The Service Value Method for Design of Energy Access Systems in the Global South

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***Abstract*—This paper presents the Service Value Method as a novel means to gather and interpret end-user needs, aspirations, and contextual factors to improve engineering design practice of energy access systems for the Global South. The method adopts a service-oriented approach and consists of a rapid and effective field exercise to gather qualitative and quantitative data from end-users in focus groups. This exercise is suitable for enabling end-user participation in Global South contexts. The data is interpreted as Service Maps that capture end-user preferences to inform trade-offs of different design criteria, guiding the preliminary design of the energy system. The method ensures end-user needs and contexts are integrated into the design process early on. A case study is presented, where the Service Value Method was used to design solar nano-grids in Kenya and Bangladesh.**

***Index Terms*—Energy access, system design, user-centric design, nano-grids, appropriate technology.**

I. Introduction

To improve the usefulness and successful implementation of energy access systems for the rural Global South, end-user needs, aspirations and wider contextual factors must be identified and included in the design process. Typically, engineers are not trained in social science methods to uncover end-user needs, socio-cultural factors and local context, and are frequently working outside of contexts familiar to them on energy access projects. There is a need for quantitative and qualitative tools and techniques to enable engineers to take account of end-user needs and contextual factors and to integrate this into their design process [1], [2]. This paper proposes such a method that is appropriate for use in Global South contexts.

In 2013, a total of 770 million people, 11% of the global population, were living in extreme poverty (classed as living on less than $1.90 a day) [3], with the majority situated in the rural Global South [4]. Access to energy can contribute to reduced poverty and increased human development through access to improved health care, education, and profitable livelihoods [5]. To avoid negative impacts on climate change through use of fossil fuels, there is a need for renewable energy systems in the Global South to contribute to reduction of poverty and betterment of lives.

According to the IEA [6], in 2017, 992 million people did not have access to electricity. However, this binary statistic underestimates the size of the energy access problem, as the presence of an electricity supply does not guarantee value for an end-user. Many people are under-served: there may be limited and unreliable hours of supply, poor quality of electricity, unaffordable service, and financial or supply chain related challenges to the acquisition of appliances to use with the supply [7]. As an alternative, ESMAP (Energy Sector Management Assistant Program, a partnership between the World Bank and other development agencies) has developed the Multi-tier Framework (MTF) for energy access [8] under the Sustainable Energy for All initiative. Multiple dimensions of energy access are taken into account: capacity, duration, reliability, quality, affordability, legality, and health impact, resulting in 6 tiers of electricity access from no access (tier 0) to full access (tier 5). The NGO Practical Action recommend tier 3 be used as the baseline for determining acceptable 'energy access', being the first tier where energy access becomes enabling [9].

To fully benefit from energy access, that access must enable services that people can use to improve their quality of life and/or to generate income [7]. In particular, productive use services (services which can be used to generate income) are crucial to the relationship between energy access and poverty reduction [5]. Therefore, a service-oriented approach to energy access is important to ensure energy access is actually impactful. The focus is on delivery of the whole service, rather than a supply-oriented approach that just provides power. This research adopts this perspective of viewing energy access as a 'product service system', as discussed in section II-D.

Design of successful energy services requires integration of end-user needs, socio-cultural factors and local context in the design process to avoid failed or ineffective projects [5], [10]–[13]. The appreciation of the importance of including end-user needs and context must translate into the design approach for energy services. This research proposes that the design phases in Fig. 1 be used to conceptualize energy access systems design. Compared to developed economies, in the off-grid Global South energy context there is an absence of known demand, established infrastructure, and standards and specifications. Therefore, we propose that designers of electrical systems should start by understanding end-user aspirations and the services that meet them, alongside consideration of contextual factors, incorporating these aspects throughout the design process. This research focuses on the first two shaded phases of design in Fig. 1, uncovering the aspirations and services of end-users and integrating them into design practice.

A methodology to aid designers to integrate end-user needs, aspirations and context in the design process must be easily replicated due to the scale of the design challenge. The IEA

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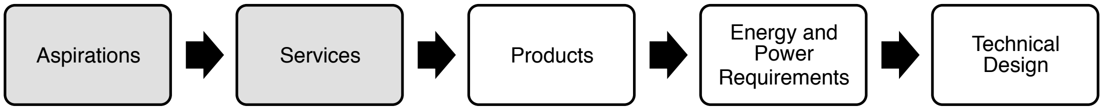


Fig. 1. Linear representation of design phases (phases could be returned to in an iterative design process in practice). Grayed boxes represent the Service Value Method scope.

predicts that 70% of new rural connections are expected to come from decentralized systems, and it is these smaller, bespoke, community-level projects for which the social dimensions and surrounding context are so important [14].

This paper presents a methodology to gather data on end-user needs and aspirations about the services that are important to them and integrate it into the design process. It also focuses on gathering an overview of important contextual factors. Data is gathered through a rapid but effective field exercise implemented through focus groups with end-users, using a three step qualitative-quantitative-qualitative approach to probe for end-user aspirations and context. The scope of the data-gathering process is sufficient to support preliminary design level decisions, determining what services the energy system should focus on providing and thus leading the designer into the specification of products phase of Fig. 1. The method is not intended to provide all the contextual information required for a successful detailed design and implementation of an energy system - rather it is a useful and efficient scoping exercise that ensures end-user needs and context are included early on in the design process. It does not include willingness and ability to pay on the part of the end-users, and we advise that this is explored through appropriate surveys as part of the broader design process (as in the case study presented in this research). The method guides the selection of services using the field-data, through a robust methodology to process the services against key design decision criteria appropriate for the project and context. The aim is to support engineers and designers who are not trained in social science methods, but it is highly recommended that it should be used in multi-disciplinary teams including social scientists and in-country partners for maximum effect.

The structure of this paper is as follows: Section II reviews the literature as an introduction to the type of data required, the challenges related to gathering the data in a Global South context, commonly used tools and methods, and the service-oriented approach. Section III describes the three steps of the Service Value Method and the method principles. Section IV demonstrates the method in action through case studies in Kenya and Bangladesh, where the method was used as part of the design of solar nano-grids for rural electrification. Finally, Section V discusses the strengths and weaknesses of the method, drawing on the case study experiences.

II. Literature Review

A. Data Gathering in User-centered and Participatory Design

Within design theory a range of disciplines describe the inclusion of end-user needs and contexts in the design process. The two over-arching design disciplines concerned with inclusion of the end-user are user-centered design (UCD) and participatory design (PD) (sometimes more recently known as co-design). There are slightly different interpretations of what each involves [15], but a significant difference between them is in the role of the end-user [16]. In UCD, the end user is a subject: they are asked for information and feedback, but are not in control of design decisions. In contrast, in PD the end-user is a partner in the design process with design decisions taken jointly, or perhaps wholly, by end-users. The role of the researcher or designer shifts towards facilitation.

In both UCD and PD, the aim is to uncover and include data about the end-users in the design process, to produce more suitable products, services, or systems. The data that are of interest include socio-cultural factors about the end-user (their needs, aspirations, values, beliefs), end-user practices (what they do, how they do it), and the context in which they live (factors external to the user that affect their environment and lives; they might be political, economic, social, surrounding infrastructure and services).

These design disciplines were largely developed outside of the rural Global South context, and require adaptation for the challenges associated with applying them there.

B. Challenges for UCD and PD in Global South Contexts

There are six important challenges associated with applying UCD and PD techniques of both qualitative and quantitative natures in a Global South context, particularly the rural and low-income context of off-grid energy systems. Some of the challenges relate to the capacity or situation of end-users and stakeholders. However, we should also acknowledge the knowledge deficits and limited perspectives of the (Global North) design teams that work in Global South contexts, that potentially undermine local, socio-cultural understandings. This is explored by Mohr [24], arguing that Global North actors intervening in energy transitions in the Global South should treat local knowledge and understandings symmetrically with their own. Cloke et al. [25] also call for symmetry in energy literacy of all project partners, from designers, to stakeholders, and end-users, through the exploration of interactions between energy systems literacy, project community literacy and political literacy. This paper examines challenges for UCD and PD from the perspective of community participants, but the limitations Global North researchers and designers bring to a project are an important consideration, and further discussion is found in [24], [25] .

The challenges listed in Table I have been gathered from literature on UCD and PD design applied to Global South contexts, ranging from the design of ICT, medical kits, to micro-finance systems. Table I gives examples of how each

TABLE I
CHALLENGES IN UCD AND PD IN GLOBAL SOUTH

Challenge	Consequence
Participants: lack of understanding of design process	Hard to engage the users in UCD exercises, and hard to recruit them [17]. Difficult to get feedback on prototypes because participants did not understand that they represented an end-product [1], [17], [18]. Low fidelity prototypes too abstract, causing confusion and misunderstanding [1], [19]. Participants lacked the capacity to participate and be creative in a PD process - 'true co-design' not possible [20].
Participants: lack of understanding of technology	Users were intimidated by the prototypes [21]. Difficult to get input on ideas or feedback on prototypes [1], [22].
Participants: low literacy	Questionnaires did not work - incomplete or unanswered [17].
Language barrier between participants and designers	Gathering feedback was difficult [17]. Working through a translator had challenges in terms of clarity of questions and understanding answers [20].
Participants are in remote/ different locations to designers	Poor transport infrastructure, lack of electricity, and safety concerns limited time on site [22]. Limited money and time meant designers couldn't get to end-users to gather data [23]. End-users were in poor rural areas, other stakeholders were in a city with full-time job commitments, meaning all participants could not be brought together for central workshops, and time for participation was short [20]. Building relationships and trust between designers and participants requires considerable time investment and physical presence, and introduction/acceptance by local authority or trusted figures [20], [21].
Cultural norms and beliefs can limit participant feedback, and be a barrier to participation	Users did not want to be impolite so did not offer useful criticism of prototypes [22]. High fidelity prototypes were not successful as people only offered compliments and appraisals, not wanting to cause offense by criticizing a costly object [17]. Hierarchical social structures meant it was difficult for participants of different social standing to collaborate and contribute equally when in groups together [20]. Participants were unwilling to show ingratitude by criticizing ideas or prototypes due to Buddhist beliefs [20]. Children (end-users) were unwilling to put forward opinions to open-ended questions as culturally they are taught not to [20]. Cultural norms meant it was not possible to bring children (end-users) to central workshops, or meet outside of their homes, as their parents were worried about child abuse [20]. Children expected to help in chores at home, so could not spend much time on the project [20].

challenge has manifested in previous research and design projects.

UCD and PD tools and methods to uncover and include end-user needs and context in design processes must be suitable to work within the special circumstances of the Global South. The following sub-section reviews common UCD and PD tools, their applicability to design for the Global South, and how UCD and PD techniques have been adapted to be more appropriate.

