Developing Responsible Innovation Systems

the case of the rural energy sector in India

Yvo Hunink
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Abstract

Technologies used in the energy sector, and many other sectors, are too complex for innovation by a single actor. Many influences from different types of actors are required to advance the technology, creating a collective innovation process. However, without the right accountability structures between different types of actors, unfavourable outcomes might emerge as the result of collective irresponsibility. Responsible Innovation is a theory that aims to improve the degree of responsibility of innovation processes, by incorporating the dimensions of anticipation, inclusion, reflexivity and responsiveness in the innovation process. However, to date this has been mostly applied to individual organisations. No framework exists that can assess and guide the responsibility of the collective innovation process of an entire system of actors. The objective of this exploratory research is to create a first version of a framework that can do such and perform an initial case study to generate insights for its future use.

From a literature review, responsible innovation in the collective innovation process was specified as the application of the intertwining dimensions of anticipation, reflexivity, inclusion and responsiveness in an evolutionary environment with actors of an innovation system that contains a constant group of institutions, while an open knowledge environment is present. Three concepts helped to define what a responsible innovation system is. Systems of Innovation helped to determine that innovation systems emerge on a regional level. The Quadruple Helix helped with the categorisation of the active institutions (Government, Industry, Academia, Civil Society) and the evolutionary characteristics of a system. Open Innovation helped to determine what an open knowledge environment entails in innovation. A responsible innovation system is then defined as an open knowledge network that allows for both emergence and evolution of the four institutions of the Quadruple Helix and the regional innovation system to develop, while the dimensions of anticipation, reflexivity, inclusion and responsiveness are mutually shared among the actors. A combined framework was constructed consisting of three elements: components, relations and functions. In the components, the actors are characterised according to the Quadruple Helix and the system is evaluated on its inclusion of all institutions. In the relations, two-way knowledge channels are revealed, with the help of Open Innovation. In the functions the three virtual spaces of Knowledge, Innovation and Consensus are created, each with its specific role of explaining interaction in the system. The Consensus Space will only form if the dimensions of an-
ticipation, reflexivity and responsiveness are found in the activities within and among the actors of the system. Also a number of conditions for a responsible innovation system to emerge were set up.

The framework is subsequently applied to the case of the Indian innovation system of rural energy technology, after an institutional analysis showed that all of the institutions are present and active in the system. The framework was applied in three data collection methods, which covered different parts of the collective innovation process, explained as the exploration, construction and implementation phases. Several local event visits showed that in the exploration phase has arenas exist where responsibility prevails, but governmental policy feedback events are far from inclusive, anticipatory and responsive. Structured interviews with 17 organisations, predominantly actors from industry and civil society, reveal that in the construction phase, inclusion of governmental and academic partners is limited. Also two-way communication channels were often absent, preventing alignment of goals and values through anticipation, reflexivity and responsiveness in the Consensus Space. From the actor analysis, CLEAN appeared to be the most central actor of the system. Semi-structured interviews with end-users showed that full inclusion is also absent in the implementation phase, while also responsiveness should be increased. The framework appeared to succeed in revealing the important interactions of an innovation system, because it became clear that government and academic actors are not sufficiently included in the innovation activities of the industry and civil society institutions, further preventing alignment of objectives in order to achieve responsible innovations. Evaluation of the conditions showed that these indeed left some gaps to be filled. Overall, the results show that actors in the system should perform more co-creation activities between institutions.

