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Beziehung zwischen Erneuerbaren Energien und Beschäftigung im Senegal

Links between Renewable Energies and Employment in Senegal

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Links between Renewable Energies and Employment in Senegal

--- English version ---

Register-No. BA EE 60/18 by

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Abstract

In this study the link between renewable energies and employment in Senegal is analyzed. The *Sustainable Livelihood Approach* is used to understand the investigated situation in a holistic view. To successfully implement renewable energies in Senegal and to have a significant impact on the employment market, the governmental framework and the technical education has to improve, to match the needs of the labor market.
Rural communities do not have all the assets to lift themselves out of poverty and disadvantages by the usage of renewable energy. Solar irrigation, off-grid systems and solar devices impact the level of education and the labor force in rural areas in Senegal. Moreover, access to a reliable energy source improves people's livelihood in terms of health, education, income and employment.
The resulting employment effect of adding 20 MW with the solar power plant *Senergy 2* can be estimated with 28.686 created jobs (0,54 % of total employment).
Upcoming power projects offer employment opportunities for graduates of the master study renewable energies. Furthermore, the demand of specialized engineers and technicians in the distribution and project planning sector will rise.

In dieser Arbeit wird die Beziehung zwischen erneuerbaren Energien und Beschäftigung im Senegal untersucht. Es wird der *Sustainable Livelihood Approach* angewandt, um das Thema ganzheitlich zu untersuchen. Um Erneuerbare Energien im Senegal zu implementieren und einen signifikanten Einfluss auf den Arbeitsmarkt auszuüben, müssen die staatlichen Rahmenbedingungen vereinfacht und angepasst werden. Ebenso ist eine Verbesserung der technischen Ausbildung nötig, um dem Bedarf auf dem Arbeitsmarkt zu entsprechen.
Ländliche Regionen verfügen nicht über Existenzgrundlagen, die sie benötigen um sich mit der Anwendung von erneuerbaren Energien aktiv aus der Armut zu befreien. Solare Bewässerungssysteme, Solare Inselsysteme und weitere solare Produkte, tragen dazu bei dem Bildungsgrad und die Arbeitsmöglichkeiten in ländlichen Regionen des Senegals zu erhöhen. Außerdem bieten sie eine Verbesserung der Lebensqualität, besonders in den Bereichen der Gesundheit, der Bildung, des Einkommens und der Arbeitstätigkeit.

Durch das Hinzufügen von 20 MW solarer Leistung durch das Kraftwerk *Senergy 2* werden voraussichtlich 28.686 Jobmöglichkeiten geschaffen, was 0,54 der ganzen Arbeitskraft des Senegals entspricht.
Bevorstehende Energieprojekte bieten Beschäftigungsmöglichkeiten für Absolventen des Masterstudiengangs Erneuerbare Energien im Senegal. Besonders der Bedarf an spezialisierten Ingenieuren sowie Technikern in der Distribution und in der Projektplanung wird steigen.

Ce mémoire examine la relation entre les énergies renouvelables et l'emploi au Sénégal. L'approche du *Sustainable Livelihood* est utilisée pour comprendre la thématique étudiée d'une manière globale. Afin d'implémenter les énergies renouvelables au Sénégal et d'exercer une influence significative sur le marché de l'emploi, le cadre gouvernemental et l'enseignement technique doivent être améliorés pour répondre aux besoins du marché du travail.
Les communautés rurales n'ont pas tous les capitals pour se déprendre de la pauvreté et des désavantages uniquement grâce à l'utilisation d'énergies renouvelables. L'irrigation solaire, les systèmes hors réseau et d'autres dispositifs solaires ont de l'ascendant positif sur le niveau d'éducation et les possibilités d'emploi dans les zones rurales du Sénégal. En outre, l'accès à une source d'énergie fiable améliore les moyens de subsistance des gens en termes de santé, d'éducation, de revenu et d'emploi.
L'ajout de 20 MW d'énergie solaire à la centrale de Senergy 2 devrait créer 28 686 emplois, soit 0,54 de l'effectif total du Sénégal.
Les projets énergétiques à venir offrent des possibilités d'emploi aux diplômés des études des énergies renouvelables au Sénégal. En outre, la demande d'ingénieurs et de techniciens spécialisés dans la distribution et la planification de projets augmentera.

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ADB	African Development Bank
ANER	National Agency for Renewable Energy
ASER	Agency of Rural Electrification
AUMN	Association des Unions Maraîchères des Niayes
BMZ	Federal Ministry for Economic Cooperation and Development
CFA	Communauté Financière Africaine
CRSE	Regulatory Commission for the Electricity Sector
DRC	Democratic Republic of Congo
ERIL	Électrification Rural par des Initiatives Locales
ESP	Emerging Senegal Plan
FCFA	Franc Communauté Financière Africaine
GDP	Gross domestic product
GIZ	German agency for international cooperation
HDI	Human Development Index
IMF	International Monetary Fund
MEDER	Federal Ministry of Energy & the Development of Renewable Energy
METFP	Ministry for Technical Education and Vocational Training
OECD	Organisation de coopération et de développement économiques
OPIC	Overseas Private Investment Corporation
PERACOD	Program for the promotion of renewable energies, rural electrification and sustainable supply in domestic fuel
PESEREE	Programme d’Enseignement Supérieur pour les Énergies Renouvelables et l’Efficacité Énergétique
PSI	Policy Support Instrument
SIE	Systeme d’Information Énergétique du Senegal
SLA	Sustainable Livelihood Approach
SMEs	Small and Medium Enterprises
toe / tep	tons of oil equivalent
TVET	Technical and Vocational Education and Training

1 Introduction

Access to electricity is an essential part of contemporary life and can be considered as an outcome and driver of development. Renewable energies can be linked to social improvements, such as employment, higher income, better educational outcomes and improved health. It can enable economic development and improve the standard of living by providing a practical solution to challenges Senegal is facing. In addition to that renewable energies can stabilize carbon emissions at a sustainable level.

The estimation of future employment in renewable energies depends on assumptions about the scale of investment and by that the capacity additions, which depend on the supportive policies in Senegal, the trend in terms of cost of energy technologies and productivity of labor. Using a people centered methodology, macro and micro investments in the Senegalese renewable energy market are being investigated as well as their implications.

1.1 Overview of the thesis

This paper is divided into eight chapters. The **Introduction** contains the structure of the thesis, background information on the topic as well as the setting and the problem statement. It serves as an orientation to understand the framework and the objectives of the project.

In the second chapter the **Research methodology** and the used approach to structure the thesis is exemplified. The *Sustainable Livelihood Approach* (SLA) is used to organize the given and conducted data and to find out more about the situation in a holistic view.

The third chapter provides **technical and economic background** and forms a basis for the main chapters 5 and 6. It contains information about the economy and power profile, as well as the education and employment outlook of Senegal.

Chapter four, **Technology strategy for sustainable livelihood**, applies the SLA on the given topic. It is investigated, which potential the access to energy technology has on people's livelihood and how renewable energies can have an impact on livelihood enhancement in Senegal.

The fifth chapter assesses the **Relation between investments in power and labor** and analyses how investments in the energy sector affect the employment sector.

The chapter closes with an example calculation, applied on the solar power plant *Senergy 2* to ascertain the labor effect.
After the analysis of investments in the power sector, the **Relation between application of renewable energies in rural areas and labor** will be presented. This chapter describes how the usage of solar irrigation systems, solar off-grid systems and small solar devices impacts the livelihood of rural communities. Based on this analysis the factors for a sustainable development are emphasized, as well as the needed job profiles in the Senegalese energy revolution and which job opportunities are created.
Chapter seven contains specific **Employment opportunities and trends** for graduates of the master course *Renewable Energy* and a **discussion** of the thesis. It aims to provide a tangible list of opportunities and contacts for graduates in this field. The final chapter contains the **Conclusion and outlook,** which can be drawn from this thesis and where further work packages of the topic are outlined.

1.2 Background

Electricity provision to the rural population in Senegal by using renewable energy plays a significant role in the further development and poverty eradication.
Renewable energies are a sustainable way to supply the energy, which is needed by an increasing population. Social barriers in the implementation of renewable energy projects lead to poor acceptance of the projects and abandonment in communities. Senegal is facing an energy deficit, which increases due to rising energy consumption. The economy and employment sector is negatively influenced by frequent power outages. To improve the deficit, the government attempts to opening investments to the power sector, improving technical education and setting up a stable energy framework. Senegalese people are experiencing high electricity prices and high costs to receive a power connection. This limits their possibilities, given by renewable energies. There are several NGO’s and companies, who are distributing solar products in Senegal. Interviews are conducted with a variety of them.

1.3 Setting and current situation

This bachelor thesis on hand with the title “Links between Renewable Energies and Employment in Senegal” is written in cooperation with the *École Polytechnique de Thiès.*

There is a lack of high-quality data resources in Senegal regarding the energy sub sector. This includes data related to capacity, plant performance, mini-grids, high-potential locations and consumer behavior. According to interviews with ministry employees, the lack is noted by the government not as an information gap, but as an institutional capacity gap that has to be filled [1]. To fill this gap the *Système d'Information Énergétique du Senegal* (SIE) was founded, but until this date, no trusted high-quality data has been released.

The thesis is written in Thiès in Senegal, biased by daily power outages and coherent information.

1.4 Secondary data

The developing research topic is highly reliant on secondary data from implementing organizations. The consulting data is independently verified on behalf of organizations working in Senegal. The process through which the data sources are constructed must be considered. In the time of data collection, most of the organizations were trying to fund their projects, so data has to be handled with care. The collected data from interviews will provide a context for discussion of the results of literature study. To underline the collected data, interviews have been conducted with the government, non-governmental organizations, corporations and charities as well as with farmers and individuals living in a rural context. The interviews are conducted in English, French, German or Wolof and translated and transcribed in English and performed following the interview guideline in Annex H.

Throughout this project, it became an additional aim to collect trustworthy data and to illustrate it in the attached Excel-File.

1.5 Problem statement and objectives

The subject of this bachelor thesis is the analysis of the links between renewable energies and labor. The theoretical assumption is that livelihood in Senegal can be improved by implementing renewable energies in rural and urban areas.

Investments in the power sector do not affect the rural communities as much as the urban areas due to missing assets. Providing access to affordable and stable electricity could provide the solution to promote sustainable development and empower people to lift themselves out of poverty.

Within this thesis, the focus will be on analyzing the employment effect of power investments in renewable energies and application of renewable energies in rural areas in Senegal. The deployment policies and governmental framework structures are investigated referring to sustainable job creation in the energy sector.
An additional objective is to work out specific employment opportunities for graduates of the master study of renewable energies, accomplished at the *École Polytechnique de Thiès* in Senegal.

2 Research methodology

A qualitative research method has been selected due to the approaches of the *Sustainable Livelihood Approach* (SLA). The main focus of the conducted interviews is to understand the subjective reality of people's livelihood and their environment. General statements are based on individual cases as part of an inductive approach. Subsequently the qualitative results are monitored by quantitative methods [2].

As main methodology, which plays a structuring role in this thesis the SLA is aiming "to promote development that is sustainable not just ecologically, but also institutionally, socially and economically and to produce genuinely positive livelihood outcomes" [3], p.14

It is enhancing the sustainability of human, social, physical, financial and natural capital assets and works on multiple levels. The multiple levels contain people-centered, responsive, participatory perspective, but also works in partnerships to act economic, environmental and institutional sustainable. The SLA is a bottom-up strategy and looks at the impoverished more like stakeholders in the development policy than victims. The process of livelihood and the improvement of reproduction conditions is investigated in the overall context of political and social relations. The SLA addresses the part of the population whose basic needs are not met. [4]

The sustainable livelihood framework, as seen in Figure 1, can refer to any practical procedure, which is offered to increase people's assets and helps to understand the dimensions of poverty in rural areas.

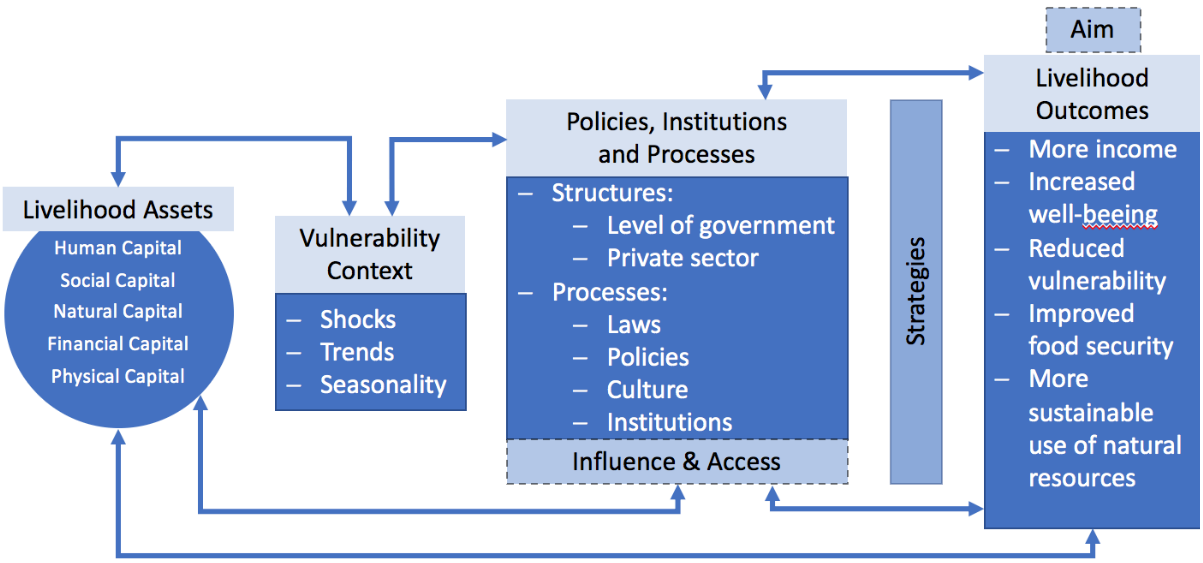

Figure 1: Sustainable livelihood framework adapted from [5], p.5

Humans have basic needs to fulfil, to progress and to develop themselves. Those livelihood assets or *capital* refer to all the external capabilities required for living. It takes the multiple factors into account, that may affect their livelihood like policies, institutions or processes.

The SLA is a useful approach for a holistic understanding of the external factors of providing of electricity to rural communities including positive and negative consequences in their vulnerability context. It can be used to review the factors regarding sustainability, why some renewable energy projects may or may not be welcomed in rural communities and which role they can play. The provision of electricity is viewed as a common livelihood strategy and is examined with both positive and negative consequences for people's assets and their vulnerability context.

A livelihood is sustainable, when it is able to recover from tensions and shocks and at the same time, maintain and improve possibilities for the present and future without damaging the environment. Rural electrification and the use of renewable energies is considered to improve livelihood and reduce poverty at the same time as it develops people's lives.

The data collection was partly limited by the language barrier to the rural community. Used quotes and interview partners are selected and categorized following the interview guidelines in the Annex H.

3 State of the art

The gap between poor and rich is increasing while the lack in electrification development stays persistent in rural areas. The economy and its growth are mostly influenced by the agricultural sector, but are suffering from the negative impact of power outages and high electricity prices due to the high import costs for resources and old grid infrastructure. [6]
On top of the already existing energy deficit, energy demands are rising, and the consumption is believed to rise in the future as well. “Conservative projections of electricity demand estimate growth at 5,6 % annually in the coming years.” [7]. Senegal has a high potential for solar, wind and hydro plants for energy production as well as biomass for thermal power, which could counteract the energy deficit and meet the new demands. Although main barriers in implementing renewable energies are delays in laws, calls and communication. [8]
The government attempts to improve the schooling rate with electrification and to reform the technical education to match the needs of the labor market. The agricultural sector contains most of the labor forces, who are commonly male and younger than 25. Nonetheless especially among youth the unemployment rate is high. [9]
The statements made are supported by additional data, which can be found in the Annex A.

3.1 Economy profile

Senegal’s economy is defined by the market sectors in rural areas. The *Gross domestic product* (GDP) increased between 2015 and 2017 every year, resulting in a growth of 6,8 % in 2017, which places Senegal 12th in a ranking of 222 countries in comparison. Collating the absolute GDP of the world, Senegal is placed on the 114th position with a net worth of $43,07 billion in 2017. [6]
The country is facing weak competitiveness of exports since the exporting sectors are mainly natural resource-based and in the agricultural sector, which is heavily depending on external influences and only on raw materials. The nondisruptive access to transport and energy represents the foundation of an economic change and growth and with it a solution to the time-related underemployment and the high energy prices.

3.1.1 Socio-economic conditions

The socio-economic situation of Senegal is characterized by the increasing gap between economic growth and demographic trends.

Senegal's population was estimated at 14,7 million inhabitants in 2017 [6], of which 56 % are living in rural areas [10]. The general public trend shows a rising number of urban population, while the rural population stays almost persistent.

On average, the unemployment rate was rising in the last 26 years, but since the change of government in 2012 it is descending slowly from 10,4 % to 9,5 % in 2017 (cf. Figure *12* in Annex A).

