UPPSALA
UNIVERSITET

UPTEC STS 20004
Examensarbete 30 hp
Februari 2020

In Pursuit of Sustainability

Decentralized Renewable Energy Services in India

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Abstract

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Based on the grand challenges of transforming the energy sector towards sustainability and harvesting the potential from decentralized solar PV, a holistic and systemic perspective is required. This study presents the case of decentralized renewable solutions in Karnataka India. The diffusion of solar home lighting systems has an environmentally, socially and financially positive impact. This study applies the interdisciplinary framework of Technological Innovation Systems (TIS) to explain the structural elements and system dynamics that create the enabling conditions for this diffusion.

Five key mechanisms that induces the systems overall performance are identified: (1) A need-based approach that allows for the customization of solutions to the need of the customer; (2) The utilization of local knowledge and authority through local champions; (3) Relentless efforts to build and maintain the personal relations with the customers, partners and employees; (4) Having a strong network with high trust and well-established channels for communication enables the diffusion of learnings and innovations in the ecosystem; and (5) Work to build partnerships that is reinforced through a social mission to serve the underserved, which forms strong connections and increases the motivation among partners and employees. Key blocking mechanisms for an increased diffusion of solar home lighting systems are: Vague national and regional policies, damaged reputation for solar technologies through substandard solar products and installations, and decreased engagement from banks.

The identification of both the inducing and blocking mechanisms has proved the value of examining system dynamics. Evaluating sustainability in the methods to diffuse sustainable technologies, and not only the technology itself, is an interesting insight from this study. These findings resonate with previous research calling for an expansion of the TIS framework to better explain system building and resource management activities.

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ISSN: 1650-8319, UPTEC STS 200004

Sammanfattning

För att transformera energisektorn mot hållbarhet och realisera potentialen från decentraliserad solenergi, krävs ett helhets- och systemperspektiv. Denna studie presenterar ett fall med decentraliserade förnyelsebara lösningar i Karnataka Indien. Studien tillämpar det tvärvetenskapliga ramverket för teknologiska innovationssystem (TIS) för att förklara de strukturella elementen och systemdynamiken som möjliggör spridningen av solcellssystem för hembelysning. De miljömässigt, socialt och ekonomiskt positiva effekterna av dessa solcellssystem motiverar undersökningen av det system som omsluter och påverkar spridningen.

Fem viktiga mekanismer som stärker systemen funktionaliteten har identifieras: (1) En behovsbaserad approach som möjliggör anpassning av lösningar för kundens behov; (2) Användning av lokal kunskap och auktoritet genom lokala ambassadörer; (3) Obevekliga ansträngningar för att bygga och upprätthålla personliga relationerna med kunder, partners och anställda; (4) Att ha ett starkt nätverk med högt förtroende och väl etablerade kommunikationskanaler som möjliggör spridning av lärdomar och innovationer inom ekosystemet; och (5) Att centrera relationsbyggande kring en gemensam vision om en socialt inkluderande lösning som stödjer socialt utsatta, ger både starkare partnerskap samt ökar motivation hos partners och anställda. Viktiga blockeringsmekanismer för en ökad spridning av solcellssystem för hembelysning är: Otydliga nationella och regionala policys, ett skadat rykte för solteknologier genom undermåliga solcellsprodukter och installationer, samt minskat engagemang för mindre lån från banker.

Identifieringen av både stärkande och blockerande mekanismer har påvisat värdet av att undersöka systemdynamiken för teknologiska innovation system. Att utvärdera hållbarhet i metoderna för att sprida hållbar teknik, och inte bara tekniken i sig, är en intressant insikt från denna studie. Dessa insikter överensstämmer med tidigare forskning som efterlyst en utvidgning av TIS-ramverket för att bättre förklara systembyggnad och resurshanteringsaktiviteter.

Abstract

Based on the grand challenges of transforming the energy sector towards sustainability and harvesting the potential from decentralized solar PV, a holistic and systemic perspective is required. This study presents the case of decentralized renewable solutions in Karnataka India. The diffusion of solar home lighting systems has an environmentally, socially and financially positive impact. This study applies the interdisciplinary framework of Technological Innovation Systems (TIS) to explain the structural elements and system dynamics that create the enabling conditions for this diffusion.

Five key mechanisms that induces the systems overall performance are identified: (1) A need-based approach that allows for the customization of solutions to the need of the customer; (2) The utilization of local knowledge and authority through local champions; (3) Relentless efforts to build and maintain the personal relations with the customers, partners and employees; (4) Having a strong network with high trust and well-established channels for communication enables the diffusion of learnings and innovations in the ecosystem; and (5) Work to build partnerships that is reinforced through a social mission to serve the underserved, which forms strong connections and increases the motivation among partners and employees. Key blocking mechanisms for an increased diffusion of solar home lighting systems are: Vague national and regional policies, damaged reputation for solar technologies through substandard solar products and installations, and decreased engagement from banks.

The identification of both the inducing and blocking mechanisms has proved the value of examining system dynamics. Evaluating sustainability in the methods to diffuse sustainable technologies, and not only the technology itself, is an interesting insight from this study. These findings resonate with previous research calling for an expansion of the TIS framework to better explain system building and resource management activities.

About the project and acknowledgments

In Alpbach Austria 2018 the author Max Rosvall and CEO of SELCO India Harish Hande met during an interdisciplinary conference. The meeting was an open discussion about the role of decentralized solar solutions for the 1 billion people lacking access to electricity in sub-Sahara, India and rest of the world. The author brought questions based on a field study in Kenya on this topic, the CEO brought answers based on the experiences from 25 years of ground-level operations in India. This meeting that sparked the idea for this project, where an interdisciplinary approach could be leveraged to extract the learnings from the Indian experiences. Almost one year later the project started, and this report is the result from four months of both desk- and field research in Sweden and India.

The projected has been conducted with the supervision and guidance of Sarah Alexander, senior advisor SELCO Foundation, and assistance from Shripathi Hadigal, program manager Selco Foundation. Your contributions are highly appreciated.

The support and supervision from prof. Marcus Lindahl are greatly appreciated, and the insightful comments and support from Agaton Svenaeus, resulted in this final version of the report.

Finally, thanks to all respondents from SELCO India for your patience with my questions and enquires.

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1. Introduction

Access to energy is fundamental for modern society and everyday life of all people. Many of the grand global challenges presented by United Nations (UN) like no poverty, good health and well-being, sustainable cities and communities, and climate action, have a strong interdependence with the target of universal access to clean energy for all (UN General Assembly, 2015). The complex character of these global challenges calls for holistic solutions, i.e. solutions based on a systemic understanding of the challenges' structural elements and the interdependencies between them (Geels et al., 2008). These global challenges need interdisciplinary thinking that considers the multiple dimensions of sustainability beyond the often used and insufficient indicators of economic development or technological diffusion.

Renewable energy technologies should be considered the way forward to secure energy access for all (Ellabban et al., 2014). Not only are all renewable energy sources carbon-free, but many of them, like wind and solar, are also modular in character. This gives them the important ability to provide energy in a decentralized manner, suitable for use in remote areas without any connection to a centralized power-grid. Decentralization has some significant implications for the least developed areas where 1,1 billion people currently lack access to electricity (World Bank, 2015). These areas all share three market characteristics that make the diffusion of renewable energy technologies important and significant: there is plenty of untapped potential, there is high growth in the demand for energy, and environmental and societal dividends are typically higher than in more developed regions (Martinot et al., 2002).

The global energy-mix for electricity generation is currently based on the non-renewable sources coal (39%), natural gas (23%), nuclear (10%) and oil (3%), while the renewable alternatives, which are dominated by hydro (16%) and non-hydro (9%) sources like wind and solar photovoltaic (PV), remain less significant (International Energy Agency, 2019). India is the third largest electricity producer in the world, with a heavy dependence on coal. Only China and the US consume more coal for electricity production than India (International Energy Agency, 2019). The challenge of transforming their existing energy system, while including the 100+ million (World Bank, 2017) people lacking access to electricity is huge and demands new solutions.

Creating change supporting technological transitions towards sustainability requires a holistic approach. Renewable energy solutions have the potential to reduce carbon emissions. Social reforms and inclusive solutions can reduce inequalities. Valuing long-term financial profits over short-term can increase financial sustainability. All these solutions are part of the sustainable transformation approach which uses a holistic perspective and interdisciplinary frameworks for analysis (Geels et al., 2008). The Technological Innovation Systems (TIS) framework is one of them. The TIS approach provides a holistic conceptual framework, also known as an analytical construct, that provides insights about the internal dynamics of processes that are tightly coupled with

technological change (Bergek et al., 2008; Hekkert et al., 2007). While the TIS approach has been empirically tested and validated by several studies (Alkemade et al., 2007; Negro et al., 2008, 2007; Suurs, 2009; van Alphen et al., 2009, 2008), there is still a gap in empirical results from developing countries in the global south (Blum et al., 2015). Some studies have used the TIS approach in these contexts, for example PV in Ethiopia (Kebede and Mitsufuji, 2017), mini-grids in Laos (Blum et al., 2015), cooking stoves in Ghana, Uganda and Kenya (Agbemabiese et al., 2012; Tigabu et al., 2015) and biogas in India (Schmidt and Dabur, 2014), and they all call for further TIS studies in developing and emerging contexts.

This study will apply the interdisciplinary TIS approach to the case of solar home lighting in Karnataka India with the aims: (a) to derive a systems understanding and evaluation based on the internal dynamics of system functions that induce/block the diffusion of solar home lighting in Kundapura and Chamarajanagar; and (b) to enrich the ongoing TIS debate on how applicable and useful the TIS framework proves to be in a developing country context. The following questions will be examined:

- How can the diffusion of solar home lighting in Kundapura and Chamarajanagar be understood through the functionality of System Functions?
- How can the insights from this case improve the understandings of TIS applicability for sustainable transitions and decentralized renewable energy solutions?

This paper is structured as follows: section 2 provides an overview of innovation system theory and an introduction to the TIS approach, section 3 describes the method of choice and the data collection and analysis. This is followed by section 4 with the results from the case study. Section 5 provides the TIS analysis of the case material, followed by a discussion in section 6. The conclusions from this study and suggestions for future research conclude the paper in section 7.

2. Theoretical background

This section defines the complex notion of sustainability and its application for this case. Followed by historic introduction and contemporary explanation of technological innovation systems studies.

2.1 Sustainability

Sustainability is as widely popular term to label solutions and innovations and the aspect is often included in research in various ways. The term lacks a clear cut definition and is often defined in the context of the application (Vos, 2007). An often-cited general definitions is from the World Commission on the Environment and Development Report of 1987 (the Brundtland commission) where a new language

around sustainable development was introduced. They define sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland et al., 1987). Although there are differences of the definitions, some core similarities are found around sustainability. Some of the core elements are: first is the approach to assess environmental problems with regards to economic and social aspects, second is that these relations are viewed as interconnected with some overlap between the economic, social and environmental aspects, third is the idea of intergenerational equality as the Brundtland definition refers to the ability of future generations to meet their needs, the final element is the idea of working beyond mere compliance with current laws and policies to achieve sustainability (Vos, 2007).

For organizations and businesses there is another concept that is used interchangeable with the notion of sustainability, the triple bottom line (Elkington, 1999). The triple bottom line is a framework for measuring the performance of a business and the success of an organization using the economic, social and environmental lines. The economic line focuses on the economic value provided by the organization to the surrounding system in a way that prospers it and promotes its capability to support future generations (Alhaddi, 2015). The social line focuses on the practices done to "give back" to society, like community involvement, employee relations and fair wages (ibid.). The environmental line refers to the practices done that do not compromise the environmental resources for future generations (ibid.). The triple bottom line is sometimes referred to as profit-people-planet.

This case involves to aspects of sustainable solutions, the first being the technological solution itself and the second is the sustainability of the diffusion of this technology. Much previous research has been aimed towards evaluating the socioeconomic benefits of access to electricity (Asaduzzaman et al., 2010; Barkat et al., 2002; Cabraal et al., 2005; Khandker et al., 2012; Nieuwenhout et al., 1998). The impacts of replacing a source of lighting from combustion of fossil fuels like kerosene has direct health benefits, improved lighting in the household enables studies, microbusinesses and improves safety. The total effect from electrified lighting solutions are an increased quality of life and raised living-standards. Improvements in health, education, productivity and safety, combined with the environmental benefits from utilizing renewable energy sources leads to the understanding of solar lighting solutions as a sustainable solution. This study follows the triple bottom line framework, together with the core elements from the notion of sustainable development to define the aspects considered to evaluate the sustainability of the diffusion of technology as well.

2.2 Technological innovation systems

Geels et.al. (2008) introduce a notion of sustainable innovation journeys, for which they consider four strategies as responses to environmental challenges. The neo-liberal strategy focuses on markets and getting the price right. The ecological modernization

focuses on development of clean technology and smart innovations to foster both growth and sustainable development. The deep ecology focuses on behavioral change and how green values need to replace the modernist idea of continued growth. The fourth approach is their own suggestion for a strategy called socio-technical transitions. This approach addresses change on a more systemic level and focuses on the dynamic interactions and co-evolution between markets, technologies and social groups. This approach draws from several disciplines beyond technology. Most influential are economic and management studies, sociology, political science, and cultural studies (Geels et al., 2008). The broadness of the research field leads to a wealth of frameworks. One of the socio-technical transitions frameworks that has gained some attention from renewable energy technology scholars are the Technological Innovation Systems (TIS) approach (Hekkert et al., 2007; Jacobsson and Johnson, 2000; Truffer et al., 2012). The TIS framework, and other dynamic innovation models, have evolved as part of the critique against the traditional reductionist approach (Bergek et al., 2008). The reductionist approach separates the system into its separate parts and evaluates each part individually. This is an necessary first step in an system analysis, but not sufficient to capture the overall performance of the system (Edquist, 1997). This section gives an introduction to the history and the current understanding of the TIS framework.