C. UCD and PD Tools, Methods, and Approaches

UCD and PD tools and methods can be split into two groups: some are concerned with the gathering of end-user data, and some are focused on the integration of end-user data into the design process. The tools that gather end-user data can be quantitative or qualitative. Quantitative tools gather numerical data that can be used in statistics about end-users. Qualitative tools gather non-numerical data, uncovering reasons and opinions often through descriptive phrases or narratives. Employing both quantitative and qualitative methods is useful to obtain both numerical data and deeper insight and understanding of end-user responses.

A comprehensive collection of tools focused on gathering data from the end-user at all stages of the design process has been collated by IDEO, a design consultancy, in their toolkit of design tools for social innovation [26]. Examples of methods are: interviews with participants singly and in group formats, spending time immersed in the end-user context, preparing conversation starters to get participants into discussion, prototyping, and asking participants to sort cards in order of importance. IDEO also outlines several pictorial methods, such as using picture cards in a card sort or asking participants to draw, which help to cope with language barriers or low literacy levels. Another successful example of using pictorial methods to engage participants in rural villages in the Global South is Hirmer's 'User-Perceived Value Game' [27]. Utilized in Uganda, the aim was to understand end-user values to better tailor and market development initiatives to increase end-user buy-in and acceptance. The game involved asking users to select and rank cards with familiar, every-day objects on them, and then explain the importance of them. This provided dual quantitative (the ranking) and qualitative (the discussion) data that was used to characterize end-user values and reasons behind them.

Two common methods in UCD to help designers integrate end-users into the design process are personas and scenarios. A persona represents typical users, and is a description of who they are, their behaviour, their needs, and attitudes [28]. Personas give a design team a shared understanding of the target user. A scenario is a sequence of events, such as a typical day, often constructed around the personas devised previously, that helps the designer to give context to the persona [29]. However, both personas and scenarios rely on designer assumptions to construct or else require lengthy ethnographic research that may not be possible in a rural Global South context.

Faced with the challenge of accessing participants to gather data to create personas and scenarios, Putnam et al. [23] outline a method to mine existing data for this purpose. The aim is to reduce the need to gather new data for each context when time and financial barriers exist. They use data collected in a previous research project through surveys and focus groups, about general attitudes and behaviours about technology use in Kyrgyzstan, to design a business directory app for mobile phones. This approach relies on suitable data existing for the local context and being accessible, which is not common for rural Global South contexts. Power for All launched the Platform for Energy Access Knowledge (PEAK) [30] in 2018, which recognizes this issue and is attempting to address this 'information use gap' by collating, sorting and cataloging energy access data.

The usefulness of personas has also been criticized in terms of the efficacy with which they represent large user groups well given the wide diversity and unpredictability of human behaviour [31]. A useful contribution from Beck et al. [32] describes a participatory card-sorting method that involves end-users and designers working together to create use scenarios and early design ideas, improving the accuracy of what is developed. In general, while personas and scenarios can be useful tools to visualize and consider end-users in the design process, they are likely best suited to contexts familiar to the designer.

A method that can be used to understand participants' perceptions of a particular subject is free listing [33]. Free listing is a structured interviewing method from anthropology that asks participants to list everything they can think of about a particular subject. It enables the researcher to understand the scope and boundaries of a certain domain, and when repeated across numerous participants, items mentioned more frequently can be assumed to be more important or relevant. It takes the important approach of allowing participants to suggest words without influence or suggestions from facilitators. However, it does not give participants a chance to explicitly assign relative importance to their responses, as they may not list suggestions in order of importance.

As well as the aforementioned single-technique tools for gathering end-user data or using that data in the design process, there are also methods that address the whole design process within the UCD approach. Contextual design utilizes a data collection method called contextual inquiry, where the designer spends time with the end-user while they carry out particular actions in their life or at work, conversing and observing how they do particular tasks [34]. It is based on the premise that simply asking someone how they do something will not get accurate responses because people are not good at observing and accurately reporting on themselves. After contextual inquiry, contextual design consists of a series of data interpretation and consolidation steps. Contextual design is a strong example of a structured methodology that details how to gather end-user data and use it in the design process. However, there may be challenges in performing contextual inquiry for energy access projects. There may be cultural barriers, language barriers, and site accessibility issues that prevent designers spending time with end-users while they go about their daily lives while conversing with them. In addition, contextual inquiry relies on confident discussions about the norms and practices of end-users, which may not be in the skill-set of an engineer.

Recognizing that those unfamiliar with social sciences require specific tools to enable them to take account of socio-cultural issues in the design process, Pereria et al. [35] put forward a 'value-oriented and culturally informed approach' (VCIA) for the design of interactive systems. It includes 'artifacts' (tools) that encourage the designer to consider values and culture explicitly throughout the design process, for example through value comparison tables and a 'culturally aware requirements table'. They apply the methods and approach to design of a social network for Brazilian teachers working with children who have a disability, and find the VCIA toolkit useful to draw attention to cultural issues designers might otherwise overlook. They note the difficulty in building tools that are easily used by those without social science experience, but which dont oversimplify complex concepts such as culture. The VCIA provides a useful structure for progressing the design with values and culture in mind, with a framework suitable for use by engineers, but has less of a structured approach towards inclusion of surrounding context, which is equally important.

Prototypes are used in many design projects to elicit feedback from participants, often deployed periodically during an iterative design approach. However, there are problems reported using prototypes in Global South contexts, such as participant misinterpretation and confusion (Table I). One method to address these is with technology artifacts: off-the-shelf items that are functional and easily understood by participants without having to consider abstract design concepts [1], [18]. They allow for open dialogue between designers and end-users about functionality and end-user experiences with the item, and circumvent the issue of participants not understanding the design process or new technologies.

To address the challenge of limited participant understanding of the design process or technology, Maunder et al. [1] and Hussain et al. [20] advocate for an approach that builds local capacity for participation. This 'co-evolutionary approach' requires considerable extra time and resources, training and preparing the users and their environment for the design process, but enables more equal and full participation in the design process by end-users. Hussain et al. [20] notes that over time it was possible to move towards more equal participation, as participants became more psychologically empowered through training and experience. This approach expands the role of design projects in such contexts to include local capacity building of participants, and aims to move towards a sustainable situation where external designers are no longer needed.

Watkins et al. [17], Chetty et al. [22], and Hussain et al. [20] note the importance of adapting tools, methods, and design approaches according to what is appropriate in terms of the cultural norms of the participants. This requires contextual research by the design team and/or collaboration with partners familiar with the participant context in designing exercises to use with participants. Chetty et al. [22] note that design for contexts with which one is not familiar requires this extra effort to 'incorporate [participants'] values into the processes we create', as well as into the system being designed.

Finally, Maunder et al. [1], reviewing interactive systems design for the developing world, notes that there are no user-centered design tools that do enough to uncover complex socio-cultural issues early on in the design process to avoid failures or costly changes later. They state that the practice of ethnographic techniques is the only option currently, but these are not integrated into the design process or necessarily appropriate for non social scientists to carry out. They also call for a way to include broader social and physical factors that might influence design decisions in the early stages. Similarly, in a paper detailing a case study addressing energy needs for a rural village in Mali, Bryden et al. [2] calls for a 'structured way of gathering information' to guide formation of the problem definition stage in an engineering design process. They argue that without this, engineers are at risk of making assumptions about end-users and context that ultimately lead to project failure.

D. Product-Service Systems

A useful context originating outside of design theory and methods is the concept of product-service systems (PSS). The PSS model shifts away from traditional economic models of selling a product (e.g.: air conditioning unit), towards selling a combination of products and services (e.g.: thermal comfort) that fulfils a particular demand [36]. Therefore, the economic value to the consumer can be decoupled from material and energy consumption, so the provider is incentivized to reduce resource use as much as possible [37]. This was extended in the 1990s to the concept of Sustainable Product-Service Systems (S.PSS), which are PSS offer models which offer environmentally and ethically beneficial solutions [38]. The PSS/S.PSS perspective means that the 'offering' being sold/bought is inclusive of all products and services that enable the production of the function, or outcome.

Research on the application of S.PSS to distributed renewable energy (DRE) has noted that combining S.PSS and DRE is a 'win-win' approach to addressing the energy access challenge because of economic, environmental, and socio-ethical benefits [37], [39]. For example: low-income users might be able to access services a traditional product supply model would prohibit due to the expense of the equipment, and producers are incentivized to minimize resource use, producing a capital-efficient system, the lower costs for which are passed on to the customer. In addition, a new design approach called 'sustainable design for sustainable energy for all' details the design process of S.PSS DRE systems [39]. There are a number of tools within the methodology that guide designers to consider all aspects of S.PSS when developing an S.PSS energy system, from training services to payment mechanisms, using templates, prompting cards, and other processes.

E. Reflection

To be appropriate for the low-income, rural contexts of the Global South, UCD and PD methods that interact with end-users must reduce reliance on end-users having a good understanding of the design process. Talking about what end-users know, rather than introducing technology that they may find intimidating, or be unable to offer opinions on, is also important. Participation must be enabled at a level suitable for end-user capacity. In addition, methods must be appropriate for literacy and language barriers - pictorial methods have been successful in achieving this and are adopted in this research. Although it is desirable to spend as much time as possible with end-users to understand their needs and context, in reality, money, time, and remoteness constraints are likely to limit this. Therefore, methods to interact with end-users must be effective in terms of information gathered for the time taken, given it will not be possible to do a full ethnographic study for all villages requiring energy systems. Finally, methods must be culturally appropriate and implemented adhering to cultural norms. For this, co-design of methods alongside those familiar with end-user context is an important approach, as well as building in method flexibility so it can be adapted to different cultures and end-user capacities.

This research aims to answer the call for tools and methods for UCD and PD appropriate for Global South contexts. There is a trade-off between wanting to keep time in field short, and needing detailed understanding of end-user needs and context for successful design and implementation. Therefore, the methodology proposed here positions itself in the early design process, providing guidance on gathering data on end-user needs and context to a level to support a preliminary system design. This method focuses more on immediate end-user context, such as access to markets, practices and material flows in and around the village, rather than capturing broader political and economic context. This is to maintain the method as efficient and scalable, but means it is not intended to serve as the only contextual research in the design process. It's purpose is to be positioned within a broader design process, which might include iterative design cycles, various methods of participation, perhaps supported by capacity building of end-users and stakeholders towards greater participation, as recommended in the literature. Other methods should be used in conjunction that address contextual factors flagged in the method in more detail, and broader context, to develop a comprehensive picture of the implementing context.

This research is complementary to the S.PSS approach to the energy access challenge, and offers another methodology that views energy systems from the perspective of what systems enable end-users to do, rather than a traditional supply model.

III. Service Value Method

The purpose of the Service Value Method (SVM) is to enable the design of successful energy access projects. The method has the following aims:

- To gather data on end-user needs, aspirations and surrounding context at a level appropriate for a preliminary design
- To enable designers to integrate this data into the design process effectively
- To be fast and effective in field
- To be appropriate for use in Global South contexts

The method does not limit services to be only those enabled by energy or electricity, despite the purpose of the method being to support design of energy access systems. All services that are desirable to end-users are of interest because electricity can underpin and enable a variety of services in ways end-users may not be fully aware. Furthermore, services that consist only of infrastructure may provide useful understanding of contextual factors. It is important to understand how energy and electricity services fit into the broader lives of the end-users so that a design does not conflict with existing practices they may have.

