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Modeling economic growth through renewable energy in rural developing regions

Combining system dynamics with innovation systems theory

Thesis for Master of Science degree from the Industrial Ecology Programme

JONATHAN ROTHSTEIN

Department of Energy and Environment
Division of Environmental System Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
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JONATHAN ROTHSTEIN

Tutor: Elias Hartvigsson
Examiner: Sverker Molander

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Department of Energy and Environment
Division of Environmental System Analysis
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

Cover:
Left: Local inhabitants with their solar PV panels powering an electric water pump, filling a water tank on a support structure in the village of Chitonto, Zafala district in Inhambane province, Mozambique.

Right: Local inhabitants in Chitondo village processing manioc roots in the production of manioc flour.

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Abstract

Rural regions of developing countries are characterized by little economic development and low productivity of capital. This thesis aims to investigate why the interventions launched by their national government and international organizations are seldom successful in supporting local business development. The economic system of rural communities is analyzed with a system dynamics approach, attempting to reveal internal mechanisms to better understand the dynamics of the problem. The analysis also aims to provide a new perspective on the role of renewable energy systems in the developing context, since there is an established link between energy access and economic and social development.

An innovation systems theoretical framework is applied to evaluate the innovation capacity of the rural economy, where new business ventures using adapted renewable energy are seen as manifestation of the innovation process. Lack of coordination between government and business sectors, lack of emphasis on the importance of vocational education projects and lack of access to conditional financing are some system weaknesses identified that have effect on local economic development in rural regions. The combination of the tools for analysis mentioned was useful to show how these factors interact in this dynamic problem.

Keywords: Renewable energy systems, developing countries, local economic growth, micro-financing, productivity of capital.

Resumo em português

As zonas rurais dos países em desenvolvimento são caracterizadas por pouco desenvolvimento econômico e baixa produtividade de capital. Esta tese tem como objetivo investigar de que maneira as intervenções e projetos lançados pelos governos desses países assim como organizações internacionais raramente tem sucesso no apoio ao desenvolvimento empresarial local. O sistema econômico das comunidades rurais foi analisado como um sistema dinâmico, na tentativa de revelar os mecanismos internos para melhor compreender a própria dinâmica do problema. A análise também sugere uma nova perspectiva sobre o papel dos sistemas de energias renováveis no contexto de desenvolvimento, já que há uma ligação estabelecida entre o acesso à energia e o desenvolvimento econômico e social.

Um arcabouço teórico de sistemas de inovação foi aplicado para avaliar a capacidade de inovação da economia rural, onde novos empreendimentos que utilizam energia renovável em aplicações adaptadas foram vistos como manifestações do processo de inovação. A falta de coordenação entre os setores governamentais e empresariais, de ênfase na importância de projetos de educação profissional e de acesso a financiamento condicional foram algumas deficiências do sistema identificadas que produzem efeito no desenvolvimento econômico local em zonas rurais. A combinação das ferramentas de análise mencionadas foi útil para mostrar como esses fatores interagem neste problema dinâmico.

Palavras-chave: Sistemas de Energia Renovável, países em desenvolvimento, crescimento econômico local, micro-financiamento, produtividade de capital.

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Table of Contents

1. Introduction

1.1 Background

Developing countries are characterized by, among other things, the large social and economic differences within them. The cities are commonly hubs of economic activity, to which people are drawn from the less developed surrounding countryside where poverty and sometimes famine can be found. The urban areas also work as magnets that drain the rural areas of innovative and motivated people, who see no way of capitalizing their ambition, talent and knowledge anywhere in the countryside (Beine et al., 2001).

Two apparent reasons for this strike the visitor of a rural area in a developing country. The first one is a lack of basic social and infrastructural services, such as education, health, access to fresh water, etc. The other is a lack of jobs - people are occupied by and dependent on subsistence agriculture because they have no income to buy what they need. Jobs appear where there are businesses, and businesses only appear under certain conditions – for instance, there needs to be infrastructure for the particular business to function, and there needs to be costumers to purchase the service or product the business puts on the market (McPherson, 1996, Dollar & Kraay, 2002). Infrastructure and costumers normally appear only where there already is a certain amount of economic activity.

This type of circular reasoning may be a clue to understanding the dynamics of the problem. Infrastructure, the production of human capital through education and the appearance of small businesses are all key components in rural development. (FAO & UNESCO IIEP, 2006; Van der Sluis et al., 2005). Their individual importance is well established, but the way they affect each other is less known. The argument above seems to suggest that there are feedback mechanisms between them in which the components under certain conditions affect each other.

In both the provision of basic social infrastructure and in the development business infrastructure, access to reliable energy and electricity services play an important role. It is also well established that electricity access is positively correlated with both human development index and education level.

Electricity is usually provided through a national power grid, which is expensive and difficult to extend to most parts of the countryside. Renewable energy generation technologies, like solar- wind- or hydropower can solve this problem, by the creation of micro-grids. These technologies have long been considered too expensive in the rural developing context, which may be an outdated perception. With increasing demand in the industrialized world, suppliers of renewable energy solutions have adapted to new markets, increasing production volumes and improved efficiency. The result of these economies-of-scale-effects is that prices have dropped and renewable energy systems are now more affordable and accessible than ever before (Bhattacharyya, 2013).

When projects for electricity access are launched, the purpose is usually to provide access to as many households as possible, and electricity access is usually seen as a social service in itself to facilitate everyday life. The problem with this is that people in rural areas usually don't blow-dry their hair or toast their bread – they have always made do without this and they are unsure of how to benefit from the access to electricity. Some positive outcomes of these projects occur when they are

coordinated with other social services, for example providing light for evening classes in schools, and refrigerating for vaccines in local health clinics. But since the projects are seldom coordinated with activities that create jobs, the impact of the projects on the quality of life and on poverty is usually small.

Whether these projects are about off-grid renewable energy or about extending the national power grid, they usually don't include the link from access to electricity to the appearance of businesses using electricity in a commercial and productive way, creating jobs (Ahlborg, 2012). The reason for this may be found in the very nature of different types of development and relief work.

International aid can be categorized as developmental aid and non-developmental (Minoiu & Reddy, 2010). An example of non-developmental aid is crisis relief work. When a region is hit by a famine, an epidemic of spreading disease or a natural disaster and there is a focus on providing the large amounts of food, medicine and shelter for the people. Crises get much attention in media and it is easier to raise funds for crisis relief work than to the more long sighted efforts. Since crises get much attention, they are politically easy to support. Although crisis relief work is indisputably important, the long term work of crisis prevention gets little attention in comparison. If more resources were diverted to crisis prevention projects, like opening permanent health clinics, supporting education projects, infrastructure for clean water, etc., many crises could be avoided or at least the effects of them could be limited.

Development aid is sometimes given as support to large infrastructural projects in developing countries, for instance in power production, the building or improvement of ports and road projects. These projects are usually conducted by, or in close collaboration with, the governments of the recipient countries. Other types of development projects aim to support the social services to the population, mainly the provision functioning and equipped health clinics and schools. A less common type of development projects focus on the economic development of rural communities, e.g. support small businesses that can provide the inhabitants with job opportunities.

Underdevelopment is a recognized factor connected to a societies' vulnerability to crisis. A society that has income from jobs in different sectors, and that has a capability for saving capital, is less vulnerable when a crisis hits. This suggests that aid funds should not only focus on social services for fulfilling the people's basic needs, but also on aiding economic growth in rural regions – the development of small scale businesses and the attraction of external companies to invest in an area are some examples of this. This is an area which has turned out tremendously difficult to support through development projects, for several reasons:

One reason could be that development aid initiatives sometimes are initiated by a crisis that draws attention from the government and the international community. A situation of permanent underdevelopment where people live with no margins doesn't motivate as much donations as people dying by the thousands from starvation and disease.

Another reason may be that the problem of getting economic growth going in rural developing regions is a problem of circular causality. This means that economic development starting from

"zero" is a complex problem that has internal mechanisms which affect one another and that need to be thoroughly understood for outside interventions to have any effect.

Example of circular causality: *Inhabitants of a rural community have no monetary income, because they have no jobs. They have no jobs because there are no investments made to start businesses to create local jobs. No investments are made because there are no local costumers, because they have no purchasing power (no income).*

Problems with loops of circular causality need a systematic method of approach to properly be described. Since they are non-linear, interventions based on an analysis of a single connection or variable is likely to be inadequate and to overlook important parts of the dynamics of the problem.

In an increasing number of research disciplines, system dynamics (SD) is a method used to understand circular causality by drawing causal loop diagrams (CLPs) and building system models out of the components, which are variables and the connections between them (a variable in this context could be the average income in a community, or the amount of new businesses started).

A CLP represents a theory of how a system works. After model construction it is analyzed in order identify possible ways to intervene in the system by changing policy. The type of analysis made depends on which type of system is in focus.

Traditional development interventions have, as mentioned, focused their efforts on the development of social services as the fundamental building block of development, at the cost of supporting local economic development. It could be the case that the methods for analysis used are not designed for this, therefore it could be interesting to explore other methods that have a bottom-up perspective on economic development.

It could be claimed that a community looking to use modern technologies to develop new business opportunities and to create new local markets is a type of innovation system (IS). The theory of innovation systems aims to explain how a new invention (new technology, new service) is applied commercially to new markets where it is previously unknown, how the new use of the invention is diffused and makes its way to becoming an established product on the open market, and under what conditions this is more likely to happen. The theory has been used to explain the diffusion of certain renewable energy technologies, and one purpose of analyzing this could be to provide policy makers with insights in how to support the technological and business development in a certain direction that is deemed good for society. IS does not necessarily need to include inventions which are new to the world, but the innovation can result in new applications of an imported technology, or the adaptation of a business sector to using a new technology (Lundvall et al, 2009). In an innovation system, central components to identify are actors, networks and institutions.

In current debate on IS theory there is a recognized necessity to abandon the previous market failure-approach and to view and describe the innovation systems more dynamically (Bergek and Jacobsson, 2006), therefore system dynamics is a possible method of describing the mechanisms and functions of a system. As mentioned, the type of analysis for implementation made of the SD-model depends on what type of system is in focus and on what the core problem is. From a description of a system dynamics model, the variables affecting the core problem (and the connections between

them) are identified. If this is used as input to an innovation system analysis, the central actors can be identified and the connections between variables can be interpreted as indications of the existence (or lack) of networks. Together these two approaches could be used for description and analysis, and may shed new light on the dynamic problem of rural economic growth.

1.2 Purpose and goal

The purpose of this thesis is to examine what variables affect the appearance of small businesses in rural developing regions using electricity from renewable energy systems, and what conditions are necessary for these businesses to create jobs and have a positive effect on the growth of the local economy. Previous research on rural electrification has focused on the diffusion of renewable energy technologies and the sustainability of off-grid electrification projects, e.g. Bhattacharyya (2013), Watson et al. (2012), and Gollwitzer (2014). In this study the general rural economic development is in focus, and renewable energy technologies is viewed as a key element in supporting it, an important factor which (provided other conditions are met) can contribute to solving the problem.

To investigate these matters, a study visit to Mozambique was conducted, to see the mechanisms at play first hand. The data and interview material from this study visit was analyzed and compared to previous research on other developing countries, and used as input to design a model using a system dynamics approach. The purpose is to find connections between the variables in play in the context of rural Mozambique, and to investigate if similar connections have been found in other developing countries as well.

The goal is to better understand what is necessary for economic growth to take place in rural developing regions. The insight gained should be used to understand what type of interventions by the national government and/or by non-governmental organizations can be more effective in supporting growth, development and reducing poverty in rural areas of developing countries. Another goal is to investigate the role of renewable energies; if they, besides their inherent environmental benefits, can be a tool in supporting rural micro-economic development.

1.3 Delimitations

The aim of this study was not to provide a full set of policy implications derived from a complete analysis of the problem, but to describe how the system dynamics approach can be useful to understand one of the most important problems in rural developing regions, namely the lack of development and economic growth. The aim is also to show that the theory of innovation system provides a useful tool in deriving policy implications from the system model when it is fully described, and to illustrate this with the example of rural Mozambique. There will be no claim that the causal loop diagram describing the rural community will be completely validated, but the connections and identified variables should be indicated by empirical results or in literature. Since the system model will not be completely validated, there will be no complete deriving of policy implications from the model, but some examples and highlighting some significant ones.

The causal loop diagram generated in this study is the first step to create a complete system model. No formulation of equations for the variables is done, which is why the model cannot be validated by simulation.

