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Renewable energies in the context of rural electrification and the path towards a successful rural electrification strategy in Senegal

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Affidavit

I, **MIRIAM STEINDL**, hereby declare

1. that I am the sole author of the present Master's Thesis, "RENEWABLE ENERGIES IN THE CONTEXT OF RURAL ELECTRIFICATION AND THE PATH TOWARDS A SUCCESSFUL RURAL ELECTRIFICATION STRATEGY IN SENEGAL", 73 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

Given that especially rural areas in developing countries still largely remain underpowered today, this thesis attempts to investigate the aspects that are most vital for a successful rural electrification strategy in developing countries. With its large natural resources and its enormous potential in terms of renewable energies to be exploited for the matter of modern energy generation, sub-Saharan Africa is in the focus of attention. Based on the assumption that rural electrification rates in sub-Saharan Africa remain extremely low today due to a lack of appropriate strategies in most countries, the purpose of this master thesis is to contrast the current knowledge about the most favorable policy measures and factors for a successful rural electrification strategy to the strategy of Senegal, a country that has shown its commitment to work towards these ends but has failed so far to achieve satisfactory outcomes in terms of access rates. The first section provides the reader with an overview on rural electrification in developing countries and presents the state of rural electrification in sub-Saharan Africa. It elaborates on the region's energy uses patterns, choices of renewable energy technologies for the rural context and electricity distribution, covering the actors, delivery models and price reduction measures. It then highlights the various constraining factors to rural electrification. The following section looks into Senegal's rural electrification strategy. After giving a country overview, it discusses several national policy documents that reflect the country's serious commitment to provide its rural population with sustainable energy in the years to come. This section further covers Senegal's electricity sector and the use and potential of renewable energies. The present work reveals that the assumption that rural electrification rates in sub-Saharan Africa remain extremely low today due to a lack of appropriate strategies in most countries needs to be revised. For the case of Senegal, it proves to be difficult to extract the major flaws in the strategy. This is mainly due to the fact that the success of a rural electrification strategy depends on a great number of factors that extend beyond institutional, economic, policy-related, environmental and technological borders.

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List of Acronyms and Abbreviations

AFD French Development Agency (*Agence Française de Développement*)

ANER National Agency for Renewable Energies (*Agence Nationale pour les Energies Renouvelables*)

ANSD Agency for Statistics and Demography (*Agence Nationale de la Statistique et de la Démographie*)

ASER Senegalese Rural Electrification Agency (*Agence Sénégalaise d'Électrification Rurale*)

CEDEAO Economic Community of West African States (*Communauté Economique des Etats de l'Afrique de l'Ouest*)

CEMAC Economic Community of Central African States

CRSE Senegalese Electricity Sector Regulatory Commission (*Commission de Régulation du Secteur de l'Electricité*)

DPES Senegalese Economic and Social Policy Document (*Document de Politique Économique et Sociale*)

DSRP Strategic Document for Poverty Reduction (*Document de Stratégie pour la Réduction de la Pauvreté*)

EAC East African Community

ECOWAS Economic Community of West African States

ERIL Senegalese Local Rural Electrification Initiative (*Electrification Rurale à Initiative Locale*)

FEMA Forum of Energy Ministers in Africa

GNESD The Global Network on Energy for Sustainable Development

GTZ German Agency of Technical Cooperation (*Deutsche Gesellschaft für Technische Zusammenarbeit*)

IEA International Energy Agency

IMF International Monetary Fund

IRENA International Renewable Energy Agency

LPDSE Senegalese Political Letter for the Development of the Energy Sector (*Lettre de Développement du Secteur de l'Energie*)

LPG Liquefied Petroleum Gas

MDGs Millennium Development Goals

MPI Multidimensional Poverty Index

NEPAD The New Partnership for Africa's Development

NGO Non-Governmental-Organization

OMVG Organization for the Enhancement of the River Gambia (*Organisation de Mise en Valeur du Fleuve Gambia*)

OMVS Organization for the Enhancement of the River Senegal (*Organisation de Mise en Valeur du Fleuve Sénégal*)

PAP Priority Action Plan (*Plan d'Actions Prioritaires*)

PERACOD Programm for the Promotion of renewable Energies, Rural Electrification and the Sustainable Supply of Domestic Fuels (*Programme pour la Promotion des Energies Renouvelables, de l'Électrification Rurale et de l'Approvisionnement Durable en Combustibles Domestiques*)

PPER Rural Electrification Priority Program (*Programme Prioritaire d'Électrification Rurale*)

PRSE Plan for the Recovery of the Energy Sector (*Plan de Redressement du Secteur de l'Energie*)

PSE Plan for Senegal's Emergence **(***Plan Sénégal Émergent*)

PV Photovoltaic

RETs Renewable Energy Technologies

SENELEC The National Electricity Company of Senegal (*Société Nationale d'Électricité du Sénégal*)

SMEs Small and Medium-sized Enterprises

SNDES National Strategy for Economic and Social Development (*Stratégie Nationale de Développement Economique et Social*)

T & D Transmission & Distribution

WAPP West African Power Pool

WEO World Energy Outlook

WEM World Energy Model

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1. Introduction

According to the 2011 report of the International Energy Agency (IEA), more than 1.3 billion people around the world have no access to electricity, with almost 95 % of them living in sub-Saharan Africa and Asian developing countries (WEO 2015). Around 89 % of these people live in rural areas. (Javadi et al. 2012: 403) Given the 2011 IEA report, sub-Saharan Africa also has the lowest access to electricity in rural areas with a rural electrification rate of 14.2 % whilst in terms of population, the region ranks first in the world with 585 million people without access to electricity (WEO 2015). Table 1 shows the number of people without access to electricity in the world.

Table 1: Electricity access in 2009 – regional aggregates (WEO 2015)

	Population without electricity (million)	**Electrification rate (%)**	**Urban electrification rate (%)**	**Rural electrification rate (%)**
Africa	587	41.8	68.8	25.0
North Africa	2	99.0	99.6	98.4
sub-Saharan Africa	585	30.5	59.9	14.2
Developing Asia	675	81.0	94.0	73.2
China & East Asia	182	90.8	96.4	86.4
South Asia	493	68.5	89.5	59.9
Latin America	31	93.2	98.5	71.8
Middle East	21	89.0	98.5	71.8
Developing countries	1314	74.7	90.6	63.2
World*	1317	80.5	93.7	68.0

*World includes OECD and Eastern Europe/ Eurasia

Africa's low electrification rates, particularly in rural areas, correlate with the continents extremely high poverty levels in precisely those regions. The affected populations often live in fragile contexts and remote areas. They commonly lack access to the most critical services such as good schools, healthcare, safe water and certainly electricity. Economic shocks, food insecurities and climate change aggravate this situation significantly. World Bank (2015) While bearing in mind that the provision of energy services is a necessary but not sufficient condition for poverty alleviation in developing countries (Brew-Hammond 2010), this work concentrates mainly on rural electrification as one aspect that has the potential to positively impact the livelihood of rural populations in developing countries.

Over the past two decades, rural electrification – the creation of energy services in rural areas – has gained prominence as an effective means to improve people's living conditions around the globe. This growth has for the most part been driven by socio-economic and political imperatives. However, technological innovations also played a substantial role in this development. (Schillebeeckx, et al. 2012). Today, it is widely recognized that rural electrification can improve social, environmental and economic parameters of rural livelihood. More precisely, rural electrification is perceived as an important means in achieving the Millennium Development Goals. (Schillebeeckx et al. 2012)

From a social point of view, rural electrification has been said to have positively impacted the quality of lighting, health, education and the connectivity to the outside world; some believe even social status. Health related improvements have been achieved due to extended clinic hours and strengthened cold chains but also reduced indoor exposure to particulate matter. With regard to education, rural electrification allows for longer study hours. The increased access to television, radio and mobile phones facilitates connectivity with the outside world. While the surge for renewable energy technologies as valuable alternatives for conventional energy sources reduces carbon emissions, the effect of rural electrification on deforestation, as such, is contested. Therefore, with the exception of wood as fuel for cooking, renewable energies make an overall positive impact on the environment more likely. (Schillebeeckx, et al. 2012).

Compared to the positive social and environmental impacts of rural electrification, the economic benefits are less clear. This is due to the fact that only very few energy sector and rural electrification projects explicitly target poverty reduction. It is therefore argued that specific programs that promote income-generating uses would need to be incorporated in rural electrification project design in order to stimulate growth. With such large numbers of people lacking access to electricity, of which the majority lives in sub-Saharan Africa, where population growth rates outpace electrification rates, future rural electrification policies, technologies, and strategies could potentially affect a significant base of the market pyramid. (Schillebeeckx, et al. 2012).

Developing countries around the globe struggle to reconcile social, economic and environmental aspects in their fight against poverty and economic weakness. Achieving economic growth and alleviating poverty in an environmentally sound and sustainable manner proves to be a threefold challenge that requires a well-defined strategy as well as strong financial and institutional support. Energy, which is said to be the *"(…) golden thread that connects economic growth, increased social equity, and an environment that allows the world to thrive*" SE4ALL (2015), and in particular rural electrification, which focuses on a specific area of intervention, are at the center of this work. Given that especially rural areas in developing countries still largely remain underpowered today, this thesis attempts to investigate the aspects that are most vital for a successful rural electrification strategy in developing countries. With its large natural resources and its enormous potential in terms of renewable energies to be exploited for the matter of modern energy generation, sub-Saharan Africa is in the focus of attention. In other words, based on the assumption that rural electrification rates in sub-Saharan Africa remain extremely low today due to a lack of appropriate strategies in most countries, the purpose of this master thesis is to contrast the current knowledge about the most favorable policy measures for a successful rural electrification strategy to the strategy of Senegal, a country that has shown its commitment to work towards these ends but has failed so far to achieve satisfactory outcomes in terms of access rates.

Chapter 2, therefore, represents a literature review on rural electrification and renewable energies in the sub-Saharan developing context. It gives an introduction to the topic and investigates the most relevant aspects with regard to increasing rural electrification rates in developing countries for improved livelihoods while considering environmental concerns and the pressure to achieve economic growth. Section 2.1 introduces the reader to the topic by reviewing the literature on rural electrification in developing countries. While, section 2.2 gives an overview on the state of rural electrification in sub-Saharan Africa, section 2.3 discusses the regions' energy use patterns. In section 2.4 the focus is on the appropriateness of grid and off grid solutions in the rural context, the different sources of energy and the choices of renewable energy technologies. Section 2.5 will then elaborate on electricity distribution, covering the actors involved, possible delivery models and different price reduction measures. The last section of this chapter will then summarize the most essential constraining factors to rural electrification.

Chapter 3 represents a case study on Senegal's current rural electrification strategy and the challenges the country faces with regard to its effort to improve the living conditions of its rural populations, achieve economic growth, and to allow for sustainable development. The first section gives a brief overview on Senegal. Section 3.2 follows by discussing different policy documents on the countries' growth and development. This part covers in particular the assumption that Senegal's government recognizes the significance of the electricity sector for that matter. Section 3.3 discusses the evolution of Senegal's electricity sector and highlights its specificities. In a further step, the different renewable energy sources used in Senegal will be presented. The last section (2.5.) will be on the development of the rural electrification sector and the actors involved.

After extracting the most widely agreed on views with regard to rural electrification in developing countries from the global debate (including strategy, policy, project and technology related aspects) and contrasting these findings to the Senegalese context, chapter 4 presents the conclusion.

2. Rural electrification and renewable energies in sub-Saharan Africa

2.1. Rural electrification in developing countries

The literature on rural electrification in developing countries covers a variety of aspects that relate to the unsatisfactory coverage of the region's rural access to modern energy services. Embedded in the overall "energy for development debate", rural electrification appears to be a hot topic and at the forefront on the global agenda towards meeting the Millennium Development Goals (MDGs) – not least because it affects a large portion of the most vulnerable populations on the globe. However, in order for Africa to "pull itself out of poverty", the provision of energy services should be seen as one of the means rather than the end (Brew-Hammond 2010).

The importance of tackling Africa's energy issues, in particular, is reflected in the various initiatives and measures undertaken by the regional actors and the international development community's active involvement. On a regional basis, the New Partnership for Africa's Development (NEPAD) has put forward a strategic development vision with clear objectives in order to meet the energy needs of the region. The Forum of Energy Ministers of Africa (FEMA) and sub-regional economic communities such as the Economic Community of West African States (ECOWAS), the East African Community (EAC) and the Economic Community of Central African States (CEMAC) have developed energy strategies towards achieving the MDGs and realizing the NEPAD objectives. International development actors such as the Global Network on Energy for Sustainable Development (GNESD) and the World Bank have been active in doing analytical work and proposing programs to address the energy for development needs. (Brew-Hammond 2010) In addition, there is a vast amount of literature, which underlines this trend. Besides investigating the relevance of energy for poverty reduction and improved livelihoods for rural populations in developing countries, environmental concerns and the pressure to achieve economic growth play a substantial role in the rural electrification debate. With regard to the aim to increase the access to energy services for rural populations in developing countries, a multitude of practical aspects that appear to be substantial to reaching this objective while stimulating economic growth without compromising the environment are discussed in the rural electrification literature.

In order to introduce the reader to this extensive topic, the main terms need to be discussed and understood as they appear in the literature and the global discourse. Given Brew-Hammond (2010), the term "energy access" is understood as "the ability to use energy" such as electricity, LPG, charcoal or others forms of energy. "Access to energy services" in turn means "the ability to use energy services". Energy services as such, have been described as the services provided by energy and energy appliances – lighting, heating for cooking and space heating, power for transport, water pumping, grinding, to site a few. They generally include all services that fuels, electricity, and mechanical power make possible. With regard to the term "electricity access" there is no internationally accepted definition. While "household access" describes the ability to use electricity in the home, "access to the grid" often refers to the proportion of a geographical area covered by the grid – also described as penetration rate – independent of the number of connected households. "Access to electricity" is also used to define the availability of electricity in areas not reached by the grid, where electricity is commonly provided by decentralized or stand-alone power sources like petrol or diesel generators, or renewable energy devices. The latter involve solar PV, wind turbines or biomass gasifiers. In the general access to energy discourse, the term "modern" is often used to differentiate between traditional forms of energy such as firewood or agricultural residues and commercial forms of energy, in particular electricity or LPG. However, "modern" is also used to describe the more knowledge-intensive technologies for example mobile phones versus traditional forms of technology (Brew-Hammond 2010). Where "access" refers to the ability of a household to obtain a modern energy service when it decides to, access is perceived as a function of availability and affordability. This approach involves that energy is available if the household is within the economic connection and supply range of the energy network or supplier, and affordable if up-front connection costs and energy usage costs can be met. However, it is important to note that high up-front cost can discourage poor income households from switching to a modern energy form even though it may be available. In other words, in a context were modern sources of energy are available this does not necessarily imply household-access. With regard to this understanding, Brew-Hammond (2010: 2292) points to the challenge that this interrelation between affordability and availability represents, in particular to energy policy planning:

> *"(…), if a government decides to maintain energy prices below costs, with a view to making energy more affordable to the poorest households, it may actually reduce availability, as the provider may find it unprofitable to extend coverage to areas where the poor reside*."

This interrelation between affordability and availability and the factors that drive them lie at the very heart of the “access-to-energy” discussion (Brew-Hammond 2010).

Since the beginning of this decade, great interest has been shown in the question about the importance of linking the development of rural electrification with productive uses for energy and poverty reduction (Cook 2011). In his paper about the challenges to reaching higher access rates to energy in Africa, Brew-Hammond (2010) suggests that: *“(…) greater emphasis will need to be placed on productive uses of energy and energy for income generation in order to break the vicious circle of low incomes leading to poor access of modern energy services, which in turn puts severe limitations on the ability to generate higher incomes*“ (Brew-Hammond 2010).

Despite its rising prominence, the literature on rural electrification, to date, barely includes multifocal research across technological, institutional and financial boundaries. The majority of the literature comprises in-depth technological and country-specific research, which Schillebeeckx et al. (2012: 688) believe to be less likely to “overcome the general failure to capitalize on past success”, when it comes to rural electrification projects, technologies, policies or strategies (Schillebeeckx, et al. 2012). In their opinion, an “integrated model for rural electrification” that incorporates four focal lenses, technology, institutional, viability and user-centric, could improve the design and the assessment of rural electrification projects. They have found that the technology and institutional lenses dominate the rural electrification debate, while the viability and the user-centric lenses were much less focused on (Schillebeeckx, et al. 2012).