It should be noted that a validation of the results generated several limitations to the research and the framework, leading to recommendations for further research. It was shown that due to multiple realities in the intersections of an innovation system, the results of the framework can not always be generalised and needs to have input from central actors of all institutions. Also, the way a component or relation contributes to anticipation, reflexivity and responsiveness should be revised, because the framework fails to capture gradations in such contribution. Next to that, the oversimplification of the characterisation of actors might prevent a good evaluation of the system. Furthermore, there appears to be a tension between effectiveness of the activities of organisations and responsibility, due to the large amount of resources that are needed. This means that to become responsible might take more time and effort, making the activities less efficient in reaching the objectives. This would make the framework more usable for the exploration phase, opposed to the other two phases, because in this phase the goal is generally to have a broad perspective, while in the construction and implementation phases a certain focus is required and intervention of many stakeholders might trouble the process. Also, the conditions of the framework should be further examined and enhanced, possibly with a role for CLEAN as the central actor. Lastly, in line with global issues, the framework could be extended with the Quintuple Helix with the environment as additional institution, so that innovation systems might also be in line with ecological constraints. Also, among some other operational limitations, the research failed to question all institutions, creating a potential bias in the results. More research is needed to validate the framework and the results, both within and outside of India.

Still, a first exploratory step has been taken towards a framework for assessing and guiding towards responsible innovation systems.

Towards Decentralized Grids

EnergyBazaar: decentralized free-market energy-trade within an isolated community micro-grid

Dirk van den Biggelaar

April 2018

Abstract

We witness the rise of prosumers: consumers that produce a surplus of energy that can be supplied back into the grid. However, for energy-trade between prosumers and consumers, a centralized and undesirable middle-man is still necessary. We developed a method to decentralize essential aspects of energy distribution between households. Macro-grids are divided into various neighborhood sized community-grids; a micro-grid. A micro-grid as a community yields a degree of self-sustainability. Nevertheless, micro-grids currently still possess centralized elements. The presence of central controllers, trading-agents or banks, maintains this undesirable situation. Decentralization of a power-grid increases end-user autonomy, independency and fairness in the system.

We propose to establish a truly transactive micro-grid: decentralized in its energy distribution, control and money-flow by deploying EnergyBazaar, a distributed trading algorithm. Concepts of game theory are used in the design to enable EnergyBazaar to solve the economic dispatch problem: agents want to individually optimize their social welfare, while the collective task is to stabilize the grid. Micro-grids make use of a decoupled hierarchical structure: primary control is responsible for fast dynamics of voltage and frequency, secondary control coordinates the economics within the micro-grid. In its core, EnergyBazaar coordinates inverter-based droop parameters within the Energy Storage System (ESS) of each agent, managing their charging/discharging behaviour. A trade-off is identified between economical gain and the necessity of surviving energy scarcity. For this, energy patterns are predicted and acted upon. In contrast to a coordinator dictating a centralized solution, EnergyBazaar creates a free market, where agents individually converge to a global Nash equilibrium. A comparison is made to show performance of both.

By rejecting centralized institutions in the micro-grid, trust challenges are introduced: achieving decentralized money-flows, the necessity of shared information during distributed optimization and the manipulation of the free-market by malicious agents. We introduce an approach of mitigating these issues in a decentralized paradigm by embedding EnergyBazaar in a smart-contract deployed on a blockchain platform.

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Institutional innovation:
Solar electrification sustenance

Rhythima Shinde
August 2017

Summary

There are more than 200 million people still without any form of electricity in India. Many of them are being approached with innumerable government schemes with the aim to achieve 100% electrification by year 2018.These schemes include, but are not limited to, Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), a Ministry setup of New and Renewable Energy (MNRE), and other efforts from different private and nongovernmental organizations. Most of these projects are focusing on the decentralized energy solutions specifically renewable, and mostly solar energy based solutions, because of the environment-friendliness, portability of solar house system, access and the abundance of sun in rural India. The DER or decentralized energy renewable sources prove to be very helpful provided the transmission loses to the distribution companies or DISCOMs, and the remote settlements in the large inconsistent and at times, harsh terrains of India.

Even though the DER solutions look to be appealing they have not been successful because of two reasons: First, there is an issue of upgrading with the increasing demand of the people. Second, the schemes of government have been focusing on electrifying a village and not the households, leaving around 90% of the households un-electrified even with a so-called "electrified" village. Thus the issues of access to all and the reliability of the solar house systems to upgrade have led to constant failures of the solar electrification projects. Additionally, the rural communities of India are very strong on their social norms and thus if a technological solution is not fitting as per their values or the informal institutions in the community, there is a high chance that it will be discarded.

