealed batteries made it easier to manage and maintain the battery system than using lead-acid batteries (PV5, PV7).

Additionally, PV13 noted that “you prepare for any maintenance cases that may arise.” PV2 stated that “there were dedicated sessions there to talk about how to keep the operation and maintenance on the actual off-grid installation.” PV5 noted another maintenance issue that included “making sure that all the conduits” are in good condition. PV6 summed it up by stating that “management [of the off-grid system] is just the owner making sure there is enough battery acid [water in the battery], making sure that the panels are clean, and checking and making sure the wires are ok…You are going to have continuous issues of needing to replace connectors or fuses, or replace wire management clips or something like that. It’s just a continuous management thing.”

Planning for an adequate budget for the maintenance plan is another management theme arising from the interviews. PV7 stated, “that is pretty much all the maintenance that there is, on a regular basis, other than making sure that you bankroll enough bucks to start replacing panels or controllers or what have you.” PE3 stated that “understanding a means to maintain the system was part of the application and vetting process which allowed the village to get the system” from the NGO. PV8 agreed that a budget is critical: "I know that they also create sort of a fund to pay for some maintenance that local folks contribute to." In summary, a cohesive maintenance plan combined with an adequate budget for it is a key factor for the successful management and maintenance of the off-grid electricity system.

Theme 7: Requirements analysis and logistics planning. The management of requirements analysis and logistics planning for off-grid electricity installations were also themes that came from the interviews. Planning the installation of an off-grid renewable energy installation in a developing country is a complex project. It requires a thorough needs analysis. Eleven of the nineteen participants (58%) mentioned this topic. Participant PV13 stated that it "starts with identifying the need" for the system. Participant PV5 claimed that "the NGO had a very good plan in terms of needs analysis, determining whether the village actually wanted the electricity." Participant PE1 verified that claim by stating, "the NGO also did an excellent job at qualifying what communities had effective leadership for supporting the installation and continued maintenance before accepting their application for a solar installation." Participant PV9 stated that the community residents helped with the process by their "involvement in knowing about the needs of their community."

Building the demand curve is a necessary step in the requirements analysis. PV6 stated that "matching the supply and demand is probably the most important thing there. That requires…study" and "you've got to build the demand curve beforehand and know what sort of technology is going to meet that." The system's size is also a critical step as PV6 stated that "the design of the management system, [is] the biggest factor, that is, being size of the system that is being installed." Participant PV9 agreed, stating that "technicians plan ahead, what it is that they need, and they can plan also the size…of the system."

Participants mentioned logistics planning as being important for these projects. When asked what the key factors for success were, participant PV14 stated that "logistics planning is probably the biggest one" and claimed that "there is a lot of planning that goes along with trying to bring everything out in one trip if possible, so that is probably the biggest part of the whole installation." Participant PV2 stated that "they [the NGO] had covered getting the materials there, everything they needed to complete the project. I think that was well covered in terms of logistics." Participant PV2 frequently emphasized that "the logistics" were crucial for the project. Participant PV5 stated that it was important too, and "so obviously we will have that logistical piece in good hands." As PV9 noted, "we are more aware of things that we have to bring including tools, acknowledging that there is not a hardware store close or not in like two or three hours driving. So staff is more [prepared with] bringing tools, and measure tools, and extra equipment."

Residents in developing countries experience a lack of resources or fewer choices than residents in developed countries. Not only is there not a hardware store close to these rural and remote areas, but these distant stores that are located in bigger cities do not have the variety and amount of supplies and resources that can be found in more developed countries. Because of this lack of choices, participants noted that early procurement and transport of critical supplies and tools were best practices of successful installations.

Theme 8: Village-centered model. Successful practices of off-grid system management and maintenance consist of a village-centered model rooted in community acceptance, involvement, and ownership. Nine of the 19 participants (47%) stated that community acceptance, involvement, and buy-in of the system were key factors for success. PV5 stated, "I think having the local community involved and having their buy-in is quite important in the installation" and "community involvement is a huge piece, that comes up over and over and over again with the people that I'm talking to." PV9 claimed that "[success] comes from the community itself because of their high level of organization and responsibility, involvement in the meetings."

The community members must be involved before the project is even started. PV8 stated that "you have to involve local folks in the planning from start to finish, right? I think the more engagement there is, the more successful it's going to be." PV6 agreed too, noting that a success factor was to have a system that was "community built." PV5 stated it as well: "so the community being a major stakeholder in the system, I think, you have to be sure they have been made aware of it. Make sure that they have a chance to, you know, question the installation, and make sure that they have been briefed on what to expect and what will happen during the installation process but also pre-installation, post-installation." PV12 stated that the "main goal is trust in management of these off-grid systems" and this is accomplished when "we form committee organizations…and these people, they select their own representatives from their people." In summary, PV9 noted that "the big portion of a project's success in this community comes from the community itself because the high level of organization that they have."

Participants mentioned community ownership, as well. PV12 stated that a key factor was to "install it and handle these systems [over] to the community." PV5 stated that "we partner with NGOs that have some sort of relationship with that community, and we turn the asset over to them, so they are the ones that are ultimately in charge of its operation and maintenance, and they may well have somebody in the community do that for them, but they would identify that person." PV6 mentioned that "you want to make sure, and this is probably a really big management concern, with them microgrid, if it, if the community-owned microgrid, everybody feels like they have ownership of it." In summary, community acceptance, buy-in, and involvement all work together to ensure that the community members become major stakeholders of the off-grid electricity system.

Theme 9: Community education and training and robust communication. Study participants mentioned that community education and training were necessary for the successful maintenance of the off-grid electricity system. Nine of the 19 participants (47%) mentioned it. PV4 noted possible issues with training of the community members:

> The model was to train a village member or two, to know how to work with the system, to reset things if there is an issue, if there is a fault, or something is tripped, reset the system back to operational. Or to do simple diagnostics and say, hit this button to see what the error message might be. The question comes up there, when you start handing that responsibility

> off to a villager, is the villager going to be there for the life of the system? That is probably not going to be the case. And then you would have to teach a backup, two people, or both if they can't be there for the next fifteen to twenty years. That sounds like it's neither. So, it's a matter of persistence and how long is the training...[and] the person may also forget what they are trained because if the system operates for two or three years and there hasn't been an issue, and either they are still there and something happens and they may go "how do I do that?"

PV3 shared that "if you're making a decision to follow this type of project, I think you have to make it work. I mean, like not just do the installation but also the education part which is pretty essential." PE4 stated that "we briefed them on the technology, on how to perform maintenance." PV4 stated that "we even had an administrator also trained locally that could get in there" to assist with the maintenance. PV8 stated that "making sure the system operates after folks have gone, and there is local knowledge to make that work" and "I think that they do some training and in the area of training with local folks, they have people that have a basic understanding of the system and the maintenance." PV9 shared that "we show community leaders how to do the maintenance and they do it in most of the communities…For once a week, the community leaders, they do [the maintenance] and they do a very good job." PV2 stated that the installation "in terms of the education aspect and the actual ability of the villagers [to perform the maintenance]":

> set up for the villagers to come in to learn about how to operate the system, especially because it was an off-grid system, which even having experience with the grid-tied systems for residents in the U.S., explain to them how to use it. It's trickier, and there [are] some challenges in there.

And PV2 also stated that:

> It's just the education and safety aspect which I felt, you know, could have been, sort of, shored up a little bit more in terms of having full lifecycle of being able to ensure, you know, the project is going to be completed safely and its actually going to have a long term ability to sustain the villagers [for] use for many years to come…Let's just say that they did indeed have a full appreciation of the operation and maintenance of the system, and what it involved, and were able to keep it maintained for many, many, years…I do feel confident, though, that there were dedicated sessions there to talk about how to keep the operation and maintenance on the actual off-grid installation, as best as they could.

PV5 stated that:

> And also the training piece, so, whatever organization is going to be responsible for the maintenance and ongoing operating of the system, that training needs to be there for the installation to be successful. So they know how to operate it and know its maintenance requirements and so forth.

Ultimately, the volunteers and project managers will be leaving the installation site. Their departure leaves the village residents as the end-users of the system. PV14 summed it up: "the end-user is your biggest resource, so their ability to troubleshoot with what you leave behind [is critical]. Was there training provided?"

This training theme leads to the next concept mentioned in the interviews: adequate documentation for the system's users. Three of the nineteen study participants (16%) mentioned leaving behind adequate documentation for the village members to use for maintenance purposes. PV13 stated that "you prepare for any maintenance cases that may arise by documenting everything from design to installation." PV9 claimed that "if there is an issue with the system, it doesn't turn on or for some reason they find that it is off, or its not charging, they also have a three-step [process] that they have to do. Turn off the system, and they know how to do it. If they forget, we will leave a printed [paper of instructions] in plastic paper." PV4 agreed that "there is written documentation that is very clear that they can refresh and try to do it." In conclusion, comprehensive and ongoing community education of the system, combined with adequate documentation, are best practices for the successful off-grid electricity system management and maintenance.

Closely tied within this community education and training theme, communication among all of the off-grid installation stakeholders was discussed by the study participants. Six of the nineteen respondents (32%) discussed communication. Part of the problem stemmed from the remote location of the system. PV11 noted that:

> There was not a way for us to, sort or remotely, troubleshot our system because there was no Internet connectivity. And at the time, there wasn't

> any sort of solution with cell phones or sim cards that provide the essential connection that was needed…That would have helped but that wouldn't have solved the major [maintenance] issues. So that was another minor hindrance."