2.3 History of innovation systems and the emergence of technological innovation systems

The research field around TIS is part of the broader Innovation Systems (IS) approach that have emerged since the 1980's. The IS approach is a combination of ideas from evolutionary theories, interactive learning theories and institutional theories (see Edquist (1997) for overview). Its core idea is that technological change and innovation is not solely a result from the input (money and personnel) into research and development (R&D) activities, but also influenced by social structures and learning processes from the production, diffusion and utilization (Edquist, 1997 p.17). Several concepts like the National Innovation System (Lundvall, 1992), Sectoral Innovation System (Nelson, 1993), Regional Innovation System (Saxenian, 1996) have developed alongside the TIS approach. Common for all these approaches is that innovation is central, but the definitions vary with the authors (Edquist, 1997 p.10). This is however not necessarily problematic, but the explicit definition and understanding of innovation is essential for the pursued analysis. The following definition will serve the purpose of this study:

"*Innovation concerns the search for, and the discovery, experimentation, development, imitation and adoption of new products, new production processes and new institutional set-ups*" - (Dosi et al., 1988 p.222; via Carlsson and Stankiewicz, 1991 p.98)

This is the understanding Carlsson and Stankiewicz (1991) draw upon in their work with providing a definition of a technological system. Their work results in a definition that has been cited by many TIS scholars (Bergek et al., 2008; Hekkert et al., 2007;

Jacobsson and Johnson, 2000; Markard and Truffer, 2008a), they suggest that a technological system

"… *may be defined as a network of agents interacting in a specific economic/industrial area under a particular institutional framework or set of infrastructures and involved in the generation, diffusion and utilization of technology*". – (Carlsson and Stankiewicz, 1991 p.111)

The concept of a system is also a central part of all the IS approaches (Edquist, 1997 p.13). A general understanding of the system concept is that it refers to

"*complexes of elements or components, which mutually condition and constrain one another, so that the whole complex works together, with some reasonable clearly defined over all function*". - (Fleck, 1992 p.5; via Edquist, 1997 p.13)

The contribution of the systemic notion to the understanding of technological innovation is that the linear model, of resource input to R&D followed by innovation output, can be broadened and other important influences can be considered, understood and potentially improved (Edquist, 1997 p.13).

When investigating a specific technology, or the knowledge it embodies, the use of a TIS approach may be considered superior to other IS approaches (Hekkert et al., 2007). Its main benefit is the ability to focus on what is actually achieved in the system rather than only studying the systems elements when looking at a particular technology in a socio-technical system (Bergek et al., 2008). In other words, the assessment of what processes that are working well or less well within a system, are dependent on an understanding of the processes/functions/dynamics between the elements. This is the major difference to the criticized reductionist approach which only maps the structural components individually and neglects their interconnections. The TIS framework is therefore a tool, an analytical construct, to be used when seeking understanding of system dynamics that can be used evaluate and potentially improve systems performance (Bergek et al., 2008).

2.4 Structural elements

Before the dynamics of the specific technology in the socio-technical system can be studied, the structural elements of the system need to be mapped. This part is in large parts based on chapter 2.2 'structures of technological systems' by Suurs (2009). The structural elements can be categorized into actors, institutions and technology, where the fourth component is the relations between them (Suurs, 2009 p.42), see figure 1 for an illustration. Two types of actors are distinguished to make a separation between the level of engagement in the TIS, enactors and selectors (Suurs, 2009 p. 42). Example of an enactor is a private firm that is highly involved in the entrepreneurial activities and market formation that grows the TIS. A selector is a more passive actor, for example a

financial institution that mobilizes resources for the TIS based on requests from other rather than on its own initiative.

The institutional component in the system is what is called ‘the rules of the game’, i.e. the formal laws and legislations as well as the informal norms, cultures and shared expectations (Edquist, 1997 p.46). These are the humanly devised constraints, e.g. social and cultural norms, that shape the human interactions between the actors in the system (North, 1990 p.3; via Suurs, 2009 p.44). A specific regulation for solar products is part of the institutional setting while the legislative body that drafted the policy is considered an actor in the system.

Technology is the second element that creates the playing field for the actors. The understanding of technology in this study is based on Bergek et al. (2008) where technology is explained to incorporate at least two interrelated meanings. It both refers to material and immaterial object, e.g. both hardware and software, that can be used to solve real world problems. Technological knowledge in both general terms and embodied in physical artifacts is also referred to as technology. As a structural element the technology could represent the current development and availability of solar products in the Karnataka state, or the mobile data network that enables web-based communication.

With a grasp of the structural elements; actors, institutions and technology. The next important understanding is how these elements are connected and what links them together. The connections include all relations between actor-actors, institution-institution, technology-technology, actor-institution, actor-technology and institution-

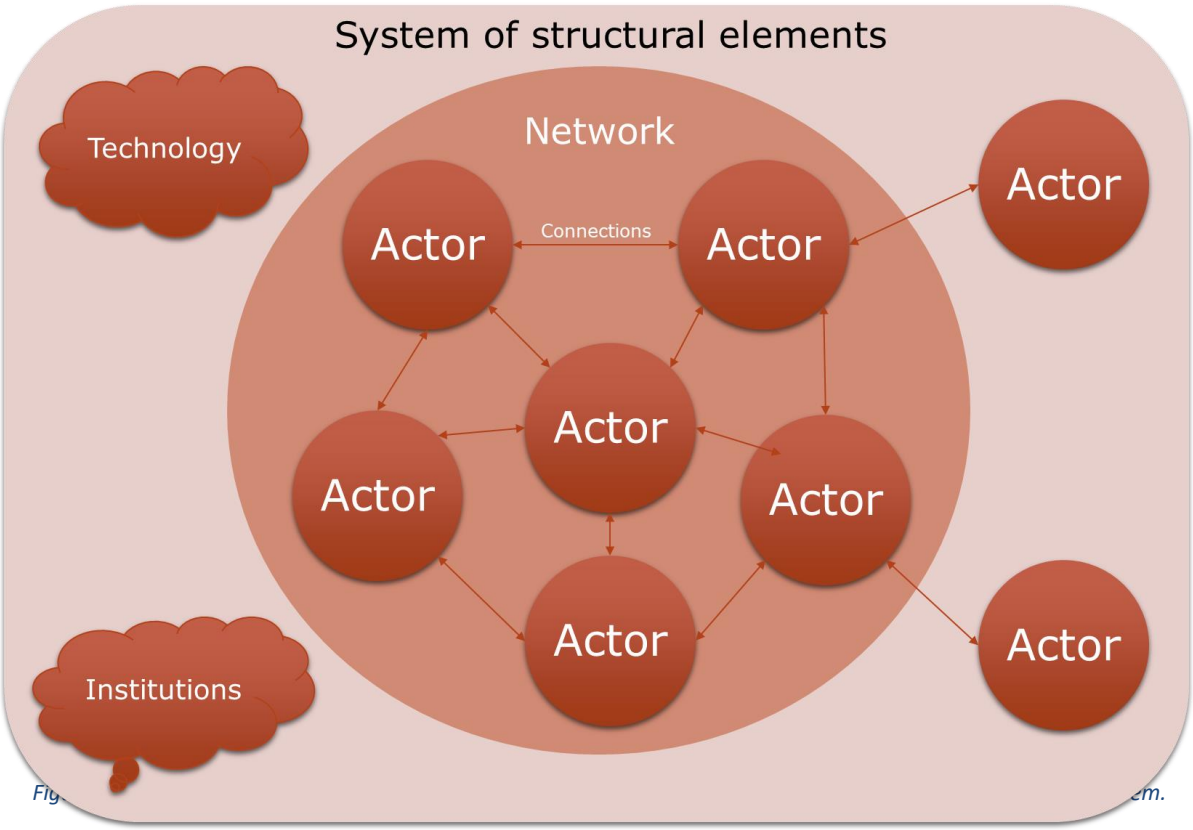

Fig em.

technology. The relations can be more or less interactive from the different parts, for example two actors, an energy service company and a local non-governmental organization (NGO) may have a very interactive and strong relationship. While the relationship between the energy service company and the current tax scheme for solar products is very static in how it affects the company. When a group of actors form a dense configuration based on a stronger link amongst them than the outside group elements, these elements can be understood as a network (Suurs, 2009 p.47). Networks are crucial for the knowledge exchange in the system (Carlsson and Stankiewicz, 1991 p.103). They work as intermediates between hierarchies (within firms for instance) and the market when the resource that is to be exchanged involves complex information that is not easily transferred via markets (Carlsson and Stankiewicz, 1991 p.103).

2.5 Dynamics of Technological Innovation System

Conducting a structural analysis of the actors, institutions, technologies and networks can provide insights in systemic features like complementarities and conflicts, with other words, drivers and barriers. These insights may prove useful but there are some important shortcomings with only conducting a structural analysis, especially when the purpose is to provide insights into an emerging TIS (Suurs, 2009 p.49-50). The structural analysis does not include the dynamics that contributes to the build-up of the system (Carlsson et al., 2002), which is problematic in the formative phase of a TIS since the structural elements should be considered as dynamic objects rather than static structures (Suurs, 2009 p.50). The results from a structural analysis is not easily generalizable due to the many national varieties among the structural configurations, which is problematic from both a theoretical and practical perspective (Suurs, 2009 p.50). What is even more problematic is the lack of performance indication from the structural analysis, since the working of the structural configuration only can be determined by the diffusion rate and market share of the focal TIS, which are data that often is lacking during the formative phase (Suurs, 2009 p.50).

These shortcomings can all be addressed when a focus on system functions, in addition to the structural analysis, is applied. A focus on system functions contributes with two fundamental changes in perspective. First, by studying dynamics instead of elements, the analysis leads to a focus on flows instead of stocks. Second, the evaluation of the system functions gives an alternative to performance analysis based on the total functionality of the systems functions (Suurs, 2009 p.51).

The concept of system functions has been emerging from within the IS, see Markard and Truffer (2008) for overview. Bergek et al. (2008) and Hekkert et.al (2007) are considered the origins of the current understanding of system functions (Markard et al., 2012). When investigating the systems functions, i.e. activities within the system, there must be limitations since the task otherwise would be unmanageable due to the vast number of activities in a complex system. A focus is therefore directed towards the relevant functions, i.e. those which influence the goal of the innovation system, to

develop, apply and diffuse new technical knowledge (Hekkert et al., 2007 p.418). The current set of functions that have emerged within the TIS field has been empirically validated in various studies around sustainable innovation (Alkemade et al., 2007; Negro et al., 2008, 2007; van Alphen et al., 2009, 2008). The set of functions is (based on Hekkert et.al (2007)):

- Entrepreneurial activities
- Knowledge development
- Knowledge diffusion
- Guidance of search
- Market formation
- Resource mobilization
- Support from advocacy coalitions

These seven functions will be shortly described here, see Hekkert et al. (2007), Bergek et al. (2008) and Suurs (2009) for more elaborative descriptions.

2.5.1 Entrepreneurial activities

Entrepreneurs and their risky experiments are necessary to overcome fundamental uncertainties. They act to translate knowledge into business opportunities and potentially innovations, where their practical adaptation and experimentation leads to a convergence of the TIS and the structural environment. Entrepreneurs are not only private firms but can also be public actors if their actions are directed at conducting market-oriented experimentation. This function is a first and prime indicator of the performance of the innovation system, if there are high entrepreneurial activities the innovation system can be assumed to be functional.

2.5.2 Knowledge development

Learning and combining new ideas are at the core of any innovation process. Two types of learning can be considered, learning by searching and learning by doing. Learning by searching includes basic research from R&D labs and universities while learning by doing is the result from entrepreneurial activities that gives insights in the emerging technology and the adaptation to the structural environment. Both sources for knowledge development are of great importance for the performance of the TIS.

2.5.3 Knowledge diffusion

The networks have an important function in facilitating knowledge exchange between actors, especially the heterogenous ones. It is understood that knowledge exchange occurs more frequently within separate communities than with actors outside the community. It is important for the TIS that communication activities among the different actors take place since they may lead to mutual understandings and thereby gradually converge the focal technology and the structural environment. The expansion

of the TIS is dependent on the increasing number of actors included in these networks with communication activities. Examples of such activities can be workshops, conferences and seminars. A second important part of knowledge diffusion is the learning by using experience that users of the new technology have, this interactive learning is considered by Lundvall (1992) the reason for existence for any TIS.

2.5.4 Guidance of search

The function of guidance of search is to provide directions in the selection of which technologies that will get funding and support. There are often great variety of new technologies that all need investments to develop, resources are limited and if they were to be distributed to all new technologies, none of them would be able to develop efficiently. The guidance of search reduces the variety through focusing on the most sought-after technologies, this selection is the result of the combined efforts from actors like policy makers, technology users, politicians and NGOs that all have expectations on the new technologies. A healthy TIS does however have a balance between focus and variety since variety is needed to stem innovation. Guidance of search can be both positive and negative, proponents to the focal TIS, whom may have conflicting interests, can for example use their influence on direct investments towards other TISs.

2.5.5 Market formation

Emerging technologies can have difficulties competing with existing, embedded, technologies which makes activities to support the focal technology important. Market formation covers the activities that contributes to creating demand, for example supporting use financially or taxing competing technologies. The creation of niche markets, where the new technology only is applied with some of its features may also help the TIS through knowledge diffusion and guidance of search.

2.5.6 Resource mobilization

Resource mobilization represent the obvious necessity of financial and natural means to support the emerging technology. It does however also include the allocation of material and human capital beyond the financial capital. All these resources can be provided by all kinds of actors, when the TIS matures it is most likely that private actors will contribute with this function to the TIS.

2.5.7 Support from advocacy coalitions

As mentioned briefly in guidance of search, a developing TIS may encounter resistance from actors with interests in a different development than the one of the focal TIS. The development of the focal TIS then needs advocacy from various actors in coalitions that can counteract the inertia from the TIS proponents. Typical activities can be lobbying and advice activities from interest groups that may provide policy and regulation in favor of the TIS. The difference from guidance of search is that the advocacy coalitions

do not possess the direct power to enforce their messages and ideas but rather depend on the actors and institutions surrounding the TIS to support the focal TIS in favor over other emerging technologies.

2.6 Feedback loops and cumulative causality

The seven functions described above should be understood as categories of interpretations, that provides insight in the dynamics of the focal TIS. These functions are also expected to reinforce each other over time (Suurs, 2009 p.58) and the fulfillment of functions can lead to virtuous cycles like positive feedback loops (Jacobsson and Bergek, 2004). There may also be negative feedback loops that result in vicious cycles instead. For example, an entrepreneurial activity that tests some function of the new technology could either prove to be useless (knowledge development) which lowers expectation (guidance of search) and leads to decreased interest for investments (resource mobilization). The inherent dynamics between the functions expose the rationality that lies behind the occurrence of separate events and provides a system understanding of how and why a TIS develops (Suurs, 2009). When studying and mapping these virtuous and vicious cycles the current conditions of the structural elements and their mutual relation to the functions are important to understand (Suurs, 2009 p.58). Since the structural configuration are to be considered dynamic objects, they may change over time, and the conditions for the feedback loops may therefore change as time and cycles passes. External factors may also affect the dynamics and there could also emerge TISs that do not have any feedback loops (Suurs, 2009 p.58).

Based on the theoretical understanding of a TIS's structural elements, system functions and feedback loops, an analytical evaluation of the functionality of a TIS can be formulated. These measures are explained in the following section.