There are three types of major solar electrification projects : Microgrid, Sharing and individual Solar Home Systems(SHS), based on the level of ownership. The first is owned by usually a private organisation with community and partially funded by the profits and the corporate, banks or government funds. These projects have a main source of energy usually centrally located and distribution lines are connected from this source to the households. Second is partially owned by community and partially by a private organisation or an energy providing firm, and completely funded by the profits. These projects have households as producers and consumers, with variety of products. Usually energy is produced a SHS on a house and the excess is sold to other households in form of electricity or charging batteries. The third is completely owned by the households and the energy providing companies act as external agents responsible for installation and repairs. All these societal level issues for the DERs are present for all the three types of projects, and have led to an overarching research question of the thesis "*Given the dynamics of rural communities of India, how can socio-technical systems of solar electrification be sustained*?"

TU Delft

Community management of resources and innovation diffusion

Breaking down the research question, the first question is posed as Which frameworks can help study the effects of all dynamic factors combined on the solar electrification systems in rural context?. Usually for understanding such effects, literature considers the projects of rural electrification from the perspective of the energy providing firms or the households. But this thesis used a different approach and looked at the rural electrification from a community level. Here the community is considered to develop management rules (institutions) to sustain the resource, which is the electricity produced by solar energy. It is similar to the common pool resource management approach where the resource is limited, as first studied by Elinor Ostrom through various frameworks (Ostrom et al., 1994). The reason to use this approach is that this approach allows to understand the community attributes and their changes at once. By considering only energy provider's or households' perspective, one can understand supply and demand of the technology or the households, respectively. But, this restricts the freedom to look at the effects of the important societal-cultural effects and their impact on the rules in the community. This is brought by community management approach, as used in the thesis.

The Institutional Analysis and Development (IAD) framework combined with the Socio-Ecological System (SES) framework looks to be most appropriate for this case to answer to some extent the first part of the research question. This part would help understanding the effects of various combination of socio-cultural, technical and economic factors on these electrification projects. These socio-cultural, technical and economic factors will also be labeled as the "dynamic factors" throughout the research. IAD framework proposes adaptation of rules of use based on the outcomes of the patterns of interaction of the actors in the system based on their individual action, to adapt to these changing factors. SES theory helps in understanding the exact variables included in the considerations of socio-cultural, technical and economic factors. But, IAD and SES, together, fall short mainly in recognizing that the individuals adopt rules which are established around a technology, only if they agree to embrace the technology. This directed the research towards studying the dynamics of innovation diffusion.

Thus it was further decided to dive into depth of the innovation diffusion theories for this research. The word-of-mouth theory lists the conditions under which the neighbors accept an innovation and the economic theory helps setting a threshold to help households decide if they will accept an innovation or not. These two theories are adapted in this research due to their depiction to reality in the rural solar electrification case of India. Thus, answering to the first sub-research question, the answer can be summarised as the IAD, SES and innovation diffusion theories together, can help in understanding the effects of all dynamic factors on solar electrification systems in rural India context.

Institutional Innovation Framework

Though these frameworks are useful, there is no clear direction on how to use them together and thus the next sub research question is posed: "*If there is no framework available, how can a new framework be developed to study the effects of all dynamic factors combined on the solar electrification systems in rural context?*" This question led to the development of an institutional innovation framework which would help understand effects of the dynamic community on such socio-technical infrastructure projects. Here, the action of an agent affected by innovation diffusion, followed by institutional diffusion and adaptation, lead to design of a new institution in the system, and this is called institutional innovation as shown in Figure 2 and explained in further paragraphs. This term was first coined by Vernon and Hayami (1984) and such a need of merge of approach was explained by Redmond (2003). The institutional adaptation and diffusion, fitting in institutional innovation was first pointed by Hargrave and Ven (2006).

