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The benefits of energy appliances in the off-grid energy sector based on seven off-grid initiatives in rural Uganda

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ABSTRACT

The aim of this paper is to build on the existing knowledge of the benefits of energy appliances for the off-grid energy market. Rural electrification schemes often focus on generating power for electric lighting and, more recently, phone charging. The purpose of this study, however, is to identify the benefits of an array of energy appliances (other than lighting) that rural electrification initiatives rarely take into account. From the literature review, and the user-perceived benefits identified through a 'User-Perceived Value Game' conducted in 119 interview settings, it is found that the top-ranked benefits pertaining to energy appliances are business opportunity, elimination of labour intensive tasks, preservation of health, protection from people posing a threat (personal security), operational expenditure, ability to acquire knowledge, feeling comfortable, food security, information access, time savings and productivity improvement. Of these, the benefits pertaining to energy appliances, as perceived by the beneficiaries whose values are often overlooked by the project implementers, are identified and include comfort, security and food security. Furthermore, the study gives a brief account of the user-perceived benefits of modern energy sources (e.g. solar home systems, solar lanterns and generators). Where possible, reference is made to the traditional energy alternatives (e.g. candles), revealing the reasons why villagers sometimes preferred traditional energy sources to more modern ones.

1. Introduction

For the global energy community, access to energy is seen as a key contributor to reducing poverty, improving the health of women and children and facilitating education [1,2]. Currently there are 1.06 billion people without access to energy services [3]. Despite increasing efforts to tackle this energy deficit, as well as large investment (estimated at US$ 9.1 billion in 2009 and US$ 13.1 billion in 2013 [4]), there has not been a significant change in the number of people without access to electricity, as seen in Fig. 1.

Electrification and development are often assumed to go hand in hand. The relationship between the two has been demonstrated by a comprehensive study that analysed 77 countries over a period of 25 years [6]. Although the researchers highlighted that this relationship is dependent on the interaction of multiple factors, electrification is seen as a key mechanism to improve living standards [7], to increase income through 'income-generating activities' [8] and to improve community services such as education and health services [9]. Despite said benefits, a rising population, a shortfall in sustainable energy projects [10,11] and partial uptake of modern energy sources has meant there has been slow progress in this sector. Regarding the latter problem, statistics published in the 'Poor People Energy Outlook' suggest that two-thirds of the people who did have electricity continued to use traditional energy sources [12]. One reason for this is the unreliability of new electric power projects in rural areas. To date, the deployment of improved lighting has commonly been accepted as a minimum target for access to energy and is seen as a contributor to reducing poverty – because of the associated health, safety, environmental and financial benefits [13]. However, for the aforementioned benefits to hold true, beneficiaries have to move away from traditional energy sources as they are expensive and lead to, for example, respiratory diseases, early childhood death, indoor fires and air pollution [*ibid*]. Whilst simple energy solutions, such as indoor lighting, can marginally help to address these issues, they may not be seen as priorities for the affected community and this can influence the uptake and sustainability of a project. Without a holistic energy approach that includes cultural shifts regarding energy appliances, people are not going to get the full benefits of electrification.

Furthermore, the sustainability of energy projects can be linked to the availability of after-sales services [13] and the beneficiaries' acceptance of a development initiative [14]. Major improvements have been made in the availability of after-sales services; however, further

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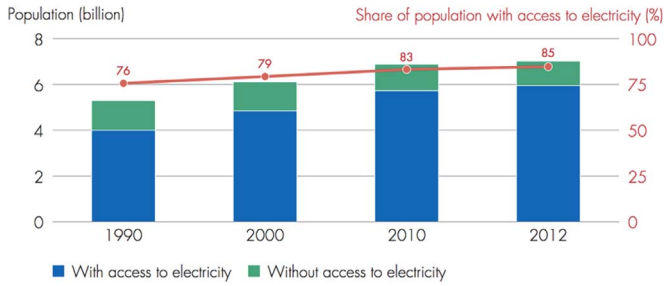

Fig. 1. Energy access timeline 1990–2012 [5].

improvements are required in communicating to end-users the benefits that sustainable energy initiatives can bring to their community. In this way projects are more likely to be willingly owned and maintained by the local end-users. This process is explained by a recent study: "*Understanding why something is important to the end-user will usually lead to an improved understanding of how a development initiative can be beneficial [...] and thus receive user acceptance because it is perceived to be of personal value to the customer. The customer will therefore care for the upkeep of the initiative, with the consequent outcome of sustainability achieved*" [15]. In line with this, the authors of this study argue that project developers need to consider more than simply implementing better quality lighting and mobile phone charging when creating sustainable energy projects in developing communities. Instead, they must additionally take into account the wider benefits that a range of energy appliances, such as televisions, street lighting or grain mills, can bring for rural communities. This is important as energy appliances can satisfy a wide array of the fundamental user-perceived values in rural households.

The aim of this study is threefold. Firstly, the study will provide a review of the benefits of electric appliances for the off-grid energy market. This is done by compiling existing literature on the benefits of electric appliances in relation to household energy use, community services and productive use. To add to this existing knowledge, this research paper then investigates the benefits of rural electrification initiatives as perceived by the end-user of electrification projects in seven villages across rural Uganda. As a result of this investigation, coupled with the literature review, it was possible to identify the principal benefits associated with off-grid energy appliances. Secondly, this research investigates the benefits of energy appliances which are considered important to end-users but not currently considered to be of significance by professionals involved in the delivery of off-grid solutions. Finally, the study concludes with a brief account of the user-perceived benefits of modern energy sources (e.g. solar home systems, solar lanterns and generators). Where possible, reference is made to the traditional energy alternatives (e.g. candles), revealing the reasons why villagers have frequently been found to prefer traditional energy sources to more modern options.

2. Literature review

The purpose of this section is to explore the benefits of energy access for household use, community services (including health care and education) and productive use, as described by literature.

As discussed above, the majority of off-grid rural electrification initiatives focus on the provision of electric light and mobile phone charging, often through solar products at a household level as this is the simplest means of providing modern energy services to rural areas [11]. Nonetheless, other energy appliances also have an important role to play in improving rural livelihoods as they can deliver a wider range of benefits than most rural electrification initiatives. To date, little attention has been placed on identifying the benefits of energy appliances beyond electric lighting and mobile phone charging. Discussed below are the potential benefits of off-grid energy access for household energy use, community services (education and health care) and productive use. This is important in order to later understand UPVs of electrification projects.

