MSc in Engineering Sustainable Cities

MASTER'S THESIS

Synergies towards a renewable energy system in Cape Verde - the case of informal settlements of the capital city, Praia

Kata Muhel

Supervisors: Iva Ridjan Skov, Brian Vad Mathiesen

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Abstract

Even though Cape Verde has abundant renewable energy resources, the access to electricity is provided by imported fossil fuels. Therefore the issue is the same in the informal settlements of the capital, Praia, where most of the households are connected to the grid, but the high, non-technical loss of the system is originated from these neighbourhoods. In this study, a both environmentally and economically sustainable option is proposed and the synergies between the actors in the area are analysed in order to determine the possible options that could be aligned with the ambitious renewable energy transition the country proposed until 2030.

Acknowledgements

I would like to offer my special thanks to my supervisors, Iva Ridjan Skov and Brian Vad Mathiesen for their willingness to devote their time and helped me with valuable and constructive suggestions and their assistance to keep my progress on schedule. I would also like to extend my thanks to the AAU International Office who supported me with a grant to carry out a research trip and collect necessary information on the topic. Special thanks should be given to professionals on the research field who were available for a discussion. I wish to thank Maria João Rodrigues and Miguel Centeno Brito for their guidance and input to consider this field as a potential topic for my Thesis research. Finally, I would like to express my gratitude to my friends and family who always keep encouraging me and supported me along the writing period.

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Acronyms	
Shortcut	Description
ALER	Associação Lusófona de Energias Renováveis
ANT	Actor-Network Theory
ARE	Alliance for Rural Electrification
BIPV	Building-integrated photovoltaics
CCILA	Câmara de Comércio e Indústria Luso-Alemã (Portuguese-German Chamber of Commerce)
CERMI	Centre of Renewable Energy and Industrial Maintenance
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EDP	Endogenous development theory
GDP	Gross domestic product
GIS	Geographical information system
INDC	Intended Nationally Determined Contributions
kWh	Kilowatt-hour
LPG	Liquefied petroleum gas
MW	Megawatt
PNAEE	Plano Nacional de Acção de Eficiência Energética (National Energy Efficiency Plan)
PNAER	Plano Nacional de Ação para as Energias Renováveis (National Renewable Energy Plan)
PV	Photovoltaics
RE	Renewable energy
RECP	African-EU Renewable Energy Cooperation Programme
SE4ALL	Sustainable Energy For All
SNM	Strategic niche management
WEF	World Economic Forum

1. Introduction

Cities are the main drivers of environmental change and they are both the problems and solutions to sustainability challenges. While the world population is exceedingly growing, it can add 2,5 billion people to urban populations by 2050, 90% of the increase concentrated in Asia and Africa. The urban population of the world has been growing rapidly and expected to reach 6 billion by 2045, and most of the urban growth will take place in countries of Africa. (UN, 2014) This growing urban population will bring many challenges to these countries when it comes to meeting the needs of the population such as housing, infrastructure, energy, education and health care.

The continuous urbanization and economic development enhance the growth of energy needs as well, especially electricity needs. Biomass is one of the main sources in the African households and around 23% of the Sub-Saharan Africa has availability to electricity with big differences between countries and rural and urban areas. (Kebede et al, 2010)

In Cape Verde, the electrification rate is high in 2010 it was 95%. The islands are highly dependent on imported fuel, so the price is affected by fuel price fluctuation therefore the price is one of the highest here in Africa. (Ranaboldo et al, 2014) The access to the electricity grid has been growing in rural areas as well as in the informal neighbourhoods in the capital, Praia, but with the increased connections to the grid and the capacity stagnating there are problems with long blackouts. The use of local resources could provide a solution as sustainable options.

Renewable energy resources, especially solar energy has a very big potential in Africa to reduce the independence on import and to contribute to a sustainable development. Even though some progress has been made in the implementation of solar applications, it has remained limited. Cape Verde being an African country has abundant solar energy resources. Even though there have been some progress in the implementation on renewable energy resources in the country, in the informal neighbourhoods in the capital, Praia the energy supply has been having difficulties.

The use of local resources could provide a solution, such as solar energy. The project will concentrate on the potential use of solar micro-grids in the informal settlements, taking into account the situation of the energy supply, it could provide a solution for that problem. The

use of local resources, especially solar energy as a renewable energy resource has a big potential in Cape Verde to reduce the independence on import and contribute to a sustainable development.

According to the conditions of the informal settlements in Praia, the capital of Cape Verde, the thesis aims to conduct an analysis on the possible implementation of PV systems in the informal settlements in Praia by defining the possible actors and their role in the processes. By assessing also the principles of environmental and economical sustainability according to the case study, as well as using different kind of methods for the research. The goal is to assess the possible outcome of using PVs in the informal neighbourhoods being beneficial towards a sustainable development of Praia and Cape Verde.

2. Problem formulation

As described in the introduction, Cape Verde is a place with a vast amount of solar energy potential as it is an island state located just off the coast of West Africa. This initiates the possibility of using solar energy as a local renewable source as an alternative for the current system which relies on mostly imported fuel. In order to get a clear understanding of the role of PV in the energy supply situation, the energy system in Cape Verde is described as well as an introduction of the relevant characteristics of the country.

In order to examine the existing and possible relations, actors that could facilitate the implementation of rooftop solar energy are identified as well. By drawing up an actor-world, it determines the role of the actors included and their objectives. Onwards, how the actors can cooperate in order to enable the transition is analysed. The analysis is focusing on the electricity sector, how solar energy works better than other solutions and as well the importance of how it is beneficial to use the natural resources available instead of the imported fuel. The actors are examined in a way of how they are involved and how could cooperation move the process forward. Actors promoting different interests are identified, such as the stable energy supply in the informal settlements, connecting the informal settlements to the formal and helping the transition towards the goal of 100% renewable energy in Cape Verde. With the help of ANT, it is investigated how the changes should be made in the network and how the actors could form new relations that strengthen the network. New actors are identified and their possible role in the implementation.

Even though solar energy has been used in Cape Verde, it is not used as widespread as the natural resources of the country would allow. As it is known by now, sustainable technologies have higher performance compared to the outdated ones, but they often do not get into the market as they fail to be developed fully. Strategic niche management provides suggestions how to overcome obstacles, which is also used together with ANT in the analysis by suggesting socio-technical experiments where the stakeholders could collaborate, exchange knowledge and information that helps the development of the technology.

The importance and benefits of using natural resources cannot be highlighted enough, especially in an energy point of view. Endogenous development theory emphasizes the advantages of basing sustainable development processes on the use of local resource endowments, such as renewable energy investments. This is extremely relevant is the case of

Cape Verde, so it is discussed why local development processes that are based on local resources are more self-sustainable and enduring than other ones based on external resources. Focusing on relevant stakeholders as they are the key for implementation of a project, gathering and analysing whose interest should be taken into account help to determine possible solutions.

2.1. Research question

By having the mentioned theoretical support and using the methodology, the following research question is determined to be answered:

To what extent are the different actors related to the transition to a renewable energy system in Cape Verde synergized in a way that it considers the improvement of the electricity supply in informal settlements of Praia?

3. Theory

In the theoretical chapter, the Actor-Network Theory was chosen to get a clear picture of the case study because of its complexity, so it will give help for the analytical chapter by its application.

Also, two concepts are presented in this chapter to complement ANT. The concept of Strategic Niche Management (SNM) has been taken into account to present the importance of having active actors in the implementation of possible new technologies. Endogenous development theory emphasizes the importance of local energy resources, thus it is a relevant concept to apply on the case.

3.1. Actor-Network Theory

According to ANT, instead of having to choose between the local and the global view, the notion of network allows us to think in a connected global entity, which remains local. The first thought of actor-network theory (ANT) was in the 1980s by Michael Callon, John Law and Bruno Latour. It seeks to understand the dynamic relation between different actors which together form heterogeneous networks. (Law 1992) People, the built environment, plants and animals, but also signs and symbols can be a part of the actor-network. This theory is going the help in the investigation of what can facilitate potential cooperation between actors in the case of Praia. The cooperation would help the possible small scale implementation of PV systems in the city's informal settlements and define the already existing and also the possible future actors help to find the missing parts of enabling the implementation.

3.1.1. Definition of Actor-Networks

The term actor network is used to describe interplay between actors in an actor world. This can be understood by simplification and juxtaposition. Simplification is needed in order to understand the actor in the context of the actor world, reducing the complexity of interests, qualities and roles so that they can serve their assigned positions in the actor-world. By saying juxtaposition, this means that there is a need to understand the actors in relation to each other,

in the network-context that they are put into the actor-world. They are in the network because of their relations to the others and their simplified role in the actor-world. (Callon, 1986) As the role of each actor is going to be presented in the Analysis, there is one actor in the network that already deals with the matter of connecting the actors and improving their relations (ALER). This fact helps the network to understand the exact role of each other which helps the improvement and forming of connections. They have been having meetings from time to time as well with possible new actors, such as the last one held in Praia together with Cape Verdean and Germany companies to discuss possibilities. The event was held by the Portuguese-German Chamber of Commerce, who is also the part of the actor network.
There are in fact many networks within the actor world, depending on the level of complexity to focus on. The relationships between the elements in the actor-world in actor networks are heterogeneous, meaning the processes that lead to change in the network are extremely complex. (Callon, 1986)

3.1.2. Definition of actor-worlds

To understand how the actors relate to each other, it is necessary to map an actor-world which helps also to understand how the actors are involved. The term actor-world is describing the network concerning a case of interest or a technological innovation, build by a person or actor to exploit this interest or promote the technology. Creating an actor-world, from Callon (1986), happens by defining roles and enrolling actors into the roles. The function of the roles is set by building a world where the actors are playing a specific role.
The actor-world determines the repertoire of actors included and the objectives they are working with, but it also determines the size of the repertoire (Callon, 1986).

After defining the actor-world, the second stage is to move from it and determine the future ideal one, this is called the translation stage. This concept investigates how the changes should be made in the structure of the Actor-World, so where the actors stand and how they could form new relations so they could create a string a powerful network. As Callon suggests, there are 4 phases of translation: problematization, interestment, enrolment and mobilisation. (Callon, 1984) During the problematization, the problem with the network is defined and it also leads to the identification of links between the actors and also those links that could solve the problem. The interestment phase should confirm the validity of the

problematization by defining the actions which stabilize the identity of actors. The enrolment phase enables the success by negotiations, trials of strengths and tricks that accompany the interresment. The mobilisation concludes the process by defining the important role of the spokesman who represents the new actors that should be involved in the process. If the actors go through this process, the network is built, although their relationship could change anytime, so the alliances are not definitive. (Callon, 1984)

With the Actor-Network theory, the power and decisions can be understood by the configuration of actor-networks, and the forming of actor worlds. By mapping the actor-network according to different sector interests, and see how they are configured in forming an actor world-surrounding the way to the transition to go 100% renewable by 2030.

It is interesting to see which actors are promoting the different interests of;
-Stable energy supply in the informal settlements
-Connecting the informal settlements to the formal
-Helping the transition towards the goal of 100% RE in Cape Verde

3.2. Strategic niche management

Strategic niche management (SNM) is an approach that could help the socio-technical transition towards a more sustainable development. It is designed to facilitate the introduction of new sustainable technologies that contributes to a shift to a more sustainable economic development as well through technological progress and social-institutional transformation. Even though using solar energy as a renewable energy resource has been recognised in Cape Verde, the need for it to be emphasized is still needed environmentally, economically and socially as well.

Even though sustainable technologies have higher performance compared to outdated ones most of the times, they often fail to be totally developed or get into the market. SNM helps to understand the nature of obstacles such as the statement that sustainability is a weaker driver for change than economic gain. SNM tries to also provide suggestions to how to overcome these obstacles. SNM suggests the creation of socio-technical experiments where the stakeholders should collaborate and exchange knowledge and information, which should enhance the learning process that helps the development of the new technology. Experiments should create ’proto-markets’ to make connection with market parties as the new technologies are not yet supported through the actual market sales. This involves the technological niches, which will evolve into an actual market niche if the incubation is working. (Caniëls et al, 2008)

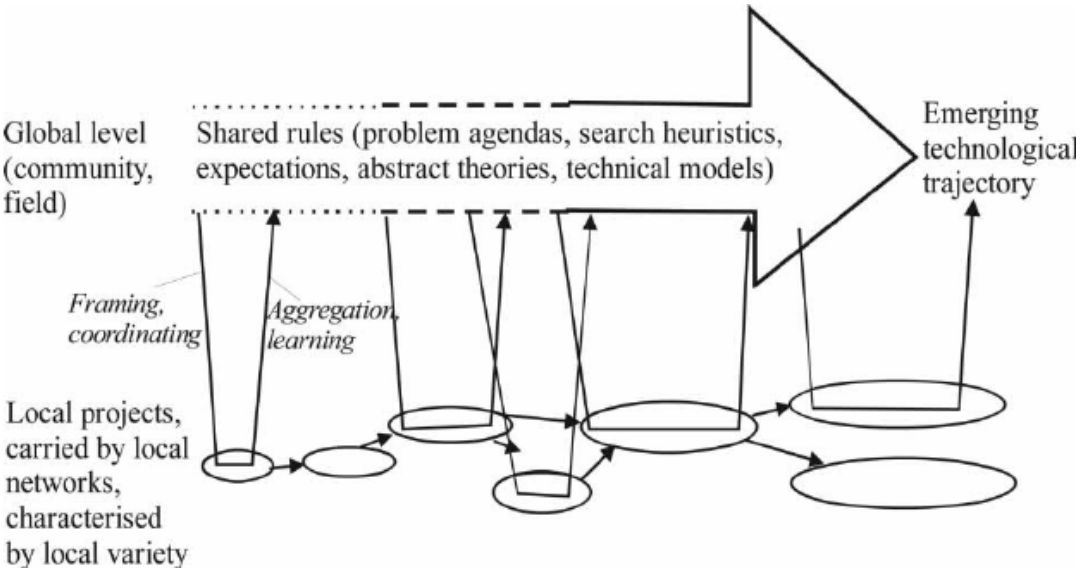

Figure 1.: Emerging technical trajectory carried by local projects (Source: Geels and Raven, 2006)

So in the case of Praia, it can be said that using solar energy is still at a niche level as it has been already used but in such a small scale that it is not yet part of the regime.