When renewable energy solutions are introduced to a rural community, they are bound to have both economic and environmental impacts. In this study, the economic implications from the newfound access to energy, or from switching out an off-grid fossil energy solution which arise from improved accessibility, are taken into account. The local environmental impacts from the renewable energy solution, or the economic implications that they may have, lie outside the scope of this study.

1.4 Research questions

The main questions in this thesis are the following:

Research question 1:

> The continued presence of underdevelopment and poverty in rural developing regions in spite of many years of government and foreign interventions indicate that there is still much to learn about the economic system of rural communities.
> How can the mechanisms determining the rate of economic growth in a rural developing community be described, and what is the role of access to electrical energy?

Research question 2:

> The problem of underdevelopment and poverty in the rural regions of developing countries seem hard to solve by interventions from the government and the international aid community.
> How can the system of causality in a rural developing community be analyzed, and how can interventions be designed and implemented to have positive effect on economic growth in terms of income and job generation?

2. Methodology overview

In order to answer the research questions (RQ 1 and 2) in the section above, several methods were used. A literature study was conducted to identify the variables and connections of a generalized rural developing community affecting the problem of economic growth. A two months field study was conducted in Mozambique, including an interview study with interviewees in government administration, rural communities, non-governmental organizations (NGOs) and embassies. The findings from the literature review and the field study were used as input in constructing the system model using a system dynamics approach. The system model was used as input to an innovation systems analysis, resulting in the identification of some key policy issues.

The literature study was conducted to find variables affecting the core problem – economic development in rural developing regions – but also to construct interview guides for the field study conducted in Mozambique, the result of which was used to support the conclusions drawn from the literature review. The case of Mozambique will serve as an example, but the goal is to through literature review compare this to the case in other developing countries to find indications that some of the problems may be general.

2.1 Interview study

The interview study took place in urban and rural regions of the Republic of Mozambique. Interviews were conducted in Portuguese, the official language of Mozambique in order to avoid risking details being lost with English speaking respondents. It was deemed that more details and valuable information can be extracted from interviews where respondents are allowed to speak freely, which is why the semi-structured interview method was chosen. It is to be noted that when conducting interviews in rural areas, interpreters were sometimes needed to translate between Portuguese and the various local languages.

The type of interviews conducted in this study was semi-structured interviews, which is a method combining the advantages of unstructured and structured interviews. In an unstructured interview, the situation resembles a recorded open conversation on a certain topic, which is later played back and sought through for valuable information. In a structured interview, there is a pre-defined set of questions on a sheet, from which the interview seldom deviates, and the questions are usually standardized between interviews (Willis, 2006).

The interviewees can be divided into two categories: key informants and individuals. With the interview guide approach in semi-structured interviewing, only some of the questions were pre-set. The exact wording was flexible and the guide used as a starting-point for the interviews. Follow-up questions were formulated during the interview, and the researcher allowed the interviewee to go off on side-tracks if it was deemed necessary. In individual interviews, people were selected to give representative information from a user-perspective, for example students in a school. When it was possible to do many interviews, it was sought to differentiate other variables of the respondents (age, sex, income level etc.) to get more reliable results (Mikkelsen, 1995). In key informant interviews, the respondent had special knowledge on the topic that was investigated. They were community leaders, energy-system technicians, farmers, authority representatives. Sometimes the

same person was both a representative individual and a key informant. For example a farmer, who was a representative as a recipient user of a newly installed electricity service, but a key informant as he had gained experience using his electricity access for value adding food processing (Mikkelsen, 1995). The interview results are described in detail in chapter 4.

2.2 System dynamics approach for modeling

The results from the literature review and the interview study was used to design a system model using the system dynamics approach. In such an approach, a system overview is obtained by creating a causal loop diagram (CLP) which is centered on a problem. In this case, the problem selected was the lack of economic development in rural regions. The CLP consist of variables affecting this problem and the connections between them and the other variables in the system.

In order to improve understanding, the CLP was complemented by a Background system tree diagram, describing the mechanisms which are external to but affecting the system in focus, on a national to international level. The system dynamics approach as a method is further described in section 3.1. The system model and background system tree diagram are found in chapter 5.

2.3 TIS approach for analysis

The data from the interviews and literature was analyzed to be synthesized into a system model. The system model was then analyzed again using an innovation systems approach, in order to identify key policy issues and possibilities for interventions. A framework designed by Jacobsson and Bergek (2006) was used, which describes how innovation systems are developed. The framework is designed to assist policy makers who want to support the innovation capacity of a certain sector, technology, region, or similar. The functions of the framework were compared to the SD model description of the current system. The Innovation system theory approach is further explained in section 3.2 and application to our research problem in chapter 6.

3. Literature review

3.1 Systems dynamics theory

When dealing with issues like economic growth and people's behavior, it can be difficult to see the causes and effects of actions regarding a problem. Problems like these seem to have no beginning and no end.

To illustrate a complex system, let's look at how we think about the problem of high unemployment in politics: If we raise the tax on labor, we get more income from tax to spend on improving the public sector. The improved education system will improve people's chances to get a job in a more specialized society. On the other hand, if we lower the taxes on labor, companies may be able to hire more people, who also pay taxes, which can be used to improve the public sector, and so on. The problem is complex because the society is a complex system. In order to properly understand this problem and be able to anticipate indirect effects of actions, a system analysis tool is needed that helps policy makers see beyond the first intuitive thoughts on solutions.

System dynamics is a tool used to map and describe complex systems which behavior cannot be anticipated neither analytically nor intuitively. It was originally developed to understand the dynamics in corporations, initially called "industrial dynamics" by its inventor Jay W. Forrester, in 1961. Since then it has proven useful in many fields, for example business administration, environmental studies, defense, economics and social science. The purpose of using this approach to solve a problem is sometimes to generate a computer simulation in order to quantify and anticipate the behavior of the system over time. It can also be to describe the causal feedback structure of the system in a diagram to get an overview (Sterman, 2000).

The system dynamics approach of a problem start with a definition of the problem, seen not as a static state but dynamic, that changes over time. A system model is drawn up to illustrate the system studied. When mapping the variables that affect the defined problem and the links between them, one attempt to identify loops of circular causality, meaning where a variable, directly or indirectly, ends up affecting itself. When these feedback-loops are identified, the model is completed with exogenous variables, meaning variables that affect the problem from outside the system. When a model is finished it should be able to reproduce the dynamics of the problem of concern by itself (Sterman, 2000).

When the model is designed the goal is to gain new insights in the problem described. For a model to be useful, it is necessary to validate and confirm the connections and dynamics described in the model, which will be described in the following section.

System dynamics modeling is done following four steps: Conceptualization, Formulation, Testing and implementation (Albin et al., 2001):

In the first step Conceptualization the following is done:

- Define the purpose of the model
- Define the model boundary and identify key variables

- Describe the behavior or draw the reference modes of the key variables
- Diagram the basic mechanisms, the feedback loops, of the system

When step one is completed, the result is a causal loop diagram (CLD) of the variables, connections and feedback loops. This is a key visualization tool to understand the dynamics of a problem. The following steps are used when the intent is to create a model on which simulations can be done. In order to test if the models' behavior corresponds to reality, or in this case to test different policy changes, the variables in the CLD can be converted in to level and rate equations, to which parameter values are assigned. Simulations can be necessary in some applications of the method but can also be left out when the system overview and structure is the sought information.

3.1.1. Validation of system models

The purpose of making a system model is to learn about a system, and in order to do that we must be able to verify that the system model we created is, to some extent, an accurate descriptions of the functions in the system we are studying. This brief summary of formal model validation theory is largely based on Barlas (1996) which set the standard for modern model validation.

The model construction process starts with an iterative process. This does not mean that it is taken out of thin air, but in fact that several of the tests and procedures used in the validation step are used by the model designer to help with the construction and linking. For instance, a modeler may believe that there is a positive reinforcing link between two variables, because he has read a study indicating the link. Here he has started the validation already during the design phase, but for a thorough validation he may later triangulate by finding several sources in literature or from empirical data which independent from each other indicate the same link.

What method for validation is more suitable depends on the type of system studied. Two categories of systems must be recognized, the causal-descriptive systems called white-box systems, and the purely data-driven black box-systems. Black box systems are for example physical systems where sequences of chemical reactions determine the outcome. When such a model is validated, the aggregate output behavior of the system model needs to be equal to data collected on the real world systems studied - an example is the forecasting models made to predict what happens in the environment with continued CO_2-emissions to the atmosphere.

White box (causal-descriptive) systems have internal mechanisms that affect the system's behavior in other ways that quantifiable output. Examples of these systems are models that involve tendencies, people's behavior, and other non-linear connections between variables. When validating white box systems, it is not enough to study the output behavior since it is sometimes difficult to measure because of e.g. the time-scale, and because the causes for a certain real-world output sometimes lie outside the scope of the study. What is sought is the validity of the structure of the system and that it can reflect the internal mechanisms that occur in the real world system studied. A white-box system should be seen as a theory of how a system structure looks and the purpose is to explain its behavior, and may also be to suggest policy changes to affect the system behavior (Barlas, 1996).

Since the white-box causal-descriptive system models represent a theory of how a system works, we must take a philosophical standpoint on how a theory can be confirmed. Because of the nature of

causal descriptive system if can prove difficult to verify or prove the theory through empirical experimentation or falsification, determining if the theory is correct or not. If we instead subscribe to the idea that validity of a theory can be based on its usefulness (including the more pragmatic views on philosophy of science like relativism, holism, etc), we can see the system model as one of many ways to describe the real system, although some ways can prove to be more useful than others.

The usefulness of a system model is thus dependent on how valid the structure of the system is. This can be tested by examining isolated variables, connections, sub-systems or the system as a whole. The examination is done by comparing the entities in the system to empirical or theoretical findings from other research (Barlas, 1996).

From a general development research theory perspective, we can add to this that if a connection is only indicated by the collected data or interview results, triangulation can be used to obtain a stronger verification, meaning that several different sources can indicate the same connection (Mikkelsen, 1995).

3.2 Technological innovation systems

Innovation is the process when new commercial applications are invented for a new technology. A technological innovation system (TIS) describes a set of processes driving the "development, diffusion and utilization of new technologies" (Bergek et al., 2008). A TIS includes firms and other organizations (actors), networks and institutions, and is most commonly used to describe the introduction of a new technology to a society. However, the system in innovation systems theory can also refer to a geographical area, like national and regional innovation systems (NIS and RIS) (Freeman, 2002). In this application the innovation system is explained as a set of institutions that contribute to innovation in the geographical area in question (Sharif, 2006; Freeman, 2002).

New technologies are usually not viable on the market as they first are invented; there needs to be a process of trial and error finding the right commercial application for the technology, for this to happen there need to be investments. If there are no commercial applications for the technology that meets a demand in a small market, the technology is unlikely to improve and develop into something viable for a mass market. The step to commercial viability for utilizations of the technology in question is more likely to take place if there are institutions contributing to this.

3.2.1. Different views on innovation systems

Technological innovation systems has been discussed since the mid 1980's by scholars like Chris Freeman (2002) and Bengt-Åke Lundvall (2010), with the basic idea that technological progress is not linear and that technology co-evolves with society in ways that can be studied in a structural manner. Different scholars have had different scale perspectives and focus points; the early ones started out with national innovation systems, others continued on by putting a certain sector, region, company or technology in focus for the innovation system (Lundvall, 2010).

As the concept developed, a distinction was made between systems that with a base in science and research develop inventions that are new for the world, and systems who manage to import new technologies from outside the system and develop new commercial applications and utilizations adapted for the home market. Some scholars like Viotti (2002) and Matthews (2009) suggest that the

latter type of systems are not systems of innovation but national learning systems, since they generally do not produce science based inventions new to the world market. Freeman and Lundvall argue that if the desired outcome of intervening in an innovation system is economic growth, aiming interventions in policy only at supporting new technological inventions may not be the most effective approach, since growth is more connected to the diffusion and use of new technologies.

In order to apply innovation systems theory on real world problems, one must first agree to a definition of innovation systems. One definition that represents this broader view described above is presented by Lundvall et al. (2009):

"The national innovation system is an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socio-economic structures which determine the rate and direction of innovation and competence building emanating from processes of science based and experience based learning".

This definition suggests that systems that absorb new technologies and manage to diffuse them and produce new commercial applications of them should be included in the term "innovation system". Moreover, the way the term "innovation" is commonly defined is in favor of this view. Innovation is commonly referred to as the commercial application of a new technology, compared to "invention" which describes the production of new technology.