2.1. Household energy use

Research shows that the majority (> 80%) of the energy consumed from traditional sources of energy in rural areas is for household activities such as cooking, water heating, lighting and space heating [16,17]. Based on the literature review, listed below are the most common electrical appliances used in rural households and their associated benefits [8,11,18–34].

1. **Television**: Improved access to information, access to modern communication channels, entertainment, awareness creation.
2. **Electric cooker**: Reduced operational expenditure, environmentally sustainable fuel, labour-saving for women through reduced need to collect fuel.
3. **Electric light**: Brighter light at night time, additional hours to study, health benefits from reduced use of kerosene, labour-saving for women through reduced need to collect fuel, reduced operational expenditure, extending the working day, providing extra hours for study.
4. **Radio**: Improved access to information, access to modern communication channels, entertainment, access to knowledge (awareness raising campaigns).
5. **Mobile phone charging**: Reduction of communication costs, mitigation of transport costs connected with mobile phone charging, banking access, improved literacy.
6. **Fridge**: Reduced chance of food poisoning, increased variety and quality of the diet through improved micronutrient intake.
7. **Washer/Dryer**: Labour-saving (generally for women).
8. **Street lighting**: Improved security and increased comfort in rural settlements at night (particularly for women).

2.2. Community services

The availability of electricity is seen as crucial to improving access to community services like health care and education [12,35,36]. Moreover, energy access in rural areas can help to attract and retain skilled workers such as teachers [28] and healthcare workers [29]. Listed below are the benefits of electric appliances related to education and health care.

2.2.1. Education

To date, globally there are approximately 200 million children attending primary and secondary schools which are not connected to energy services [28]. Inclusive and quality education is a key driver for sustainable development, as described by Sovacool and Ryan: "*Education is also widely recognised as one of the most essential components for poverty reduction*" [28]. According to UNESCO's 'Education for All', 58 million children worldwide do not attend school and 100 million do not complete their primary education [25]. The majority of those not receiving adequate opportunities for education are girls [*ibid*]. Reasons for the gender inequality include the time intensive daily chores conducted by girls, such as the collection of firewood, and inadequate hygiene facilities: "*Adolescent girls' concerns over privacy, particularly during menstruation, influence their education decisions and can act as an obstacle to school attendance*" [37]. Improving the infrastructure of schools, such as energy access, can be vital for improving rural livelihoods. It helps to shift the imbalance between rural and urban communities by making rural dwellers more competitive, such as in their ability to receive higher levels of education. Summarised below are the findings pertaining to the benefits of energy technologies and facility support functions at school of the following studies [25,28,30]:.

1. **Electric light**: Extended classroom hours (enabling early morning and after-dark teaching), increased time for reading and homework, improved literacy.
2. **Computer**: Access to information, access to knowledge, narrowing of educational and social gaps, improved computer/digital literacy, employment opportunities, socialising which can provoke intercultural awareness.
3. **Radio**: Enhancing awareness of current events.
4. **Television**: Access to educational programmes.
5. **Mobile Phone**: Mobile learning.
6. **School laboratory and workshops**: Conducting laboratory experiments, enabling schools to expand vocational offerings in engineering, welding, metalwork, carpentry.

2.2.2. Health care

According to WHO, "*Energy access is a critical enabler of access to medical technologies, and thus an important determinant of the effective delivery of essential health services*" [29]. Despite this, a study found that only 36% of hospitals in the surveyed countries in sub-Saharan Africa have reliable energy access [38]. Whilst there are different energy requirements pertaining to the size of the health centre and the services offered by said facilities [31], electricity access in health centres can significantly improve a wide range of health services (immunisations, basic emergency treatment and surgical services) through, for example, extended night-time hours, faster emergency response and improved equipment. Listed below are the most common electrical appliances used in health care [18,29,31].

1. **Mobile phone:** Faster emergency response, access to mobile-health applications, improved communication between health care staff and/or facilities.
2. **Television:** Access to tele-health applications, facilitation of public health education.
3. **Electric light:** Night-time care, extended hour of operation, child delivery at night, improved quality of medical services, such as the support of surgical proceedings.
4. **Computer:** Improved management of larger hospitals.
5. **Medical equipment:** Delivering adequate treatment and care, to operate the equipment and to manage healthcare waste.
6. **Refrigerator/freezer:** Used for storing blood and vaccines.
7. **Incubator:** Prolonging life.
8. **Water Pumping:** Access to water.
9. **Electric cooker:** Thermal energy needs for cooking and water heating.

2.3. Productive use

The EU Energy Initiative Partnership Dialogue Facility holds the view that the "*residential use of electricity improves the quality of life of the rural community while PURE [productive use of renewable energy] in rural areas leads to increased rural productivity, higher economic growth and a rise in rural employment*" [32]. Additionally, agricultural practices are the dominant source of income in most developing countries [39]. Therefore, improving agricultural practices is a critical element for the economies of developing countries as it is linked to increased rural productivity, food security, higher economic growth and a rise in rural employment [32].

In addition to the agricultural sector, rural electrification initiatives can greatly benefit the local service sector by providing electricity to hairdressers, beer halls, shops, kiosks and local repair and maintenance businesses for instance. Additionally, small and medium enterprises (SMEs) that undertake labour intensive activities such as milling or fruit and vegetable processing can greatly benefit through increased productivity. Nonetheless income generation is not an objective of most rural electrification initiatives. A study undertaken by Terrapon-Pfaff *et al.* found that, out of the 23 projects studied, in the 12 projects that mentioned productive use of energy the actual utilisation of the energy for productive use by the end-user was modest [11]. Discussed below are the benefits that can be attributed to small-scale energy solutions for productive use of the following studies [8,12,18,21,27,33,40]:.

1. **Lighting**: Extended opening hours.
2. **Mobile phone**: Improving agricultural and labour market efficiency, coordination with suppliers and distributors, service delivery platform.
3. **Television:** Entertainment business, access to market news, access to weather forecasts.
4. **Fridge**: Preservation of fresh produce for sale on the weekly markets, ability to sell cooled products.
5. **Irrigation System**: Improved yields, higher value of crops, greater reliability, growing during periods when market prices are higher.
6. **Grinding/milling/husking**: Value added to product from raw agricultural commodity; unburdening from laborious and time-consuming tasks usually performed by women.
7. **Radio**: Access to market news and weather forecasts.
8. **Machinery:** Increased productivity – e.g. machine sewing.