In order to measure the human development, the United Nations are taking the life expectancy at birth, mean years of schooling and the gross national income per capita into account. Senegal's Human Development Index (HDI) value for 2015 is 0,494, which is placed in the low human development category and ranking it on position 162 of 188 countries. The main reason for the rise of the HDI in the last 25 years is considered to be the improvement of the expected years of schooling, which increased by 111 %. The HDI is below the average of 0,523 in Sub-Saharan Africa. (for detailed breakdown cf. Figure *13* in Annex A); [11]

Corresponding to the *Human Development Program* 51,9 % of the Senegalese population is living below the poverty line, which includes having a smaller income than what is necessary to meet basic needs. Basic needs are defined as the absolute minimum resources necessary for long-term physical well-being. [9]

Despite programs raising the HDI, the gap between the poor and the rich is increasing in some rural areas. It is considered to rise, because the mean household, the HDI compares with, is closer to the household in rural areas, so changes in the urban areas do not affect the HDI as much as minor changes in the rural areas. Taking into account that in urban areas “most households being relatively richer than the mean household in the country”, the impact of changes in growth rates are less significant. [12], p. 13f

At a socioeconomic level the rising HDI is also related to a high population growth rate of 3,90% every year. In 2018 43,4 % of the population are under the age of 15. The national food security and nutrition survey concludes in 2018, that 17 % of the Senegalese population has no secure access to food. [13]

Further socio-economic indicators can be viewed in the Table 6 in Annex A.

3.1.2 Currency stability

The *Communauté Financière Africaine* (CFA) franc is considered as a low risk currency in West Africa. It is issued by the *Central Bank of West African States* and pegged to the Euro with a fix rate of CFA655,96 to 1 €. As a common currency, it is shared with eight countries in West Africa and six countries in Central Africa. The CFA franc zone is considered as a safe trade partner due to the exceptional combination of a monetary union and a zone with fixed exchange rates. All countries participating have a developed trade with European countries, especially France.
Despite with the CFA franc providing currency stability, Senegal suffers from unexpected unsteadiness in terms of trade in macroeconomic interactions, as there are no flexible exchange rates to use as an absorber. The high independency on raw commodities is an additional uncertainty factor in Senegal's economy. [14]
Nevertheless the stability given by the peg to Europe will result on the long term result in low inflation and eventually foster growth [15].

3.1.3 Economic growth

The economic growth is influenced by three main sectors and the public services. The primary sector contains only agriculture, the secondary sector mining, energy, gas and water, industries, public works and housing and the tertiary sector contains trade, transport and telecommunication.
Due to the negative impact of drought and power outages, the economic growth rate dropped to its lowest point in 2011 with a rate of 1,8 %. As already mentioned above, in the following years it significantly improved to 6,8 % in 2017 [11]. The flux is driven by lower oil prices and improved export performances. The growth rate is mainly affected by the primary sector, which is influenced by the weather conditions. The access to reliable energy and transportation would provide the opportunity for a transformation of Senegal's agricultural and clean energy sector and offers greater investment security.
The Senegalese export industry is dominated by agricultural products, commercial fishing, fertilizer production, phosphate mining and since the 2014 discovery of oil and gas resources on the Senegal-Mauritanian border, also on oil exploration projects. While preserving macroeconomic stability, Senegal relies on donor assistance and foreign investment.

2012 elected president Macky Sall sustained the *Emerging Senegal Plan* (ESP), which aims to increase economic growth. To complete the ESP, Senegal is receiving support by the *International Monetary Fund* (IMF) under a *Policy Support Instrument* (PSI). The ESP comprises 27 projects and 17 reforms to restructure the Senegalese economy. One of the already finalized projects is the commissioning of the *Tobene* power plant in 2016. The government aims to achieve with the structural change of the economy a 7 % to 8 % economic growth rate by 2035, fueled by increasing exports and direct foreign investments. With the ESP Senegal is broadening its growth base to four new divided sectors: agriculture and agri-food, housing, mines and tourism. [6]
The development of the GDP including a forecast by the IMF can be viewed in the Figure *14* in Annex A.

3.1.4 Energy prices

76,5 % of the general income in 2017 is used for household consumption, which includes amongst others electricity expenses [6]. In comparison, in the same year Germany is using 53,7 % of their GDP for household consumption [16].
Electricity prices in Senegal are the highest in Africa. Since *Senelec* is no longer subsidized by the government to hold low prices, on one hand the financial stability of the company improved, on the other hand the prices for consumer increased. In 2016 the average price for lower voltage electricity was 121,86 FCFA /kWh, for medium voltage level 114,61 FCFA /kWh and 87,70 FCFA /kWh for high voltage [17]. As can be seen in Figure 2, the difference in low voltage electricity prices to countries like Benin and Ghana is negligibly small as well as the higher difference to Germany. Especially in the industrial sector, using medium and high voltage, the distinctions with more economically developed countries, like Germany, is to be noted. Ghana and Senegal boast no large discrepancy between household and industrial energy usage. For Benin, there is no high voltage data available.

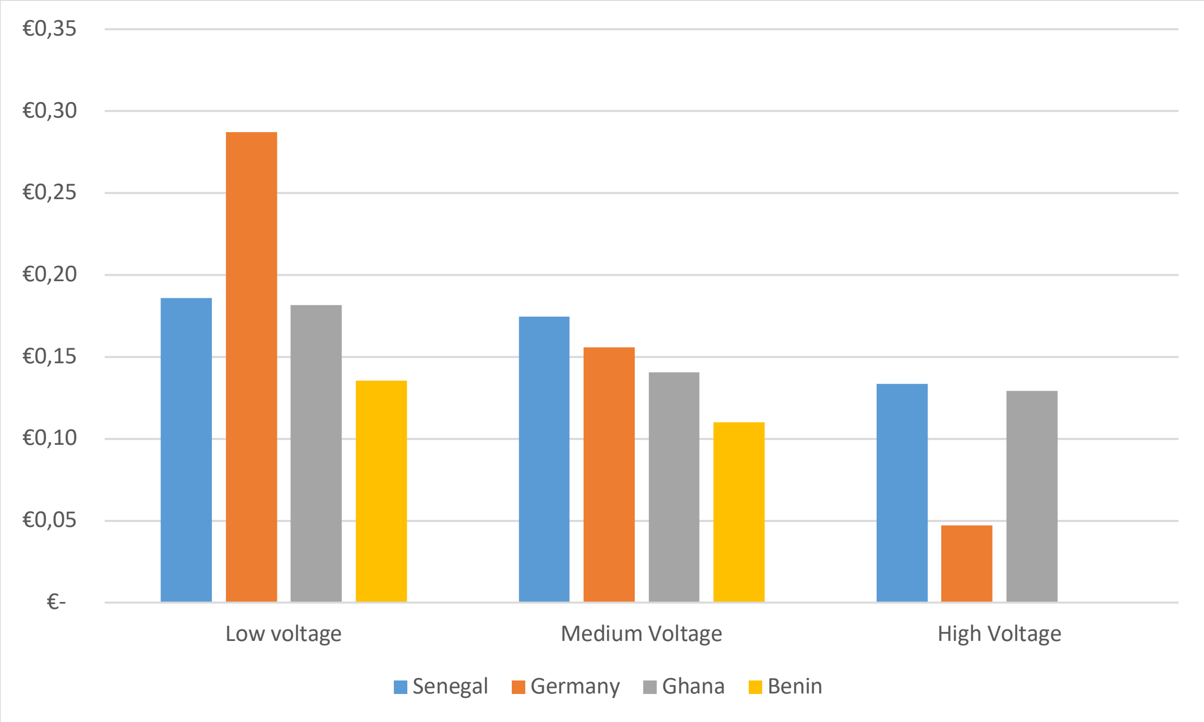

Figure 2: Electricity prices 2016 in €/kWh SN: [17], DE: [18], GH: [18], BJ: [19]

As stated by Mr. Issa Rohou Laye Sonko, engineer of renewable energies at the *Ministry of Petroleum and Energy of Senegal,* "there are three main problems, that make the price of the electricity high, the first are the machines of *Senelec*, which are very old and due to that you have big losses." In addition to that the transporting grid is outdated and the import costs for fuel are rising while at the same time energy needs are also rising. [1]

Senelec claims an average wholesale cost of energy generation of CFA70/kWh (0,11 €/kWh). According to Table 1, biomass can be identified as a lower cost of wholesale. At the present there are no official feed-in tariffs for Senegal, they still have to be negotiated with *Senelec*, but the *Renewable Energy Law* built the basis for such tariffs.

Table 1: Senelec wholesale prices from renewable energy projects [20], *p.45*

Energy source	**Wholesale prices of *Senelec***
Biomass	CFA 66/kWh
Solar	CFA 120-130/kWh
Wind	CFA 85-95/kWh

Due to the recent geological findings of gas and oil resources in the area, Senegal is developing their legal and regulatory framework, the *Petroleum* Code.

Over the past five years fuel and gasoil prices are falling again since they reached their maximum in 2012. [17], p.32

3.2 Power profile

Senegal's electricity sector is split into three main divisions: *Senelec,* the national electricity company, the Agency of Rural Electrification (*Agence Sénégalaise d'Electrification Rurale; ASER)* and the Electricity Regulatory Board (*Commission de Régulation au Secteur de l'Electricité; CRSE*). On account to the *Federal Ministry of Energy & the Development of Renewable Energy* (MEDER), the whole energy sector deals with inefficient technologies, a low developed distribution grid, a lack of regulatory framework and non-transparent weak financial structures [1].

A key component of the Senegalese power sector is the ESP, which aims to make Senegal a nascent economy by 2035. To achieve this aim, it is necessary to expand the access to electricity, particularly in rural areas, increase the affordability of electricity and to disengage from imported fossil fuels.

Since Senegal's energy demands are rising, the country's energy profile is starting to be dominated by coal and diesel: 2016 a 52 MW diesel plant and a 125 MW coal plant came online. Renewable energy projects, which are already financed will produce 165 MW in total at the end of 2018: *Senergy 1, Senergy 2, Cap des Biches Expansion, Cao des Biches* and *Ten Merina N'Dakhar*. In 2017, 90 % of Senegal's energy outcome was provided by imported heavy fuel. [8]

A main objective of Senegal is the approach of electrifying decentralized villages with small grids called *Électrification Rural par des Initiatves Locales* (ERIL) with renewable energies. Private producers play a minor role in the energy district due to difficult access conditions to the grid. [21]

3.2.1 Energy framework

The key stakeholders of the energy framework in Senegal are divided into the public sector, the private sector, the civil society and donors.

The MEDER and its related ministries, the *Agriculture & Rural, Water & Sanitation, Industry & Mines* and *Environment & Sustainable Development* manages the specialized government institutions, which are helping to implement Energy policies.

Those relevant government bodies are the CRSE, the ASER and the *National Agency for Renewable Energy* (ANER). As well regional as local government actors also play a key role in the energy framework, by providing the theoretically possible environment and land to off-grid projects. Several financiers invest in energy projects across the market; they can be subdivided into donors, development banks and other investors as well as civil society actors, including non-governmental organizations. *Senelec*, the national electricity company, manages 100 per cent of transmission and distribution as well as a part of generation. The missing electricity generation is made by independent power producers and some ERILs and off-grid power generators. To further stabilize the grid, *Senelec* buys captive power generators to insert excess power to the national grid. (cf. [22], p. 69)

3.2.2 Energy mix

There are various disclosures about the exact amount of energy mixture in Senegal, to illustrate this issue two different additional assertations can be viewed in Figure 15 in Annex B. In 2017 the USAID published a total installed capacity of 864 MW with 733 MW from fossil sources, 60 MW hydro, 50 MW solar and 21 MW undefined power source. Taking the finished projects of 2017 into an account, the undefined source is considered to be biomass (cf. Figure 3).

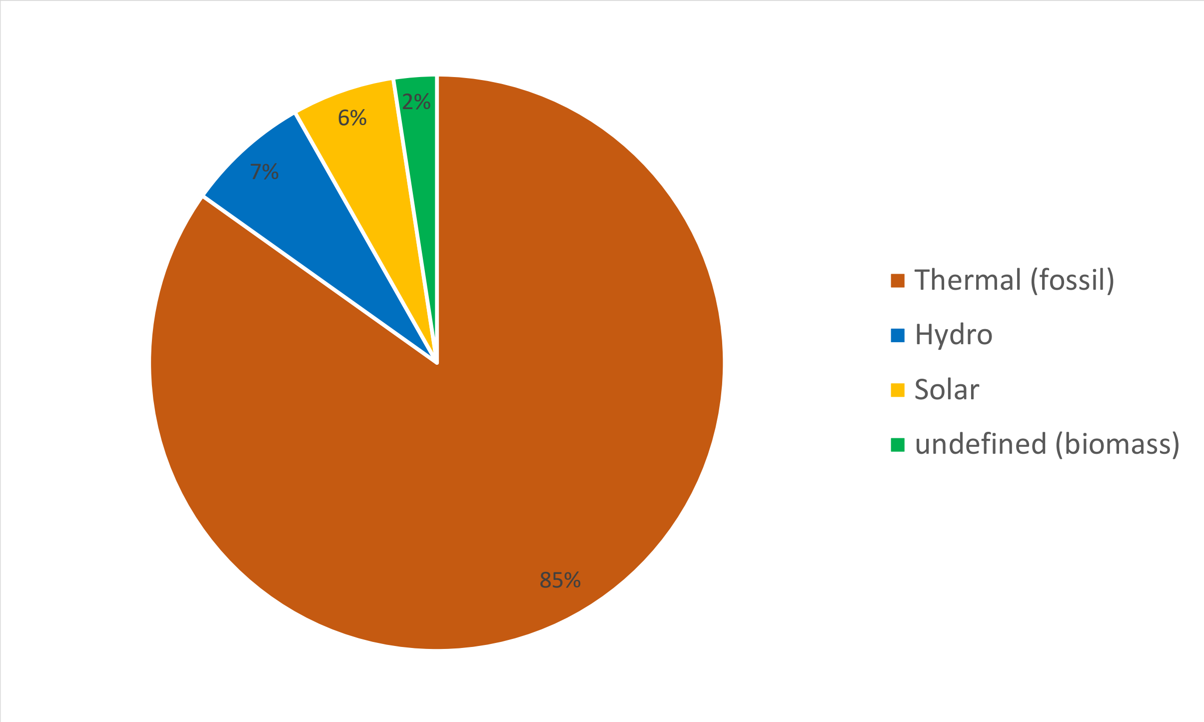

Figure 3: Installed energy capacity 2017 [17]

In addition to a production of 3.332.450 MWh in total, containing 563.692 MWh of renewable energies in 2016, the decentralized solar energy production is assumed to be 6.233 MWh [23]. As a result of this Senegal produces 16,92 % of their needed energy with renewable energies in 2016 (calculated with data from *Senelec*, 2016 [17]). In 2017 the renewable energy share is believed to be less, because some plants could not contribute to the energy mix due to missing financial resources for maintenance. As a consequence of the robust thermal oil and gas sector, Senegal is risking to fall short on the target of the Paris climate agreement, to reduce gas emissions by 21 % by 2020.

3.2.3 Electricity outages

Electricity supply is a major constraint for Senegal's socio-economic development. Outages are causing a slowdown to the economic activities, including the closing of small businesses in food processing, textile and tourism sector. On top of the already existing energy deficit, the country's energy needs are increasing and larger companies are reporting decrease in revenues of around 30 % caused by energy outages. [24], p.26

Small and Medium Enterprises (SMEs) are playing an increasing economic role in Senegal's wealth and employment. Though, they appear to be more vulnerable than larger companies to changes in the business environment and to electricity outages. Power outages can interrupt the production process and cause time delay. Plus, broken equipment due to electricity outages or inconsistent voltage has to be replaced or repaired. In addition to that, power shortages are causing an extra cost for the consumer, as generators or other alternative short time energy sources have to be used. All these impediments lead to lower productivity and efficiency. [25]
At least 37 % of businesses, based in Senegal, own or share a generator [26]. Especially SMEs are struggling to afford their own power generator; for those profitability as well as external funding is a risk. According to Table 2, SMEs witness around 26 electricity outages per month with a typical duration of 2,3 hours. For large enterprises the number is slighter due to different contracts with *Senelec*, they experience an average of 15 outages with an average duration of 1,6 hours a month. But larger companies do lose a higher percentage of their annual sales due to electrical outages.

Table 2: Electricity and power outage related issues - 2013 adapted from [26], p.13

	SMEs	**Large Enterprises**
Average price per kWh	173,0 FCFA	198,1 FCFA
Average electricity consumption per month	2.599,0 kWh	62.22,1 kWh
Number of outages per month	25,8	14,9
Duration of typical outage	2,3 h	1,6 h
Losses due to electrical outages in % of annual sales	4,8 %	8,3 %

3.2.4 Electrification

The national electricity access rate is around 65 %, although it drops to 38 % in rural areas. As can be seen in Figure 4, even if the rural and urban population experienced a similar growth of electrification, the gap between them would remain constant. In the year 2000, there was an attempt to privatize the electrical grid. On the basis of this approach, the data in the aforementioned year is not digestible. Figure 4 shows that the main part of the population with higher access to electricity is living in the urban and peri-urban districts.