The technology lens covers the electricity distribution system and the selection of specific technologies and their regional and environmental appropriateness. Currently there is no clear consensus on the choice of system properties most conducive to electricity distribution. However, it is increasingly agreed on the view that both centralized and decentralized solutions can be superior. This depends on the context and needs to take into consideration changes in technology, subsidies and institutional capacities. When it comes to the choice of technology, the main factors are the cost of energy and the cost of the environmental impact it entails. In order to understand cost drivers and get robust estimates of energy costs, it is necessary to assess a multitude of cost parameters. Some essential cost parameters are:

- Price volatility of diesel for diesel generator sets
- Natural resource endowments
- Available infrastructure
- Proximity of electricity distribution infrastructure

(Schillebeeckx, et al. 2012)

With regard to natural resource endowment, Schillebeeckx et al. (2012: 690) states: *"The stronger the availability of natural resources that serve as an energy source – be it water flow, solar irradiation or wind – the cheaper energy production could be."* The availability of infrastructure is another important cost parameter; in particular road infrastructure that affects both the cost of fuel transport and the costs of servicing and maintaining a given technology. These costs are especially relevant in countries were the local transportation system is underdeveloped. With the impact of extreme weather and climate change related events becoming more and more severe, especially in developing countries, environmental concerns increasingly drive technology choice. However, providing electricity access to the poor without compromising a country's ambitions with regard to climate change poses a great challenge to decision-makers. (Schillebeeckx, et al. 2012) With regard to the technology lens, Schillebeeckx et al. (2012: 690) state:

> *"Distributed technologies, decreasing RET[1] costs and increasing fossil fuel and distribution prices, in combination with a better understanding of technology-related cost drivers and rising environmental concerns, prove to be fundamental determinants of the technology lens."*

(Schillebeeckx et al. 2012)

The institutional lens focuses on governance, covering policy design and access, and on the formation of partnerships that can deliver the desired services. Governance, which refers to the process of designing and enforcing the rules of the game, is crucial for creating a supportive rural electrification environment. While *"[t]he rules of the game are encapsulated in the energy policy of the government"*, as Schillebeeckx et al. (2012) put it, the lack of a strong supportive environment, which implies significant

[1] Renewable energy technologies

government backing and strong political will, can significantly impact the success of electrification projects (Schillebeeckx, et al. 2012).

In the context of governance, the decision on the order for access to regional electrification is recommended as the first step. This implies that a certain set of parameters will be used to decide who will get access first and in order to determine what regions will be electrified in the near term. Possible parameters to prioritize regional access are:

- Regions with the lowest marginal cost per connection
- Regions with the lowest incidence of electricity connectivity and highest poverty index (The Peruvian case)
- Other differentiators such as level of commercial development and infrastructure investments (The case of Costa Rica and Thailand)

(Schillebeeckx, et al. 2012)

The importance of transparency in energy policies should also not be disregarded, because *"[t]his transparency in combination with an enforcement and independent regulatory framework can spark entrepreneurial activities of independent power producers, who require official authorization to build and operate power plants, to sell energy to utilities and to gain access to transmission and distribution (T&D) system at acceptable prices."* (Schillebeeckx et al., 2012: 691)

In order to develop concrete rural electrification projects and to provide services to rural populations, governments cooperate with various partners. This multipartite approach is based on the understanding that each partner benefits from the strengths of the other and that the respective weaknesses can be mitigated; governments thereby improve their capacities to deal with the complexity of rural electrification. In this context, four different roles can be observed: implementation, capacity building, knowledge and finance. Implementation is about the physical realization of projects on the ground. Usually utility companies, governmental departments and private sector businesses execute this task. With regard to knowledge, partners can contribute to institutional capacity building and bring knowledge about local customs and technical solutions. Capacity building is in part carried out by utilities and includes branching into specific rural electrification agencies in order to develop the skills required for the successful implementation of rural electrification strategies. Finance relates to a variety of lenders that provide grants or loans and thereby co-construct a supportive environment for rural electrification investments. These lenders range from global organizations like the World Bank to micro-financing institutions that operate locally but also informal savings groups. The investment in financial means happens through loans, subsidies, affordable credits and tax reductions or through international systems such as the Clean Development Mechanism. In general most partners incorporate more than one role. This is generally the case for large global institutions. The World Bank, for instance, can enact all roles while also influencing governance (Schillebeeckx, et al. 2012).

The viability lense refers to the "revenue structure of the consortium's business model" (Schillebeeckx et al., 2012: 691). Schillebeeckx et al. (2012:691) define the latter as *"[…] the organization of financial flows between the partners, the customers and the potential third parties"*. They argue, that a project is viable if these financial flows cover the following:

- The acquisition of technology,
- Delivery of electricity,
- Maintenance of the system, and
- All personnel costs.

(Schillebeeckx, et al. 2012)

With regard to the consortium's business model, *"[t]he approach chosen by the initiating partners is situated on a continuum between completely commercial (no subsidies at all) and completely social (100% subsidized)."* (Schillebeeckx et al., 2012: 692) Incompletely commercial projects where end users do not pay for some aspects of the total cost dominate. This is when the financer comes into play. He can choose to partially fund:

- Capital investment,
- Spare parts,
- Operations and maintenance, and/ or
- Electricity.

(Schillebeeckx, et al. 2012)

It has been suggested that fully subsidized schemes are not optimal for long-term viability. However, the local market price needs to be affordable and therefore partially subsidized due to the low-income and low-consumption character that describes rural populations as future customers. In addition and with regard to an imperfect world with imperfect markets, viability has another important dimension: time. Governments play an important role, as they can provide a multitude of incentives in order to make a project viable: incorporate the time-dimension of the project, increase affordability and reduce risk and uncertainty for these populations (Schillebeeckx, et al. 2012).

Finally, the user-centric lens is defined as the one putting the user in the center of business model design and attempting to understand the need of customers, end users and affected communities (Schillebeeckx et al., 2012: 692). Investing in understanding these needs is essential in the context of rural electrification and needs to be intensified given Schillebeeckx et al. (2012), as the success or failure of an innovation strongly correlates with a specific technology meeting the needs of the potential users or not. Consequently, understanding the problem the technology is meant to solve delivers high returns. With regard to the user-centric lense, Schillebeeckx et al. (2012) have analyzed the literature and deduced three core second order concepts that they consider to be fundamental in order to understand user needs: affordability, reliability and local embeddedness.

Affordability enfolds three distinct yet intertwined concepts. The first concept refers to capital access. Rural populations being characterized by low income, few savings and a lack of experience in purchasing durable goods are faced with exacerbating credit needs for investment in electricity generating technologies. To add to this situation, credit markets often do not exist or require collateral and/or a regular income stream, which the rural poor generally do not possess. This explains why lump sum down payments or installation fees for RET seriously impede the diffusion of RET (Schillebeeckx, et al. 2012). A further concept refers to the size, timing and duration of periodic payments, the latter referring to the combination of periodic charges including tariffs, operation and maintenance, spare parts and interests. These three are considered to be vital drivers of affordability. Schillebeeckx et al. (2012) assume that rural populations prefer longer payback periods over higher periodic fees so to avoid diverting too much of their sparse income from other pressing needs. They further point to the fact that the moment of payment can be adapted to local needs. Third, with periodic payments that can be fixed or (partially) variable, depending on the revenue of the business model, this variability of costs adds considerable risk to the investment. This problem of risk also occurs, when ownership is transferred, because suddenly the customer has to bear the operation and maintenance risks and associated costs (Schillebeeckx, et al. 2012).

With regard to understanding the users needs in the context of rural electrification, reliability represents another concept that Schillebeeckx et al. (2012) consider as essential, because it represents an important parameter in the customer's decision-to-connect. They define reliability as a combination of quality, service level and sufficiency, where the latter is understood as the timely deliver of desired quantity. In order to ensure high quality standards and increase customer confidence, quality control systems, labeling, standardization, and regulation have been suggested. These are in particular important when threats to quality such as unavailability of spare parts, non-upgradeability of aging networks and incompatibility of equipment with the environment need to be countered. Service primarily covers the financial and operational responsibility of the operation and maintenance of the installed system. To increase the needed support for installed equipment and maintain its functionality, Schillebeeckx et al. (2012) suggest to shift the responsibility to the service deliverer or to increase local competences through basic maintenance training and simple manuals. Finally, the sufficiency of supply is determined by the quantity of electricity provided at the moment when it is needed. It has been found that customers who depend on PV systems are less satisfied than those connected to the grid, due to an insufficiency of the quantity provided. However, the greater satisfaction of grid users can be explained by the larger amounts of electricity used by them. (Schillebeeckx, et al. 2012)

Local embeddedness refers to the aspects of a project that relate to the change people in targeted communities experience in their environment (Schillebeeckx, et al. 2012). With respect to this, Schillebeeckx et al. (2012) mention three constituent factors: community involvement, cultural sensitivity, and competence building. It has been argued that community involvement happens on two levels. Community involvement on a process level - the participation of rural populations in the designing, planning, implementation and operations of rural development programs - is considered essential for the sustainability of such programs. This understanding relates also to the importance of an improved acceptance of new technologies, which can be achieved through the involvement of the community right from the conception stage. Community involvement on an outcome level is said to be equally important. Giving local communities ownership makes the success of a program more likely as it can increase sustainability because of the ability to generate a sense of community ownership (Schillebeeckx, et al. 2012).

Another important aspect that has been found to be crucial for the success of rural electrification programs is cultural sensitivity. Because the extend to which rural electrification programs incorporate local habits and norms into their design can determine the success or failure of a program, it has been stressed that more attention should be given to cultural values, traditions, beliefs, norms and social structures, particularly in developing countries. A new technology should therefore be managed by its meaning, embedded in everyday life and its use should be integrated with social dynamics occurring within the relevant society. All of this can increase local acceptance of electrification programs and contribute to their sustainability (Schillebeeckx, et al. 2012).

Competence building is a third important aspect when considering the changes rural users experience in their environment. It can reduce operational and maintenance costs by teaching users how the installed system works and its limitations. The provision of material that explains the handling, maintenance and that outlines common issues and solutions can lead to a further involvement of locals. Models can be developed in which community members maintain their own system and carry out simple repairs. They could even handle collections on behalf of the power company. Therefore, involving locals can lead to an important reduction in operation and maintenance costs, reduce system losses and allows for non-payment minimization (Schillebeeckx, et al. 2012).

When it comes to energy policies, Pandey (2002) argues that besides aggregate economic growth, equity of distribution and sustainability of resource use are important policy priorities for developing countries. In particular when considering that the distribution of modern energy is skewed or inequitable, excluding partially and most often completely economically disadvantaged rural and urban populations from its supply. Moreover, the economic livelihood of those populations generally depends on traditional agriculture and traditional industries that rely on a sustainable use of locally available natural resources. Given Pandey (2002), the use of natural resources, however, remains unsustainable, threatening the livelihood of traditional communities, and contributing to local pollution, global emissions and depletion of fossil fuel reserves. He (2002) therefore stresses the importance of understanding the barriers to equity and sustainability in order to model them. He (2002) adds, that weak governance structures promoting inefficiency in state-owned industries, weak financial institutions, trade barriers, and large underdeveloped markets impede against effective implementation of energy policies promoting sustainable development. This leads to the understanding that the design and the implementation of policies that promote equity and sustainability, along with economic growth are substantial for a developing country. (Pandey 2002) Various policies applied to rural electrification are investigated worldwide and the results are classified on country basis and different parameters, such as successful and unsuccessful policies, utilized technologies, implemented project, while taking into account barriers and difficulties (Javadi et al. 2012: 405).

Policies and strategies to support rural electrification are being assigned on a global as well as on a governmental level. The former involves a number of baseline policies and some broad policies that demand the governments around the globe to implement their commitments. These include national pledges to reduce greenhouse gas emission, plans to phase out fuel subsidies and to prevent the increase of the global average temperature of more than 2°C by limiting the concentration of carbon dioxide to around 450 ppm in the atmosphere. Within this global 'framework' that aims in increasing the electricity connections for rural populations throughout the world, while taking into account environmental concerns, the World Bank, for example, tries to support developing countries with their electrification reforms with the objective to encourage competition and increasing incomes. The World Bank tries to increase efficiency, change the state electricity companies into business institutes, establish independent authorities, and transform the operation and maintenance activities to the private sector (Javadi et al. 2012: 405-406). Quite often, countries start to improve rural electrification in partnership with international companies or organizations (Javadi et al. 2012). On the national level, the governments themselves have assigned a number of policies. In order to overcome with the problem of lack of electrification in rural areas, different approaches have been applied with strongly varying success rates (Javadi et al 2012).

2.2. State of rural electrification in sub-Saharan Africa

With its 54 fully recognized sovereign states, Africa is the world's second-largest and second-most-populous continent. Sub-Saharan Africa as in the focus of this thesis, consists of all African countries that are located fully or in part south of the Sahara and is generally organized in four sub-regions: West Africa, East Africa, Central Africa and Southern Africa.

Figure (1): Sub-Saharan Africa and sub-regions map
Available at:
https://aphg2015mhs.wordpress.com/2016/01/10/sub-saharan-africa-map-quiz/
[accessed on March 21st 2016]

In sub-Saharan Africa, growth strengthened to 4.5% in 2014 from 4.2% in 2013. In a difficult global environment, the continent is said to still continue to make process. However, a key challenges remains: translating growth into faster poverty reduction and greater well being. Due to a rapid growth in population, GDP per capita growth remains low, at around 2%. The region's growth has also been less effective in reducing poverty levels when compared to other regions. Especially immediate-term external shocks and domestic fragility affect the continents achievements towards these ends. The recent falls in commodity prices have a strong impact on most of the countries in the region as well as climate change, persisting conflicts and the outbreak of Ebola (Bridi 2015). Given the 2015 African Economic Outlook, innovative development strategies are needed, in order to allow for the continent to progress (African Economic Outlook 2015).

Despite its rapid economic growth and an increase in energy use by 45% since 2000, sub-Saharan Africa struggles to make use of its rich energy resources to improve energy supply for its populations (IEA 2014: 13). The IEA (2014: 32) reports that "[*N]early 80% of those lacking access to electricity across sub-Saharan Africa are in rural areas, an important distinction when considering appropriate energy access strategies and technical solutions.*" It is further stated, that "*[…] unlike many world regions, sub-Saharan Africa is expected to continue to see significant growth in both urban and rural populations.*" (IEA 2014: 32)

The following table gives an overview on West Africa's population by country, GDP per capita, total electricity net consumption, urban and rural electrification rates.

Table (2): Overview West Africa[2]

Country	Population in millions in 2014 (a)	GDP per capita in US Dollars in 2014 (b)	Total electricity net consumption in 2012 in Billion Kilowatt-hours c)	Urban electrification rate in % in 2013 d)	Rural electrification rate in % in 2013 e)
Mauritania	3.3	1,275.0	1	47	2
Mali	15	704.5	0.9	53	9
Senegal	13	1,067.1	2.6	90	28
Gambia	1.8	484.1 (2013)	0.2	60	2
Guinea-Bissau	1.6	567.8	(s)	37	6
Guinea	11	539.6	0.9	53	11
Sierra Leone	5.4	766.0	0.1	11	1
Burkina Faso	17	713.1	1	56	1
Niger	16	427.4	0.9	62	4
Nigeria	166	3,203.3	25	55	37
Côte d'Ivoire	22	1,545.9	4.7	42	8
Ghana	24	1,441.6	8.5	92	50
Benin	9.3	903.5	0.9	57	9
Togo	6.8	635.0	1	35	21
Liberia	3.8	457.9	0.3	17	3
Cape Verde	0.5	3,641.1	0.3	100	84

In contrast to the strong global trend to urbanization, population growth in sub-Saharan Africa has been split relatively evenly between urban and rural areas. However, only 37% of the region's populations live in urban areas. (IEA 2014) The rural population is

[2] Sources:

a) EIA available at: https://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=93&pid=44&aid=33&cid=r6,&syid=2007&eyid=2011&unit=MM [accessed on March 24th 2016]

b) Data World Bank available at: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD [accessed on March 24th 2016]

c) EIA available at: https://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=2&aid=2&cid=r6,&syid=2008&eyid=2012&unit=BKWH [accessed on March 24th 2016]

d) e) World Energy Outlook available at: http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/ [accessed on March 24th 2016] characterized by high poverty levels and irregular income flows. This is reflected in the extremely low per capita consumption of modern energy in rural sub-Saharan Africa, where levels of traditional biomass energy use are very high (Karekezi & Kithyoma 2004: 17). Given the African Energy Outlook 2014 (IEA 2014: 33), average residential electricity consumption per capita is 317kWh per year for those that do have access. However, this number comes down to 225 kWh when excluding South Africa. The former is equivalent to about 20% of Europe's average residential consumption per capita. In rural areas electricity consumption is significantly lower. Rural electricity consumption ranges only between 50 to 100 kWh per year. (IAE 2014: 33)

> "*For a five person household, annual consumption of 50 kWH per person could, allow the use of a mobile phone, two compact fluorescent light bulbs and a fan for five hours a day. In urban areas, households generally own more appliances, such as televisions, refrigerators or an electric water heater.* "
> (IEA 2014)

In order to increase the access to electrification, almost every country in the region launched a rural electrification program. The most common financing mechanism for such programs is a levy imposed on electricity consumers. While funding for rural electrification has increased in most countries over the years, this increase did, however, not result in the expected rise in access to electricity for rural populations (Karekezi & Kithyoma 2004: 34). This is mainly due to the high price of electricity, which if provided in rural areas is unaffordable for the poor (Karekezi & Kithyoma 2004: 35). Karkezi and Kithyoma (2004: 35) therefore call for policy makers to rethink the design and implementation of rural electrification programs. They (2004: 36) stress in particular the importance of a detailed assessment on grid extension in that matter.