Even though SNM stands still in developing phases as it has been developed just recently and has been used mainly as a research tool, it can be used for improving the design of experiments, evaluating policies in the past or designing future policies on niche management. One of the main characteristics of a niche creation process is that the creation often requires a co-operating actor network. The participating actors should develop a common core view about their relationship such as how they co-operate and how they are proceeding with the technology. Their strategies, practices and expectations should follow the same direction. (Hoogma et al, 2000) So it means, that with complementing the previously mentioned ANT with SNM, the suggestions made using ANT can be used in the process SNM tries to investigate. Also a suggestion is that for a successful experimentation the new technology should be open for further development in different directions, so that the processes can work together. This also applies to ANT as the network should be open for new actors to join. The technology should be in a stage where it hold a promise of benefit for the stakeholders but flexible enough for formation and extension. It is not only the characteristics of new technologies that matter for successful niche experimentation, but also the features of the actors, so that the experimentation on the new technology can be active. So it is important to examine each actor and their roles when it comes to research the possibilities of implementing solar panels in the informal settlements of Praia. By experimenting on the technology to provide solar energy the actors can evolve as well, but for that they need to define their role and features for the process.

The instability of a regime can create opportunities for experiments, as the niches are usually developed so they could provide solution instead of the given unstable issue of the regime. When this occurs in the regime, the actors in it could be interested in the niche as it promises an option for the future. So the case fits here, as solar energy provides a sustainable option for the city to deal with the issue of the electricity supply, the matter is that how the actors could cooperate to make this niche the part of the regime. Also when the regime becomes unstable, the actors could adapt the niche as a solution for the problem. It can be said that the current situation in these settlements in Praia is unstable enough to adapt renewable energy as the niche that could provide the solution. To enable successful niche development, the availability of sufficient institutional support, skills, knowledge and techniques should also be available in the existing regime. One of the crucial points for implementing renewable energy techniques in Cape Verde is the local work force. Although the situation is getting better as the

universities now have related faculties to accept students who can later be a valuable addition with the gained knowledge for the field. But at the moment the country is lacking in skilled workers for development, that's why they need input from abroad. (Interview – Abreu, 2017)
A regime shift does not only rely on a new technology, but also the management of the transition process. By bringing the actors together, enabling learning from different experiences, exchanging lessons will enhance the success of the process, thus it plays a crucial role. The role of the government is to plan the creation and building of the new regime, but it is important to combine decentralised market incentive policies, central directives and direct network formation activities for policy effectiveness.

Even though SNM is still in an experiment stage, together with Actor-Network Theory can promote the importance of defining a network where the actors collaborate with each other while focusing on the same dimensions and discuss the process.

3.3. Endogenous development theory

Endogenous development theory emphasizes the advantageousness that the territories base their sustainable development processes on the use of local resource endowments. Renewable energy investments provide an example of how those local resources (both physical and human) can be exploited in order to improve the prospects of the local population engaging them in an enduring rural development process. It is assumed that local development processes that are based on local resources are more self-sustainable and enduring than another process based on resources that are mostly external to the local community/territory. (del Río et al, 2007) Cape Verde is a good example to prove this, as it has been mentioned before, they import fossil fuels for producing most of the electricity, while they could use the natural resources. They pay one of the highest prices for electricity because of having to import the fuel, and the price of fossil fuels will most likely increase, so it is environmentally and also economically unsustainable to use. Meanwhile, renewable energy resources such as solar energy are natural and local resources that could change the current system. For the informal settlements, it would be an even bigger advantage, because of the unstable current situation.

Endogenous development is a bottom-up development process and it is based on the use of local resources (in contrast with top-down). Endogenous development theory is a territorial approach to development that refers to growth and capital accumulation processes of territories that have their own culture and institutions, upon which investment decisions are made. EDP is the local actors' answer to the challenge of globalization. Renewable energy projects are in-between these two, they take advantage of the physical resources of the area while the technology and the know-how are usually from outside the area. (del Río et al, 2007) For Cape Verde, it would be important to also provide local knowledge and work force for the possible projects.

Local actors are the key to the implementation of a project, they need to support it. Stakeholder analysis is a useful tool as it is a process of systematically gathering and analysing qualitative information to determine whose interest should be taken into account when developing or implementing a policy or program.

Relevant stakeholders in renewable energy projects:

- local population
- local NGOs/other actors
- actors outside the region
- local government
- RE generators and investors

3.4. Operalization of theories

This paragraph is for the explanation of how the theories are connected to the methodologies and how they will be further elaborated in the analytical chapter. The above mentioned theories are interconnected with the Actor Network Theory, so the other two theories are revolving around it. Actor Network Theory will give a framework for the analysis, so it will be investigated with its help, how the different actors can help the implementation of PV system in Praia, by defining the economical and environmental features.

The analytical section of the case study is structured using several methodologies. A wide range of documents, plans, programmes, projects and policies is revised in order to have a clear and inclusive picture of the challenges and complexity that programs such as the Sustainable Energy for All have to face. Furthermore, examination of the case study and semi-structured interviews with experts of the area assists to the description of relevant actors.

In the next paragraph a general insight of the research methodologies and the purposes for the case study is defined, as well as the application in the empirical section.

4. Methodology

In order to answer the research question, data collection process has been carried out. Through the case study of Praia, Cape Verde, specific interviews with experts, and literature review, different empirical findings and methods have been used. The empirical analysis of the report is built up from qualitative and quantitative research methods, to gain information and knowledge from different angles in order to have more validity in terms of discovering the background that leads to the analysis.

4.1. Qualitative methods

Getting an insight and uncover reasons for a given problem is the main purpose of qualitative methods. It has the focus on understandable situations and the desirable data is deeper. The results cannot be quantified and measured. The point is to understand the reasons and motivations of a problem. (Csépányi, 2017)

Qualitative methods are used in the form of a case study and literature search.

Case study as a method

A case study research is able to accommodate different techniques and it is used when there is a need for an in-depth knowledge of a particular phenomenon. Case study is a preferred research strategy when the phenomenon and the context are not distinguishable. (Yin, 2003)

Praia, Cape Verde was chosen as a case study, due to its complexity, but at the same time with a phenomenon, that exists in other African countries as well. Not every country in Africa is like Cape Verde, but since they are in the same continent, they have relations to each other. The argument for using a case study for the report is that it generates reflections for the future and it is going to help the research in the area. (Flyvbjerg, 2010)

The goal of using the case study as a method is to demonstrate the different development of the African context and to show that it could be possible to implement similar solutions that already exist and effectively used. The case study does not try to generalize as areas in Africa

are very different as well, especially that Cape Verde is an island and has slightly different characteristics than most of the countries in the continent.

Interviews

One of the most common methods for qualitative data collection is the form of interviews. It can be organised in different ways that handles the inputs, so it help to understand the context and the complexity of the issue. The applied type is the semi-structured interview, which usually covers a set of questions or topics that needs to be covered during the interview. For this project, semi-structured interviews have been applied to gain a broader knowledge and perspective of the subject of the interviews. All of the interviews were conducted in English language. The purpose of the interviews was to get a better understanding of processes and the relations between actors involved in the network.

Literature search

In order to get a better understanding about the interests of the Government of Cape Verde, the plans for going 100% renewable by 2030 various reports and literature have been used, as well as to get a better understanding of Cape Verde itself, solar energy and the relations in ANT.

4.2. Quantitative methods

Quantitative methods focus on measurable data and numbers. The main purpose is looking for regularity and to understand and generalize the results from the sample data. The results of a quantitative research are viable and accurate if the results are coming from a representative number of samples (Csépányi, 2017).

The quantitative analysis will contain data collection and data generation from the case study and from the interviews as well.

5. Background knowledge

5.1. Introduction of Cape Verde

Cape Verde consists of 10 islands 400 kilometres off the coast of Senegal, with the population of approximately 540.000 inhabitants. Surrounded by the Atlantic Ocean, the country has hot and dry climate with scarce rainfall. Therefor the country has very limited natural resources, and it is extremely dependent on imports, over 80% of the food that is consumed is imported. Most of the water that is used in the country is coming from desalination plants as well. (SE4ALL, 2015)

Cape Verde has been benefiting from foreign aid and development, which enhanced its economic growth. The country's economy is service oriented which contributed to the GDP with 70%, while the sector of tourism represents about 20% of the GDP. (Cape Verde renewable Energy Plan, 2011)

Cape Verde is considered lower-middle-income country since 2008, even though as it has strong connections and dependent on relations with Europe, the crisis in 2008 slowed down the GDP growth. As a consequence of being middle-income country, it is not eligible for concessional loans from major international institutions. The economy is based on the tertiary sector, where 53 % of the population is employed and tourism is the fastest growing sector. (Cape Verde renewable Energy Plan, 2011)

The population of the country is quite young, with 39% under the age of 17 and living in urban areas (61,8%) in 2010. (Cape Verde renewable Energy Plan, 2011) As it can be seen of Figure 2., the urban population is constantly growing, while the rural population is stagnating.

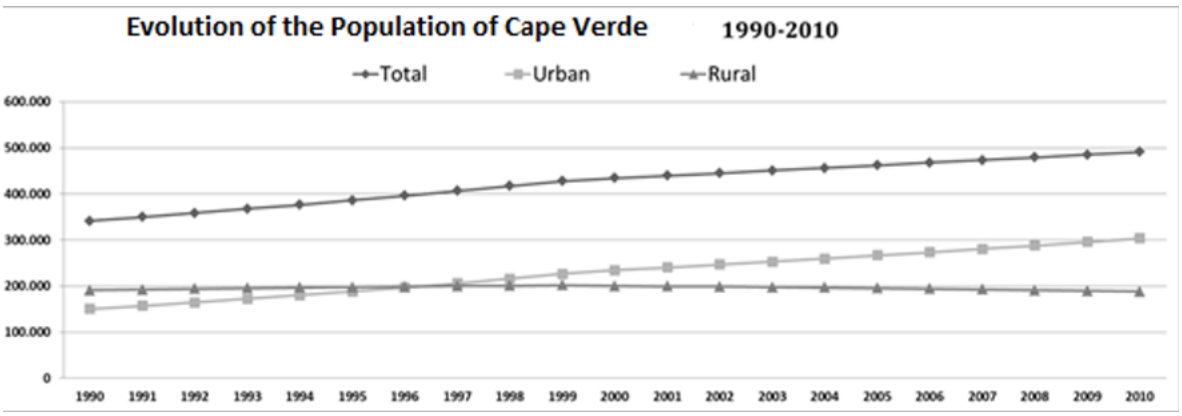

Figure 2.: Evolution of the population of Cape Verde (Source: SE4ALL, 2015)

The average literacy rate is 77% for women and 88% for men. Most of the children access the first cycle of secondary education, while little more than 6% of the population had higher education completed in 2010. Although since the University of Cape Verde exists, those who wish to acquire university degree do not have to leave the country, which leads to the annual growth rate of 32,3% of those obtaining a college degree in the last decade. (SE4ALL, 2015)

The country suffered from periods of draught and famine during the first half of the 20th century, so the development process has not been easy. As it has been mentioned before, most of the drinking water is coming from desalination, this way they managed to solve the problem of shortage on drinking water. But at the same time, the process of desalination requires using a big amount of energy resource. Since Cape Verde's power supply is mainly originated from imported petroleum products, these kinds of processes and highly polluting and coming with big amount of greenhouse gas emission. (SE4ALL, 2015)

Cape Verde had its independence from Portugal in 1975, when less than 20 % of the population had access to electricity and now it is a country that is preparing to reach 100% access before 2017, not to mention the goal of universal coverage of electricity planned to be covered with renewable energy sources at a lower cost by 2030.