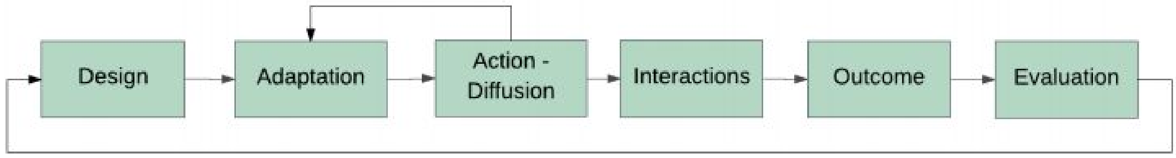

Figure 2: Proposed framework of institutional innovation

The proposed framework fills the gap of the IAD framework of understanding the impact of the individual decisions and development process of institutions based on these decisions. IAD misses out on understanding the exact process of development of institutions, where the process of institutional adaptation and diffusion goes on simultaneously. In case of socio-technical infrastructures as innovations, the adaptation of institutions occur at two levels: before the innovation is accepted by majority, and after the innovation is accepted by majority. The institutional adaptation before the innovation acceptance leads to top-down rules (institutions) usually applied by the authority controlling the resource or the community heads. The adaptation after innovation acceptance leads to development of usage rules. These usage rules are again of two types: decided by evaluation of individual utility, and resource/community utility. These rules are defined by an evolutionary process of rules variation, outcome and adaptation.

The institutional adaptation is simultaneous with institutional diffusion, where the institutions are passed on from one member to another in the community. This follows similar rules to innovation diffusion like word-of-mouth, where a new member adopts rules based on the benefits of the adapted rules. Note that here institutional design is restricted to the same definition of adapting a new institution by majority. These institutional rules are adapted at different levels of actors and individuals. Different properties of the resources and communities help develop individual components of the institutional innovation framework. A summary of this framework can be seen in Figure 3 and 4.

Context study of rural solar electrification in India

Now that a framework is developed for answering the question, it needs to be applied to the given case. Thus, a further sub research question is posed: "*What are the existing effects of the different dynamic factors on the solar electrification in rural India?*" To understand the existing effects thoroughly, after a thorough context study based on literature, more than 20 interviews were conducted on-ground and online with energy provider and communities in presence of energy provider. The interviews developed a very clear insight into these aspects of the electrification project: technology, energy provider characteristics, community characteristics, actors properties and involvement, operations and maintenance, market settings and funding, institutions (Formal and Informal), success and sustainability parameters for the electrification project.

