Bushlight India, a new approach to rural electrification in India

Identifying and addressing structural barriers to remote village electrification

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ABSTRACT: The Bushlight India Project ran from 2008 – 2011 and saw the development of an innovative implementation model for remote village electrification (RVE) in India, using renewable energy (RE) based decentralised energy systems with village-wide reticulation, anchored by specially developed demand side management (DSM) hardware. The project built on the achievements of Bushlight in Australia, which has worked with more than 120 remote aboriginal communities since 2002 to successfully implement reliable and sustainable renewable energy systems. The Bushlight India project involved collaborating with a network of Indian grass root non-government organisations (NGOs), RE Industry participants and government agencies, to adapt the implementation model used by Bushlight in Australia to suit the remote Indian village context.

While the project exceeded expectations in terms of the environmental, social and engineering outcomes it has also led to a greater understanding of the major structural barriers to widespread remote village electrification in developing countries. This paper explores these barriers at both at the individual village level as well as at large programmatic scale and reflects on the key lessons learnt during the Bushlight India Project which have the potential to inform new large scale programs aimed at facilitating greater access to reliable energy services for remote villages.

1 ACCESS TO ENERGY

At least 1.8 billion people still lack access to modern energy services and the socio-economic benefits these are widely accepted to bring. In India more than 100,000 villages exist without access to electricity. This is a major factor inhibiting the development of local economies and while the majority of these currently unconnected villages are scheduled for connection to the grid at some time in the future, at least 10,000 are too remote for grid electricity to ever be a technically or economically feasible option. This fact, along with the rapidly changing cost-equations for the production and distribution of fossil fuel based energy means renewable clean technology has a clear and obvious role to play in meeting the needs of people living in remote locations.

Efforts to date at reducing this energy poverty, both in India and elsewhere have tended to focus on heavily subsidized government-led centrally managed programs. While there have been a number of notable successes implementing small, service-specific devices such as solar lanterns, there are no recent examples of a successful move from demonstration to large scale roll out of village scale renewable energy systems; and overall there has been a dispiriting lack of progress in reducing the number of people in energy poverty. With the number of people without access to a reliable source of energy arguably growing, many have now concluded that government led initiatives have been a failure and that the commercial sector must play a greater role in meeting this need.

Given the scale of the problem and the immense investment required, it is reasonable to expect that future solutions must involve the private sector, however the access to energy debate risks losing focus on its ultimate objective when lowest cost and commercial viability become the sole prisms through which success is measured. Residents of remote villages in developing countries require reliable energy services in order to engage meaningfully with the mainstream economy, improve health and education prospects, and commence the transition from poverty. For this they require a range of energy services and different amounts of energy depending on their pattern of livelihoods and their aspirations. Furthermore, people's energy demands and aspirations cannot be easily quantified as they usually involve obtaining an in-depth understanding of needs and expectations around quality and reliability, flexibility of access, availability and manageability. The most appropriate and sustainable supply solution will depend on these needs, which change over time as people's aspirations and energy consumption patterns grow.

The issue is therefore more complex than simply making and marketing a solar lantern cost effective enough that even the poorest most remote household can afford and access it; if that household actually wants and needs energy services which that lantern cannot provide to meet their livelihood needs and aspirations, it can then only be seen as a partial, temporary solution. If providing access to a reliable source of energy is to result in meaningful and sustained improvements to people's lives and economic situation, there needs to be a range of solutions developed and promoted that suit the varying energy service needs. Cost then becomes simply one part of the equation and accessing finance merely one of the interrelated barriers that needs to be addressed.

Even in very poor communities it is often found that residents can and do pay for energy - sometimes at a rate significantly higher than their urban counterparts. Ironically, due to government policy and institutional cross-subsidisation, urban residents often do not pay the full cost of energy provision. While financiers and funders may demand commercially viable business models for service delivery based on consumers in remote areas paying back fully on investments, there are underlying social equity issues in expecting the poorest, most marginalized sectors of society to do so.

2 EXISTING APPROACHES TO ELECTRICITY SUPPLY IN OFF-GRID COMMUNITIES

For those living in remote areas without access to an electrical grid, options for improving access to electricity and its associated services can be grouped into three main categories: small portable lights (solar portable lights but also hand crank and chargeable); solar home systems (SHS's); and community mini-grids powered by renewable energy (solar, wind, hydro) and/or diesel generators (though due to the remoteness of the villages in question, fossil fuel costs and access difficulties usually preclude these as primary generators).