A distinction is made between 'household' services and 'community' services to distinguish between services accessed at the homes of end-users compared to services accessed more centrally, and open to the whole community. This is useful from the perspective of an energy system design because the location of the point of delivery of the service matters for design of the transmission and distribution components of the system.

To capture end-user needs and context, the first step in the SVM is a data-gathering step, in the form of focus groups run with end-users using an exercise called the Service Value Test. To enable designers to take this data into account in a way that contributes to a successful system design, the second step is a data interpretation process. Quantitative service value data and qualitative service context data are used to construct service maps, displaying service popularity and evaluating services against key decision criteria for the design. Finally, in the third step the service maps are used to make key design decisions about what services the system will be designed to support.

A. Step 1: Data Gathering: Service Value Test (SVT)

Real data must be gathered from end-users to enable understanding of their needs and aspirations and an overview of relevant design context. Fig. 2 outlines the steps that comprise the SVT method that gathers data through focus groups with end-users. The following section describes the underlying principles of the methodology, explaining why it is structured as it is. The SVT was developed in collaboration with academic engineers and social scientists, and in-country project partners who were familiar with the local context, to ensure it was appropriate for use in the target rural villages.

1) Principles of the SVT methodology:

The methodology of the SVT captures what services end-users want to see in their households and communities in the future, to show the designer what services, and therefore what products, are important to consider in the design. The first step of the method asks participants to suggest aspirational services. To avoid influencing participant choices, facilitators should not make their own suggestions (beyond an initial example) as they may not reflect participants true needs and aspirations. To address potential literacy and language barriers, services are captured in pictorial form, and a central service chart is used to collect the suggested services so that participants can keep track of their suggestions.

The SVT method is devised to pick out individual and group preferences in terms of the relative importance of the services, producing quantitative data from which the most important services to the end-users can be discerned. The method to do this needs to be quick and efficient to be possible in one focus group gathering, to address the challenges associated with accessing participants in remote or rural areas. It must also be easily understandable to cope with potential low-literacy rates. Therefore, participants use counters to demonstrate the value of each service on the service chart, placing more counters on more important services. Each participant uses counters of a different color so it is possible for facilitators to discern individual preferences and priorities from the whole group response; it also aids participants in keeping track of their own response throughout the exercise. However, to avoid group-think or strong personalities influencing decisions of individuals, participants first make their choices in isolation from the rest of the group on individual service chart index cards without conferring with each other, before transferring their results to the main service chart.

The emphasis of relative service importance achieved by the distribution of counters on services depends on the method participants use to indicate the value of the services. Free Assignment gives a more balanced indication of a participant's preferences, and group results show less disparity between popular services and less popular services in terms of the number of counters assigned. However, this method is more time intensive and may be difficult for participants with low numerical literacy because of the number of counters/crosses involved. Alternatively, group results from the Ranking method are more likely to result in a few very popular services with the bulk of the counters, and some services with no or very few counters. While this can be useful to clearly highlight what the highest priority services are, there is likely to be less distinction between the less popular services compared to when Free Assignment is used.

The SVT method seeks to reveal underlying needs that motivate the suggestion and valuing of a service through a discussion that enriches the quantitative data from the first two steps. Although experts in their own context, end-users may lack an understanding of technology and subsequent opportunities afforded by energy access. By understanding underlying needs, designers can consider how best to meet those needs through energy access solutions, services and products that may not be within end-users' awareness, and which they therefore are not able to suggest.

The discussion also aims to gather an overview of the context in which services exist, uncovering how end-users currently meet the underlying need, how they envisage using the service, what other services are involved, and what barriers might exist to successful utilization. The design must be aligned with current and aspirational practices, and if new practices are introduced, these must not be inconvenient or

<u>Focus Group Set-up:</u> 10 participants per focus group with two facilitators and translator if required.

<u>Equipment:</u> A1 Service chart, pictorial service cards (pictures or symbols of anticipated services, some blank), non-permanent marker pen, Blu Tack, A5 service chart index cards, pencils, colored counters, audio recording equipment, camera.

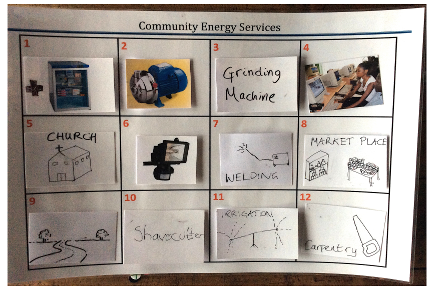
Step 1: Participatory Listing (Qualitative)

Separate SVTs are run for household services and community services.

a) Participants are asked to suggest services that they need or want to have in their homes/communities.

b) A commonly found example may be used as a demonstration.

c) Representative pictorial service cards representing suggestions are attached to the A1 service chart.



<u>Facilitation questions/statements:</u>

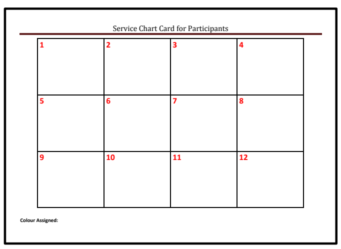
What services would you like to have in your household/ community in the next few years?

Household services *are things you want in your home. E.g.: lighting and mobile phone charging.*

Community services *are things that would benefit the community, that many people might use. E.g.: a health center and a primary school.*

Step 2: Value Judgment (Quantitative)

a) **Individual:** Without conferring, participants indicate service preferences on a service chart index card with crosses using either Free Assignment or Ranking methods.

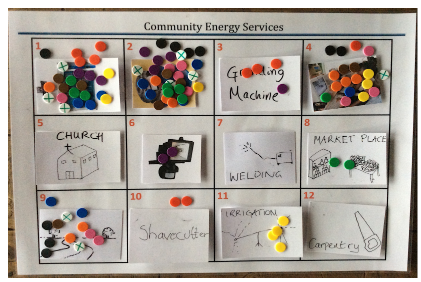


b) **Collective:** Participants transfer individual choices to the service chart using colored counters (one color per participant.)

<u>Options for value quantification:</u>

Free Assignment: Participants place 20 crosses/counters anywhere on the chart with more crosses/counters showing greater importance.

Ranking: Participants allocate 4, 3, 2 and 1 crosses/ counters to indicate their 4 most important services.



Step 3: Value Exploration (Qualitative)

Participants are invited into group discussion to explore:

- Reasons for service/product suggestion and importance, revealing underlying needs and priorities.
- How they envisage using the service (including when), to understand how it might fit into their lives and to reveal associated context.
- How they access the service now (including when), to understand more about current practices and to reveal more associated context.

<u>Facilitation questions:</u>

Do you agree with the group results? Why/Why not?

Why is [service] important to you / the community?

How would you use [service]?

When would you use [service]?

How do you access the [service] at the moment?

What else needs to be in place for you to benefit from [service]?

Fig. 2. Service Value Test method.

contrary to current practices to the extent that end-users do not engage with the system. Additionally, knowing when in the day the service is required is important for energy access initiatives using solar generation due to the diurnal irradiance cycle. Energy storage will be needed if energy is required when generation is not possible. The discussion should be managed to reveal these contextual factors that influence the practicalities of implementing the service and whether or not it will be successful. For example: egg incubators are important for rearing chicks to sell at the market, but equally important to the success of the venture is access to vaccinations so that chicks survive post-hatching, and the means to get them to a market place.

2) Further SVT Implementation Details:

In step 1, if participants contribute products rather than the service that that product enables, it is advisable to clarify what service that product is associated with. Some products can be used in different ways, and end-user intention may differ from facilitators' assumptions. For example, a fridge might be suggested to enable the sale of cool drinks, to store vaccines in a surgery or veterinary setting, or to store food in a domestic or business context. If more than one use of a certain product is suggested, it is up to the facilitators whether these services are represented separately, or together through the suggested product, in which case the discussion in step 3 would seek to understand more about the different uses and their context.

It is advisable to run several focus groups for each project context, separating participants according to demographic traits, to obtain a cross-section of views and ensure fair representation. Due care must be taken that suitable participants are chosen, and that the process is fair and equitable. Further implementation details regarding equipment, participants and process can be found in Appendix A and Appendix B, including suggestions to reduce as much as possible barriers to participation due to cultural norms.

B. Step 2: Data Interpretation: Service Maps

The second stage of the SVM uses the popularity data and service context data from the SVTs to construct service maps. Service maps portray each service, including service popularity, against key decision criteria for the energy access project. This section outlines the steps required to process the SVT data and construct the service maps.

1) Identification of Out of Scope Services:

Given the SVM uses a broad definition of services, some suggestions from participants may be out of scope for an energy access project. To determine this, services are separated into three categories according to the extent to which electricity is a primary component in the service:

1) Services for which no electricity is needed
2) Services which require additional infrastructure alongside an electrical component
3) Services which only require electricity

All services that have no electricity component are judged as out of scope of energy access projects. However, out of scope services still offer useful information about participants' needs and aspirations, and may enhance understanding of the context of services to which electricity can contribute. Therefore, they are still included on the service maps without association with the decision criteria, with the popularity data displayed.

2) Decision Criteria:

Service maps show each service relative to how well it aligns to key decision criteria for the design of the energy system. These criteria should be chosen according to the project context, guided by the aims of the project and by end-user needs. It is advised that one/several criteria are selected to represent some aspect(s) of the practical feasibility of implementation of each service. Subsequent criteria should represent project aims or underlying end-user needs, therefore capturing a trade-off between what is practically feasible and what the project aims to fulfill. For ease of visualization, two criteria can be chosen, though clearly each service has multiple characteristics and there are likely to be numerous criteria that it would be good to take account of in design decisions. Therefore, it is equally possible to choose more criteria and to explore other visualization options, though there is a trade-off to be considered in terms of usability of the method and the results and method complexity.

The following sub-sections define two decision criteria relevant for energy access projects for rural villages, and describe methodology for evaluating services against them. They may not be relevant for all energy access projects, and users are encouraged to adapt the methods to fit project contexts. Judgment of services against the criteria should be informed by the discussion data gathered in the third step of the SVT, and supplemented by further research. Input should be sought from those familiar with the project context to ensure contextual understandings and interpretations by external investigators are accurate. If it is possible to quantify the extent to which a service complies with a decision criterion, a metric can be defined and calculated for each service; otherwise a categorization of services that represents some kind of ranking in respect to the criterion is advisable.

a) Near-term Economic Benefit:

'Near-term Economic Benefit' (NTEB) is an important decision criterion for energy access projects that seek to provide energy services for income-generation, and for communities who identify and rate income generating services highly in the SVT. The criterion encompasses the following considerations:

- Whether the service enables production of a good/service that can be sold (e.g.: chicks hatched using an incubator can be sold, security lights cannot).
- Whether the good/service can be sold outside the village to external markets (e.g.: clothing) or inside the village (e.g.: salon) - and thus whether the good/service takes advantage of external markets, bringing in external income.
- Whether the service complements or enhances an existing service that generates income (e.g.: a TV in a hotel).