PV14 stated that "it's a rural installation then obviously there is more than likely a communication gap where you can't monitor things remotely. Or it takes a little while to diagnose any problems or even identify them in the first place." Participants discussed communication between the installation team and the villager residents. PV2 stated that:

> The biggest other dimension of it was after we departed, if communication of how to actually operate the system to the villagers was actually deep enough so that it would be sustainable for the long term beyond, you know, our tenure there…I'm not fluent at all in [the local language], I couldn't really tell whether or not the villagers were really deeply understanding and sort of, you know, just having an appreciation for what would be involved with the operation and maintenance of this system.

PV4 stated that:

> Does a villager know that there is an outage, the lights don't come on, an outage, they check the system and the solar contractor sees the same thing, and is there a way to walk through [with] the villager, maybe to take corrective steps, a work-around, or whatever it might be? Of course, that implies that the system has telecom ability to get data from the jungle, which may not have service, and to tap to [the nearest city]. And I don't

know how easy that is, or not, but there could be a data connection, if you have better service, and if there is, sure would like to take advantage of it.

In conclusion, providing adequate communication among all stakeholders, with the possibility of Internet connectivity, could prove to be beneficial in trouble-shooting maintenance issues of these remote off-grid electricity installations. Successful installation, maintenance, and sustainability of the system are dependent on robust communication among all stakeholders, extending beyond language and cultural barriers.

The following was the second sub research question: How can these key managers of the off-grid systems successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity?

Table 7

Themes Addressing the Second Sub-research Question

Themes and subcategories	*N* = 19
10. Devices and Equipment to Connect	15
11. Source of Internet Signal is Critical	10
12. Experienced Teams and In-Country Support is Vital	
Experienced Team Members	7
Skilled Contractors	6
In-Country Support	8
13. Use of Off-Grid for Internet Connectivity is Site Specific	
Source of Electricity First	6
Priorities of Electricity	4
Power Needs Analysis	5
14. Affordability & Cost	4
15. Community Acceptance and Awareness	
Community Embraced Technology	4
Awareness of Benefits of Use	5

Note. Themes 10-15 listed here.

Theme 10: Devices and equipment to connect. The necessary devices and equipment must be available and at the location to utilize the off-grid electricity system for Internet connectivity. Fifteen out of 19 study participants (79%) discussed the need for Internet connectivity devices and equipment. PE4 stated that "I know that computers need some sort of interface program or cable port to allow you to connect to other devices (modem, router)." PV11 stated that "I think having the technology" is a crucial factor. PV4 stated that the off-grid system would:

> power any Internet connected devices [that] you would need at that end to receive or send, obviously. The question is, what are you trying to connect with? Is it a phone or an installed device? Or a computer, or laptop, or desktop? So, it would power the interconnect devices as well as the application or source on which you are going to use the Internet.

PV7 stated that:

> The only way that you would be able to connect to the Internet would be if you had some kind of cell service; that is where you could have a personal hot spot. That's number one. Number two, you can use it if you have a satellite system and whatever power needs that either one of those have you can do, you can use a regular router, but see you still have to have some kind of a tie, like a fiber line or a telephone line or something like that.

PV5 explained:

> Is the [off-grid] an appropriate vehicle to distribute the Internet? Because the only way that you would distribute the Internet through the grid, would be to use Ethernet over powerlines, EOP, powerline Ethernet. For

> example, I use that in my house. I have a router plugged into a box in the basement that I have boxes that plug into the wall. In any outlet, I can tap into and get Ethernet connection from. And that is a well-established technology that may be applicable with this. Little things which you need for getting the signal are pricey. And not to say that it can't be cheapened. Given that the infrastructure for cellular communication is already widespread, and 5G requires much smaller cells, 5G is actually a good use case. If you have a 5G, if you want to spread 5G connectivity, you probably need to have a 5G cell at the [off-grid] or a few different ones depending on the size of the [off-grid] spread along the periphery so that 5G connectivity is available throughout the system, if not the area. And those can be trunked through the wires that you are sending power through anyhow and at the hub, at the management center, you can tap into a satellite link or something like that for more bandwidth length. That would enable you to get the Internet…And, having electricity and having the cell phone, WiFi connectivity, you could run more powerful computers, you could spread more opportunity that way just by having available access to more powerful computing.

The most frequently mentioned suggestion for the choice of devices to use for connection to the Internet in these rural and remote areas concerned the use of cell phones (PE1, PV1, PV4, PV5, PV6, PV7, PV8, PV9, PV11, PV12, PV13, PV14, PV15,). PE1 stated that "the rural communities I did my installations in were not affluent enough to have computers. However, many had cell phones." PV1 stated that "from what I remember or understand was that the school has lights and some outlets and they would be able to plug in cell phones or whatever devices they would need, so I would think that they would get Internet through their phones if they were able to charge that at school." PV4 stated that the off-grid system could be used for "plugging in perhaps computers…and cell phones" and "the people, they have their phones so what they do is they just start using the phones to get the web." PV8 stated that "I'm sure it is different in every single place, but if people already have cell phones," then they have Internet connectivity. PV14 stated that:

> for people living in that poverty level in undeveloped countries…if their cell phone provider puts up the antennae, then they can access through their phones, through a smartphone…They are going to have at least a very tiny solar [electricity] system that will light the house and charge their cell phone and their smartphone will give them the Internet feed. And an uplink to a low orbit satellite.

PV9 noted that:

> we are getting in touch with young people. Most of the time, these young people are the sons or daughters of the community leaders because they are good with technology, and they are the ones that manage the smartphones. So, yes, it is possible to get Internet, but people are more inclined to get it from their cell phones.

PV14 stated that:

> I think what we are seeing in developing countries is kind of a leapfrog over the landline. So, in the past, places where you might be able to have a phone system that provided Internet connectivity, there is typically a phone line available with that.

Users are leap-frogging the traditional infrastructure in two ways: using the off-grid renewable energy system bypasses the traditional electricity infrastructure. Using cell phones and other wireless devices is bypassing the traditional cable Internet infrastructure. However, PV1 noted that “don’t you need the router? Or the network? To connect it through your phone, you need some sort of system.” By some sort of system, PV1 was referring to a connection to the Internet itself. Directly related to having the devices to connect to the Internet, the source of an Internet signal must also be present.

Theme 11: Source of Internet signal is critical. Connecting to the Internet is dependent on the ability to receive an Internet signal. Ten of the 19 study participants (53%) stated that there must be the availability of an Internet signal in order to successfully manage a connection to the Internet. PV2 stated that “they actually were able to bring in, I’m sure, some sort of means by which the villagers could actually access the Internet” although details were not forthcoming from that participant. PV3 stated that:

> One the of the communities that I was taking care of, there was a city in the North central part of the country… [the off-grid installation] was for Internet itself, just bypassed for cell phones network, Internet. So we did the installation of the system on the school and there was an antenna next

> to it so you're going to have reception on that. It's like forty or fifty foot around.

PV4 mentioned that "it's more about can you get the signal to these very remote locations?" and "Is the signal going to go deep into the jungle?" and:

> From a signal perspective, if they had a signal, then the solar would be producing the power, and as long as it is the right voltage for the Internet devices, it should work just like anything else down there, the lighting, the plug load, etc. So it seems like it is more of an issue, how do you get a signal to their area in a country that there are repeaters or transmitters down there?"

PV13 was confident that "even if it is remote, there is still cell phone coverage out there." PE4 stated that "this area was remote, but the signal should span a large number of miles to reach nearly anybody, so it provided the proper equipment, the Internet should be within reach." PV9 stated that "what they need to do is also the cell phone companies, they have been installing in the past years more Internet so that people can receive a better signal." PV15 stated that:

> People living remotely have two options right now. Everybody, I think, uses satellite [in this participant's area]. And some of us can use the direct line WiFi. Line of sight WiFi. And then the low earth orbit satellite systems, SpaceX and I think Amazon is doing one, one or two of the companies are kind of coming along after, they are, you know, behind SpaceX. SpaceX has 60 satellites in orbit now, and they are launching

> another sixty this month or this week or something like that. So they will have a basic system up and running, and that is going to open things up for people who can't get the line of sight stuff. The satellites will be low enough so that the latencies won't be noticeable because the signal has to go far less distances. It's just up and back almost immediately.

PV15 claimed that "if you are talking about someplace in rural Africa or rural Asia, the cell phone towers will appear, and the Internet will travel via the cell phone towers. And I think SpaceX and smaller companies will provide the ISP service to the cell phone towers."

PE1 stated that "in most of these communities, they were located in valleys and did not have access to WiFi or even satellites." PE3 noted that "not all areas are going to be able to pull a powerful enough signal to connect to the Internet." Attentive management of how the villages were going to be able to receive the Internet signal would be a key factor in Internet connectivity.

Theme 12: Experienced teams and in-country support is vital. Having both trained support people and in-country support people are critical components of managing the off-grid electricity system installation and its subsequent use for Internet connectivity. Eight out of the 19 study participants (42%) discussed how important it was to have trained personnel or in-country support staff for the sustainable operation of the off-grid electricity system and its extension for Internet connectivity. For the off-grid installation, the experience level of the installation team members was a key factor. Team members could include trained volunteers, trained professionals, and seasoned project managers. PE1 stated that "a few of us [the volunteers] had experience with wiring, electrical, batteries, and solar." PE4 stated that "it also helped that a handful of the volunteers or workers were either trained professionals (electricians, etc.) or have had a certain level of experience of building the fixed racking system, bolting the panels to the racking system, connecting the electrical wires to their point of interconnections, and make sure the project was full operating with the inclusion of the battery storage components." PV1 noted that "there was a particular volunteer that had a lot of installs before" and "basically there were a few people that were knowledgeable enough to make it a successful outcome." PV3 said that

> [With] this type of system, you need to have hands-on touching, wires, and this and that and what it means, connecting the wires, how much power you're going to get, you have to understand that, and having experienced it in order to know how to teach people.