In the absence of the grid, solar PV is commonly perceived as the best choice for rural sub-Saharan Africa, especially for dispersed rural households and enterprises. It is further promoted as being a cheaper option than grid-based electricity in the long run. While the dissemination of PV technology has been prioritized by most national renewable rural energy strategies, the results are rather unsatisfactory, as no significant increase in access to modern energy has been registered, in particular for rural areas. With the rural population being characterized by low and irregular income flows the costs of a typical low-end PV household system still remains the main barrier for the dissemination of this technology (Karekezi & Kithyoma 2004: 36). Although, substantial financing, in particular grants and credits, has been provided to various initiatives promoting PV technologies in rural sub-Saharan areas, these measures have not significantly impacted the level of rural electrification in the region. Another drawback of the PV technology is that it highly relies on imported components and therefore leaves little room for local job creation (Karekezi & Kithyoma 2004: 39). Karekezi and Kithyoma (2004: 40) also point to the fact that, *"[P]romoting a technology such as PV with high import content in countries facing massive fall in export earnings is not good macro-economic practice."*[3] Karekezi and Kithyoma (2004: 37) claim that, *"[t]he most successful renewable technologies in rural Africa are likely to be the ones that can generate income and facilitate the start-up of small or micro enterprises"*. They further declare that the PV technology, however, is not appropriate for powering rural enterprises (2004: 37) and that *"(…) future renewable energy strategies in sub-Saharan Africa should de-emphasize PV and give greater prominence to a wider range of renewables that offer more attractive opportunities for income generation and job creation"* (2004: 40).

Despite past efforts to accelerate access to improved energy services in rural areas, no significant growth has been registered with regard to the use of modern sources of energy in most sub-Saharan countries. Today, biomass still remains the dominant source of rural energy (Karekezi & Kithyoma 2004: 29). Given the African Energy Outlook 2014 (IEA 2014: 36) solid biomass - mainly in the form of fuel wood and agricultural waste - is almost exclusively used for cooking in rural areas, compared to a more diverse use of fuels in urban areas. With regard to enabling rural populations to access sustainable sources of energy for economic and social development, renewable energies are often recommended as the most appropriate energy technology (Karekezi & Kithyoma 2004: 30). One of the main reasons for this are the global policy approaches to reduce the GHGs and the effects of fossil fuels on the environment (Javadi et al. 2012: 407). This fact is also reflected in the numerous rural energy initiatives that are for the most part based on renewables. The only exceptions are initiatives that focus on areas where rural grid electrification is possible (Karekezi & Kithyoma 2004: 30). Given that the majority of rural energy initiatives in Africa apply renewable energy technologies, a country's renewable energy policy, can be assumed to give a good picture on the policy support for rural energy. However, this requires a well-defined rural energy policy that promotes renewable energies, as Karekezi and Kithyoma (2004: 30) stress:

[3] This refers to the fact that revenue from unprocessed commodities, which are often the main export of sub-Saharan countries, is diminishing.

“Most governments do not have a clear-cut policy on the development and promotion of RETs, which continue to be undertaken within an energy planning and policy vacuum. This is in contrast to the conventional energy sector (electricity and petroleum), which in most cases has well-elaborated policy documents and development plans. RETs and rural energy policies are often subsumed in energy policy documents. As a result, rural energy development follows an ad hoc path, with little recourse to national energy plans, which are rarely available or else out of date and inadequate”

(Karkezi and Kithyoma 2004: 30).

The origin of most of the early policy initiatives in the region lies in the oil crisis of the early and late 1970s, when the first Ministries of Energy and departments dedicated to promote sustainable energy policies including the development of renewable energy technologies, were established. Efforts have been made during the crisis in developing alternative forms of energy to partially substitute for conventional energy resources in many sub-Saharan countries. However, as soon as the crisis subsided governmental support for this undertakings and most renewable energy activities diminished significantly. The lack of dedicated policy documents on renewable and rural energies has in part prevented foreign aid institutions to invest in renewable energy projects in the region (Karekezi & Kithyoma 2004: 31). In addition to this evolution, most of the countries in the region lack independent rural energy agencies. While the conventional energy sector, in most countries, has well-established institutions and agencies, rural energy institutions are either non-existent or exclusively focusing on grid electrification rather than considering other rural energy technologies. Low budgetary allocations to renewable energies further demonstrate limited policy support in many countries. While more emphasis is placed on the petroleum and power sector that supply a minority of the population, little attention is paid to renewables, in particular biomass, that supplies the majority of it (Karekezi & Kithyoma 2004: 31). Sustainable renewable technologies, even if generally considered as efficient tools to reduce energy poverty, can only achieve this goal whenever they are conducted based on an appropriate policy (Javadi 2012: 402). Karekezi and Kithyoma (2004: 33) share this view by arguing that, *“[r]ural energy programs in Africa are unlikely to register significant development and dissemination without supportive government policies, which are backed by the requisite budgetary allocations”* (Karkezi and Kithyoma 2004:33).

The emphasis towards rural electrification policies has fluctuated over time and has strongly been influenced by the World Bank. The last shift by the World Bank and other international development institutions, towards a strategy based on poverty had a more significant implication for rural electrification programs than previous approaches. Paul Cook (2011) states that most projects today target either welfare improvements, increasing electricity supply or institutional development. The latter relates to utilities and private sector development and includes training and operational support as for example provided in Senegal and some off-grid regulation projects. In many cases, the World Bank support for off-grid projects is linked to renewable energy schemes and is commonly a component of a larger project. Moreover, many of the World Banks' off-grid projects are considered pilot projects (Cook 2011).

The current situation, however, shows that the private sector has not developed electrification in rural areas on the scale envisaged with privatization. Given Paul Cook (2011), this is the case weather consideration is given to investment in rural electrification through either privatized utilities, forms of public-private partnerships, increased use of subsidization through output-based aid and development assistance. To a very limited extent, this deficit has been filled by the growth of local micro and small-scale private providers and community-based cooperatives. They have, to some extend, compensated for the failings of large-scale privatization and publicly owned monopolies either through stand-alone or mini-grid systems (Cook 2011).

2.3. Energy use patterns

In sub-Saharan Africa the household sector is the major consumer of energy. The high amount of biomass used in rural areas is also the reason why rural households account for higher consumption levels than urban households (Karekezi & Kithyoma 2004: 19). Sub-Saharan African households consume energy mainly for cooking, lighting and space heating. While cooking accounts for more than 90 percent of the energy consumption, the rest is for lighting and space heating, which is required only in areas with cold climates. Although wood fuel remains the first choice of energy for these activities, kerosene lamps or candles are also used when it comes to lighting (Karekezi & Kithyoma 2004: 21). Electricity constitutes only 7% of final energy consumption in sub-Saharan Africa. It has been stated that the residential sector represents only 27% of total electricity consumption due to the low amount of electricity–consuming devices per household and limited disposable income. (IEA 2014: 40) The levels of household energy consumption and the types of energy used depend mainly on availability and costs. Karekezi and Kithyoma (2004: 21) state that with an increase in income, the use of modern energy amongst rural households rises. This is also reflected in the differential energy consumption patterns if one compares low-income and high-income rural households. While low-income rural households mainly rely on biomass as their primary source of energy for cooking, high-income households use modern fuels such as kerosene and LPG (Karekezi & Kithyoma 2004: 21).

Despite its inefficiency and harmful impact on human health, firewood remains the most common source of cooking energy in Africa. Nearly 730 million people in Africa rely on it, mostly with inefficient stoves in poorly ventilated space. In the IEA's Energy Outlook 2014 (IEA 2014: 34) it is stated that *"[A] transition to cleaner cooking fuels and appliances is not straightforward, as people who have access to modern fuels, such as LPG, natural gas, biogas or electricity, may also continue to use solid biomass for cultural or affordability reasons, […]".* Karekezi and Kithyoma (2004: 22), however, argue that the reason for it might lie in its availability as a 'free' source of energy, as in most cases firewood is collected rather than being purchased. They (2004: 22-23) further highlight the links between biomass combustion and respiratory illnesses in women and children. While women and children appear to be much more exposed to and subsequently adversely affected by particle emissions from biofuel smoke due to their closeness to biomass-based cooking fires, men suffer less often from respiratory infections (Karekezi & Kithyoma 2004: 23). The importance of the relationship between rural biomass energy and women's work and well-being is evident given that they are users of energy sources, producers of traditional biomass fuel, and play a crucial role as educators on the collection, management and use of fuels (Karekezi & Kithyoma 2004: 23-24). While electricity access is generally given more attention than this issue, several countries have implemented programs for the promotion of clean cooking fuels and stoves. In Senegal, for example, strong policies and incentives have supported LPG use, which have resulted in less than 25% of the urban population using solid biomass for this purpose. (IEA 2014: 35)

Kerosene is widely used for lighting in sub-Saharan African rural areas. However, the use of this source of energy is very much dependent on the willingness of rural households to invest in the rather high cost kerosene lamps and fuel. Firewood is another important source of light as it is much cheaper and easier to access especially for low-income households. Electricity offers a third energy option for lighting. However, only high-income rural households can, if at all, access it due to its high up-front costs. With regard to the high amount of investments that have been undertaken in the recent past to promote solar PV for meeting rural household's lighting needs, no significant impact on rural electrification levels can be observed (Karekezi & Kithyoma 2004: 24).

Although fossil fuels and conventional energy sources such as electricity seem to play a minor role in rural energy supply, their contribution should not be neglected as they bear the potential for productive uses. Rural economic activities such as small agro-processing activities and small-scale commercial establishments such as shops, restaurants and guesthouses require energy sources such as diesel and electricity. This is also true for the proper operation of key rural institutions such as hospitals, dispensaries, and schools (Karekezi & Kithyoma 2004: 20). With regard to productive uses of energy and in the context of rurality, Karekezi and Kithyoma (2004) sub-divide them in the energy use for agriculture and the use of energy in SMEs. Throughout sub-Saharan Africa the agricultural sector employs most of the working population. (IEA 2014: 47) Agricultural commodities commonly dominate the export sector of most sub-Saharan African countries. Despite a heavy dependence on agriculture and the abundant energy sources of the region, the use of modern energy resources remains low (Karekezi & Kithyoma 2004: 24). Karekezi and Kithyoma (2004: 24-25) show concern about this and assume that this could be an indicator that the agricultural sector does not get adequate attention from policy makers in terms of provision of high-grade energy services.

With regard to agricultural activities, Karekezi and Kithyoma (2004: 25) state that, *"[t]he energy needs of agricultural production in rural areas range from intensive power use in transport, water lifting and pumping, land preparation, and primary and seedbed cultivation, to lighter power requirements for weed control, planting, transplanting and harvesting" (Karkezi and Kithyoma 2004: 25)*. They further indicate that human labor continues to be an important source of power for such activities in the region. This can be derived from the limited use of mechanized agricultural practices in the region (Karekezi & Kithyoma 2004: 24-25).

Another important source of power for agriculture in rural areas is animal traction, mainly with cattle and donkeys. However, in contrast to much of Asia, the use of animal power is rather underdeveloped in most of Africa (Karekezi & Kithyoma 2004: 26). The use of renewable energy technologies, in particular small hydro plants for shaft power and electricity generation; biogas plants that provide sludge for use as fertilizers; and solar cop dryers, have demonstrated an encouraging level of success in meeting the demand for energy for agriculture in rural Africa (Karekezi & Kithyoma 2004: 26). In this context, Karekezi and Kithyoma (2004: 26) emphasize the potential of wind power for the agricultural sector, in particular in the form of wind-driven machines for water pumping and for irrigation. They state that most countries in the region have wind energy potentials that are sufficient for water pumping but do not exploit it fully due to the high initial costs of this technology (Karekezi & Kithyoma 2004: 26).

Given Karekezi and Kithyoma (2004: 27), small and micro rural enterprises, in the sub-Saharan African context, refer to entities that largely rely on family members and less often on non-household members, while they are mostly based in the informal sector. They distinguish between commercial or service enterprises and production enterprises. While, the former include small shops, rural guesthouses and battery recharging centers to mention some, the latter refer largely to agro-based or forest-based activities such as saw milling, grain milling and pottery making (Karekezi & Kithyoma 2004: 27). The reliance on family labor in small and micro enterprises is a widely shared characteristic of sub-Saharan rural areas. However, the types of enterprises vary given the cultural and socio-economic conditions. The use of biomass as a source of energy for small and micro enterprises in the region is still dominant. However, lighting, motive and shaft power needs are invariably met by the use of modern energy sources such as electricity from the grid or generator sets, kerosene, solar PV, diesel generators, wind pumps, and wind generators amongst others (Karekezi & Kithyoma 2004: 28).

2.4. Integrating renewable energies in the energy mix: Grid versus off-grid solutions and technology choices

With the aim to generalize the access to electricity in rural areas, diversification is frequently cited as necessary for an efficient and sustainable electrification strategy, both in terms of technology and source of energy (Diouf et al. 2013). For that matter, renewable energies not only bear the potential to improve energy security by reducing the reliance on imported fuels but can also provide local employment for deployment and maintenance, particularly in remote areas. They further help diversify the energy mix in a sustainable manner. (IEA 2014: 56)

The following table shows that, compared to the rest of the world, with the exception of the countries of the Middle East[4], Africa not only generates the smallest amount of electricity in billion KW/h but also is the least diversified region when it comes to the different power sources for electricity generation (Javadi et al. 2012).

Table 3: World net electricity generation based on power source, estimates from 2009 (Javadi et al. 2012)

Region	**Net electricity generation by power source in Billion KW/h**				**Total**
	Conventional thermal	**Hydroelectric**	**Nuclear**	**Geothermal, solar, wind, wood and waste**	
North America	3057.60	660.10	894.73	176.58	4789.02
Central & South America	297.01	684.17	20.6	36.77	1038.02
Europe	1755.99	560.06	865.29	274.47	3455.81
Middle East	755.85	10.26	0.00	0.31	766.42
Africa	**483.92**	**97.68**	**13.00**	**4.26**	**598.86**
Asia & Oceania	5452.63	901.80	529.23	119.06	7002.72
World Total	12 671.47	3145.17	2568.72	615.42	19 000.78

It has been stated that the transition from fossil fuels to renewable energy resources, allows for access to electricity in different natural condition, ranging from island, plain areas, mountains etc. (Javadi et al. 2012). Given Javadi et al, (2012) availability, cost-effectiveness, financial support, implementation, and feasibility are the main factors that determine the choice of different power sources by different countries. However, when it comes to the choice of the solution – centralized or decentralized – there is general consensus (Javadi et al. 2012). While grid expansion and centralized solutions such as mini-grids might be appropriate for villages with a population organized in high

[4] Most of these countries are oil-extracting countries with large reserves.

density of habitations, small villages or such with highly dispersed populations require different solutions because of cost (Diouf et al. 2013: 926).

In the framework of the World Energy Model (WEM) provided by the IEA, it is suggested to combine different solutions such as on-grid, mini-grid and isolated off-grid taking into account the regional cost and customer density to identify the electricity providing option in each region. While the regional cost per megawatt-hour of an established grid is cheaper than of mini-grid or off-grid solutions, the cost of extending it in sparely population area, remote or mountainous area is very high. Grid transmission over long distances in rural areas not only includes high cost but also high technical losses (Javadi et al. 2012). This is also the reason why the majority of rural areas favor a connection via mini-grids or small, standalone off-grid solutions, given Javadi et al. (2012). Unfortunately, the cost factor influences the technology choice in a way that most electrification programs prioritize grid extension over decentralized solutions, which once again leaves out the most vulnerable populations (Diouf et al. 2013: 926).