Small lighting devices such as solar LED and CFL lanterns have been successfully implemented across Africa and Asia through both government programs and private enterprises. These devices are well suited to fully market-based delivery mechanisms, where centralized mass production can be linked to effective supply chains all the way through to small enterprises working in remote areas, thereby reaching "the last mile" and achieving a lowest cost solution. Product differentiation is around cost, build quality and reliability, local access to service centers, and market spread. As previously identified however, these devices offer a limited service - usually a single light point, with some also having some limited mobile phone charging capacity. The business models that have been most successful in this sector are built around costs that allow individual households to purchase devices outright at the point of sale through integrated distribution chains, though 'pico-credit' schemes are also now reasonably common.

Solar home systems are usually comprised of a 35-120W solar module with a small charge controller and battery, and though these have largely been promoted through subsidized government distribution programs, they have also shown a degree of marketability where communities or sectors of a local population are energy poor but not necessarily income poor. These provide a much increased level of service - at an equally increased cost – but have the drawback of making system owners both consumers and managers of their energy supply, shouldering the full burden of operation and maintenance as well as the purchase price.

Community mini-grids comprise of a central power generation plant and a small electricity network used to distribute electricity to residents. Depending on location, demand and fuel/resource limitations, these systems can supply either a single village or households and businesses across a number of villages. These systems represent the upper end of the service spectrum for remote villages and although typically supply (fuel or resource) constrained, they have the potential to provide power of equal availability, quality and reliability as conventional grid supply. Operation and management of the mini-grid system may be undertaken by a third-party with which individual consumers have supply contracts, paying according to an agreed level of service delivery.

In practice centralized mini-grid systems are notoriously difficult to establish and sustain, and the energy services they typically deliver are limited, thereby negating many of the key benefits of such an approach. The key reasons for this are:

(i) the high initial capital cost of establishment and resulting high cost of energy to achieve repayment of the initial investment;

(ii) difficulties in establishing functional institutional management structures to help ensure systems remain operational and financially sustainable over the system life; and

(iii) technical and social challenges in ensuring equitable access to energy services across communities whilst maintaining a high quality and availability of supply to all residents.

Deciding which of the three categories of supply options is most appropriate in any specific situation requires the careful consideration of a range of factors, first of which should be a full assessment of people's energy services needs. This should take place in the context of not only their economic capacity and livelihood patterns, but also of their aspirations and the potential impact on residents and the community of access to reliable and affordable energy services. There is questionable financial or social justification for providing a service that while meeting people's immediate needs quickly becomes insufficient. Other important considerations include the availability of local resources and access to markets (for supply and technical service.

Notwithstanding the identified needs and aspirations of a community, it is a common reality that capital cost is also a key (if not the main) factor in determining the final supply solution for any particular situation. This can occur because of the erroneous assumption that people will be satisfied with just some of their needs met and that this will in any case assist them to develop economically. This approach may be justified if additional services can in fact be provided at a later date, however it assumes that additional funds to meet these needs will be available and that these minimum energy services will increase income to such an extent that people will be able to afford to upgrade their energy services. It is our experience that these assumptions are rarely reflective of actual circumstances.

People's demand for modern energy services develops as their aspirations and consumption patterns grow. This does not directly correlate with income. A recent study in India by the World Bank found that this only happened once rural households got above the 5th decile of income (Khandhker, 2010). It does however highlight the important fact that while demand may initially be low, it will increase; and a solution only aimed at meeting immediate, modest energy requirements will not provide an appropriate long term sustainable energy supply without significant further investment.

3 WHAT DO PEOPLE WANT THEN?

It stands to reason that people do not so much want electricity *per se* but the services it can provide such as lighting, cooling, phone charging and pumping water. Depending on their livelihood patterns (what they do, where they live, how they live) and their aspirations, their service needs and wants can be assessed with reasonable accuracy and summarized in an "energy budget": e.g. so many hours of lighting with so many lights, so many hours of fan use, etc. Device consumption rates can then be applied to quantify the daily energy demand in Wh. Due to the highly seasonal nature of people's usual primary livelihood activities in these villages (i.e. agrarian) the energy services people want and need will vary, if not from month to month, then season to season, as potentially will the overall quantum of energy.

