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Original research article

Mini-grids and renewable energy in rural Africa: How diffusion theory explains adoption of electricity in Uganda

Jonas M. Eder[a], Christopher F. Mutsaerts[b], Pranpreya Sriwannawit[c,*]

[a] Faculty of Management, University of Trier, Trier, Germany
[b] BearingPoint, Amsterdam, The Netherlands
[c] Department of Industrial Economics and Management, KTH Royal Institute of Technology, Stockholm, Sweden

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ABSTRACT

With diffusion theory as the point of departure, this study analyses the factors that influence the adoption of renewable electricity from individual households' perspectives. The analysis is based on a case study provided by a Swedish energy service company operating in rural Uganda. The company distributes electricity to rural households via a mini-grid powered by a biomass gasification system. Three critical dimensions are identified to be crucial for adoption: technical, economic, and social. First, there is an emphasis on the relative advantages of the new technology. Second, there are economic requirements regarding a viable financial system for adopters, especially in such a low-income market. Third, the social dimension is critical, particularly the importance of foreign firms collaborating with local actors. We further suggest that a lack of understanding of local communities can lead foreign companies to fail in diffusion attempts. While we focus on Uganda, the results of our research are highly relevant for foreign actors who attempt to penetrate rural markets in developing countries in general.

1. Introduction

Electricity access is crucial for development, particularly among low-income inhabitants of developing countries [1] (see Mukasa et al. [2] in this Special Issue for a review of the literature showing that the causation is not always straightforward). However, 1.3 billion people worldwide spend their lives with no access to electricity, nearly half of them in sub-Saharan Africa [3]. Because of limited financial resources and the dispersed and scarce availability of infrastructure in rural areas of sub-Saharan Africa, the equitable distribution of electricity via a national grid is difficult to achieve. Hancock [4], in this Special Issue, discusses the hurdles in the wider implementation of renewable energy in Sub-Saharan Africa, which underlines the importance of empirical investigation in this region. Moreover, climate change challenges emphasise the urgent need for a shift from traditional fossil fuel-based electricity production. Additionally, innovation in the technological infrastructure and production and use of energy could potentially be beneficial to climate change mitigation [5]. Thus, efforts to introduce small and medium-sized renewable energy systems should be based on international technology transfer, i.e., from developed to developing countries [6]. Innovative energy systems have proven to enhance quality of life and potentially stimulate entrepreneurship [7].

This study focuses on Uganda, where only approximately 4% of the population in rural areas has access to electricity [8]. Because of the poor infrastructure, the national grid can only be found along the main roads that connect the major cities. Therefore, people without access to the grid use alternative energy sources such as kerosene and diesel engines. Furthermore, Ugandans may perceive charcoal as a non-sustainable energy alternative because of its potential to harm the environment [9]. In addition to the improvements stated by Musinguzi et al. [7], enabling electricity access for the remaining 96% can also have a positive impact on welfare and the sustainability of livelihoods [10–12]. There are, however, two main reasons that connecting these people to the national grid is neither realistic nor feasible. First, it is a matter of the prioritisation of municipalities and governmental institutions because there exist multiple other economically attractive opportunities. Second, Uganda has only limited capacity for power generation. One way to solve this lack of electricity access could be the use of decentralised power generation technologies. Ideally, these should

* Corresponding author. Tel.: +46 87908735.
E-mail addresses: jed@munich-innovation.com (J.M. Eder), chris.mutsaerts@bearingpoint.com (C.F. Mutsaerts), pranpreya.sriwannawit@indek.kth.se (P. Sriwannawit).

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be through renewable sources, the subject of this Special Issue. However, there are hurdles both to providing these technologies, and to getting people to adopt them.

There is a significant literature on the diffusion of product innovations for low-income communities in developing countries. However, few scholars have investigated how the failure of technology transfer and diffusion can be reduced or managed. Our research attempts to provide these insights, drawing on existing literature as well as new empirical data. We chose to use case study analysis to assess a rural Ugandan village with a power plant operated by a Swedish energy company. Because of the urgent need to enable electricity access in sub-Saharan Africa and the lack of empirical research in this context, this study sheds light on the early stages of diffusion. Taking its theoretical point of departure from the diffusion theory of Rogers [13], this company's approach – distributing biomass-based electricity through a mini-grid – was analysed from a multidimensional perspective. We chose this specific company because of its innovation in the sub-Saharan context. Similar bioenergy technologies have been introduced in Uganda, but they have not yet been widely adopted [14]. Buchholz et al. [15] addressed a multidimensional approach to assess the different contexts in which sustainable bioenergy systems are embedded. To utilise the full potential of biomass residues, additional research is required that should, according to Okello et al. [16], address the technological, economic, and social dimensions that increase the adoption of innovation within social systems. Fri and Savitz [5] stress that the movement through different stages of diffusion is not linear and requires complex feedback loops. The aim of this study is to identify the factors of each dimension that influence the adoption of renewable electricity from individual households' perspectives with empirical insights.