An example used by Lundvall et al. (2009) is the success of the Scandinavian countries, who at the time of their rapid industrial development rather absorbed new technologies from abroad and made commercial use and found new utilizations of them by quick learning and adaptation. Another example that might be mentioned is the Japanese quality management phenomenon that developed in the 1950's. A recognized condition under which innovation systems may develop spontaneously is when there is an abundance of skilled labor (Bergek et al., 2006) and some sort of overthrow of the old system regime, which was exactly the situation in post-war Japan, where the military industry had collapsed. With the "clean sheet"-situation provided by the collapse of the industrial society from the war, Japanese engineers, entrepreneurs and decision makers looked for the most modern ideas to guide them in rebuilding their industry. The ideas of American scholars William Edwards Deming and Josef Juran were too controversial to be accepted in rigid industrial societies of the US and western Europe, but were applied and further developed in Japanese industry, which started delivering products that were superior to their western competition in quality and price (Friedman, 1988).

This example shows that systems with the capacity to import knowledge and technology and adapt it to the home market can both develop the knowledge further and contribute to economic growth. It also shows that working innovation systems can fundamentally change society and it begs the question of how innovation systems emerge. In the case of Japan the development of an IS was connected to a drastic societal change. Some TIS scholars have further investigated what societal functions need to be in place for innovation systems to develop.

TIS scholars Bergek & Jacobsson (2006) have developed a framework of the required functions. These are:

- Knowledge development: the research being done and experience accumulated on how new innovation in the system can take place.
- Entrepreneurial experimentation: The commercial applications of new technologies needs to be discovered and developed into market viable services or products, this require entrepreneurs who have the capability to experiment with the technology in question, and its possible use together with already known products or services.
- Influence of direction of search: Simply put, for there to be innovation, coordination between the interests of the actors on both the supply and demand sides is necessary, which only seldom happens by itself. Innovation has spontaneously appeared where there has been for example an abundance of skilled labor in a certain field, abundance of a natural resource, or similar (Bergek et al., 2006). In other cases, the direction of search has to be influenced.
- Market formation: Innovation in a new IS can be held back due to lack of, or underdevelopment of the market. This can sometimes be solved by the creation of niche markets (or nursing markets). A niche market may be a specialized market where an invention fills a certain need and is the only available product, for example early solar cells on satellites. The niche market provides the new invention with a 'learning space' to develop and improve further to eventually be ready for the larger market (Bergek et al., 2008).
- Resource mobilization: The new innovation system is in need of resources, for example human capital and financing in order to develop.
- Legitimacy: The new technology needs to be accepted in the society for there to arise a demand for the new products and services.
- Development of positive externalities: Once the above functions set in, they may have a positive impact on each other. For instance, improved legitimacy can affect resource mobilization positively in the form of investments, which in turn increases entrepreneurial experimentation, and so on. The positive effects have also been known to spill over into other innovation systems, i.e. other regions or sectors (Bergek et al., 2008).

3.2.2. TIS and system dynamics

It is recognized among innovation system-scholars that a systems view should be adopted when attempting to understand the processes that determine conditions for innovation. This is exemplified by the abandonment by some scholars of the idea that policy for innovation should be designed to avoid market failures, where the market fails to generate an optimal economic resource allocation from society's point of view (Bergek et al., 2006) It is argued that policy makers cannot strive to design interventions to find a static optimal situation, as the notion of market failures suggest there is, in a constantly changing and dynamic world. This argumentation rimes well with the world view of the system dynamic (SD) theory (chapter 3.1). Jacobsson and Bergek (2006) argue that the Pareto optimality should be abandoned as a goal and the aim should be to look for "system weaknesses". Both theories aim to look at a systems components – "functions" in TIS theory and "levels" or "stocks" in SD – in order to better understand the mechanisms of a system. TIS theory focuses specifically on innovation and what drives it, whereas SD is much more general. A system model generated by SD reasoning could be used as an input for a TIS analysis, which is the method in this study.

3.2.3. TIS and the developing context

When the innovation systems approach has been suggested to be applied to development countries, the objections has sometimes been that aiming for the development of innovation systems is "setting the bar too high" for developing countries; the best they can hope for is a learning systems, as described in Viotti (2002). If the broader definition of innovation systems suggested by Lundvall et al. (2009) is applied, i.e. if the innovation is considered also to be an adaptation of modern technology in the local context, the innovation systems approach is applicable to developing countries. The innovation system approach could help policy makers in developing countries to gain insight in where in the system interventions and efforts to reduce poverty can have the most effect.

In order to make a proper analysis of the situation and conditions for economic growth in rural developing areas, analytical tools like system dynamics and TIS are necessary. However, there is also need for understanding of the economic situation in the rural communities themselves, which will be the focus area of the next section.

3.3 Small business support for poverty reduction

The household economy for families in the rural areas of many developing countries is built on subsistence agriculture; what you can cultivate on the small patch of land you own (or rent) is what your family needs to eat, if you have excess of something it is sold or traded - A sack of corn for a chicken, a couple of baskets of fruit for a package of sugar, etc. If there is money changing hands it is always small amounts. This way of getting by is common where there are no jobs, which means no income, which means nothing is saved for a rainy day, except maybe the agricultural products suitable for storage, which are few. This situation makes families vulnerable for any type of unforeseen problems - weather events like floods or draughts affecting the harvest, illnesses requiring expensive medicine or doctor visits are among the more serious ones. Children are considered part of the workforce and are pulled out of school if they are needed to work at home. The lack of income affects food security, health, education and subsequently any possibility to improve the situation in the future (Dollar & Kraay, 2002).

The effects of this situation are most apparent when there is some kind of crisis, like an extreme weather event affecting the harvest. Starvation and disease are imminent, and society's way of tackling the problem has often been to focus on the basic needs, providing food and health care to those who need it. Starvation is easy to see from outside, even being unfamiliar with the context. The local or national authorities quickly accumulate resources to send to the crisis area with help from the international aid society, food, medicine and medical personnel etc., resolving the immediate crisis. This response ultimately leaves the core problem unresolved – vulnerability due to lack of income, due to lack of jobs.

Economic growth policy in developing countries is usually about attracting foreign investors, or keeping the big local ones from moving abroad. The policy seldom supports the creation of small business initiatives, and it is not usually seen as a means of poverty reduction (Dollar & Kraay, 2002). One reason may be that the support of small businesses in rural areas is sometime seen as an impossible task. The reasons usually given are lack of infrastructure necessary for running any business: Electricity for operation and roads for transporting products and supplies are the most

fundamental ones. Another problem mentioned is the lack of human capital; educated people to employ as workforce. In the following sections some of these problems that inhibit local businesses will be discussed.

The lack of small scale business development is sometimes explained by low education levels in the population. The strong counter argument is that entrepreneurial spirit is rather something that is rooted in our struggle for survival, and very common in the developing world in forms westerners are not always used to. I end this section with a quote from development economist Hernando de Soto:

> *"The cities of third world and former communist countries are teeming with entrepreneurs. You cannot walk through a Middle Eastern market, hike up to a Latin American village, or climb into a taxicab in Moscow without someone trying to make a deal with you. The inhabitants of these countries possess talent, enthusiasm, and an astonishing ability to wring a profit out of practically nothing." (de Soto, 2009)*

3.3.1. Factors affecting the growth of small firms

In the field of development economics, it was initially thought that large capital investments in governmental and private firms generate a type of growth which will ultimately exterminate poverty. This view is reflected in the behavior of both governments of developing countries and the donor community, but results have indicated that this type of growth creates large inequalities in developing countries and is ineffective in reducing poverty (de Soto, 2009). Since the 1970's Micro- and small enterprises, or MSEs, are by an increasing number of scholars seen as an engine of growth (McPherson, 1996) which is able to generate a type of more diffused economic development which have more effect on poverty. According to a series of studies conducted by Daniels et al. (Daniels, 1994; Daniels & Fisseha, 1992; Daniels & Ngwira, 1992; Fisseha, 1991; Fisseha & McPherson, 1991), an average of 22% of the adult population in five countries in Sub-Saharan Africa (SSA) where employed by MSEs, compared to only 15% employed by larger registered companies or government enterprises.

An interest has been taken in what factors contribute to the birth and growth of MSEs. The level of education, training and experience of the proprietor of the firm has been shown to be linked to the growth of the business. There has been an established connection with both specific education, like technical training (McPherson, 1996; Daniels, 2003), and general education (Van der Sluis et al., 2005).

The factors that affect MSEs also seem to vary between the sectors. For instance, *capital-intensive* businesses like construction, auto-mechanics, welding, tailoring are constrained by the lack of access to capital for initial investments (Daniels, 2003; Nzekwu et al., 2013) and access to infrastructure. These capital-intensive industries are more common in the rural areas, whereas *labor-intensive* businesses (such as simple repairs and all type of vending) are more common in the urban areas. In urban developing areas, labor-intensive businesses grow fast since their growth is based on a labor surplus (Daniels, 2003). This difference in the nature of businesses that exist in rural and urban developing areas respectively, may explain the slow growth in the rural areas and fast growth in

urban areas. From a policy perspective, a whole different approach is needed depending on which type of businesses (and what type of region) the policy-maker aims to support.

Another important factor to consider is the lack of transparency and access to unbiased information on the performance and economy of firms. This makes the firms' reputation in the sector critical for success, more so than in western economies (Goedhuys & Sleuwaegen, 2002). This factor may have impact on the private sector's willingness to invest in new technologies such as renewable energy.

3.3.2. **Human capital**

Funds from the humanitarian aid society and the national governments of developing countries are spent in great quantities on educational projects in rural areas as a means to reduce poverty (FAO & UNESCO-IIEP, 2006). Two difficulties with these efforts are (1) the focus on general education as a social service as opposed to training in entrepreneurship and skills usable in the local context, and (2) the "brain-drain"-mechanism (Beine et al., 2001). A common reason given by private sector actors when asked why they don't invest in activities in the rural regions is the lack of human capital (Ahlborg, 2012).

The "brain-drain"-mechanism is described by Beine et al. (2001) not as the emigration of engineers, physicians or top level professionals for which the concept is sometimes used, but rather the part of the population who is fairly high educated if compared to the average. In a rural community where there are no jobs from the beginning, young people who receive training or education will, if opportunity is given, move to somewhere they can capitalize on their new found skills. This has turned out to be the case especially for electricians, mechanics and other maintenance personnel.

The type of human capital required is of course dependent on the type of business. Examples of skills needed are machine operators, machine maintenance and administrational personnel. The appearance of new businesses is also dependent on encouraging the entrepreneurship in the local population. As de Soto (2009) suggests, entrepreneurship is common in developing regions. Creativeness in ways to make a living is even further developed there than in the industrial world since survival may depend on it. Turning entrepreneurship into local economic growth is a matter of education and improving conditions for investments.

3.3.3. **Micro-credits**

The main principle of micro-credits is to give poor people the possibility to realize their ideas on how to start or expand their business. It is based on the idea that if funding is donated as start-up capital with no pay-back requirements, there is less incentive for the operator to make it into a viable business, which has been indicated by several studies (Hashemi et al., 1996, Pitt et al., 1998).

An entrepreneur is someone who sees possibilities to expand or create a new business. He or she realizes that there is a demand for a service or product here that can be executed or produced with the right input or work and materials. In order for the entrepreneur's idea to turn into a business, he usually needs a capital investment, which can either be his own savings, a donation or a loan. Since the success of the Grameen-bank initiative in Bangladesh (Hashemi et al., 1996), micro-credits have gained attention as a serious partial strategy for poverty reduction. The idea is to give small loans

with low interest and long pay-back periods, with the purpose of creating jobs and spurring local microeconomic development.

Many development intervention projects start with an assessment of the needs by the interventionist, often an NGO. With an outside assessment as a starting point, there is always a risk that faulty assumptions are made and that local and cultural factors are overlooked. Since a large portion of the population of rural developing areas is involved in agriculture, bringing subsistence agriculture to organized agro-processing activities is a common goal, investing in equipment for value-adding activities. Business development in rural developing regions is most often capital intensive – any form of food processing or other type of equipment of machinery requires capital for a start up investment. This is certainly true for renewable energy technology equipment, and the best policy to support this type of business development is to improve access to capital through credit programs (Daniels, 2003).