Given that people often already pay significant amounts for energy (e.g. kerosene, candles, wood), it can be assumed that what they want next are better services than those they are currently accessing: that the quality of light is better, there is less indoor pollution and less risk of fire etc; that in addition to increased amounts of energy they want improved quality, reliability and flexibility. A reliable daily supply of electricity allows people to plan their activities to use it most efficiently on those services they want and need on a day to day basis. This flexibility in how the energy can be used provides people with the starting point for planning and developing new, productive applications of their energy, and dependability and reliability means people can structure their household budgets free from external price fluctuations.

Experiences from the Bushlight project in Australia and the Bushlight India project have reinforced the importance of this message: people want and are willing to pay for an energy supply that is sufficient to meet their livelihood needs and aspirations, but value at least equally the ability to reliably access this energy and use it for purposes they determine as the need arises.

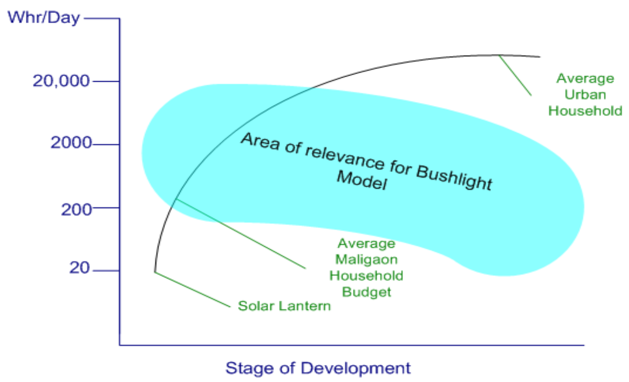

Fig. 1 *Daily demand vs stage of development*

Figure 1 shows an approximation of the demand curve of electrical energy based on experiences in India and Australia with the Bushlight Model. The term stage of development refers to the level of electrical energy consumption a household or community identifies as its current need, which must be informed by its perception of paying capacity and its current willingness to pay, which in turn relate to its livelihoods and aspirations. As can be seen, the demand curve rises rapidly as basic needs are met, continues to rise quite sharply as patterns of consumption change as income increases, before slowly tapering off. The "Average Maligaon Household Budget" is in reference to the village of Maligaon in western Orissa where the Bushlight India Model was implemented.

This demand curve emphasizes the journey many communities embark on when they first access reliable energy services. This needs to be clearly articulated and understood when discussing appropriate solutions and the current and future costs involved. Marginalized communities remain so if they set off on the development path only to be restricted to the lower end of the curve due to the inability of energy services to meet their evolving needs.

4 THE BUSHLIGHT INDIA MODEL

Many models currently exist in India for supplying energy services to remote communities where grid-extension is not a viable option, however these models are predominantly supply-side focused with cost being a primary determinant. One of the risks of this approach is that it may not result in outcomes that accurately reflect the reality of remote communities' developmental aspirations nor their willingness to pay for energy services.

The Bushlight India Model distinguishes itself from existing models by enabling communities with the resources, capacity and motivation, the opportunity to access electricity that is: reliable: supply is available 24 hours a day, 7 days a week; equitable: each consumer is assured access to a fixed amount of energy every day; of a known amount: residents determine their own 'daily energy budget' through the facilitated 'energy budgeting' process; and of a known cost: tariff levels are set prior to energy budgeting based on realistic life cycle system financial models.

It achieves this through an inclusive village energy planning process based on:

- the establishment of village level governance structures for managing systems and service agreements, and
- the design and establishment of mini-grid RE systems that are robust, standardised, of a capacity to meet agreed village needs, and protected from over-demand by innovative central and household level DSM hardware.

