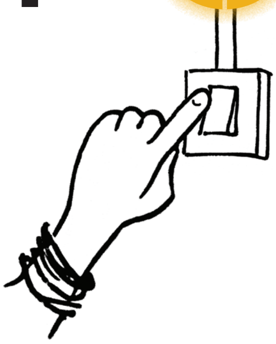
POWER TO THE PEOPLE



Designing a better prepaid solar electricity service for rural Indian villages

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Master of Arts Thesis
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Collaborative and Industrial Design Program

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Doing this thesis has been a challenging and insightful experience. There are hardly more rewarding things to a designer than the possibility to work with a new technology that can have such a major impact on people's lives.

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/ ABSTRACT

In recent years, frugally-designed solar microgrid electricity services have emerged to meet the need for affordable, reliable electricity services in rural India. However, despite the life-changing benefits of these services and overall customer satisfaction, uptake remains lower than expected. This thesis investigates this phenomena from a human centered design perspective, to examine the role design can play in improving the long-term sustainability of these services.

The research question is investigated through a case study of one such service, operating in four rural villages in Uttar Pradesh, Northern India, using a field-based constructive design research approach. One of the key foci is the system's accessibility by differently-literate users. Through a process of field-based redesign and prototyping of the system's meter, the thesis provides concrete technological recommendations for addressing accessibility challenges and supporting well-informed energy use decisions. Engagement in this process, along with contextual interviews and observation in the field, led to deeper understanding of everyday energy use issues and concerns of the people, and implications for implementation of microgrid services. Insights and findings are presented with textual and visual narratives to illustrate the daily lives of the participants in relation to the village and household energy context.

The research found that a combination of competing energy sources, extremely cost-conscious consumers, accessibility challenges for differently-literate users, and a preference for better suited lighting products hindered uptake of the microgrid service. Based on these insights, four service design improvements were developed to a design proposal phase. They include the meter redesign, a capacity-building program for the service's entrepreneurs, an account notification text messaging service, and a rechargeable electric lantern.

The thesis includes a discussion of a number of wider systemic considerations in the energy context that influence how rural households relate to and use energy, which are beyond the purview of design to directly influence at the village level. Addressing these will require systemic changes, such as policy reforms, economic development and behavioural change in order to ensure the long-term viability of prepaid solar electricity services. While design alone cannot solve all the challenges facing these services, it can make a valuable contribution to their introduction, enjoyment and long-term sustainability, and thereby significantly improve the lives of the many currently underserved rural Indian villagers.

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01

INTRODUCTION AND BACKGROUND

The first chapter gives an introduction to the thesis topic and its context. It briefly introduces the Indian energy context and the challenges to prepaid electricity services in rural India. This chapter also sheds light on previous research and positions the role of constructive design research in the thesis. It then opens up the research questions and objectives of the thesis. In addition, the thesis process is described including an outline of the structure, aiding navigation through the research and its findings. Next, background on energy service provision in rural villages is provided in a description of the study setting and an overview of solar microgrids and their frugal innovation. Included here is a comparison of prepaid electricity services to enlighten the reader on the characteristics of these services.

1.1/ CHALLENGES TO ELECTRICITY SERVICES IN RURAL INDIA

Access to reliable electricity is an on-going problem in India, particularly in rural areas. While there has been improvement over the last decade, with India leading in global electrification, in 2014 the International Energy Agency (IEA) reported that 240 million people in India (20% of the population) lacked access to electricity (IEA, 2015). The World Bank's figures for 2016 are a slightly lower, estimating that 205 million Indians live without electricity1. Both the IEA and World Bank report that the large majority of the electricity-deprived reside in poor rural areas where extending electricity services poses greater technical and economic challenges for service delivery by utility providers. This lack of access leads many rural dwellers to pro-actively seek their own energy supply rather than relying on government. This is problematic because obtaining many of these energy sources is expensive (e.g., market-priced kerosene) and inconvenient (e.g., travel for pay-per-charge batteries). In addition, many come from environmentally damaging and physically harmful fuels, namely kerosene, diesel, or firewood (Numminen & Lund, 2016). Meanwhile, innovation in renewable energy generation is growing, and solar powered electricity is becoming a viable solution to India's pressing energy access problem (REN21, 2015). In the context of rural electrification in India, increased battery capacity and a decrease in the cost of solar technologies has led to a variety of affordable off-grid energy solutions.

A rural electricity solution that is gaining ground is the solar microgrid (SMG). SMGs distribute electricity generated from a local rooftop installation to multiple dwellings in a village. A common business model for energy distribution from SMGS is a prepaid electricity service. The SMG system and prepaid business model are a "frugal innovation" (Radjou & Prabhu, 2014) designed to provide affordable electricity to customers through small, incremental cash payments similar to popular "pay-as-you-go" mobile phone services. With this development, prepaid electricity generated from a microgrid offers an attractive alternative to the costly and harmful energy sources commonly used in rural India.

This thesis focuses on a particular SMG prepaid electricity service offered by Boond Engineering (Boond). Boond has installed 27 SMGS in unelectrified rural villages in Uttar Pradesh. The central SMG infrastructure is hosted by a local agent, referred to as an "entrepreneur", who also sells prepaid credits to customers. Delivery and consumption is monitored by electricity meters in the customers' homes.

Boond faces several challenges to the business viability of the SMGS on the

1/ According to The World Bank online database, 15.5% of India's population of 1.324 billion lack access to electricity. Sources: data.worldbank.org/country/india; data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=IN.

customer side. A key challenge is bridging the gap between the cost of electrification, which is the cost of infrastructure and maintenance, and affordability for end users. Batteries need to be maintained at a minimum 50% charge to prevent long term damage and costly replacement; therefore managing demand is crucial to affordability. In addition, despite the life-changing impacts of electricity, household consumption remains lower than expected, thus impacting Boond's profitability and the long-term viability of the prepaid service.

To address these challenges, Boond designed and manufactured a new and improved meter that manages dynamic pricing based on battery supply and customer demand. One of the key features of the dynamic pricing is it encourages customers to utilise higher energy consuming appliances (fan and TV) by charging a discount price for their use. Dynamic pricing also adjusts to charge customers a normal price when supply is high, and penalises customers with a premium price when supply is low to discourage use and preserve supply. As a result, this new meter plays a greater role in influencing customer behaviour than the more basic, earlier meter models. Thus, there is greater emphasis on the design of meter-customer interactions and how the meters influence behaviour and the overall service experience.

1.2/ RESEARCH ON PREPAID ELECTRICITY SERVICES

There have been a number of studies on Boond's products and services in recent years. These previous studies have been conducted mainly from business sustainability, economics and engineering perspectives (D'Agostino, Lund, & Urpelainen, 2016; Numminen & Lund, 2016; Urpelainen & Yoon, 2016) using quantitative methods, such as surveys, computer systems monitoring and literature reviews. Consequently, a solid body of knowledge on the system performance, business viability, and technology innovation has been developed. Nevertheless, although the previous studies touched on some of the social aspects of the service, they have not investigated individual customers and their daily interactions with the meters. Given the rising prominence of the meter's role in influencing uptake of the service, there is a lack of design-oriented studies – specifically information, service and interaction design – that investigate the people and the context that the service takes place in. As a consequence, the effectiveness of the dynamic pricing is unclear and the behaviours relating to electricity consumption remain elusive. Field based design research, which observes and interacts with people in the environments where they live and work through a design lens, is the ideal method to conduct these studies (Koskinen *et al.*, 2011).

"The aim is to turn fieldwork into an exercise of imagination rather than mere data gathering."

[Koskinen *et al.*, 2011, p. 76]

In contrast to highly structured quantitative methods and large sample sizes, design research focuses on small sample populations and its methods are exploratory, interactive and generative in nature. Working with these methods deepens the researcher's understanding about people, their needs, thought processes and behaviours through first-hand experience (Fulton-Suri, 2003). In particular, ethnographic design research is undertaken to gain specific understanding of the value that customers derive from a product or service through immersion in the everyday, direct, and indirect, interactions of customers with the service (Stickdorn & Schneider, 2010). These kinds of investigations inspire and fortify designers to create valuable insights that inform innovation and on-going service development (Van Dijk, 2010). Thus, in this thesis, design research is an integral part of a longer design process with an ultimate goal to design a better prepaid electricity service for people in rural India.

1.3/ OBJECTIVES AND THESIS RESEARCH QUESTIONS

This thesis sets out to investigate the meter's role in uptake of the service by conducting qualitative, field-based design research. By employing qualitative modes of inquiry, I attempt to understand the daily lives of Boond's customers, their relationship to domestic energy consumption and their interactions with Boond's prepaid electricity service. This will be undertaken and demonstrated by using contextual interviews, experiments with design props in the field, and visual/textual narratives to become informed about the daily lives of Boond's customers, their relationship to domestic energy consumption and their interactions with Boond's prepaid electricity service. The spirit of my work in reaching this goal is best summed up by the following quote from Jane Fulton-Suri (2003, p.54):

> *Through observation, we become informed, and through empathy, the human connection, we are inspired to imagine new and better possibilities for people.*

The resulting insights from the inquiries will inform opportunities for design. These opportunities will be addressed in a further research and development process to conclude with a design proposal for improvements to the electricity meters and on-going development of SMG prepaid electricity services.

The main research question of this thesis is:

/ *How might Boond's prepaid service be improved so that it brings more value to customers and also increase uptake?*

The main research question is supported by the following guiding research questions:

/ *How do customers interact with and become informed by the prepaid metering system?*

/ *How do customers value and use the prepaid electricity service?*

The main contribution is to demonstrate how field based constructive design research and its methods can support development of SMG prepaid electricity services.

1.4/ RESEARCH PROCESS

The study began in September 2016, spanning over one year of design research desk research, literature review and field work. The first six weeks was used to familiarise with the wider themes of energy poverty and electricity for development and delve into literature on solar-powered electricity services relating to Boond's case. The initial brief was formed in October 2017 followed by a one month process of planning and preparation for a field research trip to India in late November 2016. This involved developing a research plan, preparing materials and equipment, coordinating logistics, and securing professional field support services.

Next, a 10-day trip field research trip to India was made. The field research in India was informed by constructive design research (Koskinen *et al.*, 2011), an approach that emphasises constructing knowledge through design practices such as interacting with people, making things, experimentation, creating and using visuals to communicate ideas. In a field context it emphasises first-hand experience over fact-finding. Four villages were visited on long day trips which involved house visits, interviews, interactive props and observation. In-field analysis and synthesis of the day's findings followed in the evenings.

Following ten days of field research in India, a formal analysis and synthesis process took place from January to May 2017. This was carried out using multiple methods such as affinity mapping, customer stories and visual review of images from the field gain an understanding of the data. This was complimented by desk research and literature reviews when needed. The findings were presented in a joint-session with the Aalto University partners. Next, a further round of affinity mapping resulted in several design opportunities for idea generation. After a summer break the solution phase began and continued until early 2018, concluding with research and development of four design improvements to the service.
The process is shown in Figure 1.

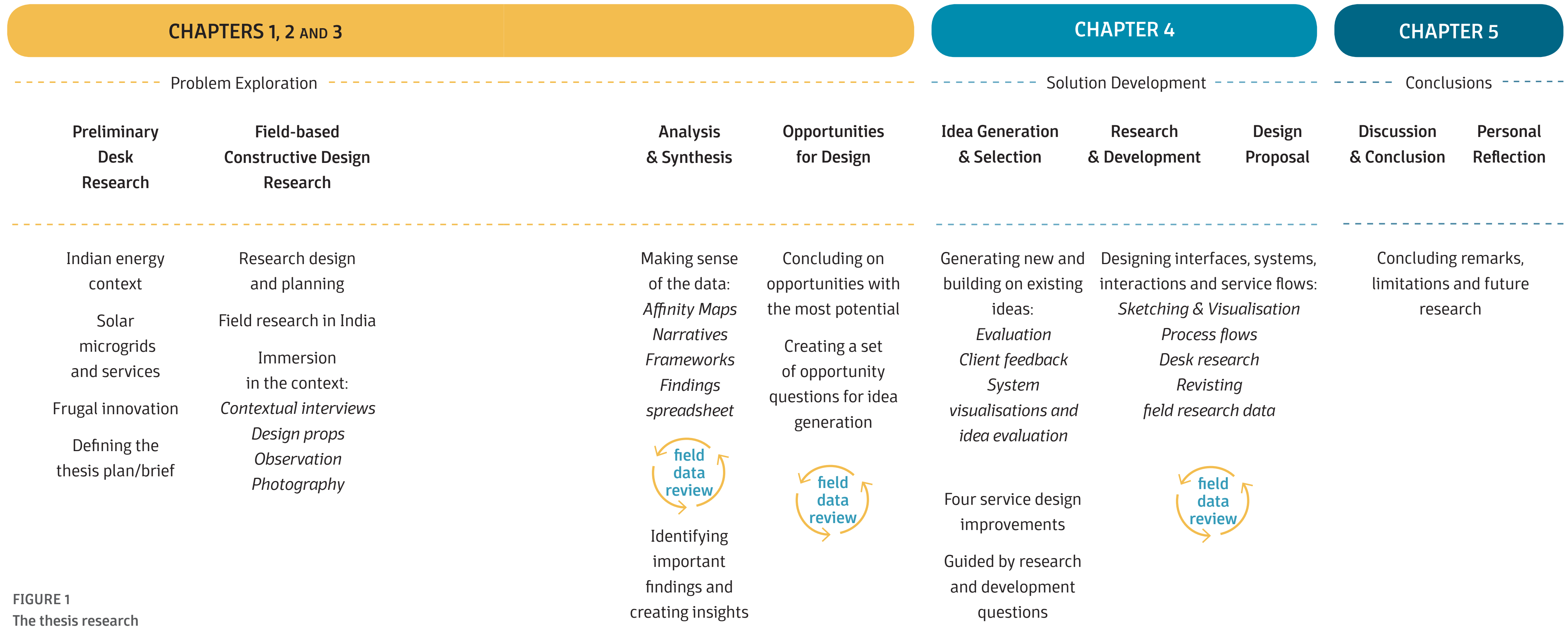


FIGURE 1
The thesis research process and book structure.

1.5/ STRUCTURE OF THE THESIS

The thesis is structured into five chapters. The first chapter introduces the reader to the thesis topic and sets the tone for the rest of the thesis. First, it introduces the energy context in India and outlines the need for design research, followed by the goals of the thesis, its research questions and the research process. An overview of the study setting is given to familiarise the reader with the context. Next, the background on the thesis topic is provided with an introduction to microgrids and Boond's prepaid service and its operating context. Solar-powered electricity services are put into perspective by benchmarking three service providers, followed by an introduction to "frugal innovation" and its relevance to the Boond service.

Chapter three provides a thorough description of the research methodology. It introduces constructive design research and design ethnography and their application in field research. The field-based research methods are described in detail touching on the participant protocol, logistics and provides a glimpse in to the daily routine of the field trip. To close, an overview of the analysis and synthesis methods is provided.

In Chapter four the fieldwork conducted in four villages in rural India is documented. The findings and insights are presented, including participant stories and visualisations. Topics emerging from the data are related to Boond's service and the meter design. The chapter concludes with a summary of opportunities for design to be carried forth to the solution phase.

Chapter five focuses on the output of this thesis, design proposal. The idea generation and evaluation process is briefly described before a more detailed presentation of a design proposal addressing improvements for the service. The chapter closes with description of how the solutions relate to the main service actors.

Lastly, chapter six concludes the thesis by discussing its purpose, objectives and contributions. It brings up the limitations as well as the possibilities of future research. The chapter closes with concluding thoughts on the overall thesis experience from a personal perspective.

1.6/ THE STUDY SETTING IN RURAL INDIA

The study takes place in four villages in Unnao district, a region populated by 3.1 million people in Uttar Pradesh state. According to Census India 2011 data, the majority of households in rural Uttar Pradesh are without an electricity connection. Although in some areas infrastructure has been in place for years, households are yet to be connected. Chronically unreliable and unaffordable service and distrust of energy providers discourage people from pursuing a connection (Jain *et al.*, 2015).

In 2016 Boond installed microgrids in 27 non-electrified villages around Unnao district. Each microgrid has the capacity to serve 40 households. At full capacity the 27 microgrids are capable of providing basic electricity to 1080 households and hold the potential to impact the lives of over 5900 people in these 27 villages.

VILLAGE POPULATION & CONNECTIONS

Village population, number of dwellings and number of microgrid connected households (Boond subscribers):[2]

Aanth	305	61	37
Dhaukal Kheda	345	69	30
Khatrin Kheda	385	77	28
Pasintola	380	76	32

2/ Approximate village household numbers in January 2017, provided by Boond Engineering and are based on an average household size of 5.5 inhabitants.

Literacy rates for the study area are worth mentioning because low textual literacy presents many daily challenges to the rural poor that go beyond basic reading and writing. Numeracy, and digital literacy (how information technology is accessed, understood and used) is also impacted.

This has implications for design of the electricity meters and communication of energy use information. To understand the scope of literacy, the following numbers provide an overview:

/ The population of the Unnao District has a literacy rate of 66.4%. This is slightly below the state average and well below the national average of 74%.
/ Literacy rates for the four villages[3] in the thesis study are reported lower than the Unnao average ranging from a low of 47% literacy in Khatrin Kheda to 59% in Aanth.
/ On average women make up less than half, around 40%, of the literate population in the villages.

The majority of the Unnao population live in rural farming areas, making agriculture the main industry and source of employment. As is the case in many poor, rural areas, incomes fluctuate throughout the year, influenced by the agricultural cycle and seasonal work. In both rural and urban areas of the district roughly a quarter of the workforce is employed in vocations such as the civil service or labour in the many factories (Census of India, 2011). Based on findings from this thesis research and Boond estimates, household incomes in the study villages fluctuate from 6-12,000 rupees (Rs.) per month. For context, the lower amount works out to €2.63 per day, which is just above The World Bank poverty line of €1.60. A social scientist with Boond described the financial situation in the villages as, "people earn enough to sustain themselves at a basic level".

3/ Literacy data from the 2011 India census was not available specifically for each village in the study. Figures are derived from data for a larger sub-regional cluster that includes several neighbouring villages.

Scenes Dhaukal Kheda and Pasintola, two villages in the study.

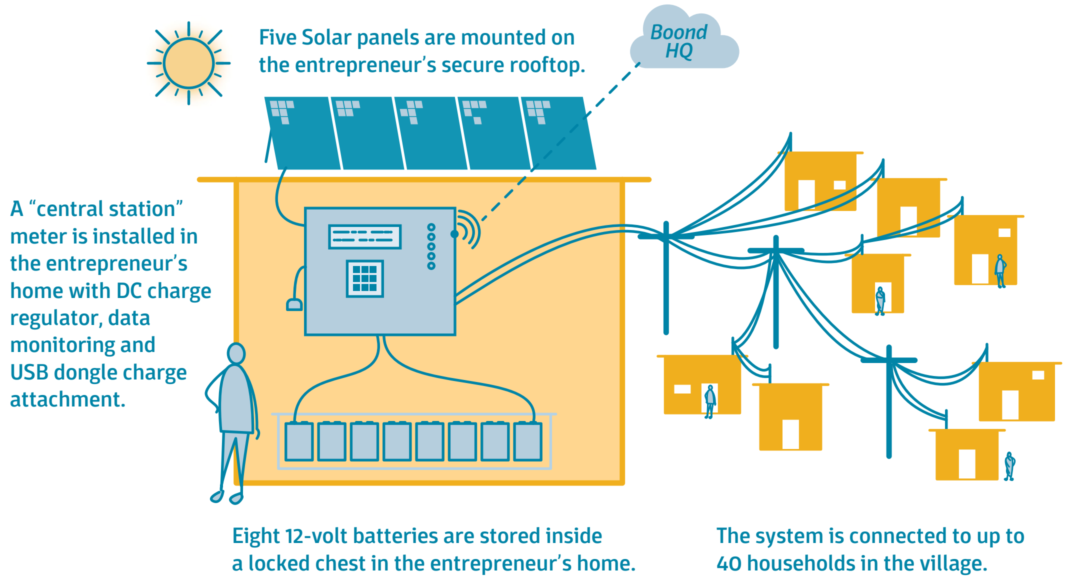


FIGURE 2
The Boond Microgrid system.

1.7/ SOLAR MICROGRIDS AND THEIR FRUGAL INNOVATION IN RURAL INDIA

An SMG is a discrete energy system consisting of distributed energy sources (including storage, and generation) and loads capable of operating in parallel with, or independently from, the main power grid. SMG plant capacity usually ranges between 2-10kW. This capacity allows for 5-8 hours of basic lighting, mobile charging, and sometimes one or two small appliances for up to 100 households per plant. SMGs consist of power generation ("PV" photo voltaic panels), storage (12 volt acid batteries), distribution, and controls such as voltage regulation and switch gears. Like traditional electrical grids, microgrids consist of power generation, distribution, and controls such as voltage regulation and switch gears. However, microgrids differ from these grids by providing a closer proximity between power generation and power use, thus, resulting in increased efficiency and reduced loss during transmission.

Boond's village SMG distributes electricity generated by a single rooftop solar PV installation to multiple nearby dwellings. Currently, Boond's 5 kW system delivers DC current for basic electricity needs for up to 40 dwellings in a village. The system may be expanded to serve a greater number of homes if warranted by demand. The Boond microgrid system is illustrated in Figure 2.

The solar installation at an entrepreneur's dwelling is connected to homes by transmission cables and includes a central station meter which communicates wirelessly to Boond headquarters in Delhi. Energy supply is stored in a bank of eight DC batteries.

From the standpoint of a customer, the benefits of microgrid over their other energy options, including an SHS, are that infrastructure costs are shared by many. This affords robust and high quality equipment which provides reliable electricity and bright light from high efficiency LED bulbs. The equipment is maintained and serviced locally by the entrepreneur and consumption is metered by the watt hour, meaning customers only pay for what they consume. Compared to grid electricity service in rural

STATE ENERGY PROVIDER		CONSUMER OWNED	PRIVATE COMPANY
Carbon		Solar	
Post-paid Electricity	**Kerosene**	**Solar Home System**	**Boond Prepaid**
Provided by State energy utility	Monthly 1 litre State subsidy coupon	Privately owned	Installation fee
Monthly flat fee for unlimited use	Bought from Public Distribution System supplier/shop	Bought outright, micro loan or NGO program	Pay-as-you-go
		Consumer maintains equipment	Entrepreneur maintains and facilitates

FIGURE 3
Four common models of "electricity as a service" in India.

Uttar Pradesh, which is renowned for blackouts and charged by a monthly flat fee, the prepaid service offers a reliable, flexible and affordable electricity supply. However, there are limits to the microgrid power supply. High wattage appliances such as a fridge and a conventional TV are not supported and demand can outstrip supply in certain conditions, thus, leading to blackouts.

For reference, an overview of the four common models of electricity (or lighting) as a service and their relation to the provider and energy source are described in Figure 3.

