Gaps and barriers preventing effective implementation of micro-grids in India

A summary of technical, financial, social, operational and political factors

Definition: A micro-grid is a collection of distributed loads or generation sources into a single system through distribution wiring, with the ability to operate in isolation from the centralised national grid. The system could provide power for a remote village, a collection of enterprises, an institute campus or a number of other sites. The rated power of this system could range up to hundreds of kW, and the generation sources could include solar, wind, hydro, diesel or the national-grid.

SELCO FOUNDATION

Introduction

This is a point-of-view document on micro-grids, based on a one year investigation into the technology model through pilot projects, discussions with practitioners, government bodies, policy think-tanks and international groups. The details of this study are not given here, only the conclusive thoughts to date. Reports on individual pilots, particular aspects on design and comparisons of the suitability of micro-grids to particular ground issues are being put together separately. This document aims only to give a clear point of view on micro-grids and to establish the ways in which SELCO Foundation can help build the micro-grid ecosystem.

In particular this document lists out and briefly explains the **potential benefits** of micro-grids specifically. These benefits are a result of connecting loads and generation sources together, not benefits resulting from having decentralised generation. In other words these benefits only apply to micro-grids and not to individual home systems. The next section lists the challenges, or **barriers and gaps**, currently in the ecosystem that prevent or restrict access to these potential benefits. The promises of micro-grid technology are currently not being fulfilled due to these barriers, so to access them the barriers need to be understood and tackled. How SELCO Foundation can help in tackling these barriers is then discussed or, what can the organisation do to **build the ecosystem** surrounding micro-grids

This document does not try to differentiate between micro-grid technology models. For example, some models use micro-grids to provide power to customers without end-user financing, some aim to provide a higher level of service than individual systems (e.g. solar-home-systems). Instead this document aims to give a complete picture of all the potential benefits and current barriers/gaps, but does not assess models which only access some. The purpose of this is to clearly show the difficulties that exist for practitioners aiming to use micro-grids to their full potential, to help guide ecosystem building efforts.

What questions should we be asking?

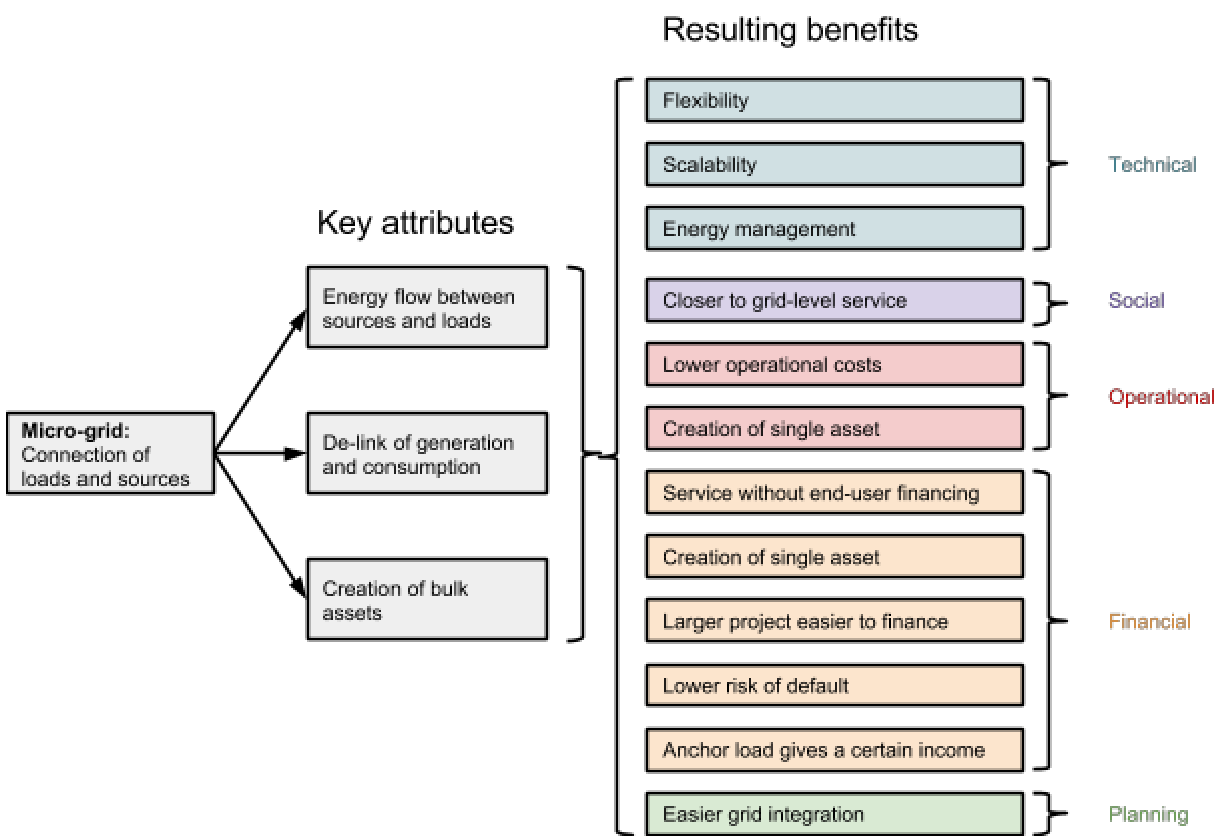
The first stage of discussion should be to establish the right questions to ask. Micro-grids are essentially a *connection* of individual systems into a single system. Therefore the questions asked should be around the implications of this connection first. We should separate the potential benefits of DRE solutions from the potential benefits of connecting systems together. For example the potential of distributed solar to provide immediate energy access in remote areas applies equally to micro-grids, solar home systems or solar pump systems. But micro-grids have the potential to more effectively manage energy resources. The questions that need to be addressed regarding micro-grids are therefore around *connection*, or moving from individual systems to a micro-grid. These 3 questions form the outline of this document.