Having trained staff and access to seasoned professionals was also part of the system's success. PV2 stated that "the staffing, I think, was appropriate and adequate…having at least four, having two in-country folks dedicated to that organization, who would provide and manage the volunteers as well as one or two people who were brought in to sort of act as stewards for the whole operation." PV4 noted that the NGO "probably had done dozens if not hundreds [of installations] by now." PV9 noted that "these days we have technicians that are paid and hired by [the NGO] and they are full time employees." PE3 stated that:

> one particularly important piece, especially when you're relying on novice volunteer work is to have skilled workers close. The volunteer organization partners with an installation professional to manage the actual installation. Solar or anything electrical should be managed by professionals as it can be dangerous to work with if you are not careful.

PV2 agreed by saying that "bringing in the subcontractors to help work the process in terms of getting the installation done, was good" and "some subcontractors were brought in to hasten the process rather than rely completely on the labor provided by the volunteers, the participants of the trip." PV1 concurred with "having the construction company there, to help guide that process, and make sure everyone really didn't mess up anything."

In-country coordinators and support were vital components for a successful system. PV4 stated that "the group out of [the U.S.] had in-country coordinators, two or three folks there, as well as they had an in-country solar contractor who was experienced in doing these sorts of projects" and

> they had a good system where you could come down, work on school buildings. The contractor could walk in, maybe do an hour or two of walking around the building figuring out what was needed and that whole system was pretty forgiving.

PV5 noted that:

> the technical expertise and the local expertise of the installation is important…We always hire in-country installers…There is a list in [the

> country] of licensed solar installers and we will actually write a request for proposals and we will get some bids from those companies and so, we rely on that local expertise and that in-country technical expertise…[The] in-country talent was helping the volunteers do the work, so that none of us were actually very talented or experienced in that area.

Support is critical not only for the installation itself but also for long-term maintenance of the system and the off-grid system's subsequent use for Internet connectivity. Eight of the nineteen (42%) study participants stated that in-country support was vital for the off-grid system's future sustainability. PE2 noted that the NGO "had staff based in [the country] who were committed to long-term support of the system, and would follow up with the community about their off-grid system and any issues, and provide assistance when needed." PV4 agreed with this observation:

> The key ingredients, here, I think, and I'll elaborate on this in the other questions, is you had to have, in my mind, an in-country, in a developing country like Nicaragua, an in-country solar expert who would be left behind and to maintain that system.

PV4 noted that in installations in another country, the "local staff of [the NGO] was located just a few blocks away. They can come over and check up on the system" and "the thing was we trained a local ASAP staffer so the U.S. NGO had a staffer in [country] who could go out and check the system, had the keys to get into the room." PV5 stated that "in solar, I think, the maintenance of it can be straightforward. You know, you have a partner, it's the local entity that is going to be operator." PV6 stated that "you would want to contract with an owner/operator company, an operations management company…to make sure that the system is maintained." PV8 said that "they also go to each project that [the NGO] installed, [with] technical knowledge, they visit each project once every year to see how it is going." PV12 noted that "there is an expert responsible for all of them, for any maintenance, basically for two years, he is responsible for the warranties of the system." Moreover, PV14 stated that the system's success was contingent on "leaving somebody with the ability to perform the proper maintenance." In conclusion, having experienced and in-country personnel is a key success factor for the off-grid electricity system's installation, maintenance, and extension of using it for Internet connectivity.

Theme 13: Use of off-grid for internet connectivity is site specific. The system's management for Internet connectivity system requirements is site-specific, depending on the country's Internet infrastructure and the location's priorities for electricity use. Six of the 19 study participants (32%) mentioned that in order for the residents of the village to have Internet connectivity, there clearly must be a source of electricity first. PE3 stated that "the general concept of being able to supply electricity to areas away from the power grid is first." PE4 stated that "The area was remote but the signal should span a large number of miles to reach nearly anybody so if provided the proper equipment, the Internet should be within reach. However, you need electricity first." The obvious first step is that the residents need the power, the source of electricity, to obtain Internet connectivity, and that power would be provided by the off-grid electricity system (PV4, PV5, PV8, and PV15). The off-grid "provides power and the connection to the Internet doesn't care where the power comes from…there is no interaction between the source of the power and what the power does," as stated by PV15. PV6 asserted that:

> When you talk about the energy service, separate from the energy itself, when you talk about how you need to provide the electricity, provide energy, in say, an unelectrified town in rural India or Africa, or something like that, what people ignore is the fact that they need to actually provide energy services which is what helps people. It's not the energy itself which is going to help people. Having energy, having electricity, will give people options. What they need is the service that the energy provides. They need to pump water. They need it for light. They need it for heating. They need it for cooking, etc., or cooling, whatever it may be.

PE4 asserted that:

> The panels would help facilitate power to the inverter and then there would be cable that would run throughout the walls and ceiling beams to bring about the use of several light bulbs and outlets, with the idea of the school eventually using the plugs for computer usage for education purposes. Never saw this implemented and not sure if they have access to the Internet now, however, this project undoubtedly made that idea a lot more realistic.

Now that these villages have electricity, the next step is determining their priorities for the use of electricity. Four of the nineteen study participants (21%)

discussed local village priorities for the consumption of the electricity provided by the off-grid system. PE4 asserted that “they need to make sure that the system is running optimally so they can continue to consume the electricity freely and perform everything that they would like to use the energy for” and “presumably, they will be using the electricity for other purposes (lighting, charging other devices and appliances, etc.).” PV5 asserted that:

> We have brought it up in the past, to some of our partners, because we always work with them and work with local communities to try to identify productive uses of electricity and that one rarely comes up organically. They are really more interested in having like freezers, using electricity for freezers or water pumps or something like that rather than an Internet café… [It is about] what people want and what they want electricity for. They want it for, you know, freezing things, they want it to charge cell phones, they want it to pump water.

PV11 stated that:

> So, in fact, when after we provided lighting and when the system was going well, we wanted to expand the service and so I was interviewing them on, so of what else can we power with the solar that the people were willing. And the number one answer by far was a TV. So we were thinking, oh, they might want to power their phone because it is an epi-cultural area, where people might want to know the latest price that their crop was fetching, so that they can make a better informed business

> decision. But of course we didn't mention that in our interviews. We just kind of wanted to gauge what the people themselves would want, and they wanted TV.

PV8 declared that "it's about local participation, local priorities [of electricity], and I think that if you're working against those, even if you're doing great stuff, you're going to, ultimately, you won't be successful."

Connected to the concept of the local priorities of electricity is the local needs analysis. The off-grid installation needs analysis began with a determination of how much power the village would need based on its needs. Was the concept of Internet connectivity included in the original needs analysis? Five of the nineteen (26%) study participants talked about the needs analysis concerning the use of electricity for Internet connectivity. PV2 stated that the "resource requirements" would need to be reviewed. PV8 noted that:

> I don't have a really good sense of what sort of power requirements are required for Internet connectivity, if it's a big load, or small load. But obviously you want to take that into account…you would obviously want to do some load calculations to make sure there was [load availability].

PV1 claimed that:

> if I had to do things right now, yeah, it would totally be a service that I would willing to, that I personally would be definitely willing to provide because it doesn't take that much power, that much extra power to power people's phones. I guess another way that could also be if it's in powering

> some sort of community center and you can just set up WiFi, that would also be an option.

PV7 stated that for Internet connectivity, “I’m sure it is different in every single place.” In conclusion, the use of the off-grid electricity system for Internet connectivity is site specific because it depends on the source of the electricity, the capacity of the local off-grid system, and the local residents’ energy priorities.

Theme 14: Affordability and cost. One of the management obstacles mentioned by the study participants included the affordability of the necessary technologies to provide Internet connectivity in the rural and remote villages. One of the original reasons that these villages were receiving the off-grid electricity systems in the first place was the obstacle of a high cost to attach to the traditional electricity infrastructure. By extension, the lack of financial resources for the necessary technologies to use the off-grid system for Internet connectivity is also a financial obstacle. That barrier was discussed by 7 of the 19 (37%) study participants.

Affordable devices and affordable data charges were vital ingredients, and the most common response to this was the use of a smartphone. PV15 noted that “the key is to get it down to affordable, and I think we get there via smartphones.” PV12 also stated that “there is a competition among these cellular companies.” This competition would provide more affordability of the devices. PV11 stated that:

> The easiest way that I see is to simply to power up people’s phones…[people] already have cellular services…At the time, cell phones were just becoming more accessible to the ordinary person. So to give

> you more of a context: up until like say, 2011, in Myanmar, a cell phone actually cost around $2000. And so, you know, that is in a country where a lot of people earn less that $3 a day so they were definitely not accessible. But after 2011, the local sector started to be opened up and more companies then came in and so the price was dropping at the time. Now it is pretty much the same and you can get a sim card for a dollar or less. Some companies even provide you for free, but at the time it was just at the front of market…not everyone was running around with phones [then]…They actually started with smartphones so that's how crazy it was. People went from no phones to the latest smartphone. Myanmar is quite close to China, and China has a diverse degree of smartphone manufacturers and for a lot of them it basically came down to cost. Smartphones were so cheap that it doesn't really cost any extra to buy a smartphone rather than to buy a more simple Nokia cell phone which is 60 kyats.

PV5 asserted that "the data would have to be cheap." PV9 addressed the idea of cheap data in this statement:

> These days because of technology and access to smartphones and diversity of chips for smartphones, people in the communities have changed to smartphones and there is an application that is very common here in Nicaragua called Whatsapp. So people usually don't have a plan, a cell phone plan, but they buy a recharge. So they pay fifty cordobas. Fifty

> cordobas is like one dollar. And they get that app, because the cell phone company has different packages for people to purchase. For example, you could pay fifty cordobas, which is one dollar, and they have Internet for two days.