2.4. Summary of the benefits of energy access

The purpose of this literature review was to amalgamate the benefits of energy access regarding household use, community services (health care and education) and productive use. Understanding the benefits of energy access is significant in the sense that it requires focused attention as to what the development community perceives as important. During this study it became apparent that there is good existing knowledge concerning such benefits across the development community.

Despite this, projects still tend to focus on implementing easy and quick solutions focusing on household energy (such as electric lighting and mobile phone charging).

Project developers tend to ignore the wider benefits of electricity and focus on less productive uses of electricity, and income generation is not an objective of most rural electrification initiatives. The reasons for this are complex and require more space than can be given here. However, these reasons can briefly be distilled into two main categories, that of quality and quantity, as described by Mandelli et al.: "*From one side, the lack of access to energy (quantity) may affect the access to basic needs and services; but on the other side, the lack of a reliable and affordable (quality) energy may prevent the poor tracing their way out of poverty, since they cannot activate any productive activity*" [26]. Furthermore, the existing knowledge does not fully take into account the viewpoints of the project beneficiaries. When projects are not tailored to what end-users value, the benefits of a project can be lost. Section 5 seeks to provide this bottom-up perspective by analysing the values of end-users.

3. Methodology

The aim of this research paper is to identify the benefits of energy appliances in a rural context. In particular, this study adds to existing knowledge as to why energy appliances may be beneficial by taking into account the perception of the end-user. The perception of the end-user is important because whilst rural electrification initiatives mainly focus on lighting, end-users value a wide range of advantages that may be facilitated by energy appliances. This research forms part of wider research on the 'User-Perceived Value', as seen by end-users of rural electrification initiatives and will draw upon the methodology described in [15,41], which provide more details regarding the 64 UPVs and their conception.

Discussed below are the two methods relevant for this research paper. Firstly, a 'User-Perceived Value (UPV) Game' was conducted

with 84 villagers during an initial field trip to Uganda. The UPV Game was carried out over three months during the spring of 2014. This method represents the main body discussed as part of this research paper. Secondly, an 'energy-specific survey' was conducted with 140 different villagers in the same villages. This method was carried out over two months at the end of 2014. The objective was to gather information on the context and more in-depth details concerning the off-grid energy projects pertaining to the seven case-study villages. To avoid unintentional biases on the selections and answers of the UPV Game towards energy, the energy-specific survey was conducted following the UPV Game. Thus the methodologies described below follow the structure of this paper rather than the sequence of the fieldwork.

3.1. Energy-specific survey

Here a survey specific to energy use was conducted with 20 villagers in each of the seven villages. This covered the following 5 sections: general information; personal understanding of the local electricity system; local acceptance and ownership; personal and community impact of the electricity system; and exposure to educational programmes. The aim of the survey was to identify the impact of the rural electrification initiatives upon each of the villages several years after original implementation and was thus conducted in a semi-structured way. This gave an insight into the project-specific influences on the beneficiaries as well as background information of the seven case-study villages.

3.2. User-perceived value game

The aim of the 'User-Perceived Value Game' was to investigate a) the benefits of rural electrification initiatives as understood by the end-user of electrification projects in seven villages across rural Uganda and b) the principal benefits associated with off-grid energy appliances as seen by the end-users. These findings are then compared to the findings from the literature review. The UPV Game was used as it bypasses the interviewees' predispositions and preconceptions, whilst also seeking to identify their true wants, values and needs with respect to energy appliances [15]. This game was developed as other needs assessment tools had one or more of the following flaws: being susceptible to subjective influences or interpretational issues, lacking in consistent application or lacking the ability to delve deeper into the complexity of motivators and priorities [42]. The game avoided these as it was specifically designed to identify the underlying reasoning as to why something is important (UPVs). It was also adaptable to the specific local context and introduces structure and consistency as the game remains the same throughout all interview settings. Due to the nature of the game, there was little scope for external influences.

In each of the seven villages, a total of 17 interviews were conducted (equating to a total of 119 interviews). Twelve individuals, six men and six women, were interviewed in 6 different settings. They were interviewed individually, then as part of the following groups: male group discussion, female group discussion, mixed group discussion, men discussing female choices and women discussing male choices. The interviews consisted of the UPV Game (see [15] for details on methodology, the reasoning behind the game, the importance of the language used, the definition of the UPVs, etc.). This UPV Game asked participants to select 20 out of the 46 presented items (they had also options to add items of their own choice) based on what was important to said participants. Items were not specifically electricity related, but instead revolved around everyday products or services found in rural areas of Uganda. Playing the game with such a wide variety of items (rather than energy/electricity focused selections) had the additional benefit of removing unintentional bias. Items included livestock (e.g. cow, chicken), basic electronic gadgets (e.g. mobile phone, TV, radio), household goods (dishes, soap, blanket), and horticultural items (e.g. plough, hoe) – participants could also name any additional items they perceived as important. Initial item selection was done in collaboration with experts from Uganda. Following item selection, participants were asked to rank the items selected and to explain why each item was of importance to them using 'story-telling'. For the purposes of illustrating the story-telling and corresponding coding of UPVs [*square brackets*], one example of an interviewee's selection is given below.

> "If I had solar, it can provide me with light in my home [*energy access*] and it can even help my children to read their books [*knowledge attainment*] and pass their exams other than before [*aspiration*]. I can't eat in the dark so I have to make sure I buy kerosene which is more expensive than solar [*operational expenditure*]". Baluku (Village 7)

The interviews were then analysed using a software called HyperRESEARCH [43] and evaluated using the value framework developed by [15]. This paper will only focus on selected items that can be categorised under a) energy appliances for household use, b) energy appliances for community services, c) productive use appliances powered by electrification, and d) energy source. The findings are then graphically depicted using the software developed by [44].

It should be noted, that the data has two main limitations. The first is that analysis of the literature is limited to the number of documents reviewed and as such the conclusions made are limited to this review of the literature. Nevertheless, it is still a sufficient indicator of benefits commonly acknowledged within literature. The second is that the items presented in the UPV game did not specifically focus on energy and as such the data gathered covered a broader subject. This study only cover the items that could be attributed to off-grid energy access. As a result, appliances pertaining to health care and education are not part of the results and analysis section—the UPV game gave insufficient data regarding these. Despite this, the comparison gives a useful insight into what UPVs villagers commonly link to energy appliances, outside of the obvious links and those covered in the literature.