1. What are the potential benefits of *connecting* individual systems together.
2. What are the current barriers and gaps preventing access to these benefits of connection
3. What role should SELCO Foundation play, considering efforts by other organisations and the Foundation's key competencies

Benefits of connection to form a micro-grid

This document separates out the potential benefits of micro-grids, i.e. those arising from connection of loads and sources together into a local grid. The benefits of DRE solutions in general are not discussed, this is because these benefits apply equally well to individual systems as they do to micro-grids. In other words, micro-grids should not be seen as the only way of accessing the benefits of DRE.

The following diagram illustrates the key attributes of micro-grids, and the benefits which are a result of this interconnection specifically.



Key attributes of a micro-grid that result in all listed benefits

The following three attributes lead to all of the benefits listed below, either directly or indirectly. They also cause a number of difficulties (barriers or gaps in the current ecosystem) that are also listed below.

Energy can flow between systems

With loads and sources connected together, energy can flow between houses or generation sources. This allows the system to take advantage of complimentary load profiles (e.g. daytime loads like pumping, or night time loads like lighting), or generation sources (e.g. wind and solar) , which leads to the benefits of flexibility, for example.

De-linking of generation and consumption

Whereas individual systems are designed matching generation sources to loads, micro-grids can be designed with less rigidity imposed. For example a village consisting of 20 richer households and 5 poorer could be given one system, the richer households give assurance of payback, but the 5 poorer households are given a service but the requirement for regular payments is decreased. The need for financing for every end-user is reduced.

Bulk assets are created, as opposed to household assets

A single system for a village could be installed, rather than one system per household. This leads to a number of benefits, including, but not limited to, faster electrification, easier grid integration, easier maintenance or easier financing.

Technical benefits

These are benefits to the technical design of micro-grids, making the system more efficient, lower cost and better performing.

Flexibility and facilitation of productive loads due to a better utilisation of local generation

Load demand fluctuates constantly as per the user's requirement. However generation sources do not necessarily produce power that matches this demand perfectly. The two solutions to this problem are storage and connection. The centralised grid works by connecting together many loads, such that demand becomes predictable, and different generation sources, allowing generation to be matched to demand. Individual systems use storage and oversize of generation to match demand fluctuations, leading to higher costs and potential wastage of energy. Micro-grids would operate between these two extremes, with connection reducing the need for storage (and so reducing system costs) and reducing wastage of energy. This benefit essentially leads to easier integration of **productive loads**, which may have a more variable load demand compared to lighting. It also allows users of domestic loads to use energy as they want, for example to pay extra for more energy during festivals or controlled climate storage during harvests.