Figure 3.: A view of Praia, Cape Verde (Source: Maria João Rodrigues, 2015)

5.2. Energy sector of Cape Verde

The most common fuels to produce energy in Cape Verde are LPG, petrol, oil, diesel fuel, fuel oil and JET A1. Few percent of the energy consumption come from biomass which is used for cooking as well as solar and wind energy that are used in electricity production. (SE4ALL, 2015)

Between the 90s and the 2000s, the growth rate of electricity production has been double digit numbers, in recent year this number has been around 4 %. Taking into account the ongoing investments in the capacity expansion, this number is expected to grow a little in the next years until 2020. With the introduction of the 26 MW capacity wind farm and the 7,5 MW capacity PV panels, in 2013 20 % of the electricity came from renewable resources. (SE4ALL, 2015)

Cape Verde highly relies on imported fuel such as butane, gasoline, oil, diesel fuel as it contributed by 80% to the production of electricity in 2013. Only 20 % contribution can be given to endogenous energies, biomass for cooking and renewable energy. However the penetration of renewable energy in the electric mix in the country has gone from 1,2 % in 2010 to 20 % in 2013 due to the installation of 26 MW of wind turbines and 7,5 MW of PV panels in 2010. (SE4ALL, 2015)

Year	Butane	Kerosene	Gasoline	Gasoil	Fuel oil	JET A1	Wind	Solar	Wood fuel	Gross Energy
2010	134,0	7,5	87,8	936,8	621,0	195,7	2,0	2,1	348,9	2.335,8
2011	136,0	7,5	87,7	990,2	640,3	228,4	15,6	9,0	357,0	2.471,6
2012	133,3	6,2	83,1	909,1	573,9	226,1	61,4	7,5	365,2	2365,7
2013	134,2	5,7	84,1	804,8	615,5	208,6	70,7	7,3	373,3	2.304,2

Figure 4.: The evolution of gross energy consumption (GWh) (Source: INDC, 2015)

The Government of Cape Verde has launched a plan to reduce their dependence on fossil fuels by increasing the energy production from renewable resources. They are planning to make it happen through private-sector investments and government-supported projects. The ambitious initial goal has been the generation of 100% of the electricity from renewable resources by 2020. Although last year the government went through a change, but they are

still keeping the goal, but at the moment they reconsidered the date until 2030. (Interview – Abreu, 2017)

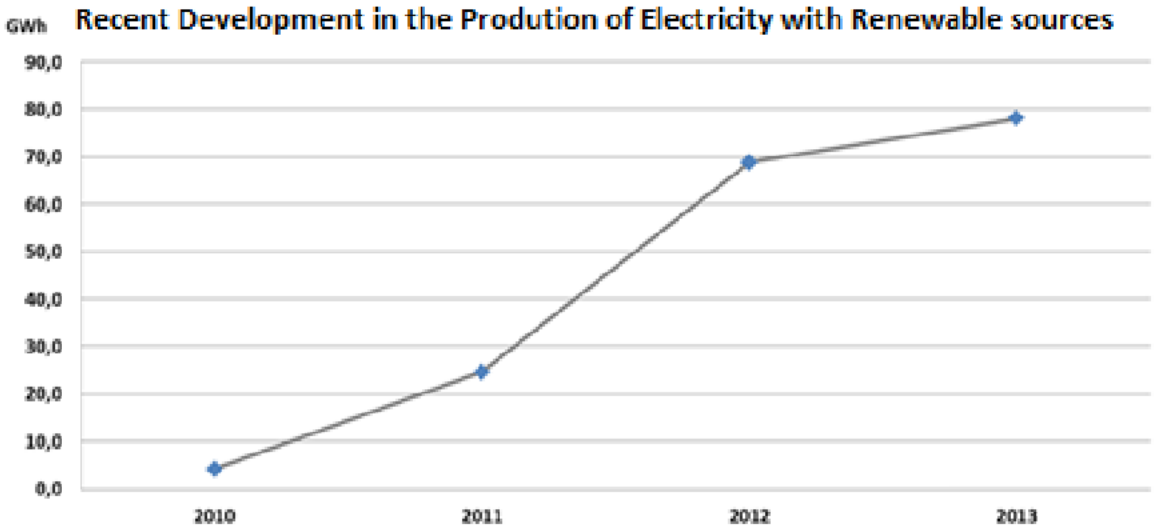

Figure 5.: Recent development in the production of electricity with renewable resources (Source: SE4ALL, 2015)

ELECTRA is the main public company operating the electricity sector in Cape Verde. Cabeólica is the largest producer of wind-generated electricity. The cost of energy in the country is high and it has even been growing in the last years.

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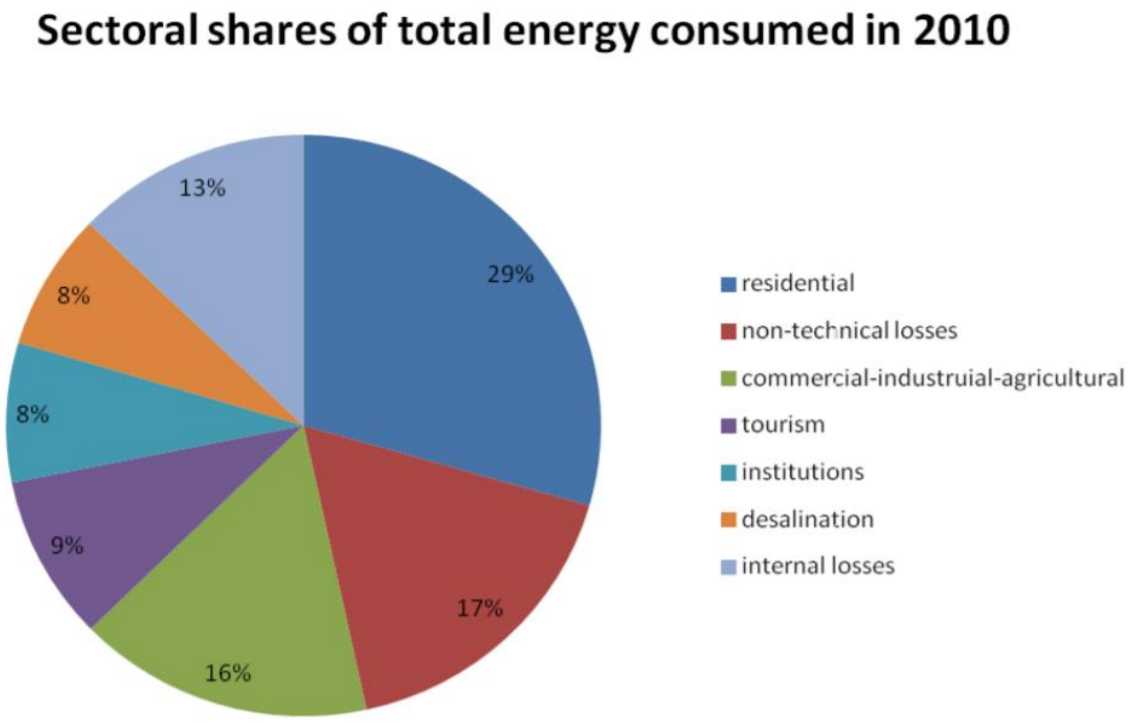

Figure 6.: Sectoral shares of total energy consumed in 2010 (Source: INDC, 2015)

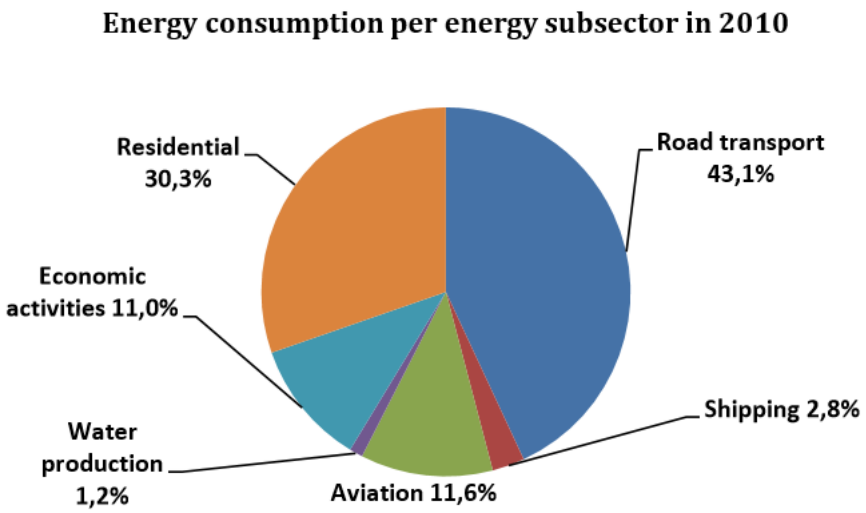

Figure 7.: Energy consumption per energy subsector in 2010 (Source: INDC, 2015)

5.3. Case study – Praia, Cape Verde

A typical urban condition in African cities is characterized by informal settlements, that are usually located in environmentally sensitive areas, built of low quality materials and are without well-built infrastructure services. The biggest problems are with these informal settlements that they are disorganized without any planned structure, ignoring any kind of regulation. (Mwaniki, 2015) This is not different in the capital city of Cape Verde, Praia. The city holds 55% of the population of the country and it is expected to grow and the reason is that the city offers a high centralization of job opportunities. (Community Severance, 2013)

Figure 8.: A view on the informal settlement in Praia I. (Source: Maria João Rodrigues, 2015)

Figure 9.: A view on the informal settlement in Praia II. (Source: Maria João Rodrigues, 2016)

5.4. Goals and ambitions

The detailed energy agenda of Cape Verde is based on the following documents that are approved at the highest governmental level:

- National Renewable Energy Plan of 2015 (PNAER)
    - National roadmap to become 100% renewable for electricity generation
- National Energy Efficiency Plan of 2015 (PNAEE)
    - National comprehensive pathway to implement energy efficiency targets from now up to 2025
- Agenda for Action – Sustainable Energy for All (SE4ALL)
    - International action agenda, approved by Cape Verde in 2015, to secure universal energy access to all, double EE rates and to double RE proportion in the energy matrix
- Joint Declaration between the EU, Luxemburg, Spain, Portugal, Austria and Cape Verde on Reinforced Cooperation in the Field of Sustainable Energy
    - Bilateral policy dialogue and framework for technical assistance on energy sourcing and energy efficiency

5.4.1. Renewable energy planning

Cape Verde has started in increase the proportion of renewable energy resources in the energy mix moving from 1,2% of electricity production from renewables in 2010 to 25% today. According to PNAEE, the energy consumption of the country will grow by 2% until 2020, and until 2030 it is going to increase by 3% every year.

Cape Verde is committed to implement the Sustainable Energy for All (SE4ALL) agenda and also intends to assume regional leadership on energy transformation in Africa. The agenda signed together with the European countries will support Cape Verde to universal energy access and enhanced electricity supply from 100% renewable resources. Their commitments formulated in these plans are achieving 100 % grid access by 2017 and achieving a 30% renewable energy penetration rate into the electric grid by 2025. Also with the international support, they plan to increase the renewable energy supply in electricity to 100% by 2025 with the trajectory of achieving 30% RE penetration rate in 2016-2018, 50% in 2018-2020

and 100% in 2020-2025. These plans include some key points that are important to achieve the goals. They plan to enhance the smart-grid in the country's 9 independent networks with state-of-the-art power conditioning, production and distribution control. One measure is to build up energy storage facilities as well, and also to design renewable micro-grids, individual energy systems (solar home systems).

The above mentioned goals require planning in the public-private partnerships, as well as procedures for licensing and certification and the creation of competitive market conditions. Financially, to reach the mentioned targets, investments are needed, which can go up to 310 million euros for the 50% target and 1 billion euro for the 100% RE penetration. (INDC, 2015)

In relation to the base scenario by 2030, Cape Verde plans to reduce overall energy demand by 20%. Key measures were needed to be envisaged for this such as reducing the technical and non-technical losses in energy distribution from 25% to 8% by 2030, improving energy efficiency of big consumers, improving energy performance of buildings and implementing green building code for new buildings, enhancing energy efficiency by creating rating labels for domestic lighting appliances and air conditioning, promoting the use of smaller distributed energy solutions for water pumping, and last but not least, promoting the building of a comprehensive network of energy service companies and clean-energy business incubators. (INDC, 2015)

The sustainable energy initiative for all has 3 interconnected objectives to be achieved by 2030:

- to ensure universal access to modern energy services
- double the overall rate of improvement in energy efficiency
- doubling the share of renewables in global energy matrix

This initiative is perfectly aligned with the strategies developed for the energy sector in Cape Verde. Although the country has made constant progress having ceased to be part of the list of least developed countries, it still faces challenges such as high unemployment (especially among young people) and rising inequalities. Renewable energy is a great opportunity for the country to support the economy and the society on the way to transformation. It will allow energy independence and access to energy for competitive costs.