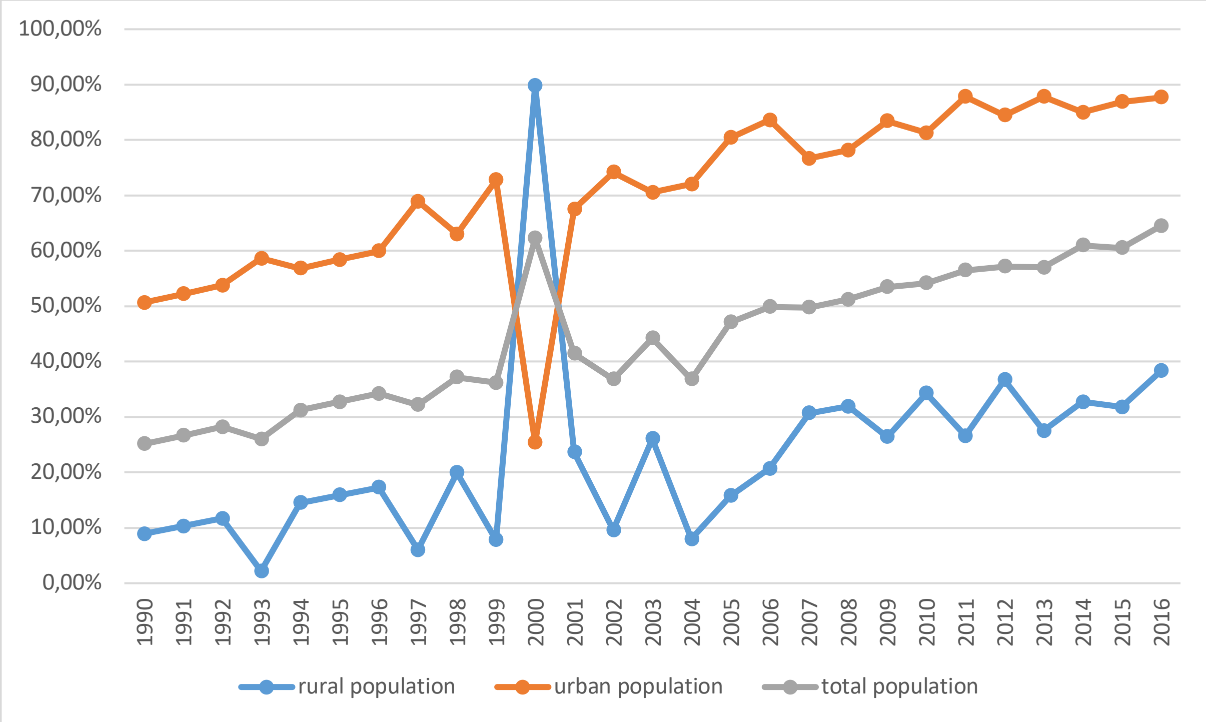

Figure 4: Access to electricity - rural, urban, total [6], [23]

To improve the rural electrification, independent power producers are free to participate in calls in Senegal's ten concession areas.

When villages are lying further than 5,4 km away from the transmission grid, the lowest cost solution to electrify them, are decentralized photovoltaic generation technologies. The transmission and distribution grid is mostly developed in the western regions around Dakar and along the northern borders. The regional grids around Ziguinchor in the south and Tambacounda in the east, are not connected to the main transmission grid. All the active power balance and frequency stability in the grid is performed inside of Senegal's borders. The hydro power plant in Mali is the only foreign support to Senegal's main grid. [27]

Old-fashioned grid structures cause *Senelec* to lose a big amount of their energy transporting electricity; a part of the further electrification and improvement will be the renewal of the grids structure [1]. The exact amount of grid renewal has been requested in addition to further present grid infrastructure information, but several data requests have stayed unanswered.

3.2.5 Energy trends

In response to climate change, Senegal is aiming to draw 15% of their primary supply from renewable energy sources by 2025 and, following the Paris climate agreement, to reduce gas emission by 21 % by 2020. [24], p. 26f

Between 2021 to 2023, the USAID and the *Overseas Private Investment Corporation* (OPIC) are planning to increase the current 500 MW generating capacity to over a 1.000 MW within the framework of the program *Power Africa*. Corresponding to *Senelec,* wind and solar capacity will reach 465 MW by 2020, which is more than the estimated technical potential *Enda Energy* is assuming for Senegal [17].

The Senegalese are consuming significantly higher energy equivalent on petroleum products and biomass than on electricity. Due to the modernization of electrical products and the future ability to spend more money on electricity consuming products, the electrical energy consumption will rise. According to that the electrical energy demand for services like cooking, which is covered by biomass and gas now, will lead to an increase. (cf. Figure 16 in Annex B)

Senegal is preparing to build a nuclear power plant in cooperation with France, the plant should be online by 2020 and will contribute to the diverse energy mix [28].

To reach the aim of 90 % electrification in urban areas until 2019 and 60 % in rural areas until 2022, the government has to invest more in renewing the electrical grid. According to linear static analysis with the data from 2012 until today, since President Sall took office, the urban electrification will reach around an 89 % in 2019 and the rural electrification a 39 % in 2022. Thus, the goal in rural communities will be missed by around 21 %. (calculation can be viewed in Annex B)

3.2.6 Energy potential

To lower Senegal's electricity prices, the government started to publish new projects as auction calls. According to Mr. Issa Rohou Laye Sonko of the Ministry of Petroleum and Energy of Senegal "the government is not […] interested to invest directly in energy projects, if there is a need they make a call of project". *Engie*/*Meridiam* won a recent call for two solar projects with a total capacity of 60 MW, which will produce electricity for less than 0,04 €/kWh, representing one of the cheapest sources of electricity in Sub-Saharan Africa [29].

The market for small solar-home systems is evolving via solar system distributors or small solar accessories being sold to the Senegalese population. Falling prices of PV panels and solar components like batteries turns solar energy into a worthwhile alternative, especially since the imported fuel and oil resources have high prices.
Senegal has an average solar horizontal irradiation range of 2075 kWh/m^2 to 2200 kWh/m^2. In the northern regions the mean global solar radiation per day is 5,8 kW/m^2, which makes it around six times higher than in Germany. [30]
Certain regions show high potential for wind power with mean speeds of 4,10 m/s in 20 m to 4,36 m/s in 12 m height [31]. The *Taiba N'Diaye* wind project on the Senegalese shore has a capacity of 159 MW and will generate its first power at the end of 2018. It is planned to deliver an uplift of 15 % to the generation capacity of Senegal [32]. In other wind zones the power can also be used for water pumping.
Biomass is abundant due to the volume of organic waste created in the agricultural sector [20].
Senegal's and Gambia's Hydro Potential is estimated at a 1.400 MW taking into an account the *Senegal River*. Even though there is no knowledge about small hydro potential for local communities and industry. [33]
Senegal has about 30 potential geothermal spots, which could produce up to 31-60 W/m^2. [34]

Table 3: Estimation of technical potential renewable energies Wind; Hydro: [20], Solar: [35], Geo; Bio [8]

	Solar	**Wind**	**Biomass**	**Hydro**	**Geothermal**
Installed capacity	85 MW *- 2017*	159 MW *- end of 2018*	25 MW *- 2017*	75 MW *- 2017*	0 MW *- 2018*
Estimation of technical potential	187 MW *- 2020*	180 MW *- 2020*	2900 GWh	1400 MW	31-60 MW/m^2

The main economic barriers in implementing renewable energies are the limited financial support mechanisms for promotion and the institutional lethargy, which appears in delays in implementing proposals and laws, which are already engaged [20].

3.2.7 Supporting programs

The following overview is not outright; it is a compilation of the supporting programs and donors, believed to have the largest leverage on the key issue.

Two major renewable energy support policies were recently established, the *Renewable Energy Law* and the *Program for the promotion of Renewable Energies, rural electrification and sustainable supply in domestic fuel* (PERACOD). Through establishing the ESP Senegal gained trust in the international investment and development community.

PERACOD targets the expansion of the electrical grid and the increase of rural electrification rates from 16 % in 2007 to 60 % by 2022. Until 2017 though, it only increased up to 39 %.

The *USAID* is investing in the energy sector with their program *Power Africa* in building regulatory capacity, creating trainings and capacity buildings for Senegal’s utility and in developing a gas sector plan in cooperation with the government. [8]

The *World Bank* is providing a $29 million development aid credit to Senegal to support the economy and strengthen the country’s institutional capacities. It is also offering technical assistance to the gas and oil sector. The Off-grid market is supported by the *World Bank Group* with their project *Lighting Africa*. By providing basic lighting for reading, working and cooking at night the *Lighting Africa* project positively affected between 2014 and 2017 541.000 people in Senegal by meeting their basic electricity needs. [36]

Besides implementing renewable energies in Senegal, the *African Development Bank* (ADB) supports the financing of state of the art technology for fossil fuels to minimize emissions and security breaches. The ADF is supporting two pillars with the main aim to achieve green and sustainable growth: the agricultural transformation and a support of production and infrastructure for energy and transport. [37]

Part of the supporting programs is also the *Programme d’Enseignement Supérieur pour les Énergies Renouvelables et l’Efficacité Énergétique* in Senegal (PESEREE). The German *DAAD* implements the program and assists four universities in Senegal to take part in the development of a more application-oriented degree course in renewable energies.

The cooperation is funded by the German *Federal Ministry for Economic Cooperation and Development* (BMZ*)* and is furthermore implemented by the *Deutsche Gesellschaft für internationale Zusammenarbeit* (GIZ), besides supporting the jointly offered master's degree in renewable energies, supporting the Government in translating their plans in relation to energy efficiency, their fields of activities are electrification and implementing renewable energies.

Except dealing with energy efficiency and education, there are programs to empower women in the energy sector by *Energy 4 Impact* or mobilizing resources in the competitive and integrated agro-poles by the *United Nations*.

An overview with further supporting programs and stakeholders, who could imply working opportunities can be viewed in Annex C.

3.3 Education profile

While on average in sub-Saharan Africa children attend 5,2 years at school, the number in Senegal is about 2,8 years [11]. In addition, 22 % of the children between five and 14 years are working instead of going to school [38]. To improve the schooling rate, Mr. Sonko, engineer at the *MEDER*, says "The first goal is to bring electricity and if you brought electricity to local population you improve at the same time the rate of children going to school." [1]. Still, in 2015, only 55,6 % of the population over 15 years old is alphabetized, the rate increased by a change of 30 % since 2013, probably due to a 7,1 % of the GDP expenditures in education.

The *Ministry for Technical Education and Vocational Training* (METFP) is working to reform the technical education and match it to the needs of the labor market. Especially in the *Technical and Vocational Education and Training* (TVET) sector is a high potential for developing the certification framework on lower and higher education. A supplementary TVET apprenticeship in lower education takes between two month and two years [39], p.48.

The *UNESCO* is taking part in this development with different approaches, like supporting the reform of the TVET policy and experimenting with mobile training units to provide educational seminaries in disadvantaged areas. Another approach is to underline the importance of restricting the higher level of education with the market needs in renewable energies with non-formal education. [40], p.7

Corresponding to the METFP, the TVET system had an estimated 400.000 to 600.000 apprentices in 2011. After implementing the project, the rate of TVET graduates who found a job increased from 7 % in 2007 to 52 % in 2010. Nevertheless, to implement it struggles with the high degree of instability and institutional inconsistencies. [41]
In field of renewable energies the TVET contains pursuant to Dr. M. Sene and M. Loum in 2012 [42] the TVET contains trainings in following professions:

- Markets of energy
- Electricity and photovoltaic solar
- Solar thermal
- Performance of the envelope: isolation, woodwork, ventilation/airtightness, cooling and air conditioning
- Civil construction for wind
- Biogas digesters

[39], p. 48

Besides this engineering training and other specified staff training courses by foreign companies, there are no other training courses available [24]. But according to Mr. Sonko from the *MEDER* a program to promote renewable energies to young school children and to spread interest in renewable energies to future engineers will start soon [1].

3.4 Employment profile

The primary sources of employment in Senegal are mining, construction, tourism, fisheries and agriculture [6].
While agriculture employs 77 % of the labor force, it is only responsible for 17 % of the GDP. As already mentioned, 60 % of the people on the active labor market are aged under 25; to change this situation and to increase the working age, president *Macky Sall* launched different initiatives in the three main industry sectors: horticulture, poultry farming and tourism. [24]
In 2017, 9,5 % of the population was unemployed. Three out of five unemployed were between 15 and 34 years old [30]. But since 2012, it follows a falling trend again (cf. Figure *12* in Annex A). There is various data about the unemployment rate in Senegal, the main differences are considered to be due to the consideration of underemployment.

The used data does not include underemployment in the terms of unemployment and considerers underemployment as an involuntary part time employment (less than 40 hours a week). Underemployment is wide spread in Senegal with 27 % of the employees; a even higher number applies to the youth [43].

4 Technology strategy for sustainable livelihood

The SLA requires development to underline the importance of existing knowledge in rural areas and scientific knowledge. Rural communities do not always have all the assets they need to lift themselves out of poverty. Parallel to developing a technology strategy, there must be an improvement of access to assets or as the SLA defines it, capitals. Renewable energies are taken as an example of a technology, which affects sustainability of rural livelihood. The access to energy through renewable energy sources has an impact on the performance of all components of the national economy including labor force. The cost effectiveness of green energy makes it a vital fuel to an industrialized economy, providing an effective solution to household energy.

4.1 High potential of energy technology

Renewable energies, if properly managed, are a self-sustaining environmental friendly technology, which are in general used in projects in rural parts of Senegal. They were utilized, because they are compatible with local rural conditions and resources endowment.

All humans should be able to possess primary goods, which reflect the basic conditions of human dignity. People, without access to these goods can be considered as *poor*, without access to energy, people can be defined as *energy poor*.

As part of the poverty reduction strategy the implementation of modern energy services plays an important role. The absence of availability of electricity to the rural communities is limiting the factor of economic and social development. Three main strategies in the energy sub-sector have been identified in the *Poverty Reduction Paper* of Senegal:

- "Promote access to energy services
- Promoting energy control and saving
- Improving the energy sub-sector management framework"

[43], p.28

Those three main strategies will be discussed in the following sub-chapters.

4.1.1 Access to energy services

Promoting the access to energy services includes the acceleration of rural electrification, the increase of renewable energy supply in the energy mix, the increase of domestic produced energy capacity and integrating photovoltaic energy in structures and public institutions in connection with storage solutions.

The access to renewable energy power in rural areas in Senegal can impact the environment by lowering the air pollution, decreasing biomass consumption and improving the vegetation cover. Furthermore, it can reduce respiratory problems and infant mortality. It empowers especially woman, by reducing their time collecting wood for energy use, for example. Due to the use of clean electricity, education can be improved in a healthy, safe and sustainable way by increasing the daylength via night lighting, which increases the time for children to study. It also gains more time for social and cultural events like night-time discussions and political talks and affects the employment sector. [44]

“The development of Renewable Energy might contribute to the rural community in three different perspectives such as by creating jobs, by creating local tax income from sold off energy and by reducing the costs of energy after the initial set up cost.” [45], p. 186. Even the creation of a few jobs may have a significant impact on isolated local communities with new developing technologies and alternatives in the labor market.

Besides increasing labor productivity and building labor opportunities, renewable energies generate income, improve health and boost educational quality. Those impacts can only be measured by realizing the process that harnesses the social and financial context of the village life. [46], p. 336.

The increase of production and energy capacity as well as the improvement of the productivity of quarries and mines will support the geological and mining activities and operations. To strengthen the sector, private involvement should be increased and supported as well as the energy rights and permits, which should be simplified for private users. [43], p.34

4.1.2 Energy control and saving

Parallel to providing alternative energy sources, environmental consciousness has to be promoted and the accessibility to modern energy technology has to be increased.

Using the TVET and other comparable programs, the human resources to manufacture, install and maintain renewable energy projects can be created. In order to implement those projects, the government has to free financial and technical resources and exempt those from taxes as far as possible.

It is “one of the greatest obstacles facing energy transitions according to Prasad and Visagie (2007) […] convincing people to adopt new energy habits which satisfy state environmental targets with their own financial insecurity.” [47]

The education relating to changing habits of energy consumption has to include not only knowledge transfer, but also demonstrations, on how in the end, modern energy technology can reduce energy expenses.

The part of the population, who already has access to energy is addressed with the promotion of energy-saving household appliances as well as energy saving in general. Due to a lack of sensitization on the rational use of energy, technical failures and over aged technical components, the energy efficiency is very restricted.

To fasten the access to renewable energies, the energy management framework ought to be improved.

4.1.3 Energy sub-sector management framework

By improving the regulation framework, implementing the institutional reforms in *Senelec* and strengthening the *Energy Information System,* additional costs to the costumers could be prevented and it would improve the reliability of energy industries due to less delays. The operational framework needs support in three main areas: regulation, investment and institution:

The regulatory framework includes implementing the ESP and TVET, which are already adopted and theoretically in place. The electricity distribution and generation are managed by *Senelec* (cf. chapter 3.2.1); still the system is not reliable in case of continuity and fixed parameters like prices per kWh. In order to implement renewable energies in private households, a policy is needed, which defines feed-in-tariffs for private energy plants.

Although the current investment is mostly done by foreign companies and banks, it should be expanded with communal banks and local commercials, they are obligated to invest in renewable energies. Also, the government ought to provide more trustworthy information to prospective investors.

