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Review Article

Application of Design Thinking Concept to Assess the Use of Renewable Energy in Rural Areas in Botswana

Seane TB*, Molatlhiwa R, Gwangwava N and Oladiran MT

Department of Mechanical, Energy and Industrial Engineering, Botswana International University of Science and Technology, Botswana, South Africa

***Corresponding author:** Seane TB, Department of Mechanical, Energy and Industrial Engineering, Botswana International University of Science and Technology, Bag 16, Palapye, Botswana, South Africa.

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Abstract

Over the past few decades, energy access has been a major challenge for most African countries due to increasing energy demand because of urban migration, increasing population, and enhanced standard of living. The issue of energy access in Botswana mostly affects rural settlements as the areas are usually far from the national electricity grid. This research was conducted using the Design Thinking (DT) approach to investigate energy availability and management in rural settlements. The DT methodology consists of six phases namely, understand, observe, define a point of view, ideate, prototype, and testing. Through the 'understand' phase, an intensive literature review was undertaken to assess the feasible renewable energy resources. In the 'observe' phase, interviews were conducted in rural settlements of the central region of Botswana. It was found out that cooking is the main energy need and the rural inhabitants travel up to 20km to collect firewood. A 'point of view' (POV) statement was then created from the interview to initiate the ideation stage. The 'Ideate' phase involved using viable technologies to generate solutions targeted at the profile defined in the POV. A selection matrix was then used to obtain the best energy solution. Through the 'prototyping' phase, a concept model biogas digester was designed for rural settlements. This paper reports on the first 4 stages of DT methodology and the other stages will be presented in future as the final part of the study.

Keywords: Design thinking; Rural settlements; Renewable energy; Botswana

Introduction

Energy supply and access continue to be a challenge for several countries in Sub-Sahara Africa (SSA) mainly due to poor infrastructure and lack of revenue. Statistics indicate that 600 million people in Africa did not have access to electricity in the year 2018 [1]. Botswana faces electricity supply fluctuations with an average of 37% and 77% access rates in the rural and urban areas respectively (The World Bank, 2017). The non-availability of utility grid infrastructures has resulted in people living in rural areas relying solely on solid fuels for their energy needs. Solid fuels in Botswana include wood and coal which are used for cooking in open fires [2]. Coal reserves in Botswana are estimated at 212 billion tonnes, of which 3.34 billion tonnes are measured [3]. The main local power production in Botswana is from a thermal station using coal as fuel. To meet the national electricity demand, the country imports electricity from South Africa and Mozabique [4]. Unelectrified regions in the country are mostly in rural settlements where fuelwood and paraffin are used for cooking and lighting respectively. The numerous health risks associated with open fires include acute and chronic respiratory diseases. Africa has over 500 000 premature deaths per year associated with household air pollution (HAP) due to open fires smoke from traditional biomass combustion [1]. The use of renewable energy resources (RES) provides a cleaner and safer alternative for energy provision. Using RES for daily energy requirements is in-line with the country's Vision 2036 goals of Ensuring energy security with safe and clean energy sources [5]. The country has a great potential for using solar power, because the

average irradiation is 21 MJ/m2 daily and 3200 annual sunshine hours (Africa-eu-renewables, 2018). Botswana, however, has not deployed solar technology significantly due to socio-economic and regulatory challenges [3].

Design Thinking, which is a concept of solving everyday problems has been employed in various sectors due to its creative thinking approach for generating solutions that are pragmatic, systematic and acceptable to end-users. The DT model suggested by HPI-D School comprises of six phases namely; Understand, Observe, Define a point of view, Ideation, Prototyping, and Testing [6]. The model was adopted for the current research because of its effectiveness in tackling the energy supply complex challenges experienced by people living in rural areas [7].

Literature Review

Botswana is a semi-arid, landlocked country with a small population of approximately 2.2 million in Southern Africa A significant portion of the population resides in the eastern region of the country and therefore much of the electricity transmission network is situated in the region. However environmentally friendly energy solutions of small dimensions can meet the energy demands of people living in rural communities.