Services are categorized into four groups according to their NTEB potential using the decision tree shown in Fig. 3. Services that provide long-term economic benefit, such as improved health and education, are combined with the enhancement category. This reflects that community services such as health care and education do impact income generation, but probably have more long-term economic impact than

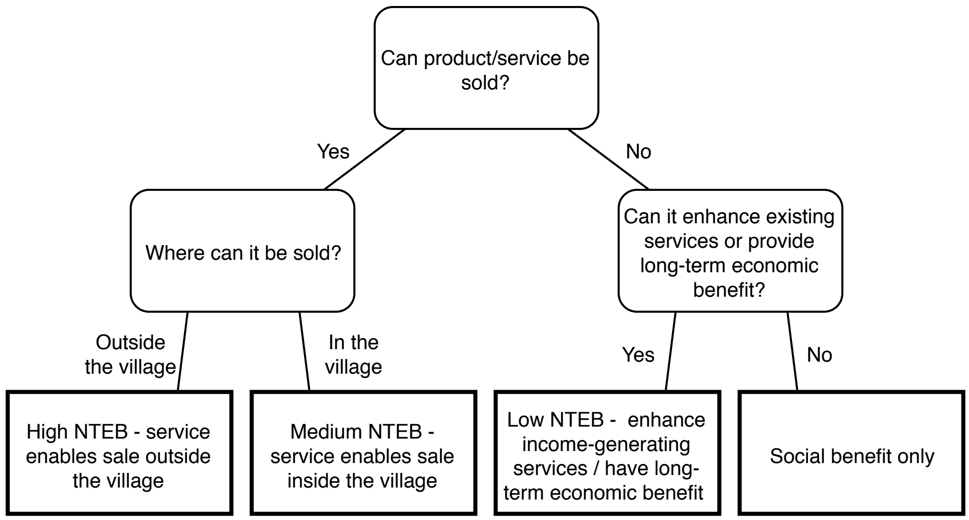


Fig. 3. Decision tree to categorize Near-term Economic Benefit (NTEB) of services.

near-term impact. The final category distinguishes services that only have social benefit, such as security lighting. Each service should be evaluated taking into account what participants envisage doing with the service, as captured during the SVT and further research if required.

b) Ease of Delivery:

'Ease of Delivery' (EOD) reflects the feasibility of delivering the services. It can be interpreted to include different factors, and here is defined to include consideration of:

- Power and energy requirements
- Infrastructure requirements
- Other aspects of service complexity, such as the requirement of trained personnel, or a required role by external entities

Firstly, services are separated into power categories as defined by the Multi-Tier Framework for energy access [8] (the columns of Table II). The power categories are then further partitioned according to services that have an infrastructure requirement, and services that have both an infrastructure requirement and additional complexity factors (the rows of Table II). The result is placement of services within one of the 15 spaces in Table II.

To form EOD categories, the 15 groups defined by Table II are combined to reflect an approximate indication of how difficult implementation of that service would be. The shading in Table II shows the group combinations, such that services in each pure power category are combined with services in the previous power category that also have infrastructure requirements, and with services with even lower power requirements that have both infrastructure requirements and additional complex factors. This method forms 7 EOD categories summarized in Table III.

Combining services in this way synthesizes the three EOD components to give a small number of EOD categories, which helps keep the outcome understandable, while still providing a reasonable distinction between services.

3) Construction of Service Maps:

Service maps show two indicators of service popularity: the number of counters the service received during the SVT by the size of each service bubble, the number of focus groups who suggested that service by the color of the service bubble. The axes are decision criteria, and services are arranged according to their categorization with respect to each the criterion.

C. Step 3: Preliminary System Design

The final step in the SVM method is use of the service maps to select the services the project will deliver. The areas of the service maps that maximize the decision criteria can be considered alongside service popularity to allow designers to make informed decisions in service selection. The choice of services leads to selection of the products and system architecture that enable those services, and then sizing of the generation, storage and distribution components of the system.

IV. Case Study: Rural Electrification System Design in Kenya and Bangladesh

The SVM was used to design a rural electrification system for two villages in Kenya, and step 1 (the SVT) was used in two villages in Bangladesh to contribute to a similar design process there. Service maps are presented for both countries, while the resulting energy system design and implementation details are presented only for Kenya, because design of the system for the Bangladesh context was undertaken by other members of the project team.

A. Project Context

The Solar Nano-Grids (SONG) project (2014–2018) investigated whether a solar nano-grid is a viable, affordable and sustainable electrification method to meet community energy needs for rural villages in the Global South. The concept of a solar nano-grid sits between the functionality provided by solar-home-systems and micro-grids, providing tier 1 energy access to a small number of households (20–50) whilst powering small-scale productive use technologies

TABLE II
CATEGORIZATION OF SERVICES ACCORDING TO THREE COMPONENTS OF EASE OF DELIVERY (TEMPLATE)

	Power Categories				
	<50W	50-<200W	200-<800W	800W-<2kW	2kW-
Electric power only					
With infrastructure (I)					
With infrastructure + complexity (I,C)					

TABLE III
EASE OF DELIVERY: 7 CATEGORIES

#	Groups included
1	<50W
2	50–200W, <50W + infrastructure
3	200–800W, 50–200W + infrastructure, <50W + infrastructure + complexity
4	800–2kW, 200–800W + infrastructure, 50–200W + infrastructure + complexity
5	>2kW, 800–2kW + infrastructure, 200–800W + infrastructure + complexity
6	>2kW + infrastructure, 800–2kW + infrastructure + complexity
7	>2kW + infrastructure + complexity

(services that enable income generation) [40]. The SONG project was a multi-disciplinary collaboration between UK academics and in-country partner organizations, working with two rural villages in Kenya and two in Bangladesh to develop solar nano-grids suitable for each context.

In 2014–2015, community consultations took place in the four communities to understand current energy practices, community needs and aspirations, and the local and national energy context. Along with the SVT process carried out with sub-groups of the communities, the consultations comprised interviews with stakeholders at the local and national level, observational visits, and household surveys of a cross-section of community members. These other methods gathered data on wider contextual factors not covered through the SVT, and obtained quantitative data about current energy practices. This included estimates of expenditure on current energy sources that were then used to assess affordability and set business plans for the energy services offered by the solar nano-grid. After the consultations, in Kenya the SVM was used to develop a technical design for the solar nano-grid.

A prototype solar nano-grid was installed in each village in Kenya in June 2016. Since then, development and adjustment has been on going, led increasingly by the communities and the in-country partner (a local NGO), as the system is adjusted to meet changing community needs and other external factors.

1) Case Study Communities:

In Nakuru County, Kenya, Lomolo B (GPS 0°00'37.39" S 36°02'30.86" E) is a village of internally displaced persons (IDPs) who were moved from the Mau forest by the Kenyan government due to a conservation project and eventually settled on land in a sisal plantation in early 2014. In late 2014, when the community consultation phase of the project was carried out, Lomolo B consisted of about 250 houses, had a dilapidated primary school, no health center, no church building and access to water was via a dirty rain-fed pond. It is 13 km from the nearest town, Mogotio, where most provisions come from and where health care can be accessed, reached by roads through the plantation that are poor quality.

Echariria (GPS 0°20'33.28" S 36°13'25.68" E) is a larger, more spatially dispersed and economically diverse community of IDPs. In 2014, Echariria could be split into three areas formed by IDPs settling in stages following electoral violence in 1992, 2001, and 2007-2008, corresponding to areas 1,2 and 3 respectively. Area 1 is easily accessible via a good road, has a primary and secondary school, a main street with shops, mills, hotels, churches, and an unregistered 'dispensary', which is serviced by one nurse. Areas 2 and 3 are progressively less well developed, with houses in Area 2 situated up a hill on a rough road on smaller plots of land than in Area 1, and in 2014 those in Area 3 lived further up the hill in donated tents. In 2014 there was no electricity into the village.

In Bangladesh, Faitang (GPS 21°46'22.7" N 92°08'08.9" E) is a recently populated (2014) village of refugees. Approximately 50 households live in old military barracks, which are dark and poorly ventilated. Water is available through hand pumps but there are issues with high iron content, causing minor health problems. There is no health facility. In early 2015, a new primary school was in the final stages of construction, due to replace the old school. A mosque was also under construction 250 m down the access road. Faitang has good access to a nearby highway (20 minutes), which is also the site of a small commercial hub with a number of businesses such as mechanics, rice milling, and welding.

Baroihati (GPS 24°17'1.01" N 90°36'38.00" E) is an old (more than 100 years) village situated among rice paddy fields in Bangladesh, of approximately 25 households. It is a well-established community and in early 2015, many households had solar equipment. Access to water is through several hand pumps, but there is no school or medical facility. Households are arranged in large buildings, which contain several households. The community is reasonably well connected to local villages, but to get to larger towns it is necessary to take a ferry across a river, increasing journey time.

TABLE IV
SERVICES CATEGORIZED BY THE EXTENT OF ELECTRICITY AS A PRIMARY COMPONENT.

Extent of electricity as primary component			
No electricity needed	Electricity and infrastructure	Only requires electricity	
Household:	**Household:**	**Household:**	**Community:**
Furniture	Solar powered shower	Torch	Improved roads (street lights)
Community:	Washing machine	Radio	Rice husking
Sanitation	Household water supply	TV	Grinding machine
Improved roads	**Community:**	CD/DVD player	Shave cutter
Crop storage	Sports playground	Fan	Power tools
Tractor and pesticides	Church	Lighting	**Both:**
Ambulance	Health center	Electric cooking	Security lighting
Financial support for the elderly	Education	Rice cooker	Incubator
Alternative mobile phone operator	Pre-primary education	Kettle	Welding
Security wall	Water	Iron	
Public transport	Community center	Computer	
Fishery	Carpentry	Printer	
Bath	Salon and barber	Mobile phone charging	
Bank (micro-finance)	Market place	Fridge	
Improved mobile reception	Garment factory	Shaver	
	Mobile phone charging center	Sewing machine	
	Both:	Hairdryer	
	Irrigation		

B. Data Gathering: SVT Implementation

Three focus groups each comprising 10 participants were carried out in each of the 4 communities, with separate groups for women, youth (defined as aged 18-30 years), and elders. Both a household and a community SVT were carried out for each group. For the household SVT, participants used the Free Assignment method to indicate their value judgment, whereas for the community SVT, they used the Ranking method. Each focus group took between 2 and 2.5 hours for both SVTs.

Two tables summarizing the content of the discussions in the SVTs for the focus groups carried out in Kenya, in terms of current practices to access that service, and why each service was important, are in Appendix C.

C. Data Interpretation: Results

1) Out of Scope Services:

Table IV shows the services categorized according to the extent electricity is the primary component. Appendix D defines each service in terms of what it was assumed to encompass for the purpose of this categorization. Services in the 'No electricity needed' column were out of scope of the project.