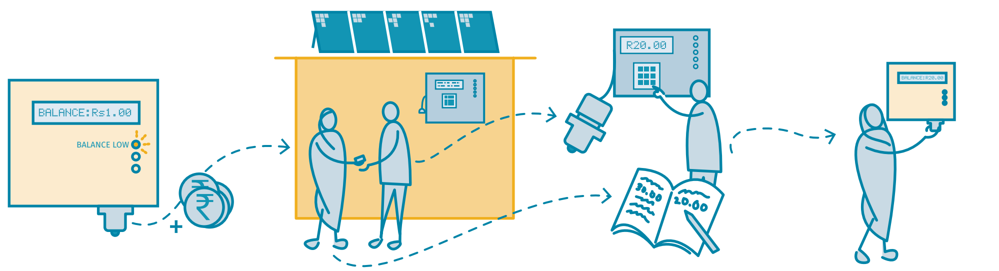
1.8/ SOLAR MICROGRIDS: AN ALTERNATIVE TO THE SOLAR HOME SYSTEM

SMGs are an alternative to an already popular electricity solution in rural India: the privately owned SHS. It is important to discuss the SHS in relation to Boond's prepaid service because many Boond customers own, and continue to use, an SHS. However, despite their popularity, the SHS has its drawbacks.

An SHS mainly consists of a solar panel, storage battery and, depending on the power capacity, usually includes one or more lighting fixtures, outlets and possibly a fan and TV. An SHS is commonly bought outright through a bank loan or a micro financing scheme through an NGO. For many these upfront costs and/or instalment payments present a barrier to entry. Furthermore, the quality of SHS components varies greatly. Urpelainen (2016) reported that most of the SHS in his study, "... are inexpensive Chinese products with a short lifespan and no warranty or maintenance" (p. 537). As a result, these low quality systems have failed to live up to the promises of vendors, in turn, leaving customers dissatisfied and cynical of the product. Another issue is that in dusty settings, common in rural Uttar Pradesh, solar panels demand regular cleaning to obtain the best results and batteries require maintenance and replacement to ensure reliable supply. Unfortunately, maintenance does not occur as frequently as it should, or at all, leading to poor performance and/or break down. Consequently the SHS, while fulfilling a basic need, remains an infeasible solution for many. By contrast the microgrid provides electricity as a service. Customers do not have to maintain the system or pay heavy up front costs. Due to its high capacity and quality, a microgrid also provides a steady, reliable supply of electricity. With the potential to connect to the grid and participate in a more stable distributed energy network, the microgrid offers an attractive alternative to the privately owned SHS.

1.9/ HOW THE PREPAID SERVICE WORKS

Affordable prepaid mobile phones have played a key role in making modern communications accessible to those with meager and unpredictable incomes. Boond's prepaid service works much the same as the prepaid model popularised by mobile phones: a



The indicator lamp flashes a warning that the balance on account is low.

The customer removes the dongle and takes it with cash to the entrepreneur.

The entrepreneur connects the dongle to the "central station" meter and adds credit while the customer records their purchase in the accounts ledger.

The customer returns home with the recharged dongle and inserts it into the meter. The power supply resumes.

FIGURE 4
The recharge process.

customer buys the phone, but the phone does not work unless he or she buys airtime. In the case of Boond's prepaid service model customers register and pay a flat fee (500 Rs. for a 20-watt system, 1100 Rs. for 60-watts) to have the electrical hardware and a meter installed in their home. The hardware includes two high efficiency 3-watt light bulbs, a 5-watt light tube, a charging outlet and the 60-watt system supports high efficiency DC appliances such as fan and TV. Customers then buy electricity credits to activate electricity supply. Credits are bought in cash from the entrepreneur. The entrepreneur uses the system's central electricity meter to transfer digital credits to the portable meter "dongle", a or USB stick, the customer then plugs the recharged dongle into the electricity meter in the home. The recharge process is illustrated in Figure 4.

In the service credit is deducted from the balance as electricity is consumed; customers only pay for what they consume and there is no expiry on the credit. From the entrepreneur side, they order credits from Boond at a 10% discount. These credits are digitally transferred to the entrepreneur's central station account. Boond collects cash payments from entrepreneurs once a month. Cash transactions are an important aspect of the service because many rural dwellers lack access to banks, are often paid in cash and they are accustomed to physical, cash transactions.

1.10/ COMPARISON OF THREE PREPAID ELECTRICITY SERVICES

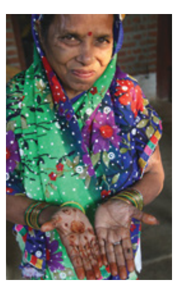
Boond is one of several key players providing prepaid solar electricity in Uttar Pradesh. Two main competitors, Simpa Networks and Mera Gao Power, have established prepaid services in rural areas in the state during the past five years. Like Boond, each company has developed its own technology and processes to serve the rural energy market in particular ways. Table 1 distinguishes the main characteristics of each of the company's services so that they may be compared.

Simpa Networks offers an SHS lease to own model using its proprietary Progressive Purchasing technology. This technology is composed of an integrated hardware component (the meters) plus a centralised cloud-based software system to manage accounts and payments. Customers use their mobile phone to buy prepaid "clean energy days" which include payback for the SHS and consumption. Once the SHS is paid in full, usually after 12-36 months, the system is unlocked and free to operate. Simpa partners with a third party SHS provider, Selco Solar Energy, and hires local representatives for sales and servicing.

Mera Gao, on the other hand, installs and maintains a microgrid serving 20 households in a village and sells prepaid energy by the week. A local representative makes weekly collections in the village at a predefined time. Each cash payment is collected, transferred to an App, and then confirmed to the customer by text message and a paper customer account book. Mera Gao prides itself as the "lowest cost microgrid in the world".

Of the three companies profiled, Mera Gao's system serves the most basic electricity needs with two LED card lights and one mobile phone charging point at a flat fee of Rs. 30 per week.[4] Simpa, by contrast, has a higher cost to entry with a 10-30% down payment on a system costing in the range of Rs. 10k - 26.6k (depending on kit capacity), and minimum payments of 50Rs. per week. The SHS includes standard LED bulbs and tubes. Some kits provide a fan or even a "Magic TV" service that provides a high efficiency monitor with access to satellite TV channels to meet needs beyond basic electricity access. This puts Boond in the middle, balancing a one-time installation fee with flexible, incremental payments to satisfy basic electricity needs.

MEET THE ENTREPRENEUR



Fulan Devi is a Boond entrepreneur in Aanth village. She hosts and maintains the solar installation on the rooftop of her family home. Motivated by her desire to develop local prosperity, she was instrumental in bringing the electricity service to her village. Fulan runs a small kiosk where in addition to selling prepaid electricity credits she stocks snacks, beverages and toiletries.

4/ The exchange rate was Rs. 76 to €1 in November 2017. Rs. 30 is equivalent to €.39. The daily cost of electricity would be Rs. 5-6, or based on a minimum €2.34 per day income, represents 2.35% of daily income. To put this expenditure in context, a 2014 survey of unelectrified households in Uttar Pradesh (Urpelainen, 2016) reported mobile phone battery charging expenses were between Rs. 5-8.3 per week.

TABLE 1
A comparison of three prepaid solar-powered electricity companies.

	MERA GAO	BOOND	SIMPA NETWORKS
SIGN UP COST	None	One time installation fee: Rs. 500, 20w meter; Rs. 1100, 60w meter	10%-30% down payment on system cost ranging from Rs. 11,250-30,000
BUSINESS MODEL	Subscription, Rs. 120 per month. Company owns equipment	Prepaid credit, no fixed minimum. Company owns equipment.	Prepaid credit Lease to own contract Licensing "progressive payment" platform to energy suppliers.
SYSTEM	Microgrid	Microgrid	Solar Home System
PAYMENT PLAN	Weekly collection fixed at Rs. 30	"Pay-as-you-go"	"Energy Service Days" prepaid 1 month in advance. Rs. 50 minimum
PURCHASE SYSTEM	Weekly in-person cash collection. Proprietary App sends customer SMS with activation code.	In-person cash payment to local Boond entrepreneur. Credits transferred via USB dongle.	In-person cash payment to authorised agent. Agent processes with mobile pay, provides customer with activation code for redeeming credits.
ENERGY ACCESS	Pre-set time, evenings only	24/7	24/7
CONSUMPTION UNITS	Unlimited, during evenings (sunset-late)	Per watt hour	Unlimited, per day
APPLIANCES	1 charging outlet, 2 LED light strips	1-2 charging outlets, 2 3W LED bulbs, 1 5W LED tube.	Varies depending on SHS size: 1-4 LEDs or CFL tubes, lantern, fan, TV.

1.11/ FRUGAL INNOVATION

Boond's prepaid electricity service was designed and developed using a frugal innovation approach. This approach has been a main consideration in the underlying principles for the design and engineering of the system, as well as a design driver in the proposal chapter of this thesis. Therefore, it is important to introduce frugal innovation and describe its qualities in context of the Boond's prepaid service.

In India, frugal innovation stems from "jugaad", a colloquial term which roughly translates as a "hack", an innovative fix or resourceful workaround. The authors of *Jugaad Innovation* (Radjou, Prabhu, & Ahuja, 2012) refer to the practice of "doing more with less" as a main principle of frugal innovation processes. Jaideep Prabhu (Innovators: The Secrets of Jugaad, 2017), attributes this to the fact that there are, "huge unmet needs in key areas like financial services, education, health and so on", adding that a lack of easy market access to solutions mean people have to "devise using their ingenuity ... often using very limited resources". As a result, he continues, citizens and companies "have become adept, even ingenious at making do, doing more and better with the limited resources they have around them to solve their problems." (ibid., 5:10-5:50)

Recently frugal innovations have emerged to address the poverty gap and a lack of access to new technologies. Frugal innovations overcome these problems to provide novel products and services to low-income earners at an affordable price (Numminen & Lund, 2016). The frugal approach to solving daily problems has been transferred into commercial products and services in many sectors, for example Kenya's M–PESA mobile phone payment and money transfer system, the Mitticool clay refrigerator, the Aum Voice prosthesis, amongst many others.

In terms of the frugal innovation in the energy sector, Numminen and Lund (ibid.) found that the key frugality aspects were "affordable energy services and a simplified technology design". They elaborated a set of criteria for frugal and sustainable energy innovation. These are: frugal design and manufacturing, affordability, local appropriateness, environmental sustainability, frugal energy use patterns (see Table 2).

Using the above criteria as a framework, the frugal innovation in Boond's service (in blue) is elaborated next to Numminen and Lund's criteria (in yellow) in the following table, thus, offering an overview of the main frugal characteristics of the prepaid service.

This background on frugal innovation in the prepaid electricity service brings chapter one to a close. This chapter has introduced the Indian electricity context and challenges to prepaid electricity services in rural India. The need for qualitative field research to better understand the people and context of use was introduced and the thesis questions, objectives and process were outlined. The background of the study setting, followed by an overview of SMGs and their frugal innovation in the rural Indian context were described to paint a picture of the rich and complex nature of the energy provision in rural villages. The next chapter will elaborate on the research methodology.

MAIN CRITERIA	COMMENTS	BOOND'S PREPAID SERVICE
FRUGAL DESIGN AND MANUFACTURING	Minimal use of resources Simplified design Durability	- Meters and household infrastructure are manufactured with minimal resource usage, and assembled from inventory that is readily available on the market. - Meter and lighting system are simplified, their rugged design and assembly is optimised to withstand local conditions (heat, dust, humidity) - Components may be easily replaced and upgraded
AFFORDABILITY	Low-cost product Provision of a more affordable energy service	- Low sign up fees - Pay-as-you-go model - Infrastructure costs are shared by all customers. - The dongle innovation harnesses an existing social network to physically transfer data, avoiding costly data fees.
LOCAL APPROPRIATENESS	Socially fit for local user preferences Skills available for operation and maintenance	- Locally hosted - Entrepreneur or other local skilled personnel maintain the solar panels and the battery unit, thus creating local employment. - Harnesses existing social networks - Face-to-face purchases in cash is local custom.
ENVIRONMENTAL SUSTAINABILITY	Use of local renewable energy sources Recycled materials Avoiding harmful substances	- Solar power is a local, renewable and clean energy source. - The microgrid infrastructure is shared by many which optimises the resources, and diminishes demand for individually owned SHSs.
FRUGAL ENERGY USE PATTERN	Efficient energy use and behaviour Modest energy output level	- The prepaid, pay-as-you-go model enables modest power consumption to cover basic electricity needs. - Dynamic pricing encourages energy conservation at times of energy shortage.

TABLE 2
Criteria for frugal and sustainable technologies providing energy services from Numminen and Lund, (2016), augmented with the main frugal characteristics of Boond's prepaid service.

02

METHODOLOGY

This chapter covers the research methodology. In the first section, the constructive design research approach is introduced. This is followed an introduction to design ethnography and a description of the ethnographic techniques applied in the field research. Next, the participants and local context are introduced followed by an outline of the field research process and related practicalities. The chapter closes with an overview of the methods used to analyse and synthesise the data from the field research.

> *"When researchers actually construct something, they find problems and discover things that would otherwise go unnoticed. These observations unleash wisdom, countering a typical academic tendency to value thinking and discourse over doing."*
>
> [Koskinen *et al.*, 2011, p. 2]

2.1/ FIELD-BASED CONSTRUCTIVE DESIGN RESEARCH

For this thesis I employed a mix of constructive design research methods to gather, analyse and synthesise the data which informed the resulting design insights. Constructive design research combines design and research to imagine and build new things, be they systems, services, spaces and products. It is used as a form of inquiry and to construct knowledge through making and testing designs. It is oriented towards understanding and redefining problems not just solving known design problems (Koskinen *et al.*, 2011).

My work made inquires into people's attitudes, perceptions and practices around energy use and how it is consumed, monitored and managed, to better understand the relationships between people, technology and the service. Primary ethnographic research was conducted in the field, followed by analysis, synthesis and design explorations to further make sense of the results. This sense making was supported by literature reviews of the energy and social contexts that were called to attention in the data analysis.

2.2/ DESIGN ETHNOGRAPHY

Ethnography is a research methodology that originates in the social sciences, namely anthropology and sociology. Ethnography in design emerged in the 1970s with the rise of computer development at Xerox Palo Alto Research Center, followed by the likes of Apple and Intel. Since then, the practice has become established, is used by academic and industrial and design organisations worldwide, and is now commonly referred to as 'design ethnography'. Van Dijk (2010) defines design ethnography as "ethnographic qualitative research set within a design context" (p.109). Van Dijk emphasises that design ethnography employs proven tools and techniques that go beyond solely observing participants. Collaborative activities are designed to directly engage the participants in the design process, prototypes and mock-ups are introduced and analysis methods are used for inspiring insights and design solutions. Furthermore, participants in the research may not necessarily be the user, or customer, of the service but could be other relevant actors or stakeholders in the service. This is done to gather a holistic picture of the service ecosystem.

Design ethnographers seek to identify with participants in order to build understanding of their practices, routines and values. They take the point of view, or standpoint, of the participants, using their language, concepts, categories and opinions to shape the research. Crabtree, Rouncefield and Tolmie (2012) emphasise that positioning designers to work from the perspective of the people they are designing for allows them to "factor the real world, real time organisation of human activities into design" (p. 2). Design teams then apply this understanding to inform and inspire design processes, to understand user needs and to evaluate systems and services.

The design ethnography techniques that were used are described next:

CONTEXTUAL INTERVIEWS

The contextual interview is a design ethnography method that allows researchers to simultaneously observe and probe the behaviours of interest in the environment where they actually occur (Stickdorn & Schneider, 2010). This method is beneficial because when participants are in a familiar environment they are prompted to remember details that might otherwise be lost in another setting. Immersion in the setting also allows researchers to observe and act on physical and unspoken cues. Stickdorn and Schneider emphasise this is important because, "what people don't say is often as valuable as what they do". (p. 163) Immersion also helps to deepen understanding about the context in which the subject of the design research occurs in a way that is not possible with traditional interviewing.

The contextual interviews in my field research began with prepared questions (See Appendix A). Prepared questions anchor the interview to the topic and act as a checklist for gathering required data. However, they are a guide and should not hinder following the participant's lead when interesting topics arise. While the researcher's attitude is "everything is interesting", interviews may drift off topic, therefore, it is important to recognise when to redirect the conversation so that time is well spent in the field.

In relation to contextual interviewing within the scope of my field research, we asked participants to demonstrate how they read the meter and to describe how they use electricity in the home. While the interview progressed, observations in the household environment prompted new questions. The participants' responses introduced novel topics into the discussion and triggered impromptu demonstrations around the home.

PAIR INTERVIEWS

When presented with the opportunity to interview two people, usually a married couple or parent and child, questions were modified to leverage the relationship between the two participants. This prompted discussion about their daily roles and routines around energy use.

OBSERVATIONS

Observation sessions usually took place during short breaks between interviews, and occasionally led to ad-hoc interviews. They provided insights into the larger village context.

AD-HOC INTERVIEWS

These were conducted in the villages and sometimes on the street, notably a pre-paid airtime kiosk worker and a solar panel appliance vendor. These would last anywhere between 3-5 minutes.

EXPERT INTERVIEWS

The first day of research involved a visit to the Boond headquarters in the city of Unnao. Interviews included an introduction to the local context and the prepaid service accompanied by a demonstration of the household meters and lighting appliances. During the field research I conducted several semi-structured interviews with the Boond team. Numerous follow up interviews were made by video call over the course of the research process.

"Shadowing provides an intimate understanding of the real-time interactions that take place between the various actors and touchpoints involved."

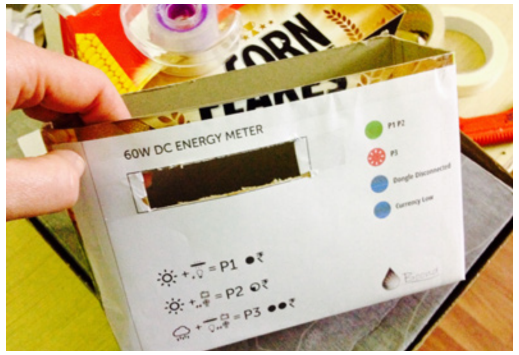
[Van Dijk, 2010, p. 156]

SHADOWING

I followed members of one household through the recharge process in order to observe the behaviour and experiences related to the activity. Shadowing began from the moment the dongle was removed from the meter, followed through to the payment and recharging at the entrepreneur's home, and then back home where the dongle was inserted into the meter. This enabled direct observations of the sequence of events and the interactions and transactions between people and the metering technology. It also helped to identify where problems occur in the process. The process was documented by video.

DESIGN PROPS

Design props were made to explore ideas and engage participants early on in the process. Not to be confused with a prototype, the props were a kind of low-risk physical sketch rather than an instrument for refining or testing a design. Buxton (2007) emphasizes that sketching at the early stage of the design process "enables ideas to be explored quickly and cheaply" when investment in the design idea is low (p.138). As such, the props were quickly built from a discarded cereal box and spare mobile phone – materials that were readily at hand. Koskinen *et al.* (2013) refer to this type of prop as a "Ready-made" and describes a designer's "selection and use of mass-produced articles" as a way "to assist creative problem solving" (p.1) by using "things at hand or cheap craft shop materials" (p.9). Koskinen *et al.* elaborate that these props are an empathic design tool that are used "in creating and exploring potential design ideas and concepts, illustrating these for conversations, giving people experiences that designers can study ..." (p.2) Furthermore, the idea is that the Ready-mades are not seen as precious objects, but rather as a working model that may be modified.



Constructing the design prop from a cereal box covered in a colour printout.

VISUAL DESIGN RESEARCH

Visual media, namely photographs and videos, played an important role in the field research and data analysis. In design ethnography, visual media not only documents the research process. The process of sorting and editing of visual media also facilitates understanding, dialogue and develops perspective, which is crucial to the data synthesis process. Creating visuals also inspires the development of insights through re-enacting events, editing and constructing meaning from images and interpreting them in novel ways (Raijmakers & Miller, 2016).

Overall, this mix of methods and field tools is designed to facilitate a semi-structured investigation that immerses the researcher in the lives of the people and context of interest. For the best results, their application call for flexibility, sensitivity and intuition on the researcher's part. Next, the participant protocol is introduced and the characteristics of the field research process is elaborated.

2.3/THE PARTICIPANTS

In total 19 households were visited, and 34 participants took part in interviews. Due to limitations of Boond's in-field resources and the unpredictability of village life, most of the interviews were not previously arranged. Instead, Boond organised the first interview in the village with the entrepreneur. Once this interview was completed the entrepreneur accompanied the research team through the village to the next interview. The close social networks in the village meant we could take advantage of word-of-mouth, or 'snowball recruitment', for the next interviews. In general, most customers were interested in our research and agreed to be interviewed. The interviews generally began with one family member, often the male or female head of the household, and usually other family members and/or neighbours joined in. The interviews lasted from 40 to 70 minutes.

To begin, the purpose of the research and the contextual interview format was explained to interview participants. Permission to take photos, video and record the interview for academic purposes was requested at the beginning of each session, agreement was captured by audio recording. Only one person declined consent, at which time the interview proceedings were terminated. The equipment included two mobile phones, a digital voice recorder, two digital cameras and a tripod.

PARTICIPANT QUOTES

Direct quotes have been translated from Hindi to English. To retain anonymity each quote is attributed to its author using a coding system.

RESEARCH NUMBERS

4 villages, total 19 households:
- / Aanth 6, Pasintola 3, Khadrin Kheda 4, Dhaukal Kheda 6.

In-depth contextual interviews:
- / 34 participants in 17 interviews including Five pair interviews
- / 2 expert interviews and central station meter demonstrations

Unstructured interviews:
- / 3 with family members in households without the prepaid service
- / 3 with customers who have meters installed but are not in use

1157 photos, 38 videos, 17 hours audio recordings, 2.25 interview hours transcribed

2.4/FIELD RESEARCH PROCESS

Field support in the villages was provided by Morsel Research, an agency with significant experience conducting rural energy access surveys in Uttar Pradesh. The Morsel team consisted of a driver and two Interpreters – one for local cultural and dialect interpretation to Hindi and the second for Hindi to English language interpretation and logistics. To begin, I led the interviews and the interpreters acted as intermediaries. In practice, this approach proved tedious because the natural flow of conversation was interrupted in the translation process. We adapted our approach after the first day, with the interpreters leading the interview questions and taking notes. The interpreters reported the responses back to me, and then translated and posed any new questions I had back to the participant. One of the benefits to this approach was it freed me up for observation and visual documentation during the interview. The main drawback was that interpretation was often delayed and in summary format. This meant that some important moments to probe deeper were missed. Select interviews were transcribed by Morsel staff and reviewed alongside visual documentation to concretise observations.

Conducting an interview with a family in Aanth village.

In-field synthesis took place in the following ways:
- / Debriefings with the support team after each research session to discuss findings, improvements to the process, and goals and plans for the next village.
- / A review of fieldnotes, photos, video and audio recordings to facilitate reflection and process observations. Cataloguing media also served to further internalise daily observations.
- / Writing a summary of the day's activities in the field served to capture reflections on emerging themes, key findings, lessons learned and informed planning for the next day's activities.

LOCATIONS

The field research took place in four villages in Unnao district. The villages are approximately an hour drive from the city of Kanpur, where I was hosted at the Indian Institute of Technology. Details of the locations are described in Chapter One, section 1.6.