The core attraction of the DT process is that it features a human-centric approach through the need-finding phase that identifies the core insights of the consumer's problem and involves end-users through the design and prototyping phases. A study conducted by Leger et al, [8] obtained innovative and more feasible solutions to environmental problems by using the DT approach as opposed to typical engineering methodology. In the medical field, the DT process was utilized for digital innovation in the health care sector [9]. The insights from people admitted in hospitals inform practitioners through the prototyping phase thus allowing for human-centered innovation. The Design Thinking process has also been employed in social entrepreneurship projects to create social innovation. Social design was taught in classrooms in Northeastern University through Design Thinking and the skills were applied to solving real-life problems [10]. The Design Thinking can also be a methodology for bringing together people of various professional expertise and experiences through interaction and data sharing to solve real-life problems [11].

The Design Thinking Methodology

The main aim of the study was to identify safe and reliable energy solutions for people living in rural communities in Botswana. The scope of the research is to promote renewable energy solutions to reduce overdependence on solid fuels for activities such as cooking and lighting. The Design Thinking methodology was adopted from Stanford University and Hasso Plattner Institute (HPI), Berlin, Germany, and it is shown in Figure 1 [12] (Figure 1). The Design Thinking Process is an unsupervised research methodology that utilizes creative and analytical thinking to solve everyday life problems [12]. The stages of the Design Thinking process are described in the following section [6].

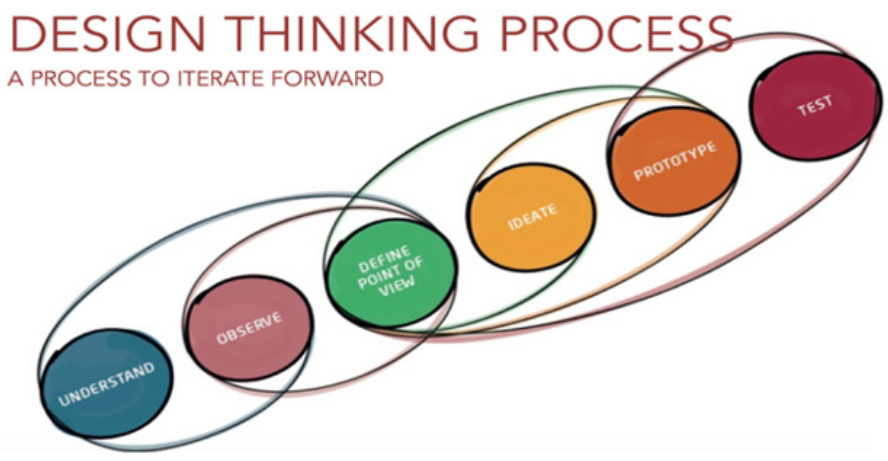

Figure 1: The Design Thinking Process Stanford model.
SOURCE: Plattner [6].

Understand and observe

The initial phase of the Design Thinking process 'Understand', conceptualizes the energy problem facing in rural communities in Botswana. The authors identified the energy sources exploited by the people and other energy sources available in their area. This phase identifies the core energy needs of the people by establishing the perspective of human-centered problem solving [13]. The authors gained a deeper people living insight into the essential needs of the customers [8]. The research team performed interviews in Dikabeya; a rural village in Botswana that does not have access to the national electricity grid. The interviewees were residents of the village and each household head responded to the questions. It was observed that:

- Paraffin is used for lighting and it is purchased from filling stations as far as 20km away.
- Dry firewood which is collected from local wooded areas is employed for cooking and heating purposes,
- The interviewees showed displeasure in the use of firewood; stating that smoke inhalation and open flames are a hazard in their homes,
- The villagers showed an interest in solar technology,
- The people are willing to use community-wide payment methods for a product that will solve their electricity problems,
- Most of the villagers have cattle, goats and donkeys as they are pastoral farmers.

From the various interviews conducted, cooking was identified as the main energy need for people living in rural settlements. They would also like to have electricity for socio-economic development of their community.

Define point of view (Pov)

The purpose of the customers' Point of View (POV) is to bring clarity to the complex problem [6]. The insights from the previous phase aids in breaking down the complex problem into smaller and more manageable questions. Defining a POV involves synthesising the interview results. The developed POV was based upon insights of one customer who uses solar power technology for operating a radio and charging her phone, spends most of the day picking firewood for heating and cooking, and uses paraffin and candles for lighting. The POV is to provide the customer with a life changing experience by incorporating renewable energy, which she is familiar with, into her daily life in an efficient, healthy, and economical manner.