4. Case study context

The seven case study villages, which provide the context for this research paper, are located in four different regions across Uganda: the West Nile Region, located in Northern Uganda (villages 1, 2 and 3); Mount Elgon Region in Eastern Uganda (Village 4); the Bwindi National Park in South Western Uganda (Village 5); and the Ruwenzori Mountains in Western Uganda (villages 6 and 7). Each village possesses a distinct village centre beyond which dwellings are more scattered. Aside from Village 5 and Village 6, it is difficult to access the five villages – access to Village 4 in Eastern Uganda and Village 3 in the West Nile Region is particularly difficult during the rainy season. The relative isolation of all villages greatly limits the economic activity occurring beyond the confines of internal economic trade such as local markets. In five of the studied villages, the main source of income is from subsistence farming and animal rearing – in Village 5 and Village 6 employment is more diverse ranking from other non-agricultural employment to business owners. All settlements are far from the main roads, making it unlikely that the national electricity grid will reach them in the near future.

5. Results and analysis

The purpose of this chapter is to report and analyse the results from the UPV Game discussed in Section 3.2. Firstly, the user-perceived benefits of the different energy appliances are reviewed. Secondly, a review of the benefits linked to the different energy sources as described by the villagers during the UPV game is given.

Note, for each particular item selected, the amount of times a value was selected with regards to that particular item is given. Because of reasons of space, the analysis is limited to a few examples.

Furthermore, because of the in-depth data produced by story-telling because of the nature of story-telling, values shown in tables two to five can be broken up into three categories: primary, secondary, and tertiary. To illustrate, a primary value of a mobile phone would be the ability to communicate [*communication*]. A secondary value might be cost savings associated with not having to travel long distances to talk [*operational expenditure*]. A tertiary value might be the ability to pay school fees; because of transportation cost savings there will be more money to pay for school fees [*school fees*]. This illustrates that villagers may express a topic of personal concern that indirectly links an item to a value category without realising. Thus, for some of the values presented in tables two to five the link to the actual item may not be immediately apparent.

To illustrate the UPVs (for UPV definitions refer to [15]) and highlight the link between energy appliance/source and perceived benefits, a number of example quotes from the UPV Game are shown. These represent a small portion of the 'story-telling' data collected.

5.1. Perceived benefits of energy appliances

Here, the aim is to identify the roles that energy appliances can play in the lives of those in developing rural communities and add to existing literature on why particular household energy appliances, community services and productive use machinery may be beneficial.

It should be noted that for the purpose of the discussion appliances were divided according to their standard usage, but this research showed that rural communities differ in that they make innovative use of electric appliances. Thus, although a fridge or a TV may be in the 'household use' section, for example, they may also be used for business purposes such as selling cold drinks and community video halls, corresponding in this instance with productive use.

5.1.1. Household energy use

Discussed below are appliances pertaining to household use, these are summarised in Table 1 below.

Out of the energy appliances pertaining to household use, shown in Table 1, a mobile phone was selected the most. The UPV most commonly linked to a mobile phone was the ability to communicate – 93% of participants selected it for this reason. Mobile phones, like other appliances, have secondary and tertiary values. A less obvious benefit pertaining to mobile phones is time benefits. This was described by Louise (Village 1):

> *"This will help me in communication [communication] and immediate feedback especially in far places [time benefit]".*

Moreover, some villagers also valued a mobile phone for its capacity to simplify their lives [*unburden*] (21%), access banking services [*banking access*] (16%) and contribute to modern living [*modernisation*] (11%). Gladys of Village 4 was representative in her selection of a mobile phone:

> "This is very important because it makes communication easier [*unburden*] [*communication*]. It is not like a long time ago when we used to send letters, which would take a long time to reach the recipient [*modernisation*] [*time benefit*]. I use my phone to get money from my relatives and also to send money. I can use a phone to get money even when I am stuck and don't have money for transport [*banking access*]".

In contrast to the literature, where cost savings were commonly linked to a mobile phone, *operational expenditure* was of lesser importance to villagers. This is a further example demonstrating the disparity between those benefits identified by the literature review and members of the rural development community surveyed in this case study.

The top three UPVs relating to radios as described by villagers were: *access to information* (100%), *entertainment* (50%) and *acquiring new knowledge* (23%), as exemplified by the Female Group Discussion of Village 7:

> "Radio helps in sensitising the nation on various issues like health, education, religious and political purposes [*knowledge attainment*]. Music can be listened to after work hence relaxation [*entertainment*] [*comfort*]. Listening to announcements thus knowing the local and international events around the world [*access to information*]".

As opposed to an alternative-fuelled stove, a larger proportion of villagers (15%) selected a charcoal stove. It was noted that villagers viewed a charcoal stove as an improvement over the traditional firewood stove. Whilst most of the reasons given were similar to those for an alternative-fuelled stove, specific reasons for preferring a charcoal stove included its *multifunctionality* and its *usability*, as described by Betty of Village 2:

> "I use the stove for cooking, boiling water and warming the room when it is cold [*multifunctionality*]".

It was noted that in Village 6 a TV featured in half of the interview discussions, although the reason for this is unclear. From the survey data it was found that the majority of villagers in Village 6 (83%) only watch TV occasionally or not at all and only one person interviewed had a TV. Comparing this to the two larger villages, where all villagers watched TV (ranging from daily to occasionally), a TV was only selected by one woman in each village (4 and 5) and one further selection by a man in 4.

From the interviews it was observed that in the two villages that did

Table 1
UPV's pertaining to household use.

Item (% selection out of 119 interviews)	User-perceived benefits (% selection out of interviews that had selected item)
Mobile Phone (68%)	Ability to communicate (93%); access to information (49%); togetherness [continuous fellowship] (43%); operational expenditure (36%); time benefits [reducing time-consuming tasks] (36%); business opportunity [the ability to run a business] (23%); unburden [reducing the labour burden] (21%); banking access (16%); modernisation (11%); entertainment (10%); security [threat posed by people] (8%); reliability (5%); multipurpose (5%); knowledge attainment (5%); income (5%).
Radio (59%)	Access to information (100%); entertainment (50%); acquiring new knowledge (23%); comfort (21%); security (14%); communication (13%); operational expenditure (6%); togetherness (6%).
Charcoal Stove (15%) (not included in Table 4 comparison)	Time benefit (47%); food security [having reliable access to food] (35%); preservation of health (35%); energy access (29%); operational expenditure (29%); availability (24%); unburden (18%); comfort (12%); role fulfilling (12%); usability (12%); multifunction (6%).
Alternative-fuelled stove (10%)	Time benefit (67%); operational expenditure (50%); preservation of environment (33%); unburden (33%); availability (33%); preservation of health (25%); food security (17%).
Television (9%)	Access information (92%); entertainment (83%); acquiring new knowledge (33%); business opportunity (25%).
Fridge (7%)	Lastingness [the preservation of produce] (78%); appealing [improvement of taste] (56%); business opportunity (44%); food security (22%).