After the success stories of the Grameen bank and some other early programs in the 1980s, micro financing has been criticized and questioned as an effective tool to reduce poverty. The background to this is that although some of the pioneer programs were successful, some attempts to duplicate them in other places failed. It was suggested by pro-microfinance scholars that microfinance institutions that follow the general advice for good banking, will both turn a profit and be effective in reducing poverty. This notion has however not been backed up by any strong empirical findings (Morduch, 2000). There is a trade of between financial sustainability and good loaning conditions. If a micro-financing program has low interest rates, it can be more generous to whom it can grant credit, and more poor households can be included in the program – if the program loses money it can be covered by subsidies from donor organizations or the government. On the other hand, with higher interest rates the financial sustainability of the program can improve, which makes the program able to help more households over more time, and the subsidies can be used for to start more social and financial programs. Higher interest rate also gives stronger incentive to work hard on the business and turn a profit, but it also leads to higher risk of failed businesses and indebting credit recipients. Morduch (2000) suggest that the way forward for micro-financing is to find a middle ground, lowering subsidies to programs but not taking them out, increasing interest rate to have a strong incentive for management, but without excluding too many households, and to have more focus on loan recipients and what they use the loan for.

Some development countries do not always have the administrational capacity to have complete coverage in registering people's assets, so many people in the rural areas in particular, have no way of proving the land they live on or the cattle they have are their own assets. This makes it impossible to get financing from most banks, since they require people to put up registered assets as collateral. (de Soto, 2009). Some micro-finance institutes have therefore developed methods to get security for their loans using by accepting non-registered assets as security. This can only be done with in-depth knowledge in the local society, which usually have ways of keeping track of peoples assets in the community, albeit informally (Aryeetey, 1998,). This problem with unregistered assets and the lack of productivity of capital is further discussed in the next section.

3.3.4. The creation of capital from dead assets

The problem with security for loans is something all financing institutions that operates in the third world faces. Without a secure system of property rights, few of the credit-givers will enter into agreements where it is not certain that the prospective credit recipient can or will pay the loan back. A common situation for the majority of the population in the third world is just this – they have assets, for instance kettle, houses, patches of land etc., but they have no official document stating that they are the rightful owner of said assets. This is sometimes referred to as low productivity of capital. Without legal assets, a financing institution has no legal way to make someone pay back a loan – if you have no assets you are bankrupted from the beginning. To these problems with working legal property rights, development economist Hernando de Soto attributes the failure of capitalism as an economic system in the post-cold war third world and ex-communist countries. The problem that there is no financing, loans or credits available for entrepreneurs of the rural development regions may not only be the lack of suitable micro-financing institutions like the Grameen bank of Bangladesh, but one step further back; even if there are financing institutions, very few of them are going to be willing to give loans or credits to people with no formal assets, i.e. no security. Assets that have no legal bond to their owner can never be used as capital, and can therefore be seen as "dead assets". The registering and titling of assets can then be seen as one way to create capital (de Soto, 2009).

3.4 Rural electrification and renewable energy systems in a developing context

If the problem with dead assets and low productivity of capital represents one piece of the puzzle to why there is no economic growth in rural developing regions, the outlines of another piece can be seen in the private sector's complains of lack of infrastructure for business activity in general, and energy and electricity services in particular.

The types of business activities that can take place in a modern society without access to electricity are limited, also so in a developing country. However, what often motivates governments in developing countries and the international aid community to spend resources on electrification projects is the social services possible with electricity access. Two examples which are often put forward are the possibility to keep vaccines refrigerated in remote local health clinics, and to provide lighting to conduct evening classes in schools for people that need to work in e.g. agriculture during the light hours (FUNAE, 2014b)

There are many types of electrification projects, but some categorizations can be made. When the government together with foreign partners launch electrification projects it is usually about extending the coverage of the national grid of distribution lines, or projects of maintaining and restoring the nation's power plants. The areas far from the national grid are dependent on so called off-grid solutions. These can be either in the form of a micro-grid, which are some form of central generation (solar PV-panels, mini-hydropower) and a small grid of distribution lines to households, stores, schools etc. Small scale electrification can also be isolated solutions to individual houses, most often in the form of solar PV panels on the roof. Isolated small industries in need of energy most often use diesel driven generators, which are also sometimes used to power micro-grids.

At present only about 13.2 per cent of the population in rural Mozambique has access to modern electricity (Cuvilas et al., 2010). The number is disputed, since the ministry of energy views access to electricity as a possibility to connect to the national grid, and claims to have numbers as high as 30-35%. However, other estimates on the access to electricity in the rural regions to be around 1%. Grid extension projects happen but for many Mozambicans it is unlikely to come to their village during their lifetime.

Since these projects are expensive, the undertakers tend to choose which parts to be electrified based on where it can be done cheapest and where the utility of the service can be maximized, i.e. where there is already a customer base for electricity services or where companies have shown interest in developing some business activity, so local jobs can be created. This can be for example areas where natural resources of some sort have been found, which attract companies interested in mining or extraction (Cuvilas et al., 2010). Rural areas where subsistence agriculture is the main livelihood for people are therefore unlikely to be reached by extension of the national grid.

Due to economies-of-scale-effects, prices on the various technologies of renewable energy have dropped and become more accessible (Gross et al., 2003). Renewable energy systems (RES) possess some important advantages over the other alternatives to rural electrification. Diesel generators can be made out of converted used tractor engines for example, and may be cheaper but will always require the logistics to provide them with fuel, spare parts and regular maintenance, which can be a problem in remote areas. Renewable systems, like solar panels, require no fuel and minimum maintenance once installed, although for a higher initial cost per capacity. In table 3.4.1 some of the advantages and disadvantages of the different technologies discussed are compared.

The included renewable technologies in the table are the most commonly used and discussed in rural development contexts. Technologies like wind power and biogas and newer renewable technologies like ocean energy (tide and wave power) are excluded because they are still in an experimental phase in many developing countries (Hammar et al., 2012). Although for Mozambique, for example, there have been studies done finding excellent possibilities for developing all the mentioned renewable energy technologies. (Tinarwo, 2008)

Table 3.4.1. *Advantages and disadvantages of the different technologies compared*

	Investment	Reliability	Flexibility	Maintenance & logistics	Business possibilities
Diesel generator	Relatively low, high power output per invested dollar	Good, depending on the quality of equipment bought.	Medium.	Required fuel supply, spare parts, maintenance personnel	Basically all, incl. Small to medium industrial activities
Solar PV	Medium	Depends on battery capacity, Enough for some uses, problematic for others. Also depends on local environment and weather conditions	High. Start out with a small system and add more when needed.	Minimum maintenance.	Lighting, water pumping, water heating small electrical appliances, small scale refrigeration.
Mini-Hydropower	Relatively high	High	Medium (site dependent)	Regular maintenance	Basically all, incl. small to medium industrial activities
National grid extension	Very high	Low. Frequent power-outs	None	Regular maintenance	Most type of business that isn't severely affected by power-outs

It may be difficult to motivate the extension of the national grid to an area only based on what economic activity might appear once there is access to electricity. An advantage with some renewable technologies is the flexibility, that small scale economic activity can be started up using for example solar panels – just enough of them to provide the electricity needed. When electricity is introduced the population learns about the different uses and may become interested in using it in their homes. This way a demand for electricity is created, which can help motivate either a grid extension or an extension of a renewable system, like a small scale hydropower plant, if it is suitable for the location (Carnicier et al., 2013; Tinarwo, 2008; Chel & Kaushik, 2010). A more extensive

review of the technical and economical advantages and constraints of a set of renewable technologies can be found in Kishore *et al.* (2013).

The lack of purchasing power for electricity is also the main reason the private sector actors mention, when asked why they don't want to invest in rural energy services. The lack of knowledge about the possibilities with electricity among the population makes the appearance of business ideas involving electricity rare. Both these factors lead to a lack of job opportunities (Ahlborg, 2012).

3.5 Bi- and multilateral aid funds

Rural electrification projects of all kinds are often financed, either directly or indirectly, by bilateral and multilateral aid funds. These injections of funds also have great impacts on the national and local economic systems which is the focus of this study.

Political trends govern the strategy for international development aid between countries and organizations. There was the de-colonization of many countries in the southern part of world in the 1950s and 60s when the distinction between 'developed' and 'developing' countries was first made. Initially, the focus was on the macro-economy of these nations. When the budget support to the post colonial governments didn't seem to have much impact on poverty, a shift of focus took place to social considerations such as health, education, income distribution, gender equality etc. This was a reaction to the former unsuccessful strategy, but also to the crises caused by the rise of food prices in Africa as an effect of the oil crisis. In the 1980's, a neo-liberal political wave in the industrialized world put pressure on the heavily indebted developing countries to make structural changes like deregulation and privatization of parts of the public sector, hoping that capitalism would be of such service to the developing countries as it had been to the western world (Emmerij, 2002).

This background has led to a diversification of the international donor community. Bypassing the national governments by giving support to organizations who work with development on the ground has come more popular, to avoid aid money getting lost in corruption and dysfunctional institutions of national governments. Aid is categorized in terms of *bilateral* and *multilateral* aid

Bilateral aid is support from one government to another, usually aimed to reduce poverty and fulfill basic needs of people like food security, access to water and health services. It is the government of the recipient country that is responsible for distributing funds and initiating projects, sometimes accompanied by expert advice in management and organization from the donor country.

Multilateral aid is when funds are given to multilateral organizations, such as the World Bank or different United Nations agencies (UN Development Program, UNICEF, UNHCR et c.), who receive funds from many donors and distribute them in many recipient countries, sometimes in the form of development projects. This way the sometimes ineffective bureaucracy of the national governments is bypassed.

Mozambique, as an example, is one of the largest recipients of both types of aid in Africa, partly as a consequence of the devastating civil war from 1977-92 which destroyed industries, infrastructure and displaced vast amounts of people. (Funada-Classen, 2013)

A problem with donated aid funds is that they usually increase whenever there is a crisis, and the funds end up going to relief work. Preventive long term work of crisis preparation and restoration of society after a crisis are less popular because they call less immediate attention.

Aid to developing countries has been strongly criticized by scholars and politicians from left to right, questioning the development aid's ability to stimulate economic growth, reduce poverty and improve quality of life. Recent meta-analysis of the vast amount of publications on the subject shows that there is a statistically established positive link between aid and economic growth (Mekasha & Tarp, 2013). However, the macro-economic growth may be concentrated to a few large firms, as opposed to diffused among the population. Thereby it has little impact on human development and quality of life factors, leaving the majority in the rural areas of developing countries unaffected (Boone, 1996). As a result of this criticism, many donor governments and international aid organizations choose to redirect aid funds from supporting developing countries' national budgets, to multi-lateral aid – direct support to organizations working with specific development projects.

It has been argued that the ability of aid funds to reduce poverty is connected to the quality of the institutions that administer their delivery. If the institutions are formed without a thorough understanding of the complex relationships between the stakeholders and actors, they may create incentives that make projects inefficient and unsustainable (Gibson et al., 2005).

These findings are interesting in this context, because they indicate the necessity of a deeper understanding of the dynamics in the economic system which is subject to a development intervention, in order to be effective. In the beginning of this chapter, system dynamics and technological innovation systems theory were discussed, which are tools to achieve this type of understanding.

Another important ingredient in system understanding is the confirmation of theory with collected empirical data, which is accounted for in the following chapter.

4. Results from the interview study

In the first section of this chapter, some key dynamics of the movement of funds and information that was interpreted from the interview study in Mozambique will be described. The interviews are analyzed and used as input for the construction of the causal loop diagram (CLD), which is presented in the next chapter.

In the following sections, a reference to interview x will be written as "IR X" – Interview reference x.

A list of the interview subjects:

1. Swedish embassy, electrical infrastructure division representative.
2. Director of private firm investing in Rural electrification solutions
3. Self employed engineer who often consults for energy ministry and FUNAE
4. Director of private firm in food processing (cashew nut) in Nampula region
5. NGO and small micro-finance institute representatives
6. Agro-business consulting firm, founder
7. FUNAE (national energy fund) representatives
8. FDA (national Agricultural fund) representative
9. FNI (national research and development fund) representatives
10. Energy ministry, renewable energy section representative
11. Representative of Belgian NGO supporting FUNAE
12. Founder and vice chairman of ADECH, rural agricultural community cooperative
13. Local inhabitant, farmer, kettle-owner
14. Local inhabitant in village with both on-grid and off-grid electricity supply
15. Inhabitant of rural off-grid community, cattle owner, farmer
16. Doctoral student in renewable energy, consultant for Energy ministry
17. University professor in Renewable Energy, firm director of renewable energy solutions

4.1 Structural problems of institutions in developing countries

In many developing countries the institutional structure is not optimal for serving the needs of the population today. In some cases the organization of the administration was once optimized for serving a large export sector of natural resources and other products in a colonial context, and has failed to adapt to the new situation being a developing country highly dependent on foreign aid and foreign companies' investments. Mozambique is one of the largest aid recipients in the Africa, and most of the received funds are bilateral budget support. Sometimes the aid funds are earmarked for a specific sector, like health, education etc. (UNICEF, 2011). In that case the funds go directly into these ministries, for them to develop projects and distribute funds to where they are most needed. One idea behind this is that if the authorities are bypassed, they will never learn to manage on their own [IR 1b]. The sector ministries are often supported with expert consultants from many donor countries to help achieve the desired effect.