Scalability and facilitation of demand growth

Having systems connected together de-links generation and consumption. Usually upgrading an individual solar-home-system, for example, requires the purchase of a new system. If the upgrade required is small, then the cost per service is relatively high. However micro-grid operators could upgrade a village system if *total* demand increases. For example, if 10 houses in a village request for one more light, and 10 request for two and five request for 1 hour of more light, upgrading individual systems in each house would be a cumbersome task, but adding bulk generation to a central system would be relatively simple.

Energy management: ability to deal with excess or shortage

By monitoring the system for excess energy generation or energy shortage the system integrator can ensure maximum use of installed capacity, or ensure that essential loads are always provided for by reducing energy allowance for non-productive loads. This therefore reduces the need for oversizing a system and gives the designer more options to optimise design and reduce cost.

Social benefits

These are direct benefits for the community, and affect how the project is seen socially.

Better level of service gives impression of final solution

Microgrids, assuming they provide better levels of service due to the benefits here described, are seen as a step closer to grid connection as compared to individual systems. The presence of transmission wiring or the potential of ensuring end-user demands are met through scaling of the system are examples of a more “grid-level” service. Micro-grids can be higher up the energy ladder, and so they may be seen as a bigger step towards development. However, end-user perceptions are difficult to predict, and depend on a number of factors.

Operational benefits

These are benefits for the distribution company/system integrator/energy services company or whoever is implementing the project. They reduce operational costs or complexity.

Lower operational costs and scalability due to easier management of energy assets

With a lower number of generation/storage assets to manage in the case of micro-grids, the costs of monitoring these systems, identifying problems and providing service reduces. With many assets connected together the net energy flows can be monitored and net shortages or excesses can be addressed at a single point. Without connection the number of systems to monitor is higher, and so the efforts involved to make changes become higher.

A single large energy asset - more attractive long term

The original cause for demand of the system may change over time, but the generation asset can easily be used for a different purpose. For example households may move from the village, so reducing the domestic load. The spare capacity could be used for water pumping. A more likely example is the arrival of the grid, in this case generation can feed into the grid, and the micro-grid can be used as backup for the grid. If comparing the applicability of this benefit with individual systems then it should be noted that larger assets have a larger number of potential uses, and a single asset is easier to move to another demand.

Financial benefits

The benefits make the project easier to finance, from whatever source.

Service can be provided where end-user financing is not possible

A micro-grid can be run as a utility by an entrepreneur or utility company, so end-users can pay for a service and not an asset. Hence the requirement for end-user financing is bypassed. Solar-home-systems could be financed in a similar way, for example a rental or pre-pay model, but the cost to the utility of a customer opting out of the service is smaller for a micro-grid: the connection only needs to be cut and energy can be used elsewhere.

Larger projects have lower transaction costs

Large projects give a boost to the loan books of financial institutions and have smaller transaction costs attached to them.

Lower risk of default with a greater number of paying customers

As collections are coming from many customers, one customer in a micro-grid cancelling the service may not greatly affect the overall success of the project. In the same way that self-help-groups are more attractive to loan to, so can micro-grid projects be more attractive to finance. For example, the idea of collective responsibility and peer pressure decreases the chance of default.

Anchor load could provide financial certainty

Anchor loads, are those which provide energy for a customer that brings assurance of payments, for example telecom towers, solar pumps etc. This adds to the certainty of the revenue generation and cash flows. This will ensure that the project remains financially viable even if there are variations in demand from domestic loads.

Planning benefits (political)