Universal Access to a Modern Energetic Services	Renewable Energy in Global Energetic Mix	Energetic Efficiency
Percentage of Population with Access to Eletricity: 2010: 80,8% 2013: 92,0%	Percentage of ER in Prodution of Eletricity: 2010: 1,2% 2013: 20%	Final Energy Intensity (final consuption of energy final/PIB em kWh/Euros) 2010: 1,5 kWh/Euros 2013: 1,4 kWh/Euros
Percentage of Population with Access to Modern Cooking Option: 2010: 70,2% 2013: 70,1%	Percentage of ER in Prodution of Hot Water Sanitary: 2010: ND 2013: ND	

Figure 10. (Source: SE4ALL, 2015)

To 2030, in the framework of the sustainable energy initiative for all, Cape Verde has adopted the following goals:

	Acesso Universal a Serviços Energéticos Modernos	
	Percentage of Population with Access to Eletricity	Percentage of Population with Access to Modern Option for Cooking
Goals 2030	**100%**	**100%**
Specific objectives	1. Network extension to the nearby Communities; 2. Electrification with renewable sources of all isolated communities still without access and away from the network 3. The scattered dwellings will benefit from the use of individual systems	1. Eradication of 3 stones and Stoves replaced by improved stoves (2020); 2. Promotion of Butane: penetration rate higher than 90%.

Figure 11.: Specific goals and objective of access to energy for Cape Verde (Source: SE4ALL, 2015)

	Doubling the Share of Renewable Energy in the Global Energy Mix	
	Percentage of ER in the production of Electricity	Percentage of ER in the production of domestic hot Water
Goals 2030	**100%**	**100% of new buildings with Solar water heater Required** **Strong adhesion (> 20%) of existing hotels and restaurants to residences solar water heaters**
Specific Objectives	1. Achieve a penetration of 30/35% of ER in Power in 2016; 2. Achieve a penetration of 50% of ER in Electric Network in 2018; 3. Achieve a penetration of 100% of ER in Power in 2020.	1. Achieve a minimum of 10% conversion of homes that use AQS to solar heaters; 2. Achieve a minimum of 25% for the conversion of hotels and restaurants that use AQS to solar heaters; 3. Achieve a minimum of 50% percent for the conversion of public buildings that use AQS to solar heaters; Note: percentage of buildings where such conversion is technically possible

Figure 12.: Specific goals and objectives of access to energy for Cape Verde (Source: SE4ALL, 2015)

	Doubling the Global Rate of Improvement of Energy Efficiency
	Final Energy Demand Reduction Relative to the Base Scenario
Goals 2030	**-20% of Final Energy Demand compared to the Base Case**
Specific Objectives	1. Reduction of 10% in consumption of diesel, gasoline, kerosene, jet A1, in 2030 compared to the base case;Redução de 10% no consumo de gasóleo, gasolina, petróleo, jet A1, em 2030 em relação ao cenário de base; 2. Reduction of 20% in electricity consumption in 2030 compared to the base case; 3. Reduction of technical losses and totals in electric network for values of the order of 8% percent.

Figure 13.: Specific Goals and Objectives of Energy Efficiency in Final Energy Demand for Cape Verde (Source: SE4ALL, 2015)

The goal of going 100 % renewable electricity by 2030 requires radical transformations. These are implying to a change of technologies, procedures, market rules, also knowledge and experience that do not exist in other countries and as well retraining and training of human resources.

The country has to be engaged to reach ambitious targets for renewable energy penetration, to reduce the consumption, but above all, to stimulate more efficient and sustainable behaviours. This has to create a relationship between citizen and the energy. To reach these goals it is very important to train professionals in all levels and to test the energy systems. If Cape Verde manages to reach the set targets, it is going to have a leading position in the renewable energy sector which is going to contribute to a significant economic impact, such as an important sustainable tourist destination or the effect on the well-being of the families because of affordable electricity. Even though today the access to electricity is more than 90%, it is far from sustainable as they have to import fuels. As Cape Verde lacks in wood resources, using it as an alternative is not a valid option and its use has low efficiency. Also desertification endangers the country as well and the protection of the environment should be in focus too. (INDC, 2015)

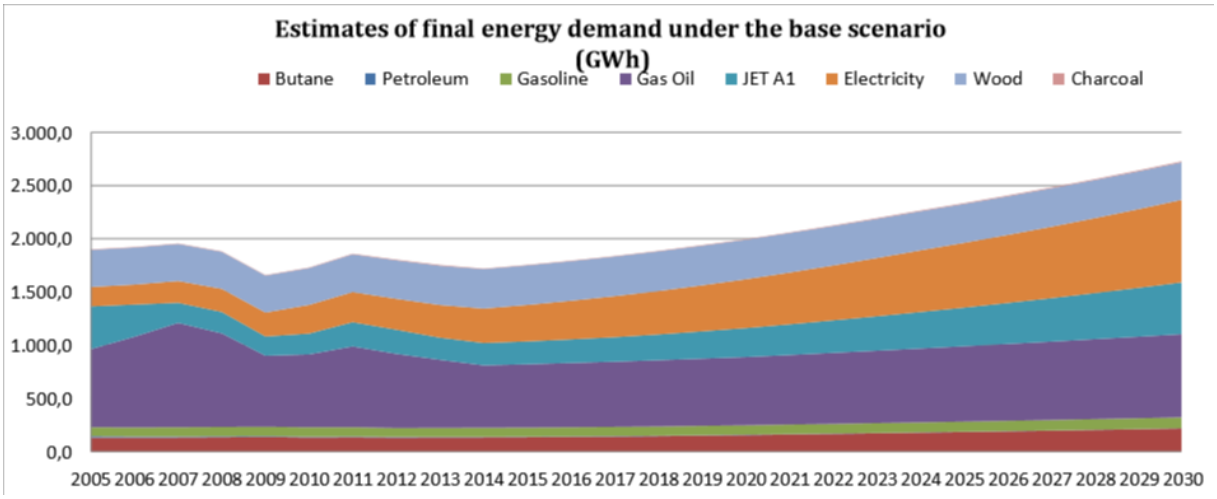

Figure 14.: Total supply of energy for Cape Verde until 2030 (source: INDC, 2015)

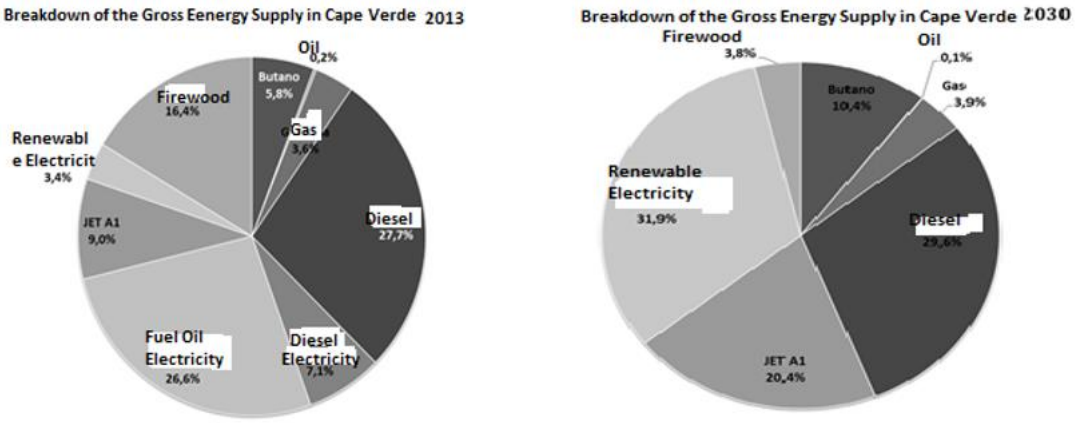

Figure 15.: Evolution of the breakdown of gross energy in Cape Verde and changes in the distribution of gross energy in Cape Verde (source: SE4ALL, 2015)

Developing the energy sector would also lead to the development of the country in environmental, economic and social ways as well. The reformation of the demand is going to be necessary to replace the current fuel based system, therefore promoting more efficient technologies and behaviour is essential to reach these developments.

6. Analysis

The analytical chapter has been carried out by using the actor-network theory as the main lens for investigating factors that are in relationship with the case. The interrelation of the actors have been analysed and to what extent these relations affect the evolvement of the transition to a renewable energy system as well as the possible improvement of the energy system of the informal settlements of Praia. It has been also analysed whether the interrelations between the actors have positive or negative influences, and whether they synergize or conflict with each other. The actor network has been separated into international, national and capital level for a clearer understanding of the network at the relations in it. Even though ANT being the main leader of the analysis, the interventions with Strategic niche management and Endogenous development theory are also considered as a complementary phase for ANT.

6.1. The actor-network

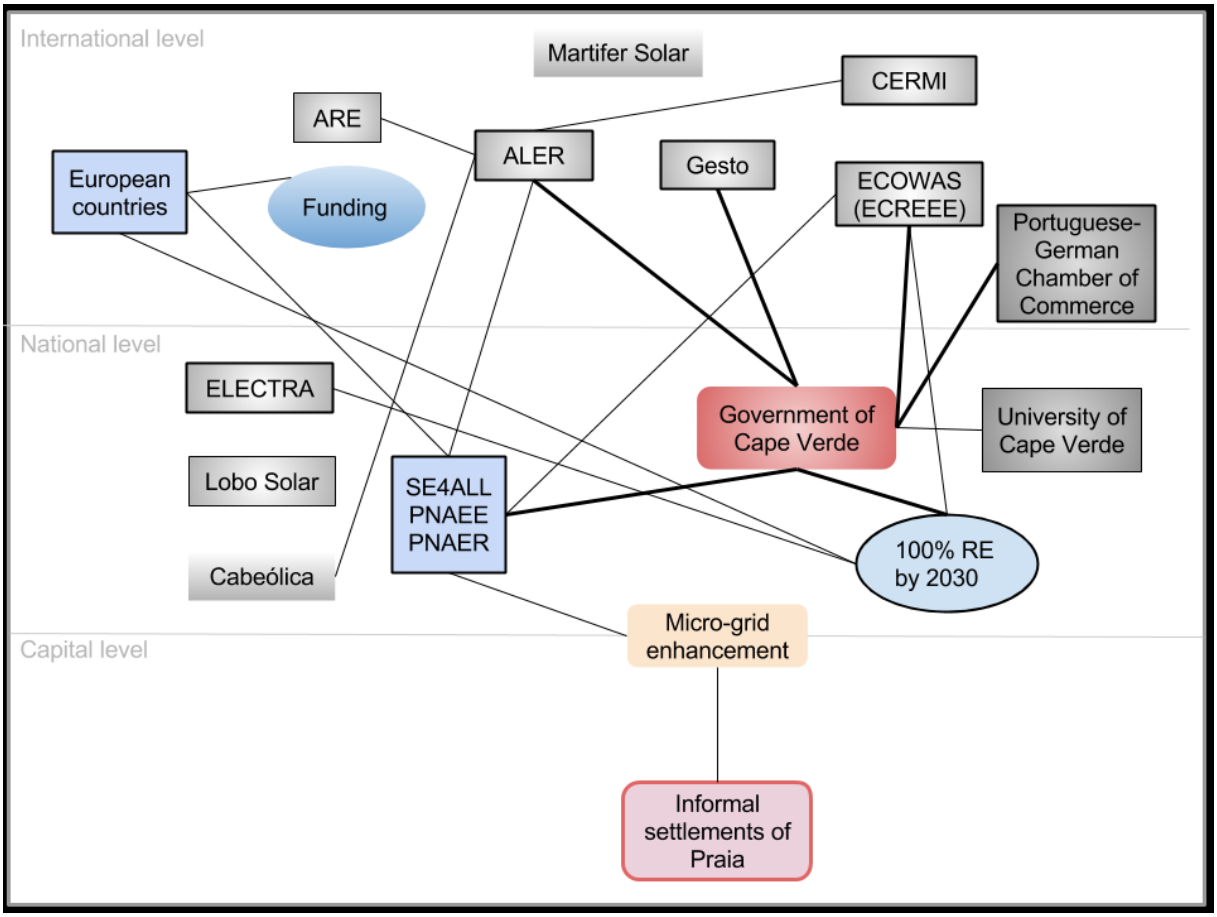

Figure 16.: The actor-network of the case (Source: Author)

The Government of Cape Verde

At the national level, the Government of Cape Verde is the main actor, where policies, strategies and plans are made and designed. The Government of Cape Verde had the initial goal of going 100% renewable by 2020. After re-estimating the costs and processes, they built the strategy of going 100% RE by 2030. This is due to the current change of the government. The Government of Cape Verde has been working together with consulting firms and international research institutes as well to refine the strategy and identify future opportunities. The involvement of the private sector in the energy sector is growing as well and the state has a supporting role in this as it promotes, facilitate and regulate the market production, so it creates the conditions for private investments in the transformation. (INDC, 2015)

By setting the goal of using 100% renewable resources by 2030, the Government also initiates the reformation of the infrastructure of the informal settlements of Praia, which has to contribute to the goal.