With the majority of sub-Saharan Africa's rural population living in dispersed settlements, the transmission and distribution costs of extending grid electricity is considered too costly for most of rural Africa. This situation, however, creates (at least theoretically) an ideal market for decentralized energy technologies that match this specific characteristic of sub-Saharan Africa's rural population. While cost-effectiveness remains a crucial factor in the choice of the most appropriate energy technology for rural Africa, renewable energies are often recommended in order to ensure environmental soundness (Karekezi & Kithyoma 2004: 21). Karekezi and Kithyoma (2004: 41) stress that in particular small and medium-scale renewables but also other rural technologies bear the potential for poverty alleviation, and should be prioritized in rural energy initiatives. Given Karekezi and Kithyoma (2004: 41), especially locally made renewable energy technologies, based on solar, thermal and animate power fall into this category. They (2004: 41) further state:

> *"These sets of renewable energy technologies are not only affordable to the very poor but can be a source of jobs, employment and enterprise creation for the rural poor in Africa."*

(Karkezi and Kithyoma 2004: 41)

Model examples for small-scale improved energy technologies, given Karekezi and Kithyoma (2004: 41-42) are: the treadle water pump, which refers to a low-cost micro-irrigation pump used in farming; solar dryers, which are easy to construct and affordable; improved stoves which reduce fuel wood requirements and improve the living conditions of rural populations, in particular of women. Others are low-cost efficient hand tools and animal-drawn implements for an increased agricultural productivity; low-cost and more efficient biomass-based combustion technologies, such as improved cook stoves, efficient charcoal kilns, brick-making kilns, fish smokers, tea dryers and wood dryers; pico and micro hydropower for shaft power used for processing agricultural products; ram pumps for irrigation; solar water pasteurizers for the provision of clean potable water and the reduction of water-born diseases (Karekezi & Kithyoma 2004: 43). Karekezi and Kithyoma (2004: 42) argue that such technologies offer a great range of income generation benefits at relatively low cost. Therefore, they (2004: 43) insist on the promotion of these technologies in rural sub-Saharan Africa by arguing that *"[a] renewable energy strategy that relies on a wider range of renewable technologies (…) can ensure that the poor select the technology that best fits their comparative advantage as well as their incomes".*

Solar PV is said to be competitive in off-grid and mini-grid applications, where the main alternative at present is generation fuelled by diesel or gasoline. (IEA 2014) Diouf et al. (2013: 928) suggest the use of individual standalone photovoltaic home systems for small remote villages or villages with a low density of population, with guaranties for a minimum electricity service of high quality and low cost. Diouf et al. (2013: 928) further stress the fact that solar home systems for remote or low-density villages should fit the environmental conditions. They should be solid, practical, easy to set up, and without need of maintenance. Moreover, there should be no compromise with the quality of the systems and simplicity of operation in order to keep the risk of breakdown low. Regarding the costs of these systems, Diouf et al. (2013:928) further argue that they need to be minimized in order to become more affordable for the end users. They should ideally be lower than candles, kerosene lamps or other alternative lighting systems added with their mobile phones battery charge payments. However, when considering that PV is generally unsuitable for powering rural enterprises given Karekezi and Kithyoma (p37) and that the investment in a PV system would mean for rural populations to allocate a significant proportion of their income in an energy technology for lighting, raises concern about the appropriateness of this technology in the rural context. This is further underscored by the little impact that electricity from PV has on cooking in rural households, being the highest end use of household energy (Karekezi & Kithyoma 2004: 38).

Hydropower is the most used renewable energy source in sub-Saharan Africa to date. However, with regard to rural electrification, this source of power might only be an economic means of electricity access on a small scale and for communities that live near the water. Moreover, a low level of regional interconnection means that there are limited opportunities to export the electricity to remote rural areas (IEA 2014: 57). Compared to hydropower, wind power deployment has been very limited in all of sub-Saharan Africa to date. The region's wind potential is estimated at around 1 300 GW and wind can be cost competitive with other technologies where the resources are good but factors such as limited market size and poorly developed power grids limit its deployment. However, for the matter of rural electrification and where adequate resources are available, the African Energy Outlook 2014 states that small hydro and wind projects can compete with solar PV for off-grid uses for the matter of rural electrification (IEA 2014: 58).

Contrary to accepted opinion, Karekezi and Kithyoma (2004: 40) emphasize the importance of biomass energy for the rural energy sector:

> *"The reality of the rural energy sector is that biomass energy use is bound to be continual being dominant. While biomass energy is often perceived in a somewhat negative light, there are attractive opportunities for using biomass energy in more modern, efficient and environmentally attractive ways."*

(Karkezi and Kithyoma 2004: 40)

At the household level, Karekezi and Kithyoma (2004: 40) deem an increased dissemination of improved woodstoves, which feature reduced heat loss, increased combustion efficiency and attains a higher heat transfer, as necessary. They further point to the various benefits that the increased use of this technology bears, such as the alleviation of the burden placed on women in fuel collection, freeing up more time for them to engage in other activities, especially income-generating activities. Improved biofuel stoves also appear to be an ideal technology option for rural institutions such as schools and hospitals (Karekezi & Kithyoma 2004: 40). At small and micro enterprise level, Karekezi and Kithyoma (2004: 41) emphasize the attractiveness of biomass as a fuel for small-scale industrial boilers that are used in many rural agro-industries. Other technologies are said to enable improved efficiency of biomass in traditional rural productive activities that are generally energy-intensive, such as crop drying, fish drying and charcoal production (Karekezi & Kithyoma: 41).

2.5. Electricity distribution: The actors, delivery models and price reduction

While in the past, state owned utilities were responsible for rural electrification this has changed over the last two decades. With a shift in the rural electrification strategy towards poverty, the World Bank strongly influenced institutional developments in particular utility and private sector reforms in many developing countries (Cook 2011). In most sub-Saharan African countries rural electrification funds and agencies have been established as an integrated part of the liberalization efforts. To date, these agencies are rather small and relatively weak. Struggle for authority and funding in a turbulent organizational and political environment, they are in constant competition with the unbundled and commonly privatized utilities. Developing new expertise in electricity supply within their own organization, considering their dependence on private sector services, presents a major challenge to rural electrification agencies (Nygaard 2009).

Alongside the utilities and rural electrification agencies, NGOs and other international development actors are involved in providing access to energy in rural areas. They often provide development interventions focusing on non-energy sectors such as water, health, education and agriculture but often including energy supply in terms of mini-grids, multifunctional platforms and solar PV. However, these are commonly installed with limited coordination with other sector needs, other development actors and the electrification authorities responsible for planning. Donor coordination, therefore, remains an important issue at that point (Nygaard 2009).

With regard to accessibility, Diouf et al. (2013: 927) argue that the choice of one delivery model over another changes from one country to another or even from one region to another and that the local available finances mainly determine this choice. This section will discuss different delivery models and subsequently, the conditions under which the consumer owned models will be more efficient than the service delivery models when taking specific parameters into account for consumer price reduction. Given Ivan Nygaard (2009), there are generally five main groups of delivery models emerging from the literature: the fee for service dealer model and the fee for service concession model, the donation model, the commercially led model, and the multi-stakeholder programmatic model.

In the fee for service model, energy companies remain the owners of the installed equipment. They collect fees from the users while responsible for maintenance or repair if necessary. The fee for service contract is sometimes comparable to leasing contracts, handing over the full responsibility of the equipment after an agreed number of years. (Nygaard 2009) Diouf et al. (2013: 927) suggest that this model is the most appropriate one for rural electrification in small isolated villages that are characterized by a lack of technical resources, standard banking loans or micro credits and incomes too low to afford up front solutions.

Fee for service providers can be utilities or new service companies. The national authority identifies them either through a negotiated process or a tendering process. The former is also referred to as “the retailer model” and the latter as “the concessions model”. The retailer model comprises the negotiation of the general conditions on price, quality and business models etc. with one or more service providers. Where existing operators are weak, market penetration is low, and competition among existing operators is limited, this model has been favored. The selected providers commonly cover distinct geographical areas. However, in principle they work in an open market. The concession model, in contrast, grants concessions to a company usually for the supply of a specified rural electrification technology to a pre-defined geographical area for a limited number of years through a competitive bidding procedure. In countries where competition is high or in those that can attract more than one external operator, this model is favored (Nyaard 2009).

In the fee for service model, the service company achieves a monopoly-like status given its agreement with the national authority. A continuous follow-up and strong and independent regulation from the national regulator or another government authority is therefore necessary (Nygaard 2009). Regarding the fees to be paid by the end users Diouf et al. (2013: 929) suggest a number of factors that should be considered in case of fees for service model, such as the cost of operation, as paying the person in charge of monitoring and fees collection, the risk of theft and breakdown, as well as payment problems of the users that may occur.

In all of sub-Saharan Africa, donors and governments used the donation model for the provision of electricity to rural infrastructure in particular for water, health and education. The donor model is a socially motivated model. However, it is commonly used under the condition that a user committee should be established to collect fees for maintenance and for reinvestment (Nygaard 2009). With regard to solar PV installations, the latter has proved to be difficult to be operational especially with regard to collecting and saving sufficient funding for repairs but Ivan Nygaard (2009: 14-15) states that failure rates vary and seem to depend on the immediate utility of the service. He further argues that despite the difficulties that arise with using the donation model, it will certainly continue especially in small multipurpose socially infrastructure projects.

It is argued that the cash and carry model, commercially led delivery model or simply cash sale, favors the development of smaller systems that generally provide only lighting and could be affordable without credit. Such a model is generally carried by the private sector (Diouf et al. 2013: 927). Usually, the consumers pay cash. In some cases, however, the retailer could grant them credit or provide leasing agreements. This model also allows the consumer to buy technical support such as installation service, maintenance and repairs amongst others (Nygaard 2009).

The multi-stakeholder programmatic model can be referred to as donor interventions that have moved from project level to program level. This model aims at a large-scale dissemination of rural electrification technologies such as solar home systems. Within the framework of such programs a multi-stakeholder program management authority is usually established. These programs involve a consumer credit option managed by specialized finance organizations and generally set technical standards. Although subsidies may be part of the program, donor support is generally limited to reducing interest rates and indirect market support such as awareness raising, finance establishment, quality assurance and training at various levels. It is also important to note that within this model, only pre-qualified dealers can participate (Nygaard 2009).

Given Ivan Nygaard (2009), the key parameters for the success in marketing a renewable energy technology for rural electrification is to reduce consumer fees. Therefore he suggests that the aforementioned delivery models should mainly be tested on their ability to reduce those fees. To this end, he stresses the importance of competition, economy of scale, finance schemes, subsidies and efficient maintenance for price reduction (Nygaard 2009).

Creating a positive environment for competition is the main challenge when markets are to be developed for a certain technology by external interventions. The commercially led model is based on free competition. However, at the beginning of market creation there will often be only one or two major players who control the market, which is little price-sensitive considering a high degree of demand from development project for example. When the market reaches a certain volume, on the other hand, this model may reduce prices due to a higher level of competition between a greater numbers of retailers. In the programmatic model subsidies or other market incentives are used to increase competition. Unfortunately, this approach tends to attract non-serious dealers that enter the market to gain an immediate rent and leave after donors have pulled-out and may completely discourage dealers that believe that the market is short term and superficial. Therefore, a longer-term commitment and a clear strategy for gradually phasing out subsidies are advisable in order to eliminate these tendencies (Nygaard 2009).

When geographical concessions are granted through bidding, either a number of potential national service providers or concessions that are big and profitable enough to attract international service providers are required. In the first case, a vibrant local market with experienced entrepreneurs is a precondition for competition. International bidding, however, mainly depends on potential market conditions than on an existing market. A major incentive for attracting international service providers in this process could be high investment subsidies. Negotiated fee for service models are appropriate in cases where the level of competition does not lead to a meaningful bidding process (Nygaard 2009).

Different sources of funding are used to finance rural electrification programs and projects and to achieve the overall objective of increased rural electrification rates (Javadi et al. 2012). When it comes to consumer finance for rural electrification technologies, the modality for provision of credit in the different models is crucial, as it is usually expensive and hard to obtain. Most technologies imply high up-front costs that are difficult to meet for rural populations. Ivan Nygaard (2009) states that micro credit schemes that are generally said to fit well with a cash-sale delivery model do not necessarily for all technologies. This is because they do not always fit the requirements of the technology in terms of credit size, group based lending, focus on women and short term lending terms. He therefor suggests the establishment and enhancement of credit schemes that are tailored to fit different technologies as a major objective, in particular, for the multi-stakeholder programmatic model. To this ends, he mentions the establishment of a credit support facility and bank partnership loan programs. With regard to the fee-for-service model, he points to the advantage that in this model financing is the responsibility of the service providers as they are expected to have better access to financing than rural customers. This certainly relates to the relatively high subsidy rates that enable utilities and foreign companies to raise sufficient capital for the investment (Nygaard 2009).

With regard to subsidies there is a general consensus that they are necessary for the expansion of rural electrification. That is why direct and indirect subsidies are commonly included in most rural electrification programs. In principal, either the consumer or the retailer can receive investment subsidies. However, in a developing countries context that is characterized by external financing, weaker states, less control and higher frequency or corruption, subsidies are generally paid to the certified companies and administered by the multi-stakeholder management authority, a rural electrification fund or other regulatory authorities. With regard to the programmatic approach subsidies are used as an incentive to promote only certified equipment, weather it be direct subsidy to buy down investment or indirect subsidy for buying down interest rates in financing schemes. However, subsidies have been blamed for creating market distortion due to their short-term nature and the fact that it creates an overheated market environment. The advantage of subsidies in the fee-for-service model is that their control is limited to relatively few fee-for-service companies. This is different in the programmatic model where there are a large number of suppliers. In the concession model subsidies have been used to lower the costs to level comparable to the grid-connected options (Nygaard 2010). Given Ivan Nygaard (2009) subsidies should be transparent, targeted and predictable for a number of years ahead, in term of a communicated exited strategy, as they have side effects in each of the aforementioned models.

While, successful rural electrification depends to a great extent on financing, technical assistance can also have a significant effect on the improvement of a project (Javadi et al. 2012).

Efficient maintenance and quality assurance represent important factors in the view of reducing consumer fees. A long lifetime and simple maintenance are crucial aspects when it comes to rural electrification technologies using renewables. Continued maintenance is often an issue in particular with regard to private ownership. Private consumers often lack necessary technical knowledge and have difficulties in identifying high quality products. In the programmatic model higher quality of the products is ensured through quality standards and certifications but failure rates can still occur due to the lack of financial means to replace spare parts. Training of technicians is another asset of the multi-stakeholder programmatic model. However, there is no guarantee that those technicians remain in the project area, maintenance infrastructure will not necessarily establish itself and consumers might have difficulties to afford replacement of spare parts to repair. The fee-for-service models allow for better maintenance, as the replacement of spare parts is the responsibility of the service provider (Nygaard 2009).

The brief overview on the different delivery models, their advantages and disadvantages, shows that their significance depends on the specific context in which the model will be applied. The stage of market development and income levels play a major role in the decision about the delivery model. However, Ivan Nygaard (2009) argues that a long-term government commitment is one of the most important factors for achieving rural electrification goals. He further states that unfortunately long-term commitment is generally not a feature of donor-supported programs nor of sub-Saharan African governments. Another factor of success in the market-based approach, given Ivan Nygaard (2009), is the inclusion of the existing financial sector in the program.

2.6. Challenges to rural electrification and the path towards a successful rural electrification strategy

Characteristic of a number of developing countries, the low level of rural electrification is commonly related to the high costs of grid expansion (Diouf et al. 2013: 926). However, many other factors strongly contribute to the unsatisfactory evolution of rural electrification in these regions. With regard to institutional challenges, Diouf et al. (2013: 927-929) state that the failure for the generalization of rural electrification is partly due to inadequate propositions and government strategies. They argue that changes in government policies, and a different approach from the private sector are needed in order to overcome the lack of electricity in rural areas. Others have argued that there are flaws in current strategies. Where rural electrification was or still is the sole responsibility of state owned utilities, low electrification rates have been commonly explained by organizational problems related to state ownership, such as politically influenced management, inefficiency and lack of resources. Recent evolutions, however, show that reforms and privatization do not, by themselves, increase access to electricity in rural areas (Nygaard 2009).

With regard to constraining non-institutional factors, Ivan Nygaard (2009) sites poverty and hence low affordability amongst rural populations, low density of consumer demand, small-scale production units and lacking infrastructure for maintenance as some of the most important ones. More precisely, low incomes and savings represent a common reality of rural populations in developing countries. Such a situation prevents them from investing up front in autonomous electric power systems to meet their electricity needs (Diouf et al 2013: 926). In the case of small remote villages with low population or villages with low density of population, grid expansion and power distribution in general becomes a problem. Another restrictive reality in the rural context is that the standard banking system does not attribute loans to its populations due to their lack of guaranties (Diouf et al. 2013: 927). Where up-front costs were met, the lack of service appears to be a serious problem for system owners in remote rural areas. Most systems are out of use in these areas because once there is a breakdown the technical repair service or spare parts are not available (Diouf et al. 2013: 927). Diouf et al. (2013: 928) highlight the importance of using local expertise as much as possible and to assemble systems locally. While developing countries are generally characterized by high unemployment rates and very low labor, these features bear the potential for job creation and cost reduction resulting in a final product cheaper than imported readymade systems. However, in many African developing countries there is still a lack of local manufacturing, which represents an additional constraint to rural electrification (Diouf et al. 2013: 926). A much less discussed but important factor with regard to improving rural electrification is the consideration of cultural aspects. Moreover, it has been argued that in order for the successful introduction of a technology there is a need to raise awareness of the advantages and acceptance. Another point is follow-up, which can influence the success of rural electrification projects.