These benefits are for electrification planning efforts

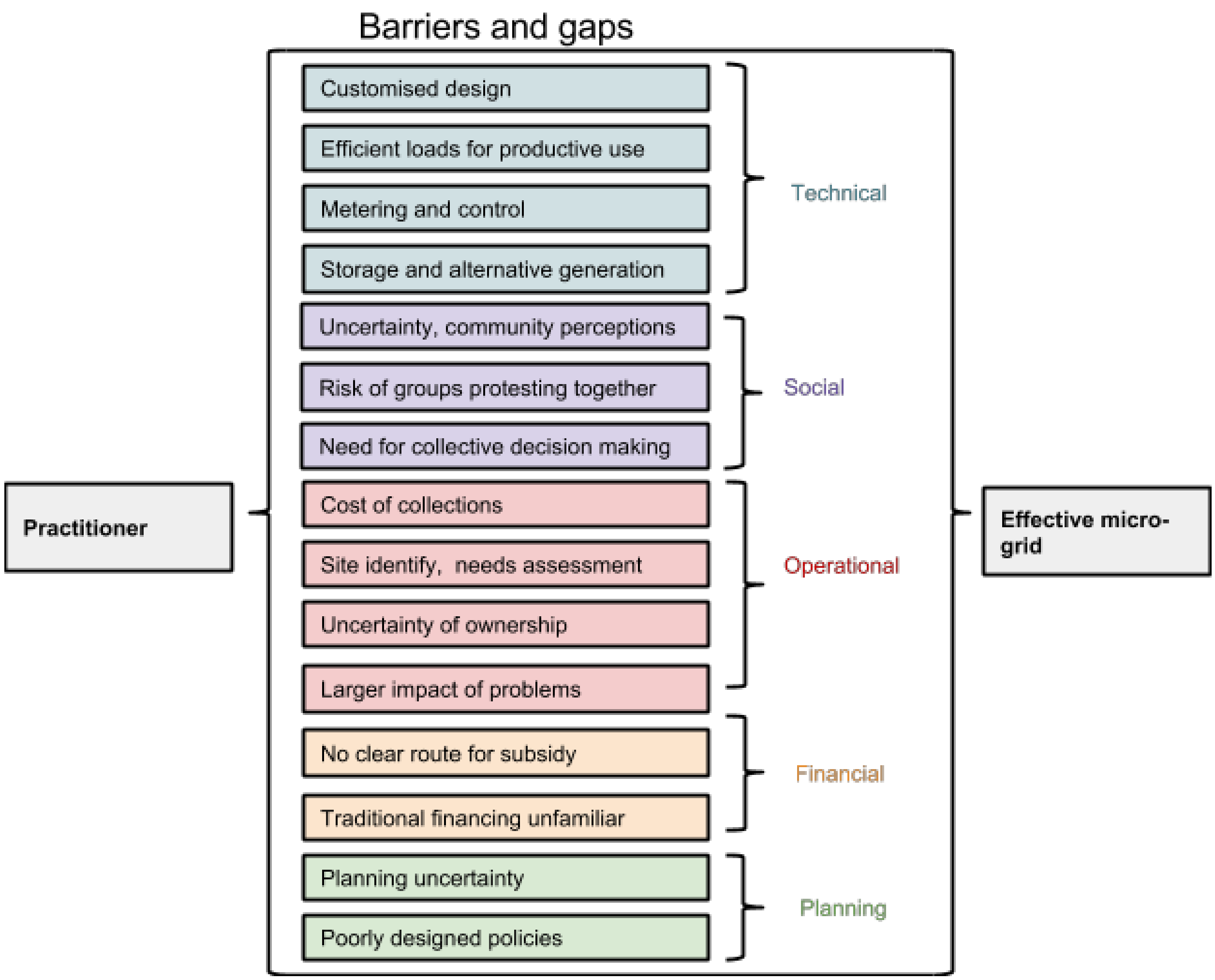
Grid integration is more attractive due to the provision of infrastructure outside of centralised grid extension efforts

Centralised grid is slow to reach villages in many states due to the improper planning, administrative hurdles and reduced prioritization owing to revenue losses associated with poor metering and collection. With DISCOMs and state energy departments increasingly facing pressure to extend grid and provide quality power to rural areas, there is a need for reforms in this sector to meet these demands adequately and profitably. Such reforms can take time, and will vary state to state. Proper implementation of microgrids in these unserved and underserved areas with the required Government support can work as an interim measure till these reforms lead to better service delivery by the DISCOMs. Micro-grids in unserved regions can provide village level infrastructure with distributed generation independent of centralised grid extension efforts. This village level infrastructure includes distribution wiring and household meters. With this installed the cost of grid extension to the village is reduced as connection to incoming grid will be possible.

Barriers and gaps preventing effective implementation of micro-grids

Below are summarised some of the key barriers currently preventing effective implementation of micro-grids, i.e. micro-grids which provide all the benefits listed above. These are technological, operational, financial and political. Note these are not points which should easily be avoided by proper set-up of a project, but barriers that exist for all practitioners currently. Some of these barriers apply to micro-grids only, but most apply to all DRE solutions. However they all play a significant role in preventing access to the benefits listed above.

The following diagram illustrates the barriers preventing micro-grid implementation from achieving the benefits listed above.