Two problems are recognized from this order of things: lots of money disappears down the ladder in due to corruption, and the division of work and lack of cooperation between ministries impedes the development of coordinated efforts between the sectors.

4.1.1. The Top-down perspective

Some of the money distributed by the government goes to the various national funds. The aim of the national funds is usually to provide financial support to projects aligned with the political goals within the different sectors, in some cases in the form of pure support and in some in the form of microloans. Here the problem with non-synchronized sector efforts becomes obvious. An example is the projects for electrification of schools and health clinics that the national energy fund FUNAE has been developing and financing. FUNAE has a central role in rural development in Mozambique, since the lack of electric energy is constraining further development of other services like health and education. Ideally, for example the electrification projects of health clinics by FUNAE should be coordinated with parallel efforts by the Ministry of Health or local health authorities, ensuring that the clinics are equipped with educated staff and supplies. Due to lack of involvement of the health and education authorities on local, provincial or national level, the projects have struggled immensely with moving forward and with follow up issues like making sure the new installations are used properly. [IR 7]

FUNAE is one of Mozambique's national funds, organized directly under the Ministry of Energy and it is declared in their mission from the government that they should strive for "Development, production and use of different forms of low cost power, and to promote the conservation, rational and sustainable management of power resources." (FUNAE, 2014a)

Some of their activities are "to supply financial assistance or financial guarantees, loans to enterprises that have as their objective the production, dissemination of production techniques, distribution and conservation of power in its diverse forms" and "install systems of production or distribution of power." (FUNAE, 2014a)

Similarly, the FDA (National Fund for Agricultural Development) sorts under the ministry of Agriculture and has their objective declared as follows:

- "Promoting access to financial services for farmers and agricultural enterprises, strengthening of inputs and products to support agricultural production markets;
- Promoting partnerships between government institutions and other stakeholders in the agricultural sector;
- Promotion of activities that contribute to the implementation of policies and strategies that encourage farming in the country." (FDA, 2014)

There are similar funds below the Ministry of Fisheries, Ministry of Science and Technology, Ministry for Environmental Coordination and Action and the Ministry of Tourism, among others.

The formulation of the mission given to these national funds poses several problems. It is stated that they should "provide access to financial services" or "supply financial assistance, financial guarantees or loans", which is interpreted as that they should in some cases support a project with financing and

expertise, and in some cases provide a project owner with a microloan. Usually the division is done so that what is considered social projects – e.g. involving schools, healthcare, providing clean water – are given financing and are not required to pay back. Projects that involve commercial activity, even on a very small scale, are required to set up a payment plan, albeit with low interest and long payback periods. This financing in the form is what development scholars consider a good form of aid distribution; projects receiving unconditional financing support are less likely to succeed due to the lack of incentive to make the business viable (section 3.3.2). The problem is when the same institution has to take on the role of aid distributer in some cases and bank in others, sometimes in the same village. This is perceived as unjust, a perception that is strengthened by the fact that this is happening in a country with high levels of corruption; suspicions of misuse of power arise quickly and the institutions' credibility drops. For this reason, FUNAE in Mozambique has suspended or decreased their giving of micro-credits [IR 7].

Another problem with these objectives is that the funds are not prompted to cooperate with one another. This flaw is obvious in sectors that depend on each-other, like energy and agriculture. Several studies have shown success in electrification projects linked to the degree of productive use of electricity on a local scale (Ahlborg, 2012; Hammar et al., 2012; Ahlborg et al., 2009).

STOP 16.05

4.1.2. The Bottom-up perspective

Since the by far most common productive activity in rural developing regions is agriculture, the connection should be made to food-processing – value adding activities to agricultural products using electrical energy or, for instance, water pumped by electricity. This is exemplified in the case of Chitondo village in Inhambane, Mozambique, where agro-processing activities were made possible through the provision of fresh water by a solar-PV driven deep water pump [IR 12]. Another example of the interdependency of these sectors is the efforts of SEPPA consulting, a small local consulting group applying for financing from the agricultural fund (FDA), to develop agro-processing activities in more or less remote rural communities of southern Mozambique. The extent to which they can help communities develop these activities is constantly limited by the access to the national grid. Electricity is needed to power refrigerators for meat and dairy products, for operating machines and provide lighting, among other things [IR 6]. Meanwhile, FUNAE installs micro-grids with power from solar photovoltaic (PV) panels in other localities, declaring that the impact on quality of life and poverty is limited due to lack of productive use [IR 7].

Another limiting factor is the different criteria that a project needs to meet to qualify for financing. The national funds showed a reluctance to finance projects that reached outside their sector, and the interest rate, payback periods and amortization terms differ between the funds giving loans. This combined with the different application processes from different funds makes for a certain level of complexity to receive loans for projects solving common problems. If an entrepreneurial farmer wants to process his products, for instance he wants to sell shelled groundnuts and peas instead of unshelled, to increase his profit (with the shell removed from groundnut and for example cow peas, they can be used as input to further food processing industry). If he lives in a remote rural community without electricity, he needs a loan for the shelling machine and for a power source, for instance solar PV panels with certain battery capacity. If there are more entrepreneurial farmers

having similar ideas for their products, in some sites the conditions are good for small scale hydropower installations. With today's complexity of funding structure, he is unlikely to receive the help he needs to apply for loans, if he has even heard about the funds.

In the village if Chitondo, Inhambane state, Mozambique, the inhabitants until recently had to walk nearly nine kilometers to get fresh water every day. Not until one of the village inhabitants had left the village to attend the university in the capital that he heard about solar PV powered water pumping. This would of course be a tremendous relief to the community. Being an entrepreneur, he also saw possibilities of creating jobs by engaging the community in food processing made possible by the access to fresh water and electricity. He started to seek contact with the various national funds to seek support for financing, and soon ran into trouble. He kept trying persistently, learning the art of writing adapted applications as he went along. The result, some 10 years later, was the following: [IR 12]

The local authorities agreed to finance the deep drilling of wells in the community, the national energy fund (FUNAE) financed the Solar PVs and electric water pumps and the national research and development fund (FNI) financed machines for food processing so a production centre could be opened. Today the struggle continues to find financing for better packaging solutions, and to extend the water pumping. The ground water pumps and the electrical system to power them were dimensioned to supply the village inhabitants with water, and has 4 solar panels of about 40 kW each, and a 10 m^3 tank for water storage, elevated approximately five meter on a steel structure. When the sky is clear, the pump manages to fill the tank in about 4 hours. Shortly after installation, families from neighboring villages started to come with their empty containers to fetch water for themselves and their livestock, which resulted in a higher demand than the capacity of the pumping system, could meet. This is now temporarily resolved by adding extra pumping capacity with electricity generated from an old rebuilt tractor engine serving as a diesel generator. The pumping is switched over to the engine when it is rush-hour or during cloudy weather. The community is waiting on funding to extend the electrical capacity of the system, or for systems to be installed in the neighboring villages, where the inhabitants now have to get their water from the Chitondo well. Aside from providing water for the people and livestock, the inhabitants use the water from the well for small scale irrigation of vegetables, and to process and refine some of their products. One example is manioc (cassava) flour biscuits, which are sold in the PetroMoz gas stations along the route to Maputo. They also produce fruit liquors, jams and jelly [IR 12].

The relative success of the Chitondo community with help from the national funds is not common, for several reasons. The first action that was taken was the local authorities (district board) paid for the deep drilling of wells. The open holes stood for two years because there was no solution for pumping available. A hand pump would not be able to provide enough water for all the families, a diesel pump would constantly need diesel which is expensive and had to be brought from far away, and there was no national grid to supply an electrical pump. Few people knew about the possibility to pump water with solar energy, and no one had heard about the possibility to apply for funding to install it from the national energy fund (FUNAE). To make this project happen one individual had to familiarize himself with the application process to three different funds, who even after the projects proven success are still unwilling to continue to finance extension of the same project. To write these applications and learn the process requires a certain level of education, especially if the starting point

is population with 40 per cent analphabetism as a national average, and the most of this being found in the rural areas. Many individuals who have managed to receive the necessary education leave the rural communities as have been discussed in section 3.1.1. The example of Chitondo describes a bit of the resistance and friction by which entrepreneurial rural initiatives are met in the current system. This resistance and friction is represented by the variable “complexity of national funds” in the upcoming system model.

5. System modeling - Causal loop diagram

The results from the interview study and literature review were interpreted and analyzed, and used as input for the construction of a Causal Loop Diagram, following the method described in section 3.1. Variables were identified that are found to have effect on the central problem of this study: The lack of local economic growth in the rural developing communities. Some variables were indicated directly by interview subjects or found as results from previous studies, some were identified as a result of the analysis.

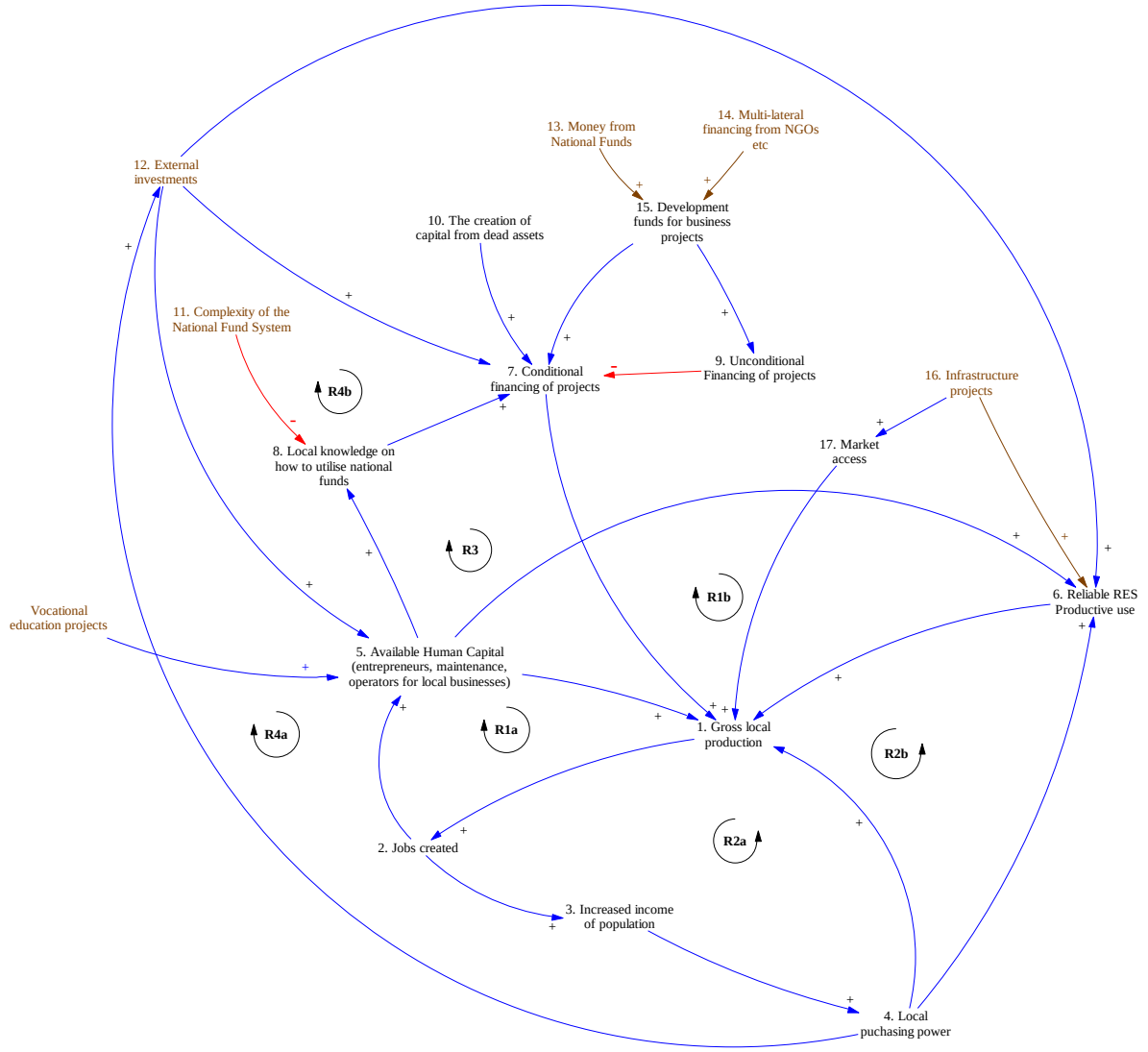

Figure 5.1. Causal Loop Diagram. The variables, connections and loops are described in the following section.