The Urja Bandhu ('energy friend'), a small electrical metering unit, is a simple technology which sits at the heart of the Bushlight India Model. Installed in every load-point, each Urja Bandhu is individually programmed to make available a fixed amount of energy (Watt-hours) to that load point over a 24 hour period. At the specified *budget reset time*, the unit makes the full *daily energy budget* available and all five display lights come on. As energy is used the lights go off, one after the other, in the same way a fuel gauge reduces as fuel is used. If the entire budget is used before the reset time the next day, the bottom light turns red and power to the consumer is temporarily disconnected. At the next *budget reset time*, all five lights come on again and the full budget is again available. Budgets are non-transferable from one day to the next. The Urja Bandhu costs approximately $65AUD to manufacture in India; around 2% of the cost of a similar (though obviously more complex) unit used by Bushlight in Australia.

Image 1: The Urja Bandhu with integrated switchboard and remote programmer.

When Urja Bandhus are connected to every load point, equitable access to energy can be ensured while still restricting the total daily demand to the aggregate of all programmed budgets. This allows accurate projections to be made of income required to meet known costs, so service fee levels can be fixed to meet the 'real' costs of operating and managing the system over it's design life. The Urja Bandhu also enables reliable revenue streams to be established and maintained.

The Bushlight India model focuses on demystifying the technology and providing people with the tools and information to understand how their system is working; including image based user manuals, operation charts and informative, intuitive interfaces on all hardware. Most importantly though, with their energy budget 'refilled' each day and Urja Bandhus designed to indicate the status of the energy budget in real time, residents choose how and when they use their energy budget on a day to day basis.

The Bushlight India Model is based on the work of the Bushlight project in Australia: an Australian government funded program that works with small, remote Aboriginal communities across central and northern Australia to reduce reliance on diesel generation and to establish reliable, sustainable energy services. Bushlight systems are generally solar energy based and provide a high quality electricity supply to meet the needs of residents of remote communities. Recognized nationally and internationally as a best practice model for rural electrification is has been successfully deployed in over 120 remote Indigenous communities across Northern and Central Australia resulting in over 140 household and community-scale systems that are supporting a broad range of energy services at the household and community level. (see www.bushlight.org.au for more information)

Its adaptation to the rural Indian context took place as part of the Australian government's commitment to the Asia Pacific Partnership on Clean Development and Climate, which provided funding for the 'Bushlight India Project' to develop and demonstrate a new approach to the electrification of villages in remote areas of India through the adaptation of the Australian Bushlight model.

Through the 'Bushlight India Project', CAT Projects worked with an integrated network of Indian community organizations and RE industry participants, as well as the Government of India, to collaboratively develop and demonstrate the 'Bushlight India Model', a widely replicable model for the electrification of remote villages using centralized solar PV energy systems - though it is readily adaptable to other supply technologies. The Model is a comprehensively documented and resourced, structured and stage-wise set of processes covering everything from initial village selection, through to village energy planning, system design and financial modeling, post-installation training and the establishment of suitable system support and maintenance networks.

5 STRUCTURAL BARRIERS TO RVE

Reflecting on the development and demonstration of the Bushlight India Model, it is clear that there remain a number of key structural barriers to electrifying remote and underserviced communities. These barriers exist at both the individual village level and aggregated at scale. Reflecting many of the issues seen by the Bushlight project in Australia, these do not exist in exclusion to each other but are interrelated and as such addressing just one will not be sufficient for making a village energy system approach to remote village electrification a viable proposition.

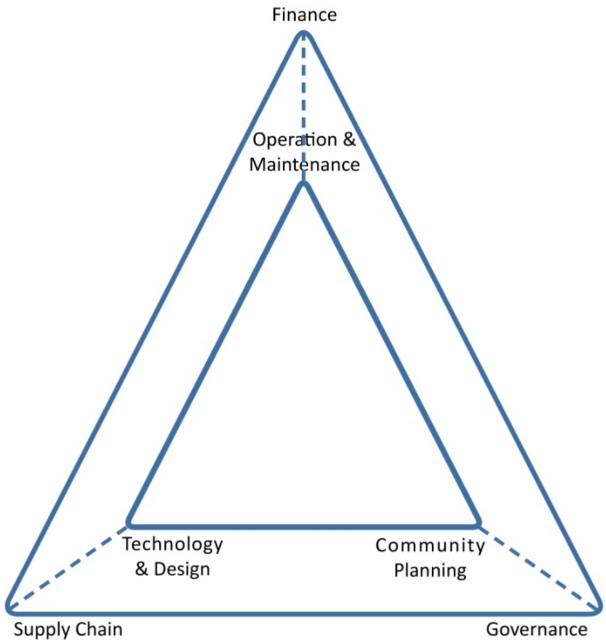

Fig. 2 *Structural barriers to RVE at village (inner triangle) and scale levels (outer triangle) and their interrelation*