2) Decision Criteria for Electrical Services:

The remaining electrical services were categorized according to the two decision criteria described in Section III-B. NTEB was relevant because one of the key project objectives was to provide electricity access to enable income generation, and it aligned with a strong theme that emerged from the discussion step of the SVTs. Income generation was one of the main underlying needs of participants and strongly influenced their suggestions and value judgments. Table V shows the resulting assignment of services to the NTEB categories split into 'household' and 'community' groups.

The practical feasibility of system delivery provides an important trade-off to NTEB and service popularity. Table VI shows the classification of services against the three EOD components. Appendix D details the assumptions made about infrastructure requirements and additional complexity for each service. For the Kenyan data, 'Health center' and 'Church' were separated by village, denoted 'Health center (L/E)' and 'Church (L/E)', because of differences in existing infrastructure between villages. Lomolo B had no existing health service and no church building, but Echariria had a dispensary building where a nurse saw patients and multiple churches in the community. This removed the infrastructure component of EOD for Echariria. In the Bangladesh context neither village had infrastructure for health, so the service 'Health center' was grouped with the health center for Lomolo B (noted 'Health center (L, B)' in the tables and service maps).

In addition, in both countries the service 'Education' encompassed improvements to current education buildings and aspirations for new institutions, like secondary schools and polytechnic colleges. To reflect this difference 'Education' is represented twice, as 'improved' and 'new' respectively. When placed on the service map, both reflect the popularity data from the generic 'Education' service, because it was not possible to separate out popularity for 'improved' education and 'new' education.

The classification against the three EOD components produced five EOD categories, shown in Table VII, with categories ranging qualitatively from hard to easy and with services split into the 'household' and 'community' groups.

3) Service Maps:

Data from the 6 focus groups in each country were collated to form one household service map and one community service map for each country. Services exist in one of 20 quadrants depending on their evaluation against the decision criteria. To avoid overlapping services, where more than one service exists in a quadrant they are spatially displaced from each other. Fig. 4 and 5 show the service maps for household and

TABLE V
CATEGORIZATION OF SERVICES ACCORDING TO NEAR-TERM ECONOMIC BENEFIT

Near-term Economic Benefit Categories: Low - High			
1 (Low) Social benefit only	2 Enhance other services / long-term economic benefit	3 Sell inside the village	4 (High) Sell outside the village
Household Services			
Solar powered shower Kettle Torch Radio Fan Security lighting Household water supply	TV CD/DVD player Electric cooking Rice cooker Lighting	Computer Printer Shaver Washing machine Fridge Iron Hairdryer Mobile phone charging	Welding Irrigation Sewing machine Incubator Rice husking
Community Services			
Sports playground Security lighting Improved roads - (street lights)	Health center Education Religious school Pre-primary education Church Water	Shave cutter Market place Salon and barber Community center Mobile phone charging center	Incubator Carpentry Welding Grinding machine Power tools Garment factory Irrigation Rice husking

TABLE VI
CATEGORIZATION OF SERVICES ACCORDING TO THREE COMPONENTS OF EASE OF DELIVERY

	Power Categories				
	<50W	50-<200W	200-<800W	800W-<2kW	2kW-
Electric power only	Torch Radio Lighting Fan Mobile phone charging TV CD/DVD player Computer Printer Shaver	Security lighting (household) Fridge Sewing machine Incubator Security lighting (community) Mobile phone charging center	Rice husker Grinding machine Power tools Improved roads (street lights) Iron Education (improved) Health center (E)	Electric cooking Rice cooker Hairdryer Kettle Church (E)	Welding Shave cutter
With infrastructure (I)		Sports playground Market place	Community center Carpentry Salon and barber	Church (L) Garment factory Water Irrigation Washing machine Household water supply Solar-powered shower	
With infrastructure + complexity (I,C)	Pre-primary education	Health center (L, B) Education (new) Religious school			

community services, for Kenya and Bangladesh, for Kenya and Bangladesh respectfully.

The service maps show that there are some similarities but also notable differences between the maps for Kenya and Bangladesh. A similarity is that broadly the same pattern of preferences are shown, with basic human needs being the most popular services (such as Lighting, Water, Education, Health center). These are followed by services that improve quality of life (TV, Radio, Electric cooking (with variants), Fan (for Bangladesh)), and services that can be used for income-generation (Sewing machine, Irrigation, Fridge, Incubator). Differences are apparent according to the culture and norms of

TABLE VII
CATEGORIZATION OF SERVICES ACCORDING TO EASE OF DELIVERY

Ease of Delivery Categories: Hard - Easy				
1 (Hard) 2kW- 800-2kW, I 200-800W, I, C	2 800-2kW 200-800W, I 50-200W, I, C	3 200-800W 50-200W, I 50W, I, C	4 50-200W 50W, I	5 (Easy) 50W
Household Services				
Welding Shave cutter Irrigation Washing machine Household water supply Solar-powered shower	Electric cooking Rice cooker Hairdryer Kettle	Rice Husker Iron	Fridge Sewing machine Incubator Security lighting (household)	Torch Radio Lighting Fan Mobile phone charging TV CD/DVD player Computer Printer Shaver
Community Services				
Welding Church (L) Garment factory Water Irrigation Health center (L, B) Education (new) Religious school	Church (E) Community center Carpentry Salon and barber Pre-primary education	Rice husker Grinding machine Power tools Improved roads (street lights) Education (improved) Health center (E) Sports playground Market place	Incubator Security lighting (community) Mobile phone charging center	

each of the contexts. The Sewing machine is more popular in the Bangladesh maps, which is emphasized by the appearance of the Garment factory, whereas the Incubator is more prominent in the Kenyan case. Food or produce processing services differ, with an emphasis on rice processing in the Bangladesh communities, in contrast to maize processing in the Kenyan communities. Other differences include that in Bangladesh, Water was a high priority household service, while it only appeared on the community map for Kenya, showing that this categorization of services is different between the two contexts. These differences emphasize that the particular services important to a community and the value of them is context specific, which shows the need for this data-gathering and processing methodology for energy access projects.

D. Preliminary Design: Solar Nano-grid

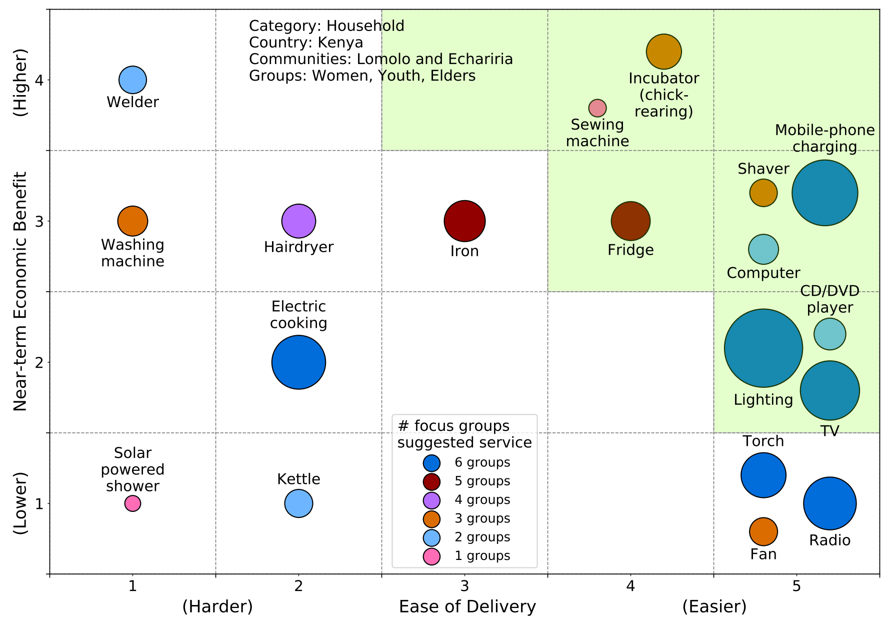
For the Kenyan context, the service maps were used to guide selection of the services the solar nano-grid would provide and build up a system design. The aim was to choose a small number of services, which would be implemented, tested, and developed with in-field learning in partnership with the communities, allowing for refinement and expansion in the future.

The shaded areas in Figures 4 and 5 show the areas of the service maps that have higher NTEB potential and more favorable EOD. The solar nano-grid was to have a central solar hub, where productive use services would be located, and provide energy to surrounding houses. Two household services were identified that had high popularity: lighting and mobile phone charging. Using efficient LED bulbs, the power requirement for household lighting is low (<20W), and the SVT discussions informed us that lighting was required in the night rather than the day (duration 3–4 hours). Mobile phone charging is also a low power and energy activity on the scale of a single household. Therefore, rather than put in transmission lines for a low power and energy requirement, portable batteries were decided on as the means of distribution of energy from the central hub to the households.

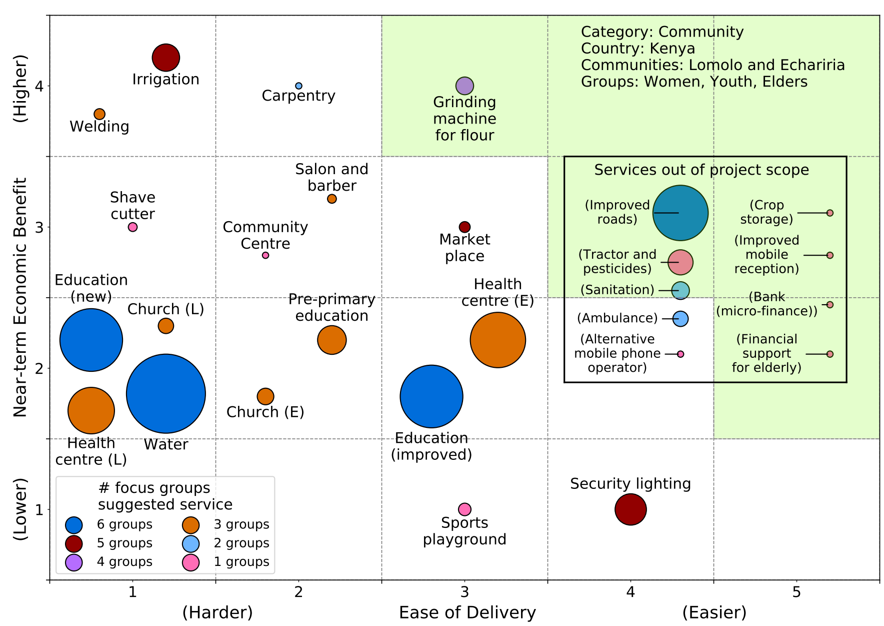
Two productive use services were chosen that would be available to the wider community with the aim of enabling income generation: an incubator for chick-rearing, and a grinding machine to grind maize into flour. Although the incubator was suggested in the Kenyan household SVT and not the community SVT, it was decided to test a centrally located service. An incubator keeps the temperature and humidity constant while the eggs are in development (21 days for chicken eggs), requiring electricity 24 hours a day. Alongside the natural daily and seasonal variation in solar irradiance, this meant electricity storage at the hub was required.