PV9 also said “they buy very cheap packages to get data and Internet and Whatsapp application, so all they need to do is just look for the signal that most of the time, in the communities, it is easy to find.” PV5 asserted:

> I think probably the most innovative type of thing that I have seen in a while is people were trying to do pay-as-you-go with smartphones where you have a smartphone that you pay on a daily payment plan versus having to buy it all up front. So things like that might work but you have to come up with a way of getting these relatively expensive pieces of equipment into peoples’ hands to make use of the data.

Competition among the cell phone providers, as discussed above, could make those “pieces of equipment” more affordable. PV11 stated that “I think the technical problems at the end of the day can definitely be solved. Especially if you have the right amount of funding [from the NGO].” In conclusion, the management of these resources for Internet connectivity is largely affected by the cost and availability of technologies, devices, and data programs used to receive and harness the Internet signal.

Theme 15: Community acceptance and awareness. Study participants shared that for the off-grid electricity system to be used successfully for Internet connectivity, there must be community member acceptance and awareness of Internet connectivity.

Four of the 19 study participants (21%) mentioned community users embracing new technology.

PV8 asserted that:

> It's a matter of, is it something that is wanted or needed or perceived by the local folks to be needed? Do people really want and need this? You've got to start there…and there has to be a lot of really buy-in, and this is a real need, and this is something that folks want…So, to that extent it's about local participation.

PV9 stated that:

> That is a very good question and it's been a big challenge for us because in some communities we see that the first day. People use the system a lot and it's very beneficial for the community. But in other communities, people just use it, like the basics, so that would depend on the community.

PV11 asserted that:

> I think having the technology, I don't think there is a reluctance on the part of the people. On the contrary, they have embraced the technology quite enthusiastically…I think the Internet is quite ubiquitous that there is going to be a corner of the Internet that you are going to enjoy. Again, if nothing, there is always social media…I think it is more of an almost emotional response, you know, other people are on the Internet, on social media, people out there are on Facebook. They want to be on it so they will be on it.

PV3 stated that:

> I think that access to technology is time versus quick absorbing or shock absorbing that is the key on this…If you don't know or have the technology, you are way behind…Not just because of the country's poor, just because they keep the culture, or they try to keep it the way it is. So, it's been for generations and generations the same way. And when you jump in to the system or to the community and bring this type of system you are breaking or breaching that generations and trying to show them there is something different…If you are going to build this type of project or bring in technology like that, it would be great if that actually involves the time of doing the continuity of the educational part with the community itself. And trying to forward people more to learn more about being open-minded because once you breach that generation, you breach that way of thinking, they will be open minded.

Embracing the off-grid electricity system and embracing the technologies needed for Internet connectivity would be factors of whether a village successfully manages the electricity system for Internet connectivity. Connected to this is the users' awareness of the benefits of these systems. Five out of 19 of the study participants (26%) mentioned an awareness of the benefits of having Internet connectivity. PV2 asserted that:

> I also think of it in the way that you are offering the ability to connect to provide perhaps opportunities that they might have never had before. Educational opportunities, maybe opportunities to manage the local

> farming economy with respect to local cities, all kinds of things…If their investment in time and learning how to actually work with it, to harness the power of the Internet is going to benefit them in some way and if the return on investment makes it worth it, I'm sure that they will dedicate resources to it.

PV4 stated that:

> There might be doctors or nurses, medical folks in these communities that need the Internet connection. It's a value…I think we see a lot of people in those sort of communities and those kind of towns, for maybe a lot of reasons, family or commerce or maybe they are to buy something there or try to sell something while there.

PV5 stated that "there needs to be a sort of awareness campaign" so that the village residents understand the benefits of Internet connectivity. Without that awareness, there will be little desire or willingness to pursue a connection to the Internet. In conclusion, successful Internet connectivity depends on the match between new technologies and the local user awareness level at each location.

Summary

From the findings, I identified internal and external forces that impinge on the managers' ability to bring the digital age and Internet connectivity to rural villages in Nicaragua using the off-grid electricity system. These were location and land issues, including the villages' remoteness and the difficulty getting to them. The land issues included land ownership for the location of the off-grid system. Additionally, the off-grid system itself might be malfunctioning or obsolete. Participants also noted that language and cultural barriers were obstacles during the off-grid system installation. The cultural barriers included the village residents' unfamiliarity with electricity and its potential danger and risks. The cost of devices and equipment and the availability of devices were additional barriers and obstacles. Moreover, an unreliable source of Internet signal or the inability to secure a reliable source of a signal was another external force that impinged on the ability to bring the digital age to rural villages.

The NGO top project managers, the installation project managers, and the experienced volunteer project coordinators encountered challenges, barriers, and obstacles with the maintenance of the off-grid electricity system. Management must provide adequate and cohesive maintenance procedures for the off-grid system to overcome these obstacles. Maintenance should include off-grid system cleaning, upkeep, repairs, and a budget for those items. Systems designers and installers should develop and follow a thorough requirements analysis and logistics planning process. This should contain both a pre-process analysis and a needs analysis. Addressing the logistics challenges with thorough planning was recommended. Overcoming maintenance barriers and obstacles could be accomplished with a village-centered model focusing on community acceptance, involvement, and ownership was also viewed as a method for overcoming the maintenance barriers and obstacles. Robust community education and continuous training were key factors for successful system maintenance. Robust communication among all stakeholders was another successful best practice for overcoming the challenges, barriers, and obstacles of maintaining the off-grid electricity system.

There were many areas that the key managers of the off-grid systems could address to successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity. These included procuring the necessary devices and equipment to connect, finding a reliable source of Internet signal, and having experienced team members, skilled contractors and subcontractors, and in-country support. Because the use of the off-grid system for Internet use is site-specific, the key managers must focus on the local priorities of the electricity and power needs analysis of the off-grid electricity system. Affordability and cost of technologies and data are key factors for successful Internet connectivity. Lastly, factors needed include community acceptance, embracement of new technologies, and an awareness of the benefits using the Internet. These are factors that need to be present for successfully extending the off-grid electricity system to provide Internet connectivity.

In chapter five, I will start with an interpretation of these findings and the limitations of this study. This chapter will contain the study recommendations. It concludes with a discussion of the social change implications of the study.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this qualitative phenomenological study was to investigate the lived experiences and knowledge of NGO managers, project managers, and the experienced volunteer project coordinators about their experiences of off-grid installations in undeveloped countries. I interviewed 19 participants using semi-structured interview questions. From the transcriptions of the interviews, I applied phenomenology to reveal patterns and themes that highlighted the barriers to successful installations and ongoing maintenance. These management obstacles that I identified from the data were relevant for extending the off-grid electricity system to provide an Internet connection. The findings indicated that internal and external forces impinge on the ability of managers to bring the digital age and Internet connectivity to rural villages in Nicaragua using the off-grid electricity system. These are

1. location and land issues,
2. an off-grid system that might be malfunctioning or obsolete,
3. language and cultural barriers,
4. the cost of devices and equipment as well as the availability of devices,
5. a possibly unreliable source of Internet signal or the inability to secure a reliable source of a signal.

The NGO top project managers, the installation project managers, and the experienced volunteer project coordinators encountered challenges, barriers, and obstacles with the ongoing maintenance of the off-grid electricity system. I identified themes from the semi-structured interviews that included the need for:

6. adequate and cohesive maintenance procedures for the off-grid system,
7. a thorough requirements analysis and logistics planning process,
8. a village-centered model with community acceptance, involvement, and ownership, and
9. robust communication among all stakeholders.

Additionally, I identified themes that included many areas that the key managers of the off-grid systems could address in order to successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity:

10. procuring the necessary devices and equipment to connect to the Internet,
11. finding a reliable source of Internet signal,
12. having experienced team members, skilled contractors and subcontractors, and in-country support,
13. recognizing that the use of the off-grid system for Internet connectivity is site specific,
14. recognizing the affordability and cost of technologies and data, and
15. community acceptance, embracement of new technologies, and an awareness of the benefits of the use of the Internet.

All of these are factors need to be present for successfully extending the off-grid electricity system to provide Internet connectivity.

Interpretation of Findings

The analysis of interviews of the 19 study participants concerning the phenomenon provided rich themes. The following section includes a discussion of how the findings confirm, disconfirm, or extend the current knowledge of the management of an off-grid installation, the maintenance of it, and extension of the system to provide for Internet connectivity. The general research question was: What are the internal and external forces that impinge on the ability of NGO managers, the project managers, and the experienced volunteer project coordinators to bring the digital age and Internet connectivity to rural villages in Nicaragua using reliable off-grid electricity systems? The following five themes address this general research question.

Emergent Theme 1: Location and land issues. One of the most frequently mentioned challenges encountered by the key informants included the remote locations where the off-grid systems were installed. As noted in the research, distance and remoteness can cause disadvantages in rural areas (Townsend et al., 2015). The geographical location of these villages and sites were not close to urban areas, which was one of reasons for the need for an off-grid system. However, extending grids to these locations is not always economically sustainable (Mohammed et al., 2017). The remoteness itself is a challenge (Willcox et al., 2015) in addition to creating a challenge for providing Internet connectivity for the villages (Pejovic et al., 2012; Sujarwoto & Tampubolon, 2016; Townsend et al., 2015). Thus, the key informants that discussed location and land challenges confirmed the existing literature.

Traveling to and from the villages was an additional challenge that I found from the data. Some of the locations were accessible only by boat or by hiking or by aircraft. Even in the locations where there were roads, in some cases, there was only a limited rural infrastructure in place for efficient and safe travel (see Ahlborg & Hammar, 2014;

Schafer et al., 2011). It was a hardship to travel to most of these locations, not only in terms of more time required but also the wear and tear on the vehicles. Additionally, weather-related conditions could make travel hazardous such as excessive rainfall or flooding that could create barriers on any open roads, thereby making them unsafe or impassable. These obstacles are challenging for logistics planning and timing the installation and implementation of the off-grid installation.