To establish the change, even more institutions are obligated to get involved in the energy sector, especially in electrification and private energy production. With the regulatory policy by the CRSE to call for tender in case of renewable energy projects an important step in integrating international actors is already made. To get access to renewable energies, there are not only power investments by international actors applied, Senegalese households have to be able to afford those energy services likewise.

4.2 Investment framework

When poor families are able to increase their income, they can spend more money on better energy services, which leads to higher chances on the employment market due to more communication and education possibilities. This cohesion is shown in Figure 5, which represents the modernization of energy devices in correlation to the income. It also shows the different types of energy sources a household uses. The typical rural Senegalese household uses traditional fuels like wood or charcoal to fulfill their basic energy needs and candles as well as battery powered devices for lighting. As the income increases, other energy sources can be used like electricity or kerosene. The upper right part of the energy staircase contains renewable energies and more efficient technologies, which produce less CO_2 and SO_2 emissions, but also increase capital costs. Reaching this part, the energy needs and the capitals regarding energy provision are fulfilled.

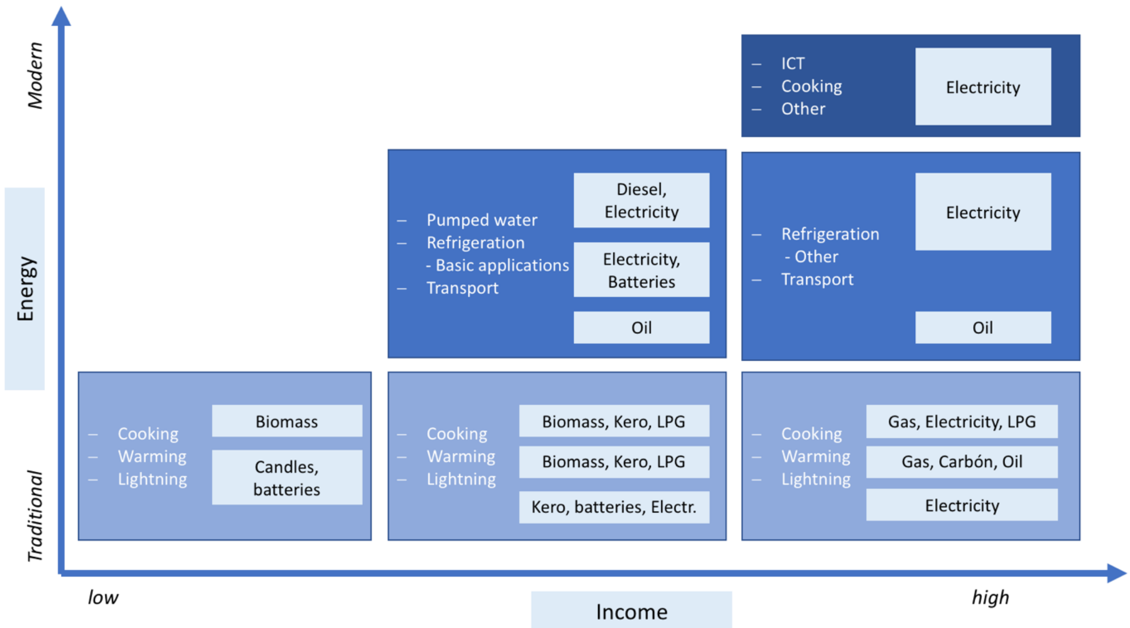

Figure 5: Energy Stairway adapted from [48], p. 12
Kero = Kerosene; ICT= Information and Communication technology

Sustainable livelihoods reinforce development and the use of renewable sources in providing energy needs for industrial use and demanding renewable energies as energy supply for rural communities. The financial capital of a community determines the electricity supply and the increments in electricity demands.

Renewable energies can be seen as a long run investment for households, but they do not have a directly financial return to the costumer. The small-scale energy systems require less specialized labor force since most of the time, they arrive preestablished. Apart of the cost efficiency, solar systems are a large expense for rural communities, even if it can be seen as a long-term investment. The greatest problem in implementing energy technologies is the lack of access to financial capital in rural communities. As a solution, some initiatives are using the *Pay-as-you-go* procedure, like *Touba Solar Rama* does in Senegal, which is supported by *IRENA* [49].

If the demand of energy is capitalized into a constructive instrument, enough interest will be generated from foreign investors to sustain investments in Senegal. New technologies like *Pay-as-you-go*, *layaway* and *mobile-banking* offer more options for communities to utilize renewable energies and to encourage jobs. *Pay-as-you-go* is a financial policy, which provides credit in advance and can be used in small amounts, especially via mobile phones or transport ticketing. It makes small credits available to people living in rural communities without the requirement of a bank account [22].

4.3 Encouraging job creation

In general, bringing new energy technologies to a developing country can change the nature of existing jobs and could both create and destroy jobs in different areas; it also creates the possibility to build a more efficient labor market. “The share of labor in the […] Renewable Energy sector will outgrow relative to the other subsectors of energy labor share.” [10], p.25

The relocated labor force can increase, if labor markets are flexible. According to the *Organisation de coopération et de développement économique* (OECD) to strengthen general education and training systems will make it easier for workers and economies to take part in the relocation of the labor market relating to new technologies [50].

Especially for woman in rural areas, renewable energies represent a new job possibility in the field of food transformation, like grinding, smoking and drying.

Also, the reached children, who have more time to study using electricity, are directly contributing to the labor market and it has a significant impact on their livelihood.

4.4 Impact on livelihood

Sustainable energy access can impact people's livelihood in all five capital areas (cf. chapter 2). Implementing renewable energies improves the health standard and increases the availability of time for people to use educational opportunities. The educational system usage is encouraged by freeing more time to study and by extending lighting time to study at night, which increases their human capital. The increased time resource is particularly relevant for woman and children, who are able to cook food safely and time efficiently with renewable energies instead of collecting firewood. An introduction of less polluting, clean energy sources can provide higher health standards, which also affects the labor market positively and reduces the congestion of public health service. The economy suffers from the effects of power cuts (cf. chapter 3.2.3) and the poor reliability of the grid system; in rural areas the possibility to move towards an off-grid-system would reduce the economic losses. Businesses can be improved by using solar powered irrigation systems for example, or by diversifying of the economic structures. Physical factors can be improved, such as the availability of resources like water, labor and market related assessments. Cultural barriers in implementing renewable energies do exist, as people not accepting new technology without being educated about their benefits and the financial risks. [51]

Figure 6 is illustrating the different impacts renewable energy can have on livelihood of rural communities in Senegal.

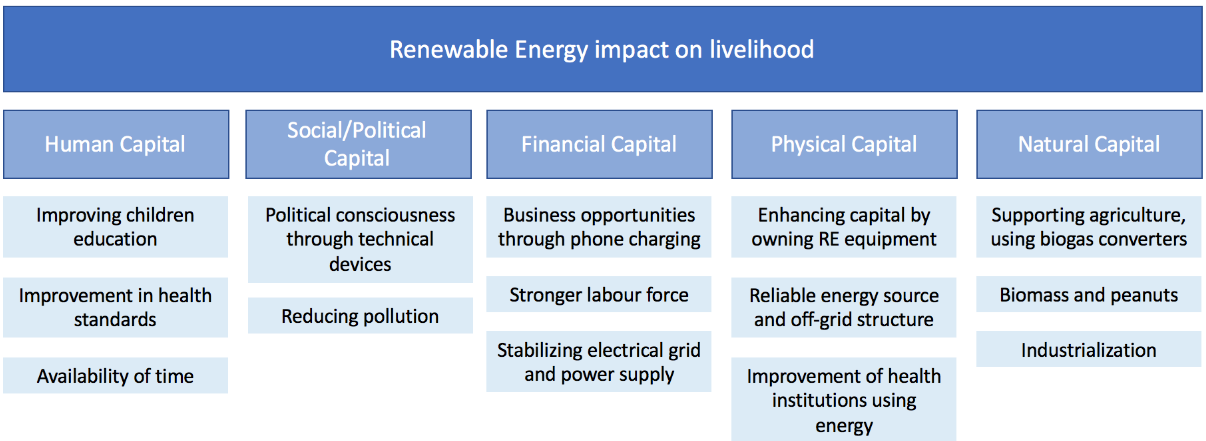

Figure 6: Renewable energy impact on livelihood in Senegal Own illustration

The human and financial capitals are the main factors, which impact on the labor market in the renewable energy sector. By supporting the educational system, the labor market is strengthened, and new business opportunities are created.
In the following two chapters the link between power investment in renewable energies on a macro and micro level will be investigated. The term investments can be seen on several levels, on one part as a financial term, on the other as a capital like the SLA describes it.

5 Relation between investments in power and labor

The *Development Impact CDC Group* found out, that west African countries like Senegal's neighbor Ivory Coast were positively impacted by increased supply and consumption of electricity in the past decade. This is visible in a rising GDP and higher employment rates in the private sector. [52]

Energy supply and demand is closely connected to the economic growth. To evaluate, how exactly the dependence is structured, the whole electricity chain including the created jobs, has to be investigated. The dependency of rising GDP on energy consumption in Senegal is captured in Figure 7. Since there was no data available about the energy consumption per citizen for the years 2015 and 2016, it is calculated using the annual sales and client data by *Senelec*. As an example, the relation can be seen in the year 2007 and 2008, where the energy consumption decreased at the same time as the GDP. Likewise, in 2013 to 2014, where the GDP rised as the energy consumption increased.

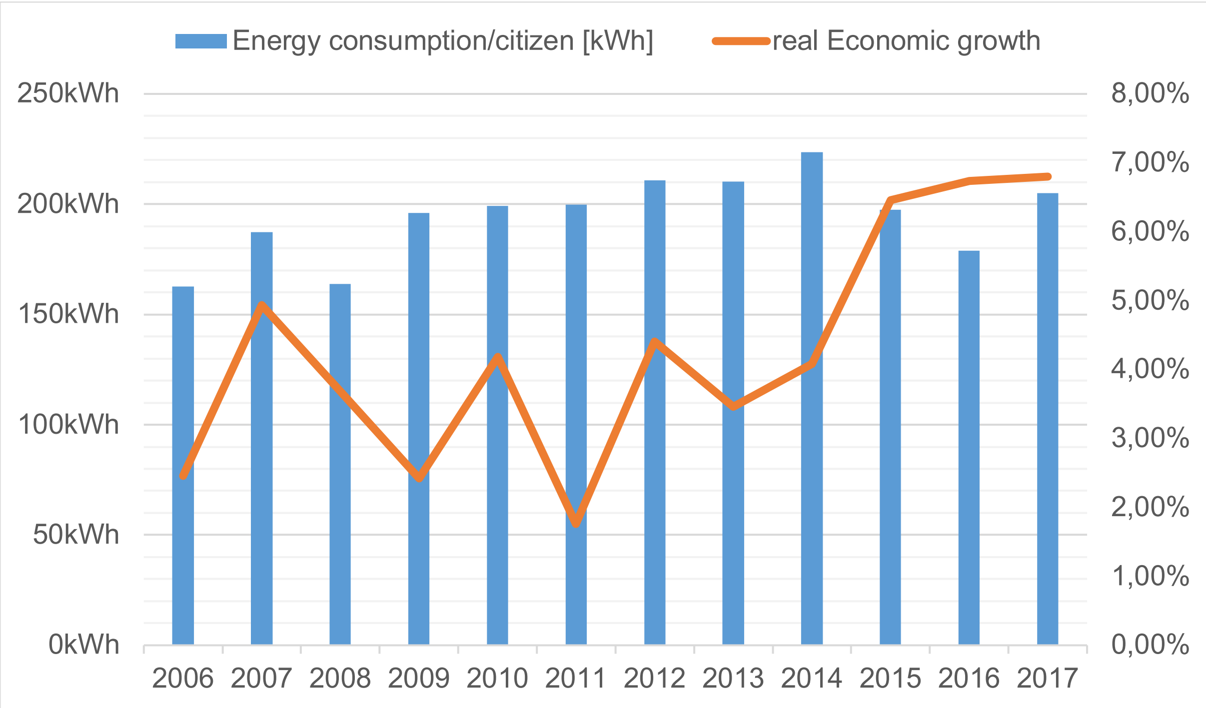

Figure 7: Dependence of GDP and energy consumption per citizen Own illustration, following [11], [17]

Investments in the power sector increase the productivity in the labor market. As part of an innovative mechanism, it boosts both domestic and foreign capital and increases financing.

Many studies investigated the dependence of GDP and energy consumption and came to different conclusions. While economy growth has an impact on energy consumption, the relation is coherent. *Akaraca & Long* studied the relation between energy consumption and employment between 1973 and 1978, in the USA. They found out, that over time, when energy consumption increased, employment went down. Later studies in the USA [53] and in other countries, like Turkey [54], are supporting this hypothesis. Although the relation in Senegal has not been investigated lately, though it was considered as positive in 2006 by *Wodel-Rufael* [52].

5.1 Power investments

The energy sector is a state-owned monopoly, operated by the national electricity company *Senelec* (cf. chapter 3.2.1). To rely only on the government and *Senelec* to invest in renewable energies may widen the existing gap between energy demand and supply. Auctions have been held on renewable energy projects to attract investors, which are struggling with the lack of effective legal frameworks corresponding to the recent development of financial mechanisms in Senegal.

The attractiveness of investing in Africa, in terms of innovative financing schemes is lowered by poor investment environment, due to high levels of risk and instability. As a result, investors are financing unsecure deals with renewable energy sources. The failure of the *Inga3* hydroelectric power project in the Democratic Republic of Congo (DRC) can be named as an example. After financial losses and high delays, the dam will export needed power out of DRC and provide little power to the Congolese people. The original assumptions were optimistic with low transmission losses, but they never technically approved. [55]

In 2017, the global new investment in renewable energies increased by 2 %, due to auctions like the ones in Senegal, the resulting tariffs in producing renewable energies are decreasing and around 50 % below the prices from 2015. Comparing the investment in developing countries and developed countries, in 2015 the balances shifted to the developing countries, which represented the majority of investments. The highest share is in solar and wind energy, therefore the investment will be further analyzed with an example of a solar park in chapter 5.4. [56], p.11f

Investment in the Middle East and Africa increased by 48 % from 2017 to 2018 [56], internal investment data of Senegal has been requested.

The political investment risk in Senegal is comparably low to other African states. The principal concern relates to late payments and insecurity regarding countries around, like Mali and Gambia. Choosing experienced local and foreign partners, good diligence and flexible structure can minimize the risk. The Senegalese judiciary system has insufficient independence, therefore the corruption can influence performance operations in a non-transparent way [6]. Closely related to the corruption, a change of law, like the past privatization of *Senelec,* is affecting an action in renewable energy as well. As already investigated in chapter 3.1.2 the franc CFA is a long term sufficiently stable currency. Supporting external regimes or partners can represent a risk of investment, like in the given example of the DRC, where about 88 % of the produced energy is presold to South Africa [55]. If an investment was made, it has an influence on the energy consumption of people and the employment rate, which will be investigated in the following chapter 5.2.

5.2 Employment and energy use

Rising energy consumption shows different effects that can be related to increased employment trends. A growing population has a greater demand of energy and therefore also a higher number of workers in the labor market. This demographic effect also affects the income, since more people in the labor market are resulting in higher domestic demands for goods and services, including energy. As shown in chapter 3.1.3, the increasing oil and gas prices, representing external shocks in general, can have an impact on the GDP and the employment force as well. Replacing old technology by new, more efficient ones, can enhance employment and education as well, as you can see in chapter 4.2. [52], p.8

According to the effect of power outages (cf. chapter 3.2.3) on the economy, it affects the labor market due to the missings in the annual income. Particularly those, working in the manufacturing sector, rely on electricity provision.

Energy use plays a fundamental part in economic growth and job creation. As mentioned above, there is a link between energy consumption and employment in Senegal, but due to missing data it cannot be investigated further. The link between investments in renewable energies and their effects in the employment sector will be evaluated in the following chapter 5.3.

5.3 Employment effects of investments in renewable energy

In economy, there are four different kinds of effects of investments in renewable energies, which are illustrated in Figure *8*. A direct effect would be the creation of jobs during the construction, maintenance and operation of the renewable energy plants. Direct effects appear to be higher in developing countries like Senegal, because the economy is more labor intensive. Indirectly there will also be a higher demand in jobs in the field of supply for the plants used in the construction and in electricity transmission and distribution, as well as in the costumer electricity service. The educational sector is equally influenced by new fields, which are created in forms of new degree programs or apprenticeship. Due to the new workers spending their wages on local goods and services, there will be more jobs induced. As a result of the additional electricity supply, more jobs in other economies can be created as a second-order-effect.