ELECTRA

Electra is the electricity and utility company of Cape Verde. The government has 51% of its uses. The electricity production is based on 9 diesel plants, 5 wind farms, and 2 solar power plants. The company is contributing to the 100% RE 2030 plan. As Electra is the electricity provider, contributing to the plan the Government made is a big step for support and towards collaboration. As the electricity production is already running on 2 solar power plants, they have experience in the process. (Electra, 2017)

Martifer Solar

Martifer Solar is a Portuguese company, having a leading role in photovoltaic industry. They are responsible for the biggest project ever built in Africa – 2 PV plants, totalling 7,5 MW in Cape Verde. The company was entirely responsible for this project, from supply to the development, engineering and construction. The 2 plants produce 4% of the total energy of the islands, avoiding the emission of 13.000 tons of CO2 annually. This construction

represents a benchmark for all other African countries to follow in terms of renewable energy. Also, it shows how viable these alternatives can be taking into account technical and economic aspects which have constituted some of the barriers in its implementation of West Africa. The 2 PVs cost about 28 million euros and was financed through a Portuguese fund for RE to Cape Verde in the total value of 100 million euros. (Martifer Solar, 2017)

ALER

After the election of the new government, Cape Verde has undertaken several initiatives to promote the national market for renewable energy. ALER has the important role as a platform for dialogue and is holding national and international workshops, taking care of the coordination between the various stakeholders. ALER carried out the mapping of all the initiatives, identifying the responsible authority and the status and will seek to contribute to that they are the most effective Working Group. They had the first meeting with the Working Group for Cape Verde in Lisbon, Portugal, last year in July. The Agency of Economic Regulation of Cape Verde, which regulates the electricity sector, also participated.

ALER conducted a survey in Cape Verde, named „Prospects of Renewable Energy Development in Cape Verde" for measuring renewable sector stakeholders' needs and expectations in Cape Verde – especially in the private sector. Among the data collected, the regulatory framework, funding and consumers' purchasing power are considered the main barriers to renewable energy implementation and development in Cape Verde. ALER is also preparing an evaluation report including results and recommendations for the next government. ALER also signed a cooperation agreement with RECP to support the promotion of renewable energy markets. The parties will cooperate to contribute to broad and sustained market development for renewable energy in Africa. They have the specific objective of the mobilisation of European and African RE companies for joint business development in Portuguese speaking African RE markets. (ALER, 2017)

ALER is a strong link between actors in the field of renewable energy in Cape Verde, although they are focusing on the big picture, so have not considered yet dealing with the special case of informal settlements. Even though, promoting collaboration between actors and possible actors is a big advantage in the field. (Interview – Abreu, 2017)

ECOWAS (ECREEE)

ECREEE is assisting the 15 ECOWAS member states in the development, adoption and implementation of national renewable energy and energy efficiency policies and targets, regulatory frameworks, standards as well as incentives and financial mechanism. The Centre is focusing on the electricity sector as well as other sectors and deals equally with grid-connected and off-grid issues relevant to rural areas. Cape Verde being the centre of ECREEE, it has access to data in the form of studies and research to help the promotion of renewable energy in a national level. They also pay attention to sensitive and isolated spots of the countries, so besides the emphasis of rural areas, which is also an important issue, some areas of the urban territories such as the informal settlements could also be considered as one of the target spots of research. (ECREEE, 2017a)

CERMI

Their vision is to position as an international centre to serve West Africa, building capacities on the different renewable energy technologies. It was established to build capacities on different technologies of renewable energy such as solar thermal, PV, wind, maintenance and also energy efficiency

> „The fight against poverty in Cabo Verde implies a strong investment on strategic sectors for the development of the country such as renewable energy."

ECOWAS ECREEE is working closely with the CERMI, so their collaboration on the electricity issue in Praia's informal settlements could be taken into account. (ECREEE, 2017b)

Cabeólica

They own the majority of renewable energy projects in CV (except the 2 solar plants) – 25,5 MW of wind power capacity spread over 4 islands. The financing of their projects came from the European Investment Bank, the African Development Bank, the African Finance Corporation, Finnfund, the Government of Cape Verde, as well as few private sector partners. Cabeólica held public consultations where their wind projects were built and also conducted

Environmental and Social Impact Assessments, which includes a process of engaging local landowners in the siting of the projects – important in citizen engagement.

Cape Verde's strategy is that it offers a complete tax exemption for the first five years of each RE project's operational life, with 50% reduction for the following 5 years.

The initial 50% RE by 2020 identified 2000 MW of solar power potential, 6 times the estimated wind power potential, in which they have leading position now. (Cabeólica, 2017)

ARE

The Alliance for Rural Electrification (ARE) represents the decentralised clean energy sector. It was founded in 2006 to provide solution in order to advance access to clean energy in emerging and developing countries. They are partner of the United Nations Sustainable Energy For All initiative (SE4ALL), as well as the main partners of the Africa-EU Renewable Energy Programme (RECP). They find it crucial to bring professional and committed partners together to synchronise and lower the impact of individual efforts. It is important for them to inform the private sector about existing business opportunities and create new ones for the future. They are focused on scalable renewable energy technologies enabling electricity access at the household, small and medium sized companies and community level.

ARE engages in a wide range of additional partnerships to improve sharing of best practices and capacity building. (ARE, 2017)

Tecneira

Tecneira is the member of ProCME Group, also within the working group of ALER. They are the reference company for the renewable energy sector, dedicated to the utilization of renewable resources for energy production. The main activities of the group consist of promotion, licensing, construction and operation of energy production projects from renewable resources. (Tecneira, 2017)

Lobo Solar

Lobosolar is a pioneer in the renewable energy sector, photovoltaics in particular. It is a system developer and integrator, founded in 1999 in Évora, Portugal. It is also active in Spain, Brazil, Cape Verde, Mozambique, Angola, The United Arab Emirates and others as well. They are specialized in the design, commercialization and implementation of PV solutions, such as mini-grid and off grid systems and solar water pumping systems. (Lobo Solar, 2017) They also reside in Praia, Cape Verde and are the member of ALER.

Gesto

Gesto is a Portuguese company, that offers consulting services and turnkey solutions in the fields of renewable energy a policy including energy master plans, renewable energy atlases, project development, grid studies, rural electrification etc. (Gesto, 2017) They have been having several projects in Cape Verde such as solar PV development in Sal island, grid management system implementation, the making of Cape Verde renewable energy atlas or the making of the 50 % Renewable Cape Verde Action Plan.

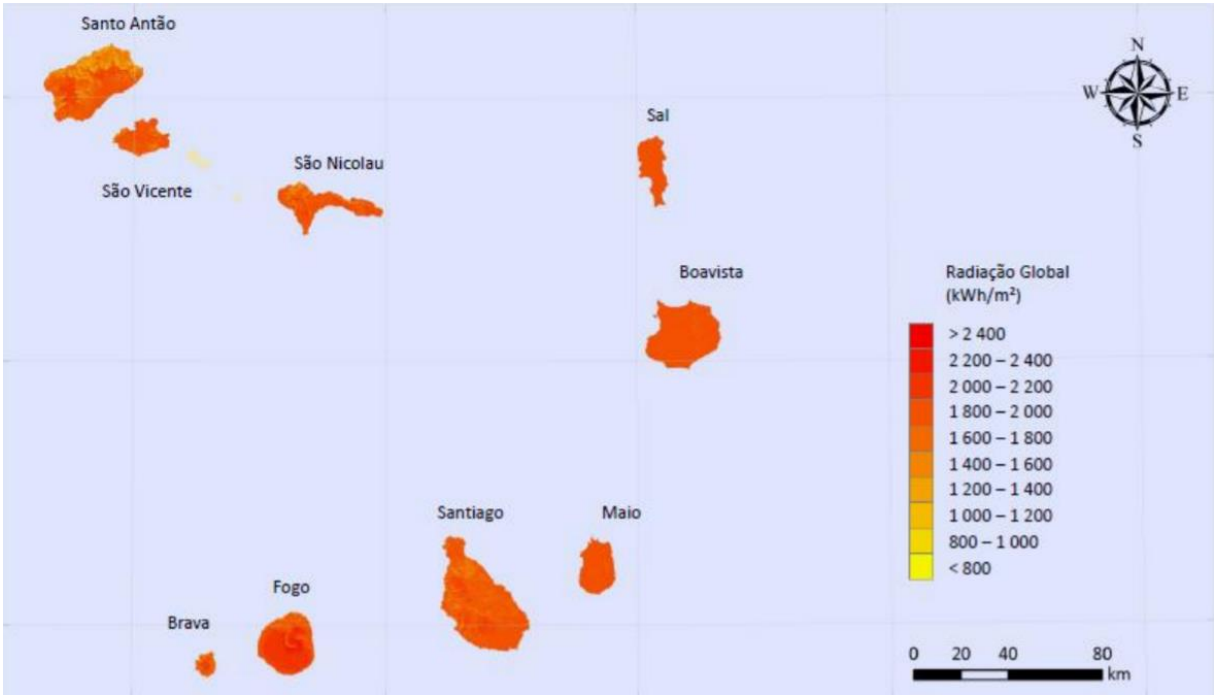

Figure 17.: Solar energy potential (more than 3500 hours/year) (Source: Gesto, 2011)

Portuguese-German Chamber of Commerce (CCILA)

It was founded in 1954 with over 1000 associates in Portugal and Germany. Their objective is to enhance the economic relations between the two countries by offering a wide set of services. CCILA supports mainly mid-size German companies in their entrance in the Portuguese market, while Portuguese companies are supported in the beginning of their expansion of commercial activities in Germany. (CCILA, 2017)

German experts and entrepreneurs have been exploring the renewable energy market in the islands. Possible German investment might happen as they are currently holding the third German-Cape Verdean Energy Symposium, where German business people got in contact with local authorities and the public and private sector. Currently the renewable energy penetration rate is 20% in the islands and the previous government set a goal of 100% renewable energy use by 2020. The government has changed last year, rethought the goal and set a new date for 2030. Their objective is to increase the effectiveness and efficiency of the existing infrastructure as well as using storage techniques.

6.2. Environmental sustainability

The broad term of sustainability has been defined and understood mostly within environmental sustainability by the World Conservation Strategy, which objective is to conserve natural resources as they are finite and to ensure development and to support all life. Even in the EU's Gothenburg Sustainable Development Strategy four out of six main objective is within the environmental sustainability such as climate change and clean energy, sustainable transport, sustainable consumption and production, conservation of natural resources. (Moldan et al, 2011)

As the three pillars of sustainability was introduced, the merits of economic and social sustainability is also acknowledged hand in hand with the environmental sustainability and it has been recognized to examine it for the clarification of its meaning. As Goodland defined the framework of the 'limits to growth' he placed environmental sustainability in the set of resource-limited ecological economic framework. (Goodland, 1995) Another approach of

Holdren is the focus on the biogeophysical aspects, such as maintaining or improving the integrity of the life supporting systems of the Earth. By this he means that this can be reached by maintaining biological diversity and biogeochemical integrity of the biosphere by conservation and proper use of natural resources. (Holdren, 1995) An important contribution to the concept of environmental sustainability was made by OECD in 2001. The Environmental strategy has four criteria which are regeneration, substitutability, assimilation and avoiding irreversibility. These refer to that the renewable resources should be used efficiently as well as non-renewables by limitations and substitutions with renewables, as well as that pollutants should not exceed their assimilative capacity. To follow the definition of environmental sustainability in the case of Cape Verde, since the country has abundant solar energy, it is viable to discuss the importance of the natural resources of the country. As it has been introduced, Cape Verde's energy system still relies on imported fossil fuels, which is clearly an unsustainable way of providing energy as the process of import itself already has big impacts on the environment, not to mention the emissions coming from the later use of fuels. Luckily it has been recognized that this cannot go further longer as the price of fuels are getting higher as the resources are declining. This can be opposed to the fact that Cape Verde is rich in natural resources, especially it has high potentials for solar and wind energy production. This means that the transition to renewables would contribute to the sustainable development of the country by having cleaner energy therefore cleaner environment and it would also have the economic benefits. Stating this means that the price of solar energy is declining. According to a recent report of the World Economic Forum, for new energy, now solar is cheaper than fossil fuels. The technology is gradually advancing and the installation costs are falling, and it is going to continue to fall, while the price of fossil fuels will not. (WEF, 2016) The fall in price could be attributed to factors like the mentioned falling installation prices and equipment costs, as well as new business ideas and the rise in cleaner energy policies. A good step for Cape Verde is setting the target of going 100% renewable even though not by 2020 as originally planned, but 2030.

Annually, over 7700 million tonnes of CO2 released to the atmosphere by the global electricity supply sector, which is 37,5 % of the total CO2 emissions. Now several methods exist for the mitigation of CO2 emissions. The development of technologies now allow increasing power station efficiency, therefore more efficient conversion of fossil fuels is possible. Also switching to low-carbon fossil fuels allows the use of high efficiency and low

capital cost which results in lower carbon emission. (Sims et al, 2003) But as it has been mentioned before, this does not seem like an option for Cape Verde. In the following section, it is discussed why solar energy is one of the most viable alternatives for sustainable energy resource for the country.