Land ownership issues were also a barrier included in the findings. Part of the pre-process needs analysis for the off-grid solar installation included collaboration with the residents and a decision about the location within the village of the community off-grid system installation. Typically, the off-grid system would be installed on community property to circumvent any land ownership issues. In some situations, the location of the off-grid system was on non-community property. When this was the case, there was occasionally some disagreement as to the choice of location. Some residents did not want the system on their property because it would take up part of their valuable, scarce property, and they would have to allow easement to it for regular maintenance. Alternatively, some wanted the system on their private property because it meant that particular resident could have more control over the community off-grid system. In some cases, the village residents did not know the actual owner of the land. Installing the off-grid system on any private property would require agreement among the stakeholders, which could be a challenge.

In addition to deciding where to put the off-grid electricity system, it might be necessary to decide where to locate the equipment that would provide Internet connectivity. In one off-grid installation discussed in the interviews, the NGO had installed a cell phone antenna to use the off-grid system to provide Internet connectivity (PV3). The base of the antenna tower was 40 to 50 feet round. Deciding where to locate it within the village physically was a challenge that needed to be addressed, with the same issues encountered for deciding where to put the off-grid system. In addition to these location and land issues, there was also the possibility of issues with the performance and reliability of the off-grid system itself.

Emergent Theme 2: Off-grid system malfunctioning or obsolete. The off-grid electricity system must have full functionality providing a reliable and steady source of electricity to provide Internet connectivity. One of the obstacles to providing Internet connectivity for these rural and remote areas was the possibility of an off-grid system that was malfunctioning or inoperable. Another related issue was an off-grid system that had become obsolete. From the findings, a malfunctioning or inoperable off-grid system could be because of interference from wildlife such as mice, snakes, or bees. This concept aligns with previous research (see Pillot et al., 2019).

The participants also mentioned broken panels, drained batteries, or problems with the charge controller, the inverter, or the wiring system. Any of these issues, or a combination of them, could result in a malfunctioning or inoperable system. PV11 stated that the off-grid system had and would continue to have issues because “they were starting off with cheap equipment.” In that case, the inverter kept burning out, and the engineers in charge of the maintenance of the system blamed it on the quality of the parts used. Lower quality parts usually resulted in reduced performance of the system. If the system contained inferior components, it would be a matter of time before it malfunctioned or became inoperable.

This finding confirmed previous findings that the level of quality of the off-grid system components is essential for the system's ongoing successful operation (see Palit, 2013). Higher quality standards typically ensure a better success rate for the off-grid system. For example, the inverter is a crucial part of the system because it is essentially the grid manager (Batzelis, Samaras, Vokas, & Papathanassiou, 2016). I also found that charge controllers that malfunction were another example of a critical component of the off-grid system. Battery damage or battery failure can result from a faulty charge controller (Pillot et al., 2019). Thus, a malfunctioning or obsolete off-grid system can be a significant obstacle for using the off-grid electricity system for Internet connectivity.

Emergent Theme 3: Language and cultural barriers. One of the frequently mentioned barriers by the participants included a possible language barrier. Not all stakeholders and experienced project team members were fluent in the local languages where the projects were located. As such, there was a significant language barrier that sometimes resulted in communication difficulties and a lack of understanding by one or both parties. This finding supports the previous research (see Barbieri, Santos, & Katsube, 2012; Jakubiak & Iordache-Bryant, 2017).

Cultural barriers were also part of this study's findings. These include differences in cultures between the residents of the villages where the off-grids were installed versus the management team's culture and the experienced volunteer project team's culture. The management team and experienced volunteer project coordinators were accustomed to living in more developed cities where the necessities such as indoor plumbing, running water, and electricity were available. The residents of the rural and remote villages were used to obtaining water from wells, using outhouses, and not typically having in-house electricity available. Lack of comfortable sleeping arrangements and lack of air conditioning to counteract the hot local temperatures were additional challenges encountered in these remote and rural villages. This was more of a challenge for the installation team because it required that they temporarily adjust to a more rustic way of life in the village during the installation of the off-grid system and any extension for Internet connectivity. This finding also coincided with previous research (see Prince, 2017; Proyrungroj, 2017).

Another difference described by the participants as a cultural barrier was that some residents of the rural and remote villages had a lack of understanding about the dangers of electricity. The management teams arrived at some of the villages and found that not all local individuals had a full appreciation of the possible consequences of not safely handling the off-grid system. Though electricity may be a new concept to some villagers, they can learn about its dangers in a short time (see Bhandari et al., 2017). Therefore, this theme may be more of an intellectual issue that could be addressed by a cohesive knowledge transfer system and training program during and after the off-grid installation, which is discussed more fully later in this chapter.

Emergent Theme 4: Cost and availability of devices and equipment. Connecting to the Internet requires the necessary technology, and the cost and availability of technological devices to connect were two significant forces mentioned by the participants. Traditionally, the necessary technologies to connect to the Internet include computers, laptops, or tablets, and a device such as a router or satellite dish. The participants noted that in some remote and rural villages, the cost of obtaining the devices was an obstacle that prohibited the residents from being able to afford them. Additionally, building the traditional infrastructure needed to connect to the Internet was typically beyond the means of these village residents. The availability of these devices was limited; the nearest marketplace could be many hours away and there was no guarantee that there would be computers, laptops, or tablets available for sale at the marketplace. This finding aligns with the research on this lack of available technology (see Freeman & Park, 2015; Sparks, 2013; Yu, Lin, & Liao, 2017).

Emergent Theme 5: Unreliable source of signal. One of the biggest obstacles to obtaining reliable Internet connectivity was an unreliable or nonexistent source of signal. Even with a reliable source of electricity from the off-grid system, and the availability of affordable devices to obtain Internet connectivity, the user needs to obtain an Internet signal that provides connectivity. Although there are broadband possibilities (Reed, Haroon, & Ryan, 2014), many of these villages were too far from the traditional Internet infrastructure to make this feasible. Further, there is the possibility of obtaining a wireless connection, but physical obstacles such as mountains and valleys could be in the way (Zander & Mahonen, 2013, Zhang & Wolff, 2004). Using the smartphone and the corresponding mobile connection is a solution, but only if there is available cell phone coverage in the area. As PV13 stated, if the cell signal was unreliable or unavailable, the Internet connection is unavailable. This lack of Internet signal is a barrier that is part of ongoing and future research by many organizations, with the possibility of multiple solutions.

The following four themes address sub-research question 1: How can the NGO top project managers, the installation project managers, and the experienced volunteer project coordinators overcome the challenges, barriers, and obstacles encountered with the maintenance of the off-grid electricity systems in rural Nicaragua?

Emergent Theme 6: Adequate and cohesive maintenance procedures. One of the best practices that the managers can use to overcome obstacles is creating a cohesive physical maintenance procedure plan and an adequate budget to fund the plan. Sixty-three percent of the study participants (12/19) noted that this cohesive plan was a key factor in the off-grid electricity system's ongoing success, thereby obtaining reliable Internet connectivity. PV3 shared that installing the off-grid system was only the beginning of the project's success. If the installation team simply left after the installation, then there was little knowledge transfer involved. In addition to the system installation, it was also necessary to provide and share a cohesive usage and maintenance plan for the system's users. Without this plan, the system could possibly be ignored or misused or incorrectly maintained.

An adequate maintenance plan includes procedures on cleaning the components of the system and ensuring that all of the components were in good working order. Adequate maintenance is crucial (Laufer & Schafer, 2011). It would provide a management plan designating the individuals who would be responsible for the ongoing maintenance. This continuous management of the system would require a regular schedule of possible preventative measures to ensure the reliability and longevity of the off-grid electricity system.

In addition to the maintenance plan itself, key stakeholders need to fund an adequate budget for it. Although volunteer residents can provide the labor, the materials have to be purchased. Distilled water to fill the lead-acid batteries would be required and a fund for any possible repairs or part replacements would be necessary. With a cohesive and fully funded maintenance plan in place, the off-grid electricity system and corresponding Internet connectivity could increase the system's reliability.

Emergent Theme 7: Requirements analysis and logistics planning. Another best practice that I discovered from the study data was the need for a thorough requirements analysis and logistics plan. Before the off-grid electricity installation, the pre-process and needs analysis was deemed to be a crucial step. Fifty-eight percent (11/19) of the participants supported a pre-process and needs analysis step to ensure a successful off-grid electricity system installation.

PV6 and PV13 stated the need for an analysis that matched supply and demand, which is true for digital inclusion strategies (see Park, 2015). When supply and demand did not match, researchers have shown that the end users were dissatisfied with the electricity system because the system either did not provide the expected amount of electricity (supply too low) or the system's full capacity was not being reached (demand too low) (see Hong & Abe, 2013; Shyu, 2013). Therefore, forecasting and matching the supply and demand as accurately as possible was considered a best practice. The needs analysis for the off-grid electricity system is dependent on the intended usage of the system. Personnel working in the medical clinic might use the system for off-hours lighting, some medical equipment, and a refrigerator for preserving vaccines, insulin, and other medications that need refrigeration. Other participants shared that some of the off-grid electricity system's uses could include cell phone recharging, home refrigerators, and television sets. Household needs could also include radios and fans, whereas community needs could include street lighting (Louie, 2018). Factoring all these needs into the analysis is an obvious critical step for determining the size of the off-grid system needed.