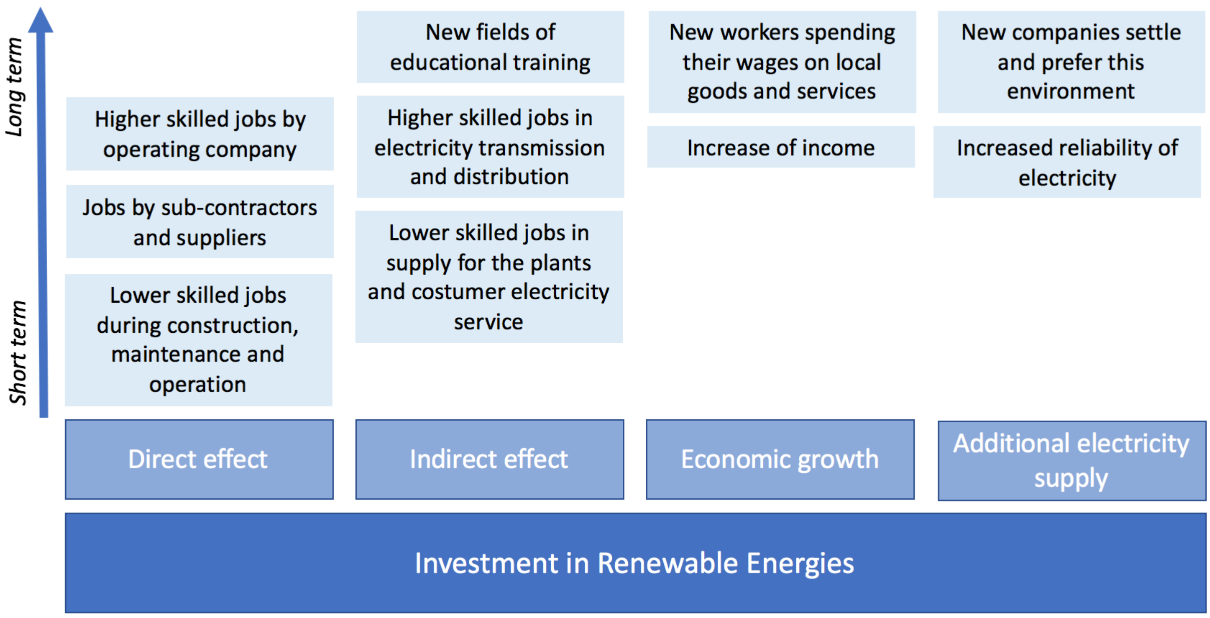

Figure 8: Employment effects on investing in renewable energies Own illustration

In order to evaluate the exact employment effects, several companies with renewable energy projects in Senegal were asked about data considering the following aspects:

- Number of jobs during construction, building and installation
- Number of long-term jobs in maintenance and operating
- Number of jobs in transmission and distribution of electricity

For all jobs, a breakdown by gender, skill level and wages paid is requested. A follow up was conducted on all unanswered requests. On the basis of missing data, the effect will be analyzed using data of the solar plant *Senergy 2* in the following chapter 5.4.

5.4 Effect on employment – project *Senergy 2*

In the year 2016, the plant *Senergy 2* was connected to the grid. As stated by *Senelec,* the power plant adds 20 MW effective solar capacity to Senegal's power supply and by that reduces the costs of generation. The costs are reduced by a lower need for rental diesel plants in high point of demand curves, furthermore because the power generated by the new solar plant is cheaper compared to the rentals. To analyze the employment effect on several economic sectors in Senegal, the output groups are divided in to two different economic agents.

The first sector benefits directly from the lower generation costs and lower electricity prices. Those companies are in manufacturing, trade or business services and are directly influenced by changing electricity prices. The second sector contains mostly companies working in agricultural sector, which does not depend on electricity. However agriculture benefits indirectly from lower electricity prices due to an increased procurement from sectors of the first group. Relating to a recent study by the *Private Infrastructure Development* Group, lower electricity prices as a result of adding *Senergy 2* and the gas plant *Tobène* to the grid, raised the total economy output by 1,7 % [52], p.13.

Given that *Senergy 2*'s capacity is used to cover the electricity demand during higher consumption periods, less diesel rentals are used. According to the data by the operator *GreenWish Partners*, *Senergy 2* created 150 jobs during construction and 25 jobs were created for operations and maintenance [57]. The jobs in the secondary sector can be investigated using a price model to analyze the effect on the electricity price, which affects on the economic output and eventually the employment sector.

The output has been analyzed before by the *Private Infrastructure Development Group* but including the gas plants *Tobène*. The methodology will be adopted and the effect calculated without the influence of *Tobène.*

Adding an extra 20 MW to Senegal’s power supply curve, shifts the supply curve to the right. To examine electricity prices over a full day, hourly power load data of each day every month of a year is needed. Such data could not be provided by *Senelec*, instead a monthly and annual average peak load is considered. Between 7:00 and 8:00 the consumption of 564 MW is 1,15 times higher than the average of 450 MW. Between 19:00 and 21:00 it is 1,44 times higher than the average [58]. Corresponding to the *Private Infrastructure Development Group,* the effect on price is a linear interrelationship, so the additional capacity of *Senergy 2* can be presumed to end in an estimated weighted average kWh cost by 4,2 %. Effects on the generation costs will also affect the final costumer price. It can be assumed, that the operator can provide the solar generated electricity with 50 % less costs than the current Senegalese energy mix [57] and the production costs are 50 % of the end-user tariffs. This is a realistic share, in comparison with studies in Uganda [59] or the Philippines [60]. Assuming that the decrease in the production cost will lead to a 2,1 % drop in the final tariff.

To calculate the effect on economic output and therefore employment, the price elasticity of electrical demands has to be considered. The price elasticity for Senegal is estimated at -0,86 in 2016, meaning that 1 % decrease in price leads to an increase of 0,86 % in electricity consumption [61]. Which sums up to a 2,44 % increase of electricity consumption by reason of the connection of *Senergy 2* to the grid.

According to the electricity factor shares in *Table 9* in Annex D, the production upscales 0,48 % for each 1 % of increase in electricity, which sums up to 1,17 %. The manufacturing sector is, as expected, the most sensitive to changes in electricity consumption. For the trade sector, it is 0,83 % and for others 0,93 %. The economic results are presented in following Table 4.

Table 4: Effect on economic output

Decrease of generation costs	4,2%
Decrease in end-user electricity tariff	2,1%
Increase of electricity consumption	2,44%
Production upscale – *Manufacturing* sector	1,17%
Production upscale – *Trade* sector	0,83%
Production upscale – *Others** sector	0,93%

* Others = construction, transport and other services

To transfer the changes in the economic output into changes in the labor market, the sectoral changes have to be calculated. The effect is computed using Senegal's latest economic input-output data [62]. Including the upscale factor for each sector, the increase in output can be calculated (cf. Table 5).

Table 5: Effect on employment per sector

	Output increase	**Additional employment**
Manufacturing sector	86.484.815,03 €	11.532
Trade sector	41.888.100,48 €	5.585
Others sector	86.762.385,29 €	11.569
Total	**215.135.300,80 €**	**28.686**

Using data from *OECD*'s latest report on National Statistics, published by the UN [63], the economic output of *Senergy 2* can be translated to the output in the employment sector using the employment intensity of the sector. In conclusion 28.686 jobs can be attributed to the additional 20 MW capacity of *Senergy 2*. Corresponding to the latest available employment data, this illustrates 0,54 % of the total employment in Senegal in 2016.
All the given employment results should not be interpreted as long-time jobs, though. Many labor opportunities involve just a few hours of work and cannot be considered as permanent. The calculation and the given factors can be viewed in Annex D.
Comparing the given jobs in Senegal per MW capacity to the Philippines, the effect in Senegal is much higher [60]. A reason for that can be that the production response of companies to the availability of electricity and the loss off outages is higher in Senegal.

Furthermore, the labor productivity in Senegal is considered to be lower than in the Philippines.

The theoretical job creation of *Senergy 2* divided into four sectors, is illustrated in Figure *9*. The sectors are arranged on the x-axis. The y-axis presents the different skill and experience levels, subdividing the employment sector. The category *Lower skilled* reflects a pre-apprentice or apprentice-level with less than a two-year credential and one to three years of experience. The *Higher skilled* category represents job fields with a master craft, bachelor's level or higher and five or more years of experience.

Similar figures have been created for projects in wind and biomass energy, they can be found in *Annex D* (cf. Figure 17 and Figure 18).

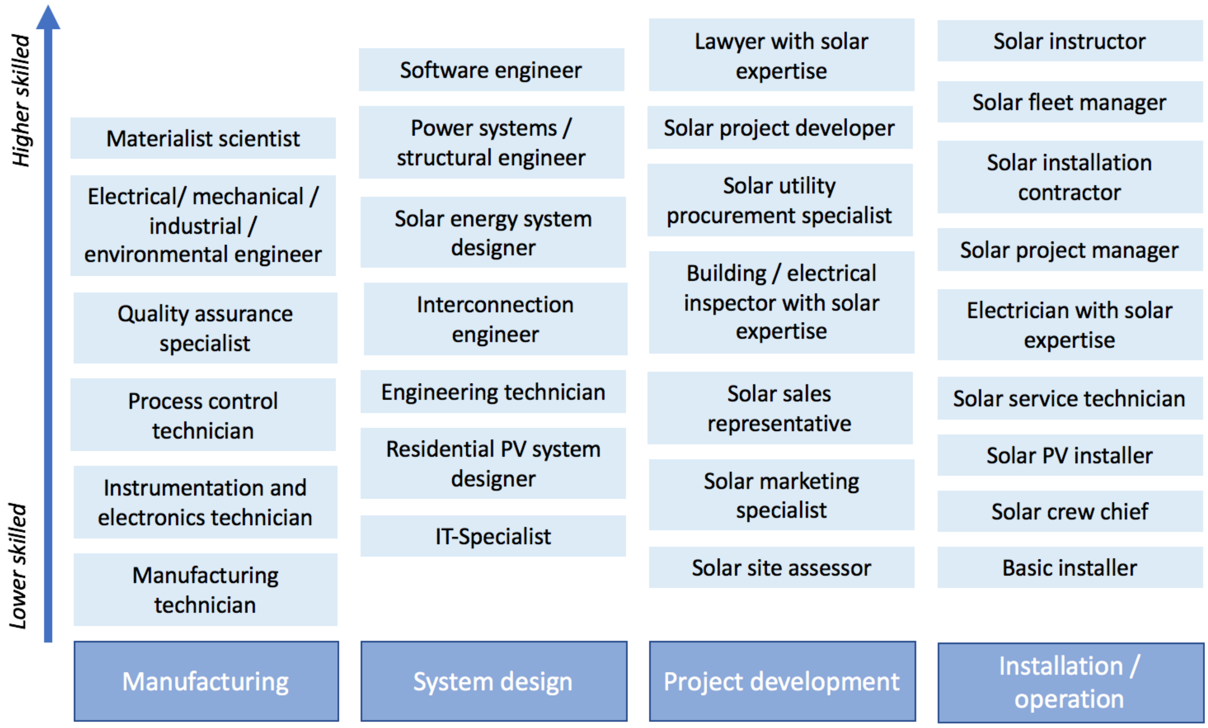

Figure 9: Senergy 2 - theoretical job creation divided in sectors Own illustration, following [64]

The definition of *lower* and *higher skilled* jobs is derived from the technical definition of professional occupations by Rothwell in 2015 [65].

In order to sustainably perform renewable energy projects in developing countries like Senegal, large-scale projects should operate effectively in corporate social responsibility strategies. Therefore, the government implemented contracts to assure that maintenance and local technical jobs can be done by Senegalese professionals [1].

6 Relation between application of renewable energies in rural areas and labor

"Among other benefits, access to electricity […] extends the daily productive hours, allowing children to study in the evenings and obtain a better education through the use of new technologies at schools" [66], p. 275. Thereby, out of an investment in small power systems the education level improves. As a result of chapter 5, with investments in power the employment productivity increases on a long-term basis as well as the education level. Investments in renewable energies are closely connected to the rising energy consumption per citizen and the increase of the GDP. It affects the labor market directly and indirectly in forms of creating long- and short-term jobs with differed skill levels. The analysis of the solar plant *Senergy 2* in chapter 5.4 results in an additional employment rate of 1.434 people per MW. Most of the jobs were created in the construction and manufacturing sector.

With investments in the power sector in rural areas, the productivity in the labor market will increase: "It would reduce the time and drudgery required for gathering firewood and other biomass resources - some of the saved time could be used for other economically productive applications in the case of adults, and for education in the case of children" [67], p. 1370.

Several organizations are working in the field of supplying rural areas with renewable energies in Senegal to improve livelihood. To underline the statement, interviews were conducted during field trips and employee trainings with *LittleSun, myAgro, Association des Unions Maraîchères des Niayes* (AUMN) and *Vitalite.* The investigated areas are the usage of solar water pump systems for rural farmers, decentralized solar systems, solar lighting and charging devices. Furthermore, the sustainability of the micro energy revolution in Senegal is evaluated and the stakeholders are compared to the German energy revolution. In comparison to the jobs created in the example in chapter 5.4, the created job profiles created in rural communities are being examined in context of the energy revolution.

6.1 Usage of solar powered groundwater-based systems

Since Senegal's local economy is relying on agriculture (cf. chapter 3.1.3), to own or have access to a reliable water resource is important for rural communities.

Water collection is a time-consuming job for local farmers. The installation of solar-powered water-pumping systems increases their income, as farmers have more time to process their agricultural products.
According to a final report of *USAID* solar-powered groundwater-based water systems have been installed in Senegal since the early 1990s [68]. A solar pump system contains a borehole with a submersible pump, a solar panel with control unit and a storage tank with either a distribution network or with stand pipes to the village. An advantage is a low rate of breakdowns, which leads to a long lifespan of the components and unattended automatic operations. Disadvantages are considered to be the dependence on sunshine, requirement of long-term budgeting strategies and the vulnerability to weather as well as theft and vandalism. As stated by Etienne Darveau, who is working together with the *Association des Unions Maraichères des Niayes* (AUMN) on installing and testing solar irrigation systems in Senegal, only solar powered systems in a pure financially perspective are not attractive at this moment [69].
USAID discovered the medium system age of installed solar pumps to be of eight years in Senegal. 77,5 % of the 31 surveyed solar pumping systems were used on a daily basis and 22,5 % were not functioning or partly operating. [68], p. 5
In Senegal, the installation and financing of solar pumping and irrigation systems is aiming to replace diesel plants. Although the systems are not subsidized by the government, they offer an economic advantage in terms of additional time and efficacy. [70], p.34
In addition to the economic advantage, AUMN monitored that automatic irrigation systems are able to replace child labor on the field and improve the children’s education. In areas, which had to stop working in agriculture, due to decreasing water levels, the impact of solar irrigation is seen in the employment sector and by rising income. [69]
Youssouf Diallo, a local water and energy specialist of the *Practica Foundation* supports this assertion: “Solar irrigation systems are helping the farmers to become less vulnerable to droughts resulting of climate change, because solar pumps are not physically limited” to a certain depth. [71]

6.2 Usage of decentralized solar systems

Off-grid solar systems are an effective and affordable way to bring electricity to people without access to the grid. As already discussed in chapter 3.2, supplying rural areas with micro grid power is cheaper than connecting them to the public grid. Micro grid power is independent from imported oil, faster and more reliable.

The approval of every tariff for off-grid ERIL projects by CRSE is time consuming.

The situation could be handled with decentralized decision-making instead [22], p.81.

The price difference between rural and urban areas per kWh is still a challenge, as well as the not existing finance structure for rural electrification for private companies. As mentioned before, the micro grid systems can be financed with pay-as-you-go or *Orange-Money*, for example.

As a study carried out in rural areas in Uganda, Tanzania, Mali and Senegal states, the energy expenses decrease by 30 % after depreciation of a decentralized solar system [72].

Decentralized solar home systems offer a sustainable way to lift rural communities out of poverty in an environmentally friendly way. Despite the already mentioned positive effects of electricity and light, if a sale of a solar home system is accompanied by technical training, future jobs and greater income can be created, which benefits the local economy. Small solar systems also effect to “help develop off-farm productive activities, such as bars, restaurants, rural cinemas, telephone shops, technical and artisanal workshops, by powering small tools and appliances […], lighting and radio/TV.” [73]

According to Frédérique Sheridan, General Manager of *Vitalite*, the development in this area is constricted by high taxes on the appliance, which come with the solar system. The taxes on cables or LEDs are amount to 44 %, even if they are specially engineered for solar power usage. In addition to that, *Vitalite* is facing problems in selling larger scale solar systems, because rural communities are not able to afford the first payment, which partly has to be covert immediately. [74]

Solar products for lighting and charging small devices are, with a marginal direct investment, more affordable to people living in Senegalese villages.

6.3 Usage of small energy lighting and charging devices

Solar lighting devices are giving children the opportunity to study their lessons at night. Corresponding to Hamad Njang, a Senegalese farmer, living in the village Ndjambour, this is the main reason families are buying and using solar light devices [75].
A study, which took place in Kenya with a sample size of around 1.400 households detects that the primarily usage of solar lights by children is for doing their homework. 80 % of the investigated children group completes their homework after sunset, which they used to do with kerosene lamps. Adults are using the light for diverse activities, such as reading, talking and cooking. [76], p.12ff
Especially in rural areas, you have to be reachable for work purposes, if you do not live close to your field, for example to check the market prices. Hamad Njang is reporting troubles to charge his phone: "It's complicated to charge my cell phone, because I have to walk to neighbors' houses and pay them to charge it." [75]. For this reason, he is not accessible all the time and has additional monthly expenses to charge his phone. Midwives and nurses are, according to Samuel Dansette, Africa Business and Sales Manager at *LittleSun* suffering of the same problems [77]. Local distributors of *LittleSun,* like Min Gnom, are reporting, that midwives in the villages are not reachable all the time, because they have to save their phone battery for making calls. With solar charging, their reachability can be improved. Relating to their reports, positive experiences were made with the usage of solar lighting devices during births, because the newborns did not inhale the smoke of kerosene lamps.
Energy access creates a more secure environment, remarks Frédérique Sheridan as well. Increasing the hours of light per day creates more job opportunities for woman in particular. [74]
In addition to that, indirect economic benefit often comes from improved access to knowledge and information, which increases the quality of livelihood.