At the individual village level a key challenge is to achieve appropriate system design and capacity through effective and inclusive community consultation and planning; this is critical in ensuring systems meet people's actual energy needs and livelihood aspirations. Also, the technology and design process must deliver systems that are robust and capable of meeting demand over their life without significant failure. Reliability of operation and supply are also critical to ensuring both revenue and cost estimates are realized. And finally there needs to be guaranteed access to effective operation and maintenance services. This is essential for ensuring reliable supply which is key to supporting local economic development, consumer demand and by extension system revenue. Sound business models at the local level cannot be built without an approach which addresses these major issues.

The first of three key structural barriers to electrifying remote and underserviced communities at scale centers around being able to access suitable levels of finance; financing at this scale requires proven models that can demonstrate reliable and sustainable revenue streams and reliable low operating cost over the system life.

Supply-chain linkages appropriate to the remote locations also need to be established incorporating standardised low operating cost/low failure technology at a scale where economies of scale can be developed to provide meaningful capital cost reductions. And lastly, functional and sustained governance structures need to be established to safeguard and ensure revenue collection, to maintain local individual institutional structures are supported and system operation and maintenance processes are being sustained. Addressing these three barriers is the key to the development of a sustainable large scale business model.

Although none of these barriers operate in isolation, any one of them has the potential to lead to the failure of a project or program. Properly formulated solutions addressing the issues at the village level will help address those at scale. Transitioning a model from demonstration (one or two villages) to scaled replication is typically a very difficult exercise. From the numerous rural electrification pilot projects that have been implemented over many years there are only a small handful of successful examples of up-scaling to reflect upon: Husk Power in India being of note, as is the Bushlight Project in Australia.

The fundamentals of the Bushlight Model as developed and applied in both Australia and India address the scale level barriers by focusing on those at the village level. Both models have a demonstrable history of success. Specific features of the model that address the village level barriers but which also offer a way forward in addressing those at scale include:

(i) a standardised design and technology strategy which allows for the development of cost-effective supply chains; standardized technology also simplifies operation and maintenance requirements and reduces costs;

(ii) structured, locally developed and sourced operation and maintenance arrangements better ensures reliable supply, leading to more reliable revenue collection over the investment/design life; and

(iii) effective community planning which results in local governance structures able to manage supply agreements and provide the stability and assurance of revenue.

Specifically, the Bushlight India Model addresses these issues through a variety of interlinked and mutually supporting energy planning, institutional and technical capacity building activities and locally manufactured, demand side management hardware.

6 CONCLUSION

Access to a reliable, affordable supply of electricity yields significant improvements in the quality and dignity of people's lives and is a key enabler of economic development, yet almost 25% of the world's population are without this basic service. Where grid-connection is not an option, how a community's electrical energy needs are met needs to be determined through a carefully developed assessment of their energy services needs, coupled with assessments of the cost and technology options available. Different needs will lead to different supply solutions, and what is appropriate in one situation may not be appropriate for another. For those villages with the need and the resources, capacity and motivation, mini-grid village energy systems represent a viable technical solution that with the right approach can meet higher energy demands and deliver the additional service requirements that people value, namely: reliability of supply and flexibility of access and use.

The establishment of viable village energy systems, however, faces a number of structural barriers at both the village level (O&M, Technology & Design, and Community Planning) and at scale (Finance, Supply Chain, and Governance); these being interlinked such that solutions which address the village level barriers can help resolve those barriers at scale. Implementation models therefore need to be developed that directly address these barriers, which are replicable and able to be readily implemented.

The lessons learnt during the development of the Bushlight India Model and its demonstration in a number of remote villages in India have contributed significantly to a broader understanding of barriers to further deployment of remote village electrification projects in India. The Bushlight India implementation model demonstrates a successful practical solution for village electrification and with further focus on barriers to large-scale program rollout has the potential to play a significant role in the provision of energy services in remote areas of India and other developing countries.

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