Cohesive logistical planning could counteract the logistical challenges that were noted by eleven of the nineteen study participants. I covered these logistical challenges in the location and land issues section in the first theme described above. Due to the remoteness of many of the locations, transporting the necessary supplies, equipment, and tools, was a significant challenge. One suggestion made by study participant PV2 was to have a thorough contingency plan for the logistical portion of the off-grid electricity installation. Another suggestion was to use in-country supplies and equipment whenever possible, thereby eliminating the possibility of barriers and obstacles encountered with supplies and equipment traveling from other countries, and any possible issues encountered at the local Customs office (PV4, PV5). Duplicate sets of tools and redundant supplies could also be part of the contingency plan. A carefully planned project increased the likelihood of a successful and sustainable off-grid installation.

Emergent Theme 8: Village centered model. A best practice of off-grid electricity system installation projects included having the main focus on the community itself: the involvement in the planning and installation, a sense of ownership of the system, and an acceptance of the system. This community involvement should begin before the project pre-analysis itself. The earlier the community members became involved and remained involved, the better the chances of a successful off-grid installation and subsequent sustainability of the system (PV9). This finding aligned with the literature (see Dillette et al., 2017; Kerr, Johnson, & Weir, 2017; Orajaka, 2013).

A related finding of this study was that the more successful systems usually resulted from a higher level of commitment and involvement of the community itself. The installations where the residents experienced a strong sense of involvement every step of the way were also the locations where the system was readily accepted and utilized on a higher level than those installations where the community involvement was not as strong. True collaboration and centering the decision making around the community leaders was a critical best practice. I directly linked to this theme to the next theme: managers can create a successful system with a high level of community education, community training, and robust communication among all stakeholders.

Emergent Theme 9: Community education and training and robust communications. Community education and training are related to theme six above (adequate and cohesive maintenance procedures). This theme also complements theme three above (the possibility of a language barrier). After the system installation is complete and the installation team is ready to hand it over to the village residents, system education and training must be a critical success factor. For some of the installations mentioned in the study interviews, a team of village residents would be in charge of maintaining the system.

Adequate knowledge transfer must take place so that this local team would have the trouble-shooting skills and knowledgeable confidence to repair the system or to know when to call for locally trained professionals. This training and education need to be done in the local language, if possible so that the village residents fully understand the knowledge that is transferred. As participant PV3 mentioned: “I couldn’t really tell whether or not the villagers were really deeply understanding and sort of, you know, just having an appreciation for what would be involved with the operation and maintenance of the system.” The local team would be the first responders in the event of any system malfunction or outage, so they must have the tools and expertise to attempt to diagnose the issues at hand.

Another concern with having village residents handling the maintenance and upkeep is the issue of continuity. Study participant PV5 stated that there was the possibility that the local person(s) trained to maintain the system might move away without passing the knowledge down to other residents. Alternatively, the system might operate so well for an extended period that when it finally does have an issue, the village resident no longer remembers how to handle the situation. Providing thorough written documentation in the local language and a training session could help to alleviate these concerns.

Connected to this theme includes the concept of robust communication among all stakeholders. As mentioned previously, the installation team was responsible for the knowledge transfer to the local team. The final knowledge transfer is only one facet of a robust communication process with all stakeholders. From the pre-planning phase to the daily usage phase, comprehensive communication needs to occur during all aspects of the project. Study participants claimed that more communication usually results in more involvement of community members, so it is a critical factor in the successful installation and subsequent ongoing maintenance of the off-grid electricity system.

Sub-research Question 2: How can these key managers of the off-grid systems successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity? Successful Internet connectivity is tied to six central themes as follows.

Emergent Theme 10: Devices and equipment to connect. As mentioned in theme four above, the lack of affordable devices and equipment to connect to the Internet can be a significant obstacle. Providing the devices and equipment is a crucial theme for successfully using the off-grid system to provide Internet connectivity. As noted earlier, these village members bypassed the traditional electricity infrastructure by having an off-grid electricity system installed. The lack of a traditional Internet infrastructure resulted in these village residents bypassing another infrastructure: the Internet infrastructure that uses cable/broadband. The village residents found an alternate way to fulfill their need for Internet connectivity.

The alternative way to bypass the traditional Internet infrastructure was through the use of smartphones. This strategy aligns with research about using mobile phones to narrow the digital divide (see Vimalkumar, Singh & Sharma, 2020). One study participant stated that the initial cost of cell phones (when they were first introduced in the market) was too cost prohibitive for many residents in the remote and rural villages. Participant PV11 stated that since then, there was considerable market competition among cell phone manufacturers. As a result, over time, the cost of technology had dropped considerably, and many residents were now able to afford using a smartphone as an Internet connection. Some cell phone providers were even giving the phones away free of cost. Residents were now using smartphones to connect to the Internet. This finding supports the analysis that was conducted by Stork, Calandro and Gillwald (2013). Smart/mobile phones had become the entry point for connecting to the Internet (see also Pandita, 2017; Park & Lee, 2015; Tsetsi & Rains, 2017; Vimalkumar, Singh, & Sharma, 2020).

Study participants noted that programs from other NGOs included providing students with free or inexpensive tablets for schoolwork. These tablets operated as smartphones did. They used some variation of available cell phone usage to provide Internet connectivity. In effect, the expensive ICT devices were not sought after and obtained. The village residents were able to adapt and find their solution for Internet connectivity using inexpensive devices such as smartphones and tablets.

Emergent Theme 11: Source of Internet signal is crucial. Another key finding of this study is that there has to be a source of Internet signal that the village residents can utilize for Internet connectivity. This signal could come in the form of a cellular phone service plan provided by one local cell phone company. Congruent with this theme is how residents use their cell phones to provide Internet connectivity. The findings from this study provided possible choices. Instead of purchasing a long term cell phone data plan, some of the village residents would purchase what is called a “recharge” and that would give them access to the Internet for a certain number of days using the app called Whatsapp.

Alternatively, the Internet connectivity could come in another form, such as Google’s Project Loon balloons or Facebook’s Internet.org project, which includes highly innovative ways such as connecting with lasers and using unmanned aircraft for delivering Internet coverage for hard to reach areas. Innovative solutions to provide an Internet signal for connectivity are in development with many NGOs and other organizations and are a topic for future research.

Emergent Theme 12: Experienced teams and in-country support is vital. A key factor affecting the success of an off-grid installation, its daily maintenance, and any subsequent Internet connectivity included have trained and experienced people to support the system. For the off-grid installation, the volunteer tourism model makes use of volunteer labor. These volunteers arrived at the project sites with varying degrees of skill, talent, and expertise regarding electricity and the off-grid electricity system’s components. Unskilled volunteer talent could harm the outcome of the project, thereby creating an obstacle to its success (see Guttentag, 2009; Sin, Oakes, & Mostafanezhad, 2015). Some of the volunteer team members did have experience in off-grid installations, but not all of them. Balancing the lightly skilled volunteer talent with local skilled contractors was a key finding of this study. Study participants PV1 and PV9 stated that this balance was a key success factor.

Once the system is installed and operational, having in-country support for ongoing maintenance is another critical success factor. The in-country support might consist of local members of the NGO who visit the installations on an ongoing basis. It might consist of having a local electrical contractor on retainer to provide maintenance and repair for the systems. It might consist of having a small group of resident volunteers who trained to maintain the system. Alternatively, it might consist of a combination of these groups. Having the talent located physically close to the off-grid system as possible was essential. Study participant PV4 stated that it was a hardship to have the experienced repair people more than a few hours away from the off-grid installation because the logistical challenges of traveling to and from the off-grid site could be a barrier. This obstacle could result in having the off-grid system being inoperable for lengthy periods. Ensuring that there is in-country support located nearby to handle outages and emergencies is a best practice for the off-grid installation for reliable Internet connectivity. This finding extends the literature about the skill level of volunteer talent using the volunteer tourism model.

Emergent Theme 13: Use of off-grid for internet connectivity is site-specific. Whether or not the off-grid electricity system could provide for Internet connectivity is a site-specific requisite. It is dependent on (a) ensuring that there is a source of electricity there first; (b) paying attention to the residents' priorities for their electricity needs; and (c) ensuring that the original power needs analysis taken into account the possibility of using the off-grid electricity system for Internet connectivity.

Having the off-grid electricity system to provide the necessary power was a prerequisite for having Internet connectivity. As noted earlier, this system must be fully functional and provide a steady and reliable electricity source. Once a steady supply of electricity is in place, it becomes a matter of allocating residents' electricity needs.

At each location, the village residents have their unique electricity needs. Medical clinics typically use power for lighting, some medical equipment, and possibly a refrigerator to store medicines and vaccines (Louie, 2018). Educational facilities would use electricity for lighting and possibly computers and other learning equipment. Individual residences might use the electricity to charge cell phones, for lighting, and perhaps a refrigerator or television. Whether or not the community desires Internet connectivity depends more on the community level of Internet acceptance and awareness, discussed in theme 15. With a steady source of electricity, and if the community decides it wants Internet connectivity, then the last step is to ensure that the off-grid system can power any devices or pieces of equipment that would be needed to provide Internet connectivity. With all of these factors in place, the next step is the affordability and cost of connecting to the Internet.

Emergent Theme 14: Affordability and cost. Once the users of the off-grid electricity installations determine that they want Internet connectivity, the next step would be to find a way to connect to the Internet. Managing the off-grid electricity system for Internet connectivity is primarily affected by the cost and availability of devices and data charges for receiving the Internet signal, as mentioned in theme four above.

In this study, I found that 7 of the 19 study participants (37%) mentioned using smartphones as a solution to the barrier of technological cost. This finding aligns with the literature about how the digital divide can be narrowed with the use of smartphones (see Park & Lee, 2015; Tsetsi & Rains, 2017; Vimalkumar, Singh & Sharma, 2020). To connect to the Internet a traditional subscription to an Internet Service Provider is usually needed for traditionally used ICT. This ongoing subscription could prove to be too expensive for the village members already living on very minimal means. Finding affordable ways to connect to the Internet is a key issue. If the connection is through a smartphone, this ISP subscription may not be necessary. Instead, there may be data fees or the need for some sort of cell phone plan or pay-as-you-go arrangement to provide Internet connectivity through smartphone use. More than one study participant mentioned this concept. With an affordable device and Internet connection, the last piece is user acceptance and awareness of the new technologies.