6.4 Sustainable development

Senegal's economic performance relies on natural resources. The transitioning towards a greener economy could help Senegal to preserve resources and promote human development. Corresponding to a report of the *Food and Agriculture Organization of the United Nations,* a survey in 2017 estimated, that diesel generators for pumping have a shelf life for two or three years and cause monthly resource costs [70], p.52.

Operational costs for solar pumps are significantly lower, so it makes the irrigation more efficient and lowers the usage of fertilizers and pesticides. It also makes a difference for women, since they do not have to carry the water for irrigation anymore, they can develop their activities in the market and improve the nutritional balance of food, which is served in their home [78]. The increased availability of water also contributes to a reduction of the carbon footprint in water supply due to less consumption of conventional energy.

The sustainability of rural electrification projects is compromised by institutional flaws like “scarcity of durability / stability and enforcement of formal institutions, weak regulations or standards, incomplete decentralization / participation and the lack of institutional adaptability”. [79], p.1.

The factors needed for sustainable renewable energy projects in rural areas in Senegal are illustrated in Figure *10*.

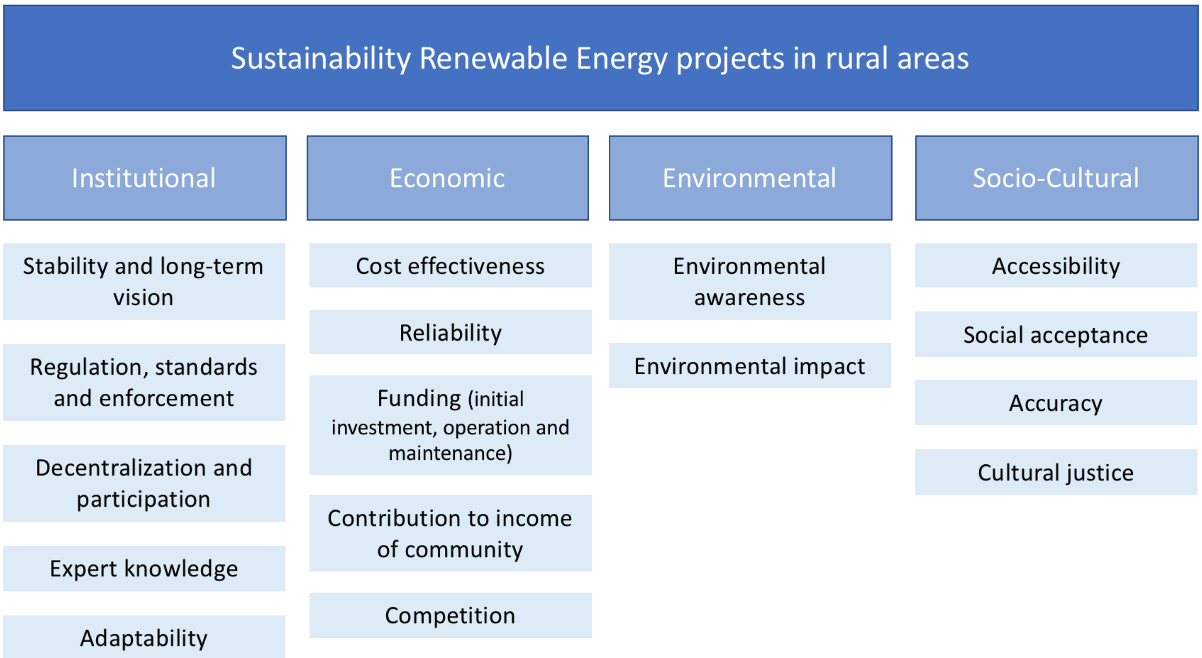

Figure 10: Factors of sustainability of renewable energy projects Own illustration, following [80]

To assure institutional sustainability, a strong and durable institutional framework is needed, which is partly given in Senegal, compared to other developing countries (cf. chapter 3.2.1). A lack of technical standards and regulations can be observed in the Senegalese energy departments, since laws are not implemented yet and in case of renewable energies many low-quality products are on the market.

To make sure that renewable energy projects are adapted to the needs of the communities benefiting from them, decentralization with participation of the actual actors in the field (cf. SLA) could be the solution. Sustainable renewable energy projects in rural areas require in planning educated experts, which opens up job opportunities for graduates (cf. chapter 7).

It is crucial to assure economically sustainable funding not only for the initial investment, but also for operation and maintenance. Since rural electrification build opportunities to increase the user’s income, local economic development can be promoted. Some renewable energy projects are not cost effective on their own directly compared to alternatives, so they have to be promoted and subsidized by governmental and private investments.

Although knowing that renewable energy projects have a long-term positive effect on the environment, the lack of environmental awareness and policies due to recycling and short lifetime of low quality products, lead to negative environmental impacts.

To ensure a socio-cultural sustainable environment, regarding renewable energy projects in Senegal, social and governmental acceptance, accuracy and cultural justice is needed in the rural areas. For a project to be sustainable, it must be socially accepted in the community and designed and implemented with active participation of the community, which creates jobs and job opportunities.

6.5 Job profiles in energy revolution

The key stakeholders in the energy revolution are participants in the public sector, the private sector, the civil society, the academic sector and the donors. In Germany and Senegal different job profiles are needed and different employment opportunities are created to implement the energy revolution. Private actors, who made advantages out of the fixed feed-in-tariffs, drove the energy revolution in Germany. In Senegal, the development of renewable energies is mostly performed by the private sector and donors, due to foreign investments.

Instable framework conditions, as already discussed in chapter 4.1.3, prevent long term investments. Though, long-term investments are required to create trainings and capacity building to let students and employees assimilate skills related to renewable energies.

Most jobs in the German energy revolution are created in the first step of the value chain, in system manufacture [81]. These jobs have grown out of traditional specialist profiles, such as mechanical engineering. In Senegal, these professional profiles can be created to drive the energy revolution with local labor force, starting with giving education opportunities to rural communities. As stated in an interview with the MEDER, the educational institutions are adjusting their curricula to the needs of the industry and project partners, so “they are obligated to take one or two students in stage [internship]” in every project [1].

Since the energy revolution in Senegal is in its early stages, cross-cutting occupations are needed. Especially in the government and association offices, policy-makers and human resources, professionals are necessary (cf. [82], p. xxiif).

As stated by the *International Labor Office*: “In least developed countries, electrical engineers, operations and maintenance engineers, technicians and tradespersons have been identified as the occupations most difficult to fill.” In addition to that, specially trained electro-mechanics and electricians for power stations and power equipment operations are needed to implement the electrification. [82], p. 100

To make a renewable energy project sustainable, as already discussed in chapter 6.4, specialists for sustainability are required, such as environmental scientists, cultural consultants and others. If Senegal wants to follow the certified emissions reduction, as introduced in the *Kyoto Protocol*, operations regarding skills for environmental matters are needed [83].

The government must set framework conditions for the energy transition, politic scientists are required to accordingly implement them and specially trained engineers are needed to plan the technical equipment. Different professional profiles have to be created and then jointly act to implement the Energy revolution locally.

Furthermore, there is a need for effective skills anticipation in renewable energies in Senegal, especially for developing countries, it is important to maximize the local employment benefit of each renewable energy project to improve livelihood.

6.6 Creation of jobs and rural opportunities

Renewable energies create job opportunities in different segments of the value chain. Corresponding to the report by *USAID,* there is few trained staff, which is able to install solar pumps in an efficient way; consequently, it opens up vacancies there.

For the performance planning, fulltime engineers in project management, mechanics and irrigation are needed. In material planning, jobs including cargo and transportation are created, like care handlers, store-keepers and accountants. As a direct effect, the solar pumping systems create full-time jobs for a local water system operator and the technicians for the maintenance. Additional job opportunities are created in the distribution channels for the spare parts needed for maintenance. Those jobs include material shops, distribution, technicians and transportation to the field.

An agent business model, like *Vitalite* is implementing it, gives employment and further education opportunities to people living in rural areas without graduating from a higher educational institute. They receive training in management and sales techniques and are encouraged to build up their own business, using solar products. By the end of 2022, *Vitalite* will have contributed to the labor market with 1.500 new jobs. [74]

LittleSun is encouraging local distributors to promote renewable energy products and to sell their lighting and charging devices. In 2018, they have a direct employment effect of ca. 120 distributors. In addition to the direct company effects, the effect of using their solar products has to be taken into an account. Solar lighting shifts the working hours to the evening and provides a reliable and safe source of light to enlarge ones business hours. The ability to charge ones phone for example, gives the opportunity to coordinate your business actions like workers in medical business or on farms. [77]

According to a survey conducted in 2016 on the employment impact of off-grid-lighting in developing countries, *LittleSun* ascertained that per million solar lanterns introduced into the market, approximately 17.000 jobs are created [84], p.160. These jobs are partly full- and half-time jobs and are created in a variety of categories, such as product distribution and retail. Further information about the categories can be found in Figure 19 in Annex E.

To create rural opportunities the pace of job creation associated with new technologies, that could replace polluting lighting fuels like kerosene, has to be maximized, while livelihood is improved at the same time. A major obstacle is that, on basis on missing feed-in tariffs, communities cannot produce their own energy to feed it into the grid.

7 Employment opportunities and trends

Corresponding to a research paper of the *international Labour Office* “there is a widespread skill shortage of engineers and technicians in all parts of the renewable energy industry, which in many countries comes from a broader trend by students away from engineering studies.” [85]. Therefore, renewable energy master graduates of the EPT have several employment opportunities in the next years. The following overview is not outright; it is a compilation of the employment opportunities and future projects believed to have the largest leverage on the key issue.

The *African Development Bank* is aiming to set up an enabling policy environment, which involves utility companies for success and increases the number of bankable energy projects. In those energy projects new employment opportunities will be created. As well as the funding pool for new projects will be increased; the support for smaller local energy projects will also be improved. To drive the small projects, major regional projects will be rolling out country-wide and contribute to the energy transformation. [37], p.38

For *Senelec,* 2018 and 2019 will be a time period of consolidation. Main aim is to implement the ESP as well as to larger scale the deployment of the eco-friendly and energy efficiency awareness program, which will create employment opportunities for graduates, specially trained in renewable energies and energy efficiency. *Senelec* is also aiming to automate the distribution with remote control switchgear, as well as to modernize the metering and remote management systems for high demand costumers. Since those technologies are rather new to the market, specialized graduates will be needed in the implementation. In 2020, *Senelec* is aiming to build an operational deployment of diversity projects, like an own business service as well as a private school for energy trades. In addition to the existing grid, an optical fiber network will be exploited. [17], p.74f

Data comparison of renewable energy graduates from the EPT in Senegal with those from TH Köln in Germany shows, that their work fields vary (cf. Figure *11*).

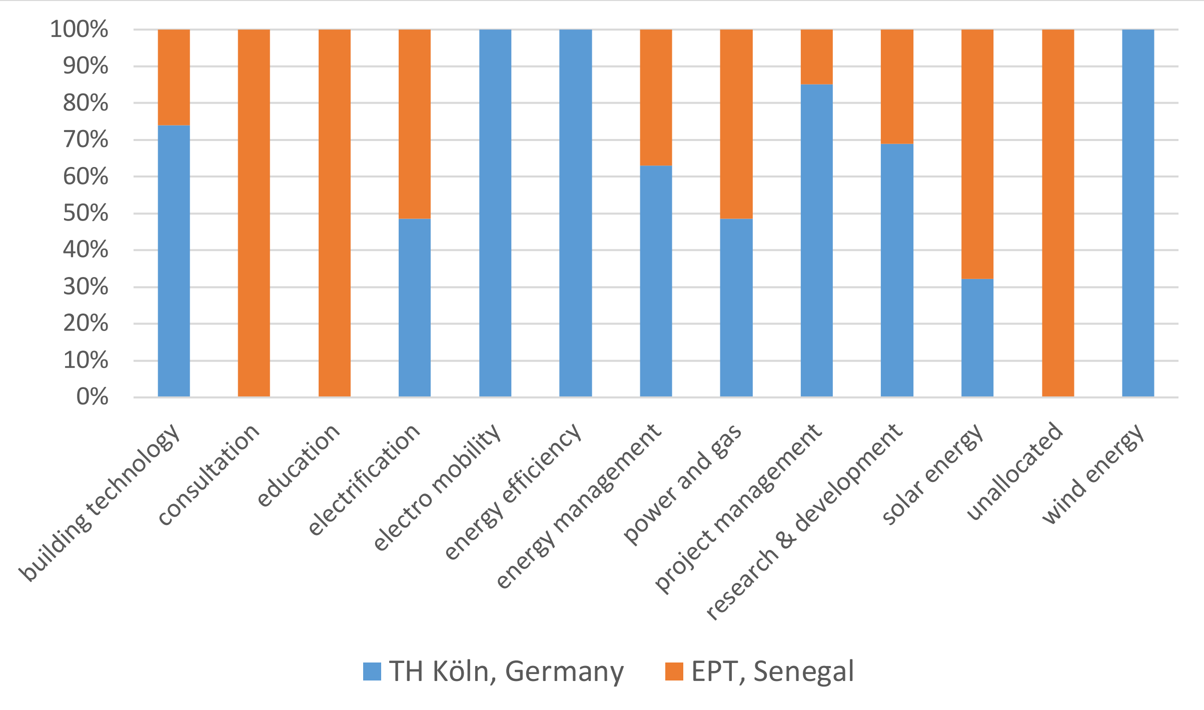

Figure 11: Job field evaluation of graduates in renewable energies Own illustration, following [86], [87]

The full comparison can be seen in Figure *10* in Annex F.

The German students [87] mainly work in energy and project management related areas, as well as in research and development. A quarter of the Senegalese students [86] are working as teachers, other popular areas are energy management and solar energy. With growing demand of specialized engineers and technicians in the distribution and project planning, the allocation will presumably change. It can be noticed that German graduates work as well in modern energy topics like electro mobility and energy efficiency, which are not considered as a main target in Senegal at the moment.

However, the implementation of the ESP opens up new working fields and positions for renewable energy engineers. In the wind energy sector, there are business potentials for project developers, service technicians, data analysts and engineers in electrics, mechanics and construction. Therefore, further employment opportunities in the *Taiba N'Diaye* wind project will be created. The solar energy sector unveils new capacities in the domain of photovoltaic and system builders, investigators for solar solutions and electrical engineers.

Biogas offers business potentials as well for designing engineers, service technicians or educators, but is not considered as a main energy target area in Senegal. [88], p. 316-325

During the research for this thesis, various companies and organizations, working in the field of renewable energies, were contacted. Those contacts can be used for further research and cooperation. The approached organizations and institutions are listed in the contact list in Annex C besides other stakeholders in the renewable energy sector.

8 Conclusion and outlook

In retrospect, the following conclusions can be drawn from this research: the use of renewable energies offers the opportunity to diminish energy dependence, reduce the emission of CO2 and create new employment in Senegal. Thus, jobs are created in the private and public sector, as well as in the civil society, the academic and the donor sector. Even if the possibilities are theoretically given, the main part of the population cannot benefit from them. Rural communities in Senegal do not have all the assets they need to lift themselves out of poverty and disadvantages. Following that, the five capitals mentioned in the SLA can be enhanced by renewable energies.

Influencing children's education and bringing an indirect economic benefit in form of access to knowledge and information with a reliable energy access can improve the human capital. Investments in the power sector can increase productivity in the labor market; simultaneously it is strengthened by investing in the educational system and in technical trainings. Implementing renewable energies is followed by less usage of fossil fuels powered lighting systems, which improves the health standard. A direct benefit for the labor market is the extra availability of time, renewable energies are bringing to rural communities.

To implement renewable energies in Senegal and stabilize the electrical grid, the energy sub-sector management framework has to be improved to promote access to energy on one hand and to promote energy controlling and saving on the other hand. Using modern technical devices gives the opportunity to enhance the social and political capital as well as to reduce local pollution.

Energy plays a fundamental part in the financial capital and the connected economic growth, which is affected by the frequent power outages. To see the link between renewable energies and employment, the whole value chain has to be investigated. Investments on a macro level have influence on the economic growth and the labor market. This can be seen in the example of the solar power plant *Senergy 2*, which approximately created 1.400 jobs per MW in the sectors manufacturing, system design, project development, installation and operation. Investments on a micro level in the rural communities can increase the productivity in the labor market as well by encouraging small individual businesses with solar products and the benefits of electricity. Models, like the agent or distributor model to sell solar products, create job opportunities for people in rural areas.