Section 2 discusses the theoretical foundations of this study, with a focus on the diffusion of innovation in developing countries and how this phenomenon is embedded within socio-technical systems. Section 3 provides an overview of the energy service company that we used for our case study. Section 4 describes our research approach and Section 5 discusses our findings. The article ends with conclusions and implications.

2. Literature review

This section discusses the theoretical complexity and mechanisms of diffusion process based on three main themes: innovation in developing countries, diffusion process, and the interplay within socio-technical systems.

2.1. Innovation in developing countries

Entering a developing country with an innovation that is perceived as new within the social system is always a process rather than a product breakthrough. This process is not a single event that occurs at a specific point of time; rather, it is necessary to transfer knowledge and skills so that the innovation is successfully adopted [17]. Other scholars such as Schumpeter [18] state that to achieve overall increased value, a specific new innovation must be perceived as significantly better than its preceding version. An innovation is defined by Rogers [13, p. 12] as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption".

When an innovation becomes accessible to people within a social system, it can potentially quickly sweep through and take over competing solutions. If this occurs, the innovation is labelled disruptive [19,20]. Initially, a disruptive innovation must compete with existing innovations, but eventually it is able to capture the entire market [20,21]. In low-income markets, a space can be reached in which disruptive innovations and thus new competition can arise [19]. According to Prahalad [22], targeting low-income communities in developing countries should be a key to businesses' central mission to create sustainable energy, products, and innovations. To be successful in these communities, companies should activate, inform, and involve low-income populations. Co-creating a market that fulfils the needs of this segment can help to alleviate and overcome poverty [23]. Karnani [24] suggests that reducing poverty is only possible by increasing a community's real income, which can be achieved by either lowering prices or increasing its disposable income. Providing access to renewable energy may be one of the keys to raising disposable income.

Multiple scholars argue that innovations in developing countries are exposed to local barriers and conditions, especially in the areas of energy [25] and business modelling [26]. Aubert [27] states that in developing countries, these barriers can be low incomes, low education levels, and bureaucratic organisational structures that hinder the successful promotion of the innovation. Furthermore, a lack of logistical infrastructure slows the diffusion. Wüstenhagen et al. [28] confirm that the transfer of new energy technologies is bound to certain infrastructures. Another impediment to technology transfer and diffusion is that the innovation can be misinterpreted or incompatible with the values of a specific targeted system. This observation is aligned with a study of Troncoso et al. [29] on the social perceptions of a technological innovation that was implemented in rural Mexico. This study shows that adoption is restricted by potential adopters' perceptions. Troncoso et al. [29] note that businesses need an implementation strategy that targets different adopter behaviours, as well as a long-term vision. Additionally, in a study focusing on the assessment of bioenergy alternatives in Uganda, Okello et al. [16] found that the adoption rate of bioenergy technologies can potentially increase if policies can make it more affordable.

2.2. Diffusion of innovation

Rogers [13, p. 5] describes diffusion as "the process in which an innovation is communicated through certain channels over time among the members of a social system". This subsection discusses the theoretical foundations of diffusion theory based on four elements: innovation, communication channels, time, and social systems; as well as a potential "chasm" [30] between the early adopters and the adopting majority.

Various individuals and population groups may perceive the same innovation differently, depending on certain characteristics. The first and perhaps most obvious attribute that adopters seek in new technology is relative advantage: "the degree to which an innovation is perceived as better than the idea it supersedes" [13, p. 212]. Greenhalgh et al. [31] emphasise that potential users will likely not consider the innovation if they do not see relative advantages, which are foremost measured in economic returns. Moreover, there are decisive social factors such as user satisfaction and prestige that influence an individual's perception of the relative advantage of innovations. Furthermore, Rogers [13] discusses four additional aspects that affect adoption: compatibility, complexity, trialability, and observability.

Communication is the process through which information is created, received, and shared. A main goal is to achieve mutual understanding among the participants. The two most powerful communication channels are mass media and the interpersonal exchange of information. The latter is more powerful in convincing a social system to accept a new innovation [13].