Power to the People: Designing a better prepaid solar electricity service for rural Indian villages

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IndiaHCI'18, December 16–18, 2018, Bangalore, India

ACM ISBN 978-1-4503-6214-6/18/12.
https://doi.org/10.1145/3297121.3297134

Abstract
Locally generated solar-powered electricity provides relief to electricity deprived villages in rural India. However, despite many positive impacts of prepaid solar-powered electricity services on customers day-to-day lives, consumption remains relatively low. This poses challenges to long term business sustainability. The aim of the Master's thesis, *Power to the People: Designing a Better Prepaid Electricity Service for Rural Indian Villages*, is to investigate the role of household smart meters in increasing uptake of a prepaid domestic electricity service in rural India. Through a case study of a local electricity service provider the daily lives of the service's customers and their relationship to domestic energy consumption is investigated. A human centered design perspective informs design improvements to the meters and service design. The thesis concludes that while design can play an important role in improving the service, there are larger socio-economic forces at play that ultimately have the greatest influence on uptake of the service.

Author Keywords
human centered design; field-based constructive design research; design ethnography; prepaid solar electricity.

Figure 1: The solar-panel installation on an Entrepreneur's rooftop.

Figure 2: The household installation includes a meter, several lights and a charging outlet.

ACM Classification Keywords
H.5.m. Information interfaces and presentation: Miscellaneous.

Solar microgrids, prepaid electricity and the challenges to these electricity services in rural India

Solar microgrids (SMG) are a rural electricity solution that is gaining ground in India. The SMG in this study distributes electricity generated from a local rooftop installation to up to 40 households and the business model for energy distribution is prepaid electricity. The SMG system and prepaid business model are designed to provide affordable electricity to customers through small, incremental cash payments similar to popular frugal "pay-as-you-go" mobile phone services. With this development, prepaid electricity generated from a microgrid offers an attractive alternative to the costly and polluting energy sources (kerosene and the pay-per-charge auto battery) commonly used in rural India.

This study focused 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 rooftop infrastructure (Figure 1) 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 (Figure 2).

Boond faces a major challenge to the business viability of the SMGs on the customer side. Despite the reported positive impacts of electricity on customers lives, household consumption remains lower than expected, thus impacting Boond's profitability and the long-term viability of the 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. As a result, this new meter plays a more active role in influencing customer behaviour than the more basic, earlier meter models. Thus, there is greater emphasis on the design of meter-customer interactions, how the meters influence behaviour and the overall service experience.

Previous research on prepaid electricity

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 [2,5,6] 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 context that the service takes place in. As a result, the effectiveness of the dynamic pricing is unclear and the behaviours relating to electricity consumption remain elusive. Field-based constructive design research, where designers use a design lens to observe and interact with people in the environments

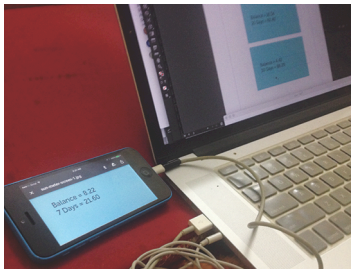

Figure 3: Revised display content was mocked up onto an iphone.

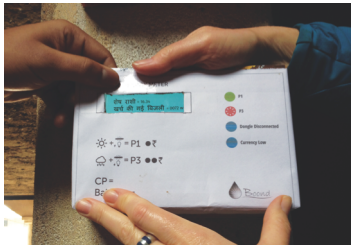

Figure 4: The prop was constructed from a Corn Flakes box, with a redesigned graphical interface laser-printed and glued onto the box surface.

Figure 5: A participant interprets the text and icons on the meter design prop.

where they live and work, is an ideal method to conduct these studies [4].

The field-based constructive design research approach

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.

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 [4]. In the study that this paper covers contextual interviews were conducted during field research and design props were introduced to facilitate dialogue and contextual observation.

Contextual interviews

Through the method of contextual interviews the study made inquiries into people's attitudes, perceptions and practices around energy use, as well as how they consume, monitor and manage it, to better understand the relationships between people, the technologies they use and the service. Primary ethnographic research was conducted in the field, followed by post-field analysis, synthesis and design explorations to make further sense of the results.

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 [1] 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 a spare mobile phone – materials that were readily at hand (Figures 3–5). Koskinen *et al.* [3] refer to this type of prop as a "Ready-made", describing 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 intent behind Ready-mades is that they are perceived by participants as a mundane model that may be modified in the field rather than precious or exotic objects not to be touched.

Results from the field research

The interviews and props activities revealed that participants found reading the meter challenging. This was due to shortcomings in the physical design and placement of the meter, and in part to textual content that posed challenges to differently literate users. Also, pre-existing domestic energy use and related social practices in the home had a strong influence on the uptake of the service. Two key insights that arose from the interviews and props activity are described next.

Firstly, in terms of reading the meters, participants were mainly interested in their account balance (the word "Balance" was previously familiar to participants from prepaid mobile phones), however the other data on the display was overly technical and irrelevant to users. The majority of the text was inaccessible because English, a foreign language to many, was used on the display and meter case. In addition, the placement of the meter high up on the wall hindered a clear view of the display, thus discouraging a clear view and interaction with the meter. Moreover, multiple members of the household – and in some cases the extended family – take part in the day-to-day monitoring of the meter and prepaid balance. For example, in some households a literate child takes on the role of reading the meter and reporting the balance to a parent. The child may also estimate timing for the next recharge. In some households both children and adults take on the recharging role on an ad hoc basis, while in another a relative from a nearby household takes on the meter reading role. Although family members possess varying levels of literacy, responsibility and means of communication, the meters were not designed to be accessible to such a broad profile of users. The research also found that the dynamic pricing function did not influence customer behaviour. Evidence suggests that this was because participants were simply not informed about the feature nor was it made explicit in the meter design.