Technical barriers and gaps

Difficulty of customising design - matching solutions to the local needs

To access the benefits of flexibility and scalability solutions need to be designed which match the individual needs of a community. Whereas a centralised grid provides energy for whatever need, decentralised energy systems must be designed to match the local needs. This design process requires detailed understanding of load use, load specification, ability to pay and other site specific factors, adding complexity to design. So the fastest growing micro-grid companies today must provide kit-type setups, where there is no designing of customised systems. Whilst these companies have the ability to provide basic services quickly they do not offer any real advantage over a solar-home-system to the end-user.

Efficient loads for productive use - anchor loads and livelihoods

To access the benefits of flexibility, particularly the ability to power livelihoods, more efficient loads are required to ensure that powering these loads from renewable energy is affordable. Efficient LED lighting, and also low power TVs or radios, have made basic energy services powered from solar affordable. Recently there have also been efficiency improvements for motor loads, for example small sewing machines, mixer-grinders or ceiling fans. However for non-domestic loads these efficiency improvements are yet to be easily available for end-users. Some examples: commercial tailoring shops often use inefficient clutch motors or rice mills are usually powered from old grid-connected motors. With a low grid-power per unit cost the incentive for high efficiency loads is low. Hence availability and serviceability of these loads in rural areas is low. Persuading people to change machinery for their livelihoods is not easy. *However to power livelihoods cost effectively the system integrator must also often upgrade the loads used.* There are very few examples that demonstrate a micro-grid providing power for a livelihood in a commercially attractive way.

Metering and control - flexibility and grid integration

To allow for flexibility of load use some type of power limiting and energy limiting must be used. This is to stop overuse of the system at a bare minimum, but also to allow people to be charged per use if desired. However, whereas regular grid metering requires a standard AC meter, produced on mass for low-cost, micro-grid meters which serve generally lower income households are currently low-volume high-cost items. To reduce costs there should be some type of standardisation of distribution infrastructure. This standardisation would also facilitate grid integration, and prevent double efforts when grid reaches a site. Currently the focus of development efforts in metering is towards smart meters and high-tech solutions, whereas the current need is for low-cost solutions that provide the essential functionality only.

Storage and alternative generation sources

Whilst solar PV is close to reaching grid-parity in generation cost, and larger wind is similarly priced, the need for storage in an DRE system increases costs far above grid-parity. The most widely used and currently most practical solution are lead-acid batteries. These require replacement at least twice in a PV system's 20 year lifetime, and so lifetime cost of storage is very high. If storage costs were to reduce in a similar way to how PV panel costs reduced, the impact on the off-grid (and electric transport) markets would be large. However any proposed solution must consider serviceability in remote locations.

Another way to reduce storage costs is to reduce the need for storage. For DRE systems this is best done by adding complementary sources of generation. For example pico-hydro systems are seasonally complementary to solar, as is wind to some extent. Additionally using diesel to backup a solar-battery system could help reduce the battery autonomy required. Alternative renewable sources are currently very site specific; the exact capacity available is not easy to establish, so transaction costs would increase. Furthermore the hardware required to control both renewable and traditional generation sources, in combination with solar, is not straightforward and not easily available for a low price.

Social barriers and gaps

Uncertainty of community perceptions

While microgrids are perceived as a step up from individual systems, some communities may have the perception that it's still not good enough because they're not electrified by the central grid. Such perceptions are created due to years of receiving promises and timelines for central grid electrification from local administrators and politicians. In such cases, suggestion of alternative solutions like microgrids, may not receive the required support and participation from these communities. This can lead to uncertainty in project sustainability.

The need for collective decision making

As a micro-grid brings a group of people together with one solution, collective decisions are required. The need to persuade many people of a solution is an operational difficulty. Furthermore, different social groups within a community could cause particular issues for cohesion, particularly in India where caste politics are common.

Risk of social groups protesting together

Models which rely on collections by an outside organisation run the risk of bulk opposition from the community. If a system is given to a single owner, the impact of them refusing to pay, and so refusing the service is low. However if a community unites to refuse the service the impact is large.

Operational barriers and gaps

Cost of collections

With sites often being disperse and remote the operational costs involved in collecting revenue from each are high. Companies operating micro-grids must therefore build up the ability to manage these collections, which has so far added large overheads. Models that take advantage of existing collection mechanisms offer a guaranteed collection agent, for example end-user financing for solar home systems from rural banks, linking utility to rent (e.g. a micro-grid in a labour camp) or partnering with financial institutes that have strong community links for micro-grids, e.g. SKDRDP in Karnataka. If collection mechanisms must be built from scratch then overheads increase, and risks are high.