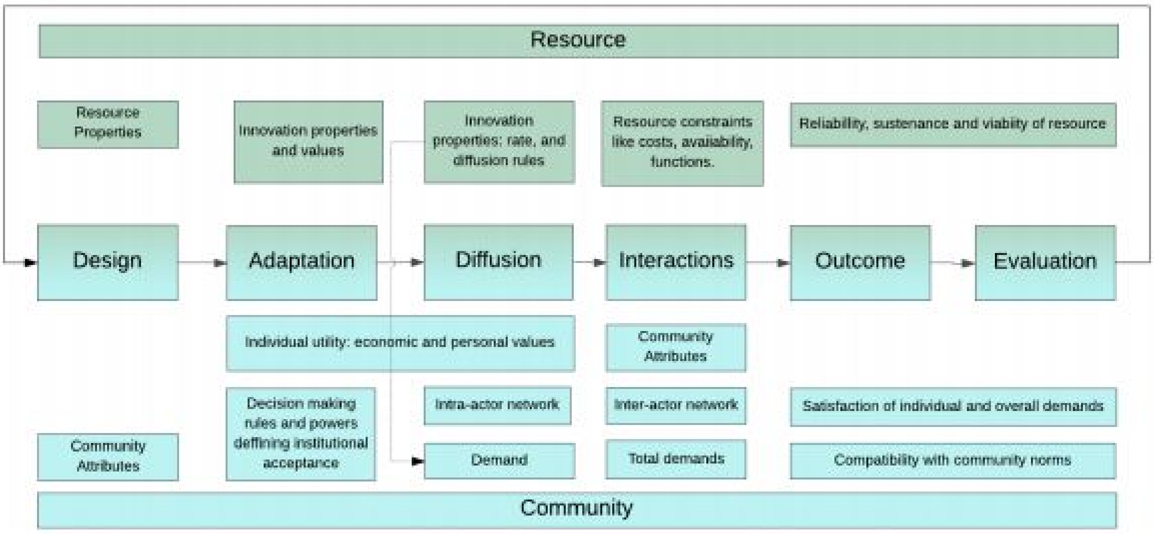

Figure 3: Resource and community attributes defining the institutional innovation framework

The main interviewing organisations were: *Gram Power, Gram Oorja, Mera gao power, Selco, Manthan, Simpa, Piconergy, Rural Spark, SolShare*, where the first four are microgrids, the next three are SHS and the next two are sharing projects. The different actor charts gave these types based on roles and responsibilities: Energy provider firm, Manufacturer, Households, village committee, government and NGOs. The first three are considered to be the most critical actors due to the resources they govern, with local and national governments as a context setter. The analysis of these interviews to understand the process in the electrification projects, shows that the microgrid projects have higher number of collectives choices and other projects are very operational in nature. Collective choices are the decisions taken by the interaction of actors, where one common decision (choice) is chosen by all the actors. The collective choices are completely absent in the case of individual SHS and thus these projects will be kept out of the context of further analysis.

The above analysis of the actors and processes is aimed at understanding the effects of the dynamic factors on the rules of the communities. These rules further help to define the effects on the resource usage and the community, and thus help in defining the success and sustenance of the projects. This relation between the success parameters and the resource usage and community parameters need to be more explicit. Thus, further research is done on understanding the success parameters for such projects. A lot of research is already present in the field of the rural electrification domain on success factors, and following it, the major parameters of success came out to be affordability and accessibility for community, reliability and viability of technology, socio-cultural and political sustainability of the project with long term sustenance and profitability and positive environment impact of the project. Based on an analysis of these success parameters on statistical and visualization based result, it was seen that: (1) the success parameters stayed similar for the ownership basis i.e. there was not much difference for microgrids, sharing and SHS project, (2) but the results varied as per the involvement of the stakeholders e.g. profitability was important for a project where village committee was involved.

Framework for comparison of projects

The next step is to define operational structure of developed framework to help find the effects of factors on the project. This leads to the next sub research question: "*Given the developed/ existing applicable framework, how can the effects of the combination of dynamic factors on the solar electrification be obtained?*" Based on the actor and process analysis, it is difficult to jump to finding the effects of the socio-cultural and institutional factors. Thus simulations in form of agent based model would be performed. But this first needs operationalization of the framework to develop this actor and process analysis into a system which can directly help check these effects. Such a system can be some form of model, and here as the focus is on the actions of the agent, an agent based model will be used. But even developing an agent based model would need a designing concept. Here, the MAIA (Modelling Agent systems based on Institutional Analysis) framework developed by Dr. Amineh Ghorbani was used which has a foundational (physical, collective and constitutional), operational and evaluative framework.

The foundational framework helps lay down the actor networks, the action sequences and the physical components with the different institutions. The operational structure lays down all the decision rules with the action situations. Finally, the evaluative framework helps define the success parameter variables which can be used to compare different models and performance of each model. Here, the institutional innovation framework comes into role for defining the rules after every action situation and this is defined in the operational framework with a proposed module: "rules-check". This is introduced after the action situations' design in the operational structure of MAIA. This helps to evaluate the gap between the individual utility and resource/community utility, to define the exact usage rule. Additional to the MAIA, as can be seen in the following Figure 4, the different methods followed in the research helps define the different components of the proposed institutional innovation framework.