The involvement of local agents is important for the future development of renewable energies, especially since the energy mix in Senegal is based on traditional energy sources and the acceptance of modern costly technologies is mostly not given. Furthermore, there are as well jobs created in the higher and middle educational sectors as engineers or technicians, specialized on renewable energies.
In terms of physical capital, decentralized off-grid systems open up more opportunities, especially when the rural community is involved; furthermore having access to a sustainable source of energy, creates greater income. The diffusion of solar off-grid systems is still restricted due to high taxes and missing governmental framework conditions. Having access to a reliable energy source and off-grid structure creates business opportunities and enables longer opening hours or reachability.
Renewable energies can be, likewise, used to support the agricultural transformation and improve the natural capital, in forms of biogas converters or solar irrigation systems. By closing the energy gap in rural areas, they contribute to a green growth and encourage agribusinesses and agricultural entrepreneurship.
Despite the positive economic outlook, the country is still facing challenges in terms of development, institutional frameworks and energy provision. By reason of gaps in policies and regulations, the rural electrification is only slowly moving forward. The energy revolution into the direction of renewable energies is more developed on account to foreign investments. Although the government sees renewable energy as a potential solution to the high electricity tariffs and wants to improve the access to energy, only a small amount of the energy mix is renewable.
As a result of future electrification and adding clean energy capacity to the grid, the energy equivalent on petroleum products and biomass will decrease and the demand for electricity will increase. The rural electrification goals will be missed in 2022, thus as a solution the investments in renewable energies and micro-grids must increase.
Moreover, during the research, it appeared that most of the institutions and organizations talked to do not know that qualified engineers in renewable energies were educated in Senegal. Consequently, the advertising of the university program and training courses regarding renewable energies to local industry should increase.

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Declaration

I, Eva-Maria Grommes (1106498), certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person where due reference is not made in the text.

Place, date, signature

Confidentiality statement

Third parties may access this work without permission of the author. The information contained in this document may not be copied or disclosed publicly unless otherwise expressly approved by the author.

I, Eva-Maria Grommes, therefore declare, that my bachelor thesis may be disseminated.

Place, date, signature

Confirmation of submittal

I hereby confirm that Eva-Maria Grommes (11106498) has submitted her bachelor thesis today.

Place, date, signature

10 Annex

Annex A: Economic Profile

Table 6: Socio-economic indicators

Socio-economic indicators	***data***	***est.***	***source***
Population	14.668.522	2017	[6]
Population growth rate	3,9 %	2017	[13]
Unemployment rate	9,5 %	2017	[11]
Rate of active population	39,1 %	2013	[89]
% of working children (5 to 14 years old)	22 %	2016	[38]
Rate of maternal mortality (for 100.000 births)	315 deaths	2015	[6]
Life expectancy at birth	62,1 years	2017	[6]
Occurrence of HIV/AIDS among adults	0,28 %	2016	[90]
Gross schooling rate (TBS) primary school	84 %	2014	[91]
Illiteracy rate	49,7 %	2012	[91]
Electrification - total population	64,5 %	2016	[11]
Level of Urbanization	44,4 %	2017	[6]
GDP - real growth rate	6,8 %	2017	[6]
Population below poverty line	51,9 %	2014	[9]
HDI value (rang: 162 of 188)	0,494	2015	[11]
No secure access to food	17,0 %	2018	[13]

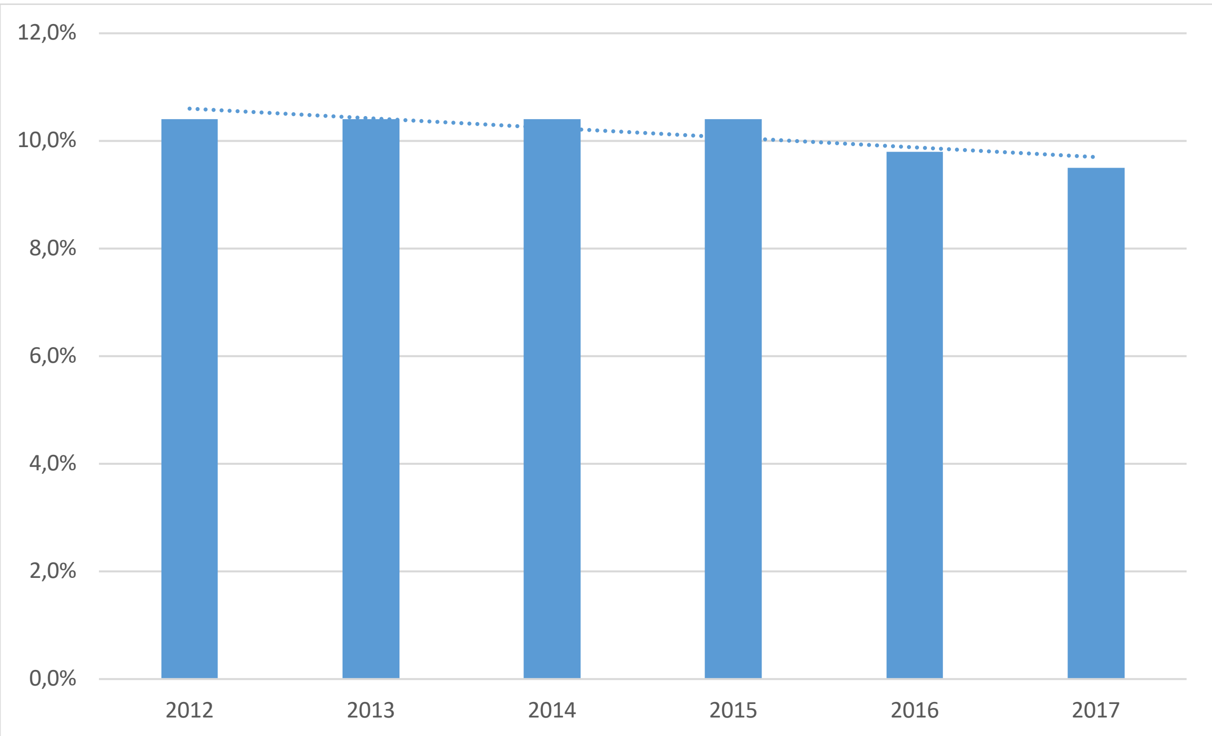

Figure 12: Unemployment rate 2012-2017 Own illustration

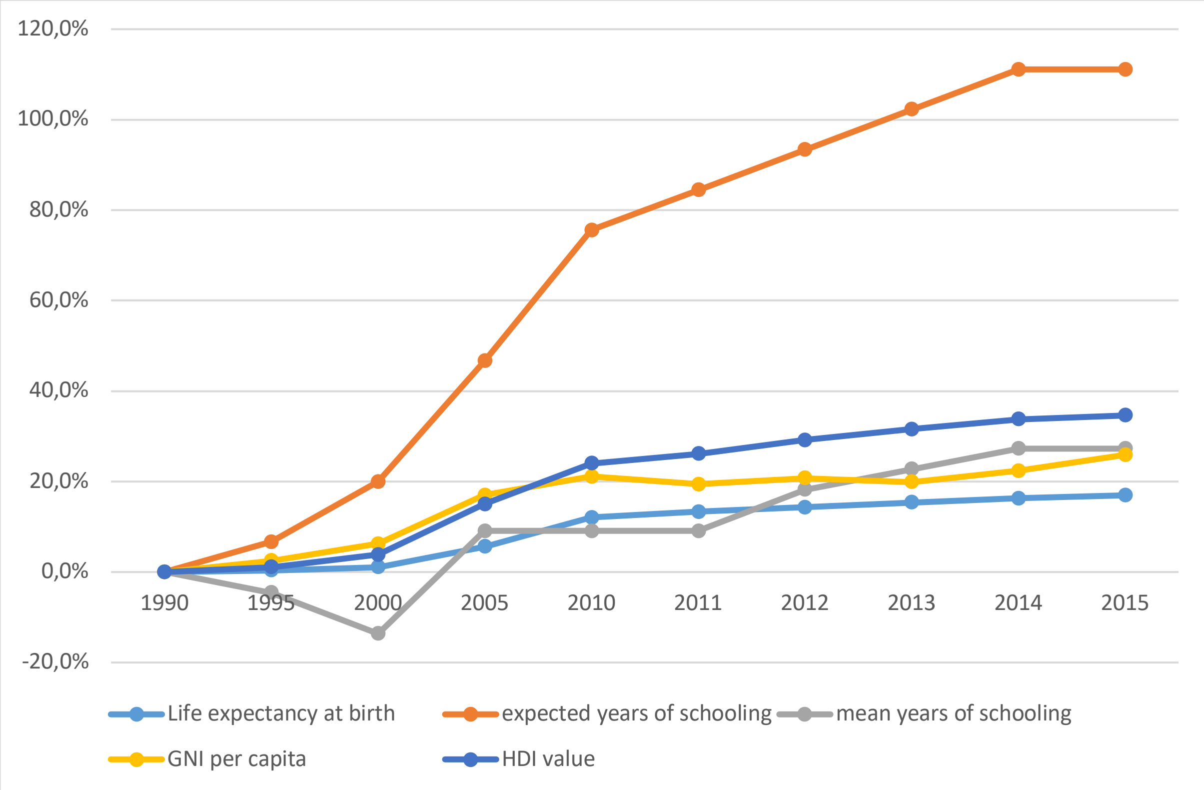

Figure 13: HDI percentage increase by category Own illustration

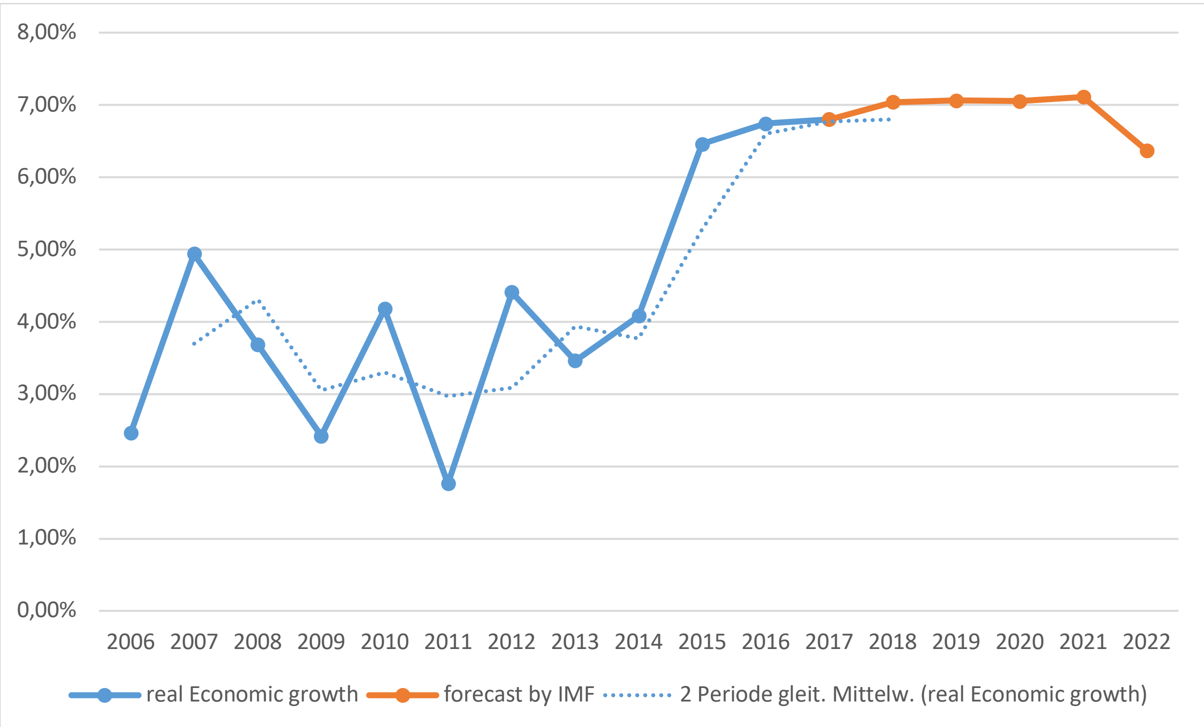

Figure 14: Real economic growth incl. forecasts Own illustration

Annex B: Power profile

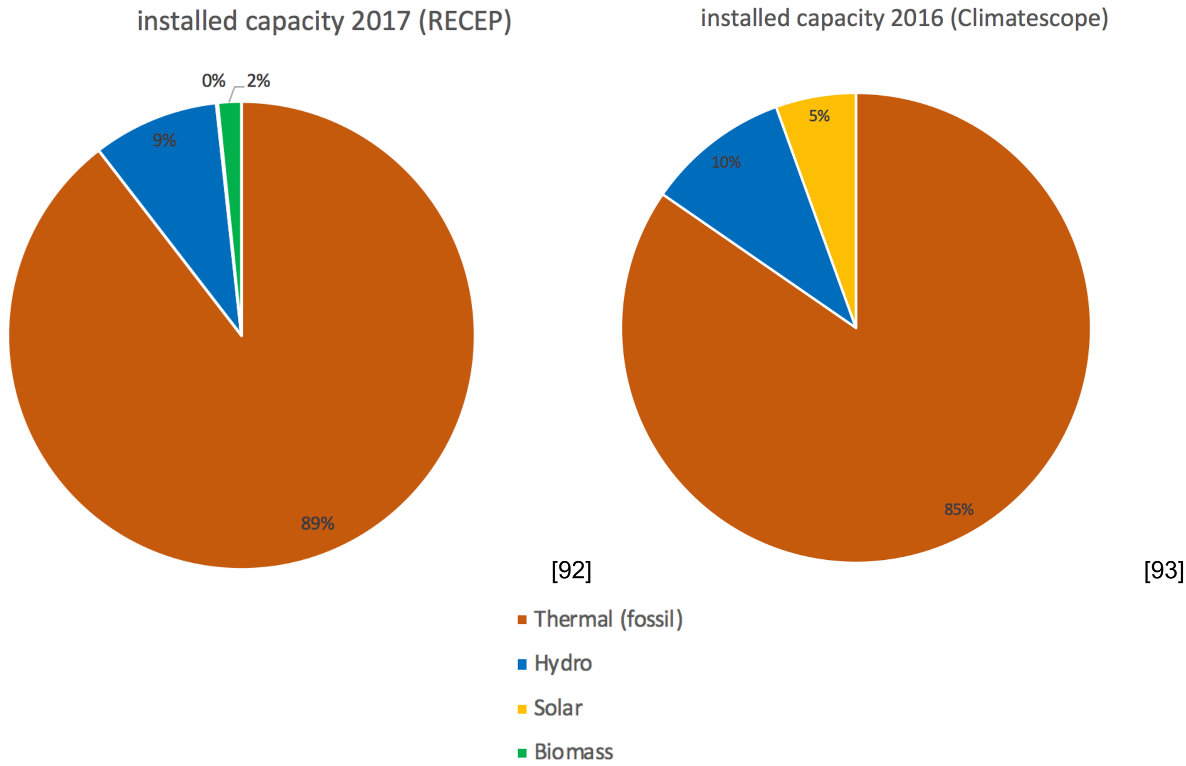

Figure 15: Installed power capacity 2016/17 Own illustration

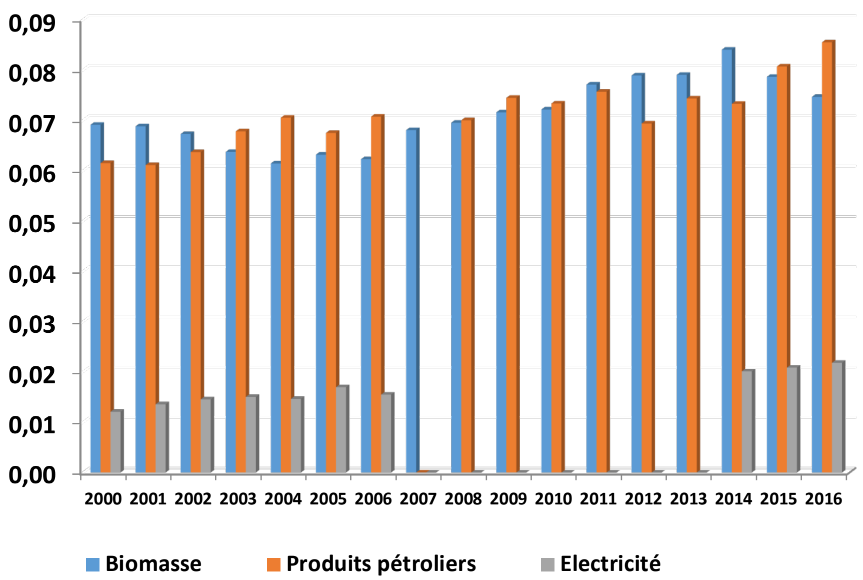

Figure 16: Evolution of final consumption per inhabitant in toe [23]

Trend analysis of urban and rural electrification since 2012

Table 7: Trend analysis of urban and rural electrification since 2012 [23]

	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*difference*
rural	36,7%	27,5%	32,7%	31,8%	38,3%	35,6%	36,4%	37,1%	37,9%	38,6%	39,4%	*20,6%*
urban	84,5%	87,8%	85,0%	86,9%	87,7%	88,0%	88,6%	89,1%	89,7%	90,3%	90,8%	*0,9%*

The orange marked data is calculated with a linear trend analysis. Two equations have been used:

$$a = \bar{y} - \overline{bx}$$

$$b = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sum(x - \bar{x})^2}$$

Equation 1: Forecast analysis

x denotes the year and y the percentage of electrification in each sector. The average difference of the x and y range is calculated and is applied onto the next year. The forecasts are believed to be linear.