Emergent Theme 15: Community acceptance and awareness. The final theme of this study is that successful Internet connectivity depends on the match between new technologies and the local user acceptance and awareness level at each individual location. The new technologies included the off-grid electricity system and Internet-ready devices. To use the off-grid electricity system to provide for Internet connectivity, study participants noted that two additional conditions must be met: the users must have an acceptance of the technologies and have an awareness of the benefits of connecting to the Internet.

The study participants were divided in terms of whether the village residents had an acceptance of the new technologies. Although some of the study participants (4/19) stated that village residents they communicated with had embraced the technology and wanted it, there were also a few instances (2/19) where the study participants noted that some villages had members where the technologies were not so readily accepted. This related to Roger's (2003) diffusion of innovation theory. Some villages had members who were early adopters of the new technology of the off-grid electricity system. They quickly embraced it and saw the potential for its use.

Other villages had more conservative members who were not so ready to adopt the new technologies. Study participant PV3 stated that they noticed that some of the village residents were entrenched in tradition and were not so ready to accept and embrace anything that would result in significant changes to their current way of life. If it meant a big adjustment for the village residents, then it was initially treated with fear and distrust. Sometimes, PV3 claimed, the younger generation would be able to convince the older generation to try new things. However, for the most part, some village residents refused to accept any changes to their current way of life. Adopting a new piece of technology was not attractive to these residents.

Even after accepting the new technologies, the system users need to be aware of the benefits of the Internet. Without a knowledge of the benefits that connectivity to the Internet provided, the off-grid system users would probably not pursue a connection to the Internet. As study participant PV12 claimed, it was only when some village residents saw others receiving some benefit from the Internet connectivity that it increased the awareness of the benefits of Internet connectivity within the village. This increased value could be in the form of communication with others who had moved away from the village, or connection with others via social media, or some form of entertainment, or some other value received from the Internet connection. When the village residents saw this, they became interested in connecting to the Internet themselves. With this awareness of the benefits of the Internet, combined with an acceptance of the new technologies, the village residents were ready to utilize the off-grid electricity system fully.

Connecting the Findings to the Gaps in Literature

The first gap in the literature included connecting the barriers, challenges, and obstacles from using voluntourism as the business model for the installation and the management of off-grid installations and the subsequent extension of the system to provide for Internet connectivity. As noted in chapter four, I identified themes from the data to address the main research question and this gap in literature. From the findings, I identified internal and external forces that impinged on the managers' ability to bring the digital age and Internet connectivity to rural villages in Nicaragua using the off-grid electricity system. These were location and land issues, including the villages' remoteness and the difficulty getting to them. The land issues included land ownership for the location of the off-grid system. Additionally, the off-grid system itself might be malfunctioning or obsolete. Participants also noted that language and cultural barriers were obstacles during the off-grid system installation. The cultural barriers included the village residents' unfamiliarity with electricity and its potential danger and risks. The cost of devices and equipment and the availability of devices were additional barriers and obstacles. Moreover, an unreliable source of Internet signal or the inability to secure a reliable source of a signal was another external force that impinged on the ability to bring the digital age to rural villages.

The second gap in the literature connected the best practices of the management of off-grid systems with the best practices using voluntourism as the business model. From the data, I found that the NGO top project managers, the installation project managers, and the experienced volunteer project coordinators encountered challenges, barriers, and obstacles with the maintenance of the off-grid electricity system. Management must provide adequate and cohesive maintenance procedures for the off-grid system to overcome these obstacles. Maintenance should include off-grid system cleaning, upkeep, repairs, and a budget for those items. Systems designers and installers should develop and follow a thorough requirements analysis and logistics planning process. This should contain both a pre-process analysis and a needs analysis. Addressing the logistics challenges with thorough planning was recommended. Overcoming maintenance barriers and obstacles could be accomplished with a village-centered model focusing on community acceptance, involvement, and ownership was also viewed as a method for overcoming the maintenance barriers and obstacles. Robust community education and continuous training were key factors for successful system maintenance. Robust communication among all stakeholders was another successful best practice for overcoming the challenges, barriers, and obstacles of maintaining the off-grid electricity system.

The third gap in the literature was using off-grid to provide Internet connectivity. From the data, I found here were many areas that the key managers of the off-grid systems could address to successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity. These included procuring the necessary devices and equipment to connect, finding a reliable source of Internet signal, and having experienced team members, skilled contractors and subcontractors, and in-country support. Because the use of the off-grid system for Internet use is site-specific, the key managers must focus on the local priorities of the electricity and power needs analysis of the off-grid electricity system. Affordability and cost of technologies and data are key factors for successful Internet connectivity. Lastly, factors needed include community acceptance, embracement of new technologies, and an awareness of the benefits using the Internet. These are factors that need to be present for successfully extending the off-grid electricity system to provide Internet connectivity.

I identified these themes to answer the general research question and the two sub-research questions. From the study findings, each sub group of themes adds to the existing body of literature. The main gap in literature was the management barriers and issues encountered using the off-grid electricity system to provide Internet connectivity. Although some researchers focused on the off-grid system from an engineering perspective, other researchers focused on the off-grid system by focusing specifically on the business model used. In this study, I focused on the off-grid system from a business management perspective. The identified themes form a framework for successfully extending an off-grid electricity installation to provide for Internet connectivity.

Limitations of the Study

In this study, I investigated the lived experiences and knowledge of NGO managers, project managers, and the experienced volunteer project coordinators about their experiences of off-grid installations in undeveloped countries. The first limitation of this study was the choice of purposive sampling. My sampling plan was to start with the top management of the NGOs I had traveled with for my two trips to Nicaragua in 2013 and 2014 and branch out from there. With this sampling strategy, I aimed for a sample of 15-20 study participants. This sampling strategy yielded a final sample of nineteen study participants. No new themes arose after the 17th interview, so the sample size of 19 for this study was appropriate. Although this was an adequate sample size for a qualitative phenomenological study, it was difficult to transfer the study results to other settings. Although the study participants discussed off-grid installations in Nicaragua, Zambia, Tanzania, Myanmar, Pakistan, India, and the United States, the depth of knowledge might have increased with a larger sample size. Future research could address this limitation with a more representative sample of the population of off-grid electricity installations globally.

The second limitation concerned the data collection method of semi-structured interview questions. I collected the data in only one format: the interviews. As noted in chapter one, semi-structured interviews from participants using self-reported data could be hard to verify due to possible personal respondent bias or selective memory issues. Participants may choose to answer the interview questions to show their NGO or other organizations in the best possible light. As a researcher, when I became cognizant that this was possibly occurring, I reminded the study participant that their identity and the identities of their organizations would remain confidential. This reminder usually resulted in the study participants answering the questions truthfully so that they did not necessarily show their organizations in a positive light. I also returned a transcript of the interview to each study participant to correct or change their responses, with the goal of a more accurate representation of their experiences of the phenomenon.

The third limitation that I encountered concerned the choices for the conceptual framework of this study. I used two theories and one model: the systems theory (Checkland, 1994, Jackson, 2003), the technology acceptance model (Davis, 1986 & 1989), and the diffusion of innovation theory (Rogers, 2003). Other theories and models were applicable to this study, but those listed above provide the best fit given the phenomenon. These limitations did not knowingly have any effect on the possible contribution and significance of this study.

Recommendations

For this study, the general management problem addressed was that NGO managers, project managers, and experienced volunteer project coordinators encountered management challenges that prevent implementation and maintenance of these off-grid electricity systems and its subsequent use for providing Internet connectivity. The specific management problem was that these challenges caused management barriers and obstacles that interfered with a smooth flow or an easy transition of resources for easily accessible and affordable Internet connectivity for rural village residents using the off-grid solar electricity installation.

This study may be relevant for the key managers who implement the off-grid electricity systems, including those using the volunteer tourism model. Some NGOs and other organizations had their operating plan in place, and they typically tried to duplicate it with each new off-grid installation. This operating plan included a business model, a method to choose the locations for the installations, and a project management team that implements the installations. Preferably, the chosen business model used would take into account the financial, legal, and political environment where the off-grid installation would take place.

From the emergent themes, best practices for successful off-grid electricity installations include addressing the challenges, barriers, and obstacles identified in this study's interviews. For each specific village, the entire process needs to begin with community involvement. As the study participants mentioned, the earlier the community became involved, the more likely that the installation would be successful. Managers need to resolve the location and land issues before the installation begins so that the installation team and the village residents knew precisely where the off-grid system was to be located. A solid pre-analysis and supply/demand system analysis should be thorough and completed early in the process. Preparing the installation team about the language and cultural issues would be another best practice as well.

This community centered model should include continuous robust communication among all key stakeholders, community training and education concerning the awareness and dangers of the off-grid electricity system, and some form of community ownership of the off-grid system. Additionally, logistical planning is key for a successful installation.

This logistical planning should include the likelihood of many contingencies. Duplicate and redundant tools, equipment, and supplies would be beneficial, but the managers need to balance this with a realist budget.

The final step in the off-grid electricity installation handoff should include a knowledge transfer from the hosting organization and the installation team to the users and village residents. The knowledge transfer team should preferably conduct it in the local language. It could include a demonstration, a workshop, and a written manual. Users of the system should be able to replicate any simple diagnostic procedures of dealing with system malfunctions or outages. They should also know when it is time to call in an experienced local contractor to repair the system. Having a network of local trained contractors would be beneficial at this point so that the village residents would have an idea of where to turn to for this need. Moreover, the maintenance budget that would be set up should be managed by the local team and should provide for supplies (distilled water, fuses, and other replacement parts) and any repairs and maintenance for the off-grid electricity system.