3. Case study design and data analysis

This study examines the contemporary and complex issue of the diffusion of solar home lighting solutions in Karnataka. When approaching a problem like this a qualitative single-case study provides a suitable research method, since the researcher is allowed to study and attain an in-depth and holistic perspective on a real-life problem (Yin, 2018). The overall research method has followed the six steps proposed by Bergek et al. (2008):

1) Defining the TIS in focus
2) Identifying the structural elements
3) Analysis of the system functions
4) Assessment of the functionality of the systems functions
5) Identify inducement and blocking mechanisms
6) Specify key policy recommendations

The research process is not as linear as the list may imply, progress has been made through an iterative approach where findings of structural elements or system functions have contributed to the holistic understanding and final results. The methods used to design the study, collect- and analyze the data are further described in this section.

3.1 Study design

Both general case research theory (Yin, 2018) and applied TIS theory (Bergek et al., 2008) stresses the challenges and importance of defining the case and object in focus. Based on their recommendations, an iterative approach was taken in the process of defining the focal TIS and adjusting the purpose accordingly. A descriptive approach for the case study was taken since the study's purpose is to describe a phenomenon in its real-world context (Yin, 2018). This study focuses on the contemporary functionality of the seven TIS functions.

Initial delimitations and choices were guided by the experience of the collaborative partner for this study, SELCO Foundation. The technology in focus was decided to be solar home lighting given that it is the longest selling product thus far in the SELCO India product portfolio. It is the best-selling product of the company, based on its basic use-case for providing lighting to customers in any type of area and environment. Livelihood products like sewing machines or roti machines were also considered for this project. Their dependence on the product-market, as part of the value-chain, for the products produced with the solar application would make the system analysis more tedious and therefore the solar home lighting products were selected. The understanding of solar home lighting technology will include both the physical products and the application of lighting and its impact. The Karnataka state was chosen based on the access to the local market leader SELCO India. Two out of 42 branches, Kundapura and Chamarajanagar were selected based on their output performance in terms of sales and the availability of the branch manager. The high performing branch Kundapura represents a mature market where the branch has been present for 22 years. While the Chamarajanagar branch only has been established for eight years and has significantly much lower sales. The Chamarajanagar branch represents a less-developed market.

3.2 Data collection

This case study was based on the primary sources interviews, on-site observations and emails, and existing literature like reports, policy documentation and other documents. The data collection process had an iterative approach, being flexible and adaptive to new findings and using triangulation to validate information. A thorough introduction the company was given through eight initial presentations and meetings with different employees at the main office in Bangalore. This company introduction might have led to a neglection of important aspects but was consider much more efficient than attempting to create an own background narrative from shattered sources. The given narrative via the introductions was continuously tested during the continued data

collection. Based on the background knowledge, a first draft with interview questions was compiled. A pilot interview with a previous branch manager was conducted to test the interview questions in terms of scientific sufficiency, cultural appropriateness and use of comprehensible language.

To ensure the constructed validity of the case study the results and analysis was reviewed by experts and specific data was confirmed via email after the field visits. A database was constructed with the continuous findings, from where the resulting analysis was extracted. The emails referred to as EM1, EM2 and EM3 are found in this material and contain complementary data and clarification about collected data. The interviews for this study were semi-structured with few quantitative- and mainly qualitative questions. This allowed interviewees to bring their perspective and validate or dismiss previous findings. See appendix 1 and 2 for examples of interview designs. The nine semi-structured interviewees are presented in table 1.

Table 1: Overview of 9 semi-structured interviews with information about the code for future reference, the organization, the title of the respondent and whether the interview was translated from the local language Kannada to English or not.

Reference	Organization	Title	Translated
SI1	SELCO India	Department head	No
SI2	SELCO India	Department head	No
SI3	SELCO India	General Manager	No
SI4	SELCO India	Assistant General Manager	No
SB1	SELCO Branch	Senior Branch Manager	Yes
SF1	SELCO Foundation	Program Manager	No
SI5	SELCO India	Department head	No
SB2	SELCO Branch	Branch Manager	Yes
SF2	SELCO Foundation	Program Manager	No

3.3 Data analysis

Following the six-step process, step 3 *analysis of system functions*, 4 *assessment of system functionality* and 5 *identification of inducement and blocking mechanisms*, all include an analysis of the case material. Measuring the performance of the system functions and the overall functionality of the system is one of the major challenges for analyst and policy makers (Bergek et al., 2008). Suurs (2009) concludes the following three approaches to evaluate TIS performance; output performance, performance based on system functions, and performance based on cumulative causation. This study utilizes the two first approaches based on the limitations by using a descriptive study.

The measured output from a TIS is the diffusion and utilization of technology. This can however also depend on the purpose of the TIS analysis. When studying the diffusion of

sustainable technologies different dimensions of the sustainability aspects can be measured, like social, environmental and economic aspects. The data collected for this study is evaluated based on output of solar home lighting systems in both numbers and value. Economic inclusion through solar loans is used to analyze the economic impact on sustainability while previous studies are used to determine the social and environmental impacts of using decentralized renewable solutions. The output performance is used as the main indicator for long-term sustainability evaluation (Suurs, 2009 p.65).

Performance based on system functions is a suitable complementary performance indicator when access to output measurements is limited (Bergek et al., 2008). There is no established threshold or framework to be used in the evaluation of the functionality of the system functions, instead expert opinions are the basis for evaluation (Suurs, 2009 p.65). The method to be used is to listen to the enactors and selectors in the TIS and based on their testimonies let the evaluation emerge as a socially constructed judgement from within the TIS (Suurs, 2009 p.65). Beyond this approach, two bases of assessment have been identified in the literature; the phase development of a TIS, and system comparison between two TISs (Bergek et al., 2008). This study uses two samples of spatially separated subunits of the TIS, the Kundapura and Chamarajanagar branch. This provides a complementary picture of the diffusion of solar home lighting products in Karnataka where system comparison is used to highlight differences in local and common system functionality. The in-depth interviews with the enactors in the system and their perception of system functionality is used as the base for the evaluation of system functions. This understanding of weaknesses and strengths of the internal dynamic of a TIS is a result from the understanding of inducement and blocking mechanisms that enable/disable the systems overall performance (Bergek et al., 2008). The system actors' joint testimonies about their operations was therefore used to make a holistic analysis of inducement and blocking mechanisms.

3.4 Limitations and ethics

This study applies an interdisciplinary framework with focus on technology and its diffusion through a system of innovation. The choice of solar home lighting solutions in Karnataka was guided by the accessibility to the case company. This access was both essential for the making of this study, and at the same time limiting. The company has built their own support system over time and their positioning on the market (see section 4 "SELCO India" for further details) has made the importance of external actors of less importance for the diffusion of solar home lighting systems in Karnataka. The company and its employees are the most suited audience to provide insights about their operations and the supportive system they have built. While the singular perspective from the company gives the study vulnerabilities towards company biased information. The information has therefore been triangulated through validation by experts from the external R&D partner that was the collaborating partner for this project. External sources to validate specific data and information has been used for further triangulation

and validation of the emerging narrative given by the enactors of the system. The accessibility to the company's staff gave priority to utilizing these resources to the fullest extent during the field visit to Karnataka India. Researching and gaining access to external actors in the system was not possible, but this could provide further insights from the studied TIS.

The choice of technology, solar home lighting systems, reduces the study to a narrow scope of the available technologies for lighting solutions. The need for lightning is assumed obvious during night hours, but there are several other solutions available like; burning of fossil fuels like kerosene and candles, diesel generators for electricity, other solar solutions and connecting to the grid (if available). The narrow focus on standalone solar home lighting systems limits the empirical analysis of system performance to this specific category of solar solutions.

The vertical scope, focusing only on the diffusion of technology, neglects the up-stream innovation in the value-chain. The company in the case utilizes only domestic manufactured components for their system, but these vendors are most definitely part of other TIS with international knowledge transfer and development. This scope follows from the regional focus that is being applied due to the access of information through the case company. The TIS for solar home lighting systems could have a national and/or international focus, but this case is limited the unique learnings from one case of TIS system building during 25 years. Which can provide learnings based on the case context instead of a total understanding of the much broader TIS analysis with other spatial limitations.

Limited resources further guided the choice of a descriptive approach instead of an explanatory case study. The explanatory case study would allow an attempt to explain how and why the functionality of the TIS functions is interdependent through cumulative causalities and feed-back loops. The importance of vicious and virtuous cycles has been argued by several TIS scholars (e.g. Bergek et al., 2008; Suurs, 2009) and is hereby acknowledge. It would be an interesting approach to apply on the case of solar home lighting solutions in Karnataka.

Beyond the emphasis on highlighting the conscious delineations of technological field, vertical focus, spatial focus, understanding of technology, temporal focus, Bergek et al., (2008) further encourages the analysist to describe the analytical choices. These were, for the purpose of this study, guided by the empirical findings from the interviewed informants. A focus was given to the mechanisms that were named to reinforce the development and diffusion of knowledge that induced the diffusion of technology. The TIS framework has a meso-level focus which leaves specific micro-level perspectives like specific customer interactions, and macro-level perspectives like national economic trends, outside the scope of the analysis (Markard et al., 2015). The meso-focus guided the analytical choices towards the structural elements and system functions that were identified in the immediate relation to the branch-level and the supportive departments.

This might lead to the neglection of micro- and macro-level relations in the TIS that affects the TIS performance and leaves the analysis subject to the meso-level findings.

To ensure high ethical and moral standard for qualitive research, the consent of the informant was carefully considered. The trustworthiness and rigorousness of this study is based on the four principles of credibility, transferability, dependability and confirmability by Shenton (2004), and the construct validity, internal validity, external validity and reliability by Gibbert et al. (2008) were considered.

4. The case of solar home lighting in Karnataka India

This section introduces the case of solar home lighting solutions in Karnataka India and the business strategies that guided the case company's activities towards profitability and long-term sustainability during 25 years of operations.

4.1 Solar PV in India

With the second largest population and third largest economy, India is growing to become a global powerhouse (World Bank, 2019). India's recent growth and transformation to an industrialized economy have mainly been, and still are, fueled by coal and other fossil energy sources (International Energy Agency, 2015). The economic development between 2011-2015 raised 90 million people out of extreme poverty, while at the same time the income gap between the different income levels increased (World Bank, 2019). The higher income-levels are increasing their living standards while the poorest become relatively poorer (International Energy Agency, 2015). The latest report on multidimensional poverty notes the massive progress India has had with increasing income-level for their population, while 373 million people still experience acute deprivations and 8.8% of population are living in severe multidimensional poverty (Oxford Poverty And Human Development Initiative and United Nations Development Programme Human Development Report Office, 2019).

Access to electricity is generally acknowledge as an important necessity for combating poverty (UN General Assembly, 2015). Government efforts to electrify India dates back to 1948, one year after the independence from the British rule, with the enactment of the Electricity Supply act.

The journey of electrification has included twelve phases of five-year plans with focuses ranging from electrification of irrigation systems, rural village electrification and finally universal access to electricity. 100% village electrification is claimed from 2018-04-28. The condition for which a village is declared electrified is 1) basic infrastructure like distribution transformers and lines are installed, 2) 10% of the households are connected, 3) public places like schools and hospitals are connected (Government of India, 2019). As these conditions indicate, the 100% electrification of villages in India

are far from sufficient to meet the target of true universal energy access. High prices for electricity and long power failures are named as some of the main reasons for customer going with decentralized solutions (SB1, SI4). The high transmission losses of more than 20% (Government of India, 2019) combined with an energy efficiency of a coal fired power plant of 40%, are used to question the sustainability of the centralized electrification strategy (Situmbeko, 2017).

Another way to electrify these remote and underserved villages could be decentralized and renewable solutions. The national initiatives and mandates for electrification and renewable energy are governed by two ministries. Ministry of power that was established in 1992 and the Ministry of New and Renewable Energy established in 1994. The Indian Renewable Energy Agency and the Rural Electrification Corporation are further governmental actors that act alongside independent state agencies and initiatives, which makes the regulatory and supportive institutional landscape quite complex (Banerjee, 2015).

Akoijam and Krishna (2017) has, in their analysis of the impact of the Jawaharla Nehru National Solar Mission (JNNSM), compiled a timeline and mapping of the relevant solar policies since 1982 in India. The JNNSM was created in 2010 and consists of three phases, phase-I 2010-2013, phase-II 2013-2017 and phase-III 2017-2022. The objective was to install 20 000 MW grid-connected PV solar, 2 000 MW off-grid PV solar, 20 million square meters of solar thermal collector area for industrial applications and 20 million solar lighting systems for rural areas by 2022. The analysis of the JNNSM and the effects on the innovation ecosystem in India concludes that the results from phase-I are ambiguous and cannot be evaluated individually, international support inform of financial assistance and technology transfer are needed to achieve the more ambitious targets for phase-II (Akoijam and Krishna, 2017).

Complementing the JNNSM on the state level of Karnataka, is the Karnataka Solar Policy 2014-2021 where the initial minimum target was 2000 MW installed solar generation and 3% of total electricity consumption. These targets were updated in 2018 to add 6000 MW solar generation and achieve 8% contribution of solar energy sources of total consumption. The policy focuses mainly on utility scale- and rooftop grid-connected capacity and sets merely vague, but supportive, targets for off-grid solar and decentralized distributed generation. The policies focus mainly on utility scale- and rooftop grid-connected solar and are therefore criticized for not including decentralized renewable solutions as a serious alternative (SF1).

The policies are created and implemented through the different levels of the administrative system illustrated in figure 2. India is a federal union of 28 states of which Karnataka is one of the southern states. Karnataka is further divided into 4 divisions, 30 districts and 500 community development blocks. Each block has a number of panchayats, i.e. villages, in total there are 5788 panchayats in Karnataka. The nation is unique in its diversity of cultures, languages and ethnic groups, best described as countries within a country. The official language in Karnataka is Kannada. Hinduism

is the major religion with about 80% practicing of the total state population of 60 million people.