TIME OF YEAR

Energy use behaviours are influenced by seasonal weather and events. This impacts which contexts and activities may be observed and what may be on the minds of participants. For example, the field research took place during the cool winter months which meant electric fans were idle. Fans are highly valued for cooling young children in the summer heat, and observations of villagers' fan use during summer months would have been beneficial to the research. Conversely, because there was heavy winter fog during some of the field research, resulting in lower supply, this presented the opportunity to make contextual inquiries to find out if, and how, participants responded to changes in pricing under Boond's dynamic pricing model. Finally, it was wedding season which provided insights into village electrical usage at this special time of the year, but also affected participant availability.

"Synthesis is a creative mash of common sense and research and stresses design opportunities rather than theory."

[Koskinen *et al.*, 2011, p. 76]

2.5/ ANALYSIS AND SYNTHESIS

The research data was analysed and communicated using a mix of methods including affinity diagrams1, photo analysis, and written participant stories. A report on the preliminary findings was provided to Boond and the findings in their entirety were presented in a joint-session meeting with project sponsor Aalto New Global and my Advisor. Feedback from the presentation resulted in further analysis to deepen insights. Participant data was summarised and collected in a spread sheet. Results from the affinity diagrams were placed in frameworks to communicate their results.

The second phase of analysis included another round of affinity mapping and synthesis into frameworks such as a touchpoint matrix and concept maps. In addition, sketching cognitive and network maps served to develop my understanding and early ideas, and a review of the participants' meter consumption data (provided by Boond) elaborated on their electricity spending. Desk research was conducted to enlighten the findings from the field research. The research delved into India's sustainable energy strategy and kerosene subsidies (IEA, 2015; Jain & Ramji, 2016). It also covered the topics of the financial lives of the poor and how money is managed in a rural Indian context (Collins, 2009). In terms of technologies applicable to prepaid electricity, mobile phone use by low-literate users was investigated, and examples of energy use data display and communication were explored (OVO Energy, 2016; Utilita Energy, 2017; Wattson, 2009). The desk research and deeper analysis were of an exploratory nature and helped to eliminate ideas as much as elaborate others. Research was supported by follow-up discussions with Boond. The conclusion of this process resulted in design opportunities for development to a design proposal phase.

1/ "Affinity diagramming is a technique used to externalize, make sense of, and organize large amounts of unstructured, far-ranging, and seemingly dissimilar qualitative data." (Lucero, 2015, p. 231)

Data synthesis methods included affinity mapping and visual analysis of photos from the field.

03

GATHERING INSIGHTS

This chapter covers the field research findings and insights. It describes how participants arrange and provide for their energy needs, including how they make use of Boond's service on a day-to-day basis, and in particular how they interact with the meters. The chapter identifies some of the primary drivers of people's attitudes, habits and behaviors relating to electricity use. In the first section, the analysis process and resulting affinity map are discussed. The Findings and Insights section begins with participant stories to introduce a few of the people that use prepaid electricty. Then, the results are presented as a collection of findings and insights presented under three main themes: The Entrepreneur's Role, Understanding the Meters and Energy Use Decisions. The chapter closes with conclusions regarding the findings and insights, and presents opportunities for design to carry forward in to the solution phase.

3.1/ MAKING SENSE OF THE FIELD RESEARCH RESULTS

The affinity map that I used for analysing the data from field research produced 23 groups of notes organised under six themes. While the scope of the affinity map was framed by the guiding research questions, a new topic emerged from my analysis of the fieldwork, and which I could not have been aware of before conducting the fieldwork. This topic, *managing a mix of energy sources*, is highly relevant to how customers value and use the prepaid electricity service. Therefore, it was included in the affinity map. An abbreviated list of the themes and their subgroups are shown in the affinity map below.

The guiding research questions for the affinity map were:

/ *How do customers interact with and become informed by the prepaid metering system?*
/ *How do customers value and use the prepaid electricity service?*
/ *How do people use Boond and integrate it into their current/pre-existing mix of energy sources?*

AFFINITY MAP THEMES

The electricity service is an investment in children's futures, productivity, quality of life, and property security

- Light at night increases study time for children, work productivity
- Light brings families/village together for socialising into night
- Relieves boredom/drudgery
- Light relieves concern for livestock security and hazardous insects/snakes in the home

Guessing cost of electricity and consumption

- Not knowing the price of electricity and the hourly cost of appliances
- Guessing at, or ignoring, the meter lights (pricing levels)
- Installers explain/demonstrate the basics of meters
- Entrepreneurs have basic understanding – like customers they also guess at prices/metering

Meter position and interface present challenges to reading

- Trying to see the meter's LCD monitor from below
- English is a foreign language
- Security from children touching, and tampering/theft hinders interaction

Managing a mix of energy sources to conserve energy spending

- The Energy Mix acts an energy source contingency plan
- Spending on Boond when it provides the most value for money
- Kerosene/SHS is seen as a cheaper alternative to Boond when high-quality light is not necessary
- A Light bulb in strategic location supports multiple tasks by several users
- Allocating the most appropriate energy source for the task
- Using the SHS exclusively for light/phone

Engaging/Interacting with the meter

- People look for the "Balance" before and after use
- Curiosity and active involvement in metering, experimenting
- Acting only when balance hits zero
- Meter reading/recharging is a shared task
- More literate family members (often children) read the meters and manage the account

Mobile phone use is basic/limited on feature phones

- Prepaid phone plans as a point of reference
- Monthly spending on phones more than Boond
- Women use mobile phones for voice/media, not texting
- SMS/mobile pay attitudes, cash is king

3.2/ PARTICIPANT STORIES

The stories introduce three actual Boond customers and one entrepreneur that participated in the study. The stories are based on the interviews and my observations during the home visits, and reflect my interpretation of those events. These stories of these participants are most relevant because they best illustrate some of themes that are discussed in the findings. They provide a glimpse into the participants' lives, mainly touching on how they monitor, use, allocate finances to and value energy sources, including electricity.

Rakesh is a good example of an extremely cost-conscious customer with a strict daily budget for electricity. His story demonstrates how families read the meters and prioritise kerosene and electricity use. Laxmi and her family exemplify an household with a larger budget for electricity and some electricity sharing. Their story shows how use is allocated between Boond's service and their SHS. Sangeeta is an example of a customer that pays no attention to the meter. Her story shows us how a family cooperates with the service. Sarvesh, an entrepreneur and customer, demonstrates a proactive use of electricity for social and economic benefit. His story tells us about an entrepreneur's motivation and the challenges of the role.

A note about the photographs. While the participants agreed to be photographed for the study, their names have been changed to preserve anonymity.

"I never read the meter … my cousin handles this."

SANGEETA

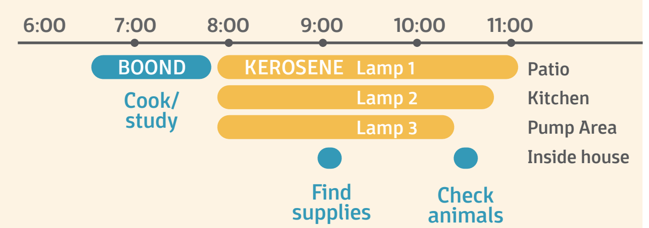
Sangeeta is a widow and lives in a multi-generational household with her two sons. Her uncle, who lives in another dwelling in the village, signed up the household for Boond's service. Sangeeta is a bit suspicious of the meter, she can not read the display or make sense of its controls. All she does is switch the lights on and off. She uses them sparingly because electricity is expensive. In the beginning, her cousin used to come to the house to read the meter and charge the dongle. But now her own son, Deepu, has learned to check the meter and recharge the dongle by watching the cousin. Usually, he checks the balance three to four times a day, before and after switching on/off the lights. Sangeeta herself knows the dongle needs recharging when there's a black out. She then finds some rupees to give to Deepu to recharge the dongle. She usually recharges Rs. 30 at a time, which lasts about eight to ten days.

"We tell people Boond is good because you only pay for what you use."

RAKESH

Rakesh is a day labourer in the fields surrounding his village. He lives with his family in a single-story brick house, with a large patio area that includes room for grain storage and a water pump. His income fluctuates depending on the local harvest and weather. After returning from the field in the evenings he switches on the 3 watt light bulb on the outdoor patio for an hour and a half around 7 to 8 pm, while four of his six young children study and his wife cooks dinner on the roti oven. The family has an electricity budget of one rupee/day, which he meets by switching off the lights once the routine of cooking and studying is completed. The other light bulb and light tube are for "emergency only", when the family quickly checks on the animals safety and for finding supplies in the storage room.

RAKESH'S LIGHTING TIMELINE



After cooking and mealtime is finished, the family lights two or three kerosene lamps outdoors for washing up dishes, doing household chores and socializing during the remainder of the evening. He uses kerosene lamps because he thinks they are cheaper than Boond electricity, and the family does not need bright light for the remaining tasks. His wife disagrees about the cost of kerosene lighting, feeling that it is quite expensive because they use not only the 1 litre of subsidised fuel costing Rs. 17, but an additional 2 litres at the costly market price of Rs. 40 per litre, for a total monthly cost of Rs. 97 (i.e. more than 3 times the amount of their daily electricity budget)

Rakesh can not read English text, so he delegates meter reading to his eldest daughter and son who are in public school. His son, 6 years old, regularly climbs up on a sack of rice kept below the meter as a stool and reports the balance on the meter. Rakesh is proud that his son taught himself to read the meter by observing the lights and the balance, and his son enjoys the task. Rakesh recharges the dongle depending on cash at hand, usually Rs. 10-20 a day or two before his credit runs out.

“When I start charging my phone. It gets charged in one to two hours and takes 2.25 rupees and in this one [feature phone] 1 rupee.”

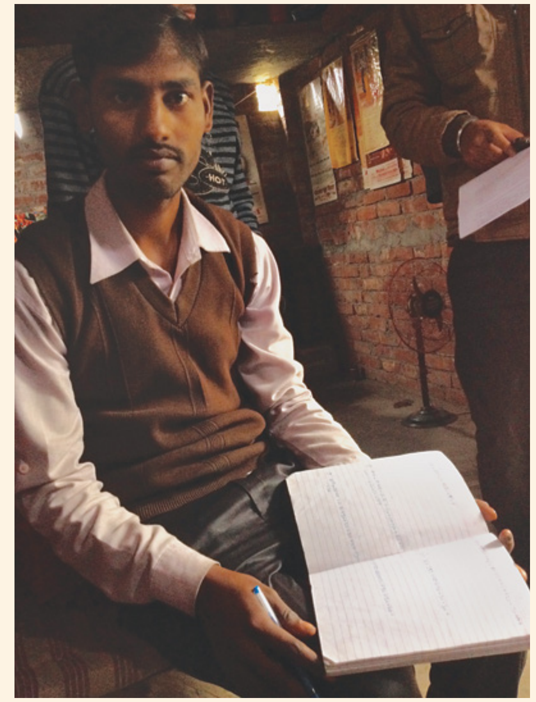
LAXMI

Laxmi lives in a spacious two-story brick house with her husband and two daughters. Laxmi convinced her husband to sign up for Boond service. The family uses the service for two-three hours a day, using the 3-watt light for the family room indoors for studying and eating. In addition to the prepaid service, Laxmi also uses the family’s SHS, which they’ve owned for seven years, mainly for lighting up the cooking and washing up area in the outdoor patio kitchen. But, when there is not much sunshine and the SHS battery does not charge, they use to the Boond outdoor light bulb instead.

Laxmi herself keeps track of spending by looking at the balance on the display. She’s not sure what the other flashing readings are, but does not feel a need to find out. Laxmi’s eldest daughter actively monitors the meter, checking the balance before and after use. She figures out how much she has spent by deducting the balance from the last recharge. At first, she timed how long it took to charge her phone, checking the balance on the meter before and after charging. She’s not sure what the “currency low” light is or why it occasionally switches off. She generally recharges the meter when the balance is at three or four rupees to avoid blackouts. There are three phones in the household: a Xiomi brand smart phone Laxmi calls a “Chinese media phone” and two feature phones. Laxmi charges them on Boond’s system.

“We put the bulb here because everyone sits here and eats together.”

Laxmi recommends electricity to her neighbours because the service is reliable and she only pays for what she uses. This is better than the grid electricity service in the nearby town – she has heard it is unreliable and that there are power surges that electrocute people and cause fires.



“If the electricity stopped we have to leave the field earlier because we need to prepare our crops before it gets dark. With electricity we can stay in the field longer.”

SARVESH

Sarvesh is in his early twenties and lives in a large two-story house with his father, mother, and four brothers. His father is a land owner in the area; his fields produce leafy vegetables to sell in the local markets. The family is well-connected and was a catalyst for bringing Boond into the village and getting people to sign up. To date, there are 28 households using the service plus a few more late adopters have signed up and are waiting for installation. Sarvesh has already seen the benefits of the light. In the evenings the family and labourers gather under the family’s patio light to prepare vegetables for the morning market. This frees up time to work longer in the field during daylight and because they no longer prepare their goods in the morning, they get an earlier start at the market, a competitive advantage. Plus, the family stays up later and spend time socialising together in the evening which has lifted a degree of boredom from the evening ritual.

“We have so much to talk about. So, now we can go to sleep later because we can talk with the light.”

Sarvesh maintains the system’s five solar panels on the rooftop of the family home, with the “Central Station” meter installed below on the second floor. He cleans the surfaces every week, and ensures the batteries are maintained and securely locked up. It is mainly an unfinished storage area so he does not spend much time up there. After the last customer recharge he noticed the “currency low” lamp started flashing, but thought that meant he had somewhere around Rs. 50-100 left in his account. It turns out that his account was almost empty and the other night he ran out of credits to sell. In turn, he could not make a recharge for a customer. The customer was annoyed with him. Sarvesh was able to order credits by phone that night but they were not transferred to his account until the next business day.

3.3/ FINDINGS AND INSIGHTS

The following section discusses the findings and insights in three themes: the entrepreneur's role, understanding the meter, and energy use decisions. A "finding" is based on actual observations, experiences and conversations that occurred during fieldwork. "Insights", on the other hand, take findings to the next level by challenging and provoking in order to assess their significance. For design, insights serve to highlight opportunities by providing a starting point for innovation, or to introduce important aspects for consideration when designing improvements or innovating a new service.

THE ENTREPRENEUR'S ROLE

> *"I installed it in my home because I am the Pradhan of this village. If I will not install it in my home then how will I convince my villagers to use it and install it in their house? I took it to encourage everyone."* [Entrepreneur]

3.3.1/ Entrepreneurs are a key link in the Boond service

Entrepreneurs play an important role in the Boond service. They are the public face of Boond in the community and are the first point of contact when problems arise. In addition, they facilitate and promote the service by fielding complaints, providing instructions, troubleshooting, and recruiting customers. Crucially, they facilitate one of the key touch points in the service, recharging the dongle. They are an intermediary between Boond and the customers and the human link between the central station meter and household meters (Figure 5) and the main communication channel between Boond and the customers. This means Boond depends entirely on the diligence of the entrepreneur for the effective facilitation of the service.

Despite their important role, it appears they are missing some training which hinders their capacity to carry out the role with confidence. The entrepreneurs that were interviewed demonstrated confusion over pricing as well as the meter functions of their household meter. For example, when entrepreneurs were asked to describe the significance of the meter readings and indicator lights on their household meters, other than the balance and currency low light, most did not answer correctly. This could partly be attributed to the meter design, but also ineffective training. They were equally unclear about the price of electricity and none of them knew about dynamic pricing. One entrepreneur was confused about the significance of the 'currency low' light on the central station meter, and due to this, had previously run out of credits to sell customers. What this demonstrates, in short, is that entrepreneurs, the main contact for the service, are not much more fluent with the service than the customers. Given that the entrepreneurs are the local face of the service, their ability to provide adequate customer service significantly effects both customer experience and efficiency for Boond.

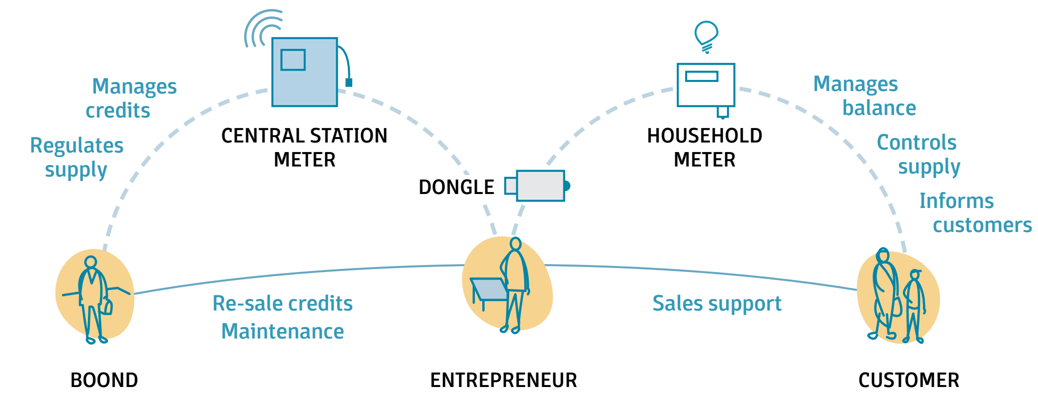


FIGURE 5
The Main Service Actors: entrepreneurs are at the center of the service, and are the physical and social link between Boond, customers and the two electricity meters.

> *"If we will use small bulb so it will charge one rupee for an hour. And tube light will charge for double the amount."* [Entrepreneur]
> The actual costs is 60 paisa for the bulb and Rs. 1.20 for the tube.

When Boond assesses the suitability of a village for installation of its service, identifying a responsible entrepreneur is a major consideration because of the key role he/she plays. One example of the impact that failure to recruit a suitable entrepreneur can have on Boond's service is the situation in the village of Pasintola. There, the original entrepreneur did not work out – he quit or was fired, depending on who we spoke to. As a result of the disruption caused, the service was halted for three weeks while a new entrepreneur was recruited.

Another example of the key role that entrepreneurs play is in the initial establishment of the Boond service in their village. Two of the entrepreneurs interviewed were the prime mover for initially bringing Boond's service into their villages, and played a critical role in recruiting customers.

In light of the proactive steps these entrepreneurs have taken, it is useful to understand what motivates them. Firstly, there are financial incentives. Entrepreneurs buy credits from Boond at a 10% discount and re-sell credits at a full price. What appears to be a greater incentive is that they are key players in electricity provision, thus improve quality of life, helping the village to develop and building social capital. The result is a small income for the entrepreneur, and perhaps more importantly an electricity service in the village that entrepreneur personally benefits from along with his or her neighbours.

> *"I want that my village will develop and progress more. If electricity will come in our village, every house and community will develop, and our children will study very easily in the light. And all work will complete very easily. We need this light."* [Entrepreneur]

RECHARGING THE DONGLE

It's 8:00 pm and the balance on the electricity meter is running low. Archana is annoyed with herself, she forgot to buy credit early in the day. She calls her eight year old son Bikash to her. She pulls the dongle out of the meter and suddenly the house goes pitch black, only the glow of two kerosene lamps flickering on the stairway provide light. In the glow of the flame she passes several coins and the dongle to him and tells him to rush over to the entrepreneur "Fulan Devi"'s for a recharge.

"*Come on!*" Bikash signals to his brother on the way out. They rush off across the patio, past their grandfather who's sleeping on a cot outside, and run up the dark pathway to the Fulan Devi's snack kiosk. Having reached the bottom of the stairs the light from the patio shows them the way up the stairs to the patio where Fulan Devi is chatting with a customer. Bikash passes the dongle and tells her "10 rupees recharge". He then finds the recharge ledger in a stack of notebooks on the kiosk shelf. He diligently records his name, date and recharge amount on the family's page in the ledger. He carefully checks it over, and waits to get the dongle back so that he can copy the number down.

Meanwhile, Fulan Devi walks over to a dark corner of the patio to the central station meter. Holding a flashlight, she steps up on the edge of her bed to see and reach up to the key pad. She inserts the dongle in the plug outlet and then punches in a one and then a zero, hits enter and listens for two beeps and the red indicator light on the dongle to turn green. Silence, the red light glows. She pulls out the dongle, inspects the plug connection and tries again: one, then zero, enter. No response. She shakes her head, pulls out and tinkers with the dongle connection once again, patiently punches in the numbers once more, pressing hard on each button on the keypad. Then pauses. Finally, on the third try the meter registers a double beep, the dongle light turns green. She nods, pulls out the dongle and passes it on to Bikash to finish filling in the ledger. The boys then dash back into the darkness, returning back to the house at a steady trot, past the sleeping grandfather on the patio and through the front door. "We're back!" Archana takes the dongle and puts it back into the meter. Bright light floods the main room and front patio of the home. She checks the meter and sees there is a little over Rs. 10 balance. Archana picks up her broom, and continues sweeping, while her mother settles back into her night watch on the patio.

UNDERSTANDING THE METERS

FIGURE 6
The balance and currency low lamp are the main attraction on the meter.

3.3.2/ The account balance is all that matters

Participants engage with the meter primarily to check their current balance and recharge the dongle. In addition to the balance, the meter screen continuously scrolls through displays of five readings: voltage, current, power and watt-hour consumption in each price level. Participants disregard these readings while they wait for the word "Balance" and numbers to appear (e.g. Rs. 10.00). The word "Balance" is familiar to people because prepaid mobile phone balances are reported in English. It is likely that through previous experience with mobile phones people have learned to derive meaning from the English word "Balance". To further reinforce this understanding, some participants described that the Boond installers gave them a quick introduction to the meters and explicitly told them to look for the "Balance" on the screen to track their spending.

> *"I do not look for watts only rupees. I am not literate that much to check other things."* [aaH1]

Many participants said that they did not know what the other text on the screen meant. In terms of the indicator lights, several participants were familiar with what the "currency low" lamp meant and said they observed that it went out after recharging. None of the participants knew what the price indicator lights meant. The visualisation above demonstrates the information that is meaningful to a participants by blacking out parts of the meter that are ignored (Figure 6)

In general, participants reported that they check their balance before switching on a light, and just before or after switching it off (Figure 7). They do this for several reasons: to monitor their balance, estimate the next recharge (based on their past consumption history), and to confirm spending estimates as a way of keeping mental track of overall spending. Due to the fact that the service was introduced into people's homes only two to eight weeks prior to the field research, it is reasonable to infer that participants may be assessing their level of trust in the system by confirming their estimates and verifying their consumption and that this behaviour may subside over time.