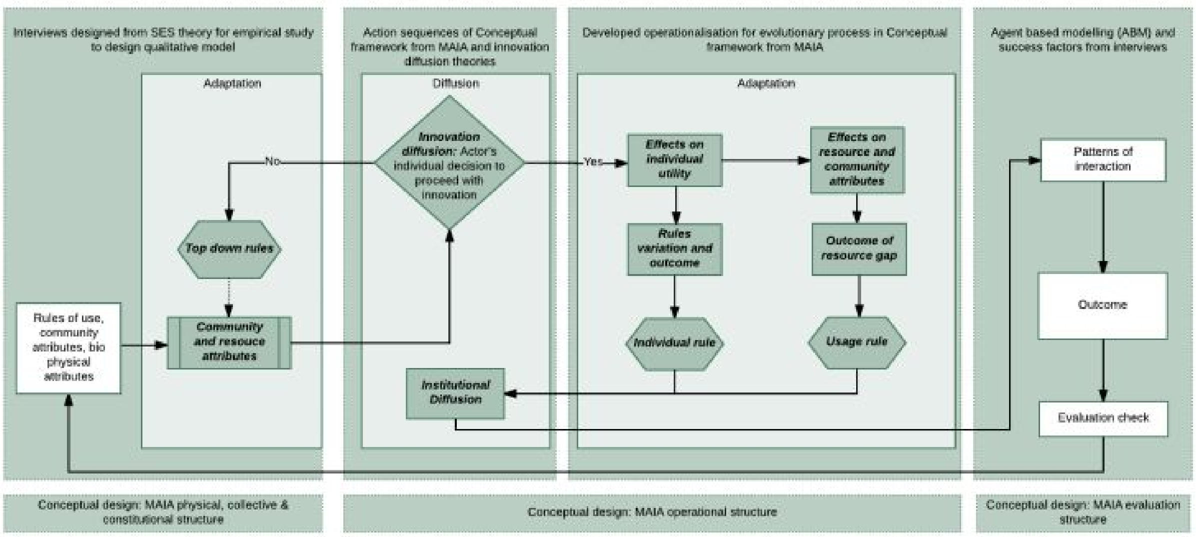

Figure 4: Theoretical framing with methodology

Effects on projects

Finally, that the operational structure to find the results is framed as shown in the above figure and discussed in last section, the next sub research question is "*Given the developed framework, what are the effects of the combined dynamic factors on the solar electrification* *in rural India?*" Looking a the major effects of the sharing and microgrid projects, it can be seen that the sharing projects don't allow the income rise to be met with the increase in demand, while the microgrid project shows a lack of profits due to the payment skips in the project. Also, the demands based upgrading in more easier in a microgrid project but difficult to achieve due to lack of profits, while this is very difficult in sharing projects due to higher installment costs of the project upgrading. One of the solutions to this is to merge the two projects i.e. develop a hybrid project with the inclusion of microgrid to meet the higher demands at a lower cost (microgrid installments are lower). This also helps reducing the cheating behavior as in pure microgrid, because now people have incentives to be producers. As seen from the three models (i.e. microgrid, sharing and hybrid projects), the major insights in the effects/ behaviors of the models were as follows:

1. Laggards never get electrification: Laggards or the non-acceptors of the innovation get left out of the network of electrification. This is highly because of the demand-rise of the products and the incomerise of the early acceptors to a level that they become producer. So even if the laggards want to be the consumers later, there is no motivation for the producers to sell more kits to households and thus the market itself has saturated to provide any more transactions. The same case is with microgrid and sharing, with former missing out on consumers due to payment skips and sharing switching to stable market much faster than sharing project (demands are met faster now using microgrid).
2. Importance of connectivity: Connectivity of the agents with each other is more important for a household to decide to become a producer or not, especially in sharing and the hybrid project. This is even more important than affordability.
3. Rise and dip in the consumers/producers: Due to the replacement and operations & maintenance tasks, the reliability of the products become questionable, and less is the reliability more is the variation in the number of producers and consumers. Upgrade of income and connectivity helps bringing the rise to the market to a limited extent.
4. Microgrids' profits: The profit of microgrid is the biggest risk to the project because of the unaccountable behavior of the community accompanied by heavy operations tasks. There are many more reasons like the village committee changes, which keep the profit random and non-positive.
5. Hybrid project wins (significant differences based on statistical results): Comparison of the projects can be done on the following parameters which helps in showing that the hybrid projects is much better than the other two projects:
    a. Afford and Access: In terms of affording, microgrid always turn to be much cheaper due to smaller payments, while in terms of access, the hybrid projects make a network which allows adding a new household much easier and beneficial for the network.
    b. Operations and demand rise (Reliability): Operational issues are more frequent with sharing and hybrid, but more larger (due to large size of the source) with microgrid. But the hybrid projects are more complicated due to presence of both and thus the least convenient for operations. But at the same time, the hybrid projects are better at meeting high to low demands than the other two.