Ideation

The Ideate phase of the HPI Design Thinking model involves using viable technology to generate solutions targeted at the profile defined in the POV. The POV aids in the process of idea generation to solving the problem [14]. The ideation phase explored various ideas in line with the POV by using 'How To (H2)' questions in conjunction with technological literature. The method yielded ideas that allowed diversity in thinking and innovation but consistent with the POV. The ideation technique used is the ABC Brainstorming & Forced Association method which considered (Lupton, 2011):

- How to help the customer not to travel long distance for her energy needs?
- How to help the customer to use renewable energy for her energy needs?

The selected feasible res in rural areas: After several discussions, based on the insights received from the observation and POV phase two matrices were crated to assist in decision-making. Through research into the various renewable energy sources, biogas production using cow dung was selected as the best viable option for the customer's cooking energy needs. Table 1 presents a decision matrix to identify the best suitable RES (Table 1).

Table 1: Matrix solution to identify the RES solutions specific for rural areas.

Screening Criteria	Solar Lighting	Solar Cookers	Biomass Cooker	Hybrid System (Solar/ Biomass)
Cost	1	0	1	1
Convenience	1	0	1	1
Adaptability	1	1	0	1
Feasibility	1	0	1	1
Efficiency	0	0	1	1
Net Score	4	1	4	5
Rank	2	4	2	1
Continue	Combine	No	Combine	Yes

Table 2: Matrix solution for the feasible RES solution design.

Screening Criteria	Single Homestead	Community (Gas Piped)	Community Biogas (Central Collection)	Community Biogas Plant (Central Collection with Solar Lighting)
Cost	1	1	1	1
Convenience	1	0	1	1
Adaptability	1	0	0	1
Feasibility	1	0	1	1
Efficiency	0	0	1	1
Net Score	4	1	4	5

Rank	3	4	2	1
Continue	No	No	No	Yes (Develop)

From a thorough analysis, a hybrid solar and biomass system was identified as the best feasible solution for the rural settlement. According to the Agricultural Statistics brief (2015), the cattle population of the country was just above 2 million so that cow dung is abundant (Statistics Botswana, 2016). The authors then evaluated the final energy provision based on the feasible renewable resources available in Botswana [15].

Design type of the res solution: There are various hybrid solar and biomass energy solutions for different settlement types. (Table 2) shows a matrix to identify the best solution for a typical rural area (Table 2), A single homestead, community gas piped, community biogas (central collection), and community hybrid solar and biogas energy solutions were fed through a screening matrix. On analysis, the central community biogas plant with solar lighting was the best option.

Idea concept validation

The decision from the last phase is that a hybrid renewable energy plant consisting of a central biogas unit and a domestic solar system should be developed for the community. Biogas would be used for cooking and other thermal applications, and solar energy would be employed for lighting and to recharge batteries. The design of biogas and solar units will be separately processed through the remaining stages of the Design Thinking methodology and reported in a future communication [16].

Conclusion

People living in rural areas rely on solid fuels for energy provision for daily activities. The continued use of solid fuels such as fuelwood has been reported to have detrimental health effects on children and women. The Design Thinking process was adopted in this study to understand the challenges of energy provision experienced by people living in rural areas and identify alternative energy solutions. The process enabled the authors to utilize creativity and critical analytical thinking to identify a feasible and clean energy alternative to solid fuels for people living in rural areas. The Design Thinking process comprises six phases, namely, understand, observe, define, ideation, prototyping, and testing. Through the 'understand' phase, the authors identified the status of the actual energy use of the people as per their cooking and lighting needs. In the 'define' phase, various brainstorming techniques were used to determine the energy needs of a particular customer.

The 'ideation' phase found possible clean energy solutions considering environmental impact and easy access to resources. Through a matrix analysis of the energy solutions, community biogas production with solar lighting was the best probable energy solution. The major advantage for biogas production is the availability of abundant cow dung that is a raw material for biodigestion. The remaining stages of Design Thinking will be used to complete the synthesis of a solar energy plant and central biogas generation unit. The report will be presented in a future communication.

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Conflict of Interest

No conflict of interest.

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