Technological advances offer opportunities and declining costs for renewable energy technologies that could meet the share of the fast growing world energy demand. Hydro-electricity for now is the most developed renewable resource, but it has some societal and environmental barriers. One of them is the location of possible sites to use hydro energy, which has high transmission costs. There is a risk of flooding as well which causes damages for the biological carbon stock. Wind power accounts for about 0,3 % of the global installed generation capacity, supplying around 0,1 % of the global electricity. Cape Verde already has wind farms producing clean energy, and the largest one is implemented by Cabeólica. Biomass is a renewable resource that has good potential to provide renewable energy to rural areas as it is widely distributed. For capturing solar radiation there are time variations for daily and seasonal fluctuations, therefore there is a need for energy storage. Areas near the equator receive twice as much solar radiation as places around the 60' latitudes. The costs of PV is gradually falling because of manufacturing scale-up and mass production techniques, therefore now there is a growing market in the PV power generation systems with off-grid applications for rural locations especially in developing countries. (Sims et al, 2003) So according to the data, what makes solar the best solution among renewables? First of all, the area has to be specified, which is currently Cape Verde. The territory the report focuses on is located in the capital, Praia. Informal settlements are not a rare phenomenon is the city, as urbanization is also present here. The term informal refers to the fact that the housing units constructed have no legal claim and the housing is not aligned with the current planning and building regulations of the city. (UN Habitat, 2015) They usually lack in infrastructure and services which is also the case in Praia's informal settlements. Several projects in the world, as well as Africa and even in Cape Verde focuses on the improvement of rural areas, such as rural electrification. At the same time, the problem also exist in the urban context in the form of the informal settlements, which should be focused on as well as sometimes in these settlements the conditions are even worse than in rural villages. In the case of Praia, the situation with these settlements is not very bad as they have access to basic infrastructure and they are connected to the grid. The problem is that they cannot pay for electricity so most of the households are stealing electricity which causes big amount of losses in the system. This

means they are dependent on the grid still, but since they cannot afford to pay for it, their dependence causes losses which are disadvantageous for the whole system. In rural areas the viable option for not having the proper infrastructure to provide electricity is an off-grid system as it is designed to work on its own and it does not have to be connected to the main power supply or any other power grid. Though it only relies on solar panels to produce power which can be stored in batteries. Solar energy has a lot of advantages, but also a drawback is its unpredictable nature which is due to the dependence on sunshine hours which are variable. Even though the Sub-Saharan Africa has the appropriate conditions, this problem is not something that could be a main issue.

There has been also an off-grid solar energy system implemented in the small village of Monte Trigo on the island of Santo Antão in Cape Verde. It is a 100% PV system with integrated storage and it supplies all the households and businesses which pay a fee for the use of electricity. Operation is public and private as well, where the municipality has invested, but the main input came from donation. (Circuitor, 2017) This project demonstrates the feasibility of clean-energy mini-grids in Cape Verde and shows that these systems can help achieving the target of 2030.

Concerning the previous mentioned applicability of solar panels in rural areas as an option to solve the problem of the energy accessibility, the urban conditions come up as well. Much of the developments are taking place in rural areas, the recognition increases on under-class urban areas that also have limited access to modern forms of energy. These communities, which involve the informal settlements of Praia as well, have very similar problems in accessing electricity as people in rural areas. Even though not all of the renewable options are suited for urban areas, solar PV is one of the technologies that suites.

Also, to demonstrate with some examples, there have been successful solar PV implementations in the area. It not only provides the access to sustainable energy, but also has economic and social advantages. One example is coming from Nairobi, Kenya, where they launched a solar PV assembly project in the biggest slum area. The Kibera Community Youth Programme created jobs, and it was an important factor for this area as it is known as an area with high rate of unemployment between young adults. Also, poorly-built houses were retrofitted with roof insulation and solar water heaters in a low-income neighbourhood of Cape Town. The outcomes have reduced the emissions, reduced heating bills, improved

health which can be also credited for the training of locals who were engaged in the works. (Simon, 2013)

It is known that renewable technologies are safer to offer solutions to many environmental and social problems associated with fossil and nuclear fuels. Among these, solar energy technologies provide environmental advantages compared to the conventional energy sources, so it contributes to sustainable development. Their main advantage is in connection with reduced CO2 emissions and any kind of air pollution or waste produced during their operation. It also has the positive implication of reducing the emission of greenhouse gases, regeneration of lands, or reduction of transmission lines of the electricity grids. From the socio-economic point of view it has the benefit of increasing the energy independency, providing work opportunities, securing the energy supply by diversification and accelerating rural electrification in developing countries as it was mentioned. (Tsoutsos et al, 2005)

Africa is currently facing energy crisis which is not due to the lack of resources but to the lack of infrastructural support and technology to harness these resources, also the renewable ones. One of the biggest concerns is the forest resource which is declining, as the supply is difficult to sustain and the demand is growing. This is also the case in Cape Verde, desertification has been a problem of the country. (Bujage, 2006)

Solar energy is an attractive option to use as renewable energy in Africa as it is naturally decentralized and available in a big supply. The costs are falling even though at the same time the technology is improving and it has a lot of availability for support from institutions as well that support low-carbon solutions. The average annual direct irradiance of the Sub-Saharan region, where Cape Verde is located as well, reaches at least 5 kWh/m2/day, which is the minimum level for efficient power provision from solar thermal facilities. (Murray et al, 2010)

6.3. Economical sustainability

A sustainable economic model looks like something that ensures that fair distribution and efficient allocation of resources and the growth of the economy maintain a balance with the ecosystem. In a company point of view, sustainability includes also functioning profitably over time. (Pearce et al, 1990)

In a developing economy, solar energy investments are becoming more and more necessary as there is an energy crisis in Cape Verde as well due to the over-dependence on fossil fuels which are finite. If looking at the sunshine hours in Cape Verde (since sunlight is the primary energy source), the annual temperature for most of the country is about 26 degrees. (SE4ALL, 2015) Located in the Sub-Saharan region, it is among the sunniest areas of the world, PV is set to become a major source of electricity.

So far, Cape Verde did not have the technical solutions to start to transform the energy system. In the current system, the biggest problem is the non-technical loss of electricity which is coming from the fact that households are connected to the grid, but not paying for electricity. This is the case in Praia's informal settlements and electricity prices are really high, around 0,28 euro/kWh. (Vilar, 2011)

As several literature and Isabel Cancela de Abreu from ALER also mentioned, one of the biggest problems are the institutional and technical capacity of the implementations. That seems like the reason for needing to have conferences for experts on the field, besides the funding, mostly from Germany. The latest conference has been hold recently in Praia for the third time for the purpose of networking (under the name of German-Cape Verdean Symposium on Energy and Bilateral Meetings) and it was organised by the Portuguese-German Chamber of Commerce (CCILA). The positive sign was that 29 Cape Verdean companies were present beside the 6 German ones with promising results.

As it has been highlighted before, Sub-Saharan African countries are net importers of oil, therefore there is a direct link between their economies and the availability of fossil fuels. As in Cape Verde, the supply of diesel fuel becomes so expensive that the supply of electricity is limited. As Cape Verde's goal is to have the electricity supply from 100% renewable energy by 2030, it needs a lot of dedication and planning. As the informal settlements are currently not in the main focus of the energy planning, their role should be emphasized as well, as their important nature of being the part of the biggest urban area of the country, therefore a big vast of the population are effected. A both economically and environmentally beneficial option is proposed in form of a hybrid system of solar PV and diesel, a flexible concept.

6.4. Flexible concept – a hybrid system of solar PV and diesel

This option is proposed as a possible runner-up. This means that a drastic change in the system cannot happen day-by-day, it needs time for the transition to happen. Therefore, a hybrid system is proposed as a possible solution for the current problem of low electricity security, losses in the grid and the unsustainable use of imported fossil fuels.

A hybrid system is a combination of two or several different sources of energy, which in this case is the mix of solar PV and diesel generator. The production cost of electricity from hybrid solar PV and diesel power plant becomes more competitive with the cost of electricity produced from pure diesel generators. In these systems the diesel generator reduces the PV component, while the PV system decreases the operating time of the generator, and with this it reduces the operating costs of the diesel generator. (Yamegueu et al, 2011) This system could reduce the dependence on the increasing oil-price risk and could minimize the environmental damage due to the burning of fossil fuels.

The operating cost of PV is low compared to the diesel generator, but its capital cost is high. The maintenance cost for PV are less compared to diesel generator, so they again in balance. The energy supply coming from the diesel generator is always available, while the energy supply coming from PV is dependent on solar radiation. (Yamegueu et al, 2011)

6.5. Theoretical relations

6.5.1. Introduction of a new technology – smart microgrids

As strategic niche management proposes, the introduction of new sustainable technologies contributes to a shift to a more sustainable economic development through technological progress. To follow this, the implementation of solar PV micro-grids in the informal settlements is proposed as a solution instead of the current unstable and fossil fuel based system. It can be said that microgrids in Cape Verde are still in the status of a niche, as it has

been recognised as a sustainable option, but it is not yet the part of the energy production, just as solar energy itself.

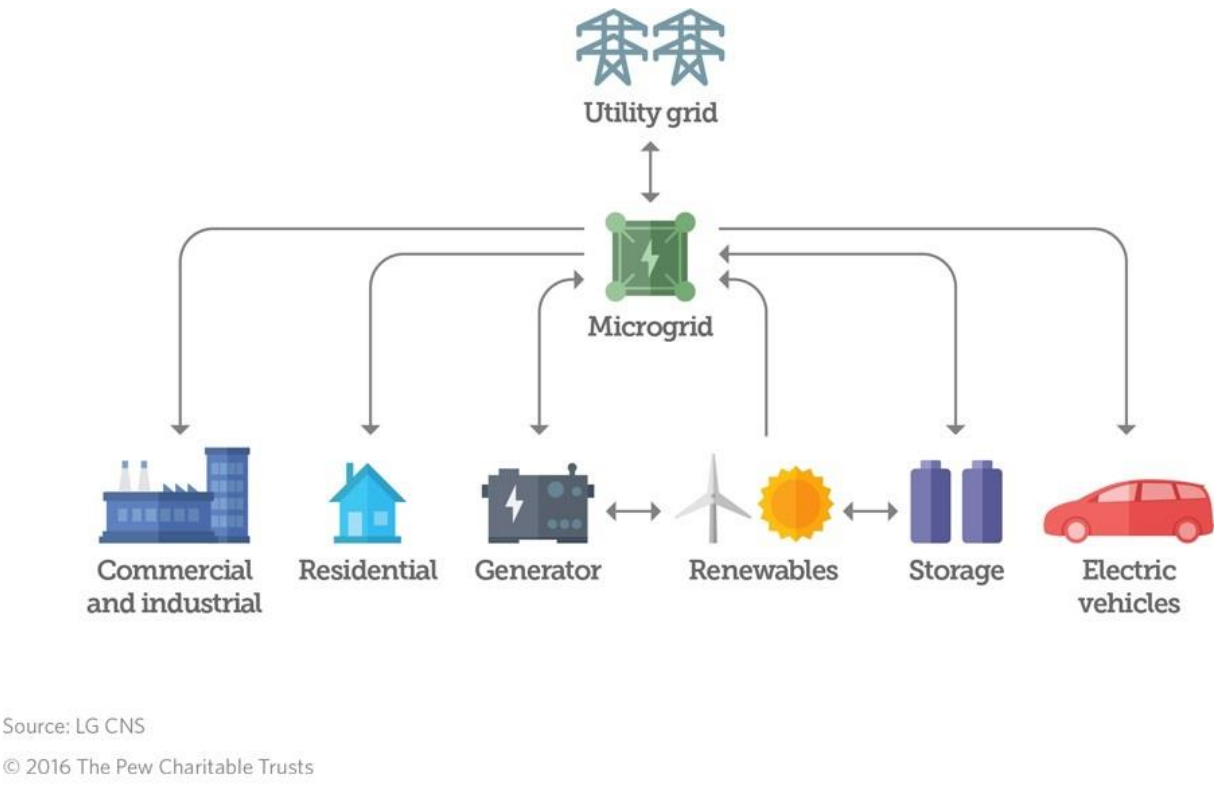

Figure 18.: Demonstration of how a microgrid works (Source: LG CNS, 2016)

A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid. (Fu et al, 2013) Microgrids interact with the utility grid and can operate independently as well in case of limited availability or outage. There are more and more urban areas where the development of small decentralized PV production is happening and they are integrated to buildings. The name of this technology is building integrated photovoltaic (BIPV) and these are mostly for self-feeding of the building itself equipped with a PV and it can operate both grid connected and in islanded mode as well. (Sechilariu et al, 2013) So it means it can also receive power from the utility grid, and the excess power can be traded back as well. Building integrated photovoltaics are a small scale solution for informal settlements, but it could have many advantages, especially in contrast with the current situation. By implementing these flexible systems on buildings, the electricity supply would always be ensured. Besides, the solar energy would be a shift to a more sustainable development of the city. It would help to reach the goal of 2030, and for that these kinds of transitions in the system are crucial. This

option could bring the twofold opportunity of reducing greenhouse gas emissions and improving urban energy security and resiliency.