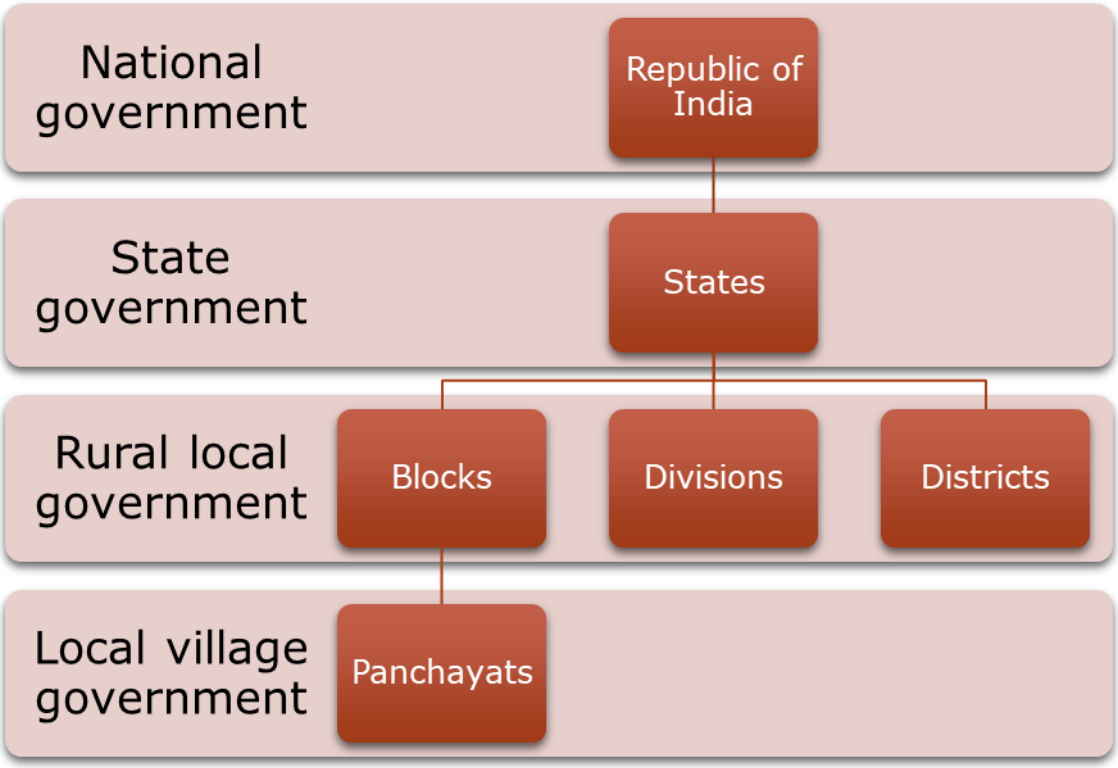

Figure 2: Simplified overview of India's administrative system from national to village level. Source: "Gram panchayat," 2019.

During phase I and II of JNNSM, funds were provided to the local village levels for subsidizing and generating solar projects. This led to a generation of lighting projects in villages and tenders from solar companies were called for (SB1, SB2). The decentralized authority structure of the Indian administrative system gave the rural local government the authority to select their local partners and projects. This led to some corrupt behavior where local officials required provisions of the projects and tenders were not assessed based on quality and viability (SB2). In the panchayats and blocks where officials instead looked after the public interest these schemes worked well in providing lighting solutions in underserved areas (SB1). These schemes are not available in the same extent since the ministry of power declared a 100% electrification of villages (SB2). There are however other regulations that also affect the availability of funds for solar lighting projects. In 2013 India became the first country to make corporate social responsibility (CSR) mandatory (Government of India, 2013). This has led to an increase of funds from private companies that subsidize and support lighting projects in underserved areas (SI2).

4.2 Standalone solar home system

Great potential for solar energy, ambitious national goals and a large domestic manufacturing capacity makes India one of the global forerunners for solar energy (Manju and Sagar, 2017). The domestic installations of solar energy are however quite heterogenous since the technology is highly modular and scalable. Large scale solar plants are connected to the grid and build in central locations, while small scale solar can be installed on rooftops with and without grid connections. A separation between grid-connected and off-grid solar is therefore natural. Further categorization within the off-grid segment follows current industry practice (International Finance Corporation, 2018). The smallest product segment is called Pico with a watt peak (Wp) of 0-10.99. Solar Home Systems (SHS) are the products with 11 Wp that are prepared for plug-and-play installations where the component-based are the solar systems with a Wp higher than 11 and a variation of components that enables applications like lights, fans, TVs or radios that are installed separately. Larger off-grid solar installations that only supply one customer can be referred to the commercial category and the solar installations that provide a group of customers through a small grid is called a minigrid. All these categories are referring to photo voltaic (PV) solar generation that utilizes electrochemistry to convert radiant energy into electricity.

4.3 SELCO India

Sustainability has been one of the guiding principles at SELCO India since it was founded in 1995. By then the company registered as a private limited company by the books and as a social enterprise by the mission. The four founding owners are all not for profits owners who all share the same vision to create social impact in a financially sustainable way. All profits from the operations are therefore reinvested in the company's operations and employees and the owners does not receive any dividends. Solar home lighting products have been at the core of the company's operations since the beginning (SB1). Through need-based solutions the company has targeted the underserved customers, with regards to access to electricity, in Karnataka for 25 years. Today the company employs +500 people and the four owners remain. The founder and initial CEO left the executive position within the company in 2014, he is now CEO of the research and development partner SELCO Foundation that operates for the sector in large.

The social mission is about serving the underserved and centering actions around humans. Part of this is to provide asset-building ownership models and inclusive payment schemes for the customers who often lack financial means to pay for the systems upfront (SI4). This enables the customers to reap the benefits of long-term investments in renewable energy solutions and provides many customers with a first bank loan which initiates their relationship with the local financial institution (SB1). By centering the operations around the idea of "it is all about the people" - (SI5),

sustainability has been achieved through an extreme emphasis on the personal relation with customers, partners and employees (SI3, SI4, SI5).

The company has kept its entrepreneurial way of operating through creating opportunities for the employees to be innovative and reinforce the social mission to strengthen the internal motivation for continuous improvement (SI4). Many incentives like subsidized bank loans, parental care schemes, accident insurance and other social security mechanisms further incentivize the employees to stay within the organization (SI3, SI4, SI5). The human relations (HR) department also supports the different levels of the organization to provide pathways to grow within the organization to keep talent and knowledge (SI5). The profit sharing between the employees has a bottom-up approach where those employees closest to the on-ground operations first get their shares and the higher-level managers are rewarded only when means are sufficient to first cover the lower-levels (SI3).

One challenge the company faces with its large organization and high emphasis on personal relations is that all employees are expected to absorb and endorse the social mission and being able to communicate it on behalf of the organization (SI5). This entails that basic understanding of the organization and its mission must passed on to all employees. This is further reinforced through annual and need-based motivation trainings where success stories are shared to exemplify the impact of the operations and the connection to the social mission (SI5). Sharing these success stories and best practice examples has long been a strategy of the company in their relation building with customers and partners (SI4, SI5).

Creating awareness and building trust has been key components for the success of sales and service for the company (SI4). The strategies to achieve this has varied but the concept of local champions has proven to be a very successful approach. A local champion is someone who has local knowledge and authority, for example a local religious leader, politician or village head. This person is then educated in the social mission of the company and the success stories and their impacts are used as proof to provide internal motivation for the local champion to promote the company and its services. The perception of the local champion as someone with authority bridges the lack of trust from new customers and creation of awareness and trust is achieved (SI5). The same approach is used in the work with engaging local finance institutes in solar loans to the customers who are unable or unwilling to buy the solar systems in cash (SI3, SI5).

A dealership model was once implemented as a solution to scale the operations, where local offices became responsible for both sales and service. This experiment ended with failure (SI5). Lack of sufficient follow-up service and a customer touchpoint that enabled need-based solutions and generated trust, damaged the company’s brand and general perception of the technology (SI5). This led to the implementation of another, more successful model. In this model local champions, called business associates, are leveraging their local authority and reach to drive sales for the local branch office (SI4).

One interesting insight about these business associates is that their own perception of their role in regard to the company has great effect on their performance. If they are well familiar with the social mission and view their work as important for their local community, they are more engaged than if they consider themselves as solar product retailers (SI4). This concept of business associates that only works with creating awareness and trust with customers, and not with any installations nor service, has been efficient for reaching remote and underserved areas (SI4). Due to their commission-based salaries, a recent reduction in schemes subsidizing the products has made their work more difficult and their performance has decreased (SI4).

The company has since the start positioned themselves as an energy service company, instead of a solar product retailer. The high emphasis on guaranteeing the functionality of their installations is used as one of the reasons to achieving a sustainable business (SI4, SB1). By providing aftersales service and giving guarantees for the products they have ensured customer satisfaction and built trust with them as a service provider, and equally important in the solar technology (SI4). Because the local public perception has a tendency to judge the whole solar system technology as malfunctioning when in fact it often is one component of lesser quality (SI4). Education through product displays on local events, customer and partner referrals, stories in local news media and local champions are the strategies that has proved to be successful for the company (SI4, SI5). Foundational for all this work is to have well-functioning installations with customers who can give their testimonies of satisfaction (SI4).

The back-bone of the company are the local branches that serve geographically divided regions with both installation and maintenance of a wide range of solar applications. There are currently 47 sales- and 10 service branches in India, and 42 of them are located in Karnataka (see figure 3). Each branch is operating as an independent energy enterprise. The organization places a lot of emphasis on the utilization of local knowledge of the branches since the regional context varies significantly from branch to branch. Each branch has a branch manager who is the executive officer in the branch and reports to a senior branch manager. The senior branch manager usually has the responsibility to support and advise a few branches in neighboring districts. An assistant general manager takes care of a few senior managers and reports to the general manager. A meetings structure is in place to share learnings and solve problems for the branches. All branches have a weekly meeting in where any type of problem and learning is shared. This is then brough with the branch manager to a monthly meeting with the senior manager, where the assistant general manager is also present. All branch managers, senior managers, assistant- and general managers meet each quarter in the head office to openly share issues, learning and innovations (SI5).

The internal communication is also done through emails, messaging applications and an internal magazine that is printed for the employees (SI1, SI4, SI5, SB2). The messaging applications has brought new opportunities for the company to easily connect their different employees and have them share learnings and success stories seamlessly (SI5).

This, which is made possible through good access to internet via Wi-Fi or mobile data connections and affordable smart phones, has increased productivity and internal motivation among the employees (SI4, SB1, SB2). New digital systems for accounting and customer support are also being implemented in the organization to increase the efficiency and information management (SI3, SI4).

The company has its main office in the state capital Bangalore. Twelve supportive departments operate out of this office. Employees engaged in the supportive departments are often also in the role of a branch manager, senior manager, or assistant manager. The supportive departments are an important part of the ecosystem approach that the company has developed during its 25 years of ground-level operations. In short, the ecosystem approach consists of five supportive pillars that affects the success of the local branch; Finance, Capacity building, Technology, Policy and Infrastructure (WWF India and SELCO Foundation, 2015). Each pillar represents a range of organizations, ideas and activities that reflects the category name, for example finance captures the important partnerships with local financial institutes that enables suitable payment schemes for the case company's customers. The end goal of the supportive departments and ecosystem approach is to increase the sales of the technology in focus.

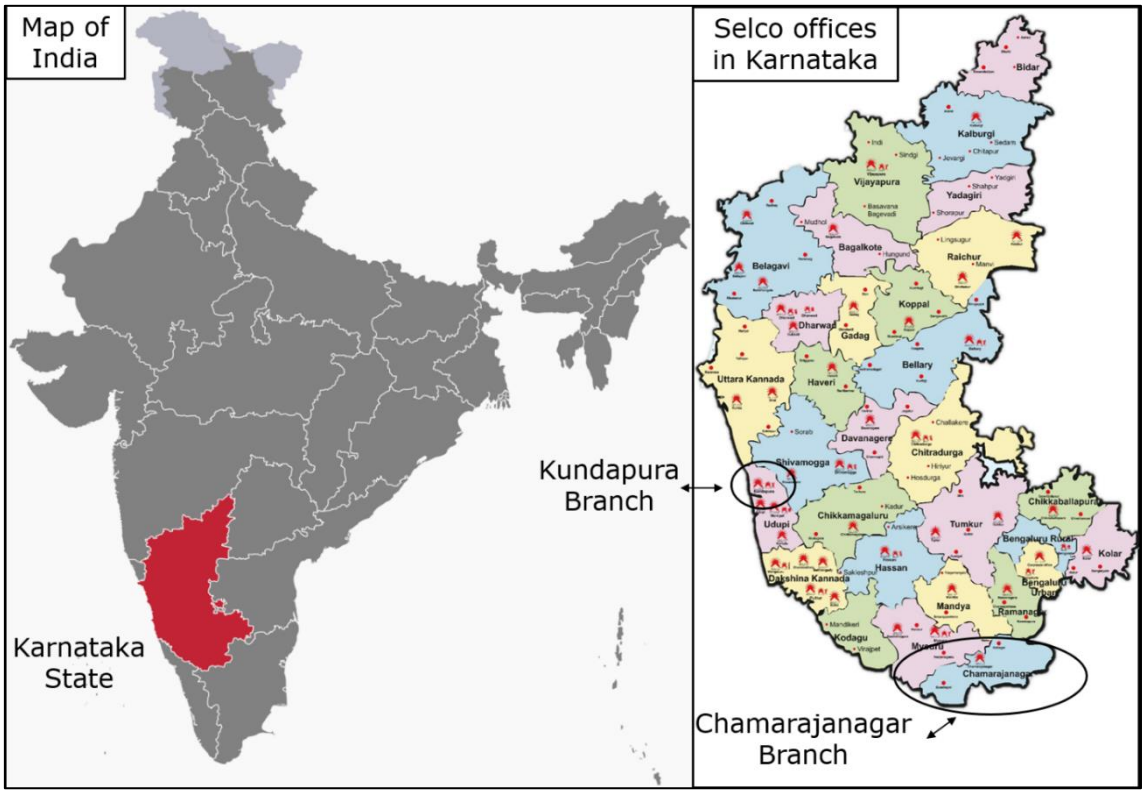

Figure 3:Map of Indian and state of Karnataka to the left. Map of Karnataka districts and SELCO India offices in Karnataka, with branches Kundapura and Chamarajanagar high-lighted.

There is further an incentive system developed to direct the efforts of the branches in alignment with the social mission, i.e. providing renewable energy and modern technology to the underserved population (EM1). This system gives the sales executives points that are being used to evaluate their performance monthly and annually. Their

ratings are the used for salary and promotion negotiations. Out of 100 points, 50 can be achieved through reaching the set sales target for the employee. 20 more can be gained through a quality enquiry, which means an enquiry with a potential of being converted into a sale. Selling at least two livelihood systems per month gives 15 point and the same goes for at least two bank loan funded systems monthly. This is a way of incentivizing the sales executives in the field to expand their efforts beyond pure sales targets and include more challenging customers. Customers who may not have a relationship with the bank and providing them with a payment scheme from some local financial institution like a non-governmental organization (NGO) or micro finance institute. The company was founded with this social mission of inclusion but has gained financial sustainability through being commercially oriented in their groundwork (SI3). This commercial focus entails setting up cost structures that are determined by the business generated, non-extractive profits margins and local vendor partnerships. The branches are expected to deliver revenue and be profitable, which leads to decision making and behavior that favors easy sales in high numbers (SI3). The social mission, through the incentive system and periodical motivational sessions, keeps the employees motivated to stay focused on the social mission (SI3, SI5).

This approach, of targeting difficult customers, places the company in a peculiar position on the market with almost no competition for their products. Even though there may be, and has been historically, a presence of solar lighting products in Karnataka and the branches, they tend to serve other customer segments where the company does not focus their efforts due to its social mission (SI3, SI4, SB1). The component based solar home lightning system varies in total effect from 20-180 Wp (EM2). All the installations are sold with a one-year guarantee and a service commitment of five years. This separates the products from the Pico product segment where solar lamps and micro-systems are sold without guarantees and after-sales service. Other component-based systems are typically larger roof-top solar systems with inverters and grid connection (SI3, SI4).