5.1 Variable specifications

1. **Gross Local Production:** The sum of all economic output generated by businesses in the community. This variable includes both the starting of new businesses and the expansion of already existing (local and foreign) businesses. The dependency on the variable “Conditional

financing of projects" may be stronger for the opening of new businesses, but is still relevant for old businesses as well in the problem of concern (if the type of expansion referred to is to contribute to economic growth). Different types of business may also have different strength of the connections to the other variables, e.g. different businesses have different dependency on electricity infrastructure.

Positive links:

- 1. Jobs created

References: IR 17, 13, 12, 6, 3 and section 3.3

2. **Jobs created**: The amount of paid job opportunities in the community.

   Positive links

   - 4. Increase of the population's income
   - 6. Available human capital: Job opportunities may attract skilled labor from outside the community and help to get those who are from the village to start.

   References: IR 16, 12, 6, section 3.3 and 4.1

3. **Average income of the population**

   Positive links

   - 5. Local Purchasing Power

   References: IR 16, 14, 12, section 3.3

4. **Local Purchasing power:** As the income level in the community rises, the inhabitants become consumers of internally and externally produced goods and services.

   Positive links:

   - 1. Gross local product
   - 12. External investments: An increase in the amount of external investments increases for the same reason, more local consumers makes the community more attractive for investors.
   - 6. Reliable RES electrification: A recognized reason why the private sector do not invest in RES in the rural regions is that the lack of purchasing power among the inhabitants will make cost recovery for electricity services difficult. With this barrier out of the way, the private sector is likely to be interested.

   References: IR 4, 2, 16, Section 3.3, 3.4 and 4.1

5. **Available Human Capital**: The local availability of skilled workforce, either by education, training or experience. The type of workforce most interesting may be in maintenance for electrical or production installations, operators and administrator/economists for local businesses, people able to initiate application process for money from national funds, and entrepreneurs. This variable is dependent both on how much training and education that goes on locally, and on the community's ability to attract workforce from outside by for example job opportunities.

   Positive links:

- 1. Gross local production: the presence of entrepreneurs leads to more business opportunities explored by new and old firms.
- 6. Reliable RES Electrification: With more available maintenance personnel the reliability of any installed system will go up.
- 8. Local knowledge on how to utilize the national funds: The more people with higher education that are attracted to the community, the more people who are able to understand and apply for grants, loans etc. from the national funds, and for loans from the conventional banks.

References: IR 12, 4, 17, 6, section 3.3, 3.4 and 4.1.

6. **Reliable RES for productive use**: Refers to the availability of renewable electricity services usable for productive activities, which is dependent on investments by private firms, public investments, the presence of maintenance personnel, logistics for spare parts, power production uptime, etc.

   Positive links:

   - 1. Gross local production: When more households and businesses are electrified, the necessary infrastructure is in place to launch new business ventures; dairy products, frozen fish and meat, cold drinks, food processing, etc.
   - 13. External investments: It directly affects the amount of outside investments since an area with electrical infrastructure is more attractive and provides more business opportunities.

   References: IR 12, 13, 3, 2, 4, 16, 17 and section 3.3, 3.4, 3.5 and 4.1

7. **Conditional financing of projects**: Loans, credits or other types of financing that you need to meet some kind of condition to qualify for. Projects that are financed this way have a higher success rate due to the incentive to make the business viable.

   Positive links:

   - 1. Gross local production.

   References: IR 12, 5, 7 and section 3.3.

8. **Number of inhabitants capable of utilizing the national funds:** A certain level of education and/or experience is necessary to understand the complex system of national development funds, described in section 4.1 and in this section below variable 11. Complexity of the National funds. Complexity of the National Funds. This variable reflects the amount of people in the community who are able to push an application process to receive funding for projects.

   Positive links:

   - 7. Conditional financing of projects.

   References: IR 3, 12, 7 and section 4.1

9. **Unconditional financing of projects:** For some projects financing is provided from the government or elsewhere without any condition to fulfill, or any requirement to pay back – in short, funds are donated instead of lent. Experience and research has shown that this is a

strategy that has positive long term effects for social services and fulfillment of basic needs, for instance clean water provision, health and education services, etc. For projects that are meant to enhance economic growth and create jobs, this is a poor strategy, since it does not give the local operators of the project strong incentives to make the business project viable. If the leaders of the project have sought financing for their own idea, and ventured risk with their own capital to receive financing, they are more likely to succeed. Noteworthy is that there is no link in the system model connection between variables 10. Unconditional financing of projects and 1. Local Economic growth, or with 2. Possibility to start or expand businesses, this is because field experience and research show that the connection is very week if it can be found at all.

Negative links:

- 7. Conditional financing of projects: The causality here is that funds that are used for unconditional financing of business projects *is not used* for conditional financing (like micro credits), which would have better effect.

References: IR 5, 2 and section 3.3.

10. **The creation of capital from dead assets:** Refers to capital in the form of unregistered assets, for example houses, livestock and land, which are registered as formal assets and made available for use as collateral for loans from organizations and banks. This is sometimes referred to as the productivity of capital and is further explained in section 3.3.4

    Positive links:

    - 7. Conditional financing of projects: If a larger portion of the inhabitants' assets are registered, they can be used as collateral for loans and credits, which makes it possible to qualify for financing even from private banks.

    References: IR 6, 13 and section 3.3.4.

11. **Complexity of the National Development Funds:** The National funds in Mozambique are financing institutions that distribute donated and governmental funds to support development projects. Each fund has a mission to support projects in a specific sector, for example energy, agriculture, education etc. Each sector is governed by a ministry, which also controls the national fund of that sector. Thus, the responsibility is divided between the national funds on a basis of development sector, e.g. the National Fund for Agrarian Development is under the Ministry of Agriculture. Many rural projects require a wide range of experience and competences from different sectors to succeed, for instance the water pumping example in section 4.1.2, which creates a complex situation on the ground for financing development projects. Added to this is the complexity that comes from the unclear mission statements for the funds, as to which type of projects should receive conditional and unconditional financing.

    Negative Links:

    - 8. Local knowledge on how to utilize the National funds. Se explanation above and for variable 12.

    References: IR 12, section 4.1

12. **External investments:** The amount of investments by private firms from outside the community.

    Positive links:

    - 1. Gross local production: invested capital in local businesses can help them expand
    - 6. Reliable RES electrification: Since there is no given energy solution to a new business venture in the community, the outside investment could include investment in small scale energy production for its own business and sell the excess electricity on the market.

    References: IR 16, 17, 7, 6 and section 3.3 and 3.4

13. **Money from National Development Funds:** National funds distribute donated and government funds in their respective sectors, sometimes in order to support local businesses in order to enhance local growth in the rural regions. These funds are either distributed as pure budget support to business projects or in the form of a loan with a pay-back plan, acting as a micro finance institute. The latter form of fund distribution is uncommon even though it is included in the national funds' mission plans. Some examples of such funds in Mozambique are FDA (agriculture), FUNAE (energy) and FNI (Research & Development)

    Positive links:

    - 15. Development funds for business projects

    References: IR 7, 8, 9, 12 and section 3.3 and 4.1.

14. **Multilateral financing from NGO's etc.** Non-governmental aid organizations sometimes support development projects with funds directly, bypassing the national government. These funds are, as in the case above, delivered either as direct financial support of in the form of credits and loans. See section 3.3.

    Positive links:

    - 15. Development funds for business projects

    References: Section 3.3

15. **Development funds for business projects:** Funds that are earmarked for projects aimed at local economic growth, support of small businesses, micro-credits, job creation etc., i.e. not aimed for social service projects.

    Positive links:

    - 7. Conditional financing of projects.
    - 9. Unconditional financing of projects

    References: IR 1, 2, 3, 12, and section 3.5

16. **Infrastructure Projects**: The government, and sometimes NGO's, undertakes infrastructure projects ranging from national electricity grid extension to the construction of roads, air- and seaports, etc. Through the national development fund under the energy ministry they have also launched projects involving renewable energy technologies, most commonly solar photo-voltaic panels and mini-hydropower stations. These projects are usually launched to provide electricity services to households, health clinics and schools, but can lead to a

diffusion of knowledge about electricity and sow ideas for businesses. They can also provide the small electricity access necessary to test their ideas and encourage further investments. It should also be noted that some companies in the energy sector, mostly in the business of exploring fossil energy resources, contribute to the development and diffusion of renewable energy technologies, often as a manner of corporate social responsibility (CSR).

Positive links:

- 6. Reliable RES electrification
- 17. Market access

References: IR 1, 7, 10, 16, 17 and section 3.3 and 3.4

17. **Market access**: Infra structure projects such as roads connecting the community with transnational highways and seaports can make it possible for local products to be sold on a regional, national or even international market. It can also be necessary for small and medium businesses to upsize, since they may need to import supplies for packaging, etc.

    Positive links:

    - 1. Gross local production

    References: 7, 10, 6, 16 and section 3.3 and 3.4

5.2 Feedback loops

R1a: The Job-creation Loop

- 5. Available Human capital
- 1. Gross local production
- 2. Jobs created

The local economic output is produced by local businesses. Many entrepreneurs and proprietors of small enterprises claim that a barrier for expansion of their business is lack of access to human capital, i.e. skilled employable workforce. Local workers with experience or training will only stay in the community if there are jobs available, which there only is if there are businesses to employ them.

R1b: The RES Capacity-Loop

- 5. Available human capital
- 6. Reliable RES Electrification
- 1. Gross local production
- 2. Jobs Created

The lack of maintenance personnel has been established as a barrier for reliable RE service, and to the willingness to invest in new system. Available human capital includes availability of maintenance personnel locally.

R2a: The Growth-Loop

- 1. Gross local production
- 2. Jobs created
- 3. Increase of population average income
- 4. Local purchasing power

Increased local production leads to increased income of proprietors and workers in the local businesses. Increased income leads to an increase of the local purchasing power, which provides the local businesses with more costumers able to spend. This leads to the birth of new businesses and to increased profit of old businesses.

R2b: The Viable RES-Loop

- 1. Gross local production
- 2. Jobs created
- 3. Increase of population income
- 4. Local purchasing power
- 6. Reliable RES Electrification

The link between local purchasing power and the private and public sector investing in electrification has been established by Ahlborg (2012), the lack of local purchasing power has been seen as a barrier to electrification.

R3: The Financing-Loop

- 5. Available human capital
- 8. Amount of people able to utilize national funds
- 7. Conditional financing of projects
- 1. Gross local production

A certain level of experience, literacy and education is necessary to be able to push through an application to one of the national funds, and people who have this experience are more likely to have knowledge of the existence of the funds. If the local community has the capacity to access these resources, more entrepreneurs can get access to the start-up capital they need to launch new businesses. This leads to an increase in the gross local production.

R4a: The Human Capital-Loop

- 4. Local Purchasing Power
- 12. External investments
- 5. Available Human capital
- (links in with R1a and R2a)

Outside investments in local businesses and also outside businesses expanding and creating jobs is likely to happen after the Local purchasing power go up. Outside investments in turn attract skilled labor.

R4b: The Attracting Financing-Loop

- 4. Local Purchasing Power
- 12. External investments
- 7. Conditional Financing of projects
- (links in to R3, R1a-b and R2a-b)

Outside investment also provides the opportunities for local entrepreneurs to get investors in business projects from the private sector, i.e. conditional financing. It is likely that this mechanism

sets in after a while when the system has matured, in the beginning the local entrepreneurs will not be able to take loans on the conditions the private sector offer, which is a recognized barrier (Ahlborg, 2012, IR 2, section 3.3.1). In the beginning, financing needs to be provided by other institutions, e.g. micro-credit institutions (section 3.3.3).