Table 2
UPV's pertaining to community services.

Item (% selection out of 119 interviews)	User-perceived benefits (% selection out of interviews that had selected item)
Street Light (9%)	Security (100%); energy access (30%); comfort (20%); safety [danger from animals, items or nature] (20%); wellbeing (10%); business opportunity (10%); mobility (10%).

have fridges (for example, in beer halls), none of the interviewees selected a fridge. Instead, in contrast to other villages, it was more common to select a water jug. For example, the women in Village 2 believed that an evaporative water jug is even more effective in cooling water than a fridge, and according to the women in Village 4 water from a pot is very refreshing. Furthermore, some villagers made reference to fridges being expensive, as described by Felice (Village 1):

> "[A pot] saves money from acquiring fridge which is expensive [*operational expenditure*]".

5.1.2. Community services

Discussed below are appliances that have a benefit to the community as a whole. It may be noted that in contrast to the literature review, the community services section is limited to street lighting as the data pertaining to appliances linked to health care and education was insufficient. The perceived UPVs of villagers associated to street lights are shown in Table 2.

The female group of Village 4 were representative in their selection of street lights for the following reasons:

> "Security light helps to see thieves in the streets [*security*] and hence fosters economic development as theft rate is lowered [*well-being*] as well as unnecessary injuries from snakebites during darkness [*safety*]".

According to Miriam (Village 2), street lights did not just protect from thieves on the streets but also from thieves trying to break into her house, a benefit that was especially important for people that live along a road [*security*]. Further to this, she valued the *business opportunity* that street lighting provides:

> "[Street lighting] helps people who want to do night-time business [*business opportunity*] because they have access to light [*energy access*]".

In contrast, Henry from Village 2 valued the improved *mobility* that street lighting brings:

> "They are important because I can easily move at night [*mobility*]".

5.1.3. Productive use

Subsistence farming is the principal source of income in rural areas of Uganda [45]. The benefits of energy for agriculture according to the literature were discussed as part of Section 2.3. Note, this part of the study will focus exclusively on the items selected by villagers as part of the UPV game that are part of agricultural activities and can be powered by electrification initiatives (shown in Table 3). Accordingly, other agricultural items, such as a hoe, were excluded.

For a grain mill, there was a correlation between the main source of income in the village and the selection of a grain mill. For example, in Village 5, where the main source of income was related to tourism (30% work in farming), only one person selected a grain mill. This is in contrast to Village 2 where 80% of interviewees worked in subsistence farming and a grain mill was selected in nine of the 17 interview settings. The following description provides a representative example (Baluku, Village 2):

> "This can help me save a lot of money that I was taking somewhere else because I am able to grind my own maize and millet [*operational expenditure*] and also make money from the community—people who bring their food stuffs to be grinded hence becoming employed and income generating for the family as well [*business opportunity*]. A maize mill saves time because pounding manually takes long [*time benefit*]".

The other agricultural electrically powered appliance selected was an irrigation system. This selection is illustrated by Joyce, a woman from Village 2, who gave the following response when asked why an irrigation system was important to her:

> "[...] this water helps all my crops grow well [*productivity*] and then my family will have plenty to eat [*caring*] [*food security*]".

In contrast, Jackson from Village 5 selected an irrigation system for *reputation*. He wanted to be admired for his resultant agricultural output:

> "...once it is admired [*reputation*], many can be attracted to buy them and I get much money [*income*] which can be used to look after my family [*caring*]".

Collins from Village 1 instead valued the *reliability* of irrigation systems:

> "rainwater is unreliable yet the community here entirely relies on farming [*reliability*]".

Further to this, Samuel from Village 6 saw an irrigation system as a *business opportunity* because he can produce crops during dry season, giving him a competitive advantage over other farmers.

5.1.4. Discussion energy appliances

Here, the perceived benefits from the UPV Game and the literature (Section 2) are compiled and discussed. This will help to identify a) the principal benefits associated with off-grid energy appliances; and b) the benefits which are not part of the current energy debate.

Table 4 below provides a combined matrix showing the benefits pertaining to the 'User-Perceived Value Game' and those identified from the literature review. These are marked according to the following key and the values are displayed in approximate order of importance:

* – Literature review and 'User-Perceived-Value' Game
o – Literature review only
x – 'User-Perceived Value Game' only

Table 3
UPV's pertaining to productive use.

Item (% selection out of 119 interviews)	User-perceived benefits (% selection out of interviews that had selected item)
Grain Mill (27%)	Business opportunity (59%); unburden (31%); time benefit (31%); food security (22%); income (22%); access to area [ability of someone to access the area] (19%); modernisation (16%); productivity [increased rate of output] (13%); preservation of health (9%); time management [ability to plan ahead] (9%).
Irrigation System (7%)	Water access (78%); productivity (56%); caring [ability to care for family members] (22%); food security (22%); income generation (22%); school fees [ability to pay school fees] (22%).

Table 4
Summary of literature review and user-perceived benefits pertaining to electric appliances.