There is competition from local vendors who retail solar products in addition to other electronics in small shops, these vendors can offer lesser prices but usually do not offer installations nor service (SB1). The company therefore competes with quality and service rather than price, which is a challenging task with customers who have difficulties with prioritizing long-term benefits over short-term rewards in the form of cheaper solutions for lighting (SI4). Competition is however called for since it forces the company to improve business and solutions (SI3). The issue of competition is somewhat of a controversy since the company takes on the responsibility of serving the underserved on equal conditions, similar to the commitment of the state and the national grid (SI5). While still acting as a private company without any direct subsidies from the government. Competition in the meaning of solutions for lighting is however present from different sources like burning fossil fuels like kerosene and candles, burning biofuels and connecting to the power-grid.

The company had sales of 29 329 solar home lighting systems in the Karnataka region during 2018, which is about 0.4% of the rural households (EM1, Indian Village Directory, 2011).

4.4 Supportive departments

The case company, with its 25 years of providing solar home lighting for the underserved customer segment, has created an ecosystem to support their branches in Karnataka and rest of India. This ecosystem has been captured as a conceptual idea but takes its form in the supportive departments and their operations out of the head-office. The departments; Logistics, Design and pricing, Customer service, Business associates, Accounts, Financial inclusion, Mission support, Special projects, Marketing and sales, Training, and Human relations, all serve a specific purpose yet align with the overall goal to increase the sales and installations of the products (EM3, SI5). Each department has a head of the department and include a few half- or full-time employees.

The departments have emerged and evolved over time and some are tighter coupled with day-to-day business operations of the branches like Logistics, Customer service, Design and pricing, Marketing and sales (SI3, SI4). They are all using economies of scale, from a large organization, to give a competitive advantage to the branches in the form of better prices or higher quality on products and services (SI3, SI4). Design and price hold an important task in accurately designing and pricing customized solutions for the customer, if the renewable energy solution is to be truly sustainable (SI4). Accounts, Human relations and Training department are all supportive departments where administrative and educational tasks are being operated in a centralized manner to achieve a more efficient organization (SI3, SI5). Corporate social responsibility is a department that finds and builds relations with other companies that have CSR funds available and are willing to invest in certain projects (SI2). The CSR and the Mission department are therefore tightly coupled since the Mission department manages the distribution of CSR funds to the branches (SI2). The Special projects department has a similar function as the Mission department, in designing and planning larger and special projects (SI1).

The Business associates and Financial inclusion department are different in their functions. The Business associate's department focuses on supporting the business associates with training and administrative support and are therefore indirectly connected to the branch (SI4). While Financial inclusion focuses on training the company employees and local financial actors in how to leverage current policy schemes and government subsidies for solar products and projects (SI5). Their purpose of advocating for financial inclusion of solar customers are shared with all employees, but the efforts from the department are more focused and targeted on the higher levels of financial actors (SI5). The purpose, supportive activities and impact for increased sales, of each supportive department are presented in table 2.

Table 2: The 12 supportive departments of the company, based on semi-structured interviews SI1-SI5. The table states the given purpose, a summary of the supportive activities the deparment engages in and their impact on the ultimate goal; increased sales. The number of employees is separated on branch employees and those employed in the head office. A final summary of the identified system functions from each supportive deparment is presented with the following coding: Entreprenerial Activities (EA), Knowledge Development (KDE), Knowledge Diffusion (KDI), Guidance of Search (GS), Market Formation (MF), Resource Mobilization (RM) and Support from Advocacy coalitions (SA).

Supportive department	Purpose	Supportive activities	Impact for increased sales	Number of employees	Identified system functions
Logistics	To supply the material to the branches and handle the relation and negotiations with vendors.	• Delivers products to the branches • Takes responsibility for delivery and stocking with insurance and risks • Bargains with vendors about price, quality, quantity, credit days and guarantees. • Committed to supply products within three days for the branch • Gives discounts when stock supply are in excess to incentivize the branches to sell the products. • Quality-checks the products from the vendor by random checks. • Gives feedback to the vendors on their product performance based on reporting from Customer Support. • A favor is given to small scale domestic suppliers to support them in their business-building.	• Route planning for deliveries creates cost efficient distribution. • Large orders gives more bargaining power with vendors which results in better quality and lower price for the branches. • Quality-checks and insurance of stock reduces the risks and work for the branches. • Commitment to supply the branches within three days gives the branches good opportunities to serve their customers with short notice and deliver on time. • Discounted products increase the ability to sell for the branch.	Branches: 41	• EA • GS • KDI
Design and Price	To create customized designs accurately priced.	• Designing and pricing the customized requests for the local branches. • Educating the customer in solar technology and the system optimization based on their need. • Generate an impact assessment after finished projects. • Share learnings from innovative projects in the formal network, the messaging group.	• Expertise knowledge in design and pricing of systems helps the branches to deliver efficient and accurately priced systems to their customers. • Educating the customers gives them an understanding for the pricing and an appreciation for the design and quality used, leading to higher customer satisfaction and potential referrals to other customers. • Harvesting the impacts from a project provides internal motivation for SELCO employees and can be used as marketing and educational material for new customers. Building trust both among the employees and potential new customers. • Sharing the innovative projects inspires and motivates the employees to try new things and replicate the projects in their region, which may lead to unexpected business opportunities.	Head office: 2	• EA • KDE • KDI • MF
Customer Service	To build and maintain the relationship with customers.	• Committed to provide service to all solar products, both SELCO's own installations but also competitors installations. • Committed to serve a customer request within 48 hours. • Committed to include the financial provider in the work and solutions provided for the customer. • Creating different channels for customers to engage and request service: o Toll free number o Direct number to technicians o Email to branch office o Reception in branch office • Arrange marketing and service campaign regularly. • Provides feedback to logistics department about faulty products to be renegotiated with the supplier.	• Referrals from satisfied customers drives sales and customer awareness through word-of-mouth marketing. • Confidence from local partners like financial institutes, NGOs, schools and hospitals are gained through being available and showing a presence in the local community, which leads to more projects and better relations with local partners. • Higher confidence with the bankers and financial actors leads to a higher availability to finance for the solar customers which leads to increased sales.	Head office: 4, Branches: 354	• EA • KDI • MF

Business Associates	To enable local retailers to sell SELCO systems commission-based.	• Enabling the location and introduction to unknown customers through a local person who already have credibility with the customer to bridge the initial gap in trust in SELCO and solar technologies. • Creating a network to share learnings and methods for sales. • Accessing local networks through brand ambassadors. • Incentivizing innovative ways of getting sales and new customers.	• Greater reach for inaccessible customers. • Increased initial confidence from the customer which gives trust in SELCO and solar technology. • Learnings and innovative methods are being shared in the central network. • Internal motivations and financial motivation incentivize innovation and creativity.	Head office: 4, Branches: 500+	• EA • KDI • MF • SA
Accounts	To keep track of the expenses and revenue of the branches and making sure they are making profits and following their planned budgets.	• Manages all salary payouts for whole SELCO India • Reimburses the branches for their expenses • Handles all vendor payments • Keeps track of budget for each branch • Training and education for all accounts staff in the branches • Specific support for any branch with special needs	• Handling of the accounts in a centralized way brings more efficiency to the system. The branches can focus on their main task to do sales, installations and service and trust the Accounts department with the numbers and bookkeeping. • Centralized education brings expertise and knowledge development for the local staff and a networking opportunity to share learnings in.	Head office: 15	• KDI
Special projects	To assist the branch with larger and/or special request projects from the customers, and to initiate new innovative designs and projects that serves as pilot projects for the branches to benefit from in the future.	• Provide designs and pricing for special projects that require specialized expertise. • Handling customer relationship with communication, negotiation and education. • Also provide the branches with inquires to boost their sales.	• Expertise knowledge in technology, finance and customer relationships supports the branch to plan, execute and finish challenging projects which leads to increased sales and get more educated and skilled employees at the branch. • Engaging with customers increases customer awareness and may lead to future referrals to other customers and projects which increases the sales of the branch. • Generation of special projects from the department leads directly to increased sales for the branch.	Head office: 5	• EA • KDE • KDI • MF
Financial Inclusion	To educate and advocate for financial inclusion of solar customers.	• Meeting once a month with the bankers to sort out any issues and solve problems. • Establishing and maintaining good relations with the local and state-level financial institutions that may provide finance to the solar customers. • Generating awareness among financiers of solar technology and SELCO operations. • Negotiating with bankers about interest rates and providing subsidies and discounts for the banks to accept the solar customers as bankable customers.	• Innovating and educating bankers about new financial schemes, payment methods and ownership models unlocks capital that enables customers to afford the systems.	Head office: 5, Branches: 60	• EA • KDI • SA

Marketing and Sales	To generate marketing material based on SELCO operations and educate branch staff in communication and marketing skills.	• Identifying internal innovations and stories and transform them into marketing material that can be used by the branches. • Design special programs to be used by the whole company to create momentum around a certain product category. • Educate branch staff in communication and marketing skills to improve their ability to build confidence from customers in solar technology and SELCO. • Support any branch with special need for marketing support, based on request.	• Through awareness and confidence building in solar technology and SELCO's customers are more possible to buy solar products. • Education of branch staff increases their abilities to communicate and sell effectively.	Head office: 2	• KDI • MF
Corporate Social Responsibility	To make funds available for the branches to subsidize and partly finance projects with a strong social and environmental impact.	• Provides funding for the branches suggested projects • Takes care of the relations with CSR donors and creates the required documents and stories from the projects. • Actively seeks out funding that may be available for the projects in need of funding.	• Increased funding leads to more projects done and more systems installed. • Storytelling and sharing of learning motivate employees and increases the awareness of solar technologies and its positive impact.	Head office: 3	• KDI • RM
Mission	To support the branch in customization and processing projects that are closely aligned with the SELCO India Mission.	• Design and develop technological challenging projects and products • Connect more "difficult" customers with finance schemes for solar products • Guide and educate branch personal in processes and technologies that are more complex and demanding. • Get out in the field and generate projects that are closely aligned with the SELCO mission and include the local branch in the project. • Inform the branches about the possible funds that are available for them to create mission projects with.	• Expertise knowledge in technology, finance and customer relationships supports the branch to plan, execute and finish challenging projects which leads to increased sales and get more educated and skilled employees at the branch. • Generation of mission projects from the department leads directly to increased sales for the branch. • Information about the available funds may lead to more initiated mission projects with the branch and more systems will be installed.	Head office: 3	• EA • KDE • KDI • GS
Training	To educate branch employees in various skills.	• Designing yearly training program. • Design and hold training sessions for all SELCO staff. • Visit branches and support with motivation when needed.	• Educating the branch staff increases their skills and abilities to do their operations in a more efficient and productive way which leads to increased sales. • Motivating the staff increases their performance and ability to sell more systems.	Head office: 4	• KDI • RM
Human Relations	To assist the branch with recruiting and training of new employees.	• Takes responsibility for the recruitment process for all employees. • Drafts and generates internal policies to support their employees in terms of insurance and social security schemes. • Support the branches with regular admin work in interaction with the main office. • Supports the branches in tracking and evaluating employee performance. • Holds motivational and inspirational events when needed in the branch. • Supports branch with conflict management when needed.	• Maintaining good relations between the employees enables them to do efficient work and increase their sales.	Head office: 2	*No functions identified*

4.5 Strategic partnerships

Beyond the supportive functions that the 12 departments provide the company has some strategic partnerships with other actors in the sector. The SELCO Foundation is an NGO that focuses on R&D and is highly involved with the case company's operations (SF1). The foundation was founded in 2010 based on the learnings from the case company that there was a need to create and develop enabling conditions to design and deploy sustainable energy solutions for the poor. They now have around 30 different partners where the case company's is their major R&D partner (SF1). The two organizations share office location in Bangalore and are separated in two different floors, which makes sharing of information and learnings easy. The foundation now has a focus on innovation for livelihood products and solar home lighting are mainly used as supplementary solutions for the livelihood products to be functional during night hours as well (SF1). The close partnership between the company and their R&D partner has led to many synergies where learnings easily can be converted into new solutions for customers (SF1). The many opportunities for the R&D partner to test their solutions in pilot projects together with the company are valuable for the empirical validation of new innovations (SF1). All solutions and innovations developed by the research partner are open-source and intended to support the sector as a whole.

The same R&D partner, SELCO Foundation, was one of four founding members of the energy access network CLEAN in 2014 (SF2). CLEAN is a clean energy access network that works to support, unify and grow the decentralized clean energy sector in India (CLEAN, 2018). The case company is also a part of this network that does lobbying and policy reform work in Delhi on behalf of the decentralized renewable energy sector (SF2). The company's perspective and ideas reach the network through three types of activities. The first is direct engagement when the network requests and engages their members to collect opinions about a specific topic or policy (SF2). The former CEO and founder of the case company's is also part of the board of the network which indirectly infuses the company's perspective (SF2). The final one is also indirect, through the R&D partner who also is a member of the network and in some issues represent its partners, which the company is one of (SF2). This membership with the CLEAN network enables the high-level policy work to come from a unified voice of the sector and leaves the company to focus on unlocking and influencing local policies (SF2).

The financial partnerships are also very important for the success of the company's sales (SI3, SI5). A decrease in government schemes for solar solutions, combined with a drop in interest from the established banks has reduced the availability to credit (SI3, SB1). Both a periodical shift of bank staff every third year that makes building long-term relationships difficult and higher pressure on profitability on the bank offices leads to less interest in small loans due to the higher work-load that is required (SI5, SB1). High interest rates and extensive documentation processes make the customers reluctant to applying for bank loans (SI3). Local actors like NGOs, micro finance institutes and

rural cooperation banks are therefore involved in financing solar loans, and partnerships with these actors has proven to be a key success factor for the company (SI3, SI5, SB1). Most of these actors are only active in a few districts in Karnataka where the company has branches, but Shri Kshetra Dharmasthala Rural Development Project (SKDRDP) has a reach with its own branch offices all over Karnataka (SI3). SKDRDP is a charitable trust that empowers rural people through providing infrastructure and finance through micro finance (SKDRDP, 2014). A close partnership has evolved between the company and SKDRDP where the trust takes responsibility for the setup and maintenance of payment schemes that allows solar customers to buy the lighting systems without upfront payments (SI3). Beyond the ground level financial partnership with SKDRDP and other financiers, some companies that invest CSR funds into the company's projects are made partners. These partnerships are carefully maintained through personal relationships with each partners representative (SI2). This maintenance work involves some challenges in aligning the projects that were funded with the story that the CSR donor requires to motivate the donation (SI2). Similar to the differences in CSR projects and the various types of financial relationships, is each branch and their context somewhat different over all of Karnataka. Two branches, Kundapura and Chamarajanagar will serve as samples of energy enterprises operating in their own ecosystem context.