Two participants gave accounts of

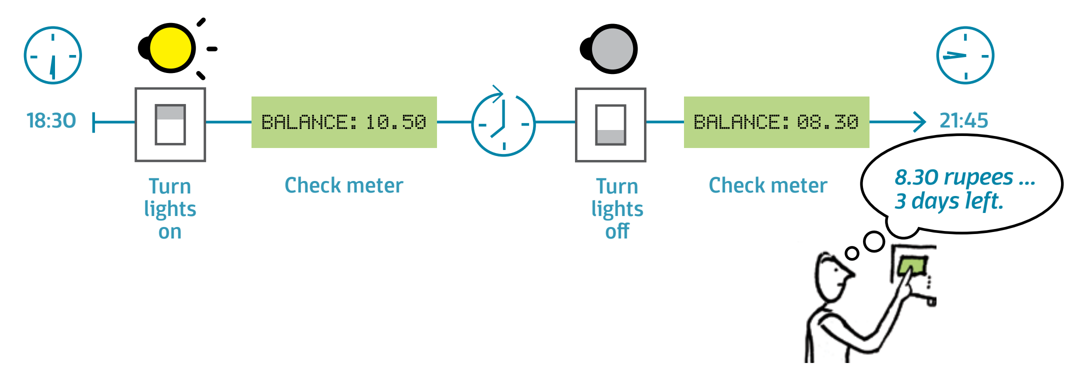


FIGURE 7
Participants check their balance before and after switching the lights.

"... 'proximate literacy' is the ability to rely on others who either are sufficiently competent in using the device, or are literate and can take the user through the steps requiring textual understanding."
[Chipchase 2013, p.6]

experiments that they conducted to check the cost of electricity. One described how he checked his meter balance before and after keeping a light on for exactly one hour, in order to determine hourly cost (Figure 8). The other said she checked the meter balance before and after charging a simple phone and then again for a "Chinese media phone" (a low-cost smartphone) to compare the costs to charge each phone (she reported that it cost Rs. 1 and Rs. 2.5 respectively).

"It's like on the phone when you get it recharged you can talk. But when there's no rupees you can't." [dkH3]

FIGURE 8
A participant demonstrates how he ran an experiment by timing the light bulb to find out how much electricity costs for one hour.

3.3.3/ Meter reading is often delegated to others with greater literacy skills

"I check the meter 3-4 times in a day and I give updates to my mom."
[Deepu, kkH4's young son]

Often the illiterate adults in the family, usually those paying for the service, do not monitor or read the meter themselves. Rather, they delegate the task to their school-age children, or depend on a relative living in another household to do so. Chipchase (2013) refers to this kind of behaviour as *proximate literacy* – a strategy to overcome gaps in literacy by asking more literate people for help. In doing so, people entrust particular tasks, by delegation, to more literate family members or helpful neighbours. Based on the interviews, the main reasons for delegating meter reading that emerged were not only low-textual literacy in the participants' first language, Hindi, and low numeracy (the ability to understand and work with numbers), but also no knowledge of English. This was confirmed during the interviews when participants were asked if they could read the English meter text and describe its meaning. In most cases they were unable to answer correctly. In conclusion, in the design process it is important to recognise that there may be several people in a household that perform various tasks to manage the account. This ranges from reading the meter, to monitoring spending and recharging the dongle.

FIGURE 9
The position of a 60-watt meter in one of the households.

3.3.4/ The meter placement hinders engagement with service

"Boond recommended to put it up this high, to keep out of reach of the kids." [aaH3]

In many of the households, the meters are installed at a height on the wall that makes it very difficult to view the screen. While their placement is within arm's reach of the dongle, in some cases this is 30 to 50 centimetres above the eye level of a typical householder (Figure 9). This is done to deter tampering (electricity theft) with the meter. Indeed, the position of the meter could be interpreted as a signal of distrust toward the residents of the home. Some participants said that they either requested or were advised on the high position to avoid unintentional damage, mainly by young children. In addition to the position of the meter, the English text printed next to the indicator lights is extremely small and fine which hinders legibility, particularly in dimly lit rooms common to rural houses. Another issue is that the small LCD screen only supports two rows of 16 English characters each, which limits the amount of textual information that may be displayed. To tackle these limitations, abbreviations of words are used (i.e., "CP" for "consumed power") and present even further challenges to non-English readers (Figure 10). On the positive side, the meter's LCD display is backlit in bright green which helps visibility in low-light settings.

"Maybe kids can reach there and they may destroy this meter, now no one can reach there except my son." [kkH4]

FIGURE 10
The 20-watt meter.

FIGURE 11
A participant climbs up on a bed to get a good look at his meter.

FIGURE 12
A boy stands up on sacks of rice to read the family's meter while his father looks on.

"*I observed myself how to read the lights*" [son of dkH6]

To view the meters, participants have to take special measures. Some step back from the meter and go up on their toes to improve their view. Another elderly participant with limited vision climbs up on a nearby bed or chair to position himself in front of the meter (Figure 11). Similarly, households with children that regularly read the meter keep one or two sacks of rice below it for the child to climb on to when reading the balance or removing the dongle for recharging (Figure 12). The height of placement makes the meter inaccessible, presenting a deterrent to those that may be motivated to learn through experimentation or memorisation. Considering the obstacles that the meter placement presents to children in particular, it is impressive that many have taught themselves how to read the balance and understand the indicator lights under these conditions.

A sketch from my fieldnotes compares the current meter position and the field of vision of the display (in green), to an early idea for a lowered meter position with a downward angled mounting platform.

3.3.5/ Opportunities for mobile phones to facilitate the service

Along with lighting, charging a phone in the home is a primary need that Boond's service addresses. All of the participants, except one, reported owning at least one mobile phone. In terms of spending on phones, some participants reported monthly mobile phone airtime expenses from Rs. 20-100 per month. When compared to these same participants' electricity meter consumption data, phone expenses were often higher than on Boond electricity. Granted, airtime is more expensive than electricity, however, the allocation of spending is an indication of the value participants place on mobile communication. Considering the greater capacity of the phone to alert, provide richer text, sound, store and share information, the mobile phone presents a compelling case for extending the meter capability to an external device. Given these established links to mobile, using the phone, particularly SMS messaging, to facilitate the service seems to be an obvious next step. That said, there are several obstacles to the adoption of mobile phone services that need to be considered.

OBSTACLES TO MOBILE PHONE SERVICE ACCESS

Firstly, many of the women interviewed reported that they do not personally own or have access to a phone, and if they do use one it is shared by the family. One participant reported that she is not permitted by her husband to use a phone. For those women we interviewed that own or share a phone, many reported that they primarily use phones for making voice calls or "dropped calls" (a method of sending a "coded" message by hanging up after a number of rings, thereby avoiding charges), as well as for watching videos. As women are amongst the prime beneficiaries of electrical lighting in the home, it is important to consider that a number of women would likely be excluded from taking advantage of any mobile services offered by Boond.

"*They don't even know Hindi. [My wife], She cannot read Hindi.*" [ptH2]

Secondly, taking into account that close to half of the participants reported having only one phone in the household it is important to consider who has possession of that phone. The mobility of a phone is an important factor when considering SMS messaging as an extension of meter communications because it is often the case that the primary user of the phone, often a male member of the household, is nowhere near the meter when he gets a message. Participants indicated, for example, that a husband may be away working in another state or the son may be out working in the field. In this case, an SMS alert would fail to reach its target audience, those at home using electricity. On the other hand, in the future SMS messages that link to mobile payment services may well be of value to families when the account is paid by a wage earner living away from home.

"*These people are not well-educated, they don't know English, so they cannot read the SMS.*" [ptH2]

Finally, most of the participants reported using feature phones. Although these phones have a greater capacity to communicate information than the LCD meter displays do, operating the phones is textually and numerically intensive. This textual intensity can be extremely demanding for users with low levels of literacy and a lack of fine motor skills due to non-practice in writing, and often excludes them from mobile services (Chipchase, 2008; Friscira, Knoche, & Huang, 2012; Matyila *et al.*, 2013). Consequently, phone activity tends toward the basic tasks of making and receiving calls, opening and sorting messages, watching videos and playing games. More demanding textual-based tasks such as sending and receiving SMS messages, especially by women, may also be problematic and require asking someone else for help (Friscira *et al.*, 2012; Wasan & Jain, 2017).

MOBILE PHONE OWNERSHIP IN RURAL NORTHERN INDIA

Mobile phone uptake in my study group is higher than the average northern Indian rural population. To put the findings from the field research into perspective, I made a review of data from a recent survey (Aklin, 2016) of over 8500 rural households without electricity in six northern Indian states, including Uttar Pradesh. The survey results found that 81% of respondents owned at least one phone, and of these, only 31% owned two or more phones.

In my findings, 95% of participants reported owning at least one phone, much higher than the survey result of 81% ownership of at least one phone. In the villages I surveyed 50% of the households reported owning two or more phones.

While this illustrates that in the villages I surveyed the obstacles to SMS adoption would be lower than in the population in northern rural India in general, it must be emphasised that my sample size was much smaller and less reliable.

MOBILE PHONE USE BY RURAL INDIAN WOMEN

In a recent study by Wasan (2017), rural Indian women gave the following reasons for not owning a mobile phone: the cost of the handset, lack of need, fear of handling the phone, and feeling it is inappropriate for a woman to own a phone if the man of the household already has one. Cherie Blair Foundation (2013, cited in Wasan 2017) found that women who had become adept at using their phones still only used them for making and receiving calls.

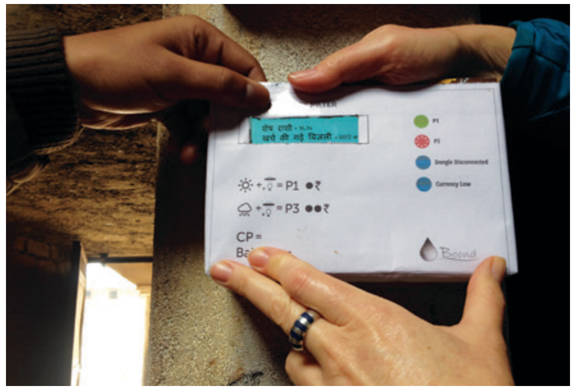


FIGURE 13
The first prop was constructed from a Corn Flakes box and a redesigned graphical interface was laser-printed and glued to the surface. The price legend showed a sun + light bulb icons and a single rupee coin for price level "P1", and a cloud + light bulb icons and two rupee coins for price level "P2". Meter screen content was displayed in Hindi to explore its readability and/or appeal.

FIGURE 14
A participant interprets the text and icons on the meter.

FIGURE 15
A participant reads aloud the text on the display. This young boy is responsible for reading the family's meter on a daily basis.

3.3.6/ Insights into literacy: exploring context with props

I made two props to explore my ideas for using Hindi on the meters, and to investigate if using icons as a substitute for text might be an effective way to communicate. The first prop was discussed with four participants and the second prop with one.

The containers for the props were made from discarded boxes. The box was trimmed and a window was cut out to accommodate an iPhone screen. I rendered a series of screen mock-ups in Illustrator and used the phone as a display positioned inside the box window. The display on the first prop showed consumption information in Hindi including the words "balance", and "consumed power". The meter interface was redesigned to include a price legend made up of icons, then laser printed and glued to the box (Figures 13 to 15).

The second prop display showed daily, seven- and 30-day accumulated consumption in English language, and icons for the indicator lights on the meter (Figures 16 to 17).

RESULTS FROM THE PROPS

Meter graphics:

/ The icons for sun and cloud and a rupee coin were not easily recognised by the participants.
/ One participant reported that the cloud represented the meter, and another that the sun was an "on" icon for the meter.
/ One participant related that the icons meant, "when it is sunny, it is P1, when it is cloudy it is P3." (Figure 14). This indicated that the basic concept was understood, however, the legend failed to convey how the weather impacted electricity supply.
/ None of the participants recognised the rupee currency symbol, nor the black circles as coins. One participant recognised the coin as a *bindi*, which is a red dot commonly worn by Hindu women on the centre of the forehead.

"If it is sunny, so it will cost only one rupee. If it is rainy then it will cost around three rupees." [kkH1]

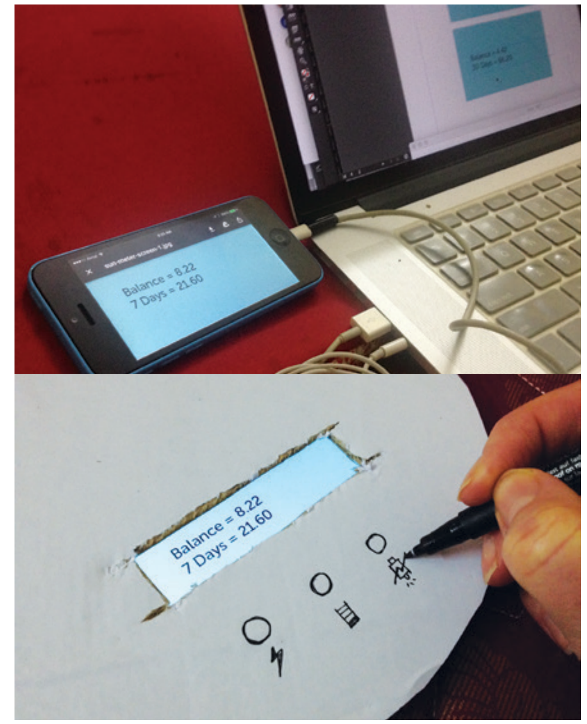


FIGURE 16
Screens with balance and daily, seven- and 30-day consumption were mocked up on a computer and the indicator lights were labelled with icons common to those used on electronics interfaces.

FIGURE 17
The second meter prop, which was hand-held to engage the participant in discussion.

Meter display:

/ Participants could read numbers and understand the significance of the number to their balance. They also understood "balance" and "consumed power" in Hindi.
/ One school-age participant struggled to make the connection between the price legend and the P1 and P3 labels on the indicator lights (Figure 15).

Only one participant engaged with the second prop. This participant, a young mother of several young children, admitted that she could not read. She did try, but after a few moments she indicated that she could not answer (Figure 17). To avoid causing embarrassment or stress we put the prop aside and proceeded to other questions.

The actual making of the prop aided synthesis of early findings, inspired ideas and investigated a few early solutions. The participants interaction with the props brought to light the challenges of reading English text and deciphering icons, also a foreign language. More could have been done on my part to prepare the participants and the interpreter for the prop exercise. I conveyed that the intent of the prop was exploratory and that there were no right or wrong answers. Nonetheless, from time to time the interpreter quizzed the participant, who, I detected, felt pressured to answer correctly. Pressure was amplified by the group of onlookers gathered around the interview scene.

A NOTE ABOUT THE LCD DISPLAYS

The LCD character display satisfies many frugal and practical requirements: it is readily available, economical, energy efficient and has low heat emissions. According to the meter engineer, by choosing English as the meter screen language standardization and efficiency was prioritised over readability. As a consequence, consistency then dictated that the text printed on the meter case be in English.

3.3.7/ Boond is one part of a larger household energy mix

The findings of the field research show that most of the participants interviewed (21/22) have adopted Boond's electricity service in addition to at least two other energy sources for their domestic needs. Only one of the participants reported utilising Boond's service exclusively. In addition, 15 of the participants reported owning an SHS for between one to six years before the Boond service arrived in the village. The results from these interviews suggest that participants satisfy their light and power requirements by managing a number of sources to meet their lighting and phone charging needs and budget, and to ensure redundancy in the event one or more sources fail. This mix of energy sources includes Boond's pre-paid electricity service plus any of the following incumbent sources:

FIGURE 18
The mix of energy sources may include an SHS, a pay-per-charge auto battery and a kerosene lamp.

FIGURE 19
A participant disconnects phone charging cables from the Boond system and reconnects them to the SHS battery to charge the family's two mobile phones.

a privately-owned SHS[1], kerosene, and/or automotive batteries[2] (Figure 18). These sources and their use by participants are shown in the table in Appendix B. These findings present an important insight that participants have a variety of sources to choose from and, therefore, may consider multiple factors when deciding which energy source is best to satisfy the task at hand.

> *"Both are good. It depends on that person's budget but according to me solar panel [SHS] is better because we have to spend only once. My second option is, that if our solar panel is not working, in that case we can use Boond by doing a recharge."* [kkH3]

Data from the field research indicates that participants frequently alternate between energy sources, depending on the task-lighting required. For example, some participants reported that once work that requires bright light, such as studying or detailed handiwork, is completed, they switch off Boond light bulbs and turn on a portable LED lamp (often charged on an SHS), or even light a kerosene lamp.

> On the patio … *"we switch on Boond, do some work, then switch it off and burn a kerosene lamp."* [dkH3]

The reasons the participants give for switching is that the portable LED lamp light is sufficiently bright, or that it supports tasks that require mobility such as moving around areas of the home, property or village that are unlit. A mobile phone may also be used for the same purpose – one participant demonstrated that she uses her phone flashlight at the kitchen stove, "to see better when I am cooking". Participants also described using their SHS exclusively to charge their mobile phones because, as one participant stated:

> *"We charge the phone on the SHS because it doesn't cost anything. We don't pay additional."* [aaH2]

Another participant demonstrated how she switches wires from the SHS battery to the Boond outlet to charge her mobile phone when the family's SHS battery is low (Figure 19). Multiple participants mentioned that one of the Boond light bulbs was installed in a strategic location in order to guard their livestock from thieves. They make periodic

1/ A SHS consists of a solar panel, a charge controller and 12 volt battery for excess energy storage.
2/ The automotive battery may be accessed directly from the participant's vehicle (for example a tractor) or it may be a "pay-per-charge battery". A pay-per-charge battery is a dedicated 12-volt battery that the owner takes to a shop in the nearby town and pays a service provider to charge.

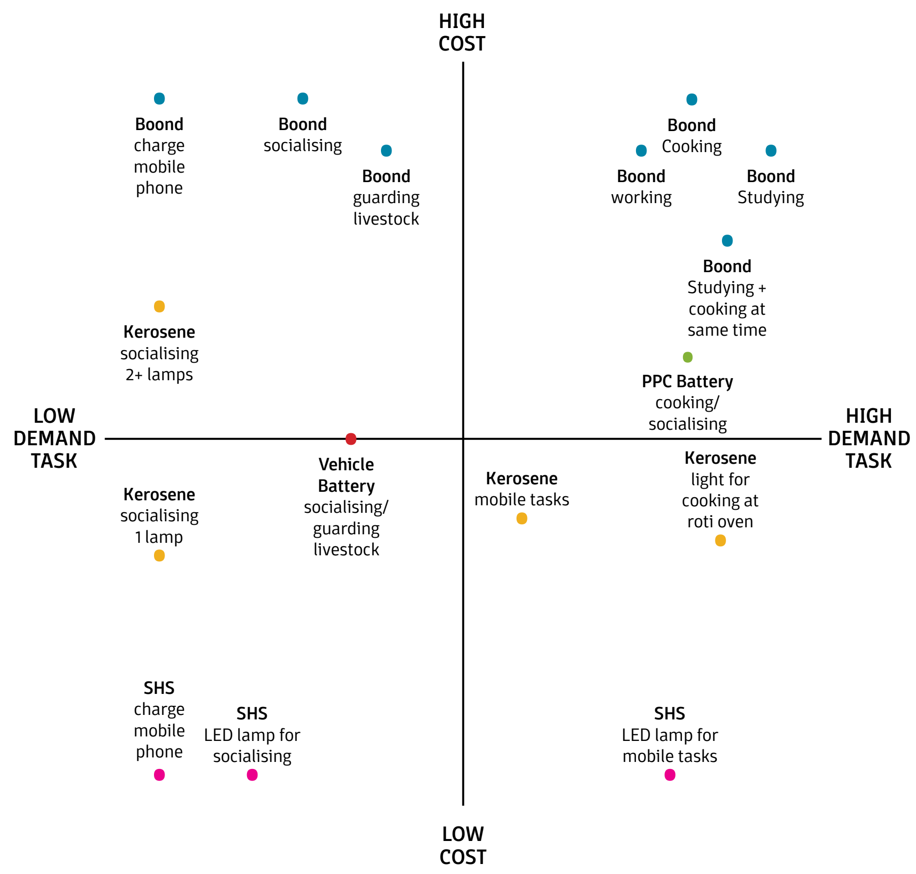


FIGURE 20
The energy use matrix shows the allocation of energy source in relation to low and high demand of task and perceived low to high cost of the energy source.

checks or leave one bulb on all night as a deterrent. Based on results from interviews it may be concluded that the participants have two core objectives when making energy-use decisions: to utilise the energy source most suitable for the task and to minimize their overall energy costs. The energy mix matrix above shows where the various energy sources fit into "low/high demand" tasks and "low/high cost" quadrants (Figure 20).

> *"There is a huge difference from before the light and now – I can look after my cattle and can see if there is any snake or other poisonous insect at night."*
> [aaH3]

In terms of minimizing overall energy costs, one way participants accomplish this is to perform tasks under the same light at the same time. Four of the participants with children that study under Boond light reported that they prepare their evening meals in the same room, at the same time, and with the same light used by their children for studying. During an interview, one participant pointed out a Boond light bulb that she requested be installed in a specific location in the main room of her home so that while her kids study under the light, in her words, 'some light reaches the kitchen'. Several other female participants mentioned a similar tactic for utilising light cast from a distant patio light while preparing meals in their outdoor cooking areas. These strategic decisions indicate an effort to choose the quality of light best suited to the task at hand, and multiple family members performing tasks at the same time, if possible. However, this clustering of activities under one centrally-located light strongly suggests that the other one or two lights included in the Boond service package may be underutilised. If this is the case, examining how the light offering might more closely meet the needs of customers could prove fruitful.

MR LAL'S "CREATIVE" ENERGY USE

For many of the participants we met, managing their energy mix involves on-going workarounds to ensure supply and to save money. One participant's setup in particular demonstrates this type of activity. A year prior to signing up for Boond, Mr Lal (name changed) purchased an SHS. Mr Lal bought the system outright. It included the solar panel, a 12 volt battery and two light sockets. Shortly after installing the system, a storm swept through the village. It blew the solar panel off of the roof, damaging it beyond repair. Nonetheless, Mr Lal continued to utilise the battery that he had invested heavily in by having it charged at a pay-per-charge battery service in a village five kilometers away. A full charge costs Rs. 40 and lasts for about two weeks of general use; one light bulb in the evenings, phone charging and occasional use of a small fan.

In the meantime, Mr Lal's son signed him up for Boond's service and the system was installed. Mr Lal prefers Boond's lights because the bulbs are much brighter than the one on his battery-powered system. Nevertheless, it bothered Mr Lal that he was not using the 12-volt battery he had paid dearly for, and he felt that it was cheaper to draw from the battery for lighting. He decided to cut one of the LED light bulbs from the Boond system and rewire it to his 12 volt battery. While making the change he relocated the bulb to a doorway so that the light shines into two rooms, thus increasing the light's reach and usefulness (shown on the before and after part of the floor plan sketch in Figure 21). In the end, he mainly turns on the Boond 5-watt light tube on the patio for security and to periodically check on his animals throughout the night.

> *"It is cheaper to charge the phone on the battery."*

Mr Lal's workaround is significant in that he combined existing resources to save money and in doing so recoup some of the losses he suffered from the storm. The biweekly 40 rupee cost would be comparable to similar that of the prepaid electricity service, however, add travel time and expense for delivery to/from the charging kiosk, and the battery is a less efficient energy source. Nevertheless, Mr Lal believes he is at an advantage with his workaround. The implication of the workaround is that Boond's service is being underutilised and Rs. 40 is spent on a competing energy source.