c. Consumers and Producers: The number of consumers is highest in the microgrid, and the number of producers will be highest in Sharing and Hybrid, leaving the sum to be almost the same.
d. Profits: The profits are highest in the hybrid due to management of losses in microgrid and the profits to the producers, while only one of each is present in the other two, with microgrid having losses.

Policies and Recommendations

Now that the best project is known as the hybrid projects, the next sub research question is "W*hat new policies and rules can be developed which would help change these effects to improve sustenance of the solar electrification in dynamic context?*". These policies and recommendations here are addressed to majorly two segments of stakeholders: one, the energy providing firms and especially those who are ready to accept innovations with time and are inclined towards a sharing project e.g. *SolShare* and *Rural Spark*, but even microgrid companies with more innovations in their side like *Gram Power*, with smart meters, can find the recommendations helpful. The SHS projects like *Manthan* can focus on the more adoption of the social level innovations, due to lack of funding support and extreme poverty in the end user segment they are catering to. Once, they are able to help everyone get minimum electricity, the more technically advanced solutions can be integrated in their project. Finally, the local governments cannot directly use these recommendations, but their involvement while such implementations smoothen the process of development of electrification projects.

• The recommendations for all the energy providing firms are as follows:

1. **Switching to Hybrid projects is beneficial for both sharing and microgrids**: Especially for the microgrids, this is more beneficial, due to the presence of infrastructures. Sharing (and SHS) projects would face heavy investment initially, but more number of consumers would help in payoff and thus both projects should invest in it
2. **Introduction of grid has heavy impacts**: But reliable products and contracts with central grid can help here on introduction of grid. The latest possibilities of PPA (Power purchase agreements) by central government, can help arrange these contracts.
3. **Laggards can be included using pay as service model and in-house manufacturing**: This would help solve the issues of affordability in poor rural areas. Lessons from Barefoot college for in-house manufacturing, incorporating community knowledge development, and women empowerment would be helpful here.
4. **Demand wise payment helps reduce demand-income gap**: Demand versus income gap can be reduced with demand wise payment and electrification i.e. microgrid can be only used when the demands are high enough to prevent cheating.
5. **Resource and individual utility gap is important to decide usage rules**: These usage rules are the compensation, prioritization (distribution) or constraint rule for usage of the resource in the community, increasing the profits and access of the resources.

• The recommendations specifically for the microgrid energy providing firms are:

1. **Community energy system should be grown as economic hubs**: It is important to have a steady growth in these community energy systems - i.e. there constant development like a livelihood organisation/ economic hub is important to prevent decline in number of producers and consumers due to increasing demands or the replacement costs piling up.
2. **Prioritization rules help get community back on ground**: In cases of emergency, distribution from community pool should be used in such cases. If these rules are not present, the community might lead to completely stop using the resource.

• The recommendations specifically for the sharing projects' energy providing firms are as follows:

1. **Variety of the products should be experimented**: Energy variety doesn't have any effect on the number of producers, buyers, but the effect on profits might be different. For example, in the case of Rural spark, the more modular products have helped to cater to different amount of demands more easily.
2. **Cashless payments**: They would have a heavy positive impact on the profits of the energy providing firms, because this would save a lot of hassle and investments in terms of time for the energy provision firms.