4.6 Kundapura branch

The following part is based on an interview with the senior branch manager, previous branch manager, of Kundapura branch (SB1).

The Kundapura branch was started back in 1998 with one technician and one sales executive. It is located in the Udupi district in the coastal region of Karnataka, see figure 3. The same region where several of the major national banks originate from. Udupi district is shared with two other branches and the Kundapura branch is doing very well. It has been the top performing branch of the company for several consecutive years and employs some 40 people. The branch currently serves 30 000 customers in its area and are adding a focus beyond lighting products to also sell more livelihood products. Lighting products are however still considered an important product that always will be in demand. The region has a well-developed road infrastructure where most parts of the business area is accessible through proper roads (SB1).

Telecommunication is also well established which has improved the connectivity between the employees, customers and partners in the area. The non-physical connectivity has especially improved the operations in areas where the quality of roads is insufficient. In these areas the company is developing and expanding a concept called model villages. A model village is a rural community where basic infrastructure like electricity, road network and water supply are substandard or lacking. The company with the supportive department and the local branch office then makes an effort to provide the village with a range of solar solutions based on the villages' needs.

Examples are streetlights, home lighting, copy printers, blowing machines, fridges and milking machines. These projects often receive some CSR funds and work as examples of how the company operates and how the social mission translates into actual impact for villagers. The model villages in Kundapura are used as examples to showcase for potential and existing partners to build confidence and trust in the company and the solar technology. Local banks and financial institutions are also often involved in the ownership and payment structures setup for the customers.

The branch emphasis a lot on local knowledge and learnings. The sales executives and technicians rarely spend any time in office but rather out in the field talking to existing and potential customers. The issues and ideas from the customers are brought back to the branch via the weekly meetings where all branch employees share their learnings and use collective problem solving to resolve most issues. This is the main approach used for innovation, be receptive to customers' needs and deliver solutions based on solar technology. Many of the employees are not specifically trained in solar technology but they all participate in an initial training program with the company as part of their intro to the organization. They are also further educated through periodical training sessions from the training department. Some of the employees have received a basic training in solar technologies through a local educational center that has a good relationship with the Kundapura branch.

The long presence in Kundapura has given the branch and the company a strong brand name. Many customers are however still unaware and uneducated in renewable energy solutions. The main barriers for the branch in building trust and confidence with the customers are the solar systems functionality during rainy season and the high price level. The branch is continuously investing in education and creating awareness for these customers. This is for example done through a monthly service campaign where all branch employees host an event with some local champion who gives a speech and customers gets a discount on service of their installations. Local bankers and financial actors are often invited to these kinds of events to increase their awareness and build their confidence in the company as a long-term committed service provider.

There have previously been larger projects in the district where several solar solution companies were involved in supplying a group of customers with solar solutions. After a few years the bankers approached the branch because the customer stopped paying back on their loans. It turned out that the other solar suppliers did not provide sufficient service for their customers, in contrast to the Kundapura branch. This led to a lack of confidence from the bankers and the customers in the solar technology and companies. The Kundapura branch then provided service to the other companies' installations to restore the customers confidence and rebuild the trust from the local bankers. This is an example of an ongoing process of building and maintaining confidence from both customers and partners. A key factor for the Kundapura branch in this process has been the personal relations with local decision makers from various organizations.

When faced with the challenge of finding a financial solution for 100 solar customers the branch is confident that the established network with various financial institutes would be able to provide funding for all 100 customers. Based on the situation of the customer different financial actors would be approached. For those who have a credit history and already are customers with one of the national or regional banks, these banks would be used for solar loans. The people who lack a previous relation with a credit institute would be introduced to the local micro finance and rural cooperation banks for payment schemes. NGOs like Lions- and Rotary club, the mission department and SELCO foundation would be approached to provide subsidized solutions for those customers denied by both previous options.

Beyond the financial relationships the branch engages with several local NGOs that provides education and support to special abled children. These installations help the branch to reinforce their work as a social enterprise for both its employees, its customers and new partners. An example of this work is an installation of solar panels for lighting and digital education in the Tallur Family Trust school, that was financed by one of the national banks. The project became a local success story and the branch received several inquiries of similar installations based on the referrals to that one project. Relationships with local panchayats, villages, are also of great importance. The local leader does not have any influence of state policy or law, but their social authority makes their approval of solar installations very crucial for accessing customers in the panchayat. The strategy of the branch to build these relations is to try to make the local leader into a local champion, where their authority can be reinforced through association with the solar installations.

The evaluation of the supportive departments performance in their work of supporting the Kundapura branch operations is considered well-functioning. The branch is successful in its operations and the supportive departments are contributing to this success. The efficiency of the customer support and logistics department could however be improved to increase the quality of service for the end customer further.

4.7 Chamarajanagar branch

The following part is based on an interview with the branch manager of Chamarajanagar branch (SB2).

The Chamarajanagar branch was established in 2014 and now employs 9 people. They cover the whole Chamarajanagar district which approximately equals an area of 100km in radius. The district has many forest areas and the communities living here often lack or have substandard access to grid electricity. The Chamarajanagar branch currently serves 2500 customers of which 25% are estimated to be remote rural customers. Roads are of shifting quality and many of the forest areas are only reached through mud and clay roads. All product deliveries are done by motorcycle, partly because of the road status. Telecommunication is mostly good and described as “not bad” in the remote communities.

There is one educational center in the district that educates students in basic solar technology knowledge. This has been helpful for the branch in employing new staff. The education only teaches theoretical knowledge and all new employees goes through an internal training with the company before they start working with customers. The same educational center is used to access contact details to potential customers. Lists with contact details to the people somehow associated with the educational center are used for direct marketing of the branch's services.

The branch also engages with potential customers through demo days where they go and visit local or industry events and showcase their products. Social media platforms are also used to engage with and listen to customer needs. The branch is slowly and incrementally trying to build customer awareness and confidence in the company brand and solar technology. One barrier for this work is the habit from customers to judge the entire solar technology based on the malfunction of one product or component. This is an especially a problem since many low-quality Pico solar products are distributed in the region. This type of products are cheaply sold or freely distributed without any service option and eventually they malfunction due to low quality. When the product malfunctions they are disposed, and the customers associate all solar solutions with low quality disposable products.

One given reason for the unsustainable distribution of these Pico products is corrupt local authorities. Regional and local funds are made available to support lighting solutions for remote communities. The local authorities then give out tenders for the solar companies to bid for. Low price is usually favored, and some officials expect to be paid some percentage of the total value as a bribe to win the tender. This has led the branch to lose many of these tenders that otherwise could have supported their business. The tenders are then repeated yearly because the solar solutions cannot sustain, and more low-quality Pico products are distributed in the same areas.

The Chamarajanagar branch instead applies a need-based approach where the customers' need is assessed prior to the installation. The after-sale service is then important to build the confidence from the customer and its surrounding social network, where the word-of-mouth is considered an important marketing function from the case company and the Chamarajanagar branch. The branch consistently installs demo systems in villages without any previous positive experience from solar solutions. This accelerates the word-of-mouth marketing of the branch and its products, especially when the grid is insufficient in providing electricity, the only source of lighting in the village is the demo installation. This strategy is a part of the long-term efforts of the branch and the company to improve the public perception of decentralized solar solutions.

The branch has also partnered with local NGOs that support the branch with projects and events that create awareness and build confidence in the company and the solar technology. The major partner for the branch is the SKDRDP and its local branch. Beyond doing demos and directing new customers towards the branch, about 80% of all

financial schemes for the branch's customers comes from SKDRDP microfinance. The reason for this is that very few national and regional banks are serving the solar customers.

In 2011 the financial literacy in the district was very low. The case company therefore stepped in to mediate some solar loans for the rural communities which led to financial inclusion. After the successful repayment of the solar loans many customers went ahead and set-up a second loan. Unfortunately, many customers had difficulties repaying these loans, which led to a governmental loan waivers scheme. This scheme did however not only support those customers in need, but also incentivized the other repaying customer to default their loans to access the government funds provided. This led to a bad credit history where about 60% of the customers have defaulted on a loan. With a credit history like this it is very difficult to involve national and regional banks for these customers.

When faced with the challenge of finding a financial solution for 100 solar customers SKDRDP finance is assumed to cover 80 of these. The remaining 20 would be introduced to other local microfinance, NGOs and the only national bank present in the area. If that would not work out SELCO Foundation or the internal mission department would be approached.

The branch manager is satisfied with the performance of the supportive departments in their work to support the Chamarajanagar branch's operations.

4.8 Kundapura and Chamarajanagar branches

The two branches Kundapura and Chamarajanagar serve as two samples of local energy service providers in Karnataka. Their different stories and operations provide the insights from which the system can be evaluated. Here follows a summary of the quantitative and qualitative input from the two branches. The immediate story the data in table 3 tells is the major differences in presence in the market, size of market, size of area of operations, value of sales, number of employees and customers served.

The majority of both branches' potential customers earn less than 5000 INR (70$) per month (SECC, 2020) and the average cost for a solar home lighting system is 12 000 INR (170$) (EM1). The average rural household consumption in Karnataka in 2019 is estimated to be 1.77 kWh/day (Government of India and Governemnt of Karnataka, 2020), and the price is about 5.5 INR per kWh (The Hindu Business Line, 2019). The solar home lighting system would be repaid after 3.4 years with these estimated numbers and the assumption that consumption and price is constant. The financial partner SKDRDP provides different types of payment schemes but a typical one has no upfront payment, is repaid over a period of 2-3 years, collects payments weekly and charge a 16,7% annual interest rate (EM4). The weekly payment is mainly based on the household's alternative cost for lighting like kerosene or firewood, and the solar

solution gives them a way to build an asset for their household while meeting their lighting needs.

The Kundapura branch has been operating in their area for 22 years and during that time served some 30 000 customers. While the Chamarajanagar has a more recent introduction to the market with only six years of operations and 2500 customers served. The branches sold 784 and 500 solar home lighting systems for approximately 9.4 Million INR and 6 Million INR respectively during 2019. Both branches have access to the same supportive system from the main office. The national and regional regulations are the same. Differences in structural elements are mainly found in the local partnerships and the local history of solar technologies which affects the public perception and attitude towards the technology from customers and partners.

The strategy of focusing on building personal relations with the partners based on continuous interactions and collaborations favors any actor that has spent more time in the game. The higher number of employees also enables a larger reach per time unity in the work with establishing strong connections with the partners. Part of these partnerships are the financial actors present in the local ecosystems. The Kundapura branch has relations that dates back longtime with the banks in their district, which helps in bridging the lack of engagement that is apparent in both branches. The Chamarajanagar branch, which names more national banks as being present in their ecosystem, has only one bank that considers solar loans and the history with high numbers of loan defaults has damaged the resource mobilization in the district. They are instead heavily dependent on the SKDRDP partnership for the finance of their products. The availability of finance and functionality of resource mobilization in the both branches are reflected in the number of loans unlocked through finance for solar home lighting in 2018, where Kundapura unlocked 12 million and Chamarajanagar unlocked 5.3 million INR.

The second main differentiator, the public perception about solar technologies, is also heavily affected by the number of positive interactions the customers and partners have with the solar products. This then becomes the backbone for the word-of-mouth creation of awareness and confidence in the products. The Kundapura both has a longer presence and more employees to create these positive experiences. This is reflected in the description of the customers perception of solar technologies and the sales numbers for each branch.

Table 3: Data from Kundapura and Chamarajanagar branch of SELCO India. Based on SB1, SB2 and EM1.

	Kundapura	**Chamarajanagar**
Year of establishment of Branch	1998	2014
Employees	40	9
Customers	30 000	2500
Area of operations	40km radius (limited by seaside)	100km radius
Sales 2017	Home lighting: 1014 Other: 379	Home lighting: 400 Other: 150

	Total: 1393 Value total: 30,2 Million INR	Total: 550 Value total: 10,9 Million INR
Sales 2018	Home lighting:1254 Other: 406 Total: 1660 Value total: 29 Million INR	Home lighting:500 Other: 200 Total: 700 Value total: 13,4 Million INR
Sales target 2019 (completed in Dec.)	Home lighting:1300 (784) Other: 500 (344) Total: 1800 (1128) Value total: 30 Million INR	Home lighting:750 (500) Other: 350 (300) Total: 1100 (800) Value total: 16,7 Million INR
Financial institutions available	National 5; Microfinance 2; Rural cooperation 15	National 9; Microfinance 9; Regional rural banks 1
NGO partners	7	6
Other organizations as partners	2	0
Potential customers (Indian Village Directory, 2011)	Rural households: 71 170 Urban households: 8 403 Total households: 79 573	Rural households: 204 137 Urban households: 40 737 Total households: 244 874
Market share	37.7%	1.0%
Number of special projects during 2019 (Total value)	25 (1,5 Million INR)	15 (100 000 INR)
Number of ultra-poor projects 2019 (Total value)	300 (3 Million INR)	150 (1,5 Million INR)
Loans unlocked through finance for home lighting 2018	12 Million INR	5.3 Million INR
Total number of demo events per year (2 demo*sale exec.*week)	270 (3*2*45)	180 (2*2*45)

5. Technological innovation system analysis

The case of solar home lighting solutions in Karnataka and the enabling conditions in the ecosystem is analyzed through the TIS framework in this section. This analysis covers the structural elements and system functions of the solar home lighting ecosystem. The first sub-section will map and explain the structural elements identified in the ecosystem. The system dynamics are then analyzed through the TIS functions and the total system functionality is thereafter evaluated.