Site identification and needs assessment for successful projects

For a successful project the system integrator must match a number of factors including ability to pay, demand for energy services, availability of an operator and access to finance. These factors vary across different villages and so identifying a suitable village for a project is time consuming and costly. One way to avoid this is to offer a fixed solution for a low cost, but this will meet a limited level of customer demand, and will not offer any of the promised benefits of micro-grids. The difficulties of site-selection and needs assessment are particularly acute for micro-grids as the needs of a whole community must be met, rather than a single customer.

Uncertainty around different ownership models

Individual systems can be purchased by an end-user through a bank-loan, implying no risk to the system integrator (and hence no risk to the system integrator's service network and the other customers). However ownership of a micro-grid is difficult to define as it is a community project. If a single owner is responsible for the system, with clear negative impacts should the system be improperly operated, then the long-term viability of the project is assured. However, without a clear owner, responsibility must be given to another party, and the long-term sustainability of different models presented is still uncertain. Furthermore the lack of clarity around ownership may prevent best use of the installed asset in later phases of the project, for example with grid integration, who would receive profits from the grid feed-in?

Larger impact of problems

With many customers connected to a single system the impact of a single problem with this system is increased. Whereas complaints from single customers can be managed easily, a large number of customers will have a bigger voice and so demands for quicker service will be higher.

Financial barriers and gaps

No clear route for subsidy

To access the benefits of scalability and flexibility high quality distribution wiring and load control must be installed. However some customer segments would not be able to afford the additional costs for these; a subsidy for this infrastructure is required. Solar-home-systems can be financed through bank loans (for example), and the ability to pay can be matched with the demands for energy appropriately. However the cost of the micro-grid infrastructure cannot always be afforded through a bank loan, and there is no clear route for the subsidy required. CSR or government funds are potential sources, but these sources are not reliable.

Traditional financing institutions are unfamiliar with micro-grids

Accessing end-user financing for solar-home-systems is challenging but has been demonstrated viable. Micro-grids are less familiar to rural banks, and the business models proposed are often seen as risky to these institutions. Without good demonstrations or strong government support traditional sources of financing may not be accessible for micro-grids.

Planning (political) barriers and gaps

Uncertainty of government planning and the risk of grid connection

Connecting the central grid to a micro-grid should be seen as a benefit to the community and system integrator if the correct frameworks and policies are in place. The community would benefit from cheaper power and the micro-grid could act as back up and/ or sell power back to the grid. However with only recommendations, and no actionable frameworks in place, grid reaching a site is seen as a threat. If grid reliability is high enough customers would stop paying for the micro-grid service and the investment is wasted. In such an environment, entrepreneurs are wary of the future of the project, banks are uncertain of getting repayment on loans, donors are unsure of the impact of their funds, and investors find it untenable to provide capital.

Poorly designed policies for implementation of off-grid projects

The current policies for off-grid projects in remote areas do not promote effective implementation of micro-grid projects. This can lead to a poor opinion of these solutions in government bodies, financing institutions or with end-users. Other related policies may or may not facilitate effective implementation of off-grid projects.

What role can SELCO Foundation play?

The barriers and gaps listed above present a huge challenge to practitioners aiming to provide the ideal service to end-users. As the ecosystem is not yet developed for micro-grids efforts from a number of organisations need to be brought together to build this ecosystem, and help practitioners to provide the best service. The role that SELCO Foundation should play in this is discussed here.

SELCO Foundation has access to a collection of experts in operational, financial, political and social aspects of providing energy services to underserved and unserved communities in India. Both the full time staff, the immediate network of practitioners and the wider network or industrial, political and academic ties that SELCO Foundation has access to are well placed to provide a holistic view as to how efforts should be conducted.

To demonstrate the effectiveness of properly implemented micro-grid models, a significant number of pilot projects would be required. However, without a large operations team SELCO Foundation cannot run these pilot projects independently; a partnership with practitioners or other organisations is required.

Three teams in the Foundation can provide solutions, ideate and pilot models and disseminate learnings appropriately. Each of these teams is at different stages for each of the barriers and therefore should be contacted for the latest updates.