• The recommendations for the local governments (with collaboration of energy providing firms) are as follows:

1. **Cooperative shops prevent discrimination**: Discrimination can be tackled with cooperative shops and anonymous sharing. The collection of the small sections of society as one entity makes look at the weaker/ smaller section of society with more status.
2. **Policy impacts should be considered**: Policies can lead to generation of unanticipated demands, benefits and problems as well and it should be kept in mind. For example, policy of in-house manufacturing might lead to new community hub development and increased connectivity, and thus, such effects should be considered.
3. **Delays in the processes need to be avoided**: Delays need to be avoided as the communities have a high rate of change with terms of demands, and delays lead to a loss in the trust of the service. Thus the processes of testing and registrations should be integrated with project deployment and design. This need a steady formal regulation from the governments.

Recommendations for framework

Based on the above recommendations it can be seen that the institutional innovation framework has helped to develop policies which when applied for the case leads to better sustenance of the electrification projects. In the same way, the case study has also helped to contribute back to the institutional innovation framework.

1. **Institutional Adaptation at two level**: The institutional adaptation was developed considering before and after innovation effects. This was developed only after taking the inputs from the energy providing firms in the interviews, when it became apparent

that the top-down rules and the usage rules are differently applied based on the action of the majority to adapt or reject an innovation.

2. **Institutional Adaptation to Diffusion connection**: The link between the institutional adaptation to institutional diffusion was developed when a gap of this link was seen in operationalization of the framework for the case study. This was done via understanding the evolutionary process of rule variation, rule outcome evaluation and rule adaptation.
3. **Exact effects of resource properties**: It is important to know what exact innovation was brought into and what resource properties were changed, for the usage rule to be adapted accordingly. The framework is developed further for the consumer producers based on the different cumulative effects which define the actor's choice and thus affects the innovation diffusion. Here the cumulative effects involve the different features, varieties and serial correlations in innovation of the product.
4. **Rules based on gap between resource and community**: The case study helped understand the different types of usage rules which would help the project in terms of profitability, increasing access, etc. They were developed and included in the framework based on the resource and individual utility gap (additionally, resource availability and community gap) as compensation, constraints, and prioritization/ distribution rules.
5. **Application beyond case study domain**: Based on the case study, it was also realized that the framework needs to be further adapted for similar domains, so that the framework can be applied more generally. Only considering the tp-down rules, this framework was adapted for the consumer products and the networked infrastructures. Here, the exact effect of the social, technical and economic changes in the community on the specific components of the framework was noted. For example, the technical changes happened for the varieties in the products, or performance of the product, which affected the actor's choice to adapt an innovation. This would thus affect the top down rule for the consumer products.

Additionally, studying the limitations of the thesis and the reflection on the research approach showed what could be further developed in the research. The reflection showed need of a more comprehensive approach in institutional designs by considering not just the collective actions, but also the collection of actions effect in changing institutions. In terms of tools, the usage of some other tools like Java instead of Netlogo, using system dynamics with agent based modeling, and more detailed interviews focusing on more quantitative data, was mainly noted. Furthermore, this research can be followed up with other researches to: (1) automate this institutional innovation framework and integrate in policy designing for energy distributions (or similar socio-technical infrastructures), (2) understanding co-existence of different types of socio-technical infrastructure systems like electricity and telecommunications, when all fields have continuous innovations, and finally (3) integrating the blockchain and smart contracts technology in infrastructure design for this specific case study to be realised on-ground.

Full readings:
Thesis Yvo Hunink
(https://repository.tudelft.nl/islandora/object/uuid%3A2854250b-31c0-4780-93b6-6674cbc06a17)
Thesis Dirk van de Biggelaar
(https://repository.tudelft.nl/islandora/object/uuid%3A9b1f7b2f-fec8-4993-bcf7-37ab301c0d02)
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