5.1 Structural elements

The identified actors that enable the diffusion of solar home lighting systems in Karnataka are mapped in figure 4. The local branch office is the main enactor and represents any local energy service provider. Within the case company the 12 supportive departments all share an enactor role in actively strengthening the systems functionality through various activities (see table 2). SKDRDP as the major microfinance partner takes a selecting role in supporting the solar home lighting

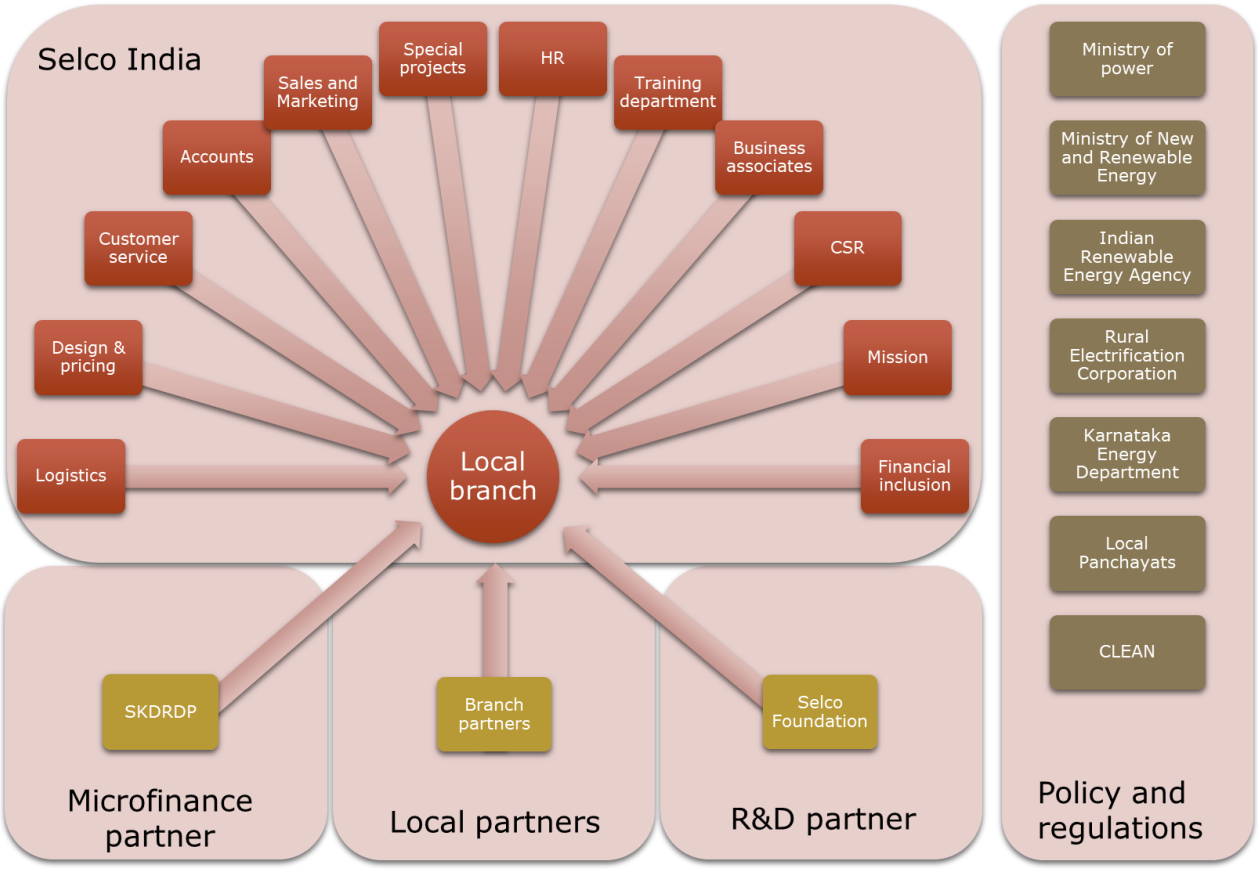

Figure 4: Actors in the solar home lighting TIS.

technology and providing finance to the solar customers. Their local branch offices and the tight collaboration with the Chamarajanagar branch through hosting demos together and promoting the solar products shows that they take on an active role in supporting the TIS. The local branch partners are of various characters and different levels of engagement. Their engagement in is best described as selectors as they assembly have different options for lighting solutions to support, and by going with the solar home lighting solutions they actively show the way for others. SELCO Foundation acts as an enactor for the whole decentralized renewable energy sector and its ways of including solar home lighting solutions in their new livelihood solutions surely impacts the rate of diffusion.

Institutions, formal laws and regulations as well as informal norms and behavioral patterns, are important for the system analysis (Edquist, 1997 p.46). India has had a long record of rural electrification schemes and solar policies have been around since the nineties. The current regulations do however lack sufficient support for decentralized solar solutions and largescale solar plants and grid-connected installations are favored in policies. The lesser interest for decentralized solar solutions is also reflected in the retraction of government funding for rural electrification through solar solutions. The new and younger bank employees with less social commitment to the local community also affects the availability to finance negatively. Public perception of solar technology is constantly changing, and the history of malfunctioning solar products has created an initial distrust towards solar solutions among many

communities. The various cultures and social norms due to the high diversity in India and Karnataka are mostly bridged by the use of local champions who already know the context. Having a social mission and periodically reinforcing the social impact of the company provides the internal motivation for the employees and other partners to perform at their top levels and support the TIS.

Enabling technologies that are newly introduced are messaging applications and digital tools that both has increased the productivity and connectivity of the company. The better connectivity and flow of information within and beyond the organization has strengthen the network tying the TIS together. the case company, and the organizational structure with the supportive departments, have created a network where the trust among the actors is high and learnings and problems are shared in an efficient and inclusive way. The high emphasis on personal relations with all external partners and customers also strengthen the links in the network. The work with local champions and business associates extends the SELCO network in multiple directions creating opportunities and connection with new customers and partners.

5.2 System dynamics

The interactions and activities among the actors in the solar home lightning TIS in Karnataka are recognized through the seven system functions described in section 2. A complementary overview to the following analysis is illustrated in table 4.

Entrepreneurial activities are identified in nine of the eighteen actors in the solar home lightning TIS in Karnataka. Many of the supportive departments witness of an entrepreneurial spirit and the two local branches run their businesses as a startup. The purposeful actions taken by the management of the organization, creating high trust and creative space for all employees, combined with a strong social security net has generated a culture that incentivizes and foster entrepreneurial activities. The high level of entrepreneurial activities and innovation for inclusive technological, financial and ownership models is without doubt an important aspect for the diffusion and sustainability of the TIS.

Innovation is ignited in the interactions with customers and at periodical meetings within the organization. The knowledge development stems from two sources in the TIS, the R&D partner and customer interactions. The R&D partner is a mix of learning by searching through research and learning by doing through participating as a partner in new projects. Interactive learnings from customer interactions are the key learning by doing that the branches and project departments are innovating from. The learning by doing and many customer interactions are a result from the need-based approach taken by the organization as a part of ensuring sustainable solutions for their customers.

Knowledge diffusion is the most frequently engaged system function, 13 out of 18 actors are engaged in knowledge diffusion in the TIS. The meeting structure with weekly, monthly, quarterly and annual meetings where all the actors within the case

company are included is identified as a major contributor to the knowledge diffusion within the TIS. High emphasis is also placed on the creation of awareness and education of partners and customers which engages both the branches and many of the supportive departments in these activities. Finding and recruiting local champions is also a key strategy to diffuse knowledge about the solar home lighting technology to new customers and partners. Where the message has higher chances of reaching and resonating with the audiences due to the local authority and trust already placed on the local champion. The work with creating high quality customer service also increases the receptive abilities of the TIS towards customer experiences and learnings from using. Advocacy from senior management, Financial inclusion and CSR departments are also channels used to strengthen the knowledge diffusion. Investing and building the strong personal relations with partners is a strategy that eases the flow of information between the actors and induces the knowledge diffusion.

The guidance of search is mainly done by the external partners and actors of the company. The banks, microfinance- and NGO partners are choosing the direction of rural electrification and implementation of decentralized renewable solutions through their supportive partnerships. The national and regional government also affect this directions and development with their subsidy schemes and policies for electrification projects. From the internal organization the Logistics department, in their negotiations and relations with the suppliers, has an impact on the direction of development for the technology. The Missions department has some internal guidance of search in their selection of which projects to supportive with CSR funds. The R&D partner is also affecting the direction the TIS develops based on their selection of research projects to engage and invest in.

Market formation is mainly done through personal interactions with customers and word-of-mouth testimonials of experiences with solar solutions. The branches are using their own employees and local partners to engage with as many customers and create awareness and build confidence in the company as a service provider and the technology as a sustainable solution. The Customer support, Business associates, Sales and marketing and Special projects departments all engage in market formation activities in their interactions with existing and new customers. Strategies to have old customers tell their testimonies and using their installations as showcases are important for creating demand and trust for the technology. The reoccurring service campaigns, and demo events are also activities focused on market formation.

Financial resources are mobilized both through the CSR department that channels private donors and companies' funds to projects in the branches, and the local partners in the branches. NGOs and charitable trusts are approached to unlock funds that can catalyze solar projects. The SELCO Foundation is also a part of the resource mobilization through its support with funds for special projects in the branches. The Training department also engages in the mobilization of human resources and expertise through the annual training sessions for all employees.

The Financial inclusion department has a special focus on securing the support from financial advocacy coalitions. Its training programs for bankers and many engagements with the financial industry are aimed at increasing awareness and willingness to act in favor of the development of decentralized renewable solutions. The business associates and local champions are on a similar mission with all the networks and coalitions they engage with. Being a member of the CLEAN network and actively engaging upon their request is also activities that strengthen the support from advocacy coalitions for the decentralized renewable energy sector as a whole.

Table 4: Overview of identified system functions in the 12 supportive departments, SKDRDP partner, SELCO Foundation partner and the two branches and their local partners.

Actors within the TIS	Entreprenurial Activities (EA)	Knowledge development (KDE)	Knowledge Diffusion (KDI)	Guidance of Search (GS)	Market Formation (MF)	Resource Mobilization (RM)	Support from Advocacy coalitions (SA)
Logistics	X		X	X			
Design and Price	X	X	X		X		
Customer Service	X		X		X		
Business Associates	X		X		X		X
Accounts			X				
Special projects	X	X	X		X		
Financial Inclusion	X		X				X
Marketing and Sales			X		X		
CSR			X			X	
Mission	X	X	X	X			
Training			X			X	
Human relations							
SELCO Foundation		X	X	X		X	
SKDRDP				X	X	X	
CLEAN							X
Kundapura Branch	X	X	X		X		
Kundapura Partners				X	X	X	
Chamarajanagar Branch	X	X	X		X		
Chamarajanagar Partners				X	X	X	

5.3 System performance

With the individual assessment of each system function it is now possible to assess the systems overall performance and identify the inducement and blocking mechanisms effecting the diffusion of solar home lighting systems. The simplified output analysis provides the conclusion that the system is well functioning with 29 329 sold solar home lighting systems in Karnataka 2018. The ability to continuously make profits, while including the more challenging customer segments, proves the financial sustainability of the company's operations. The more interesting analysis of how the company and branches succeed in their sales, i.e. diffusion, of solar home systems involves some more complexities than sales numbers. Five key mechanisms that enable and reinforce the system functions have been identified. Three blocking mechanisms have also been identified as hinders to even further diffusion of the solar home lighting systems. All eight mechanisms and their connection to the system functions are illustrated in figure 5, together with the suggested policy changes to support the diffusion of this decentralized solution for access to renewable energy.

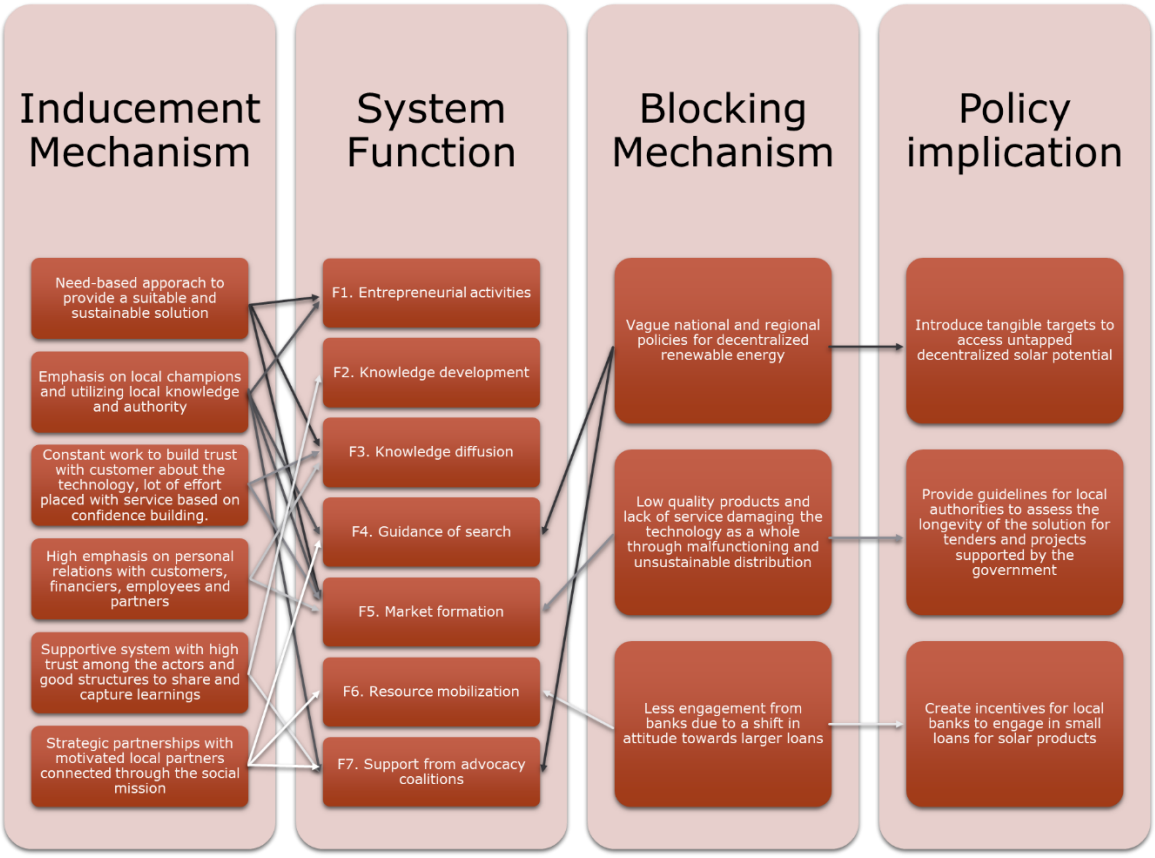

Figure 5: Illustration of the effects of the inducement- and blocking mechanisms on the seven system funtions, and the policy implications based on each blocking mechanism.

The system functions closest to the core operations of the company, being entrepreneurial activities, knowledge development, knowledge diffusion and market formation, are all well-functioning. Key strategies and enablers for this are the need-based approach, the utilization of local champions, the continuous work with gaining

the trust from the customer through building personal relationships to the company in various ways, and of course providing a safe and encouraging culture for entrepreneurial activities withing the organization. A big part of this relationship building is the ownership of service that the case company has taken in order to ensure the functionality of the technology beyond the installation. The business associate set-up, with local associates that promote and generate enquires from their local networks has also been a successful strategy. The social mission is identified as a key motivator for both employees and the local partners, whos' engagement becomes a part of the common goal around serving the underserved. The strategic incentive system for the sales executives also helps the organization to stay aligned with the social mission while using all their innovative abilities to generate business. Interactive learnings and innovations are enabled through the many channels for communication within the network, both structured and spontaneous.