If we look at the neighbourhood scale, it is important to mention the social perspective of it as well. The relationship of the microgrid to the national electric grid can be analogized to the urban community's relationship to the nation state. These informal settlements are quite isolated from the formal part of the city, but they are still on the grid. By having a less dependent relationship between the neighbourhoods and the grid, the non-technical losses could be solved as they are mostly coming from the informal settlements by stealing. Transitioning the electric system away from the centralized grid structure toward a series of interconnected local microgrids could turn the focus of the electric system to the urban neighbourhood. Also, since it could be an independent generation and distribution system, the energized section of circuits separate from the larger system. If the area disconnects from the centralized grid, the islanded area transitions from redundant infrastructure to the primary power source for all customers connected to the islanded area. When it is connected to the grid, the microgrid functions as a secondary electricity system that complements centralized operations. This microgrid system allows for power to flow in multiple paths and the reliability increases, because the system has multiple layers of electricity. Introducing the solar microgrid as a technological niche in the system could also break the seal on the utility compact, because it would introduce competition in the energy industry. (Jones et al, 2015)

It is a long path for solar microgrids to become the part of the regime in Cape Verde, but the goal of going 100% renewable by 2030 is aligned with the transition. The 100% RE goal and the transition for the informal settlements to use sustainable energy to provide electricity for the urban poor enhances each other, so as the theory of Strategic niche management emphasizes, the introduction of this new technology could contribute to a shift to a more sustainable economic development as well through this technical progress.

6.5.2. Local development – based on local resources

As endogenous theory emphasizes, local resources should be supported to improve local development processes, such as renewable energy investments. It assumes that local development processes that are based on local resources are more self-sustainable and enduring, which has been looked up on in the case of Praia. The current system is based on

resources that are external to the local community in the form of fossil fuels, which is imported as Cape Verde has poor natural resources.

This theory also highlights the importance of actors, especially local ones that are present in the case as well. The main local actor is the government of Cape Verde, and it is the most important actor that supports the implementation of renewable energy systems in the country, therefore it is in the interest of the government to develop the energy supply of the informal settlements in the capital as well, as the switch to the use of local resources is a part of reaching the 100% RE by 2030.

As these kind of renewable energy projects are based on the local resources, so they take advantage of the physical resources, while the technology and knowledge of the implementation are usually from an outside area. This is relevant as well, because Cape Verde lacks local knowledge of renewable energy implementation, as well as adequate work force that are aware of the maintenance of these systems, like solar panels. This is where another important local actor comes in, the university. The University of Cape Verde offers several programmes that are relevant to provide adequate knowledge to students, thus future professionals who can contribute to the development of knowledge about renewable energy implementation and urban planning, therefore their deep knowledge of the local context as well as broader experiences from studies can also contribute to the development of services in the area of renewable energy implementation and development, for instance in the informal settlements.

6.5.3. Relations in the actor network

In the past years, Cape Verde's goals and visions are focused on the transition to a renewable energy system, instead of the current fossil fuel based system that besides is highly unsustainable, also very expensive. The pursuit of the objectives is characterized by a wide range of actors that integrates an actor-network in international, national and capital level.

In the middle, the main actor of the national level as well as the main actor of the whole network is the Government of Cape Verde as it includes all the strategies and plans that are designed for the renewable shift. The Government is in partnership with the private sector in the form of the action agenda of the Sustainable Energy for All. The SE4ALL action agenda

is part of public policy documents, including also the National Action Plan for Energy Efficiency (PNAEE) and the National Action Plan for Renewable Energies (PNAER). The development of these is coordinated and supported by ECOWAS (ECREEE) ensuring the coherence with energy policies. As Cape Verde is the host of the ECOWAS it intends to assure regional leadership in the energy transformation in Africa. (INDC, 2015)

Financial support implies cooperation between actors as well. The strategy of the energy sector is based on the growing involvement of the private sector which is the key factor for financing renewable projects, as it will replace public investments. This is where the role of the state becomes important as well, as it can act as a promoter and facilitator, as well as the regulator of the market production. This can create the conditions for private investments as according to the initiatives, it can offer dynamic, innovative and energy efficient options. The private sector is already an existing entity in the energy system, such as Gesto, Lobo Solar, Cabeólica and Martifer Solar, which are companies implementing or designing renewable energy solutions and have been having ongoing projects in the country. Gesto and Martifer Solar are Portuguese companies, so international involvement is present as well. Some European countries are present in the Cape Verdean scene besides Portugal, such as Austria and Spain. They have a joint declaration between the European Union, Luxemburg, Spain, Portugal, Austria and Cape Verde in the field of sustainable energy which is part of the energy agenda (PNAEE, PNAER, SE4ALL) that is approved by the Government. The aim of this is a framework for technical assistance on energy sourcing and energy efficiency, as Cape Verde is lacking technical support locally. In relation to this, as the lack of technical knowledge and support appears to be an issue, it is proposed in the SE4ALL document to create a postgraduate programme on different aspects of energy production and consumption. Even though the annual growth rate of those attending to higher education was 32,3% last year, the country requires professionals and constant innovation with improvement in the processes and technologies. So by now, Cape Verde depends on the technical knowledge in the field of renewable energy of international entities.

An important actor in the international level is ALER. ALER is a Portuguese non-profit association to promote renewable energy in Portuguese-speaking countries. They support the Government of Cape Verde in revising the legislation of the energy sector to make sure there are favourable regulatory requirements, so it has a strong connection to the country. The objective of their working group is to gather members who are interested in the Cape Verdean market. Besides, the member of the working group are also Cabeólica, Tecneira and ARE as

well. According to Isabel Cancela Abreu, this is the only place where the private sector can share their views and understand what they have in common. Their main objective is to put together the private sector and understand what their interests are and to promote this towards the government. Since the private sector of the renewable energy is not organized, it needs to be coordinated and that is what ALER tries to perceive. Also, the companies in Cape Verde, who could also be part of the network, are small and each of them alone cannot change things, therefore if they get together in a platform and identify priorities then it is easier for them to get to their goal.

The goals and practices mentioned in the PNAEE, PNAER and SE4ALL plans are coherent, and the enhancement of renewable energy micro-grids are also promoted because of their financial sustainability and the high cost of diesel run systems in isolated areas are giving the opportunity to test these technologies. In addition to the promotion of innovative practices they plan to finance micro-grids in home scale. For this, partnerships with banks and international partners are needed and also private involvement to overcome the financial obstacles. Since they recognized the importance of having a transition in the energy system of isolated areas, this could further develop to the examination of them, which includes informal settlements as well.

The case of informal settlements of Praia carries a very local and specific issue, even though it interacts with projects that have been in process in the country. As it already has been mentioned as the goals of the PNAEE, PNAER and SE4ALL are in alignment with the possible development of the informal settlements, even though a separate paragraph is needed to specify the case of these areas as they slightly differ from both typical urban and rural areas.

6.5.4. Constraints in the network

By examining the actor-map, it reveals that the main actor is the Government of the country, who has been a part of the planning of the transition and supports it. If the international level is looked upon, for small scale solar panel implementation Martifer Solar is not relevant as they work with bigger scale. ALER is the organization that holds a lot of actors together, even though they focus on the national scale, so on Cape Verde, even though the actors they bring together can eventually consider city level projects as well.

6.5.5. Synthesis of the analysis

In relation to the case study, the proposed objectives to improve the situation in the informal settlements can be seen as a micro-actor that should be a part of the network, so eventually become an actor. It is essential to highlight that solar micro-grids have been used as a solution for electricity supply in many places in developing countries, therefore it is not a typical solution in an urban context, especially for a neighbourhood that is already connected to the grid. So in this case, it is a question if it can even become from existing as a niche, to the part of the regime in an urban context. It is more difficult to place solar panels in cities due to the density, but building implemented solar panels have been mentioned as well as a viable solution for cities, so these could be considered as an option with the micro-grid for the informal settlements. The idea of having a system that can connect and disconnect from the grid relies on the fact that the current energy system of Cape Verde relies on fossil fuels therefore the supplied energy is coming from there. The goal of 2030 to reach 100% penetration of renewable energy to provide electricity is an indicator for this, although the transition has to happen step by step and the extremely high losses in the grid caused by stealing indicates the necessity for the shift to happen in these areas first.

7. Conclusion

The informal settlements of Praia and their case of electricity access is a known phenomenon among the Government and the mentioned actors as well. It is just recent that several entities started to recognize the importance of the lifting-up of these areas of the city. However the electrification of rural areas has been emphasized by several research, as it has been mentioned by ALER, the urban poor areas should not be forgotten as well as the situation can be worse as in rural areas. In the case of Praia, firstly the use of imported fossil fuels and the issue of high losses in the grid call for a solution. The proposed solution happen to be aligned with the ambitious goal of having the access to electricity from 100% renewable energy resources by 2030.

Micro grids, as it has been proposed, could be a viable option to solve the problem of the informal settlements. They can connect and disconnect to the grid, which means flexibility. When a system has multiple layers of electricity, reliability increases because there are multiple paths for power to flow. It could also operate disconnected from the utility system, but could also reconnect and sell any excess resources back to the interconnected grid.

As Cape Verde being a previous Portuguese colony, it has attachments to Portugal, in a beneficial way. Portuguese companies are present on the islands as well as projects already implemented and in process. Despite the wide range of actors, projects and plans, no research has been conducted on the issue of energy supply in the informal settlements of Praia, even though this issue plays a vital part in the losses in the grid, which is now around 40%. As the actor-network has been examined, it can be said that first of all, there is a need to finance the lifting-up of the informal settlements. This role could be devoted to international investors who already see potential in implementing solar PV in Cape Verde. The regulatory framework makes it possible to import renewable energy equipment for cheaper price, therefore the import of solar panels would cost less. As they do not have the technological capacities to produce this equipment it is a viable option.

It is possible to conclude the necessity of synergy between the actors such as the Government in a way of including the issue of informal settlements in the renewable energy planning process in alignment with the goal of 100% renewable electricity by 2030. This goal is a proposal for radical transformation of the sector and implies a deep change in the technology and procedures. It also implies knowledge and experience, therefore the training of human

resources for the challenge. In the end, Cape Verde would be in a leading position in the renewable energy sector, which is not only an asset to sustainable tourism, but also a possibility to provide services with significant economic impact. Also, the impact would be also significant as the residents could have access to sustainable and affordable electricity and this has an impact on the economy and the well-being of Cape Verdeans.

8. Perspective

In this project, the possible implementation of PV system in Praia's informal settlements is examined through ANT, SNM and EDP. The results show, that one of the crucial point of improving the conditions in these settlements is the collaboration of the necessary and right actors. However, besides the already existing actors that could help the process, several possible actors appeared to be relevant.

As it has been mentioned, a conference was held recently in Praia, where several German companies participated, who showed interest in the market and are looking for Cape Verdean companies to partner with. One interview was conducted with Dr Thomas Walter from Easy Smart Grid GmbH from Germany. The political will is there to transform the energy system of Cape Verde, but so far they do not have technical solution to proceed. This company recognized the problem of the non-technical loss of electricity in the grid, when the homes are connected to the grid, but not paying for electricity, therefore ELECTRA makes losses. This is an important realization of them, as it could bring further discussions to the table if there are going to be further collaborations with the companies that attended the conference or as well could wake the interest of further companies from the private sector. This indicates to mention possible actors that could join the existing Actor-Network with contribution to the proposed solution. Besides Easy Smart Grid GmbH, also Leipziger Energiegesellschaft mbH, PA-ID GmbH and SUNSET Energietechnik GmbH joined the conference that was held in the beginning of May in Praia for possible investors to meet and as these German companies as specified in small scale solar panel implementation, the informal settlements could be one of their target.

During the interview with Isabel Cancela de Abreu from ALER, a few possible actors according to her views were proposed. Even though the universities in the country have been expanding their choice of courses with relevant programmes in the topic of renewable energy, they are not connected to any entity directly. It would be beneficial for both the university and students, as well as for companies to meet future professionals by some kind of cooperation in the field. A creation of a National Renewable Energy Association was also proposed by Abreu and it should be done by national stakeholders as it already happened in Mozambique. Financially, the African Development Bank could be a target as they finance renewable

projects, such as wave energy plans, but since Cape Verde has abundant solar energy, it could be a relevant argument for support solar panel implementations.

It has been suggested that micro-grids could be viable solutions, another kind of assessment of the possibility comes up. This is the use of GIS to make solar radiation analysis directly on buildings of the informal settlements that would give a visual and technical proof of the viability of the implementation. An already existing solar atlas is demonstrated in the following.