Diouf et al. (2013: 927) concluded that the first step to successfully implementing a generalized solution to reach a 100% rural electrification in developing countries should be to quantitatively evaluate the energy needs of rural areas and compare them to the average income of the populations. They argue that the financing scheme should be determined with regard to the income and current monthly energy expenses of these populations. Javadi et al. (2012: 403) insist that the supply of electricity is obligatory in order to enhance the living conditions for rural populations and to achieve 100% access to electricity. While Diouf et al. (2013) and Javadi et al. (2012) focus on a 100% rural electrification for developing countries, Karekezi and Kithyoma (2004: 40) insists that the rural poor in sub-Saharan Africa urgently need technologies that can rapidly raise their incomes and at the same time provide improved energy services to the rural areas:

> *"Energy technologies that are primarily designed to generate electricity are unlikely to be the best candidates, primarily for reasons of cost."*

(Karekezi & Kithyoma 2004: 40)

In this context, Karekezi and Kithyoma (2004: 43) recommend the redesign of rural energy programs to encompass other non-electrical, mechanized and animate technologies, as they appear to be more affordable to rural populations and enable income generation. Therefore they state:

> *" Sub-Saharan African countries need to develop rural energy strategies that rely on a diverse set of technologies that are not confined to PV electrification and that reflect their national natural endowment profiles as well as the incomes of the poor, who constitute the majority of rural sub-Saharan Africa inhabitants. If a proportion of the funds for rural electrification were allocated to the promotion of non-electrical technologies, this would result, given their low cost, in the significant dissemination of these technologies."*

(Karkezi and Kithyoma 2004: 43)

On the institutional level and in the view of an ideal rural electrification strategy, Karekezi and Kithyoma (2004: 43) recommend:

> *"In the near term, the ideal institutional solution would be to transform current rural electrification programs and agencies into rural energy agencies that are given the mandate to disseminate the rural energy technologies mentioned*

above[5]. This institutional innovation would allow a portion of the very substantial rural electrification levies and funds to be used to disseminate and promote non-electrical renewable and rural energy technologies. In many sub-Saharan African countries this change could result in a massive increase in funds available for renewables and rural energy technologies, and, at a stoke, transform the renewables and rural energy subsector."

(Karkezi and Kithyoma 2004: 43)

Karekezi and Kithyoma (2004: 43) further suggest that proactive and long-term renewable and rural energy policy and institutional innovations should be promoted:

"The policy programs should be designed to demonstrate the economic and environmental benefits of renewable technologies to sub-Saharan Africa's poor; and they should propose short- and medium-term policy initiatives that would engender large-scale dissemination of renewables. Priority should be given to highlighting the real and tangible economic benefits (such as job creation and income generation) that renewable and rural energy programmes can deliver to the region at both the micro and macro levels."

(Karekezi & Kithyoma 2004: 43-44)

With regard to job creation and income generation, Karekezi and Kithyoma (2004: 44) claim that in contrast to conventional and centralized energy projects, renewable and rural energy technologies are generally more labor-intensive and therefore represent a way to encounter problems of employment of the urban and rural poor.

With regard to regional disparities and insufficient spatial inclusion, policies that target specific regions and places are often too scattered in order to achieve the desired objectives. Moreover, "non-spatial" policies with strong regional impacts have yet to reduce regional fragmentation and to empower local actors. It has been argued that some sectoral national policies have positive spillover effects on regional development. (African Economic Outlook 2015)

[5] Karekezi and Kithyoma (2004: 43) refers to small and medium-scale renewables but also other rural technologies that bear the potential for income generation and are environmentally friendly. See also section 2.4 on renewable energy technologies as off-grid solutions.

Specific attention should also be given to decentralization and the empowerment of local actors for the matter of development policies, which include rural electrification policies.

> *„Decentralisation, a process for transferring powers and resources from the central government to lower levels of government, can also strongly affect regional development, including by empowering local actors and containing the rent-seeking behaviour of the elite.*"
>
> (African Economic Outlook 2015: xxiii)

However, a lack of capacity and transparency are highlighted as the main obstacles to effective, decentralized governance. (African Economic Outlook 2015)

Another policy-related argument is that *"[R]egional, context-specific policies should not work in isolation from national and sectorial policies",* as narrowly-defined sectoral approaches often almost exclusively frame government action, which hinders effective problem-solving at the local level (African Economic Outlook 2015: xxiv).

The African Economic Outlook highlights the following as challenges that can arise:

- Sectoral policies alone overlook local knowledge, aspirations, resources and dynamics.
- Ministries may intervene along administrative boundaries, instead of focusing on functional areas, where social and economic activities effectively take place.
- Top-down, sectoral policies are exposed to risks of insufficient co-ordination, duplication and inter-ministerial competition.

Finally, sectoral lenses tend to limit action to a few specific tools, overlooking the complexity of problems.

3. Case study: Towards a successful rural electrification strategy in Senegal

3.1. Country overview

Senegal is the most westerly country of Africa's Sahel region. To the west it is bordered by the North Atlantic Ocean, to the north by Mauritania, to the east by Mali and to the south by Guinea and Guinea-Bissau. Senegal is one of the world's few countries to have a near-enclave within its borders. From the Atlantic coast, the Gambia penetrates to the center of Senegal along the river Gambia. Senegal's capital, Dakar, is a peninsula situated in the extreme west of the country. (Government of Senegal 2014) Senegal has a national territory spanning 196 712 km^2 and a population of approximately 13 million inhabitants (ANSD 2014). The country is organized in 14 regions, 113 municipalities, 370 rural communities and about 14 400 villages. There are over 20 ethnic groups (World Bank 2014) and the population is generally concentrated in the west and in the center of the country. 55% of the population is rural and about half of the urban population lives in the overcrowded Dakar region (RGPHAE 2013).

Senegal is for the most part flat, with some low hills towards the southeast. While the soil is generally dry and sandy, the vegetation ranges from steppe in the North to savannah in the center and tropical forest in the South. There are four rivers on Senegal's national territory: the Senegal (1700 km), the Saloum (105 km), the Gambia, which is Senegalese over only 300 km, and the Casamance (300 km). The climate is tropical and dry and characterized by two seasons: the dry season (November until June) and the rainy season (July until October) (Government of Senegal 2014).

Senegal was once considered a leader in economic growth and development amongst the countries in the region. Despite its lack of vast natural resources, the country's economy achieved an impressive stable annual growth of about 5% in the late 90ies and the beginning of the 20^{th} century. This was mostly due to several economic and structural reform plans developed by the government and supported by development partners such as the IMF and the World Bank. Since 2005 however, Senegal faced serious challenges affecting its economy and hindering its development. Especially the country's lack of resources, weak infrastructure, unfavorable investment environment, and widespread poverty are factors that contributed to Senegal's fluctuating growth rate, representing serious obstacles to the country's aspiration of becoming a high middle-income country by the next decade. (Africa Economic Development Institute 2014)

Table 4: Senegal's annual GDP growth (in %) from 2004 to 2013

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sub-Saharan Africa	6.1[1]	6.0[1]	6.3[1]	6.6[1]	5.1[1]	2.2[1]	5.2[3]	4.5[3]	3.7[3]	4.7[3]
Senegal	5.9[2]	5.6[2]	2.5[2]	4.9[2]	3.7[2]	2.4[2]	4.3[2]	2.1[2]	3.5[2]	4.0[2]

[1] (Africa Development Indicators 2012/13, 10); [2] (World DataBank 2014); [3](Regional Outlook 2014, 80)

While Senegal's economy relies mostly on the service sector (65%), and the growing areas of telecommunications and tourism, agriculture contributes to a lesser degree to the GDP of the country (17%). (Africa Economic Development Institute 2014) However, the agricultural sector employs a large part of the rural population and its vulnerability to unpredictable weather and the lack of proper energy and water infrastructures severely weaken the country's agricultural production (Africa Economic Development Institute 2014). Fishing, phosphate and mining also largely contribute to Senegal's economic growth and appear to be prominent areas for foreign investment. However, overfishing, depletion of resources, changes in world commodity prices, and unreliable weather pose a serious threat to the country's economy and contributed to the recent decrease in growth (Africa Economic Development Institute 2014). Another important contributor to Senegal's current economical situation is the high level of population growth. The country not only faces severe unemployment rates but also high prices in food and oil, resulting in widespread poverty. The lack of natural resources and inappropriate infrastructure make the country very much dependent on external sources.(Africa Economic Development Institute 2014). Senegal's unfavorable investment environment lies in a small, inflexible market and insufficient infrastructure. Moreover, the country lacks proper courts and legal systems, along with a complicated and ineffective bureaucracy, scaring foreign businesses and investors (Africa Economic Development Institute 2014). Despite the launch of a National Commission for Action against Non-Transparency, Corruption and Misappropriation, Senegal still has a serious problem regarding the transparency of public funds. This lack of transparency tends to raise mistrust from the international community and hinders foreign investments (Africa Economic Development Institute 2014). In the global economic competition, Senegal disposes of assets such as a favorable geographic location, close to big European and US markets, offering a large maritime facade, potential in tourism, a definite progress in terms of new information and communication technologies, but also a flow of people and transfer funds with the Northern countries, especially the transfer of migrants, contributing significantly to material and human investment (AFD 2012).

With regard to politics, Senegal is perceived as one of the most stable countries in Africa. It has considerably strengthened its democratic institutions since its independence from the French in 1960. Peaceful electoral processes and handover of power characterize the countries political history (World Bank 2014). In 2012, for the second time in 12 years, Senegal has demonstrated a democratic political alternation. The new government has expressed its willingness to lead the country towards its economic emergence. The country, however, has to face structural constraints and exogenous shocks. Its economy remains insufficiently diversified, with a still poorly integrated business fabric and export performances to be improved. The French development agency (AFD) sites the following as Senegal's major constraints to economic emergence:

- Senegal's natural resources are limited;
- The level and quality of transport infrastructure and certain public services, in particular electricity, slow down the economic development of the country, remaining encased in its region;
- The industries are concentrated around the city of Dakar;
- The economic actors are still dominated by small family and informal businesses. The agricultural sector which is of major social importance makes up for the employment and revenues of more than 50% of the population and contributes only poorly to poverty reduction;
- The business environment remains insufficiently attractive. Improving the level of education seems necessary to achieve qualification levels and know-how that can be of interest for investors.

(AFD 2012)

3.2. Electricity: a lever for growth and development

The significance of the electricity sector as an essential driver to Senegal's growth and development has widely been recognized. In 2011 the country's national electrification rate was estimated at 40%. While urban electrification accounted for 70%, rural electrification was only 22%. (IRENA 2012) It has, therefore, been understood that the key issues of the sector are the access to electricity for all in sufficient quantity and quality and at limited costs. The growth of the latter is also viewed as essential in order to create a favorable environment for the private sector. This growth is supposed to fall within a policy of environmental preservation and the fight against climate change (AFD 2008).

With regard to rural electrification, the government has reiterated its commitment to establish a better equation between economic growth and human development, through the increase of rural access to modern forms of energy. In particular, electricity is perceived as a powerful lever in the fight against poverty. Indeed, rural electricity contributes to the creation of wealth and employment, especially if developed in a multi-sectorial framework in synergy with other strategic sectors, such as: education, health, agriculture, livestock breeding, fishery, water, rural telecommunications, and new information and communication technologies. In such a context, and besides the promotion of income and employment generating activities as well as the increase in productivity in the processing, conservation and valorization of local products, rural electrification helps to strengthen the abilities of the beneficiary populations through better conditions in education and health ASER (2010a).

Over the last 10 years, Senegal's government has elaborated several national documents with regard to the country's strategies to reducing poverty and to emerge economically, as well as more concrete documents on the key sectors, in particular on the electricity sector. The DSRP, "Document Stratégique de Réduction de la Pauvreté", a document on Senegal's poverty reduction strategy that covered the period from 2003 to 2005 has failed to reach its objectives and in particular to attain a growth rate of at least 7% in order to increase sufficient amounts of employment, to significantly improve the living conditions of Senegalese households and to reduce the poverty level by half in 2015. A follow-up document, the DSRP II covering the period from 2006-2010, has therefore been elaborated. This document was to put into place an economic and social policy allowing the economic and social performances of the country to significantly increase and to put Senegal on the right path towards sustainable human development. An analysis on the insufficient performance with regard to access to the basic social services and the level of competition of the productive sectors has shown a strong correlation to the deficit in energy services. Energy consumption in the country remained low due to a weak supply with regard to demand, the high costs of access to energy services and the quality of the service. Additionally, the poverty levels in rural areas strongly correlated with the deficits in energy services. It has been recognized that several tasks mainly attributed to young women such as the collection of firewood for cooking amongst others keep them out of the education circuit and represent physical constraints and a loss of time. The DSRP II recognized the importance of the energy sector as a lever for development especially as it represents a domestic necessity and a factor of production that directly affects the competitiveness of products, working time, and the health of women. Despite some registered improvements in the sector (from 6% in 2000 to 12,5% in 2004 in rural areas), the DSRP II outlined a new strategy in order to accelerate the access to energy services for that matter. The strategy covered the following:

- Develop an institutional framework and increase the production capacity of energy
- Strengthen the productive activities
- Involve private operators, village associations and local authorities with regard to the development of infrastructure and energy services
- Ensure the financing of activities for the development of the energy sector
- Diversify the sources of energy and technologies
- Promote the management of energy and renewable energies
- Implement an investment program for the access to energy services to allow for economic and human development
- Improve and secure the access of populations to domestic combustibles
- Reinforce the access to energy services in rural and peri-urban areas in order to facilitate the functioning of basic infrastructure (schools, health structures, conservation infrastructures, etc.)
- Improve the access to hydrocarbons

(DSRP II, 2006)

The PSE, “Plan Sénégal Emergent”, represents another important document that has been elaborated in 2012 and aims at Senegal’s emergence by 2035 through the adoption of a new development model and strategy. The document gives more detailed and concrete information about the governments intentions with regard to the energy sector. The strategy laid down in the PSE reflects the government's ambition to assure a large and viable access to energy at low cost and states the following objectives:

- Allow for electricity prices amongst the lowest in the sub-region (~60 to 80 FCFA/ kWH);
- To halve the electricity bills of households;
- Eliminate associated power failures and losses until 2017;

(PSE 2012)

With regard to the sub-sector of electricity the following objectives have been set:

- To put into balance the supply and demand through the commissioning of new production capacities (1000 MW);
- Diversifying the sources of electricity production through a choice of sources based on coal, gas, hydroelectric, solar and wind, in order to balance the energy mix and;
- Update and expand the transmission and distribution network;
- To ensure a better control of the energy demand through awareness raising, the promotion of electric energy efficiency solutions for households and the deployment of low energy lights, prepaid energy meters, smart meters,, and strengthening an incentive-based price policy;
- The restructuration of the electricity sector through the pursuit of the transformation and recovery of the SENELEC (national utility), the encouragement and perpetuity of private operator and investor interventions in production and the development of private production units, strengthening the institutional framework and regulation;
- Strengthening the regional and sub-regional cooperation with, in particular, the promotion of two big hydropower projects (OMVG and OMVS) and the West African Power Pool (WAPP).
- A development plan for the production 2013-2017 foresees the installation of 800 MW over this period given the following production mix: 5% diesel oil, 20% gas, 5 % hydro, 26% fuel, 25% coal and 19% other renewable energies.