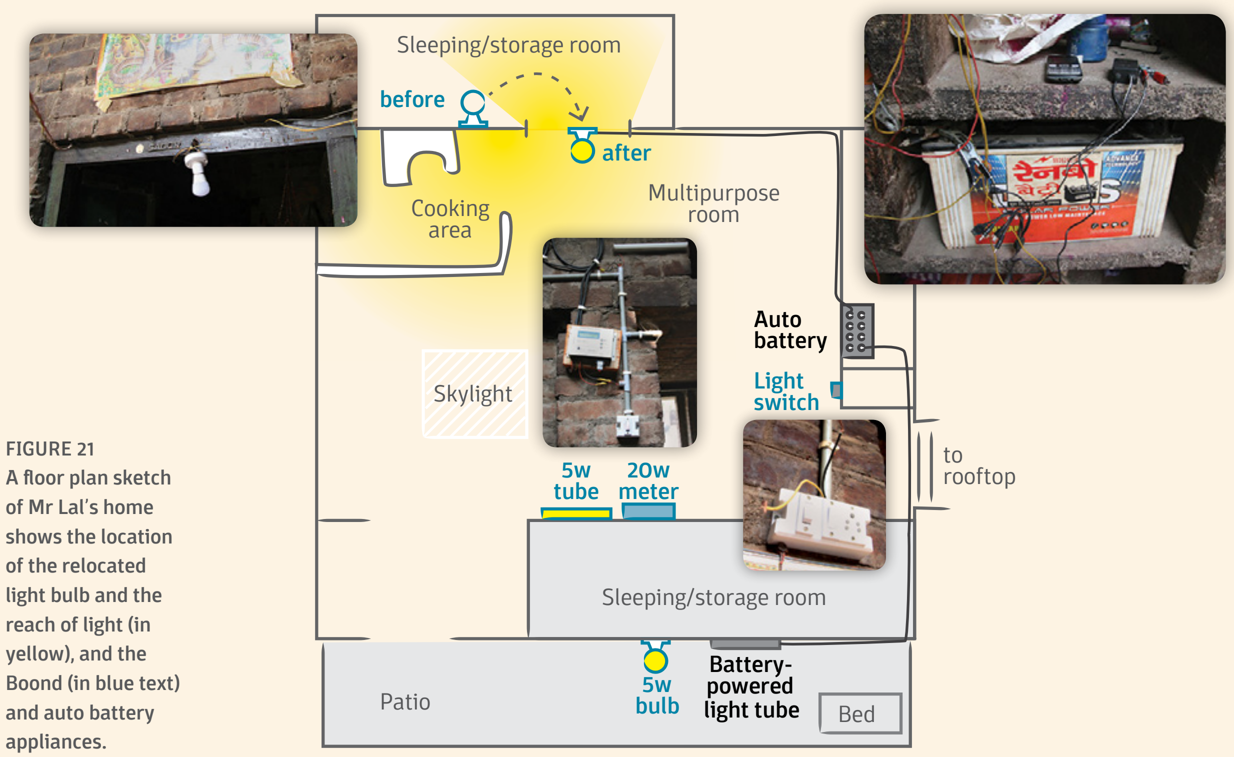


FIGURE 21
A floor plan sketch of Mr Lal's home shows the location of the relocated light bulb and the reach of light (in yellow), and the Boond (in blue text) and auto battery appliances.

FIGURE 22
Kerosene lamps are placed in dark, well-ventilated areas of the home for added light and socialising.

THE LURE OF KEROSENE

The negative health and environmental impacts from burning kerosene are well known (Lam *et al.*, 2016; Mills, 2012). In addition to more widespread environmental impacts, at a household level its impacts are eye infections and respiratory problems caused by smoke exposure and inhalation, and house fires and soot damage to the home. Many participants expressed they are motivated to quit kerosene due to health reasons alone, and the prepaid electricity service helps them to do this.

> *"Though the cost is a bit high, it is safe for kids – they can touch wires and there is no danger of shock, no eye problems ... it is healthier than kerosene, the service is continuous, and no pollution."* [aaH7]

However, there is a hurdle to ending kerosene use entirely: the government kerosene subsidy. In India, citizens in lower income strata are entitled to subsidised kerosene (Jain & Ramji, 2016). In Uttar Pradesh, the government provides a 58% subsidy on one litre of kerosene per household per month. This means that instead of paying Rs. 40 in the free market (or more), every family receives one litre of kerosene for the subsidised amount of Rs. 17. While the subsidy has been a fixture in the financial lives of the lower income groups, change is occurring. As recently as 2017, the subsidy has been reduced in an effort to shift consumption away from petroleum products to clean energy (Garg *et al.*, 2017) and to more efficient use of fiscal resources. Despite these changes, some participants continue to burn kerosene lamps. This could be a combination of customs, preference, perception of cost, and it could be the government subsidy provides much-needed needed relief to the consumer, and in doing so, encourages consumption.

3.3.8/ Despite satisfaction with prepaid electricity, kerosene use continues

Results from several studies have shown that there is widespread dissatisfaction with kerosene lighting (Urpelainen, 2016), and that kerosene consumption is reduced with access to affordable, reliable solar-powered electricity (Aklin, 2017). A study into kerosene alternatives (Jain & Ramji, 2016) found that amongst rural people there is overwhelming support for capital funding for solar lanterns in exchange for a reduced kerosene subsidy. When asked, participants in this study reported that they consume less kerosene since using Boond's prepaid service. Nonetheless, despite a desire to quit using kerosene, nine out of 22 participants said that they persisted with its use to meet some of their lighting needs.

> *"I buy 2 litres now. I used to buy 5 litres of kerosene before Boond."* [aaH3]

Given the other options available, why is kerosene still in use? Kerosene in India's energy supply is a complex issue, influenced by economic, cultural and political interests (Jain *et al.*, 2015; Jain & Ramji, 2016). These issues aside, in addition to being perceived to be cheaper than Boond, a kerosene lamp provides two qualities of light that are not met by Boond lights: portability and soft light.

Not to be confused with the bright light emitted by a pressurised or hurricane lantern, the participants in the villages burn a single-wick lamp that provides a soft light similar to a candle flame. A kerosene lamp may be burned for soft lighting in a part of the home where there is no light bulb. For example, one participant burns a lamp nightly to light a well-ventilated stairway. Also, she occasionally carries the lamp to other locations in the home, for example to the rooftop to provide light while cooking on roti oven and to an unlit storage room to find supplies. Several other women reported using kerosene lamps in their cooking areas, which are often outdoors where electric light does not reach. For these purposes, the lamp supports a need for temporary light as well as portability.

> *"We used diya (kerosene lamps). The places where the light is not present we use diyas there."* [aaH6]

Soft light illuminates a dark area of the house to create a sense of security (Figure 22). It is also supports low-demand tasks such as socialising on the patio. Given that the Boond lighting is recognised for its bright light, and perceived as being expensive in comparison to their other lighting options, it is conceivable that customers make a correlation between the brightness of light and their perceived (high) cost of the Boond service. Cost-conscious customers who can choose between soft light options, such as kerosene or LED lamp, and Boond's bright light, may choose soft light because it is dimmer, and, so they believe, saves them money. Or, they may be choosing soft light for aesthetic reasons. In either case, Boond's light does not meet customers' need for a certain quality of lighting.

Boond lighting is far brighter than portable LED light strips or compact fluorescent bulbs powered by an SHS. Participants often commented that the best thing about Boond is the brightness of light, but that the service is costly. Despite these accolades, participants do not appear to take the energy efficiency of the Boond service or lighting quality into account. Apparently, in some situations the quality of light does not bring enough value to warrant spending the extra money.

3.3.9/ Boond is perceived as more costly than it actually is

Participants use guesswork to estimate the cost of their Boond electricity usage, and in doing so it appears they estimate electricity costs as higher than they actually are. For example, a number of participants guessed that the normal hourly price for a 3 watt bulb is one rupee, but it is actually much less at 60 paisa. Participants have a more accurate idea of their daily spending than the hourly cost because they check their balance daily, often before and after use.

> *"Only using it for LED bulbs cost us around 400 rupees in a month, despite only using it for some hours."* [aaH3]
> According to meter data, the maximum this customer spent per month was Rs. 100.

Longer-term spending on Boond proved more problematic to estimate. Participant showed a tendency to overestimate the amount they spend per month, sometimes by 3 to 4 times, when compared with their actual meter data. There are several factors at play to suggest they simply lose track of their spending over time. Generally, customers recharge in small, frequent payments as their income allows. These multiple, sporadic recharges over longer periods of time are more difficult to track than one or two regular longer-term periodic payments. Apart from an account ledger kept by the entrepreneur, the only official record is on the dongle, and that amount changes with consumption. As a consequence, customers are left to keep their own records, review the account ledger or to guess. This is significant because when energy-use decisions are being made based on costs, the cost of Boond electricity is inflated against more established and easily quantifiable sources such as kerosene or the pay-per-charge auto battery.

> *"As it costs us quite high, so we use it only as per our requirement. We use it at dinner time or if we have to do something outside, we switch off the light inside the house, or if we have some work in the house the switch off the light outside the house."* [aaH7]

3.4/ FINDINGS AND INSIGHTS CONCLUSION

To begin with the role of the entrepreneur in service facilitation, the research revealed that entrepreneurs are in the initial phase of the learning curve and need some time and training to fulfill the vital role they play as main intermediary between Boond and its customers. There is potential for them to play a more active role in promoting the service and its features such as dynamic pricing. In addition, the process for ordering resale credits for the central station and depositing payments to Boond is labour intensive, it could benefit from digital tools to automate some aspects.

The second theme, "Understanding the meters", revealed that people are mainly interested in their account balance. The other information provided by the meters is inaccessible due to choice of language, and the placement of the meter hinders a clear view of the display and interaction with it. Moreover, multiple members of the household – and in some cases the extended family – take part in monitoring the account. They possess varying levels of literacy, responsibilities and means of communication, yet the meters are not designed to be accessible to such a broad profile of users. The dynamic pricing model, which could influence customers' consumption and provide incentives, is not understood because it was not explained to customers and is not made explicit in the meter design.

Finally, and perhaps most importantly, the research demonstrated that while participants reported that they are satisfied with the prepaid electricity service, it is not the only energy source in the village. There are a variety of energy source options to choose from. Customers' energy use decisions are influenced by perceptions of the value for money of the source and its suitability to the task. As the new electricity provider in the village, Boond has to compete against incumbent energy sources that are well established in people's homes and their routines. Another perception Boond has to overturn is that its service must be much more expensive than some of the incumbent, yet lower quality, energy sources.

The research and the resulting findings and insights identified problems at the household and village level of the service. These problems may be addressed by design to improve and increase uptake of the service. However, it is important to acknowledge that lights, fans, TVs and phone charging consume low levels of electricity, and in the rural Indian context, there is only so much electricity that people are able to afford and reasonably consume. It will take greater change in the Indian energy system regime, microgrid expansion and grid connection, rising incomes and digital payment uptake, battery improvements, and growth in e-mobility and climate conditioning to increase the viability of prepaid electricity services. However, systems change is slow and uncertain, and in the meantime it's essential to deliver the most effective service possible within the current regime. Therefore, I embarked on designing service improvements that could be phased in over time. And one that leverages a potential change in the kerosene subsidy to challenge the regime. The insights identified a number of opportunities for design. They were collected, refined and shortlisted for idea generation.

OPPORTUNITY QUESTIONS:

/ *How might Boond build the capacity of entrepreneurs to be better promoters and ambassadors of their service?*
/ *How might the meters communicate to a broader profile of users?*
/ *What is the most effective application of mobile communication, given feature phone use, in a frugal context?*
/ *How might people be incentivised to shift away from kerosene?*
/ *How could Boond's offering more closely align to customers' lighting needs?*

In the following chapter the design development phase is covered including a presentation of the design proposal.

Participants in their family home in Khatrin Kheda village.

A participant in Daukhal Kheda village.

The entrepreneur for Aanth village.

04

DESIGN PROPOSAL

This chapter proposes four service improvements I designed for prepaid electricity through village microgrids based on the insights from field research and resulting opportunities for design. While the solutions are informed by the field-based research, these solutions may apply more broadly to microgrid and prepaid electricity services contexts. The chapter begins with a brief introduction to the design process, and then describes the process for generating ideas and evaluating them, including feedback and a system mapping exercise. Next, four design solutions are presented, with the process also described in detail to enlighten the rationale and final outcomes. To close, the relevance of the proposed solutions to the main actors in the service are illustrated in an updated main service actors diagram.

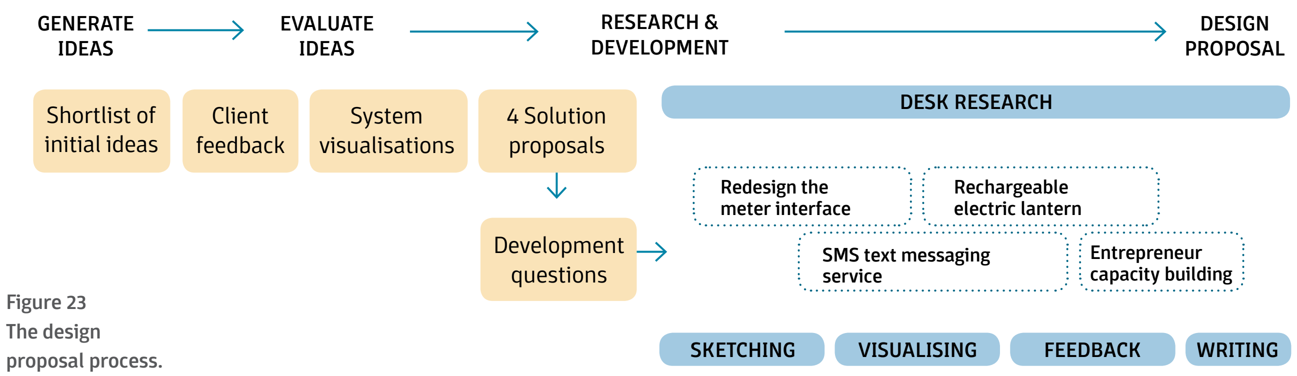


Figure 23
The design proposal process.

4.1/THE DESIGN PROCESS

The design proposal process began by generating ideas from the opportunity questions developed in the analysis phase. Then, ideas were shortlisted and evaluated using client feedback and a visualisation exercise. Next, four ideas were chosen to develop further and development questions were written to guide the design research. Design techniques including sketching, visualising, and scenario writing were used to elaborate the designs. Feedback from the client provided evaluation and feasibility advice, and desk research supported the work throughout. The meter interface and messaging service were designed in parallel – learning from one informed the other. Next, the rechargeable lantern and entrepreneur training were developed. The process is illustrated in Figure 23.

4.1.1/Idea generation

A set of initial ideas was generated in response to the opportunity questions. Next, ideas that were deemed technically unfeasible or not frugal were eliminated. Ideas with the most potential were shortlisted to the preliminary ideas shown on the following page in Table 3.

4.1.2/Client feedback

The ideas were discussed in several phone meetings with Boond throughout idea development to explore the level of interest and technical and business viability. The feedback is summarised as follows:

/ Some modifications to the existing meter model were well received.
/ The SMS messaging, mobile pay, and the entrepreneur's role in behaviour change ideas were encouraged.
/ The kerosene-related ideas were discounted because the subsidy is an energy policy issue and the low energy consumption for charging a lantern does not support the business case.
/ Hardware changes related to Boond's meter/lighting were met with resistance due to additional costs they incur.
/ Redirecting excess energy supply to a village-based service was previously investigated by Boond and deemed unprofitable, therefore, it was not of interest.

The feedback was balanced with the broader role I envisioned that design could play in the service. This meant that I eliminated some of the design ideas that garnered an unfavourable response, and I retained those that I believed justified further investigation by the design process.

OPPORTUNITY QUESTIONS	SHORTLISTED PRELIMINARY IDEAS
How might Boond build the capacity of Entrepreneurs to be better promoters and ambassadors of their service?	Hands-on training on service and meters Training customers on installation day Customer to customer support/training Introduction videos provided on phone, YouTube Village meeting/event at installation completion Annual entrepreneur party, entrepreneur award Annual Boond movie night in the village
How might the meters communicate more effectively to a broader profile of users?	Lower meter to eye height of adults Small catch/lock secures dongle from children Children's "Boond stool" for reading meter. Kept on wall, printed with fun/educational electricity facts Sticker on meter with prices, website, contacts, and poster. Audio alerts, choose from a menu of 'ringtones' Rename pricing levels: Economy, Peak, Emergency.
What is the most effective application of mobile communication, given feature phone use, in a frugal context?	Service information in video/audio (via SD card) Entrepreneurs employ mobile pay to buy/sell credits Boond radio and podcasts/mp3s SMS Messaging Service: - Monthly account summary - Daily deals when excess supply, e.g., 2 for 1 - Refer a friend, earn credits - Price alerts, check balance, contact support
How might people be incentivised to shift away from kerosene?	Swap kerosene subsidy coupon for prepaid electricity credits Cost comparison tool – kerosene to prepaid electricity Price comparison sticker on kerosene lamp Kerosene lamp replacement service: third party provides lamps on a buyback scheme. Boond provides a discounted rate on charging appliance during the day.
How could Boond's offering more closely align to customers' electricity needs?	Rechargeable CFL bulbs, unscrew and transform into a portable lamp at night Motion detectors on outdoor/paddock lighting Collar lights on livestock, charged on electricity Light dimmers on bulbs – two to three light levels Village communal services (e.g., charging station) powered by surplus energy, run by entrepreneur or a customer

TABLE 3
Opportunity questions and the short listed preliminary ideas.

4.1.3/System visualisations

Next, I conducted a visual analysis of the ideas to investigate their potential. I sketched the context of the service at various scales, focusing on interactions in the systems that Boond operates in. The scales were: the state and district, stakeholders and customers, the Boond system for entering at the village and household level, and individual household energy use. The sketches – both the making and their tangible results – clarified my understanding of the systems and the transactions that take place in them. In doing so, I was better able to relate the preliminary ideas to the parts of the system they address. Next, I situated the ideas in the systems and hypothesised about their feasibility, viability and desirability using the sketch as a background. I did this by writing the idea on a note and placing it on the sketch, and then wrote questions and ideas on another note (Figure 24). Based on the discoveries from this process, I eliminated some ideas, and then refined four ideas and developed development questions to further explore their feasibility. These ideas were then explored and developed to solution proposals presented in the next section.

The four ideas developed in the design proposals are:

/ Entrepreneur capacity building program
/ Redesign the meter interface
/ Boond SMS text messaging service
/ A Rechargeable electric lantern

FIGURE 24
Systems visualisations sketches, clockwise from left: Boond at the village and household scale; transactions between the main service actors, exploring systems for sharing excess energy supply, Boond at the state and district scale; a customer's energy source interactions.

4.2/ THE DESIGN SOLUTIONS

4.2.1/ Entrepreneur capacity building program

Development Questions

/ *How would a training program be efficiently delivered to the entrepreneurs?*

/ *What other support could Boond provide to the entrepreneurs?*

The initial idea was to provide training sessions that build the capacity of the entrepreneur so that he/she is better able to train customers and support them on an on-going basis. Given that both the entrepreneur and Boond staff are on site during the installation period in the villages, it makes sense to fit the training into this time frame. In addition, training could be carried out using the installed equipment, thereby promoting learning by doing.

The entrepreneur training consists of four steps: sales and customer support, the microgrid and central station, and the household system and meters and a village meeting (Figure 25).

Step 1: Boond trains the entrepreneur on the microgrid system.
Step 2: Boond trains on the service and central station and household meters.
Step 3: Entrepreneurs train the customers on the service and meters in the evening when all members of the household are likely to be at home. This is done to provide consistent information and a good start to the service. Training could be supported by how-to videos shown on the entrepreneur's phone and may be uploaded to customers' phones for future reference.
Step 4: Once the entire village installation is complete, Boond holds a village workshop training for entrepreneur and all customers to address any outstanding issues and questions.

The training could be part of a larger resource, The *Entrepreneur's Toolkit*, consisting of:

/ Information and training videos on three topics:
- Service introduction video explaining the service including pricing and features
- Microgrid maintenance and central station meter user guide.
- Household system maintenance and meter user guide.

/ A quick reference visual guide to the central station meter and the household meter interfaces provided on laminated cards.

/ Maintenance guide for microgrid including cleaning process and schedule.

/ An incentive program could provide a flat fee bonus when an entrepreneur signs up a new customer. In addition rewards could be given for re-sale credit payments made by digital or electronic bank payment. The idea is to incentivise entrepreneurs to encourage their customers to pay for recharges with mobile pay. This then establishes funds in the entrepreneur's bank account to purchase resale credits by digital payment.

This is a preliminary list. Further research into entrepreneurs' practices would go a long way to revealing how best to support their work.

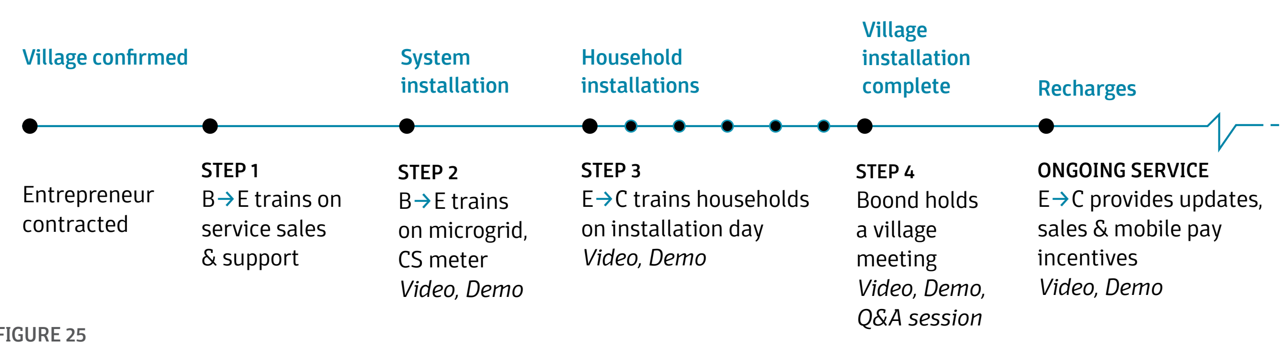


FIGURE 25
The entrepreneur training model.