As the two branches Kundapura and Chamarajanagar are serving as samples of the diffusion of solar home lighting systems in Karnataka, their differences are analyzed through the present structural elements and the system functions. The overall performance evaluation of the two branches gives that both branches are operating in a sustainable way to diffuse solar home lighting products with both environmental, social and economic impacts. The Chamarajanagar ecosystem is not as well performing as the Kundapura branch mainly based on the shorter presence in its market and the history of financial and technical failures to achieve sustainability. The latest years sales numbers do however indicate that the Chamarajanagar branch is steadily increasing its sales and catching up with the top performing Kundapura branch.

Vague national policies and targets for decentralized renewable energy solutions is identified as one of the three policy implications from this study. Articulating quantitative targets for decentralized renewable energy solutions, based on further sustainability assessments of strategies to provide universal energy access, would give the sector the proper guidance and governmental support to untap the potential in decentralized solar solutions. The decrease in engagement from local banks could be countered through schemes that incentivizes or directs the efforts from the banks to take on small loans to solar customers. Low quality and short-lived solutions that damage the reputation of solar technologies could be prevented through new guidelines for local authorities enforcing an evaluation of sustainability and longevity of the solutions chosen for tenders and projects. These three policy implications would provide the guidance of search, ease the market formation, encourage resource mobilization and provide support for supportive coalitions that further enables the diffusion of solar home lighting solutions in Karnataka.

6. Discussion and TIS applicability

This study has so-far focused on the systemic understanding of the diffusion of solar home lighting systems. This section discusses the applicability of the holistic framework TIS that has been applied to evaluate insights from the case. First are the strengths of focusing on system dynamics highlighted through examples from this case. This is followed by a discussion of the missing parts of the TIS to explain the management of resources and differentiating between entrepreneurial activities and system building activities. The role of TIS in socio-technical transitions is finally discussed and the contributions from this case are presented.

6.1 Ecosystem and the TIS approach

One very important assumption for this thesis is the need for holistic thinking and a systems approach in order to understand and accelerate the diffusion of new technology. The whole body of innovation system research has built upon this assumption since the 1980's. This is however in conflicted by a techno-centric perspective, where the technology and its inherent qualities and capabilities are the sole focus. The more reductionist ecosystem approach introduced by SELCO Foundation is therefore a first step towards a system understanding and acknowledging that other parts of the system, beyond the technology, needs investments and innovation in order to increase the diffusion of the technology.

Insights about the system dynamics drawn from the results of this study, based on previous studies in technological innovation systems, provides examples of system understanding that can be used to further improve the ecosystem approach. When applying a focus on system dynamics where the seven system functions are separated from the structural elements, which are mixed as factors in the ecosystem approach, a more clear-cut and precise understanding is possible. Three examples of this are:

- The business associates are important actors, but their presence in the ecosystem approach is not to obvious. They support the system through four system functions, entrepreneurial activities, knowledge diffusion, market formation and support from advocacy coalitions. The ecosystem analysis of the business associates places them as stakeholders of the infrastructure factor (WWF India and SELCO Foundation, 2015), while their actions of engaging with customers and local authorities has them affecting the capacity building and policy and regulation factors. Recognizing them only as stakeholders for the infrastructure would therefore not give the complete understanding of how the business associates supports the system through their interactions and innovative solutions to sell the solar home lighting products.
- The partnership with SKPRDP has on the local levels developed into a strong relation where the microfinance institute is also supporting the market formation through their activities with the local branch and customer interactions. Their

natural place in the ecosystem is with the financial stakeholders, but their other activities for creation of awareness within the system has them supporting the capacity building and infrastructure as well.

- This study supports the understandings from innovation system research that interactive learnings and knowledge diffusion are key for the continued success of technological diffusion. This is captured through the continuous presence of the system function knowledge diffusion with the actors of this study. The ecosystem approach misses this important dynamic within the system where some of the knowledge diffusion would be identified through the capacity factor and the other only recognized as the internal operations of the energy enterprise that is assumed in the model. The same is true for the success factor of the high emphasis on personal relations, i.e. strong network connections, which is only recognized as 'relevant stakeholders' in the ecosystem approach. Indicating only the existence of networks and not the dynamics within and among these networks.

6.2 System-building and entrepreneurial activities

The ecosystem approach makes an assumption of the energy entrepreneur as being present in the region or neighboring region, and assess the system surrounding the assumed energy enterprise. The TIS framework instead includes the energy enterprise and the activities it engages in. This highlights the system functions that the branches engage in, but the TIS framework, as introduced in this case, does not explain the activities done by the branch and the organization in large to ensure the sustainability of operations. This issue of agency and actor-focus has been recognized earlier (Markard and Truffer, 2008b), as well as the insufficiency of the TIS framework to cover the structuring and creation of value chains through networks (Musiolik and Markard, 2011). The system function *resource mobilization* merely covers the financial and human resources made available for the TIS while other resources are not explained. The resource management is limited to be understood as *entrepreneurial activities* when a central enactor builds the system from within. Musiolik et al. (2012) recognizes this and introduces a new perspective that combines TIS studies with a resource based view. This perspective includes common culture, trust, shared goals or reputation also appear important factors for the successful development of new technologies, next to financial and human. They also stress the importance of strategic management of organizational resources for the purpose of system building and use the concept of a system builder. This provides a promising framework to be applied on cases similar to this one. Where a distinction between *entrepreneurial activities* aimed towards technological and financial innovation, and system building activities aimed towards creating a supportive system for the continued diffusion of technology, is done. Next step could be to further introduce sustainability as an aspect of the strategic management theories used to expand the TIS framework (c.f. Musiolik et al., 2012).

6.3 TIS as part of a sustainable transition

The application of TIS analysis has the recent years included the emergence of technologies in sectors like energy, transportation or water. As these technologies mature and diffuse, they have the potential to overthrow other established technologies in respective sector. The TIS analysis is therefore view and applied as a key-framework in transition studies (Markard et al., 2012), even though it was developed for other purposes (Carlsson et al., 2010). This raises the question whether the framework can be used to explain socio-technical transition. Markard et al. (2015) summarize three critiques against the applicability of TIS for socio-technical studies. The critique encompasses the inability to account for nor explain the rigidities of incumbent socio-technical systems, the neglection of conceptualizing the dynamics between the focal TIS and other socio-technical systems, and lastly that the TIS lacks a clear theoretical foundation. The critique is met with a recognition of the frameworks current inability to cover all aspects of a socio-technical transition, but that it has the potential to do so in the future. The same group of contributors to the research field argue that there in fact is a theoretical foundation with explanatory value that has the potential to evolve into a concept to be used for studies in socio-technical transitions, but as of now it is limited to the analysis of dynamics and performance within TIS that may be a part of a larger socio-technical transition (Markard et al., 2015). This case, with the static focus on system performance of solar home lighting systems, has contributed to the system understanding of decentralized solar diffusion in Karnataka. This has proven to be a neglected sector in the socio-technical transition towards a sustainable energy system in the region. This case contributes to the systemic understanding of the potential impact that could be realized through further diffusion of decentralized solar solutions, which is a part of the larger transition needed to shift towards sustainability.

7. Summary

This study was conducted in response to the complex challenges of global poverty reduction, sustainable energy systems and universal energy access, i.e. sustainable development. A case study in the Karnataka district in southern India has served as an example of how the diffusion of a decentralized renewable technology is enabled, and under what conditions. The interdisciplinary TIS framework has led to the following conclusions around the local ecosystem and its actors.

The dynamics within the studied system are well covered through the seven system functions: Entrepreneurial activities, Knowledge development, Knowledge diffusion, Guidance of search, Market formation, Resource mobilization, and Support from advocacy coalitions. The approach of investigating the dynamics beyond the structural elements, i.e. the actors in the structural setting, has provided insights and enabled an analysis that reveals the impact from corporate strategies to increase the diffusion of

solar home lighting systems. The five key approaches that have enabled and reinforced the system functions are:

1) A need-based approach that allows for the customization of solutions to the need of the customer enables more sustainable installations and ensures satisfied customers.
2) The utilization of local knowledge and authority through local champions and employees is working to bridge the trust gap and accelerate the building of awareness and confidence of the customers and partners.
3) The relentless efforts to build and maintain personal relations with the customers, financiers, partners and employees are enabling a long-term market formation and strong network connections.
4) Having a strong network with high trust and well-established channels for communication enables the diffusion of learnings and innovations in the system.
5) The work to build partnerships that aligns around a social mission to serve the underserved forms strong connections and increases the motivation among partners and employees.

Key blocking mechanisms for an increased diffusion of solar home lighting systems are: Vague national and regional policies, damaged reputation for solar technologies through substandard solar products and installations, and decreased engagement from banks.

The case is an interesting application for the holistic TIS framework due to its centering and strong dependence on one organization within the system. The company has, during its 25 years of operations, built a system that covers most of the system functions and is able to operate 42 local energy service branches in Karnataka. The high emphasis on building strong personal relations with local financiers and partners enables them to fulfill the remaining system functionalities needed to increase the diffusion of technology. Building a network of supporting actors within the organization, which is centered around a very specific social mission, has resulted in a successful and sustainable system that enables the diffusion of sustainable energy solutions. Strategic management like the business associate set-up, the incentive system, the structural meeting schedule to share learnings, the ownership of after-sale service and strong partnerships with local financiers are all part of the successful operations of the organization. The TIS framework is, however, in need of further development and future studies to be able to encompass the vastness of socio-technical transitions and better explain the micro-meso-macro linkages within complex systems. Revisiting this case with the complementary strategic management theories introduced by Musiolik et al. (2012) could provide further insights to system building with a central actor. An event history analysis could further reveal some ‘motors of innovation’ based on the cumulative causalities (Suurs, 2009) that drove the case company towards financial sustainability during its 25 years of operations.

Beyond the theoretical contribution, this study also provides insights about the local diffusion of decentralized renewable energy solutions that can be used to formulate

guidelines and strategies to further strengthen the TIS and enable the diffusion of solar home lighting systems. Policy makers can utilize their power to provide guidance of search for the whole system through suggested subsidy schemes and enforced sustainability assessments. Financiers and investors can, through the understanding of the system's dynamic, invest their efforts and resources where they have the most positive impact for the system. Which in this case would be creating and providing payment solutions for the customers to enable a long-term solution for asset creation and financial inclusion for all.

The case of decentralized renewable energy solutions plays only a minor role in the overall transition towards sustainability, but this study highlights the potential it has too provide sustainable solutions for all. The pursuit for sustainability will require efforts on all levels and this case shows how an understanding of system dynamics can enable this pursuit further.

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Appendix A: Interview guide supportive department

- What is the purpose of this supportive department?
- How is the branch supported by this department? What activities/tasks are done by the department and the branch?
- Why is this supportive department and its work important for the increased sales and installation of solar home lights?
- What does the process for a “typical” branch request look like? Can you give an example?
- How many employees are affiliated with this supportive department?
- How are you incentivized to innovate by SELCO? How is the innovation captured?
- What are the major challenges for the supportive activities that the department is working with?
- Would you say that this department is well functioning in its work with fulfilling its purpose to support the branches? What could be improved?

Appendix B: Interview guide branch manager

Warm up

Basic information:

- When was the branch started?
- For how long have you been BM? For how long have you been with SELCO?
- How many people are currently employed in the branch?
- How many customers do you serve currently?
- How large area are you active in?
- How many systems did you install last year and this year?

Structural elements

Actors:

- What organizations do you engage with for the purpose of selling/installing solar home lighting? What are their names, and can you give a brief explanation of the partnership? I would like to know all kinds of partnerships, from financial partners, sales associates, customer relationships associations, medical partners, educational partners, NGOs.
    - Objective: Map all the actors in the local branch ecosystem and their relation to SELCO branch.
- What other companies do you know of that sells solar lighting products in this region? Are there any NGO that provides solar lighting products?
- What financial actors are present in this region and potential partners to you? Microfinance and local banks, please name all that you know of.
    - Objective: Map all the financial actors in the branch ecosystem.

Institutions:

- Do all of your customers know about solar lighting technology before you approach and talk to them? What do they say about solar lighting, are they positive or negative about the products? What is their main problem with your products? Why?
    - Objective: Understand the perception of solar and norms/ideas that may affect the customers consumption.
- *Have you collaborated with the local village or community leaders? What have they done to promote solar lighting products?* In what way have their local decisions and policies affected you?
    - Objective: Map policies and regulations that affect the local branch ecosystem.
- Why do you collaborate with the local partners? How does the partnership affect your way of building trust with other partners and customers?

Technologies:

- What about infrastructure in the region, do you think that the infrastructure like roads, electricity and communication are good? What improvement in these would be good? In what way would that help you sell solar lighting products?

    - Objective: Map the present and lacking technologies and infrastructure that enables and blocks the sales of solar lighting products.
- What other technology or product, more than these basic infrastructures would you say are important for you to sell the solar lighting systems? Can you think of any technology or product that would be helpful for you to sell more solar lighting products?
    - Objective: Map the present and lacking technologies and infrastructure that enables and blocks the sales of solar lighting products.

Networks:

- Is there any professional network for people working with solar products in this region, where you are a part? How do you meet other people working with the same type of projects that you do?
    - Objective: Map formal networks within the branch ecosystem.

Extra:

- For how long do you offer service on the solar home lighting packages? What guarantee times do you give?
    - Objective: Cover basic info about the package deal offered by SELCO.

Systems functions

- When you have an issue in the branch and need help from some of the supportive departments, how do you proceed to get their support? Is it only through the weekly meeting and then the senior manager that goes through the minutes?
    - Objective: Assess the functionality of the supportive departments and thereby the systems functions.
- How are your employees trained? Are trained staff available on the job market?
    - Objective: Map the system functions of knowledge development and diffusion and also resource mobilization. “capacity building”.
- How do you innovate? What innovations have you used to increase the sales? How do you document and share the learning from an innovation from the field? What knowledge is shared with other actors or SELCO India? In what formats are these learnings shared?
    - Objective: Map system functions of entrepreneurial activities, knowledge development and diffusion.
- Is there any NGO or company that educates customer of solar lighting products and different qualities of products?
    - Objective: Map system function of knowledge diffusion and guidance of search.
- If you were to have a village of 100 household that would like to install solar lighting products tomorrow, they could not afford the total payment so they need a payment scheme, who would you approach to fix the credit to the customers? Do you have any other alternative that you also could ask? Would it be very difficult to arrange the payment scheme, or would it be smooth?

    - Objective: Map system function resource mobilization and assessment of it.
- How do you market solar home lighting products in this region? Have you done any training with customers and partners to educate them on your products and ways of working? What has been the results from this?
    - Objective: Map system function market formation and knowledge diffusion and guidance of search.
- From where do you learn about new ways of operating, technologies, opportunities?
    - Objective: Map system function of knowledge development and structural elements of actors and institutions.

Extra questions

- What is the main challenge for you as a branch to increase your sales as of now?
    - Objective: Assessing system functionality.
- What is the main challenge with regards to the SELCO supportive departments and the overall support from SELCO?
    - Objective: Assessing system functionality.