(PSE 2012)

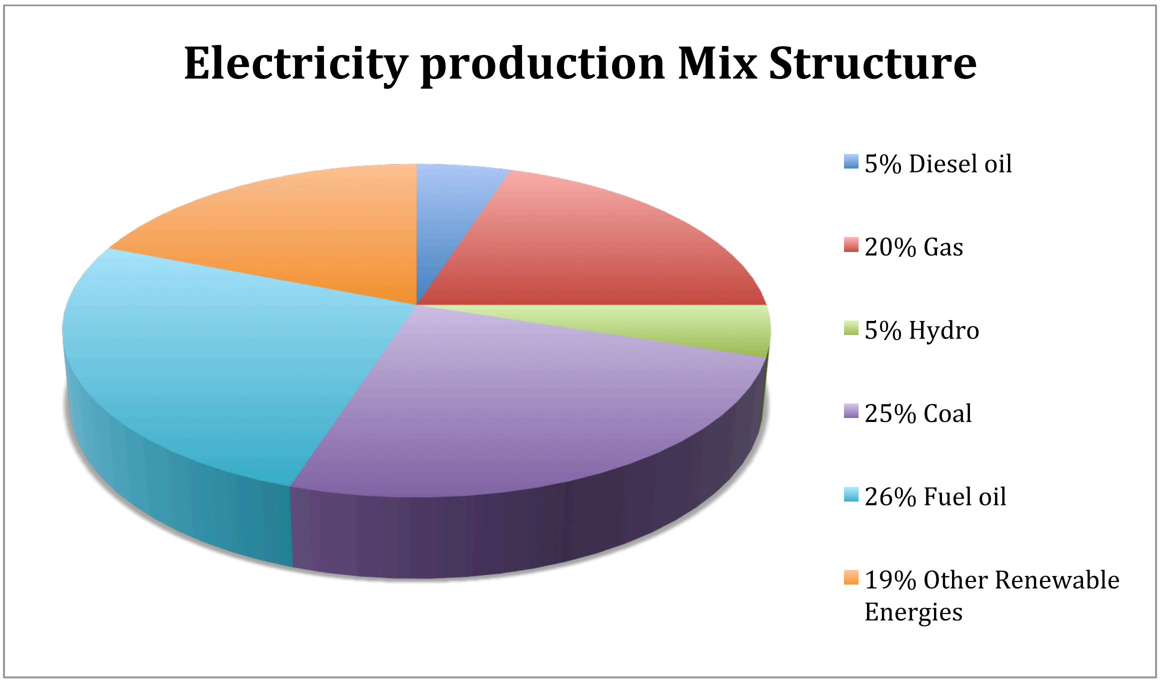

Figure 2: Senegal's electricity production mix structure for the period 2013-2017 (PSE 2012: 81)

The PSE pursues, furthermore, the orientations of the LPDSE, "Lettre Politique de Développement du Secteur de l'Énergie", the policy letter on the development of the energy sector of 2012 about electricity, hydrocarbons and the access to energy for rural areas (PSE 2012). With regard to a universal energy service for rural zones, the PSE aims at ensuring the rapid development of electricity access, more generally to energy, in order to converge towards a full coverage of the rural population. The optimistic objective laid out in the PSE is a rural electrification rate of 60% in 2018. In order to reach this objective the PSE demands the implementation of the following actions:

- The development of new sources of energy: solar, wind, biomass;
- Strengthening the usage of clean energies on the household level (butane, biogas);
- Redefining the model and parameters of the concessions currently in place;
- To densify and extend the electric grid in order to connect it to the interconnected network, that greatly profits from the development of the transmission and distribution network;
- The creation of new economic activities and an increase in productivity.

(PSE 2012)

Within the framework of the “plan d’actions prioritaires (PAP 2014-2018)”, a priority action plan laid down in the PSE, the energy sector has been ranked amongst the top five priorities and more precisely on second position after the infrastructure and transportation service sector and followed by the agricultural sector. (PSE 2012)

The “Document de Politique Economique et Sociale” (DPES 2010), a similar document that covered the period from 2011-2015, presented the following as necessary actions for the acceleration of rural electrification:

- Public-private partnerships with the development of rural electrification projects;
- The implementation of multi-sector energy projects through the development of productive uses of electricity and a priority access of social and public facilities to electricity;
- The implementation of emergency programs;
- The development of biogas and biofuels for electricity production

(DPES 2010)

Given the unsatisfactory achievements of the previous strategy papers, the follow-up document on the national strategy of economic and social development, the SNDES, has been elaborated for the period 2013 to 2017. The latter pursues to a great extend the same objectives through similar actions.

(SNDES 2012)

3.3. The electricity sector

Senegal’s electricity sector faces a deep structural crisis, which had its peak in 2006. A delay in terms of investments did not permit to keep pace with the demand of electricity growing by about 8% per year in average from 1998 to 2008. The supply deficit caused numerous power outages in the past and it still does today. In 2007, the demand of actually not supplied electricity represented about 5% of the grids total consumption (AFD 2008). The type of production installations and their obsolescence debit the operating costs of the power station and raise the cost price of the energy. In 2008, nearly 80 % of electricity came from thermal power stations that are very cost intensive as they run on fuel oil. Moreover, more than half of these stations are more than ten years old, which results in frequent power failures and an overconsumption of combustibles. Senegal's strong dependency on fossil fuels not only represents a financial burden to the country but also poses multiple environmental problems. (AFD 2008) The figure below shows Senegal's electricity production mix structure in 2012.

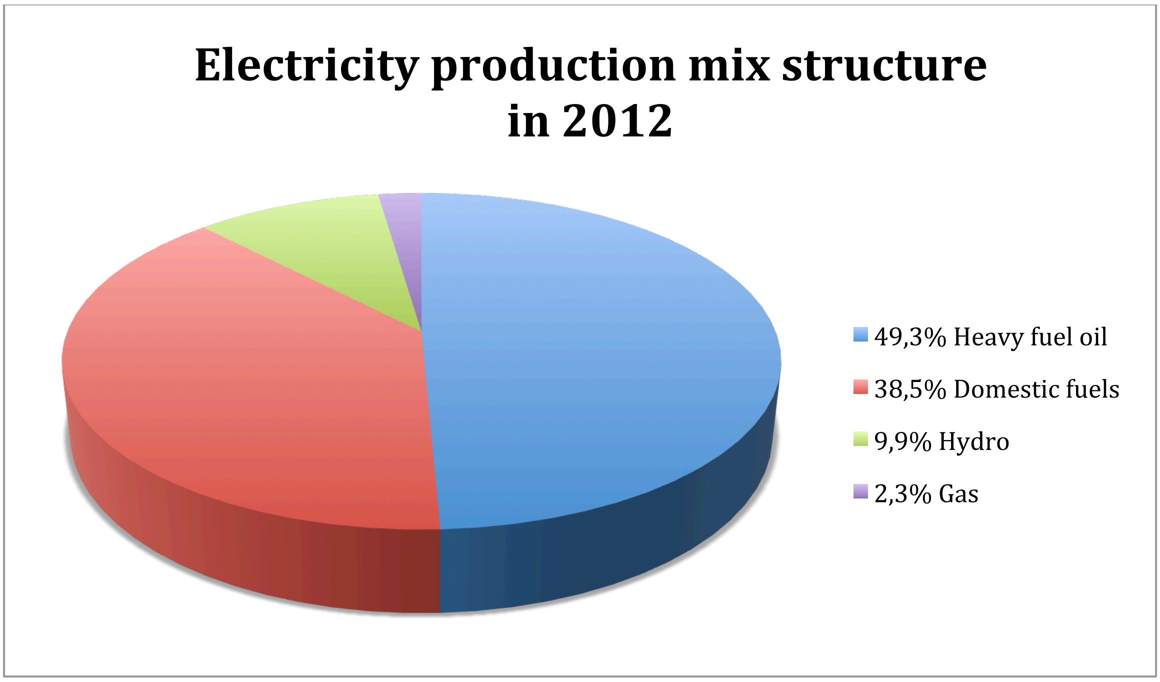

Figure 3: Senegal's electricity production-mix structure in 2012, Energymed (2014)

The tariff regulation method did not preserve the financial equilibrium of the sector. An increase of the operational cost has only partially been born by the consumers. The state has preferred giving large compensatory grants to the national electricity company, "Société nationale d'électricité du Sénégal (SENELEC)", sometimes with a delay, in a context where public resources are rare. (AFD 2008) Due to these difficulties, the results of the electricity sector do not live up to the expectations of the population and companies, despite significant amounts committed by the state. The average electrification rate, steadily increasing, remains low, in particular in rural areas (AFD 2008). Senegal's national utility, SENELEC, showing losses since 2004, has been recapitalized in 2007 by the state as shareholder in order to restore its proper funds up to at least 50% of the social capital, as required by law. With regard to businesses, the electricity tariffs remain so high that it burdens their competitiveness. Senegal's oil bill constitutes a burden, which is weighing heavily on public finances, in a context of limited budgetary resources (AFD 2008).

In this very difficult context the government of Senegal elaborated a plan for the recovery of the energy sector, "Plan de Redressement du Secteur de l'Energie (PRSE)", which was to cover the period from 2007 to 2012. This plan offered a package of targeted measures to lead the country out of the crisis; being organized around two main aspects: The organization and the development of the sector on the one hand and the governance of the sector on the other. The former incorporates an update of the sector policy letter, the actualization of the regulatory framework, the implementation of an energy master program, the financial restructuration of the SENELEC, the adoption of a master plan for investments in the sector, the diversification of the sources of electricity production towards renewable energies and the promotion of rural electrification. The latter covers the improvement of the governance of the SENELEC, the completion of institutional reform of the company and the adoption of a new regulatory framework that guarantees the financial equilibrium of the sector (AFD 2008).

In 2012, Macky Sall, Senegal's newly elected president, defined the reform of the energy sector and the development of new energy policies as one of his political priorities. The focus has been put on the need to adopt an optimal energy mix for the reduction of supply costs over the medium and long term through a policy of diversification, as well as through regional integration (Haselip, Desgain und Mackenzie 2014). In his policy letter of 2012 on the development of the energy sector – the LPDSE - the president introduces a strategy by sub-sectors. The objectives of this strategy are in line with the regional objectives set by the head of states and governments of the CEDEAO, of which Senegal is a signatory, to increase the ensure access of at least half of the peri-urban and rural population to modern energy services by 2015 in the view of attaining the Millennium Development Goals. The new energy policy has set the following three objectives:

- Ensure the regular supply of high-quality energy at lowest prices and in sufficient quantity;
- Extend the access to modern energy services for the population ensuring a more equitable distribution with a specific focus on the most vulnerable populations and the most disadvantages regions;
- Promote energy control and energy efficiency

(LPDSE 2012)

With regard to the sub-sector of electricity the following objectives have been stated:

- Diversify the sources of production;
- Strengthen the promotion of rural and peri-urban electrification;
- Encourage private initiatives;
- The operational and financial restructuration of the national utility SENELEC;
- The reform of the institutional framework;
- Strengthening regulation;
- Improve governance;
- Strengthen the regional and sub-regional cooperation.

(LPDSE 2012)

With regard to the promotion of small and medium-sized energy enterprises (SMEs) Haselip, Desgain and Mackenzie (2013) state that Senegal has recorded a diversity of successful energy SMEs especially with regard to the LPG, cook stove and off-grid solar PV markets. While they find that many of the economic, policy and institutional prerequisites for energy SME success are already in place, the country still lacks access to commercial finance. They further note that a mature microfinance sector is playing a more significant role in providing loans to rural businesses and households than concessional financing (Haselip, Desgain and Mackenzie 2014).

3.4. Renewable energies

Senegal's total primary energy supply was 157,9 Petajoules in 2009. While biomass accounted for 54% of the country's energy supply, oil products represented 40%. The remaining 6% comprised a mix of coal, hydro, natural gas and solar (Haselip, Desgain and Mackenzie 2014).

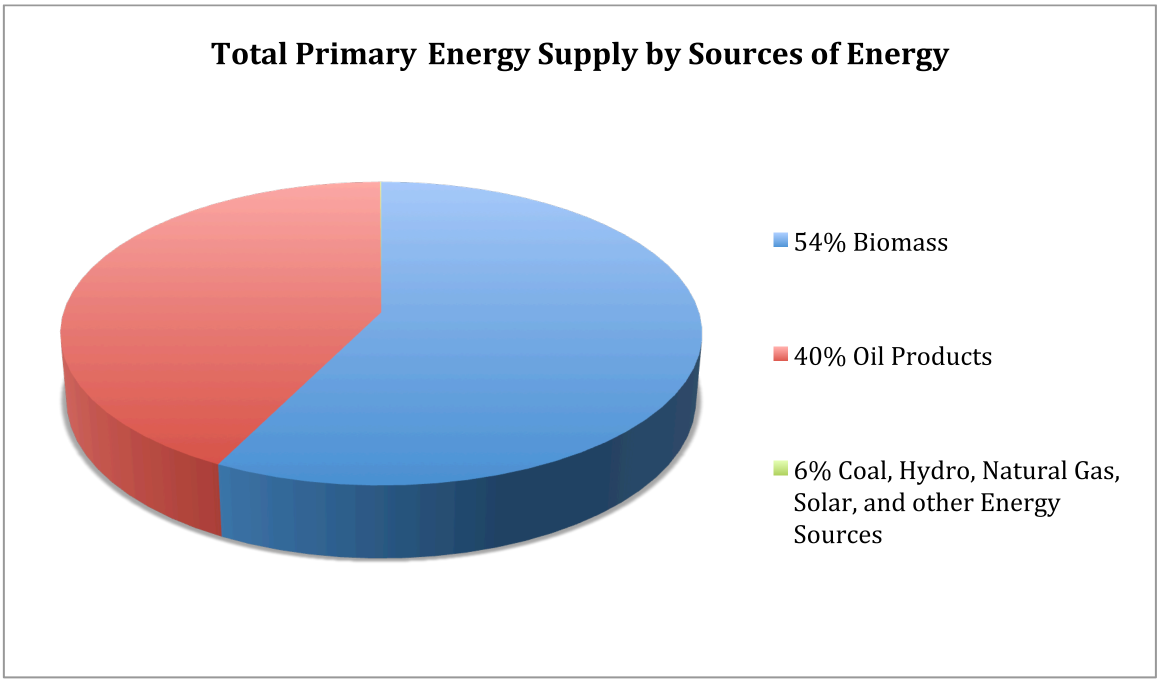

Figure 4: Total primary energy supply by sources of energy
(Haselip, Desgain and Mackenzie 2014)

In 2009, 2858 GWh of electricity were generated with only 10,2% coming from renewables including hydro (Haselip, Desgain and Mackenzie 2014).

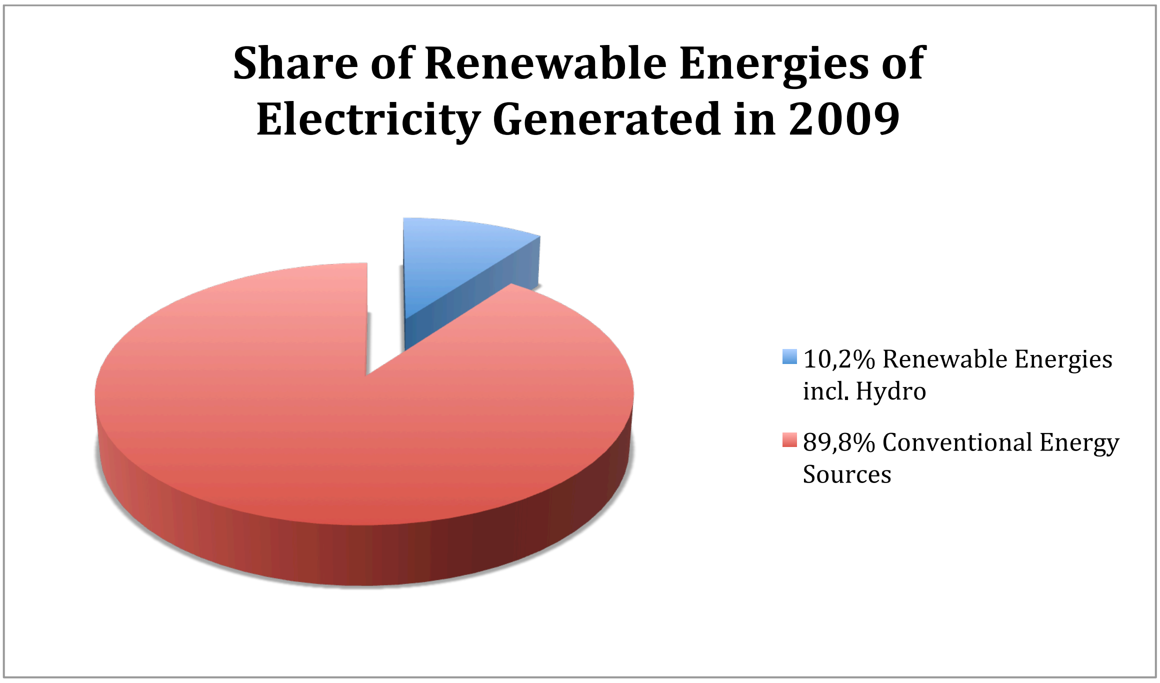

Figure 5: Share of renewable energies in Senegal's electricity generation of 2009
(Haselip, Desgain and Mackenzie 2014)

Senegal’s strong dependence on combustible fossil fuels poses a multitude of environmental problems. These include greenhouse gas emissions, the degradation of the populations living conditions and urban pollution amongst others. Just like in a majority of sub-Saharan African countries, the use of traditional fuels, such as wood and charcoal, also puts great pressure on Senegal’s forests. Consequently, it is has shown to be necessary for the country to cultivate a firm commitment to preserve its environment in order to ensure sustainable development and to contribute in the fight against climate change. The lasting energy crisis has been perceived as an opportunity to promote the development of renewable energies (wind, solar, biomass, hydroelectricity) and energy saving measures. This is why renewable energies represent one of the strong points considered by the government in order to reduce the dependency regarding fossil fuels (AFD 2008). The following objectives have been set for the sub-sector on renewable energies within the framework of the LPDSE of 2012:

- The operationalization of the “Agence pour la promotion des energies renouvelables”, Senegal’s agency for the promotion of renewable energies;
- The operationalization of incentive measures;
- Identifying and planning the investments to be realized;
- To undertake a study for the implementation of a feed-in-tariff.