The grinding machine would be the highest power service the nano-grid would support (0.75 kW). It was intended to be an alternative machine to other diesel powered machines in the community available for use for 2–3 hours a day when irradiance is high. The grinding machine takes in maize kernels, already separated from the cob, and grinds them to flour; therefore, a husking machine (0.38kW), which separates kernels from cobs, was also included in the design.

The PV panels and battery system were sized according to



(a)



(b)

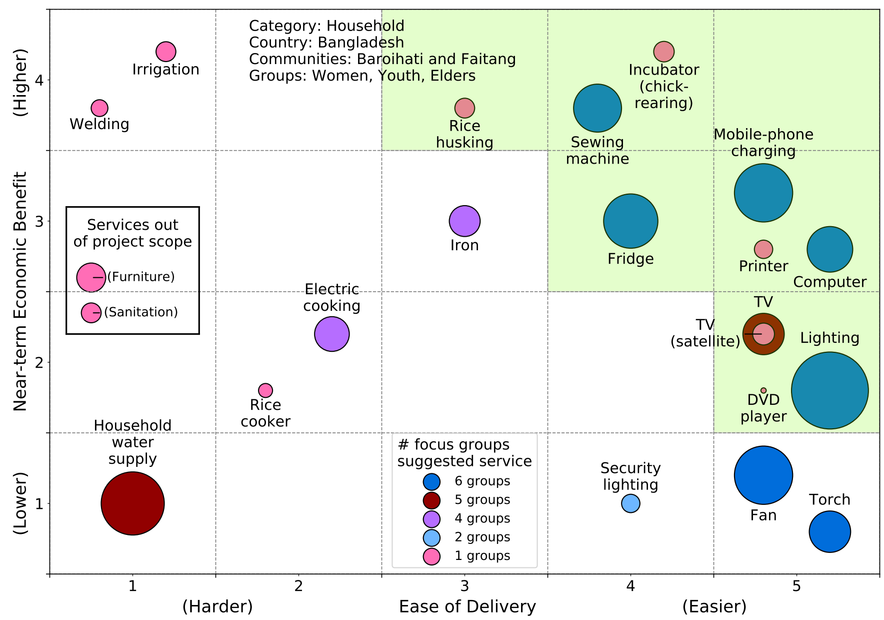
Fig. 4. Service maps for (4a) household services and (4b) community services for Lomolo B and Echariria, Kenya.

irradiation data from near-by weather stations and estimated use of the services. Additional capacity was added given it was a prototype system and demand was unclear. The prototype nano-grids consisted of 3 kW PV panels and 10 kWh battery storage. The household battery charging system consisted of 62 Wh batteries with three 3W LED lights and mobile phone charging connectors. A schematic of the solar nano-grid and the central hub in Lomolo B is shown in Fig. 6.

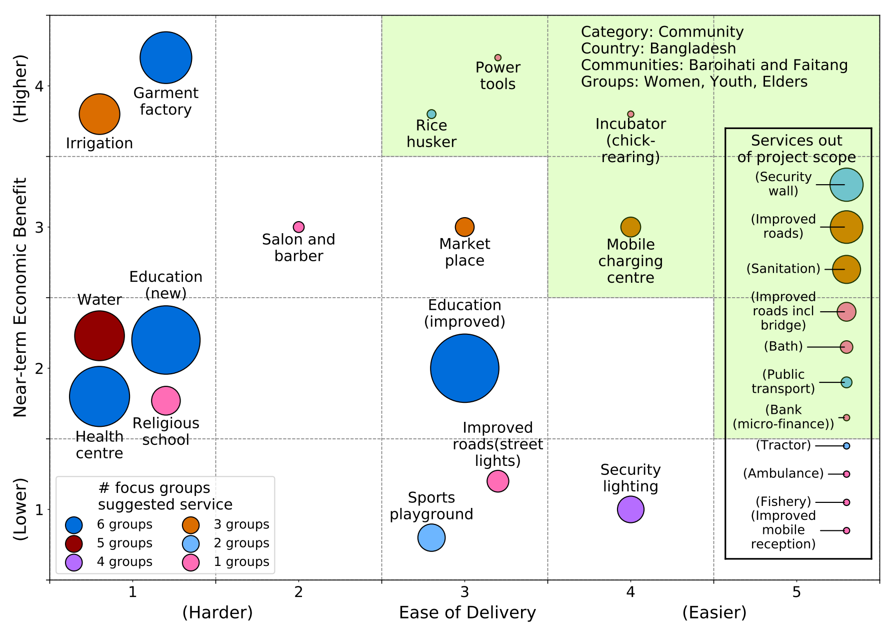
E. Solar Nano-grid Implementation

This section describes the outcome of the installation of two prototype nano-grids in the two case study communities in Kenya in June 2016, where some aspects of the design worked well, and others did not.

When the communities tested the grinding machine, they found that the coarseness of flour it produced was not suitable to their needs. The grinding machines were sourced from a company operating in South-East Asia, who had experience providing agricultural machinery to local communities there. However, in the contexts they worked in, coarse flour was desirable. In Kenya, flour for human consumption must be very fine, and the coarse flour produced by the grinding machines was only suitable for chicken feed. Thus, the grinding machine did not meet the expectations of the communities in terms of



(a)



(b)

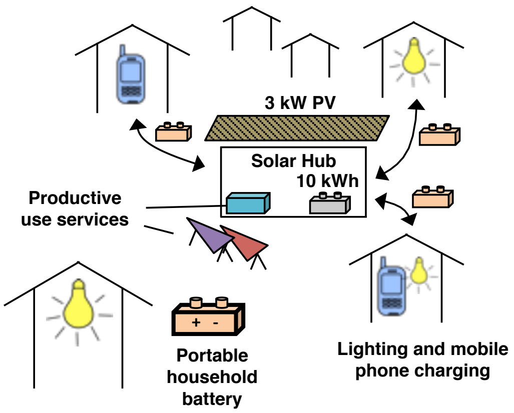
Fig. 5. Service maps for (5a) household services and (5b) community services for Faitang and Baroihati, Bangladesh.

being able to provide flour for human consumption.

The husking machine was also unsuitable for these particular villages. This was because farmers accessed a husking machine via a man who had a diesel-powered husker on a motorbike, which he drove to each farm when required.

The incubator was well received and was useful to the communities. The battery charging system was well-used but, alongside technical problems, it became apparent that end-users prioritized battery technologies with greater energy and power capacities that were more widely available (lead-acid), than the smaller size and weight of the deployed Li-ion batteries. Despite this feedback, in November 2016, a survey of users of the battery-charging system with the Li-ion batteries found that none were using kerosene as a fuel for lighting sources. This was in contrast to the results from household surveys conducted in November 2014 across a cross-section of the communities before installation: 83% (out of 30) and 85% (out of 60) of households surveyed in Lomolo B and Echariria respectively were using kerosene-based lighting products at that time. While it is possible that over time households were able to adopt more preferable lighting sources compared to kerosene lamps, it is also likely that the battery-charging system played a role in this.

Given that the highest power services were unsuitable, and



(a)

(b)

Fig. 6. Schematic of solar nano-grid prototype (6a) and photo of Lomolo B hub (6b).

not used to the extent expected (grinding machine) or at all (husking machine), the sizing of the PV panels and hub batteries was easily adequate for demand.

Since the June 2016 installation, the battery-charging systems now use lead-acid batteries that are preferable to the customers, larger incubators have been deployed, and an M-PESA (mobile money) shop has been set-up in Lomolo B. The battery-charging systems have a cost-reflective business model such that customers pay monthly until they own the batteries, after which there is a monthly charging payment for use of the charging equipment. Both the battery-charging systems and the M-PESA shop are making a profit, which goes to the Village Energy Committee (comprising community members) to support ongoing maintenance and development of the system. In addition, the M-PESA shop in Lomolo B, serving 15–20 people/day, means that customers no longer need to travel to Mogotio to access this service, saving time (1–2 hours/customer) and travel costs (200–300 KSH/customer). The chick-rearing business also has a cost-reflective business plan, is run by the Village Energy Committee, and is expected to start turning a profit this year through the sale of day-old chicks to local farmers.

V. Discussion and Evaluation

In this section we discuss the novelty and impact of the SVM in the design of energy access systems, and evaluate the extent to which the aims of the method were met when used in the case study in Section IV.

The SVM was developed from UCD and PD design approaches, and is a novel methodology to gather and integrate end-user needs, aspirations, and context, into engineering design practice for the design of energy access systems. It presents a data-gathering step that gathers qualitative and quantitative data that is required to improve the outcome of the design process. The means to extract the data is distinguished from other focus-group or interview based methods that involve post-processing of qualitative data (such as word frequency analysis and free-listing) by asking participants to make explicit quantitative value judgments to indicate their preferences. In addition, participants do not select services from a pre-existing selection, but come up with their own answers, avoiding potential bias created by limiting discussion to suggestions from the design team. It also adheres to best practice as reviewed in the literature to foster successful participation for low-income, rural end-users in Global South contexts. For example, it does not rely on participants to have an understanding of technology or the design process, and the numerical element is adaptable to suit the capacity of the participants.

The further novelty of the SVM is that it sets out a rigorous process to integrate the gathered data into design practice. The integration step is important to ensure the data informs decisions without the influence of designers' biases or assumptions. Key decision criteria are selected that reflect the aims of the project, and the services are evaluated against them using the qualitative data from the SVT. Service maps, showing the popularity data, and how each service stands relative to the key decision criteria for the project, enable designers to make decisions about what services the energy system should support.

Use of the SVM in the design of energy access systems means that the services the system must support are known, and therefore the demand of energy and power can be more accurately estimated compared to a situation where there is less information about the end-uses of energy. This means the system can be sized to reflect end-user energy and power requirements, which reduces the cost of the system in contrast to the common strategy of over-sizing systems to cope with unknown energy demand. As a result of sizing the system more correctly, system performance is improved in terms of the efficiency of energy utilization as a proportion to that generated.

In addition, the SVM enables the inclusion of services in the design that meet the needs of the community. Projects can be costly failures, or costly to correct, if an energy access system does not meet user needs and so is not useful to the target end-users. Use of the SVM integrates this important end-user data into the design process early on, reducing the possibility of large design changes later in the design process, which may otherwise occur if the system is not designed aligned with end-user needs. In addition, economic value for the community is more likely to be created when using the SVM because it highlights the services identified by end-users that enable them to take advantage of income-generating opportunities specific to their context.

A further factor required for the sustainability and long-term successful integration of an energy access system is that community members have a strong sense of ownership over the system. This is a factor that participatory design in particular, through co-design practices, seeks to cultivate [16]. Though the SVM is far from the only contact with end-users that is required for a successful project, the data-gathering SVT step is inclusive and interactive in nature, and feedback showed that participants enjoyed the process and felt involved in the project. Therefore, along with gathering the important end-user data, the SVT also has a secondary function that contributes to fostering ownership and building relationships between external actors and the community, which is crucial for the longevity of energy access projects.