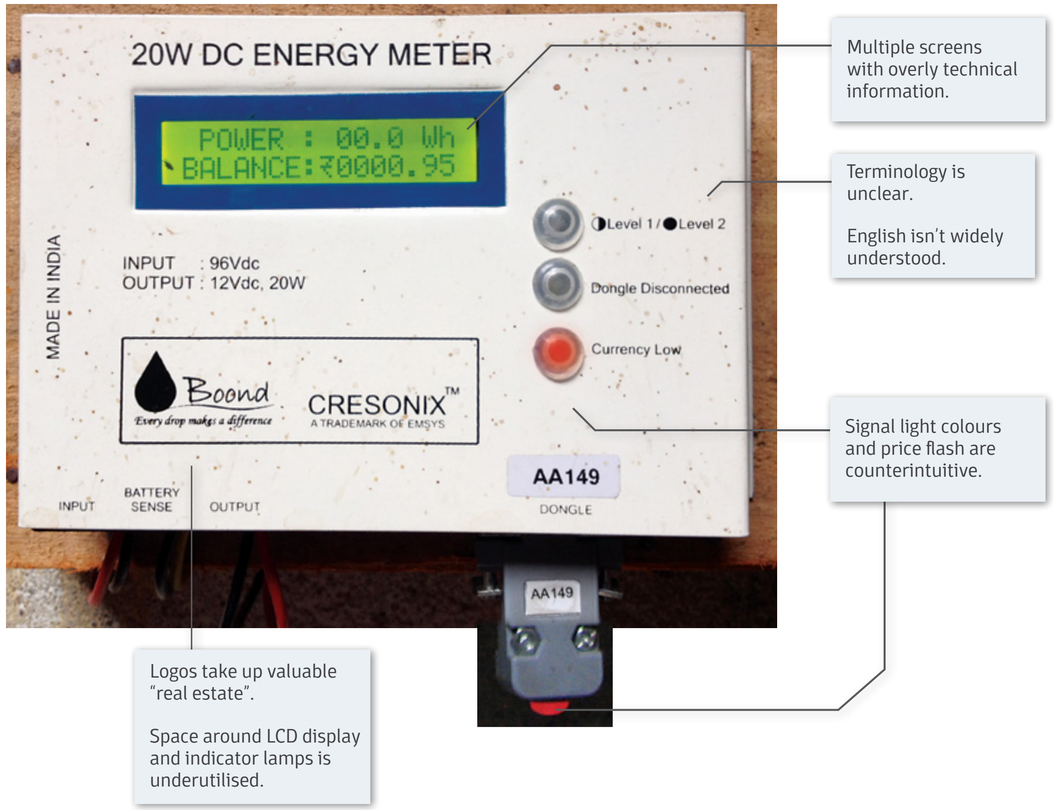


FIGURE 26
The electricity meter before the interface redesign, annotated with the identified problems to be addressed.

4.2.2/ Redesign the meter interface

Development Questions

Within the given confines of the existing meter design:

/ *What improvements could be made to the meter interface to help customers understand their energy use, prices and spending?*

/ *What language should be used on the meter?*

/ *What extra measures could be taken to communicate with low-literacy users?*

THE DESIGN PROCESS

Investigations were carried out by using a photograph of the 20 watt meter as a template for redesign. Design ideas were directly overlaid onto the photograph on computer. This approach provided direct feedback on ideas, identifying new possibilities, problems and questions which were, in turn, explored. Some ideas were abandoned, others evolved into the solution discussed below.

The solution is first presented in a snapshot, above, and in detailed "before" and "after" images in Figures 26 and 27. The before image presents a photograph of the existing 20 watt meter interface annotated with identified problems, followed by the after image which presents the redesigned meter interface and detailed annotations.[1] Following these two images a more detailed rationale is presented.

Based on feedback from Boond, the solution assumes that the existing meter form, functionality and layout would not change for future installations, but that programming and parts could be modified. Boond's meter engineer provided feedback on a draft design. That feedback has been integrated into this proposal. A next generation meter with fewer constraints is proposed later in this section.

1/ Only the 20 watt meter is pictured because it is the most popular meter. However, the same improvements apply to the 60 watt meter, which has one additional price lamp.

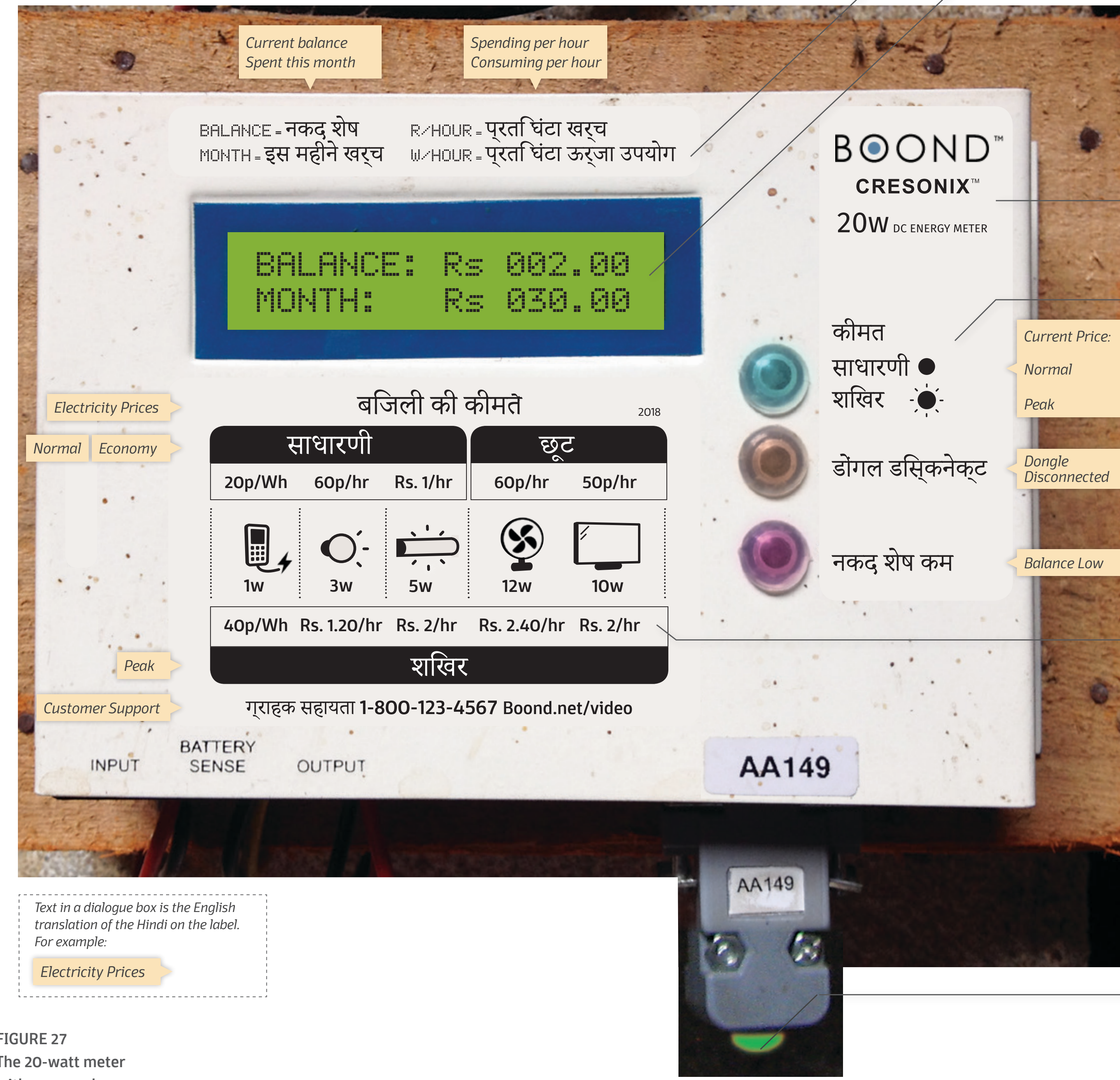


FIGURE 27
The 20-watt meter with proposed improvements.

A legend with English to Hindi (or local language) text translations describes display information.

DISPLAY
Display is simplified to two alternating screens:
· Screen 1 shows spending balances
· Screen2 shows live consumption data

One unnecessary zero is eliminated from the numeral to simplify reading. The rupee symbol (₹) is replaced with the more recognisable "Rs".

Text lines are vertically aligned to assist reading

Boond's logo is repositioned to allow space for price information.

Printed text on the meter face is changed to Hindi.

INDICATOR LAMPS
To make existing pricing levels easier to remember pricing labels are changed to Normal and Peak, plus Economy on the 60w meter.

The Peak price lamp flashes, the normal price lamp is steady.

No changes to the dongle disconnected label.

"Currency Low" is now "Balance Low", consistent with LCD display.

PRICE CHART
A price chart for mobile charging, light bulbs, fan and TV replaces branding and technical labels.

Prices on the meters are renamed:

20 watt meter
P1 = "Normal" use during high supply
P2 = Peak" use during low supply

60 watt meter
P3 = "Economy" high watt appliance use during high supply
P4 = "Peak" high watt appliance use during low supply.

Customer support contacts and a link Boond's website are shown.

DONGLE INDICATOR LIGHT
The bulb colour is changed to glow green when correctly plugged in to meter; red when disconnected.

PRICE CHART

Pricing information is shown on the front of the meter for three reasons:

/ Signal to customers that different prices exist
/ Inform about hourly costs for typical appliances
/ Disclose watt hour price levels.

The pricing information chart considers the spectrum of literacy levels of users by utilising icons, text and numbers to represent information both visually and textually. A poster of this price chart could be posted at the entrepreneur's recharge area.

The proposed icons are a starting point. Matyila *et al.* (2013) found that ideally, icons should be designed in collaboration with customers to ensure that understandable imagery is used (cited in Boyera, 2009).

LANGUAGE

The research revealed that apart from the word "balance", most customers read and understand Hindi better than English. As a result, the text on the meter face was changed to Hindi.

PRICE NAMES

To make existing pricing levels more meaningful, price names were changed from the current P1, P2, P3, P4 to Normal, Economy (60-watt meter) and Peak. The names are a starting point. Further research in the marketplace, for example mobile phone plans, could inspire development of the most appropriate terminology.

INDICATOR LAMPS

The steady and flashing states of the price lamp, used to differentiate between price levels, was reversed so that the peak price flashes. This calls attention to the higher cost of consumption and warns about low supply. The icon was updated to reflect this change.

BEFORE

AFTER

LCD DISPLAY

Many of the problems with the display were identified during fieldwork. The following analysis describes the main issues with the three alternating screens on the display (Figure 28).

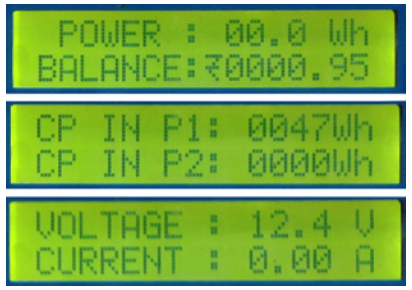


FIGURE 28
The existing meter LCD display screens one, two and three

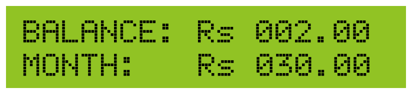


FIGURE 29
Proposed screen one

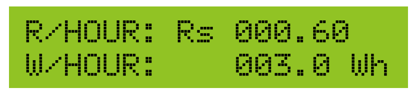


FIGURE 30
Proposed screen two

Screen one: The term "Power" is vague. Balance is the most important information; therefore, it should appear first.

Screen two: "CP in P1/P2" (consumed power in price level 1 and 2) language is cryptic. In addition, the reading is for total consumption from initial commencement of the service.

Screen three: The Voltage and Current data is diagnostic information for technicians, which can be accessed remotely. As this information is of no relevance for customers, removing the screen entirely from the display would reduce the cognitive burden on users.

The redesign proposes reducing the display content to two alternating screens, and rationalising the information into account information and consumption information, as illustrated below.

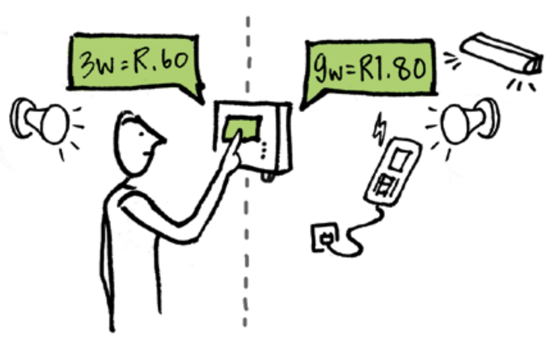
New screen one, account information:
BALANCE: Actual balance remaining in the prepaid account in real time
MONTH: Displays accumulated spending for the active month.

Accumulated monthly consumption is proposed to address the tendency to overestimate monthly spending on electricity. If a customer knows how much they are actually spending per month, then cost comparisons between electricity and other, more easily quantifiable energy costs would be more accurate. This is particularly relevant to kerosene because spending is tracked on a monthly basis due to the government system of monthly rations. (Figure 29)

New screen two, real-time consumption information:
R/HOUR: Real-time spending in rupees per hour informs users about the cost of the electricity they are actually consuming.
W/HOUR: Real time energy consumption in watt hours informs users about the amount of energy they are consuming, which can be correlated with the cost per hour reading above (Figure 30).

The combination of the two data points demonstrates transparency in pricing. Providing accurate and transparent data could go a long way in building Boond's credibility (Figure 31).

FIGURE 31
Displaying the real time consumption enables users to correlate cost to consumption and demonstrates transparency in pricing.



DISPLAY LANGUAGE

The LCD display language remains a challenge. Outstanding issues are design for a low-literacy context, limitations to the display technology and the appropriateness of English. In response to these challenges, I designed the following three approaches.

FIGURE 32
Devanagari text on a 2 line x 16 character LCD display. In this example, some characters take up both lines on the screen.

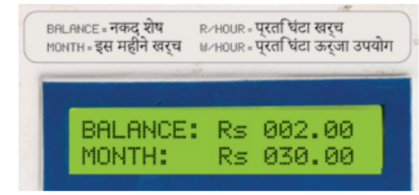


FIGURE 33
English display with Hindi translation label.

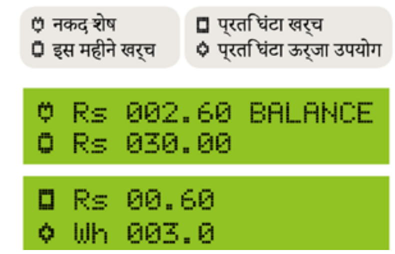


FIGURE 34:
Symbols display with Hindi translation label.

Hindi display
The Hindi labels printed on the meter face imply that the LCD display language be the same. The meter engineer confirmed that the LCD display language can be changed to Hindi by programming a custom Devanagari script character set. The display programming would be part of the normal work flow (once the characters are programmed).

However, there are technical challenges that raise several questions. These include:

- / Would there be enough space for longer Hindi expressions on the 2 x 16 character screen? Abbreviations are problematic as demonstrated in the current meters.
- / How would more complex Hindi characters render on an LCD screen, as demonstrated in Figure 32?
- / Because the term "Balance" is well recognized, should there be a break in protocol by using this English word?

English display with Hindi translation
The second approach is an English display with an English-Hindi translation of each screen printed on the meter (Figure 33). This approach affords more nuanced descriptions than the display is capable of, for example "R/Hour" is translated as "spending per hour". With English as the default display language, other languages may be easily shown in print. One drawback to this approach is it requires users to correlate two languages/alphabets between screen and print, which may be an obstacle for less literate users.

Symbols and translation legend
A third approach is to replace text with basic shapes in the display (Figure 34). A printed legend above the display provides an explanation in Hindi (or other language). Like option two above, this approach affords more nuanced descriptions and other languages may be easily accommodated. "Balance" is included due to its recognition, and to visually differentiate the two screens.

POSITION THE METERS AT EYE LEVEL

Meters should be positioned at eye level where it is convenient for adults and school-age children to view. A younger child may step up on bag of rice or other aid, as they already do, to view a meter that has been secured from the reach of toddlers. In addition a security latch could be placed on the dongle. A photo of the current meter position juxtaposed with the proposed meter placement is shown in Figure 35. A sketch illustrates an adult and school-aged child at the meter out of reach of a toddler (Figure 36).

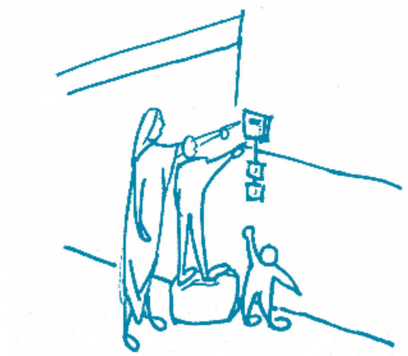


FIGURE 35
The existing meter position (left) and a retouched version illustrating the proposed position (right).

FIGURE 36 (TOP RIGHT)
Adult and school-aged child with a stool are able to get close to the meter, while it is out of reach of a toddler.

FUTURE SCENARIOS FOR METERING:

NEXT GENERATION METER

The meter interface redesign process inspired ideas that were not applicable to the existing meters, but which could be applied to the next generation meter. These ideas were driven by questions of how to communicate account information to low-literacy users in a non-textual way. Colour and sound were two techniques that stood out as possibilities. In order to explore those, I had to break away from the confines of the current design and imagine the next generation meter in the near future, and respecting a frugal approach by building on the current meter design.

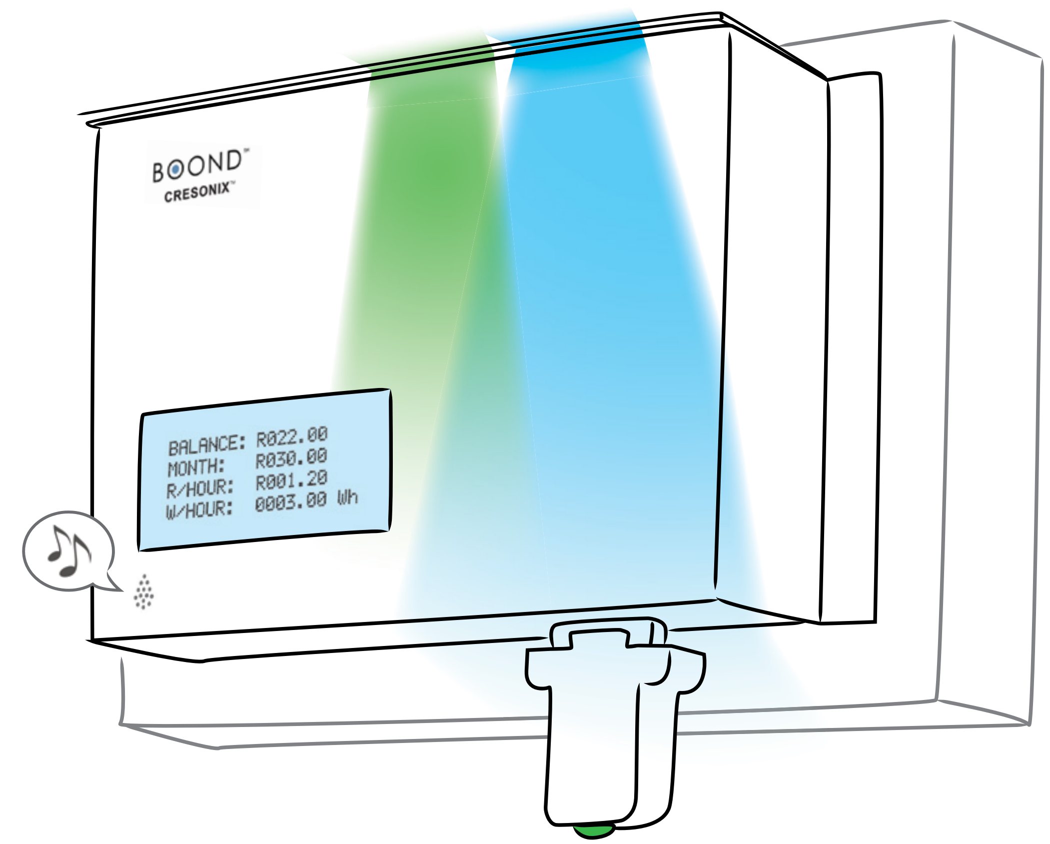
Projecting into the future, it is likely that networking Boond's meters through cellular service will be more affordable. This presents an opportunity for Boond to track usage more precisely and provide real time feedback to customers. The microgrid would be connected to the electricity grid. Villages are both consumers and producers of energy, thus, profitability of the service has increased because surplus supply is sold to energy utilities. The cost of sound, display and LED light technology have lowered, and their capacities increased, thus, making them more apt for the frugal requirements of the meters, thus, more easily demonstrating the cost advantages of Boond's services over other energy sources.

Three main ideas are demonstrated in Figure 37.

/ Bold colours could be employed to communicate the state of the account. Not only does colour substitute (OR supplant) the need for text, colour calls attention to the meter by visual cues. Coloured LED lights would spray down on to the meter face sending a more definitive message than the smaller existing indicator lamps. A green indicator light glows constantly when balance is in positive supply. A red light replaces green when the balance is low or at zero. A blue light glows when the dynamic pricing is in effect.

/ A small speaker would sound an alert when the balance is low and when peak pricing is activated. A selection of alert ringtones could be offered at installation.

/ A finer resolution screen would provide the necessary definition to support vernacular scripts. All information would be displayed on a single screen, thus, making it easier for customers to review their energy use information.



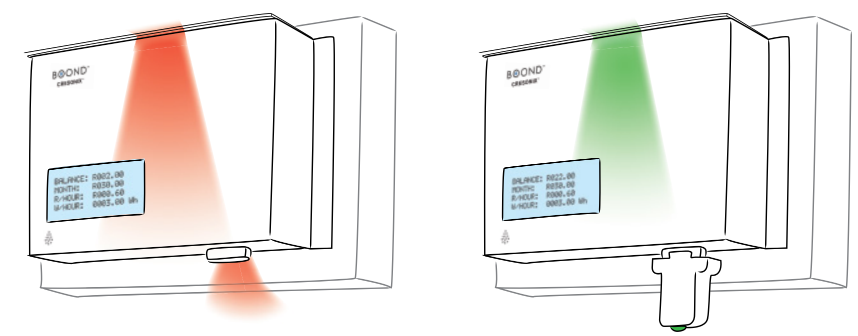


FIGURE 37
The next generation meter in various states.
Top: balance positive and peak pricing in effect.
Right: balance low and dongle disconnected; balance positive and normal pricing.

FUTURE SCENARIOS FOR METERING:

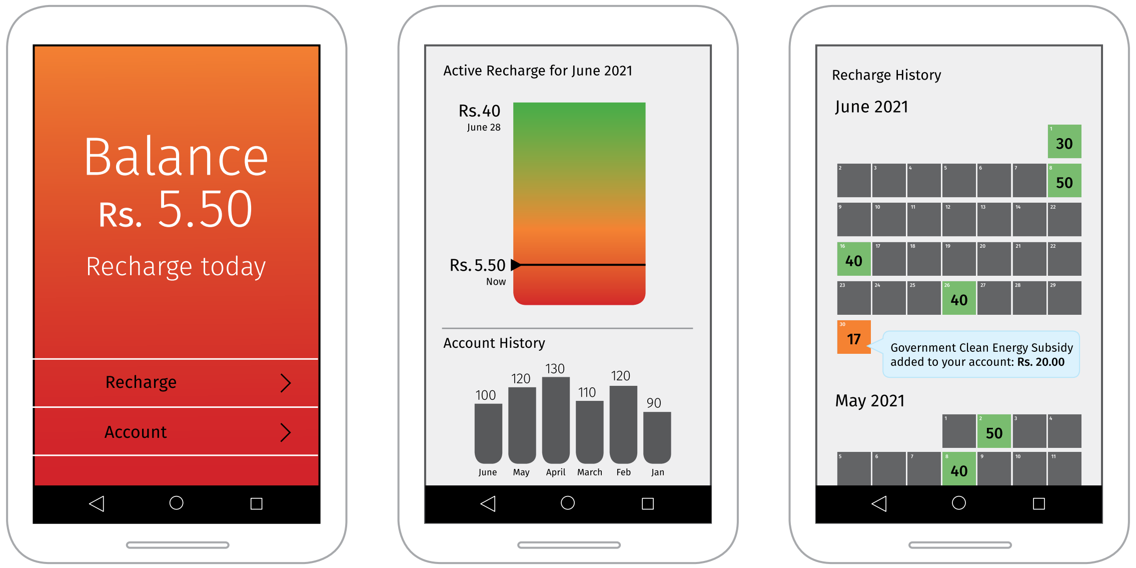


FIGURE 38
The Balance App screens one to three. The background colour gradient transitions from green to red depending on the balance level (i.e. green high, orange medium, red low). Users are prompted to recharge based on their average daily consumption.