(LPDSE 2012)

Despite the government’s multiple commitments made in the past to improve the access to energy services in particular for rural populations through a more diversified energy mix, the outcomes have been unsatisfactory. Especially, with regard to the use of renewable energies no major improvements have been registered. This has in particular been strongly critiqued by the populations affected by climate change and other negative environmental impacts. In 2013 the “Agence Nationale pour les Énergies Renouvelables” (ANER), Senegal’s national agency for renewable energies has been established by the law 2013-684 in may 2013 as stated in the LPDSE of 2012 (ANER 2015a).

The creation of the agency suggests that the Senegalese government is truly determined to shift from conventional energies to a diversified energy mix. Given Senegal’s confirmed potential to develop new energy sources, the sector would strongly benefit from this incentive. With regard to the country’s renewable energy potential solar PV, concentrated solar technologies, solid biomass, wind, hydro and liquid biofuels have been sited. However, a strong political commitment will be necessary in order to attain the objectives with regard to increasing the share of renewables in Senegal's energy mix. (Haselip, Desgain and Mackenzie 2014).

With regard to solar energy, Senegal exhibits 3000 sunny hours per year and an average global irradiation energy of 5,8 kWh/ m^2 per day. The exploitation of this energy arising has until recently been done through the photovoltaic sub-sector and the solar thermal sub-sector. The strategy for the promotion of solar energy today is directed towards household use as well towards big independent production plants connected to the grid (ANER 2015b).

Senegal also disposes of a wind potential that could be exploited in the near future through the construction of the Taiba Ndiaye wind farm project. With a capacity of 151,8 MW, this wind farm is planned to be built on two sites and equipped with 20 and 30 turbines respectively. Given the Ecowrex, the observatory for renewable energy and energy efficiency, this wind facility could generate up to 280 GWh of electricity each year, thus replacing approximately 4.1 million tons of CO2 from fossil energies over a period of 20 years (Jeune Afrique 2015).

Senegal's potential when it comes to wind energy is located along the coast in the north of the country over a distance of 50 km. The average wind speed in this area lies between 5.7 and 6 m/s. However, these numbers are very broad estimates as they often originate from extrapolations or punctual measurements conducted by project developers. ANER (2015c)

With regard to hydropower, the region possesses a potential enhanced through two big projects of the organization for the enhancement of the river Senegal, the "Organisation pour la mise en valeur du fleuve Sénégal (OMVS)", and the organization for the enhancement of the river Gambia (OMVG)", of which Senegal is a member (AFD 2008). Within the framework of the enhancement of the river Senegal, the Manantali dam situated on Malian territory is a regulatory and hydroelectric dam. With an installed power of 200 MW, it produces 800 GWh/ year on average delivered to the national electricity companies in Mali, Senegal and Mauretania (OMVS 2015a).

Table 5: Percentage distribution of electricity from the Manantali complex

Mali	Senegal	Mauretania
52%	33%	15%

OMVS (2015a)

The Manantali complex allows for the delivery of clean and cheap energy. The following table is from 2008, before fuel prices peaked:

Table 6: Price of energy from Manantali hydro plant and thermal energy

Country	Price per Kw Manantali	Price per Kw thermal energy
Mali	0,046 €	0,252 €
Mauretania	0,048 €	0,137 €
Senegal	0,048 €	0,092 €

OMVS (2015b)

With regard to the enhancement of the river Gambia, the OMVG works on the development of an energy project that incudes the construction of hydroelectric installations with an installed power of 128 MW on the river Gambia in Senegal, 240 MW on the river in Guinea and a 225 kV electric grid interconnection line with 1 677 km total length, 15 sub-stations (225/30 kV), two dispatching centers, with a thermal transit capacity (loop) of 800 MW. This line will be transmitting the electrical energy produced by the power stations of these installations and others, toward the main power stations of the OMVG countries. The objective of this project is to satisfy the growing demand in electricity in the member countries of the OMVG (OMVG 2015).

Senegal also disposes of an important potential of biomass. The country's biomass reserves are estimated at approximately 331 000 000 m^3. Besides wood and charcoal the following types of biomass are recoverable and available energies for cooking:

- Agricultural residues such as millet, sorghum, and cotton stems as well as rice husks etc.;
- Agro-industrial residues such as peanut, cotton, and cashew shells, as well as bagasse etc.;

- Harmful aquatic plants with a high proliferation such as the typha australensis as well as a local reed;

ANER (2015d)

The typha covers an area of more than 6500 hectares, representing an average potential of about 900 000 tons of fresh biomass and an exploitable potential corresponding to 13,38 % of the yearly consumption of charcoal. The river Senegal has an exploitable potential of at least 3 000 000 tons of fresh material which is equal to approximately 500 000 tones of dry material representing 150 000 tons of bio char per year. This type of biomass is today considered a valuable alternative to combustibles energies. In Senegal biofuels also constitute an emerging and promising sector even if their regulations have not yet been finalized. The available sites of this sub-sector have been estimated at 280 000 hectares in 2010 (ANER 2015d).

3.5. Rural electrification in Senegal and the actors involved

Before the 1998 reforms, the Senegalese electricity sector was characterized by a public monopoly and the state as the only investor. A lack of incentives and an attractive framework for the sector coupled with a bad allocation of resources and the absence of a long-term vision for the development of rural electrification have hampered an increase in rural access to electricity. Decentralized options and renewable energies have not been taken advantage of completely. This has not only resulted in poor access to electricity in rural areas, with an electrification rate of only 5 % in rural areas in 1997, but it also had an impact on poverty reduction. As a result, in April 1998, the 98 – 29 bill was passed and its implementation regarding an energy sector reform ordered; the “Agence Sénégalaise d’Electrification Rurale” (ASER), the Senegalese Agency for Rural Electrification and the “Commission de Régulation du Secteur de l’Electricité” (CRSE), the commission in charge of regulating the electricity sector were then created (Rural electrification Workshop – Niang 2006).

The objectives of this energy sector reform were on the one hand to make enough quality energy available to private and industrial users at a competitive price and therefore to accelerate the development of rural electrification. On the other hand, this reform aimed at opening up the market and at setting up an appropriate framework for public-private partnerships in order to increase the means of production and the sources of financing for rural electrification (Rural electrification Workshop – Niang 2006).

Energy can only produce its effects on economic growth and the fight against poverty if everyone can access it in sufficient quantity and at lowest possible cost. Incorporated in the PRSE, the diffusion of electricity services in rural areas falls within a public-private scheme. This scheme is adopted by the Senegalese authorities and consists of the division of the national territory in 11 rural electrification concessions. Those concessions are granted to private operators for a period of 25 years. For each concession, the financial viability of exploitation relies on the state's contribution of public balancing subsidies. Those subsidies are granted to the state by a lender committed to fund the concession. They are paid as the private concessionaire attains the objectives of coverage negotiated with the Senegalese agency for rural electrification, "Agence sénégalaise de l'électrification rurale (ASER)" (AFD 2008). This mechanism is referred to as the PPER –Rural Electrification Priority Program. The ERIL –Electrification Projects of Local Initiatives – represent a second mechanism that involves proposed projects that are carried out by local communities or associations under the assistance and financial support of ASER (ASER 2010b).

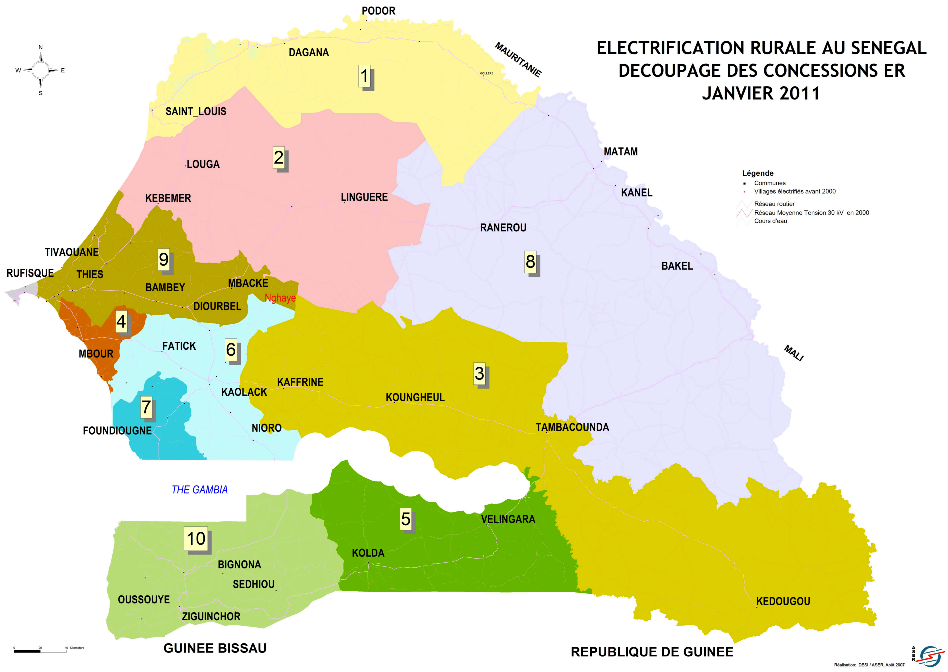

Figure 6: Rural electrification in Senegal – concessional division from January 2011 ASER (2010a)

Despite the sector reform and the government's commitment to increase access to modern forms of energy in rural areas, Senegal's rural zones remain handicapped by a weak level of development when it comes to rural electrification (ASER 2010b).

In Senegal, access to the grid is principally through the grid of the national utility SENELEC. However, the country's electrification rate is increasing both through new connections and through small off-grid systems. The SENELEC is a majority state owned company responsible for the production, the transmission, the distribution and the sale of electricity through the national grid. In recent years, national authorities have, however, adopted legislation aimed at liberalizing the sector through the promotion of private investments in generation capacity. Due to the high cost of electricity, financing of new connections through increased consumer tariffs is not possible, thus affecting the attraction of private investment (Haselip, Desgain and Mackenzie 2014).

Senegal's national electricity production is ensured by SENELEC's production facilities with a total installed capacity of 489 MW and by the facilities of private producers that account for a total capacity of 365.5 MW. This resulted in a total installed capacity of 854.5 MW in 2012 and breaks down as follows:

Table 7: Installed capacity of electricity production facilities on the 30th of December 2012

Power stations	Installed power in MW	% in 2012
Senelec	489	57,23
BOOT GTI (CC)	52	6,09
MANANTALI (Hydro)	66	7,72
Location (Aggreko-Sococim)	30	3,51
BOO KOUNOUNE (Diesel)	67,5	7,90
APR-KP	100	11,70
APR-CB	50	5,85
TOTAL POWER	854,5	100,00

SENELEC (2016a)

In 2012, rated power is 680.6 MW and has been improving in the recent years due to consistent investments in the production capacities. The table below shows that the share of electricity produced from equipment that uses fossil fuels is highest as compared to all other sources of production.

Table 8: Distribution of the production facilities by type of equipment

Type of facility	Installed capacity in MW	In %	Rated power in MW	In %
Diesel	536.40	62.77	460.6	68.56
Steam turbine	113.1	13.67	66.0	5.82
TAG	87	9.31	64	9.61
CC GTI	52	6.28	30	7.28
Hydroelectric	66	7.98	60	8.73
TOTAL	854.5	100	680.6	100

SENELEC (2016a)

The interconnected network represents the most important network of SENELEC's production facility with more than 90% of the installed capacity in 2012. This network is generally concentrated in the western and northwestern regions of the country in order to supply the most important cities. This network has an installed capacity of 634.56 MW. The non-interconnected network comprises two regional power stations in the southern region including about 26 isolated stations with a total installed capacity of 42.5 MW, which are entirely thermic and represent only 6.0 % of the countries total installed capacity (SENELEC 2016a).

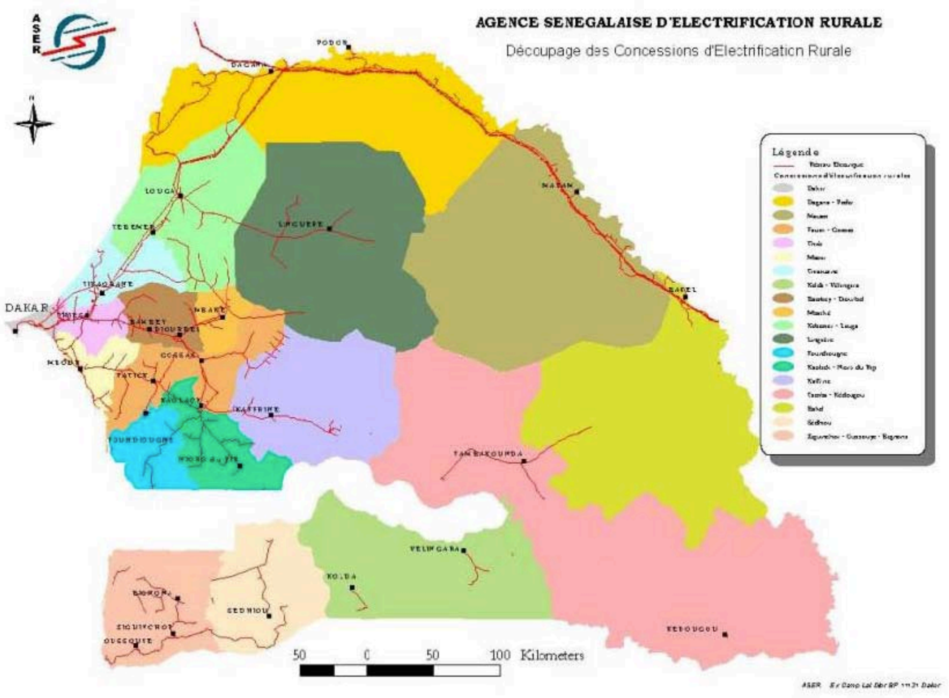

Figure 7: Mapping Senegal's electricity networks
ASER (2010a)

SENELECs responsibility to ensure the transmission and the sales of electricity includes the following tasks:

- Maintenance;
- The operation of energy transmission networks (high voltage) and of telecommunications;
- The operation of the electrical system (the supply-demand balance, optimal placement of the interconnected network's means of production);
- The purchase of power from independent producers and from auto producers as well as from the exchanges of electrical energy concluded within the framework of international agreements.

SENELEC (2016b)

ASER has been created within the framework of the law 98-29. Its principal mission is to develop and provide programs that relate to rural electrification. Moreover, it is responsible for choosing operators and attributing concession rights for any rural electrification program (Thiam 2010). Its main objective is the promotion of rural electrification and to provide the necessary technical and financial assistance in order to support the initiatives in terms of electrification within the framework of the energy policies defined by the Minister of energy. ASER (2010b)

With regards to the two mechanisms mentioned above the following have been accomplished by the ASER:

- A special rural electrification program of the Ranérou department.
- The installation of 2648 solar street lights and the electrification of 662 community centers including schools, mosques and churches through solar energy in 10 regions, financed by the Spanish African Development Fund.
- The electrification of 78 rural communities through grid connection and power generators
- The installation of 5 solar stations of 10 to 40 KWp on the Saloum Islands (1500 households), 5 desalters for the supply of fresh water, 3 cold rooms and financing of the maintenance contract.
- The installation of 6 solar stations of 10 to 40 KWp on the Saloum Islands (2500 households), 10 000 photovoltaic home systems with 50 Wc in the 7 departements
- The electrification of 57 rural communities. 55 through grid connection and 2 through power generators.