5.2.1. **Time scales**

The feedback loops that involve electrification infrastructure may happen in a slower pace in relation to R1a and R2a, since installation, financing and competence building may take time. The loop R4a may also have a longer time scale since it depends on external investors who predict there will be a continuous growth trend in the community in order to be willing to venture risk. R1a, R2a and R3 is likely to move at a quicker pace since there is usually a high demand for jobs, and local entrepreneurs may already have ideas on how to expand and initiate businesses but have been held back by limiting factors.

5.3 **Background system**

The background system is a description of some background mechanisms, including resource flows that affect the rural community system described in the system model in the previous section.

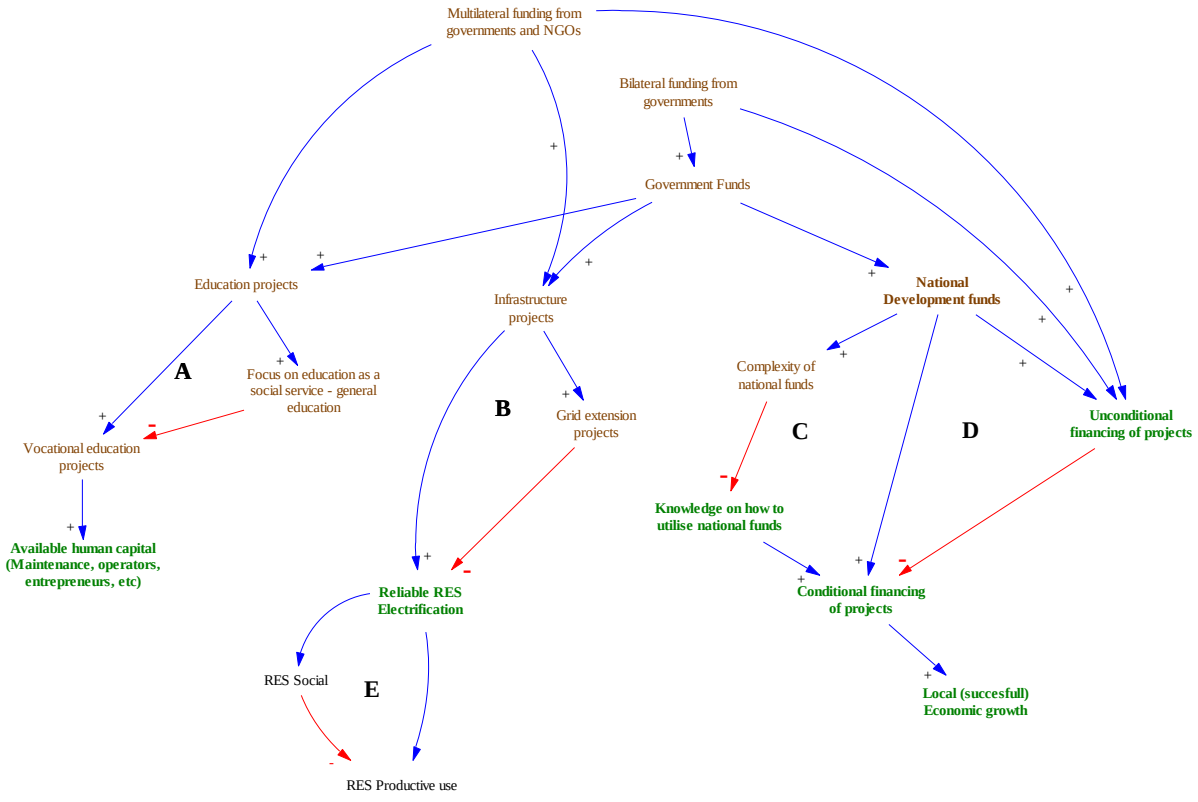

Figure 5.4.1 Background tree diagram

Four mechanisms believed to affect the functions in the rural community system are identified

A. When education projects are undertaken by the national Ministry of Education or by some NGO, it often concerns general education and is seen as a social service. These projects are

motivated by many studies showing a correlation between education level and many positive externalities in health, equality and general quality of life, etc. A type of educational project often forgotten or left behind is vocational education projects, focusing on developing skills that the local businesses may require. When these types of projects are launched, they unfortunately often show a lack of coordination with the local businesses; these projects are only valuable if they produce human capital that is put to work, otherwise the community will be drained on skilled workers. This mechanism links in to the variable 6. Available human capital (Section 3.3.1, IR 2, IR 12)

B. It is recognized that under-development in rural regions of developing countries is in part caused by lack of infrastructure, for example electricity, roads, clean water, et c. Electrification projects from the government side most often concern grid extension, which leaves large parts of the areas behind – they are simply so isolated that grid extension is not possible in the foreseeable future. If more funds were earmarked for RES electrification projects, remote rural areas could be included in the development. There is also a migration from communities without electricity access to communities that are connected, since there is easier to find work. (Section 3.3.1, 3.4, 4.1, IR 17)

C. The problems with sectoral division of areas of responsibility between the National development funds have been introduced in section 4.1.1 and 5.1. Most development projects require competences from different sectors, for example agriculture and energy, education and health, etc. Therefore, in order to apply for financing for a project, one may have to turn to several different institutions to apply for funds. Another mentioned problem with the funds is the double role they sometimes have to take on as both distributors of donated funds and a micro-credit institute – the perception on the recipients' end is that some projects get free funds while some projects get pay-back plans, which is often attributed to corruption which leads to the fund's administration losing credibility. Added to this is that the process of application is often complicated. People who are sufficiently educated and experienced to be able to push through an application process generally don't need money from the national funds nor do they live in the poor communities which are the intended beneficiaries (IR 5, 7, 12, 17, section 3.3.1)

D. The problems with unconditional financing are described in section 5.1, variable 10.

E. When RES projects are launched, either as a governmental electricity access improvement program, experimental installation, NGO or Corporate social responsibility (CSR) initiative, the selection of renewable energy technology is based on the presumed use of the provided electricity service. If the purpose is only social service, including lighting for schools, households and lighting and small scale refrigeration for health clinics, the choice of a solar PV system may be preferable. As is explained in section 3.4, different renewable technologies are preferable for different purposes. Most often the purposes differ in their sensitivity to intermittency in energy supply. For instance, a solar PV powered deep water pump can fill a tank with water whenever there is enough solar radiation to run the pump, and water is taken from the tank when needed, i.e. this system is not sensitive to intermittency. However

for the power and continuity required by most small scale industrial activities, such as milling and other types of food processing, a solar-PV system would not be enough – a mini-hydropower station or a biogas system however would serve just fine. When the initial installations are made in these projects, the imagined use of the system often does not include potential small scale industrial development, which is why a system generating less effect is often chosen. When an installation is done, it is difficult to economically motivate bringing it down and install another one with a different renewable technology, because the increased economic activity usually comes after the installation of an energy system. This leads to the community becoming locked-in to the first chosen technology and permanently unable to develop productive activities that require a more reliable energy supply (IR 17, IR 2, section 3.4).

6. Applying a TIS framework to find key policy issues

In this chapter, the background and foreground systems are analyzed and some key policy issues are identified using the innovations system framework by Jacobsson & Bergek (2006). First, a short discussion on how and why TIS theory can help analyzing this system, then the seven functions of the TIS framework will be discussed and applied to the rural economic growth problem described in the system.

The applications of TIS theory has usually been reserved for the interpretation of the term 'innovation' as the applications of completely new technology in a modern society. It has been used to describe the mechanisms involved when the new technology, for instance a renewable energy technology, develops from invention to marketable product. The goal for describing this is to identify the mechanisms in play, in order to find the key policy issues that facilitate for the new technology to develop. This is done to make policy makers able to intervene in the market. This can have several purposes, for instance that the development of a specific technology serves some desired purpose in society which would not be achieved by the free market, for example environmental gains.

If the market mechanisms are allowed function under some policy constrictions, a desired societal purpose can be achieved by influencing the direction of development. The aim of this section is to investigate if the TIS framework described in section 3.2 is applicable in a rural development context. As have been described in section 3.2.1, innovation systems do not necessarily have to refer to a new technology, nor to a specific sector of industry. They do not have to describe the invention of new technologies, but can very well describe a system where new commercial applications of imported technologies are introduced to a new market in order to enhance economic growth. In other applications of TIS involving renewable energies, the purpose has often been to find commercially viable applications of RES in order for them to develop and survive on an open market. The purpose for society is long term, the need to develop alternative energy technologies to replace fossil fuel as primary energy source. To do that, it is necessary to support firms that work with renewable energy, since their environmental and societal benefits are not reflected in the competition with fossil energy technologies on the open market. They are needed to survive and continue to develop the next generation energy technologies. The focus is on the *supply-side*, as the receiver of support from new policy and interventions.

In this case, we are also using the TIS approach to identify policy issues to support firms working with renewable energy technologies, but the focus is primarily on the *demand-side.* The purpose for society is to enhance economic growth by providing an energy source where there is none, in order to support an underdeveloped region. Primarily the purpose for helping the new and old local firms is for them to create jobs, to subsequently reduce poverty, not to develop new energy alternatives. The same purposes of applying the TIS approach as in the previous example exist, but only as secondary purposes. The primary environmental aim is the diffusion and use of renewable energy technologies in other parts of society, not the cutting-edge development and research.

The renewable energies are put at the center of this problem (as opposed to just looking at policies that only encourage economic development) because they present new opportunities in applications and combinations previously unknown to the local inhabitants. They are able to function in a fairly

isolated area, which is the situation for many rural communities. It presents the possibility of value adding activities to locally produced products, with local renewable energy for a local market. Market access does not necessarily need to be through trucks and roads or modern ports; things can be done before all communities are reached by modern infrastructure and logistics networks. The lack of infrastructure like roads and energy services is a recognized barrier for business development, and the access to renewable energy can not only break this barrier, but also act as a driver for development of other types of infrastructure; the increased purchasing power of the population and the businesses motivate the government, firms and other actors to invest in infrastructure projects.

We continue this reasoning by seeing if there are similarities between the way TIS theory is usually applied and the situation in rural developing regions. This will be done using the framework presented by Jacobsson and Bergek (2006) with its seven functions, described in section 3.2.

Consider a company producing small scale renewable energy solutions. They recognize a need for energy services in rural developing communities. When asked, the inhabitants of such communities often mention a need for freezing or refrigerating technology (Carnicier et al., 2013). This could allow them to sell cold drinks, and it could open up market possibilities to produce and sell dairy products, and it could make their most common form of capital – livestock – a much more flexible economic resource, as they would not have to sell or eat all the meat immediately after butchering an animal as they have to do now, but they could freeze or refrigerate the product for storage or transport [IR 12, 13, 15]. This is only what lies within the inhabitant's imagination; most possible applications including food processing etc. are most often yet to be discovered by the rural communities. There is contact between the communities and the modern civilizations, mostly young people going to the city or abroad to work or study, bringing new ideas back. Sometimes the contact is in the form of government or NGO poverty education or health projects. The more remote the community, the less contact there is.

There is initially no market for investing renewable energy technology amongst the local entrepreneurs, mostly because it lies outside their imagination. This can be compared with the situation for new renewables in the modern society. New technologies are often met with skepticism and disbelief. This is usually overcome with demonstration projects, where the potential future users can see and touch the new equipment, and realize the advantages. The idea of **nursing markets** seems applicable, in order for markets to develop for products and services made with the use of electricity, which in turn increase the market for energy services.

To create a nursing market, the actors in the market are given better conditions to keep their business viable than they would have had on the open market. A type of nursing market would be if the government would support the producer by buying their products to a higher price, which is then lower when the producers are able to lower production costs by scaling up or by adding value to their products. Then they are introduced to the open market. Another way to support them would be to give them access to financing by loans with low interest rates and long payback times, letting them operate with lower financial costs in the beginning. When they have reached a certain size or production volume, they are referred to the open market and conventional banks for loans. Another way to support local producers would be to increase the toll on importation and reselling of mass

produced agricultural products, to favor local producers. In Mozambique for instance, the market is dominated by this type of products from South Africa.

The need for **entrepreneurial experimentation** is an important function to support, but in this case it is both the experimentation by the suppliers of renewable energy systems and by the local inhabitants, as they may become entrepreneurs themselves with the possibilities provided by access to renewable energy. They can venture into new markets for, for instance, cold drinks, frozen fish and meat, milled grains and other types of processed food. Let us not forget about entrepreneurs in the service sector; charging cell phones, barbers, typing up and printing documents, and so on. The support of entrepreneurial activities among the users will lead to increased demand for the energy services, as business ideas spread to other communities, and as the local purchasing power increases due to increased economic activity.