	Computer	Electric light	Fridge	Grain mill	Irrigation pump	Medical equipment	Mobile phone	Radio	Alternative-fuelled stove	Street light	TV	Washer /dryer
Business opportunity	*	*	*	*	*		*			X	*	
Unburden	X	O		*			X		*			O
Preservation of health		*	O	X			O		*		O	
Security (people)		X					X	*		*		
Operational expenditure	X	*					*	X	*			
Knowledge attainment	*	*					*	*			*	
Comfort		X						X		*	X	
Food security			*	X	X				X			
Information access	O	O					X	*			*	
Time benefit		O		*			*		X			
Productivity	O			X	*		O					
Energy access		X							X	X		
Modernisation	X			X			X					
Togetherness							X	X				
Income				X	*		X					
Entertainment							X	*			*	
Communication (people)		X					*	*			O	
Aspiration	X	X										
Reputation					X							
Safety (animals/items/ nature)		X								X		
Wellbeing	O				X					X		
Lastingness			*						X			
Multipurpose							X		O			
Reliability					O		X					
Effectiveness		*				O						
Education access	O	O										
Treatment		O				O						
Caring		X			X							
Access to area				X								
Appealing (senses)			X									
Availability									X			
Mobile phone access		X										
Mobility										X		
Portability		X										
Time management				X								
Usability												
Banking access							*					
Preservation of environment									*			
Water access					*							
Longevity						O						

5.1.4.1. What are the principal benefits associated with off-grid energy appliances?. The study set out to identify the principal benefits relating to energy appliances. According to these results, in rural Uganda the benefits are *business opportunity*, *unburden* and *preservation of health* and they are attributed to 75%, 50% and 50% of energy appliances respectively. The following values are all attributed to 42% of the energy appliances: *security* (*people*), *operational expenditure* and *knowledge attainment*. The values *comfort*, *food security*, *information access*, *time benefit* and *productivity* each relate to 33% of the discussed energy appliances.

5.1.4.2. Which benefits are not part of the current energy debate (gaps)?. Adding to the existing knowledge on the benefits of energy appliances, this study has identified a number of benefits that are more important than those acknowledged by the global community.

Using the information from Table 4, Figs. 2 and 3 below graphically depict the similarities and differences with regards to the benefits of energy appliances as identified by literature and the UPV Game. The heat map shows the importance placed on different values by the respective sources, where the darker the colour the more important the value. The middle circle represents the main 64 value categories (Tier 3), the inner circle the value cluster (Tier 2), and the outer circle the high-level value cluster (Tier 1). For more details on categorisation refer to [15,41].

There were a number of benefits that rarely appear in literature – those discussed below only relate to benefits that are identified in connection with two or more energy appliances.

It was found that although *comfort* was rarely mentioned to in literature it was commonly referred in relation to the following energy appliances: radio, charcoal stove and street lighting. In these cases, *comfort* was a secondary or tertiary UPV category and was often referenced after *security*, the primary UPV. This link is illustrated by Dick of Village 4:

> "[Street lighting] is useful because my area is a growing town, security is needed. If I have streetlight it will be hard for thieves to attack because they know they be seen with street light [*security*]. It will also help me walk freely at night without any fear [*comfort*]".

Moreover, *security* (*people*) and *food security* were related to a greater number of appliances (four and one respectively) in the villagers' perceived benefits than in the existing literature. Examples of *security* and *food security* as seen by the villagers are given below.

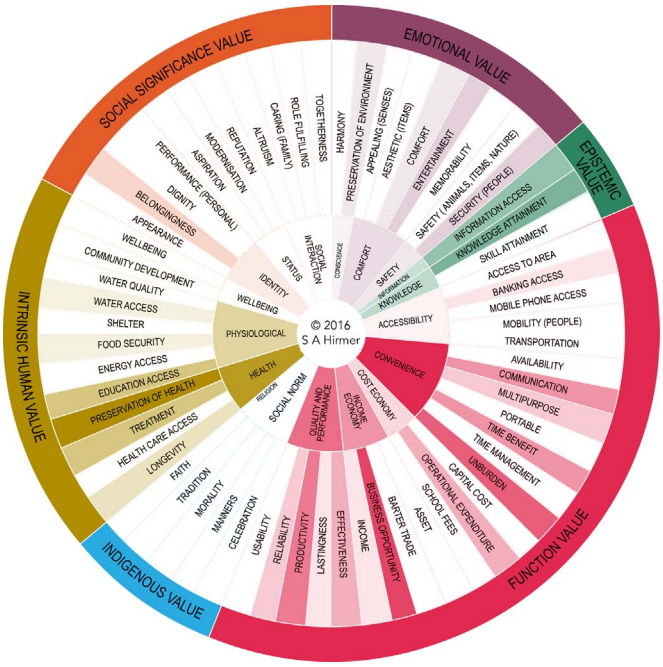

Fig. 2. Benefits pertaining to the literature review.

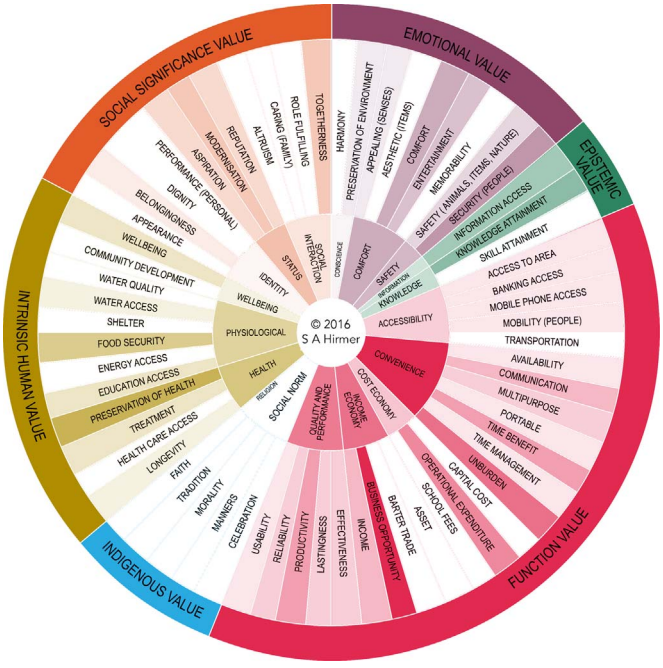

Fig. 3. Benefits pertaining to the'User-Perceived Value Game' (beneficiaries' perception).

"This [streetlight] helps me to prevent my enemies from attacking me at night [*security*]". Aida (Village 6)

"Women picked the machine because the machines available are very far [*availability*] and again women suffer to grind the flour [*unburden*] and people are yet suffering of hunger [*food security*]". Men Discussing Female Choices (Village 3)

In literature, a less obvious and rarely acknowledged link to radios was made regarding *comfort* and *security*. Villagers commonly linked *comfort* to happiness or relaxation through listening to the radio and to *security* to informing rural communities of political unrest and the movement of rebel groups.