ASER (2010a)

The CRSE is the commission in charge of regulating the electricity sector. It is an independent authority that is not only responsible for regulating the production, transmission, distribution, and sales of electricity but that also has advisory powers with regard to the Minister of Energy. Moreover, the CRSE represents an essential element in the apparatus for securing the investments in the electricity sector. The commission seeks to attain the following objectives:

- Promoting the development of electricity supply

- To ensure the economic and financial stability of the electricity sector and the preservation of the economic conditions necessary for its sustainability
- To ensure financial viability of enterprises in the electricity sector
- Promoting competition and the participation of the private with regard to the production, transmission, distribution and sales of electrical energy
- Expressing social concerns by ensuring the preservation of the consumers interests and the protection of their right with regard to price, delivery and the quality of electricity

CRSE (2014)

The national agency for renewable energies (ANER), which has been created in 2013, reflects the government's commitment to provide an appropriate and sustainable solution to the energy crisis the country has been facing the past several years implying severe economic, social and environmental impacts. The ANER is committed to materialize Senegal's vision to become an emerging country through the supply of a sufficient quantity of sustainable energy at affordable prices for the country's households, businesses, social infrastructures and institutions. Its mission is to promote the use of renewable energies for that matter. More precisely, the mission of the ANER falls within the government's commitment to attain a share of renewable energy of 20% in the country's energy mix by 2017. The ANER is in particular responsible for:

- Participating in the formulation of the country's energy policies, in particular with regard to renewable energies;
- Carrying out technical, economic and financial studies with regard to renewable energy projects and to assure the follow up of the implementation;
- Contributing to the elaboration of an attractive regulatory framework for the development of renewable energies;
- Contributing to an improved research-development and to encourage technological inventions with regard to renewable energies;
- Identifying, evaluating and exploiting the potential of available renewable energy resources and disseminating the use of equipment for the production of electricity from renewable energies;

- Elaborating and implementing information, awareness, communication, education and training programs demonstrating the technical, economic, social and environmental benefits of renewable energies;
- Implementing prospective and strategic studies for the development of renewable energies;
- Participating in the promotion of the emergence and development of businesses that are active in the field of renewable energies and to encourage investments in this sector;
- Identifying and exploiting innovative financing mechanisms for the development of renewable energies, notably the area of carbon finance;
- Elaborating and implementing the national renewable energy projects and programs and to assure their consistency;
- Developing the bilateral and multilateral cooperation in the area of renewable energies;
- Working in the area of energy management, in strong collaboration with the agency for energy management.

ANER (2015e)

The implementation of the following projects is planned within the framework of the ANER:

- Public lighting through solar power in different areas. This project is part of a program of the West African Economic and Monetary Union (UEMOA);
- Improving the performance of the heath sector in defined rural areas through the installation of electrical energy equipment with the use of solar energy. This project is financed through a Dutch cooperation (ORIO);
- The installation of a 15 MW solar power station in Niakhar. This project will be implemented within the framework of a bilateral cooperation between the United Arab Emirates and Senegal.
- The electrification of kindergartens, schools, health infrastructures, mosques, and security posts at the natural reserve Niokolo Koba. The financing of the first phase of this project is ensured by ANER.
- The dissemination of solar water heaters. Senegal's ministry of public health and social action has put this project forward.

ANER (2015f)

The “Programme pour la Promotion de l’Electrification Rurale et l’Aprovisionnment en Combustibles Domestiques” (PERACOD) is a German-Senegalese cooperation program and advising body to the Senegalese Ministry of Energy and Mines. Within a context where most of the rural electrification projects cover areas with greater population densities while small and remote villages have been overlooked, the German Agency of Technical Cooperation (GTZ) has agreed to fund further research into the rural electrification of small villages. The PERACOD program, jointly administered by the GTZ and the Senegalese Ministry of Energy and Mines, initiated and manages this research. This research includes the assessment of the choice of electrical supply systems for small villages and measures that could improve their economic feasibility amongst others. In this way it tries to identify comprehensive planning paths for small-scale rural electrification. (Contreras 2008)

A variety of other international development actors are involved in the process to allow for a sustainable access to electricity for all and at low cost by supporting the energy sector and the national electricity company, rural electrification projects, the development of renewable energies and energy management. (AFD 2008)

4. Conclusion

In a first step, this work has investigated the aspects that are most vital for a successful rural electrification strategy that aims at increasing access rates amongst rural populations while considering the potential of renewable energies as a sustainable solution in the African developing context. The findings from the literature have then been put in contrast to Senegal's strategy, a country that has shown its commitment to improve rural electrification levels but has failed to achieve satisfactory outcomes so far. The identification of weaknesses within the current rural electrification strategy that might, in part, be responsible for low access rates in the country is meant to contribute to positive developments in the country's effort to reduce poverty and allow for economic growth in an environmentally sound manner.

Chapter 2 has provided a broad overview on rural electrification and renewable energies in the African developing context for that matter. The importance of the topic has been underlined by a vast amount of literature that has been produced through the energy for development debate. Especially institutional aspects and the choice of the most appropriate renewable energy technologies have widely been discussed. However, given that most countries in the region struggle to reconcile economic growth, social development and environmental sustainability this situation indicates that rural electricity strategies should be looked at more closely and possibly revised in order to allow for an overall positive outcome covering all three. It has been suggested that in order to overcome this threefold challenge, a well-defined strategy as well as strong financial and institutional support are required.

Section 2.1 pointed to the fact that availability of modern sources of energy does not automatically imply affordability of the latter. This needs to be taken into consideration when setting the goals of a rural electrification strategy, especially when "access to electricity " is understood as the availability of electricity. While most rural populations are characterized by low and irregular income flows, making modern sources of energy affordable for them appears to be one of the biggest challenges governments are facing in there struggle to achieve higher access rates in sub-Saharan Africa. It has therefore been suggested to place greater emphasis on productive uses of energy and energy for income generation. With regard to Schillebeeckx et al. (2012) viability lens which refers to the revenue structure of the consortium's business model, it has been argued that local market price need to be affordable and therefore partially subsidized

due to the low-income and low-consumption character of rural populations. In addition, governments should provide incentives that favor viability such as increasing affordability, reducing risk and uncertainty for these populations. Another important aspect is user centrism, in other words, the importance to understand the need of customers, end users and affected populations. Three fundamental concepts have been discussed: affordability, reliability and local embeddedness. Affordability is about capital access, the size, timing, and duration of periodic payments, which can be fixed or (partially) variable. Reliability is defined as a combination of quality, service level and sufficiency, which can be ensured through quality control systems, labeling, standardization, and regulation. Community involvement, cultural sensitivity, and competence building are suggested to ensure local embeddedness. It has been argued that the participation of rural populations in the designing, planning, implementation and operations of rural development programs is essential for the sustainability of the latter. This is also said to be true when giving local communities ownership. More attention should also be given to cultural values, traditions, beliefs, norms and social structures in order to increase local acceptance of electrification programs. In order to reduce operation and maintenance costs, reduce system losses and allow for non-payment minimization, its has been suggested to develop models in which community members maintain their own system and can carry out small repairs.
On a policy level, it has been stresses that the implementation of adequate rural electrification policies that promote equity and sustainability, along with economic growth are substantial for developing countries. A number of baseline policies and some broad policies have been assigned on a global as well as on a governmental level and demand governments around the world to implement their commitments. They therefore have to be incorporated in national policies. This is quite often done in partnership with international organizations and companies, notably when it comes to improving rural electrification.

In the following, this work explored the state of rural electrification in sub-Saharan Africa. While the region has constantly strengthened its growth in the recent past and is said to still continue to make process, translating this growth into faster poverty reduction remains a key challenge. This deficiency is also reflected in the extremely low rural electrification rates in most of the countries on the continent. While the levels of traditional biomass energy use are very high in rural areas, electricity consumption is commonly very low. In order to increase the access to electricity in those regions, almost every country launched a rural electrification program. However, the results remain unsatisfactory, as the high price of this service remains unaffordable for the rural poor. No significant increase has further been registered though the dissemination of PV technology, which has been prioritized by most national renewable energy strategies.

Sub-chapter 2.3, on sub-Saharan Africa's energy use patterns, reveals that the cooking and the use of biomass, notably in the form of firewood, for that matter can't be neglected as an important source of energy for rural populations. While cooking accounts for the highest percentage of energy consumption in rural households, other uses are lighting, space heating for some regions and phone charges. Although conventional energy sources such as electricity seem to play a minor role in rural energy supply, their contribution should not be neglected as they bear the potential for productive uses.

With the aim to generalize the access to electricity in rural areas through sustainable electrification and energy strategies, diversifying the sources of energies and in particular increasing the share of renewables for that matter appears to be necessary for a region that not only generates the smallest amount of electricity but also has abundant renewable energy resources. While grid expansion and centralized solutions such as mini-grids are appropriate for densely populated villages, small villages and such with highly dispersed populations require different solutions. In particular small and medium-scale and, at best, locally made renewable energy technologies but also other rural technologies should be prioritized in rural electrification initiatives. The most important factor here is of course the cost factor of the technology. The populations concerned should be able to select the technology that best fits their comparative advantage as well as their incomes. Solar technologies such as solar home systems have been criticized for being unaffordable for rural populations especially when considering that their use is generally limited to lighting and battery charging. Moreover, they do not allow for productive uses and have little impact on cooking, which is the highest end use of household energy. Hydropower might only be an economic means of access to electricity or energy on a small scale and for communities living close to water streams. Although sub-Saharan Africa has a significant wind potential in some regions and wind can be cost competitive with other technologies, limited market size and poorly developed power grids limit the dissemination of this source of energy. However, small hydro and wind projects can compete in some cases with solar PV for off-grid uses for the matter of rural electrification. Given the reality that biomass energy use will continue to be dominant in rural sub-Saharan Africa, the importance lies in taking advantage of attractive opportunities for the use of this source of energy in more modern, efficient and environmentally sound ways. This refers mainly to an increased dissemination of improved woodstoves, but can be extended to small-scale industrial boilers for small and medium enterprises, particularly in rural agro-industries.

To date, national utilities in sub-Saharan Africa share the responsibility for rural electrification with recently established rural electrification agencies and funds. However, the latter struggle for authority and funding in a turbulent organizational and political environment and are in constant competition with the unbundled and commonly privatized utilities. NGOs and other international development actors are also involved in providing access to energy in rural areas. However, they often provide development interventions with limited coordination with other sector needs, other development actors and the electrification authorities responsible for planning.

With regard to supplying electricity to rural sub-Saharan Africa, five different delivery models have been discussed in section 2.5: the fee for service dealer model and the fee for service concession model, the donation model, the commercially led model, and the multi-stakeholder programmatic model. The choice of the model generally depends on local available finances and should mainly be tested on the ability of the different models to reduce consumer fees in order to successfully market renewable energy technologies for rural electrification. Moreover, competition, economy of scale, finance schemes, subsidies and efficient maintenance are important as they can, in combination with the different delivery models, allow for price reduction. Market development and income levels appear to play a major role in the decision about the delivery model. However, a long-term government commitment is one of the most important factors for achieving rural electrification goals. While competition, economy of scale, finance schemes, subsidies and efficient maintenance can allow for price reduction within the right context, the inclusion of the existing financial sector in the rural electrification program should also not be neglected.

Sub-chapter 2.6 discussed the challenges to rural electrification and the aspects that are essential for a successful rural electrification strategy. Inadequate propositions and government strategies have been cited as being in part responsible for the lack of electricity in rural areas. Changes in government policies and a different approach from the private sector are therefore needed. Flaws in the strategies and organizational problems can also represent constraining factors to rural electrification. Non-institutional constraining factors are poverty – hence low affordability –, low density of consumer demand, small-scale production units and lacking infrastructure for maintenance. Another restrictive rural reality is that the standard banking system does not attribute loans to these populations as they generally lack guaranties. The lack of service and spare-parts could, however, further the development of the local expertise, which in turn bears the potential for job creation and reducing the costs of the product. This leads to the understanding that local manufacturing should be strongly promoted in sub-Saharan Africa to allows for local assembling and finally a cheaper product than the imported ones. With respect to successfully introducing a specific technology the consideration of cultural aspects is crucial. Raising awareness of the advantages and acceptance of the technology is therefore considered to being necessary as well as follow up.

With regard to reaching higher rural electrification levels there are two main approaches. The first one considers the supply of electricity as obligatory for improving the living conditions of rural populations and to achieve 100% rural electrification in developing countries. The second stresses that the rural populations in sub-Saharan Africa urgently need technologies that can rapidly raise their incomes and at the same time improve energy services. This approach suggests the redesign of rural energy programs in order to encompass non-electrical and more affordable technologies. An institutional solution would be to transform current electrification programs and agencies into rural energy agencies. In contrast to conventional and centralized projects, renewable and rural energy technologies are generally more labor-intensive and therefore represent a way to encounter problems of employment. Decentralization and the empowerment of local actors should also be considered for a successful rural electrification policy as well as capacity building and ensuring transparency.

Chapter 3 started by briefly describing Senegal's economic, geographic and political background and, in a further step, discussed several national documents that reflect the country's understanding that access to electricity and more generally to energy can be a lever for growth and development. The country's initial situation with regard to economics, politics, demographics, its natural resources endowment and institutional challenges with respect to its rural electrification strategy reflects the general sub-Saharan African context that has been described in chapter 2. The country faces serious challenges that are common amongst the countries of the continent, such as weak infrastructure, an unfavorable investment environment, widespread poverty, a high level of population growth, unreliable weather, overfishing, depletion of resources, changes in commodity prices, severe unemployment rates, high prices in food and oil, which all affect the country's economy and hinder its development. With regard to institutional challenges the following have been cited: lack of proper courts and legal systems, complicated and inefficient bureaucracy and a lack of transparency with respect to public funds. However, Senegal disposes also of assets such as a favorable geographic location, potential in tourism, a definite progress in terms of new information and communication technologies, a flow of people and transfer funds with the Northern countries, and is perceived as one of the most politically stable countries in Africa.

With a rural electrification rate of 22% in 2012, Senegal has recognized that the key issues of the sector are the access to electricity for all in sufficient quantity and quality at limited costs. The government, therefore, has stated its commitment to establish a better equation between economic growth and human development, through the increase of rural access to modern forms of energy. As in most of the sub-Saharan countries, energy consumption in Senegal remains low due to a weak supply with regard to demand, the high costs of access to energy services and the quality of the service. Over the past decade several national documents on the country's social and economic development have been established, presenting strategies that involved different measures to increase the access to electricity and other energy sources. Early on, the latter presented objectives such as the diversification of sources of energies and technologies, the promotion of renewable energies, the involvement of the private sector, village associations and local authorities with regard to the development of infrastructure and energy services, the implementation of an investment program for the access to energy services and allow for the electricity prices amongst the lowest in the sub-region. Also included were objectives with regard to energy efficiency and restructuration measures, in particular with respect to the national utility. While previous objectives have not been met, Senegal continues to follow optimistic objectives such as a rural electrification rate of 60% in 2018.

Senegal's power sector, presented in sub-section 3.3, shows the typical deficiencies of the region: supply deficits that cause power outages, system losses, overconsumption of combustibles due to old production installations raising the price of electricity and institutional reforms that did not deliver the desired results. As laid down in sub-chapter 3.4, Senegal disposes of a confirmed potential of solar, wind, hydro and biomass energy to be used, however, the country does not yet tap into the full menu of options when it comes to renewable energies and presents a low level of diversification in his energy mix. Although it suggests the government's determination to shift from conventional energies to a diversified mix, the establishment of Senegal's national agency for renewable energies (ANER) in 2013 might not be sufficient. Strong financial and institutional support will be necessary in order to attain the stated objectives.

Senegal's national utility has a long history of reforms, which has also brought about the establishment of the commission in charge of regulating the electricity sector. The Sub-section 3.5 on Senegal' rural electrification and the actors involved, has shown that the country has opted for the concessions model with a division of its territory in 11 rural electrification concessions granted to private operators for period of 25 years and financial viability of exploitation relying on subsidies from the state. A rural electrification agency (ASER) has been established for that matter, as well as a national agency for renewable energies, whose mission it is to promote the use of renewable energies and to support the governments effort to attain a share of renewable energy of 20% in the country's energy mix by 2017. In Senegal a variety of international development actors are involved in the process for a sustainable access to electrification and energy in general.

Finally, this work has revealed that Senegal presents a rather common but not very favorable context for rural electrification in developing countries. The country has implemented policy measures, performed institutional reforms, created new rural electrification and renewable energy institutions, and most important, has set itself ambitious goals with regard to providing access to sustainable energy and electrification in rural areas. These goals might not have been reached in the recent past but Senegal shows persistence on its path towards a successful rural electrification strategy. Moreover, the assumption that rural electrification rates in sub-Saharan Africa remain extremely low today due to a lack of appropriate strategies in most countries needs to be investigated in more detail. For the case of Senegal and despite the common challenges to rural electrification, it proves to be difficult to extract the major flaws in the strategy. This is mainly due to the fact that the success of a rural electrification strategy depends on a great number of factors that extend beyond institutional, economic, policy-related, environmental and technological borders.

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