Knowledge development and diffusion is a function that would be important for this innovation system. The diffusion of ideas about how to add value to agricultural products, how to use electricity in a productive manner, is an area where interventions could help tremendously, and that would probably lead to increased demand for energy services. A possible way to go about this would be to consider increasing the access of education on agro-processing, small scale business management and administration, modern agriculture and logistics. There is also a need to increase research in this area, specifically in how a renewable energy technology should be selected for a certain application, and how it can be adapted to local physical condition and business requirements. Another way could be to create travelling workshops through which entrepreneurial ideas in the rural context could be diffused more quickly. These educational efforts should be coordinated with efforts in rural electrification, and reforms to create better access to and knowledge about financing.

Resource mobilization refers to both human and financial capital. As for the mobilization of financial resources, many organizations have provided donated funds for projects as a stand-alone intervention, which has been proven ineffective time and again in this context (section 3.3). The financing in the form of loans is emphasized by several interview subjects, the advantages of this is also presented in previous studies, and represented in the system model by the reinforcing loop R3. Providing possibilities for microloans with low interest rates and long pay back periods gives entrepreneurs a chance to realize business ideas and provides incentive to make projects commercially viable, which in turn creates jobs and local purchasing power, which reduces poverty in a sustainable way. With an understanding of these dynamics in mind, a key issue for policy makers is to make this type of financing possible. An issue that needs attention is how financing institutions should be able to get security for loans when so few of people's assets are registered, a problem described in section 3.3.4. This problem can in this context, policy-wise, be dealt with from two directions: The first would be to make the bureaucracy simpler for people to register their assets (land, livestock etc.) and the other to educate the personnel administrating these funds in how to get security for loans where there is no security. This has been practices in developing countries by small, independent micro-loan institutions for a long time, so the knowledge is available if there is a political will [IR 5].

If the structure for access to loans and credits described in section 5.3 and 4.2 is revised so that people with less formal education can apply for loans and other types of financing, and this is not

short cut by NGO or other donors throwing unconditioned funds into the mix, the potential users would have some purchase power and a **market formation** could take place.

Resource mobilization also refers to human capital, and to provide human capital for the innovation system, policy makers need to take a closer look at what kind of education projects are conducted in the rural areas. Several types of interventions from society can be imagined to train the local population in entrepreneurship, operation, management and maintenance of new business ventures. The brain-drain mechanism which is described in section 3.1.1 will continue to deprive new businesses with skilled personnel unless it is intercepted. This could be done by for example coordination efforts between business and education, for example by guaranteeing that the participants of a local training or education project get a job as they finish their training, or some other incentive for them to stay in the community. Several developing projects have drawn the experience that if women are trained in critical skills like maintenance, management or operation instead of men, the chances of success for the business or project increases, since women have less tendency to leave the community (Braidotti, 1994; IR 16). This can to a varying extent provoke resistance among the population due to tradition and culture; no project will succeed without being sensitive to these factors.

In many developing countries, agriculture is regarded as old fashioned and is disfavored for the promotion of manufacturing industries and raw material extraction. The problem with this is that while these industries have a positive effect on the economy, they don't create that many local jobs or improve the rural economy. It is important to work on creating **legitimacy** for agricultural practices as businesses, in order to increase the willingness for the private sector to invest in agriculture. A way to do this is for the government itself to invest, and to show that small enterprises can turn a profit if given good conditions on loans.

Legitimacy for the renewable technologies themselves is of course also important for them to enter new markets. If the local government invests in renewable technologies for their vehicles, buildings etc., it can encourage the local private sector to do the same. Creating legitimacy has specific important in developing countries, due to the lack of access to unbiased information on firms' performance, activities and economy. New actors on the local market using or providing renewable energy solutions will likely be met with more skepticism than more established providers of fossil fuel energy supply.

A number of **positive externalities** arise from rural economic growth, as is described in the system model. Growth will lead to an increased specialization among the producers of agricultural products, which leads to a demand for educated and skilled workforce, and education projects will supply a local demand instead of contributing to brain-drain. The increased income from salaries to the population creates a demand for other products and services, which keeps the growth going. The demand for energy and electricity services created by the local businesses may lead to the necessary infrastructure in place to bring electricity to households, schools and clinics, which may improve health, learning and food security. From a policy and interventionist point of view, the work here is to support these positive externalities by eliminating barriers, for instance making sure government and NGO interventions are done with an understanding of the local economic system, preferably serving a local need. For example, the education projects launched need to provide the type of

knowledge and training that is required in the local economy, preferable the projects are designed in collaboration with local private sector representatives.

A positive externality would also be the increased involvement of the private sector, described in the system model as reinforcing loop R4. From a policy perspective, this involvement could be further enhanced by for example tax reduction or other benefits for companies that invest in rural developing communities, renewable energy or small scale processing of agricultural products.

As can be seen, this application of the TIS framework puts focus on both the producer of services or goods who is adapting and using RES technology on the local market, and the suppliers of the RES technology itself. The societal benefit sought is the provision of jobs and improvement of quality of life of the rural inhabitants. By addressing some of the policy issues identified, it is possible to support the emergence of an innovation system of commercial uses of renewable energy in rural communities, which benefits both inhabitants with the provision of infrastructure and job opportunities, and the producers of adapted renewable energy technology applications by opening up new markets in the rural developing regions. It can be compared with that both the actors on the supply and the demand side are benefitted as the innovation system of a renewable energy evolves; the users by getting cheap clean energy and the supplier by getting more costumers.

7. Discussion & conclusions

The goal of this study was to gain insight in the economic system of rural developing communities, through the use of a system dynamics approach and an innovation systems theoretical framework for deriving key policy issues and identifying system weaknesses. By putting the economic growth as the central problem of the system model and the analysis, a different perspective was gained regarding the role of renewable energy technologies. If these methods are used, development interventions and policy changes made by the national governments of developing countries and international organizations can be better informed and have more effect on poverty and human development.

In the first part of this section, some general system weaknesses of the background and foreground (national and local) systems found to impede economic development will be discussed. In chapter 6, the Jacobsson and Bergek (2006) TIS-framework was applied to the rural developing economic system function by function, through which more system weaknesses were found that relates to the innovation capacity of the system, which will be listed and discussed in the second part of this section. Finally, some conclusions regarding the choice of method for this study will be given.

Discussion

For the purpose of investigating the problem first hand, a field study in Mozambique was carried out, which resulted in a series of semi-structured interviews. The composition of the Causal Loop Diagram describing and connecting the components of the rural economic system was to a large extent based on the interview results, which may lead to the conclusion that the CLD describes a Mozambican rural community. To make the system description more generally applicable, general literature on developing countries was used to confirm the connections and to complete it with more variables which may have impact. The aim was that if the system description is applied to a rural community in another developing country, it will give an interesting perspective on the problem, even if some input variables may not be relevant in the context. However, this is true for different rural communities inside Mozambique as well. Since the interview subjects all have experiences from communities with great differences, the system model generated from the Interview study alone was relatively general from the beginning.

The interview study and literature review indicate that many development projects and aid funds that reach rural communities are earmarked for social services, mainly in the provision of water, health and education services, and point to the problems this type of projects have in contributing to development on their own and in long term. The work of providing the rural developing communities with infrastructure to fulfill their basic needs is by no means unimportant and should be continued, but an astonishingly small part of this is directed to projects aimed to enhance local economic growth. Local economic growth creates jobs and reduces poverty, and the inability to save and build up reserves is to some extent connected to the inability to fulfill basic needs. A poor society is for instance much more vulnerable to crises like floods, droughts and epidemics then an economically more developed one.

The system model describes several components that need to function to get the economic growth going. For instance, if social development projects were done with an understanding of the local economic system, the same project could serve both basic needs and economic growth. For example, a government project is launched to provide water for household use and electricity for schools and clinics. The same installed infrastructure could be used to start business activities; the water could be used for irrigation to increase yield, and the electricity could be used for food processing.

For this type of coordinated multi-purpose projects, some components are required. Water and electricity cannot be given for free to local entrepreneurs who want to increase their profit using it at the cost of the community. This will be perceived as unjust. However, if it was possible for them to receive a loan, they could buy the water or electricity they need to start up a business, leading to economic activity linked to the community which is necessary to reduce poverty in the long run.

The education projects launched in rural developing areas typically see education as a social service, and concentrate on general education. This is by no means unimportant and should continue, but more effort should be put into what is here called *vocational education* and training. What is meant by this is education and training in for instance agricultural techniques, food processing, craftsmanship like carpentry, mechanics and maintenance of machines, but also entrepreneurship; basically any skill that a person could use to make a living in the local context. This is in no way an unknown concept to people working in educational development. However, without a system understanding, the result can be brain-drain (section 3.3.2). If the provision of human capital by educational projects is not combined with efforts in supporting the businesses that need human capital, there will be a drain of the human capital, meaning that if there are no jobs locally, people will move to a place where there is a demand for their skills. Oppositely, if there is a local demand for human capital and there is no local education projects, skilled people may move to the community to meet the demand. This is illustrated in the system model as the reinforcing loop R1.

The efforts by national governments to direct aid funds to enhance rural economic development are impeded by an inability to coordinate between the economic sectors. The aid funds are divided between governmental funding institutions in this paper referred to as the national funds, which are all tied to a ministry. For example, the funds for agricultural development go to the national agricultural fund, controlled by the Ministry of Agriculture. The same is true for the funds for energy, industrial development, health and education. Since rural development essentially requires contributions from all these sectors, projects tend to involve several of them. In section 4.2.2 a project involving energy, agriculture and small scale industry is described as it gets caught between the different national funds.

There is in Mozambique a local development fund called the FDD (district development fund) which does not have this sectoral division. The fund is criticized for the difficulty for people to receive funds for projects. More research is needed to confirm, but some interview respondents have indicated that these local funds lack the competence to administer loans with no security as described above, that the potential recipients of loans have no registered assets, that there are no people capable of making business plans or writing applications, or a combination of the mentioned identified system weaknesses.

Recommendations

In chapter 6 the conditions for the economic system in rural communities to support innovation is analyzed. It is deduced that there are some system weaknesses that impede innovation and economic development. The following policy recommendations are derived from the framework application.

1. Favor local entrepreneurs by developing nursing markets for producers of adapted renewable energy systems and for local agricultural products, by for example tolls on imported mass produced agricultural products, and tax benefits for renewable off-grid energy solutions.
2. Support knowledge development by training more students in applied modern agro-processing, renewable energy, small scale business management etc.
3. Supporting knowledge diffusion by travelling workshops, for diffusion of entrepreneurial ideas
4. Creating easier access to conditional financing through loans by implementing simpler procedures for registering untitled assets, and by building up capacity and competence in the national and foreign finance institutions on micro-loan management and informal security for loans.
5. Support legitimization of agriculture and renewable energy as modern businesses by government investments and demonstrations.
6. Support the development of positive externalities, for example the increased involvement and interest of the private sector and banks, by for instance tax benefits for companies investing in the rural developing economy or renewable energy.

Conclusions

The system dynamics approach is useful in the rural development context, since the problem is dynamic with many actors involved and variables affected. It reveals that the scope of the problem is across many disciplines and sectors, e.g. financing, technology, education and social issues. If policy interventions are done based on assumptions of simple, linear causality between the variables, they can be ineffective or sometimes even contra-productive. With a system dynamics approach, loops of circular causality can be identified which leads to a deeper understanding of the problem.

In this study only the first step in the construction of a system dynamics model where used, namely the identification and verification of variables, and the mapping of their influence on each other in a causal loop diagram. In order to do understand more about the system's behavior, further research is needed to do a complete model construction, including the conversion of variables to level and rate equations. With a complete model, assumptions of the effects of changes in policy could be tested through simulation.

The system dynamics modeling is useful to visualize the dynamics of the problem, but in order to design interventions to support innovation and economic development, another tool is needed. If modern technology like renewable energy systems can solve the problem of energy access, the creation of small enterprises that use energy in a productive way can be seen as manifestations of

innovation. If the rural community is seen as an aspiring innovation system, system weaknesses that specifically affect local economic development can be targeted – something that traditional development interventions often fail to do. Frameworks for supporting the functions of innovation systems can be used to design policy that supports rural economic growth, which in turn hopefully has a positive impact on poverty and quality of life in rural developing regions.

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