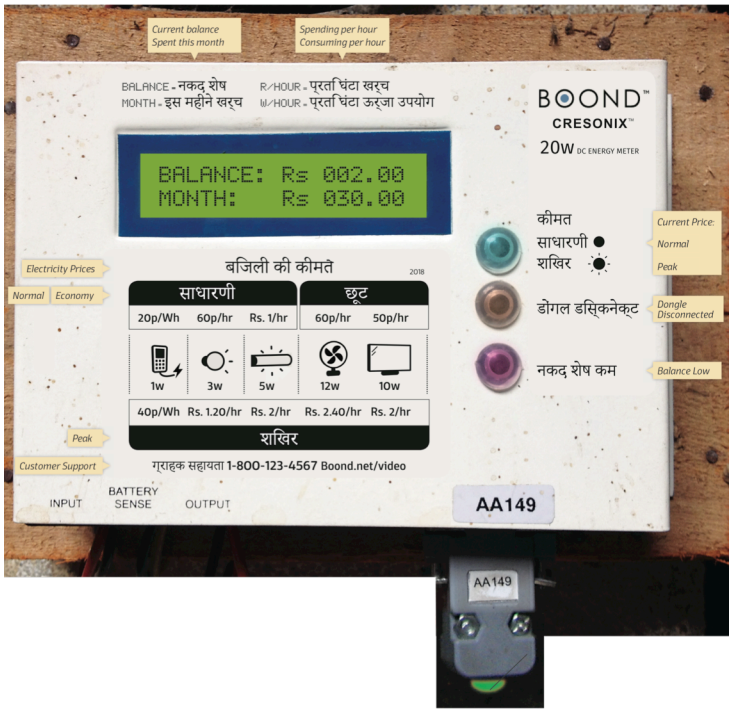

Figure 6: The redesigned electricity meter with labels in Hindi, simplified energy use information on the LCD display and price chart.

Secondly, while participants reported that they are satisfied with the prepaid electricity service, the study found that there are a variety of incumbent energy sources that participants continue to use in the home, such as kerosene and pay-per-charge auto batteries. Participants energy use decisions are influenced by perceptions of the value for money of the energy source and its suitability to the task. For example, subsidised kerosene encourages use in some settings and the sunk cost of an auto battery compels spending on battery charging services. As such, prepaid electricity competes with incumbent energy sources that are well established in people's daily routines.

Contributions

The study led to a proposal for a redesign of the existing meter. The existing meter LCD display was redesigned to show relevant consumption data, the meter case language was changed to Hindi, and a price chart to demonstrate the hourly costs for lighting and powering appliances was added (Figure 6).

The existing meter interface redesign process inspired many ideas that, due to frugal constraints, were better suited to a next generation meter design. These included communicating account information non-textually, i.e. a bold use of colour lighting and the use

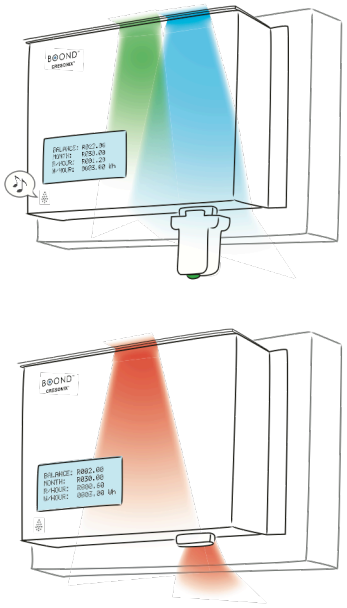

Figure 7: Next generation meter designs. Top: LCD beams show the balance in positive with a green light and peak pricing in effect in blue. An audio alert sounds at low balance and price changes; Bottom: low balance and a disconnected recharging stick ("dongle") shown in red.

of sound alerts for low balance and price changes, and a larger, finer resolution LCD display to accommodate Devanagari script (Figure 7).

Next Steps

Next, the meter redesigns require field testing. Further studies into how differently literate users navigate the service could identify design possibilities beyond immediate textual/language solutions. These studies could prove fruitful for service improvement and innovation by providing insights into the roles family members play in the realm of domestic energy use.

Discussion

The research set out to investigate electricity meter interactions and their influence on energy consumption. As a result, problems relating to the meter user interface including language, labelling and the display of consumption information were identified. In addition, a lack of provisions for differently literate users and users' different roles arose. These are significant to design which must consider both "behind and beyond the screen" interactions, because the behind-the-scenes social practices and domestic relationships are integral to service facilitation. In addition to the meters, wider societal issues such as access to education, low and precarious incomes and energy policy play a role in service uptake. These issues should be of concern to designers before, during and in on-going development of human interactive systems. In closing, field-based constructive research facilitated deeper understanding of the direct interactions with the service system and exposed wider societal issues at play. Perhaps equally as important was that direct immersion in the participants lives during research also generated ideas for immediate and future design solutions.

Acknowledgements

The author thanks all of the families that provided access to their homes, and offered their time, permission and interest during the study, Boond Engineering for their collaboration, and Aalto New Global and the Department of Design at Aalto University for supporting the field research.

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