THE BALANCE APP

Imagining a *perfect storm* of more affordable smartphones, improved network coverage, rising incomes and expansion of prepaid service reach, it is worthwhile to explore how account information may be communicated on a smartphone application. The *Balance App* provides both real-time and historical account information and links to mobile payment platforms (Figure 38).

Screen one: A home screen with the meter balance would bring real time monitoring to people's fingertips. Bold colour conveys the state of the account (green = high, red = low), and corresponds with the lamp colours on the proposed next generation meter interface. Customers may pay the entrepreneur through the recharge link to a third party digital payment platform.

Screen two: A level marker shows the current balance in the active recharge. Colour corresponds to the home screen state. The account history is shown in a bar chart to display monthly spending over the past six months.

Screen three: The recharge history is shown in a calendar format. The calendar shows all activity, including any deposits made by external agencies. Depicted here is the speculative *government "clean energy" subsidy* deposited directly into the customer's account.

While the content is designed to be visually rich to reduce the challenges of reading written text, it is worth considering that differently literate users would adopt tools to support reading and texting. Accessibility applications such as text to voice, video and voice messaging ease navigation and reduce typing and reading (Bellman, 2017).

4.2.3/SMS text messaging service

Development Questions

/ *How would a text message service work?*
/ *What data is possible to text automatically?*
/ *What notifications would be important? What would be useful, helpful, delightful?*
/ *How to make message content accessible to low-literate users?*
/ *What considerations do shared phone and proximity of the phone to the home/meter raise?*

Note: For the purpose of this thesis, messages are shown here in English. It is possible that in actuality messages would be in the local language.

THE DESIGN PROCESS

The initial idea envisioned using visuals in place of text where possible. I investigated the possibility of using images in text messages on feature phones and discovered that they do not support images or emojis. In response, I propose that text be minimal, with an emphasis on numbers, and that text-based emoticons and colour further communicate the message content (Figure 39). I acknowledge that some users will require help to read the messages, and that while this practice exists, it is not ideal.

The initial idea was a text message service that provides real time balance and price alerts and a monthly account statement to customers. In turn, customers could request account information and contact customer service.

I sketched a plan of the service, mapping the events that would trigger messages and requests along a typical monthly cycle (Figure 40). Two key issues emerged from the plan. The first was the high quantity of messages the plan generated. I identified that if there were two recharges and one price change, nine messages would be sent in an one month timespan, and concluded that this quantity and frequency of messages would be burdensome for the customer. Related to this, I suspected that a service of this scope would likely be expensive to deploy and maintain (feedback from Boond confirmed this hunch). The second issue was an oversight that the balance of the household meter is not communicated in real time to the service database. Although the central station meter is networked, the household meters do not have cellular network capability due to the prohibitive costs of equipment and data plans, and spotty rural cellular networks. This eliminated one of the main drivers for the service: notifying customers about their low balance on their phones. Despite these obstacles, I saw the potential that text messages could bring value to customers. I re-oriented my questions toward what was possible for an automated system and how that data could align with customer and business needs.

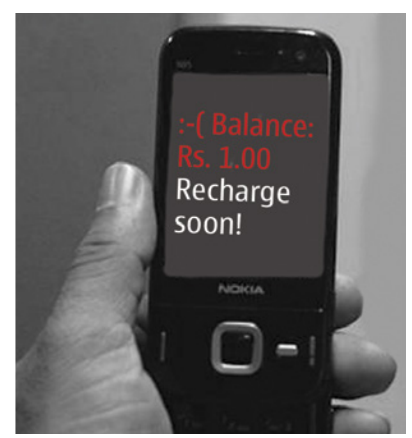


FIGURE 39
Simple messages would employ emoticons and colour to augment the text.

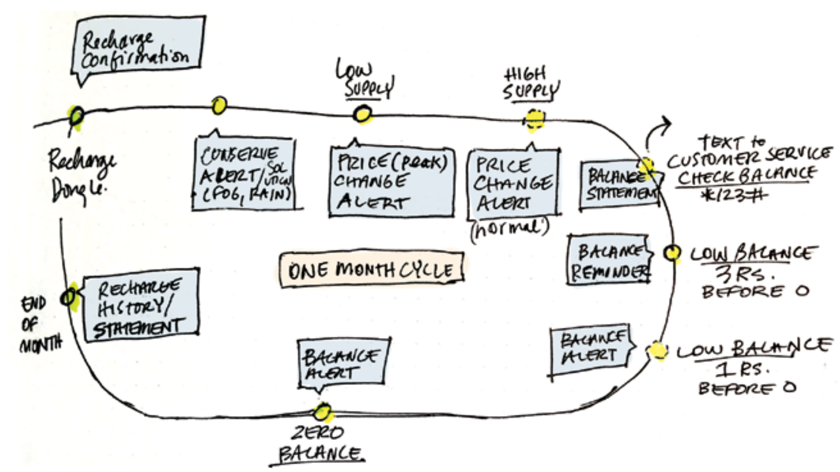


FIGURE 40
Preliminary service plan based on a one month cycle.

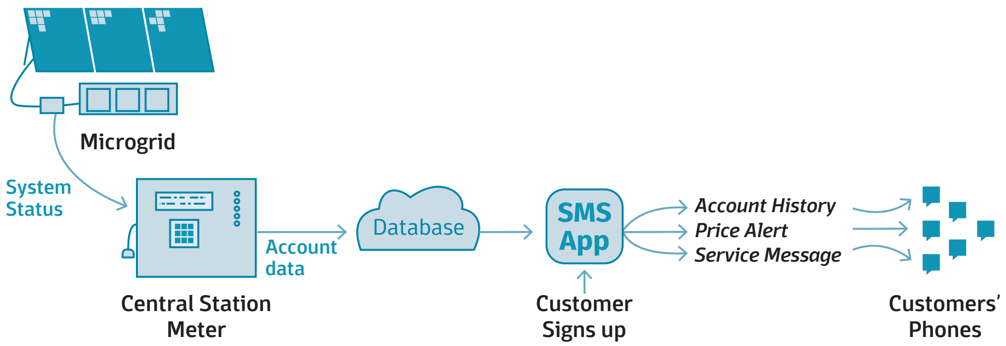


FIGURE 41
System data and customer data are collected on the database and fed to an SMS messaging application for automated messages.

Next, I inquired into the data that could be automated into a message, and of that, what data would be useful. The result is illustrated in Figure 41 and described as follows: drawing from prior knowledge, the central station meter is connected by mobile network to the database. Customer purchases and accumulated energy consumption are stored in the database at each recharge. This information could be shared with customers in a monthly statement and account history (which are both lacking from the current offering). System monitoring data (e.g., supply status) could inform customers about price changes and prepare them for low supply occurrences. This selected data could be directed to an SMS messaging application and composed into automated text messages.

The text messages were then structured into a service plan which is described next. A customer subscribes to the free service by sending a text message with her/his phone number and meter number to the customer service number. Multiple members may subscribe to the service, including a delegated friend or neighbor outside of the household. Given that a shared family phone may be out of order or off premises, the delegate may pass on any messages by word-of-mouth. Following sign up and a confirmation message, the following messages would be provided by the service:

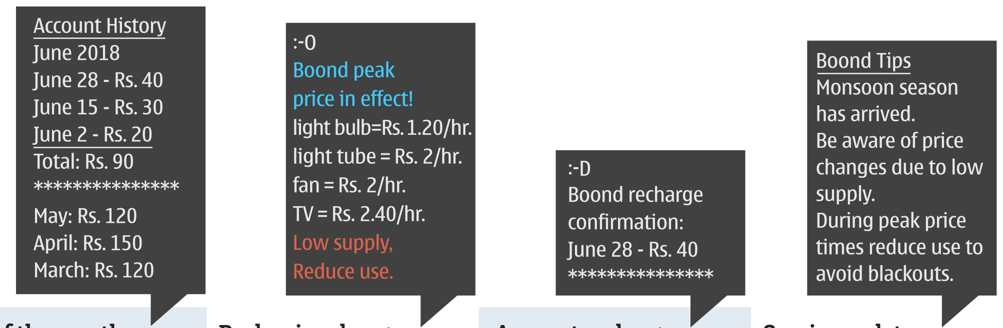
/ A monthly account history. This includes a statement of recharges in the active month, plus a list of previous months' totals. This addresses the tendency by customers to overestimate their monthly spending and provides actual data for making cost comparisons with other energy sources.
/ A recharge confirmation. This provides an accountable record directly to customers and promotes trust in the service.
/ System-related messages. These include peak price alerts and low supply warnings. Price alerts promote cost-effective consumption and 'nudging' customers toward desired behavior when supply is low.
/ Service updates, meter reading and price tips raise awareness about the service functions, managing expectations and cultivating engagement with the service.

A plan for the events that trigger the message, problems the messages address and their proposed response and outcomes is outlined in Table 4.

OUTSTANDING QUESTIONS

Questions remain about the accessibility of the messages to low-literate users. Given that the messages are textually intensive, some users may require help to read them, or they simply may be disregarded. In keeping with the meter reading practices, it is reasonable to expect that the messages would be discussed with other members of the household. Furthermore, repeating monthly account and recharge messages would become familiar over time, and it is reasonable to predict that customers would learn to recognize the important numbers in the messages through rote learning.

There is an outstanding question about the frequency of the peak price alerts during periods of fluctuating supply (during monsoon). Boond was not able to provide answers to questions about the frequency of peak price fluctuations, therefore, the following is based on an extreme scenario. If prices fluctuate daily, the frequency of alerts could become an annoyance, and as a result lose their effect. Subsequently, during a high frequency of fluctuations, an additional price alert would likely be required to announce the end of peak pricing with a normal price alert. In the event of this, a twofold increase in price change alerts would result. In this case, it may be worthwhile to broadcast a general alert covering the monsoon period, and suspend peak price alerts during seasonal monsoon. Nonetheless, the likelihood of this scenario, and the implication for message frequency, requires further investigation.



EVENT	End of the month	Peak price change	Account recharge	Service update
PROBLEMS ADDRESSED	Over-estimate monthly spending Challenge comparing energy costs No personal/accessible record of purchases Doubts about service credibility/integrity	Lack of awareness of price levels Confusion about prices Continued use during low supply Irregular service due to low supply	Doubts or confusion about account balance/ spending	Lack of awareness about service supply, pricing and features.
PROPOSED RESPONSE	*"I thought I spent more than that. Maybe electricity isn't as expensive as I thought it was."* *"How does that compare to last month's kerosene spending?"*	*"I better switch off the lights early."* *"I'll charge the phone during the day."*	*"OK, good, it went through."* *"My balance seems low. How much did I recharge last time?"*	*"OK, I should prepare to use less electricity this month."* *"Now I understand the meter display better."* *"I forgot that there was a discount price for the fan. I can afford to use it more during the day."*
PROPOSED OUTCOME	Monitor spending accurately Easily compare electricity to other energy sources Build trust in service Transition from kerosene use to electricity	Reduce use at critical times Switch some consumption to daytime (e.g., phone charging)	Build trust in service Provide and accountable record of spending	Raised awareness of prices Educate about system supply, manage expectations of service Shift to daytime use at low supply Service regularity/ dependability Battery lifespan maintained
MESSAGE FREQUENCY	Once per month	Daily during monsoon, foggy weather, extreme heat (fans)	Once per recharge, estimated 2-4 times per month.	As required, estimated once per quarter.

TABLE 4
The SMS messaging plan.

4.2.4/ Rechargeable electric lantern

Development Questions

/ *How might a lantern offer a viable kerosene lamp replacement?*
/ *What are some frugal ways that a lantern could be introduced/ integrated into the kit?*
/ *What role might a new clean energy subsidy play in the uptake of the lanterns?*

A portable, rechargeable electric lantern is proposed to address on-going kerosene use, an expensive fuel that provides poor quality lighting. A rechargeable lantern would provide an alternative to kerosene lamps, which people still value for their portability and soft light. The lantern could replace one of the 3-watt light bulbs in Boond's installation, thus, diversifying the lighting product offering to more closely align with people's needs. This attention to customer needs would position Boond at a competitive advantage as the market becomes more crowded with electricity service providers. Spending on kerosene would shift to electricity, providing customers with better value for money and increased revenue for Boond.

THE DESIGN PROCESS

The design process began with the question: What if the current Boond installation could be adapted to include a portable lantern, keeping in mind frugality? Some criteria I set based on the research findings were:

/ The lantern's rechargeable battery would be charged on the Boond system
/ It would have multiple brightness modes:
  - low for an ambient quality of light
  - medium and high for task lighting.
/ It should be easy to carry and adapt to different spaces, for example be capable of hanging from a ceiling hook or tree branch.

Several preliminary ideas were elaborated in design trials and explorations. As such, these ideas are offered as a starting point rather than a final conclusion, they are discussed next.

THE CONVERTED KEROSENE LANTERN

An early idea was to convert customers' existing kerosene lamps into battery-powered lamps. The lamp vessels (bottles, cans and metal tanks) could be cleaned, the old wick removed and replaced with a mini LED bulb and wiring, with a rechargeable battery pack inserted into the vessel or attached externally (sketched in Figure 42). Facilitation and materials for converting the lamps could be provided by a local NGO, with labour carried out during community workshops in the villages.

The converted lamp idea satisfies some frugal requirements, such as using locally available materials, labour and the villagers' ingenuity. On the downside, poor durability and dim light would be immediate concerns. The logistics of collecting the lamps and re-purposing them – they come in myriad shapes, sizes and materials – would be quite complicated. And then,

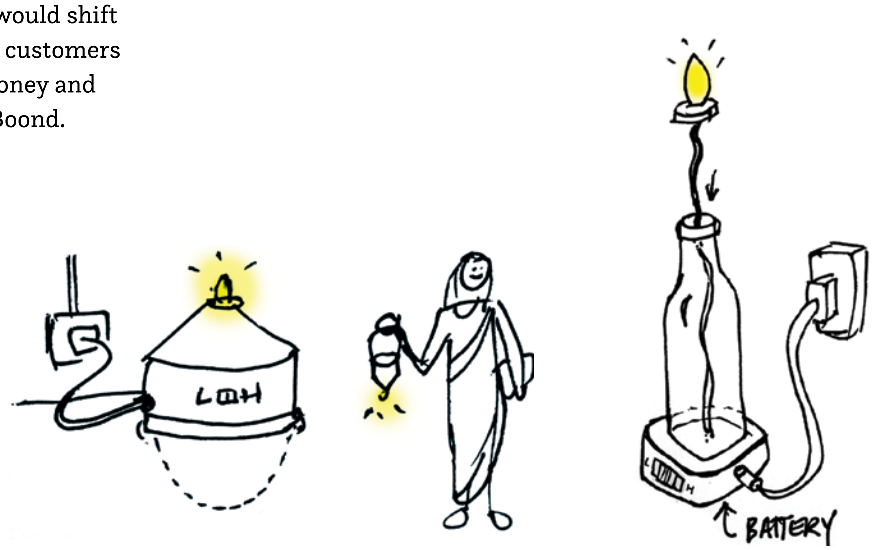


FIGURE 42
Sketches of a converted metal kerosene can with charging cable and a wire handle, and a converted bottle on an external battery base.

Kerosene lantern vessels come in many shapes, sizes and materials. Some are purpose built and others are fashioned from found objects such as this chemical canister. The sketch over the photo illustrates how this lantern might look once converted into a rechargeable lantern.

there's the question of whether people would be willing to part with their lamps ,which serve as an important backup light source in the event that electrical sources fail.

Technicalities aside, converting the lanterns might prove valuable for engaging communities in discussion on the topics of energy consumption and clean energy at a policy level. Along those lines a converted lantern as an artifact could be introduced to prompt discussion, an object of speculative design. The lamp as an artifact could be fashioned in such a way that it symbolises the transformation from the old ways of lighting with kerosene to modern, efficient clean energy. How might a lamp such as this provoke dialogue about kerosene subsidy and clean energy policy? This could be an interesting object for speculative design, an approach that uses design as a tool to create things and ideas to imagine possible futures.

RE-PURPOSED 3-WATT LIGHT BULB LANTERN

The next exploration began with the idea to re-purpose one of the existing 3-watt LED light bulbs from a mounted wall light into a portable lantern that could be plugged in, and charged, directly to the wall socket (similar to a night light, but bigger and brighter) (Figure 43). A frugal use of materials and labour were the main drivers behind this lantern idea. However, preliminary research revealed a number of technical constraints. The size and weight of the battery would be excessive for wall socket charging, and dimming the LED bulbs (if feasible) would require extra hardware that would add to this weight.

CUSTOM MADE LANTERN

Therefore, I rethought the idea to a custom-made, cable charging lantern using a smaller, dimmable 3-watt bulb (Figure 44). A frosted plastic shade protects the bulb and diffuses the light. One version explored the idea of a flame-shaped protector as a nod to the kerosene lamp it replaced (Figure 45). Ideally, the lantern would be built with the same frugal approach as the existing installation, using Boond's expertise, networks and readily available parts and labour. Retailing the lamps under the Boond brand to a wider market could justify the up-front costs of custom manufacturing.

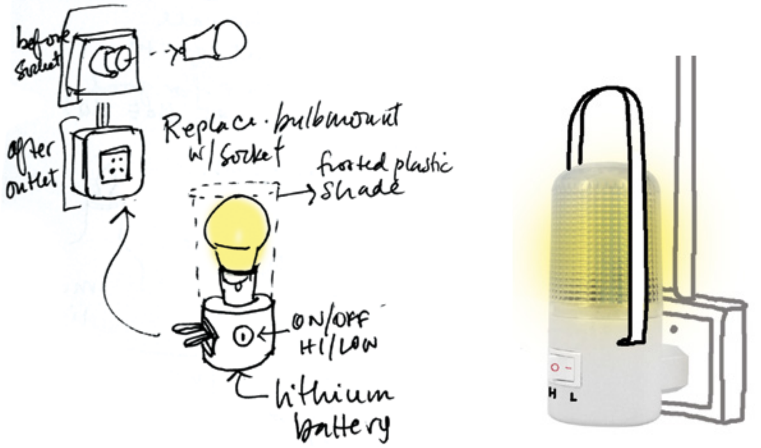


FIGURE 43
Concept sketches and an early photo visualisation for the re-purposed 3-watt bulb lantern.

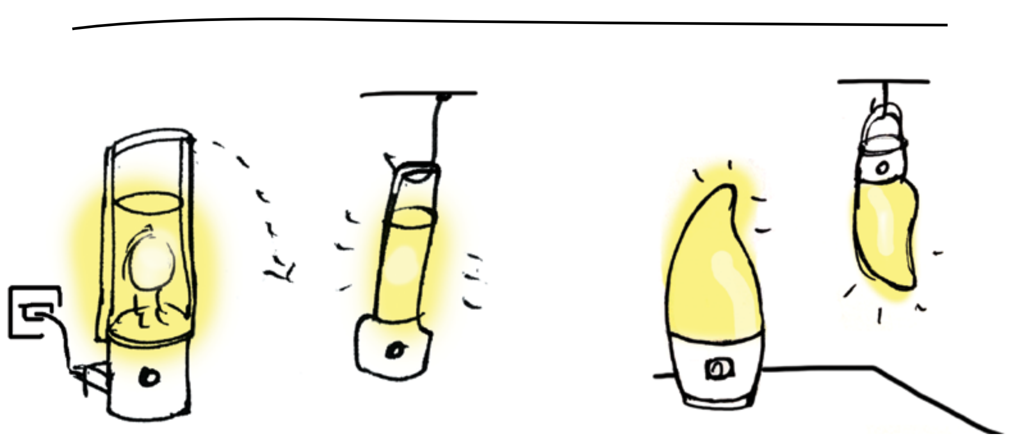


FIGURE 44 (LEFT)
The custom made lantern charges via a USB cable in the wall outlet and includes a built in handle.

FIGURE 45 (RIGHT)
A flame-shaped shade evokes the kerosene lamps that the lantern replaces.

FIGURE 47
Lanterns fill a need for portable lighting. The SunKing lighting unit adapts to a hand-held version. This suits active tasks such as corralling livestock at the end of the day and making security spot-checks throughout the evening.

MARKET-READY LANTERN

A third option would be to work with an existing lantern. There are many battery-powered lanterns already on the market. Some of these have been designed for rugged conditions and priced for frugal markets. One example is the SunKing solar-powered lantern produced by Greenlight Planet (Figure 46). The light unit has several brightness settings and can be detached from the stand for hand-held use (Figure 47), and the stand doubles as a hanger. Boond has already adapted a version of the lantern for its school lighting program; the out-of-the-box lantern normally charges directly from a separate solar panel, but it was adapted to charge on the school's microgrid system. This kind of approach could be extended to the household context. Working with an existing, proven product would be faster to deploy and likely more affordable for customers than custom design and manufacturing. It is acknowledged that theft, damage and loss are risks that would require some mechanism to minimise or prevent. Creative financing could be arranged, such as a financing model where a portion of the prepaid credit goes toward outright ownership of the lantern.

An outstanding issue that needs to be addressed is that the lanterns might be charged from other energy sources, such as an SHS. This would undermine the lantern's potential to increase consumption of the prepaid service. Further investigation into how to deter charging from other sources, for example a hardware fix or incentives, may be required.

FIGURE 46
The SunKing Solar lantern may be used as a desk lamp or hung as a ceiling light.
(photo: Greenlight Planet)

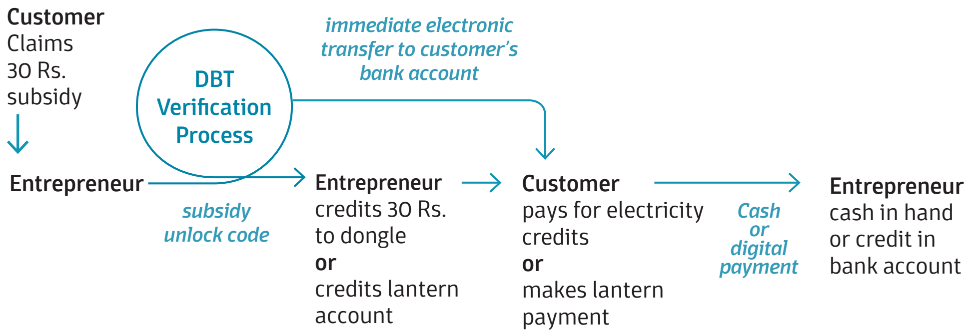


FIGURE 48
The "clean energy subsidy" payment model.