User-perceived values such as *modernisation*, *aspiration* and *reputation* were commonly linked to energy appliances that enabled technological advancements or appeared to emulate city living. *Togetherness*, referring to the ability to connect with loved ones or spend quality time with family through improved information and communication technology (ICT) and *safety*, linked to protection from wild animals, are identified as benefits of the energy appliances that enable outdoor night-time vision. In contrast, benefits commonly linked to energy appliances in the literature, namely *education access*, *preservation of health*, *longevity* and *treatment,* were rarely mentioned by villagers. One reason for this may be that, in contrast to the literature review, the UPV game's item selection was not based on prescribed categories such as household energy use, community services (education and health care) and productive use—in this paper these were only used for illustration of the energy appliances. Instead the villagers were interviewed by being asked to talk freely about why they think an item is important (story-telling).

From this we can deduce that whilst there is some understanding of what is important to rural communities, when it comes to energy appliances there are aspects perceived as important that we do not take into account when designing energy initiatives as they are not on the radar of the global energy community. For instance, considering the importance villagers placed on *safety* and *security* pertaining to outdoor movement, street lighting seems a more suitable solution for villagers—as opposed to indoor lighting. Street lighting can add benefits that go beyond those of improved illumination. Furthermore, it was noted that the biggest difference appears to be in the social and emotional categories. It is significant to note that these are less quantifiable than others and this might be what project developers struggle to identify as most assessments focus on quantifiable data and fail to understand the underlying decision factors.

5.2. Perceived benefits of energy sources

In this section, the UPVs pertaining to energy sources are discussed based on the villagers' item selection and discussion. In addition to renewable energy sources (solar lanterns and solar home systems), with the aim of better understanding villagers' preference of traditional energy sources, the following energy sources were included in the discussion: a generator and traditional sources of light, namely a candle, a kerosene lantern and a torch.

5.2.1. Review of UPVs of energy sources

Shown in Table 5 are the principal benefits of energy access sources.

In general the solar technologies garnered the same values. However, one notable disparity was the significant increase in the association of *safety* with solar lanterns. This may be due to the portable nature of solar lanterns [*portability*], which makes them useful when walking at night and threats to safety posed by injury and animal attacks are a significant concern. *Safety* was of high priority particularly in areas where physical activity linked to agriculture was high. Thomas of Village 5 is representative in his selection of a solar lantern:

"If snakes come you can also see it clearly when there is light [*Safety*]".

There was a distinction between how *business opportunity* and *preservation of health* were associated with SHSs and solar lanterns. For SHSs *business opportunity* went beyond prolonged shop opening hours and the operation of a phone-charging station. *Business opportunity* was also commonly linked to solar lanterns and in this case included running a battery-charging station, a poultry farm and the operation of a mill for grinding maize and groundnuts. Similarly, with regards to the *preservation of health*, for SHSs the benefits went beyond improved lighting (commonly linked to solar lanterns) at health care facilities, including the usage of improved medical equipment,

Table 5
UPV's pertaining to energy sources.

Item (% selection out of 119 interviews)	User-perceived benefits (% selection out of interviews that had selected item)
Solar Lantern (36%)	Energy access (95%); operational expenditure (42%); knowledge attainment (35%); safety (35%); mobile phone access (16%); portability (16%); security (14%); comfort (9%); preservation of health (7%); time benefit (5%).
Solar Home System (36%)	Energy access (84%); operational expenditure (56%); business opportunity (37%); knowledge attainment (35%); preservation of health (19%); mobile phone access (16%); security (14%); caring (9%); communication (9%); aspiration (7%); information access (7%).
Candle (14%)	Energy access (100%); capital cost (47%); knowledge attainment (29%); operational expenditure (24%); safety (24%); business opportunity (18%); reliability (12%).
Generator (11%)	Energy access (85%); business opportunity (62%); entertainment (23%); knowledge attainment (15%); unburden (15%).
Torch (7%)	Portability (100%); safety (88%); energy access (63%); security (25%).
Kerosene lamp (3%)	Energy access (100%); knowledge attainment (75%).

such as incubators, and the reduction of illnesses. This is exemplified by the description of the Female Group Discussion (Village 7) regarding the benefits of an SHS:

> "[Through] ironing of clothes to promote smartness and reduce diseases [*appearance*] [*preservation of health*]".

After energy access, the second greatest reason (62%) why villagers selected a generator was the ability to run a business [*business opportunity*]. This was in comparison to an SHS, where this benefit was only referred to by 37% of villagers. Reasons may include the limited capacity of SHSs that are available to rural dwellers. For generators, *business opportunity* was more diverse than for SHSs and included mobile phone charging, running grinding mills, operating a hairdressing salon, running video halls, having a renting business for generators, husk cutting, operating workshops such as welding and timber cutting and operating entertainment systems in a bar. This was exemplified by Hagi's reasoning (Village 6):

> "If I had it, I would hire it to people who have weddings and different party to use it since we don't have electricity. I would rent disco systems, so it can be easy for me to get cash from them. By the way I can connect it to a radio or television in my bar to entertain my customers so that I can get more cash from them [*business opportunity*]. I can use it to light my house [*energy access*] and my kids can be able to read their books and perform well in class [*knowledge attainment*]".

Furthermore, in contrast to SHSs, generators were commonly linked to powering entertainment systems such as a television. A television for watching football, for example, carried added (secondary) benefits such as *contentment* and *entertainment*.

In contrast to modern energy sources, traditional energy sources were often linked to affordability [*capital cost*] and *reliability*. Regarding *reliability*, for example, in Village 7 (William), villagers who selected traditional light sources made comments about the unreliability of electricity in comparison to kerosene lanterns or candles:

> "Candles are cost effective compared to electricity, which not everybody can afford in the society [*capital cost*] and their regulation is stable [*reliability*]".

In this vein it would then appear that the literature is misguided when it describes the *capital cost* and *reliability* of modern energy sources as a key 'selling-point' (highlighted in Chapter 2).

Further to this, the women valued the affordability of candles which are cheap to buy [*capital cost*]. As opposed to candles and kerosene lantern, the principal benefits associated with a torch were portability and safety, with respectively 100% and 90% of those selecting a torch making reference to those two benefits. This shows a clear correlation between portability and safety, which was illustrated by Tani (Village 2):

> "This is important because it helps me where a lamp can't reach [*portability*]. This torch will also help in protecting us from snakebites [*safety*]".