One possible tangent of future research could be that the NGOs or other host organizations create or continue to collect a database of off-grid electricity systems with their specifications and performance statistics. Managers could expand this database to measure the use of the off-grid system for Internet connectivity.

This study may be relevant to any management group that would want to extend the use of the off-grid electricity system for Internet connectivity. To successfully provide sustainable Internet connectivity, the barriers, obstacles, and issues identified in this study must be addressed. Best practices for extending the off-grid system for Internet connectivity include the following items. The village residents should identify that they desire to use the system for Internet connectivity. The pre-system analysis should provide a system that generates the necessary amount of electricity to power any devices needed to connect to the Internet. Assisting in finding and providing affordable Internet-ready devices and equipment is crucial. Assisting in identifying the closest local Internet signal is another critical factor.

Acceptance of the new technologies and awareness of the benefits of Internet connectivity must be present within the village. If it is not yet present, then an awareness campaign could provide it. Having examples from other communities would be beneficial, as one study participant noted (PV3). Placing the devices in the hands of the early adopters of technology might help diffuse the spread of adopting it. These devices might be the smartphones or tablets or whatever affordable Internet-ready device is available.

On the other hand, being aware of Internet connectivity's possible disadvantages is also knowledge that the village residents should have. Two study participants mentioned this concept (PV2, PV12). Avoiding the pitfalls of Internet disinformation should be part of the knowledge transfer as well so that the village residents can be informed and can be able to make wise choices about their Internet use. A study determining what the residents are using the Internet for could be a topic for future research.

A possible tangent for future study could be for the NGOs or other hosting organizations installing off-grid systems to collaborate with the organizations that are making Internet inclusion for all their top priority. Sharing the combined strengths of these groups might result in a collaboration that increases Internet connectivity for those not yet connected to the Internet.

This study could also be relevant for anyone interested in learning about how to provide Internet connectivity in hard to reach areas and for those studying how to close the digital divide. Using off-grid electricity systems to provide Internet connectivity could be a starting point for their future research.

Implications

Significance to Positive Social Change

This study could have significance to positive social change at both the management level and the village level. At the management level, the themes were used to develop ways that managers could successfully manage the off-grid electricity installation. The themes also provided a checklist of best practices for utilizing the system to provide for Internet connectivity. Together, that framework could be the starting point for a management team who is replicating the process.

On the village level, the positive social change comes from providing electricity to a village that did not have it before the off-grid installation. Using the electricity for Internet connectivity might provide positive social change with some of the benefits, including (1) finding better farming methods, (2) increasing the education with possible online resources, and (3) having access to medical knowledge. These are just a few of the possible ways that being connected to the Internet can provide positive social change.

Significance to Theory

The conceptual framework for this study included two theories and one model: the systems theory (Checkland, 1994, Jackson, 2003), the technology acceptance model (Davis, 1986 & 1989), and the diffusion of innovation theory (Rogers, 2003). Systems theory (Checkland, 1994, Jackson, 2003) worked here because installing the off-grid system in the rural and remote villages would affect the systems that already are in place at these locations. Using electricity changes the system dynamics, and this is reflective of the change in needs of the local village residents. Future quantitative studies using the systems theory as a framework would be beneficial for learning more about how these off-grid electricity systems and subsequent Internet connectivity help alleviate energy poverty at these locations.

Using the Technology Acceptance Model (Davis, 1986 & 1989) worked here as well. As noted by a study participant (PV5), the village residents would only use the off-grid electricity system and subsequent Internet connectivity if they realized that it was (a) easy to use and (b) useful to them. This is another case where a quantitative study framed by the Technology Acceptance Model would be useful. It could provide insight into what factors were necessary for both ease of use and usefulness to exist. Researchers could also use the Technology Acceptance Model to develop theories about these off-grid electricity installations.

Using the theory of the Diffusion of Innovation (Rogers, 2003) was relevant as well because the adoption of two innovations were apparent: the adoption of the off-grid electricity system and the adoption of devices and equipment needed for Internet connectivity. Future grounded theory studies or descriptive case studies could be used to develop theories related to off-grid electricity installations and subsequent Internet connectivity.

Significance to Practice

The installation of the off-grid electricity system could alleviate energy poverty by providing electricity for lighting after sunset. Adults might take night classes after working for the day. They might start having more social activities. Knowledge of weather conditions could help make their communities safer. Village residents might create new markets for existing village using the Internet or create new businesses. The availability of the wealth of knowledge of the Internet at the village residents' fingertips might alleviate the burdens associated with living in energy poverty.

Conclusions

The purpose of this qualitative phenomenological study was to investigate the lived experiences and knowledge of NGO managers, project managers, and the experienced volunteer project coordinators about their experiences of off-grid installations in undeveloped countries. For this study, I used phenomenology to reveal patterns and themes that highlighted the barriers and obstacles that prevent successful installations and ongoing maintenance and to explore ways for NGO managers and project managers to address these barriers and obstacles and expand the off-grid solar electricity to allow for Internet connectivity.

There were main barriers, obstacles, and challenges that affected the ongoing maintenance of the off-grid electricity systems and impinged on the ability to extend the system for Internet connectivity. These included (a) location and land issues, (b) an off-grid system that might be malfunctioning or obsolete, (c) language and cultural barriers, (d) the cost of devices and equipment as well as the availability of devices, and (e) a possibly unreliable source of Internet signal or the inability to secure a reliable source of a signal.

The next set of themes included ways for the management team to overcomes the challenges, barriers, and obstacles encountered with the maintenance of the off-grid system. These included (a) adequate and cohesive maintenance procedures for the off-grid system, (b) a thorough requirements analysis and logistics planning process, (c) a village-centered model with community acceptance, involvement, and ownership, and (d) robust communication among all stakeholders.

Lastly, I identified themes that would assist the management teams in successfully utilizing, managing, and maintaining the off-grid electricity system for sustainable Internet connectivity. These included (a) procuring the necessary devices and equipment to connect to the Internet, (b) finding a reliable source of Internet signal, (c) having experienced team members, skilled contractors and subcontractors, and in-country support, (d) recognizing that the use of the off-grid system for Internet connectivity is site specific, (e) recognizing the affordability and cost of technologies and data, and (f) community acceptance, embracement of new technologies, and an awareness of the benefits of the use of the Internet.

Energy poverty and the digital divide are two social issues affecting many residents of undeveloped countries. Using the volunteer tourism model to install off-grid electricity systems could help to alleviate energy poverty. Using the off-grid system to provide for Internet connectivity could help to narrow the Digital Divide. Both of these solutions, working together, could bring the digital age to developing and underdeveloped countries.

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Appendix A: Interview Protocol

Interviewer: Helen Anne Hicks

Date and time of Interview: TBD

Participant Interviewed: TBD

Participant code number assigned by researcher: TBD

Location: in-person via phone or Skype or via e-mail response or via Walden Participant Pool response

Study Title: Management Barriers and Issues Encountered Bringing the Digital Age to Rural Nicaragua

Interview Introduction

Describe the study and its research purpose. Inform the interviewee that the interview is confidential, data will be kept private, and names will not be used in the dissertation. Give an explanation of the interview by explaining the length of time, the ability to opt out of any questions, and that the conversation will be recorded and I will be taking notes.

Participant Selection Criteria Questions

1. Have you participated in an off-grid renewable energy installation?
2. Are you familiar with renewable energy technologies?
3. Are you familiar with Internet access technology?
4. Are you fluent in English?

Interview Questions (see Appendix B for alignment to sub-research questions):

Interview Question #1: Try to recall the first time you experienced an off-grid renewable energy installation. Tell me about your experience from beginning to end.

Interview Question #2: What key factors influenced the management of the outcome of the off-grid installation?

Interview Question #3: Now recall your experiences with the maintenance of the off-grid renewable energy installation. Tell me about what you encountered with the maintenance and management of these systems.

Interview Question #4: What was your perception of how these off-grid renewable energy installations can be used to provide Internet connectivity?

Interview Question #5: How can the management of these off-grid systems contribute to successful Internet connectivity?

Interview Question #6: What key factors had the most impact on using the off-grid system for Internet connectivity?

Concluding the Interview

Wrap up the interview. Offer e-mail address if participant has any follow-up questions. Ask for permission to contact them if I have any follow-up questions. Offer a copy of the transcript.

Appendix B: Interview Questions

Connecting the Interview Questions to the Research/Sub Research Questions

The general research question is: What are the internal and external forces that impinge on the ability of NGO managers, the project managers, and the experienced volunteer project coordinators to bring the digital age and Internet connectivity to the rural villages in Nicaragua using off-grid electricity systems?" The following are the sub-research questions.

Sub-research Question 1: How can the NGO top project managers, the installation project managers, and the experienced volunteer project coordinators overcome the challenges, barriers, and obstacles encountered with the maintenance of the off-grid electricity systems in rural Nicaragua?

Interview Question #1: Try to recall the first time you experienced an off-grid renewable energy installation. Tell me about your experience from beginning to end.

Interview Question #2: What key factors influenced the management of the outcome of the off-grid installation?

Interview Question #3: Now recall your experiences with the maintenance of the off-grid renewable energy installation. Tell me about what you encountered with the maintenance and management of these systems.

Sub-research Question 2: How can these key managers of the off-grid systems successfully utilize, manage, and maintain the off-grid electricity system to provide sustainable Internet connectivity?

Interview Question #4: What was your perception of how these off-grid renewable energy installations can be used to provide Internet connectivity?

Interview Question #5: How can the management of these off-grid systems contribute to successful Internet connectivity?

Interview Question #6: What key factors had the most impact on using the off-grid system for Internet connectivity?