In Section III the four aims of the SVM were outlined, and the use of the SVM in the case study communities is now critically evaluated against these aims. The first aim of the SVM is to uncover data on end-user needs, aspirations and surrounding context to an appropriate level of detail for a preliminary system design. In the case study, the SVT data was very useful to inform what services were important to end-users, the practical feasibility of implementation and the potential for economic benefit through them. However, the contextual data gathered through the SVT is not sufficient to go beyond a preliminary design to a detailed design and implementation, as exemplified in the case study: contextual factors about grinding flour and current practices around husking maize did not come up in the SVT discussion. However, it is not realistic to expect the SVT to reveal all relevant information required for successful implementation of each service due to time constraints (2.5 hours is already a significant period of time to ask participants to attend for), and the breadth of services covered. The SVT achieves a broader overview of aspirational services and the context around them rather than delving into the detail of a few specific services. Therefore, after the SVM has been used to select candidate services for implementation, further details on those services should be sought through follow-up visits and communication with the end-users, moving from a conceptual design to a detailed technical design. In the case study, in-country partner issues and team miscommunication derailed this process, which also affected the battery charging system. Aspects such as size, weight, charging time, and capacity of batteries should have been more deeply consulted on with end-users after the SVM, avoiding design-team assumptions that did not reflect end-users' views.

The second aim of the SVM is to enable designers to integrate this data into the design process. Step 2 processes the data into service maps displaying services according to key decision criteria and the popularity data from the SVTs. This is a useful and efficient way to present two aspects of the popularity data alongside criteria that are meaningful for the project, and so guide decision making in terms of what services should be chosen. In the case study, two key decision criteria were used to construct the service maps and led to a good choice in services selected for the design, despite challenges in the later implementation. However, this choice did not reflect the other main underlying theme emerging from the SVT discussions - that of a product or service saving the end-user time (see Appendix C). To better reflect end-user needs in the design process, including more of these underlying themes as decision criteria would have been useful.

The third aim of the SVM is to be fast and effective in the field, to make it easy to integrate into design processes and to address the challenges of remoteness that are common in rural Global South contexts. Although there is some equipment associated with the SVT method, it is not complicated to set up or organize in preparation for the sessions, and the case study showed that a useful depth of data was gathered for both household and community services in 2-2.5 hours. The SVT was effective in including responses from all participants through the quantitative step, because even when participants were shy, or less inclined to participate in the group discussion, their value judgments were still captured and represented in the popularity data. Also, collecting the value quantification data individually avoided group-think or stronger personalities influencing decisions.

However, a barrier to fast and effective implementation of the SVT arose during the case study, as for some groups the concept of 'community' services was not easily understood or relatable. For example, in Echariria, the three spatially dispersed areas corresponded to three different populations who arrived in the area at different times, and who had different socio-economic circumstances. There was understandably less community cohesion across these three areas than there was in Lomolo B where the people had been together (although not in that location) for a long time. Groups in Echariria took longer to understand the concept of community services, gave fewer suggestions, and required more prompting with examples of services than groups in Lomolo B. It is important that local context is considered in preparing the implementation of the SVM, and the method should be reviewed by someone from the local context to determine whether or not it will be suitable and if adjustments need to be made.

The fourth aim of the SVM is to be useful and effective in Global South contexts. The low equipment requirements are an important aspect of this, and in addition there is no requirement for on-site electricity as long as there is enough light to carry out the exercise. Additionally, in both Kenya and Bangladesh, using pictures (often hand-drawn according to participants' instructions) on the service cards worked well to bridge language barriers among the group and between the facilitators and participants. However, it was more challenging to cope with mixed language abilities in the discussion step of the SVT. Where participants with some English might use English, which was useful for facilitators, it meant other members of the group could not follow the discussion or contribute on the subject. During the case study focus groups, the translator was asked to translate from English to the local language when this occurred to ensure everyone was included, but this slowed down discussions that might have otherwise revealed other useful information.

The SVT method can be easily adapted according to what participants are comfortable with in terms of numeracy and complexity, so it is appropriate to use when literacy barriers are present. During the case study, one group was given 10 crosses/counters rather than 20 for the value quantification Free Assignment process. This made the process easier for some participants who were struggling to count to 20 and who were intimidated by the exercise. The key information can still be captured with fewer counters in the Free Assignment method, as long as the results are scaled up so that all groups are equally represented when the data is analyzed.

For participants with more advanced numeracy skills, extra information could be gathered by introducing time as a variable in the value quantification step, such that participants could either select a service for use in the day or in the night. For a solar energy project, this would reveal useful information about the time of day services were required, which has implications for the energy storage component of the energy system. This could be reflected in the service chart by splitting each box on the service chart into two, with one half representing day use, and the other side representing night use. When this was trialled during the case study for one focus group, it quickly became apparent that this was too complex, however, it might be suitable for groups where more time is available, where groups are smaller, or for participants with higher literacy levels.

VI. Conclusion

The Service Value Method addresses how to gather and interpret end-user needs and aspirations, and integrate them into contextual factors to improve the design process of energy access systems for the Global South. It advances the use and integration of social science data-gathering methodologies in engineering design practice to enhance design outcomes. This is particularly important for the Global South, where innovation and adaptation of off-grid energy systems for particular settings is required. The SVM aids design teams to select energy services for specific contexts that are prioritized by end-users and that meet their needs, so that the energy system can be designed to support them. Drawing on the service-oriented approach advocated both by energy access practitioners and the sustainable product-service systems approach, the SVM encompasses both data-gathering and design integration steps that reflect this latest understanding.

The SVM is suitable for use in Global South contexts because data is gathered in a process that can be adapted to the participation capacity of end-users in terms of literacy and language barriers, and extent of understanding of technology and the design process. The simplicity of the method in terms of process and equipment means that it can be carried out quickly in remote rural areas that may be difficult to access for long periods of time. While the method is suitable for implementation by engineers, it is highly recommended that it is used in collaboration with social scientists and in-country partners; it is best suited as a tool for multi-disciplinary teams. The SVM was successfully used to improve the design process for two solar nano-grids for rural villages in Kenya, and to gather end-user data to inform the design of two solar nano-grids in Bangladesh.

Appendix A
SVT Equipment

The following equipment is suitable for one SVT with 10 participants.

- Service chart: A1 laminated card with empty 12 box grid, placed centrally for the group to see
- Service cards: Laminated cards showing pictorial or symbolic representations (that are contextually appropriate) of different household and community services, and extra blank cards for drawing services not anticipated
- Non-permanent marker for drawing/writing extra services
- Blue-tac for fixing service cards to the service chart
- Service chart index cards: 10 A5 versions of the service chart for participants to make individual selections
- 10 pencils for participants
- 200 counters (10 different colors, sorted into groups of 10/20 depending on the preference indication method used)
- Recording equipment (audio/visual/both)

Appendix B
SVT Implementation Recommendations

People:

- Multiple focus groups should be run for the same community, separated according to demographic traits such as gender and age, to a) get a cross-section of community viewpoints and b) enable those with less social power to speak unhindered.
- For each focus group, 10 participants and two facilitators is a good balance between hearing a range of opinions and making group discussion possible and inclusive.
- Local power and governance structures should be respected and managed sensitively in the choosing of focus group members, given that the presence of strong influencers that might inhibit participation of other participants, but that community engagement may only be possible with their support.
- If a translator is required, they should be someone external to the community who is neutral to the project, chosen with cultural norms and social power dynamics in mind.
- Facilitators should be chosen in consideration of cultural norms that might limit participants freedom, willingness, or comfort to speak. For example, in a patriarchal society, female facilitators should facilitate a focus group of female participants.

Process:

- Obtain informed consent from all participants for their participation in the focus groups and for using the resulting data.
- Respect cultural and social norms while designing focus groups and selecting participants and facilitators.
- Participants expectations should be carefully managed regarding the aims of the focus group to avoid possible misunderstandings (e.g. that the exercise is not a promise of requested services).

- The translator should be briefed on the exercises before the focus group.
- The service chart should be placed on a central table and participants seated so they can see the chart and can be fully included in the exercises.
- Session rules should be agreed at the beginning of each session to enable smooth running and maximize data collection e.g.: only one person speaks at a time; all opinions are valid.
- Facilitators should be aware of their own biases and expectations and minimize the influence these have on their interpretation of responses.
- The goal of the facilitators is to create a safe, open space for participants.
- If there are mixed language skills in the focus group, it can be challenging for everyone to follow the discussion. Decide if the translator will back-translate any comments in English to the participants language so that everyone understands.
- Photograph the service chart at the end of steps 1 and 2 and collect service chart papers.
- If possible record session audio and get transcriptions, particularly for step 3 of the SVT.

Appendix C
Summary of SVT Discussion for Kenya

Tables VIII and IX summarize the key points from the discussions in the SVTs run in the Kenyan villages, for household and community services respectively. Shaded entries indicate that the service was not suggested by any groups in that community during the SVTs, and blank entries mean there was no particular discussion about that service.

Appendix D
Assumptions about Suggested Services

Table X details what each service was assumed to consist of in terms of electrical products, infrastructure and additional complexity. The electrical power of each service are noted and come from existing products or from a catalog of productive use appliances compatible with power generation by photovoltaic panels [41].

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TABLE VIII
SUMMARY OF SVT DISCUSSION FOR HOUSEHOLD SERVICES, KENYA

	Current situation		Why is the service important?	
Service	Lomolo B	Echariria	Lemolo	Echariria
Torch	Common	Common	Going to latrines at night. Walking around the village at night.	In case run out of kerosene. Going to latrines at night. Security when walking at night
Fan	Not common		It is very hot in the day.	
Radio	Common	Common	News (local and global), educational programs to advance themselves, particularly about agriculture, political programs, music	News (local and global), educational programs, particularly about agriculture, music.
Electric Cooker	None	None	Have to collect firewood, there is a shortage of it and it takes a long time	Firewood is hard to get - buy or collect it. Collecting it takes a long time, usually do this once a day. Would save time that could be spent working. Charcoal is expensive. Both have ill health effects and are dirty.
TV	Only 1 in the village	People in lower villages have TVs	News (local and global), educational programs, entertainment, sport.	(E youth: colour TV) News (local and global), educational programs (agriculture and general), entertainment (soaps, comedy)
CD/DVD Player	None	None		Entertainment Listening to sermons
Solar Powered Shower		None		Saves time. Warm showers are better
Kettle	Heat water on fire	Heat water on fire	Heat water for washing. Boil water for making tea.	Boil water before drinking. Warm water for washing.
Iron	Charcoal iron	Charcoal iron	Charcoal is difficult to get and is smoky.	Charcoal irons are heavy, dirty, not safe, time consuming. Looking neat and smart is important. Saves time compared to charcoal iron.
Lighting	Kerosene lamps or wood fires.	Kerosene lamps	Children can't read and people can't work into the night. Children studying. Able to see to cook and prepare food. Reduce accidents (cooking, snakes). Kerosene is bad for health. Wash clothes and hold meetings at night.	Children studying. Able to see when cooking in evenings so there are fewer accidents Have to buy paraffin regularly.
Computer		Use a cyber cafe in Nakuru.		Research, studying and information finding (medicine, agriculture). Advertise their business, looking for jobs. Typing letters. Watching programs.
Washing Machine	None		To have a laundry business.	
Mobile Charging	Charge during the day.	Charge in the village or at a neighbors house	Want to be able to charge at night Phones are important for: communication with friends and relatives, communication when away from the village.	
Fridge	None	None	To store milk To preserve food.	Vet wanted a fridge for vaccinations. Food storage - saves time shopping, as one has to go less frequently.
Welder	Welding services in the local town		To save time travelling to the local town. To fix farm tools as they are all farmers. To have businesses: fixing bicycles and motorbikes; making iron windows.	
Shaver				To keep children clean

Continued on next page

Continuation of Table VIII				
	Current situation		Why is the service important?	
Service	Lomolo B	Echariria	Lemolo	Echariria
Hairdryer	None	None	For beauty and for starting a salon business.	For looking smart for interviews. To manage their hair. Family members would like it.
Sewing machine		None		For starting a tailoring business.
Incubator	None	None	Poultry farming is a business opportunity.	(E women: includes lighting and heating equipment for chicks post-hatching) Can earn money from poultry farming. Can use the money for school fees. Protein is good for the health.