THE ENERGY SUBSIDY'S ROLE IN THE LANTERN UPTAKE

Development Questions
/ *How might the solar subsidy be applied to promote the prepaid service and pay for the lantern?*
/ *How to get digital payment into system/service so that entrepreneurs can buy resale credits from Boond using digital payment?*

I propose a model for using a clean energy subsidy based on two reports by the International Institute for Sustainable Development (IISD) on kerosene subsidy reforms (Garg *et al.*, 2017; Jain & Ramji, 2016). Their reports propose steps to phase out the kerosene subsidy and replace it with a clean energy, or "general lighting" subsidy. According to their proposal, the clean energy subsidy would credit consumers directly through a one-time payment for the purchase of renewable energy equipment plus an on-going monthly subsidy.[1]

In the model (Figure 48), customers claim their Rs. 30 monthly subsidy through the entrepreneur, who enacts a subsidy verification process, and receives an unlock code to confirm that the subsidy has been applied to the service. The Rs. 30 is immediately transferred to the customer's bank account, and the customer may buy electricity credits or make a lantern purchase payment with the funds (until it is paid off). Subsidy payments in India are transitioning from the physical coupon model to a digital model called Direct Benefit Payment (DBP), a program to reduce corruption and wastage in the system. With DBP, the subsidy is paid directly into the subsidy recipient's bank account. The DBP also advances the government's agenda for the "Digital India" program to nudge citizens away from cash toward mobile pay platforms (online banking and mobile payment services). In this case, a customer would then pay an entrepreneur for credits using mobile pay, and, in turn the entrepreneur may purchase re-sale credits from Boond with mobile pay. This would improve efficiency for Boond by reducing the time and cost spent on making monthly collections from entrpreneurs in the villages.

IMPLEMENTATION

In order to demonstrate the relevance of the solutions to the main service actors, they are elaborated (in green) on the main service actors diagram (previously shown in Figure 4) in Figure 49. Of note is that the text messaging service opens up a new channel of communication directly between Boond and its customers. This refers back to the insight that while the entrepreneurs are the main channel of communication between Boond and its customers, it leaves Boond to depend entirely on the their diligence to effectively facilitate the service. The SMS messaging provides an additional communication channel to the primary role of the entrepreneurs.

The iterative nature of service design supports the continual development of existing services including change within the organisation, its approach and internal processes at a system level. In fact, Ideo[2] encourages organisations to tackle existing challenges for the biggest impact. In their *HCD toolkit, a DIY guide for NGOs* they emphasise that this is particularly relevant for organisations in the development sector working in low-resource (frugal) settings:

> *"While many organizations are initially attracted to the idea of "Revolutionary" innovations, in reality an innovation pipeline that focuses on existing capabilities or targets existing customers can be the strongest strategy for the near term."*
> [IDEO and iDE, 2009, p. 137]

1/ In addition, the authors propose that the government direct another portion of the subsidy allocation to investment funding for decentralised renewable energy providers.

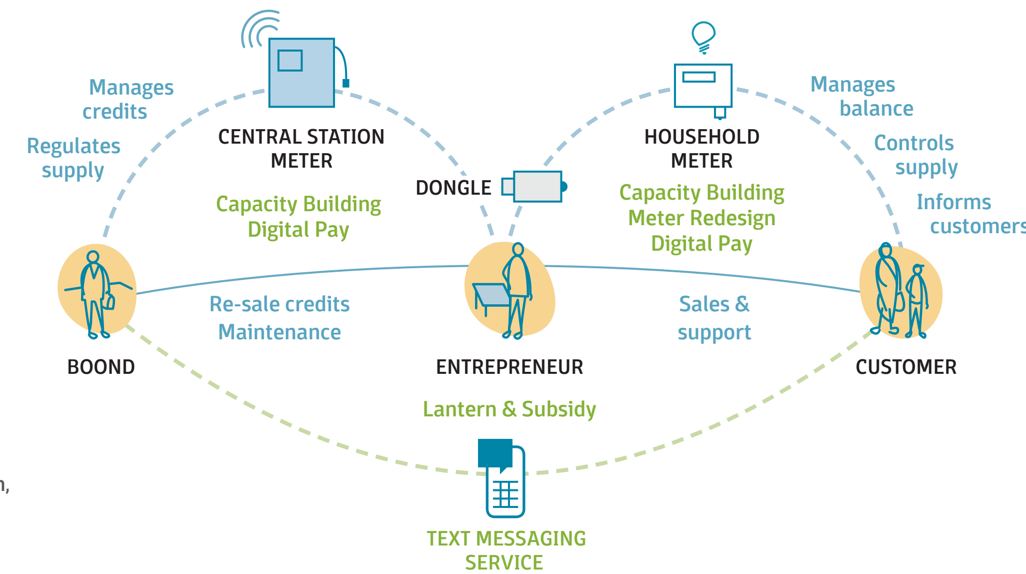


FIGURE 49
The revised Main Service Actors diagram, with the solutions added in green.

For this reason, this thesis proposes incremental design improvements that may be built on to existing systems and which can be priortised and phased in over time.

This chapter has described four service improvements including near term and longer term solutions. Although these solutions were based on the Boond case study, the intention is that they could be inspire and inform solutions for a wider range of solar powered electricity services. With this intention in mind, the research and development process were described to underscore the rationale behind the solutions.

As mentioned previously, the proposed designs are more of a starting point than a final solution. Development questions drove the process, and some of those questions remain unanswered.

The next steps would be to take the solutions into the field for further inquiry and use low fidelity prototypes to validate and refine them. In terms of implementation, the training and the meter interface redesign could be developed first. Without having the full details on the internal systems that would need to be addressed, it is my estimation that they build on existing equipment and resources and would be the easiest to develop first. The SMS messaging service and lantern development are more complex, requiring equipment and systems development, and would be a longer term process to implement.

This concludes the research and design part of the thesis. The next, and final, chapter closes the thesis and includes a discussion of relevant issues and a personal reflection on the thesis process.

2/ Ideo is a world-renowned human centered design and strategy firm.

05

DISCUSSION AND CONCLUSION

This chapter concludes the thesis with a discussion of the topics, challenges and opportunities for prepaid electricity services. It discusses some of the larger issues at play in the energy system and touches on the socio-technical influences relating to the service and its design. It also brings forth thoughts on a tension between frugal innovation and human centered design. Furthermore, it opens up the limitations of the thesis and gives direction to further research. This is followed by a conclusion of the research and its relevance to the design of prepaid electricity services in rural India. The chapter closes with a personal reflection on the thesis process including lessons from the field research experience.

"On average we are seeing that … 1.2 hours of light are gained per day, but there is a saturation point at which families seem to tail off their lighting use. This shows that there are likely upper limits to demand for more hours of light. After all, there comes a point, even with reliable grid access, where we all turn off the lights and go to sleep."

Energy Impact Report on the impact of renewable off-grid energy innovations (Acumen, 2017, p. 30).

5.1/ DISCUSSION

This thesis identified a number of challenges in the usability of the Boond service that directly or indirectly impact its uptake, and then proposed design solutions to improve on these.

In addition, the research identified a number of secondary issues that may also influence service uptake, but that were beyond the scope of this thesis to fully investigate. They are briefly discussed here as food for thought and potential avenues for future research.

The thesis proposed various service design and meter enhancements that could improve service uptake. The reality, however, is that the current uses of electricity – lights, fans, and phone charging – consume small amounts of electricity. To significantly improve the profitability of prepaid microgrid electricity in order to ensure their long-term sustainability there would need to be a broader range of electricity usage of higher wattage appliances, such as refrigeration and climate control. In addition, the introduction of light electric bicycles into the market presents an opportunity for broader electricity usage. However, given the current economic and infrastructure reality of rural Indian villages, further research would be required to assess the likelihood and realistic time frame for these developments. Another interesting development is provisions that permit village-level microgrids to connect to the grid, whereby, microgrids supply basic electricity services to villages, while selling excess power to utilities, thus improving profitability.

Another challenge for the uptake of prepaid microgrid electricity services is the existence of incumbent competing energy sources. This thesis proposes solutions to address the overestimation of the cost of the Boond service, and the unsuitability of its lighting to certain tasks, which may be driving some of the preference for competing energy sources, there may be other factors at play that are beyond the ability of design to influence. For example, there is a legacy of distrust of private electricity providers and an expectation that the State should provide electricity. In the case of kerosene, which is heavily subsidised by the State, these factors may continue to drive the preference for this energy source, even where it is shown to be less suitable and more expensive than prepaid microgrid services. Some of the preference may simply be force of habit. It is not unreasonable to expect that, over time, as India transitions toward renewable energy sources, the kerosene subsidy is eliminated (and possibly replaced with a clean energy one)[1], SHSs reach end of life, and new energy use habits and preferences are developed,

1/ Another key change that is needed is Government support for solar-powered electricity providers to compete with the dominant carbon-based energy industry. A growing interest/momentum toward financing solar-electricity projects (Acumen, 2017; The Climate Group, 2015) and a general lighting or clean energy subsidy shows promise for funding uptake of solar-powered electricity services (Garg *et al.*, 2017; Jain & Ramji, 2016).

the current incumbent energy sources will be replaced by prepaid electricity services. To help increase the likelihood that this transition happens sooner rather than later, prepaid electricity service providers must continue to ensure that their services are reliable, affordable and fit for purpose. As off-grid local energy providers such as Boond, Simpa Networks and Mera Gao are expanding into rural Indian villages, awareness of solar-powered electricity services as a viable option are creating demand. These larger systemic changes paint a promising picture for the future of solar electricity services.

An issue that was highlighted through the research, but which was beyond the scope of this thesis to explore in detail, is the extent to which some of the challenges facing the uptake of the Boond service is a reflection of the general disparity within Indian society – that is, urban vs. rural, formally-educated vs. differently-literate, affluent vs. poor, modern vs. traditional, adult vs. youth, etc. While the Boond engineering team has created a technologically-sound prepaid electrical service, there are certain aspects that reflect this disparity and may be impacting the service's accessibility, from a human centered design perspective. For example, the inherent, albeit understandable, bias of a system designed by formally-educated engineers from urban backgrounds, suggests that the implications of the socio-economic context of the rural villages in which these services would be used may not have been fully appreciated or taken into account in the design. This disparity is evident in the service when looking at the use of English language and prominence of textual communication on the meters that a differently-literate person wouldn't understand and the need to be literate in order to use the meter at all. It is also evident in the placement of the meters which show a disparity between adults and children.

An element of technological optimism, or a "build it and they will come" attitude, may have created a sense of over optimism that people would abandon existing energy practices in favour of prepaid electricity without there being a clear benefit of doing so. This optimism is evident in users' direct interaction with the equipment, for example, customers with different literacy skills interact with the meters differently. Also people have lighting needs that the Boond offering of fixed, bright light does not satisfy or exceeds, and they will naturally turn to other, more appropriate, lighting sources. Also, the degree to which prior investment in other energy sources will influence customers' energy use decisions may have been underestimated. In the end, the availability of the Boond service does not override all of the considerations that people take into account when making their energy use decisions. As one participant stated: "I have other options".

This highlights a potential tension between frugal innovation and human centered design. The emphasis of frugal innovation on technical- and cost-efficiency may conflict with the collaborative, cross-disciplinary approach of human centered design, which takes time and is not necessarily straightforward or efficient. The question of how to strike the right balance between collaboration and taking the necessary time to develop empathy with users, and a more business-driven, pragmatic process of production and efficiency, requires further consideration.

5.2/ LIMITATIONS

In view of the single visits to households during the winter months the data gathered is not representative of year-round use (e.g., summer time use is likely different than winter use). The participants in the villages, while very approachable, displayed some discomfort with answering abstract questions, and at times the design research methods came across as esoteric and felt inappropriate to the context. This limited my ability to make a deeper connection with the participants, and was in part amplified by differences in language and research approach between myself and the field interpreters. Interview transcripts were written by non-native English speakers which were often difficult to decipher. In these cases, I had to cross-reference my field notes and meter data in order to fill in the gaps.

As a result of the limited time and resources in the field, inadequate attention was paid to on-site inquiry into Boond's internal service processes. Instead, discussions by phone and email were undertaken with several team members. This was not as informative as in-person discussion would have been. This means that some internal systems and processes likely require more attention in the design proposal.

5.3/ FUTURE RESEARCH

While as previously noted the prepaid service has already had some impact on the reliance on kerosene, further research into what opportunities exist to eliminate it entirely would be beneficial. To this end, a rechargeable lantern pilot project to test feasibility and the impact it has on kerosene and electricity consumption could prove the business case and contribute to ending kerosene for lighting altogether.

Future research is required to better understand people's mobile phone habits and competence, in order to identify synergies between the mobile phone and electricity service delivery. A study of this kind could reveal potential avenues for extending the service provision to the phone. Given the predictions for increased phone adoption in India, and the government's push for digital banking, studying attitudes about cash and digital payment in the prepaid service context could provide timely insights for introducing mobile payment into the service.

5.4/ CONCLUSION

There are over 200 million people in India who lack access to electricity. The large majority of this electricity-deprived population live in rural parts of the country, where extending conventional grid electricity services is uneconomical due to the high cost of infrastructure and low profitability. Recent innovations in, and the declining cost of, solar power technologies has led to a variety of off-grid energy solutions which target the under served at the bottom of the pyramid. One of the most promising of these are SMG prepaid electricity services. While these services represent a number of cost-saving advantages over conventional grid electricity services, the market context presents a number of challenges for their introduction and sustainability (viability), namely extremely cost-conscious and frugal consumers, competing incumbent energy sources and low profit margins.

This thesis uses a case study of one particular example of this type of service – the Boond microgrid and prepaid service – to explore the role that design can play in addressing some of these challenges, and thereby enhance the viability of the service offering for both the user and provider.

The Boond service incorporates a number of frugal innovations to respond to some of these challenges, particularly use of off-the-shelf simplified components, a pay-as-you-go business model, a smart meter and rechargeable dongle, and local hosting and maintenance. However, despite these and the clearly positive impacts of the electricity service on villagers' lives, uptake of the service is lower than expected, threatening the business' viability. Previous studies have sought to analyse and address these challenges from economics and engineering perspectives. However, they have not investigated customers daily interactions with the service, and importantly, with the new smart meters. In contrast, this thesis seeks to understand the obstacles facing prepaid SMG services from an human centered design perspective. By investigating the daily energy practices of individual users, its unique contribution is in better understanding how their interaction with the service influences its value, usability and viability, and how these challenges can be addressed using a constructive design research approach.

The Boond case study led to a number of design insights that have implications for the viability of prepaid microgrid solar services in rural Indian villages. Customers currently use the prepaid electricity service to supplement several preexisting energy sources. These incumbent sources are often perceived to be lower cost and, in some case, better suited to the task at hand, creating competition for the Boond service. The case study shows that, in these cases, the Boond service will only be used when it clearly represents a cost and suitability advantage over incumbent energy sources. Another main insight was that the meter interface design, its placement in the home, and low customer awareness of the service's pricing indicate that the meter fails to influence behaviour as intended. The study revealed that in many cases the entrepreneurs – the key link between Boond and customers – are missing some training that could help them to better play their critical role.

Given the contextual challenges, the design solutions proposed in this thesis are incremental, rather than breakthrough, in nature. These include making the meter interface more understandable for differently literate users, adjusting the meter's placement to make it more accessible to all householders, extending the capability of the meter with an SMS messaging service, ensuring the necessary capacity-building of the entrepreneurs and adapting the Boond lighting offer to better fit peoples' needs. Drawing on recommendations made for the development sector, in situations similar to the frugal context of rural India, evolutionary solutions that support existing services are often more realistic, and can produce greater impact, than revolutionary ones.

This thesis demonstrates that field-based constructive design research can provide valuable insights into how villagers in rural India use prepaid electricity services. The resulting design solutions proposed in this thesis are some examples of how human-centered design can improve the viability of these frugal solar energy services. While design alone can not solve all the contextual challenges facing these services, it can make a valuable contribution to the introduction and long-term sustainability of these services, and thereby significantly improve the lives of the many currently under served rural Indian villagers.

5.5/ CLOSING THOUGHTS

My time working on this thesis has been an interesting and rewarding process. This thesis has stretched my skills and knowledge of design research and service design beyond my expectations. When I began the project, I knew little or nothing about energy microgrids, solar-powered electricity services, nor the Indian energy context. As my thesis work progressed, I learned the basics and became fascinated by the intertwined social, technological and political aspects of the topic and how design relates to it. Due to the complex systems in energy supply, one of the challenges of the project was to frame the scope of the thesis. What began, simply put, as a study of the electricity meters for Boond's prepaid service expanded to investigate the wider systems that support and influence villagers' energy use.

Planning and conducting design research in India was a rich learning experience, and presented both opportunities and challenges, and had its successes and failures. On the one hand, the villagers' interest and availability to participate in my fieldwork enabled me to learn a tremendous amount regarding the in-situ interaction with the Boond service in a relatively short time. In the first day alone, I learned about daily habits relating to electricity, heard stories about how the electricity impacted women's lives and observed how other energy sources are arranged for in the home. On the other hand, however, the language barrier was a major challenge to gaining deeper insights, and daily travel to and from the villages consumed precious field time. As a result, there were many topics I was unable to fully investigate, such as the participants' mobile phone practices, the entrepreneurs daily routines and practices and more evening observations of electricity-use practices. As an outsider, gaining access to the Indian villagers' lives in order to conduct in-depth ethnographic research is not straightforward – in proceeding with my thesis, I have had to accept the limitations of the research and human resources available. In addition to learning about the participants lives, I gained insights into my own biases and assumptions. Recognising and challenging these assumptions has been a valuable lesson as a researcher, which I consider a personal success.

Since returning from India I have pursued my interest in design ethnography and global design research by reading on the topics. Based on my personal reflections and the new knowledge I have gained since the field trip I have a better idea of how I would plan the research differently if I could do it again. The following outlines three key changes I would make to my approach:

/ **Set up a field base closer to my research subjects.** This would reduce travel time to the field and deepen immersion in the local setting. Setting up a field base would require more time, a bigger budget and greater commitment from interpreters. It would also provide an opportunity to more easily test ideas and follow-up on research in person, making the process much more efficient.

/ **Involve the interpreters/field support team in the research analysis and synthesis.** Although the team debriefed during the drive back from the field, an extra day or two to build a research wall together would have captured the local team's perspective, interpretation of events and deep knowledge of the local context.

- / **Employ visual ethnography techniques.** The way I practiced photography could have been more collaborative. For example, rather than me taking the photos I could have invited participants to capture images with their mobile phones (those that demonstrated comfort with their phones). These photos could then facilitate dialogue during the interview and contribute the unique point of view of participants in a visual record.

This project would benefit from the more collaborative approach inherent to service design. As an advocate for collaborative design, I find it unfortunate that I spent much of the time working on this project alone during the subsequent analysis and solution design phases. It is a given that the physical distance between myself and the villages posed a barrier to collaboration with customers. Closer collaboration with the client during and post-field research would have made the analysis and solution development much more efficient. It also would have generated learning for the organisation. A lack of resources at the company during a very busy time prevented fuller participation. In hindsight, it would have been better that their active involvement in the research be made a requirement of the project activities.

I am satisfied with the range of design skills and knowledge I was able to practice – and demonstrate – in the solution design process. Although the learning curve was steep, and I often felt out of my depth, the experience gave me a broader understanding of the scope of issues service designers encounter.

All in all, the project experience was very valuable. The opportunity to conduct independent primary research as part of my thesis greatly enriched my Master's studies. As a result, practical field application has enabled me to better internalise the design methods presented in my course work. It has given me confidence in better harmonising design methods, theory and practice, and provided me with valuable lessons learned for making my future collaborative design experiences even better.

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PHOTOS

All photographs are taken by the author, with the exception of Figures 13, 14 and 17 by Iba Marwein and otherwise noted.

/ APPENDICES

APPENDIX A

Contextual Interview Questions

QUESTIONS – [Village name and date]

Name ______________________________

Your replies, recordings and photos will be used for academic purposes.
Do you agree to be interviewed? Yes ____
Do you agree to be recorded and photographed? Yes ____

1) Why did you decide to sign up for electricity?
2) Can you show me how you use the meter?
3) How did you learn to use the meter?
4) How often do you check the meter, and when?

5) How do you monitor your electricity use on the meter? Can you show me?
6) How do you know your balance? Can you show me?
7) Based on your current balance, how much time or how many charges can you use? (e.g. light for 3 hours, or 2 cell charges etc)
8) Do you trust the energy meter?
   i) If not, ask why?
   ii) What is a service, or an object you use that you trust? Why?

9) Do you know that there are different prices for the electricity? If the weather is cloudy, and the charge of the battery is low?
10) The lights on the meter – what do you think they are for?
11) If doesn't know about lights:
   i) What do you think they are for?
12) Did you notice these past few foggy days that the price has changed?
   i) If so what did you do?
13) Show the Meter Mock-up. Do you understand what the meter graphics mean? (I will show the meter and ask questions during this part)
14) If the meter was an animal, which would it be? Take a sticker. Tell me why? And your cell phone? Your TV, or battery or other technology. (conversation)

15) Can we take a photo of you in front of the meter?

IN-HOUSEHOLD QUESTIONS

1) Can we take a look at your house? Please show me where the lights, charger and fan are.
2) How has electricity changed your life?
3) Have you noticed any changes to the life of the village since Boond electricity arrived?
4) If the electricity service stopped tomorrow, how would your life change?
5) Would you recommend the pre-paid electricity service to others?

<u>Questions for people that don't have pre-paid electricity:</u>
1) Why didn't you sign up?
2) Are you thinking in the future you will join?
3) Why? Why not?
4) What would change your mind?

APPENDIX B

Participant energy source use
Based on sources that participants confirmed using or were observed during interviews. Sources that are unmarked in the table may be in use but weren't mentioned by participants.
Hours per day are based on participant reports/anecdotes, the Boond hours also factor in household meter data.

Participant	SHS	Kerosene (hpd)	PPC Battery	Vehicle Battery	Boond (hpd)
Fulan Devi (E)					3 hrs
Shiv Kumar	●	● (1 hr)			5 hrs
Ram Yivas Yadav	●	● (2 hrs)		●	4 hrs
Archna Yadav	●	● (1-3 hrs)			4 hrs
Shanti Devi	●				2-3 hrs
Sujit Kumar		● (1 hr)			4 hrs
Sulochana	●				4 hrs
Dileep Kumar (E)					2 hrs
Anand Kumar	●			●	3 hrs
Rehka					1 hr
Manoj (E)					11 hrs
Chedana		● (n/a)			3.5 hrs
Nanhakke (E)	●				12 hrs
Lallu Ram			●		2.5 hrs
Sangeeta		● (2.5 hrs)			1.5 hrs
Guru Prasad		● (1-3 hrs)			1 hr
Maheshwari	●		●		2 hrs
Sarojni		● (1 hr)	●		2.5 hrs
Ram Balak		● (2-4 hrs)			1 hr

hpd = Aproximate use hours per day   PPC = pay-per-charge battery

POWER
TO THE PEOPLE

Designing a better prepaid
solar electricity service
for rural Indian villages

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