5.2.2. Discussion of energy sources

To better understand the acceptance and utilisation of off-grid energy projects this research investigated the item selection of different energy sources. The study gave a brief account of the UPVs linked to modern energy sources (e.g. solar home systems, solar lanterns and generators). Where possible, reference was made to the traditional energy alternatives (e.g. candles), revealing the reasons why villagers frequently preferred traditional energy sources to more modern options. This is in synergy with the findings from the case study analysis which revealed that villagers continued to use traditional energy sources alongside the modern energy initiatives for lighting and that the majority of people made use of multiple energy sources. Additionally, this corresponds with the statistics published in the 'Poor People Energy Outlook' that suggest that two-thirds of the people who did have electricity continued to use traditional energy sources [12]. Whilst this preference can mostly be attributed to the unreliability of the modern energy sources, another reason may be that certain traditional energy sources fulfil different roles or appeal to a personal preference. In line with this, this research seeks to discuss villagers' perception of off-grid energy sources.

5.2.2.1. What are the perceived benefits associated with off-grid energy sources and how do traditional and modern energy sources compare?. It was found that whilst most power sources (modern or traditional) were linked to the provision of light [*energy access*], a solar lantern and a torch were specifically valued for their *portability* and the associated protection from dangerous animals [*safety*] when walking outside at night. In contrast, a generator was linked to *entertainment* and a wide range of productive uses, and solar home systems were mainly associated with powering a battery-charging station to charge mobile phones [*mobile phone access*].

It was found that when comparing an SHS to a generator, the *business opportunity* afforded by a generator was more diverse than for SHSs and included mobile phone charging, running grinding mills, operating a hairdressing salon, running video halls, having a rental business for generators, husk cutting, operating workshops for welding and timber cutting and operating entertainment systems in a bar. Although an SHS on the other hand can still enable extended shop opening hours through improved lighting and mobile phone-charging facilities (commonly linked to solar lanterns), its UPVs were limited to the likes of a battery-charging station, a poultry farm or a mill for grinding maize and groundnuts. Additionally, a generator was more often linked to entertainment systems such as a television. This raises the question of whether the limited understanding of villagers regarding the benefits related to SHSs results in a lower uptake of products and a lower willingness to pay, as the secondary or tertiary benefits of

these systems are not clear. This would suggest that more effort needs to be made post-infrastructure handover. This could be in the form of communication or post-infrastructure installation capacity building activities to support infrastructure utilisation.

Additionally it needs to be considered whether the commonly available capacity of SHSs are too low as currently the offer is not adequate to beat the existing traditional products. The SHSs available to the rural market tend to have a small power capacity and can thus power only smaller appliances. This was not examined as part of this research and requires further investigation.

Nevertheless, it can be recognised that *business opportunity* acts as an incentive for people. The fact that people recognise this value in SHSs is indicative that such projects are likely to be more successful, particularly when the business opportunities are manifest from both sides (developer and beneficiary). With an increased understanding of the values of villagers, and the connection between said UPVs, it would be easier to convey the benefits of SHSs to the beneficiaries. The energy production could be related to *business opportunity* – a consistently important UPV for villagers. In this way projects are more likely to be willingly owned and maintained by the local end-users.

6. Conclusion

In order for rural off-grid energy initiatives to reduce poverty it is essential to a) achieve power utilisation through tying product/initiative benefits to existing user-perceived values; and b) to allow communities to move beyond lighting and mobile phone charging and consider the provision of additional energy appliances (such as a television, street lighting or a grain mill) for household use, community services and productive use. This is important as energy appliances can satisfy a wide array of the fundamental user-perceived values in rural households and exceed existing values such as lighting. In line with this, the findings of this study are threefold.

Firstly, from the literature review and the user-perceived benefits identified through a′User-Perceived Value Game' conducted in 119 interview settings, it was found that the top-ranked benefits pertaining to energy appliances were *business opportunity*; *unburden* (elimination of labour intensive tasks), *preservation of health*, *security* (personal protection from people posing a threat), *operational expenditure, ability to acquire knowledge*, *comfort* (feeling comfortable), *food security, information access*, *time benefits*, and *productivity* improvement.

Secondly, comparing the difference between the perceived benefits from the literature and the UPV Game provides an insight into which benefits are not currently given appropriate consideration by professionals involved in the delivery of off-grid solutions. This suggests there needs to be a greater effort to engage with the beneficiaries of projects and ascertain their needs, wants and values. Benefits currently not considered include, for example, *comfort*, *security* and *food security*. From this it can be deduced that whilst there is some understanding of what is important to rural communities, when it comes to energy appliances there are aspects perceived as important by communities that are not taken into account when designing energy initiatives as they are not on the radar of the international community. In addition, these values may play an important role in the upkeep of energy initiatives.

Thirdly, the study gave a brief account of the user-perceived benefits of modern energy sources (e.g. solar home systems, solar lanterns and generators). Where possible, reference was made to the traditional energy alternatives (e.g. candles), revealing the reasons why villagers frequently prefer traditional energy sources to more modern options. To illustrate, it was found that whilst most power sources (modern or traditional) were linked to the provision of light, a solar lantern and a torch were specifically valued for their portability and the associated protection from dangerous animals when walking outside at night. In contrast, a generator was linked to entertainment and a wide range of productive uses. In turn, this contrasted with solar home systems (SHSs). SHSs were mainly associated with *mobile phone access* by powering a charging station. This raises the question of whether the limited understanding of villagers regarding the benefits related to SHSs results in a lower uptake of such products and a lower willingness to pay, as the secondary or tertiary benefits of these systems are not clear. Nevertheless, it can be recognised that *business opportunity* may be an incentive for people, and the fact that people recognise this UPV in SHS is indicative that such projects are likely to be more successful, particularly when the business opportunities are manifest from both sides (developer and end-user). With an increased understanding of the values of villagers, and the connection between said values, it would be easier to convey the benefits of solar home systems to the end-users. For example, energy production could be related to *business opportunity* – a consistently important concern for villagers. In this way projects are more likely to be willingly owned and maintained by the local end-users.

In conclusion, the data presented in this research paper provides a snapshot of why villagers in rural Uganda perceive a number of energy appliances to be of importance to them. It is found that the values of villagers are multifarious. Although the data presented in this research paper is extremely valuable in demonstrating that there is a long way to go before the development community and project designers fully implement projects in a way end-users appreciate, it does not represent a definitive guide as to what rural communities (even in Uganda) think, but instead demonstrates the need to continually engage with their views.

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