Rural labs - ideate and pilot models

With a strong understanding of rural communities needs, in addition to the wealth of experience in SELCO India of bringing energy solutions to the poor, the rural labs can play a strong role in ideating and piloting potential models for rural areas. These pilots must be run in partnership with another organisation which is geared up for collections, for example a micro-grid company or a community development NGO with a system integrator. In particular the rural labs could help tackle the following barriers and gaps:

- Cost of collections - partnerships which tackle the issue of collections can be piloted. For example rural development NGOs can be used for community mobilisation, and the set up of a local operator.
- Site identification and needs assessment - through the pilots conducted by the rural labs, as well as taking learnings from the pilots and micro-grid projects of other organisations, models can be consolidated and advice can be easily given to practitioners on needs assessment and the choice of models. These pilots should promote models facilitating productive use of energy, as well as solutions that best fit the community's needs.
- Larger impact of problems - models which provide layers or servicing can be piloted, for example a local operator could identify and fix small issues, a local branch technician could deal with more complex issues, and only the major problems need to be passed to senior technicians.

- Social barriers and gaps - accessing the good understanding of the local social contexts will be key to designing models that are sustainable. The rural labs has good access to this knowledge, and efforts should be made to document models tried and to find those which are flexible to accommodate differing social contexts in a robust manner.

Technology team - provide technical solutions

SELCO Foundation has a team of technical consultants who have a strong understanding of field requirements so can assess existing technology, and match it to the needs or work with technology provider/ develop solutions in-house if they do not exist on the market. Therefore, any barriers or gaps which may have technical solutions can be addressed by this team:

- Customised design - matching technical solutions to local needs can be facilitated by design advice or tools. The team can make use of learnings from pilots conducted by SELCO Foundation, as well as other organisations, to put these tools together.
- Efficient loads for productive use - a part of the team is focused on livelihoods and how to facilitate productive use with renewable energy. These learnings can feed directly into micro-grid models which provide flexibility for load use.
- Metering and control - the team can assess existing technology on the market for suitability, and can work with partners to develop new solutions. With the team's direct connection with practitioners it is in a good position to guide these efforts.
- New storage and generation technologies - projects focusing on small wind and pico-hydro are being and have been conducted by the team. These learnings, as well as assessment of new storage technologies coming into market, can assist system integrators in choosing technology for micro-grids.
- Cost of collections - prepaid and mobile technology has been tipped as a good solution to reduce costs of collections. Whilst assessment of this model is primarily an operational one (how widespread is mobile money, what are the overall cost savings) the technology team can assess the technology itself, and help in any pilots.
- Site identification and needs assessment - technology can assist in site identification and needs assessment efforts. For example making use of information sources such as census data or satellite imagery could reduce the work required for needs assessment. This data should be in an easily accessible form so that potential entrepreneurs can identify opportunities, and the efforts for site surveys are reduced.
- Larger impact of problems - data logging with or without remote access can facilitate debugging of problems, as well as preventative measures to avoid problems. The technology can be investigated and tested, with the benefits of remote data logging analysed. A cost effective solution should be sought. Additionally, training for technicians and local operators can be conducted to reduce servicing burden on the central resources of a company, and so increase response time for complaints.
- Uncertainty of government planning and risk of grid connection - whilst this question is primarily one for the policy team, the technology team can assist by providing inputs for reports, for example by determining the cost of connection in certain areas, using data loggers to

Policy team - disseminate learnings

This team brings a practitioners perspective to policy discussions with government agencies, policy makers, planning and implementing agencies and financial institutions. Therefore they have the ability to push for proper government action from the right bodies, bringing practitioner focused inputs. The team can particularly focus on the policy issues:

- Uncertainty of government planning and risk of grid connection - by working with planning agencies the team can push for a clear and proper role of off-grid solutions in the electrification planning of the government. These inputs would be based on models piloted and learnings from the field, and the output would give clarity to micro-grid practitioners and financiers.
- Poorly designed policies - by taking learnings from practitioners on what works, related policies can be influenced so that they encourage proper participation of the private sector in energy service participation.
- No clear route for subsidy - as part of policy discussions, or discussions with CSR organisations, routes for subsidy can be searched for, and sustainable options promoted
- Traditional financing institutions unfamiliar with DRE solutions - awareness of DRE solutions, and particularly micro-grids, can be built with financing institutions. Pilot projects which use bank financing would be key for this activity. The situations where micro-grids are best suited need to be highlighted.