TABLE IX
SUMMARY OF SVT DISCUSSION FOR COMMUNITY SERVICES, KENYA

	Current situation		Why is the service important?	
Service	Lomolo B	Echariria	Lemolo	Echariria
Health center	No health center in the village, the nearest is in a town 30 minutes away.	There is a dispensary. It has no power, water, fridge, or laboratory. Have to go to local big town for health services. There is a private clinic in a lower village but still cheaper to go to the big local town. Can get painkillers from nearby villages.	Biggest health needs are: maternity, malaria, typhoid, TB, snake bites, gastro-diseases.	Currently have to travel far to access service. There are not enough medicines. Children have to be taken out of the village for vaccinations.
Security Lighting	None	None	(Elders: included police) Moving about safely in the night. Police required to address conflicts about land ownership and access that sometimes occur with people who were already in this area.	(Youth: included police) Theft is a problem. Important for walking around safely at night. Businesses need security to thrive. There is an alcohol problem that makes places unsafe.
Pre-primary Education			Children start learning earlier and parents have more time to work.	
Water	Collect water from a dam, but it is bad quality (also used by livestock). Collected daily by mother and/or children, 1-3 hours. It is not easy to sink wells here as the water table is very far down.	Pump for borehole is broken. Some people get water from the river, collecting daily for $\sim$1 hour, but there is risk of disease (cholera, typhoid) and sometimes it dries up. Some people buy water from others who collect rainwater or have piped water supply.	Clean water is needed for drinking, washing and for livestock. Currently collecting water takes a lot of time.	See left.
Education	There is a primary school but no electricity or facilities. For secondary school children walk far.	Primary and secondary schools, grid electricity but only lighting.	Primary school should have electricity, food, sport facilities. Nursery school would free up time for working. Secondary school required (with laboratories for science, library; dining hall could be used for community meetings). Technical college required for computer training, plumbing, carpentry, masonry, agriculture, tailoring, nursing, teaching.	Children can learn trades to make money. Problem with children dropping out of school, they need to be kept busy. Youth themselves would like more education. Polytechnic, in addition to left list: (driving, welding, mechanics, hairdressing, catering)
Market Place (permanent building with lighting)	Don't have a permanent market building	Don't have a permanent market building	Building and selling produce	Buying and selling produce
Carpentry				
Improved Roads	The community is in the middle of a sisal plantation with bad quality dirt roads to the local town (30 minutes).	Roads to the village are bad: 'Shambles'. Bad in wet weather.	So that people can come in and out easily. To access the health center at the local town. To transport farm produce. To access work opportunities in the local larger town (1.5 hours away). To allow teachers to come in to work at the school. To save time in all the travel they do.	(Women: included an improved bridge, and transportation methods - so represented general access) Required to transport goods. So people can come and go easily. Be accessible for potential buyers and sellers. Travel to big town for business.

Continued on next page

Continuation of Table IX				
	Current situation		Why is the service important?	
Service	Lomolo B	Echariria	Lemolo	Echariria
Welding				Can provide jobs
Crop storage (elevated dry storage space)				
Salon and Barber	None	There are salons in the village but none have electricity		See left.
Community center				Could run business from a community center that had access to computers, TVs.
Irrigation	Rainfall is erratic and not reliable. Droughts are frequent.	Soil is very dry. Water is scarce.	Want to sell excess produce at local town.	Could produce extra food to sell
Grinding Machine (to make flour from maize)	A couple of diesel machines in the village.	Current machines use diesel, or are manual and hard work.		Can provide jobs.
Shave Cutter (makes animal feed)				
Sports Playground	None.		For community sports, and for people to develop sporting talent.	
Bank	None.		Access to a bank account. Access to loans and micro-finance.	
Church	Currently people meet outside underneath trees for church.	None of the churches have electricity.	See left.	Want amplification of instruments and voices.
Tractor and pesticides				
Sanitation		Need safe and hygienic pit latrines, but the ground is rocky, it is difficult to dig latrines.		
Ambulance	None. In emergencies people go on motorbikes to the local town.	None.		
Improved mobile reception	Mobile phone reception is currently patchy.		See left.	
Financial support for the elderly	Currently the elderly cannot access financial support from the state. In the place they lived before being displaced, they were able to access this support.		See left.	
Alternative mobile phone operator				

TABLE X
ASSUMPTIONS MADE ABOUT SERVICES

Service	Electrical products included/ notes	Power estimate	Reference	Infrastructure component?	Additional Complexity?
Torch	Rechargeable	<10W	INFRAY Rechargeable 800 lumens LED Torch		
Radio		2W	Page 190		
Lighting	Assume 3 3W LEDs for household	9W	GRV E27 6-5730 SMD LED Globe Bulb		
Fan		5-20W	Pages 172-174		
Mobile phone charging (household)		5-10W	Nokia AC-60X Universal Fast Micro USB Charger		
TV		8W	Page 191		
DVD player		10W	PANASONIC DVD-S500 progressive scan DVD player		
Computer	Assume mobile network used for Internet connection	30W	Page 168		
Printer		20W	Pages 177-179		
Shaver		10W	Anself Hair Clipper Model: CJ-907		
Security light (household)	Two lights outside house	60 W	MEIKEE 30W LED Motion Sensor Flood Light		
Fridge	For vaccines: For food storage:	50W 45-135W	Dulas solar direct drive vaccine refrigerator VC50SDD Pages 102,109,114		
Sewing machine		30-100W	Pages 144, 146, 147, 150		
Incubator	Depending on size	80W-175W	Pages 36, 38		
Electric cooking/ rice cooker	Assume equivalent to a multi-cooker	900W	Russell Hobbs Multi-Cooker 21850, 5 L		
Rice husking		250-375W	Pages 82-84		
Grinding machine		750W	Page 76		
Shave cutter		2.2kW	Whirlston Mini Chaff Cutter 9ZP-0.4		
Power tools	Assume one tool used at a time.	400W	Page 161		
Kettle		400W-2.2kW	Page 132 LOGIK L17JBS17 Jug Kettle		
Iron		150W-1.1kW	Pages 221,222 ESSENTIALS C12IR13 Steam Iron		
Hairdryer		400W-2kW	Page 227 REVLON Harmony 2000 Dry Style Hair Dryer		
Welding		3.5kW	Trueshopping AC Arc Welder 100 Amp		
Water	Dependent on: location, ground type, water table. (Place in highest power category.)	0.9-1.4kW	Pages 60-62	Possible bore hole, possible pumping over distance, possible filtration/cleaning.	

Continued on next page

Continuation of Table X					
Service	Electrical products included/ notes	Power estimate	Reference	Infrastructure component?	Additional Complexity?
Solar powered shower	Depends on access to water.	As water		As water + additional distribution	
Washing machine	Depends on access to water. Additional for machine.	As water 70W	Page 219	As water + additional distribution	
Household water supply	Depends on access to water.	As water		As water + additional distribution	
Irrigation	Depends on access to water.	As water		As water + additional distribution	
Pre-primary education	Lighting: assume 10 inside lights (30W) and 2 security lights (60W)	90W	See Lighting and Security lighting (household)	Building	Teacher, association with national education service
Market place	Lighting: assume 10 inside lights (30W) and 2 security lights (60W)	90W	See Lighting and Security lighting (household)	Building	
Mobile phone charging center	Assume ∼20 phone chargers	150W		Assume occurs in the solar hub	
Security lights (community)	Assume 6 30W lights around central hub/central street	180W	See Security lighting (household)		
Sports playground	Assume 6 30W lights around pitch	180W	See Security lighting (household)	Sports field	
Health center	Assume vaccine fridge, computers, 20 inside lights, basic medical equipment (200W+), 2 security lights	500W +	See Fridge, Computers, Lighting, Security lighting (household)	Lomolo, Faitang, Baroihati: Building	Trained medical professional, association with national health service
Improved roads (street lights)	Assume 10 30W lights (depends on space to be lit)	300W	See Security lighting (household)		
Education (incl. Religious school)	Computer server for 6 computers (300W), 6 computer monitors (70W), 20 inside lights, 2 security lights	490W	Computer server: Page 169 Computer monitor: Page 168 Lighting: see Lighting and Security lighting (household)	Lomolo, Faitang: Building for secondary school Lomolo and Echariria: Building for polytechnic college Baroihati: Building for primary school	Teachers, association with national education service
Carpentry	Power tools (assume one at a time), 10 inside lights	430W	See Power tools	Building	
Salon and barber	3 shavers, 1 hairdryer (400W), straightener (50W), 10 inside lights	510W	Straightener: GLAMORISER Touch Control GLA023 Hair Straightener See Shaver, Hairdryer, Lighting.	Building	
Community center	Computer server for 6 computers (300W), 6 computer monitors, 1 TV, 10 inside lights, 2 security lights	490W	Computer server: Page 169 Computer monitor: Page 168 Lighting: see Lighting and Security lighting (household)	Building	
Garment factory	Assume 2 industrial sewing machines (230W), range of smaller machines (30-100W), 20 inside lights	800-1.5kW	Industrial sewing machine: page 148 See Sewing machine, Lighting	Building	
Church	Assume speaker (1kW), Miser (55W), 3 microphones (10W), 10 inside lights	1.1kW	Electro-Voice ZLX-12P 12 inch Powered Loudspeaker Yamaha MGP16X 16 Channel Premium Mixing Console Shure BLX24R/SM58 Handheld Wireless System See Lighting	Lomolo: Building	

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