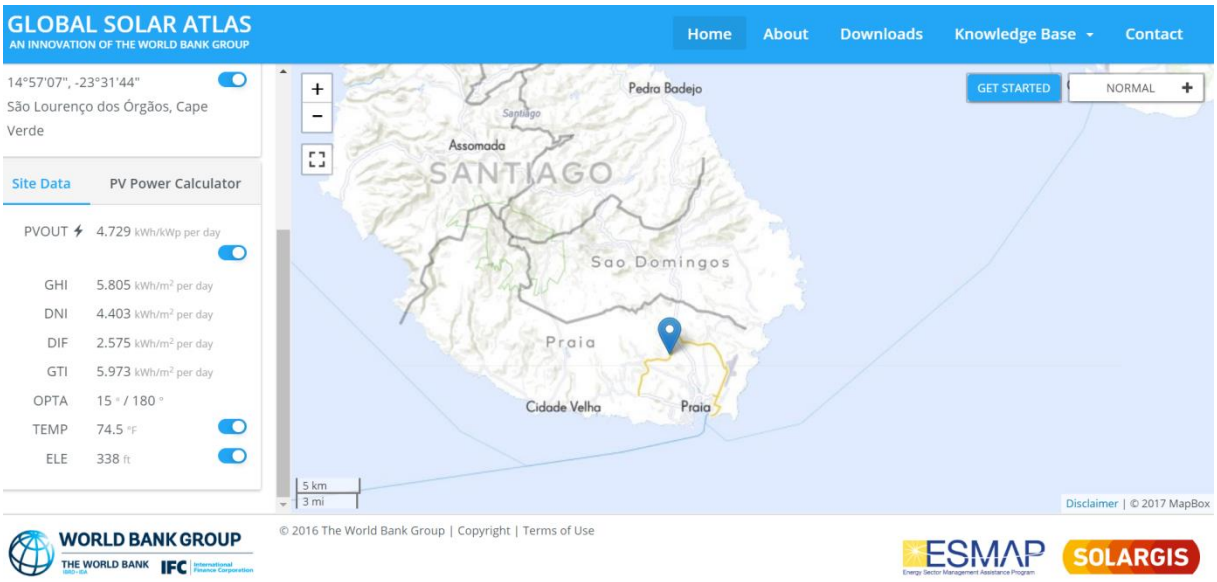

Figure 19.: Global Solar Atlas focused on Cape Verde I. (Source: The World Bank Group, 2016)

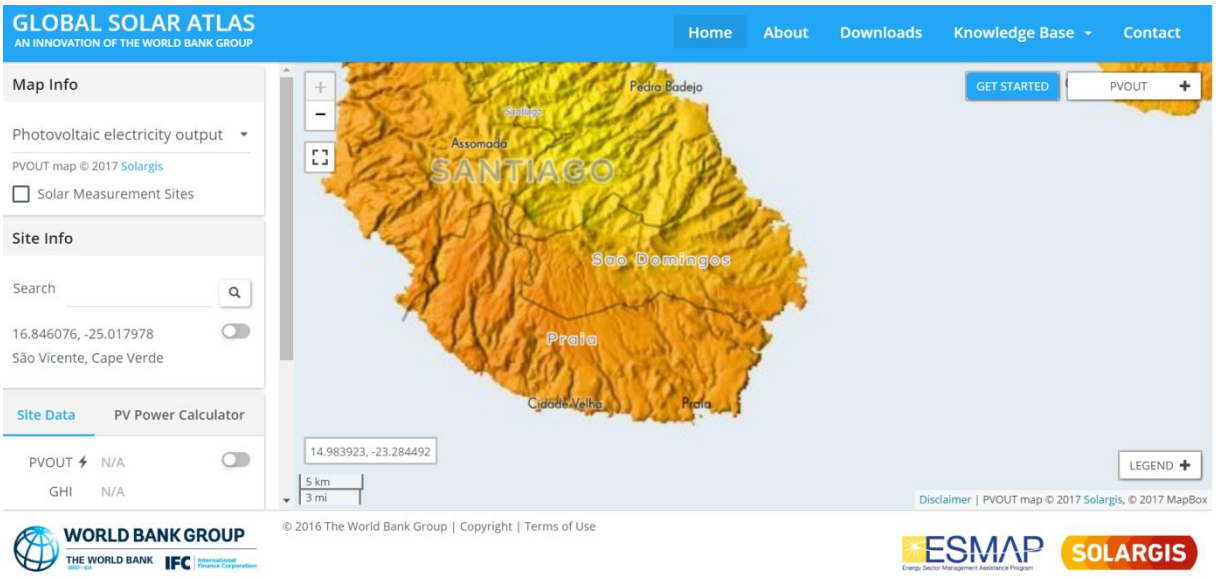

Figure 20.: Global Solar Atlas focused on Cape Verde II. (Source: The World Bank Group, 2016)

As it can be seen, it has other useful features, such as calculating the PV power by day. The only problem is that it only shows the national scale, which is also important, but a more accurate and building-scale analysis could demonstrate the data needed also for investors to see the viability. On such a map, the daily solar radiation of a building could be visualized and would give an extra dimension for the actors with more data as an input. As it was mentioned in the Analysis, BIPV could provide a viable solution for the issue of electricity supply because of its flexibility and alignment with the renewable energy plans of the country. A solar radiation analysis for rooftops on the informal settlements could be an existing proof for viability. Since there is yet no access to shapefiles that are the base of a map in GIS, that contains information on building heights, building shapes and area, it is not possible to make the solar radiation analysis on every building in these neighbourhoods. The question comes up: If these informal settlements are constantly changing, how could it be possible to solve the measurement of the data needed for such a map? This is a challenging, yet very interesting issue to possibly solve, and it would definitely help the transition of these neighbourhoods as a contribution towards a more sustainable future.

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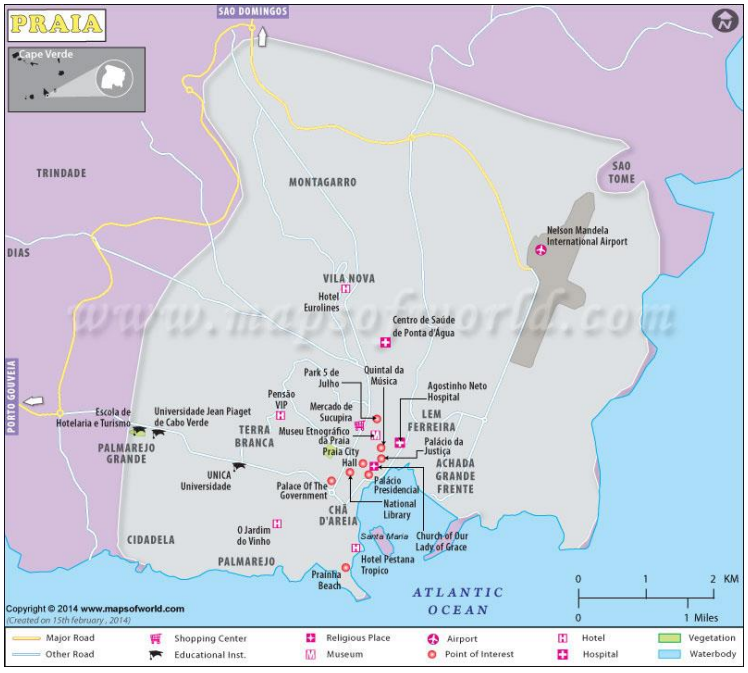
Cover photo: View on an informal settlement of Praia, Cape Verde (Source: Maria João Rodrigues)

Annexes

The Political Map of Cape Verde

Source: openworldmaps.org

The Map of Praia



Source: mapsofworld.com

The informal settlements of Praia

Source: Maria João Rodrigues

Interview transcript I.

Isabel Cancela de Abreu

Executive Director

ALER

24th April, 2017.

ALER carried out the mapping of all the initiatives, identifying the responsible authority and the status and will seek to contribute to that they are the most effective Working Group.

ALER is an association that supports the government in revising the legislation of the energy sector to make sure there is a favourable regulatory requirement. The government of Cape Verde undertook the exercise of reviewing the existing legislation, namely the renewable energy decree law and they were also thinking about launching a tender for IPPs for renewable energy. There are many donors in Cape Verde although it is a medium level development country but still they receive a lot of donor founding. The objective of the working group was to gather members who are interested in the cape Verdean market so they can look into what was being prepared.

The government of Cape Verde, the ministry of energy is a member – they had a very good relationship with the previous energy minister, he was sharing information with them so they were able to look at documents. The objective of the working group was to look into these documents and provide comments, to collect, to discuss the documents and then send them to the government, in this case the energy director. The government changed, they ended up not delivering anything. They are trying to understand if they will pick up what is left from the previous government or they will start everything from scratch. The new energy director just took office few months ago, so they have to wait how they will proceed.

The members of the working group are the members of ALER – Cabeólica, Techneira, University in Porto, external participant ARE. They have working groups on all kind of subjects or country, they meet when it is necessary. They supposed to have a follow up meeting but the members decided to wait because of the government change.

She does believe working groups are very useful and necessary – it is beneficial to have more participants. It is the only place where the private sector can share views and understand what they have in common and what is their opinion because they often meet players in cape Verde and they often complain – they have a bit of a problem identifying their needs in CV. This is one of the main objectives of ALER to put together all the private sector and to understand what are their interests and then to defend their interest near the government. A questionnaire was one of the outcomes.

The private sector of the renewable energy is not organized and there is a need to find an association who coordinate this – this is what ALER tries to do. In the future they try to create and support the creation of a national renewable energy association. It is in national level so it should be done by national stakeholders – they managed to do it Mozambique.

In Cape Verde companies are very small (besides Cabeolica), each of them alone will not be able to change things, but if they get together and identify priorities then it is easier to get something. They are gathering reports and documents and the members have access to documents that are not available for public.

ECREEE, CERMI, EU, Gesto – possible members she can see as, main stakeholders. The EU was trying to organize a working group on energy. Companies in CV – APP – mini grid in Santo Antao, Santo Nicolao, Electra, Cabeolica, ELSEC, ARE, Lobo Solar. If i am looking into household level Martifer Solar is not relevant so much because it is big scale not household scale.

Portuguese German Chamber of Commerce CCILA – renewable energy sector of CV, they are now organizing the 3rd trade mission and conference about Cape Verde (beginning of May). They have been able to gather a lot of German companies who are interested in the cape verdean market.

Environmental energy director, the retail bank – they are important actors who are outside but they should be inside.

Money comes from grants – they are very limited in the amount of projects they can do if they have no funding. As soon as the banks would give credit and favourable conditions then this whole industry could jump.

Universities are important actors too – university of CV, univesidade de mindelo in sao vicente. They are important to have specialized human resources.

RECP – promote renewables in African Portuguese speaking countries. They have an agreement that will run until December 2017, several tasks - one is translation of documents to Portuguese, translation of mini grid policy toolkits, collection of information , organization of information and matchmaking events. At the moment the contract with RECP doesnt cover cape verde.

Renewable energy action plan, energy efficiency action plan

Going 100% RE – now they are going back to 50% (as heard)

African Development Bank – they will finance wave energy plans.

ALER works in 9 countries, they can't go in depth in segments such as informal settlements. The issue of informal settlements applies to cape verde, but also applies to other African countries as well. They always talk about rural electrification and not so much about periurban – it is as hard or harder than rural areas. Rural areas - it is easy so identify and make a perimeter for it but the urban is always growing and the conditions are sometimes even worse than in rural areas – it is an interesting approach. This reality is more interesting than downtown fancy Praia.

Interview transcript II.

Dr. Thomas Walter

Managing Director

Easy Smart Grid GmbH

22th May, 2017.

They focus on using more renewable energy where it is already cheaper than fossils, which is the case in most electric grids operated with diesel or heavy fuel oil. There is the climate need and political will to transform the energy system, but so far no technical solution to do it. But this solution is very simple: As electricity from sun and wind is volatile, there is a need to adapt consumption to generation (any storage in batteries is far too expensive, and will remain so in the foreseeable future). To make loads variable, they have to offer a variable electricity price. They develop the technology to transmit and read this price in a very efficient and low cost way

One of the problems in Cabo Verde is "non-technical loss" of electricity, i.e. people connecting to electricity, but not paying. This is a serious problem (Electra makes losses and cannot invest in renewables or other measures to transform the grid).

Generally, small solar systems (e.g. solar home) make the problems worse rather than better, because electricity from these systems is extremely expensive (easily above 1€/kWh) and it brings a stigma to solar (In South Africa, I heard that "PV is for the poor, rich people can afford diesel generators")

In Germany, over hundred years ago poor people started something called "Genossenschaften" (associations); where they put together savings to provide services (banking, agricultural equipment, seeds and fertilizer) individuals could not afford. These could again be approaches for CV.

If there is an energy system with ~25% renewables and wish to make it 80% renewables at lower cost (and have the resources to invest in the necessary equipment), then they can solve it.