Annex C: Contact list and supporting programs

The following overview is not outright; it is a compilation of the contacts and stakeholders, appealed during this thesis. A follow up was conducted on all unanswered requests.

Institution(s)		**Theme**	**Contact**
AECID	Spanish Agency for International Development Cooperation	*Donors*	otc.senegal@aecid.es
AFD	Agence Française de Développement	*Donors*	Mrs. Laurence Hart: afddakar@afd.fr
AfDB	African Development Bank	*Donors*	Mr. Serge N'guessan: s.nguessan@afdb.org
ANER	National Agency for Renewable Energy	*Public sector*	info@aner.sn
ASER	Agency of Rural Electrification	*Public sector*	Baba Diallo: aser@aser.sn
AUMN	Association des Unions Maraîchères des Niayes	*Civil society*	Etienne Darveau: upadi@upa.qc.ca
Cairn	Cairn Energy	*Private sector*	Miles Warner: www.cairnenergy.com/contacts/contact-senegal/
CERER	Research and Study Centre for Renewable Energy	*Public sector*	Mr. Dr. Youm: iyoum2@yahoo.fr
CIMES	Intersectoral Committee for the implementation of Synergies	*Civil society*	Louis Seck : lseck2@yahoo.fr
CNOOC		*Private sector*	cnooc@snooc.com.cn
CRSE	Electricity Regulatory Board	*Public sector*	crse@crse.sn

ECREEE	Ecowas Centre for Renewable Energy and Energy efficiency	*Civil society*	Ibrahima Niane: senegal@ecreee.org
Enda-Energy	Energy management	*Private sector*	info@endaenergie.org
FAO	Food and Agriculture Organization of the UN	*Civil society*	FAO-SN@fao.org
GEF	Global Environment Facility	*Civil society*	Mrs. Mariline Diara: marilinediara@yahoo.fr
GIZ	German agency for international cooperation	*Donors*	Mrs. Friederike von Stieglitz: giz-senegal@giz.de
IDB	Islamic Development Bank	*Donors*	Hon. Abdoulie Jallow: info@isdb.org
IFC	International Finance Cooperation	*Donors*	Mr. Faheen Allibhoy: ADiawBa@ifc.org
JICA	Japan International Cooperation Agency	*Donors*	Senegal Office: 221 33-859-7272
KfW	KfW Development Bank	*Donors*	Mr. Dr. Jan Schumacher: kfw.dakar@kfw.de
Lekala	Taiba N'Diaye project	*Private sector*	Chris Ford: chris.ford@lekela.com
LittleSun	(social business selling solar products)	*Private sector*	Joan Le Fur: joan@littlesun.com
MEDER	Ministry of Energy and Renewable Energy Development	*Public sector*	medersenegal@gmail.com
MEPN	Ministry of Environment and Sustainable Development	*Public sector*	mepn@environment.sn
MoE	Ministry of Energy	*Public sector*	Mr. Sonko: ise212000@yahoo.fr

PED	Programme Energies Durables - Ex PERACOD	*Civil society*	Mr. Sonko: ise212000@yahoo.fr
PRACTICA	PRACTICA Foundation (water and energy)	*Civil society*	Youssouf Diallo: yousouf.diallo@practica.org
RECP	Africa-EU Renewable Energy Cooperation Programme	*Civil society*	recp@euei-pdf.org
Senelec	Société National d'Électricité due Sénégal	*Public sector*	webmaster@senelec.sn
Unido	United Nations Industrial Development Organization	*Civil society*	Mr. Victor Claude Diwandja DJEMBA: office.senegal@unido.org
USAID	United States Agency for International Development	*Donors*	Mrs. Marjorie Copson: mcopson@usaid.gov
Vitalite	(social business selling solar products)	*Private sector*	Frédérique Sheridan: frederique.sheridan@vitalitegroup.com
WFP	World Food Programme	*Civil society*	WFP.Dakar@wfp.org
World Bank		*Donors*	Mr. Mademba Ndiaye: mdiaye@worldbank.org

Annex D: Link between energy investments and employment

Table 8: Senergy 2 (S2) effect on labor market

				factor
Load demand average		392	MW	1,00
Load demand morning peak		450	MW	1,15
Load demand evening peak		564	MW	1,44
Average costumer price energy mix		0,19 €	/kWh	
Tobène & Senergy 2	capacity	60	MW	
	price effect	12,60%		
Senergy 2	capacity	20	MW	
	price effect	4,20%		
Senergy 2 - effect on costumer price				
Generation cost before adding S2		0,093 €	/kWh	
Generation cost after adding S2		0,089 €	/kWh	
Costumer price after adding S2		0,178 €	/kWh	0,021

$$\frac{dY}{dP}\frac{P}{Y} = \frac{dY}{dE}\frac{E}{Y} * \frac{dE}{dP}\frac{P}{E} = \varepsilon * \theta \Longrightarrow \Delta Y \approx \varepsilon * \theta \frac{\Delta P}{P} * Y$$

$Y = economic\ output$
$P = electricity\ price$
$\varepsilon = share\ of\ electricity\ consumption$
$\theta = price\ elasticity$
$E = anual\ electricity\ use\ [MWh]$

Equation 2: effect on economic output

$$Y = A * L^{\alpha} * K^{\beta} * M^{\gamma} * E^{\varepsilon}$$

$$\log Y = \log A + \alpha \log L + \beta \log K + \gamma \log M + \varepsilon \log E$$

$K = capital$
$M = annual\ cost\ of\ materials\ [US\$]$
$A = factor\ producticiity$
$L = number\ of\ employees$
$\alpha;\ \beta;\ \gamma;\ \varepsilon = output\ elasticities$

Equation 3: factor shares for elasticity

The same factors have been used as in the final Report *The link between Power Investments and Jobs in Senegal* by *Private Infrastructure Development Group* [59] and are based on the *World Bank Enterprise Survey 2014*:

Table 9: Electricity factor shares

Sector	*Observations*	*Factor share*
Manufacturing	92	0,480
Trade	159	0,340
*Others**	145	0,381

* Others = construction, transport and other servi ces

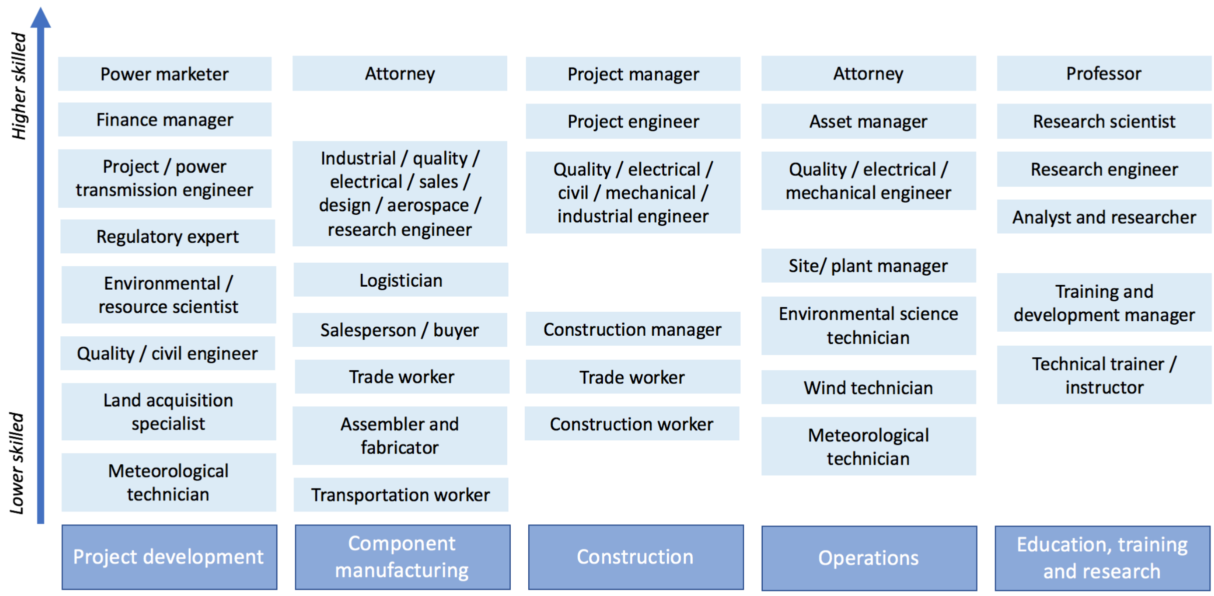

Figure 17: Wind project - theoretical job creation divided in sectors ** Own illustration, following [94]

**The career map does not cover jobs in the Administration, Communication and Safety sector.

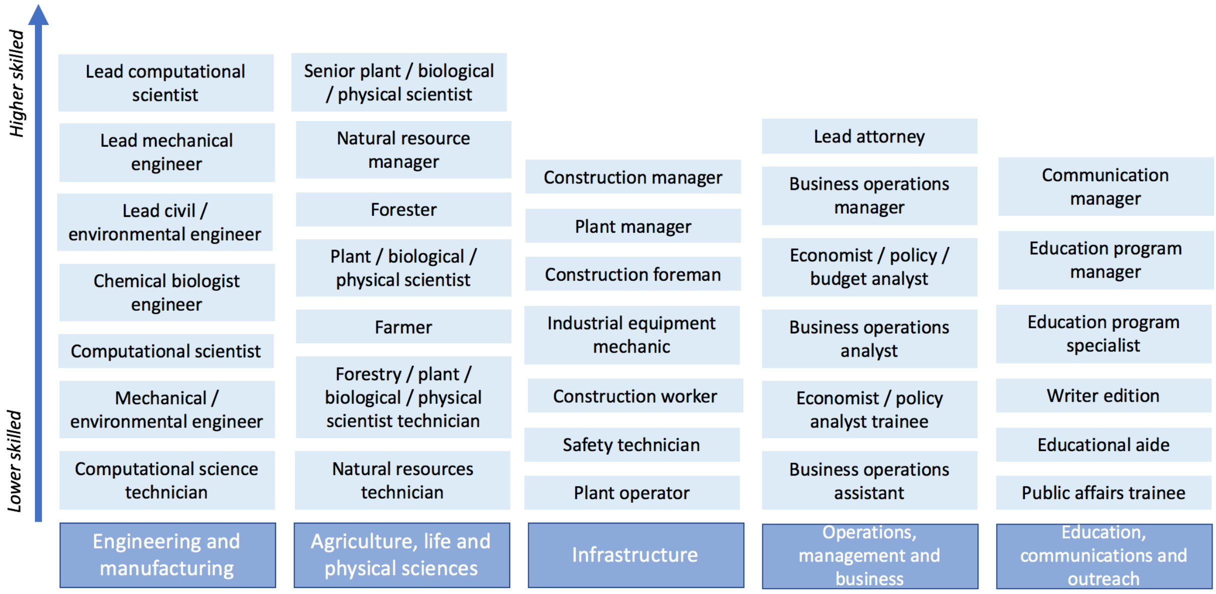

Figure 18: Bio energy project - theoretical job creation divided in sectors Own illustration, following [95]

Annex E: Relation between renewable energies and labor in rural areas

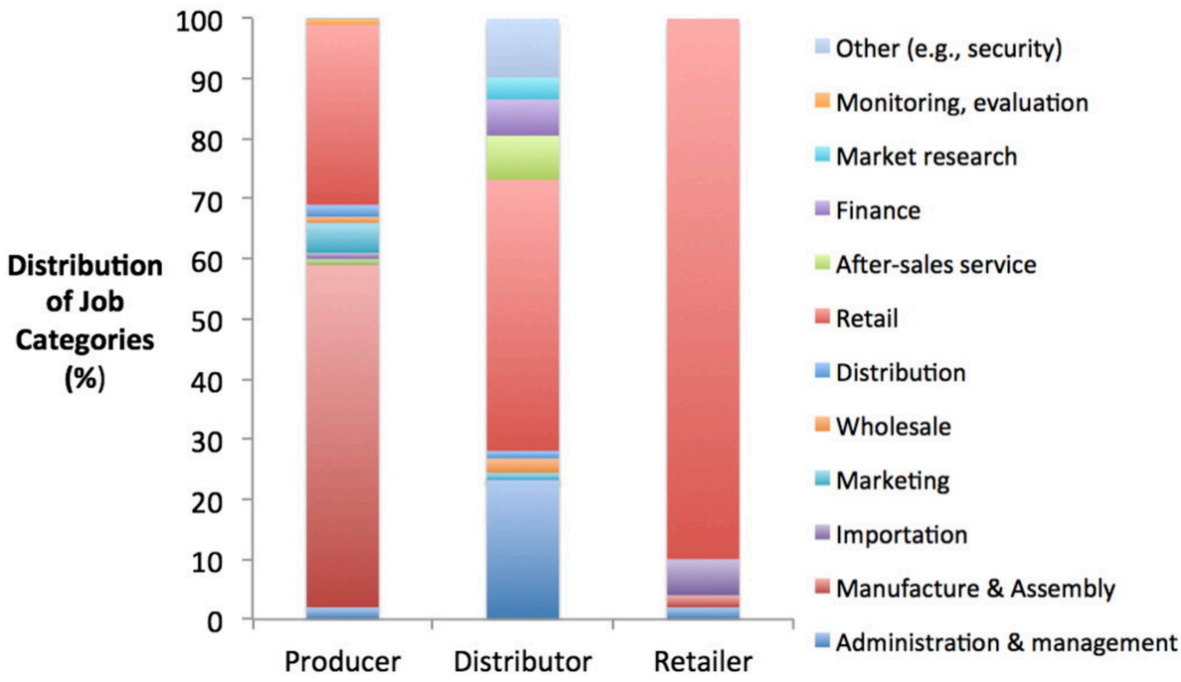

Figure 19: Type and distribution of jobs in the solar-LED lighting marketplace [84], p.60

Annex F: Employment opportunities and trends

Table 10: Job evaluation graduates EPT & TH Köln DE: [87], SN: [86]

	TH Köln, Germany		EPT, Senegal	
Fields	quantity	relative quantity	quantity	relative quantity
building technology	3	7,89 %	1	2,78 %
consultation	0	0,00 %	1	2,78 %
education	0	0,00 %	9	25,00 %
electrification	1	2,63 %	1	2,78 %
electro mobility	2	5,26 %	0	0,00 %
energy efficiency	5	13,16 %	0	0,00 %
energy management	9	23,68 %	5	13,89 %
power and gas	1	2,63 %	1	2,78 %
project management	6	15,79 %	1	2,78 %
research & development	7	18,42 %	3	8,33 %
solar energy	2	5,26 %	4	11,11 %
unallocated	0	0,00 %	10	27,78 %
wind energy	2	5,26 %	0	0,00 %

Annex G: Interviews

The following selection of quotes is part of a series of interviews conducted according to the guidelines in the Annex H.

Categories: effect, employment, future, impact, purpose

Interview	Quote	Generalization	Category
MEDER	“The opinion of the government is not to invest directly in energy projects, if there is a need they make a call of project. “	No direct investment in renewable energy projects by the government.	future
MEDER	„There is a contract between the projector and the national company of electricity, so Senegalese electricians can maintain the site every day. “	Extern companies are obliged to give jobs to local professionals.	employment
MEDER	„What we did at school is whenever we start a program we call the industrial partners to participate in the project and they tell us what kind of engineer they want. We make some agreement with them and they are obligated to take one or two students in stage, so this is our way of helping our students. “	Contracts with companies are made to provide jobs for engineer graduates in the energy sector.	employment
MEDER	“You promote the energy including renewable energies, coal and even nuclear energy in the future. It is a project. The aim is to use mixed energy. “	The main aim by the government is to provide a constant mixture of energy.	future
MEDER	“The main aim is to bring electricity to the local population. Even if it is a local small plant. “	The main aim by the government is to provide electricity to the communities.	future
MEDER	“The first goal is to bring electricity and if you brought electricity to local population you improve at the same time the rate of children going to school. “	Electricity is used to improve the education.	impact
Hamad Njang (farmer in Ndjambour)	“It’s complicated to charge my cell phone because I have to walk to neighbors’ houses and pay them to charge it.” *(in the context of using solar chargers and lamps)*	Access to electricity is shared with others and connected to troubles.	effects

Hamad Njang (farmer in Ndjambour)	“One of my kids is in school, and the rest are in Koranic school, so they will also take the light to study their lessons at night.”	Children do use solar light lamps to study their lessons at night.	Impact / purpose
Frédérique Sheridan (GM of Vitalite)	“Actually, you see the impacts, when you have lights, you live in a more secure environment, kids go to school, they have better grades. “	Access to energy creates a more secure environment.	impact
Frédérique Sheridan (GM of Vitalite)	“We do hear that people want to start their own business with our products. We explained to (woman) entrepreneurs to exploit the television to make a little cinema, get some money there. But also, the days in Senegal are very short, especially for woman, [...] By the time they can do something for themselves, with the woman groups for example, it is already dark. But now with light in the houses, they can still do some little business: Prepare some ice cream, juice or traditional herbs and soaps. […] There are small business possible and their shops can open longer with light […].	To enlarge the hours of light per day creates more job opportunities, especially for woman. Bigger solar systems create even more impact.	employment
Frédérique Sheridan (GM of Vitalite)	„ […] our business model gives business opportunities to young people. We use the agent model, so if you would like to sell for me our systems, we train you, we guide you, we promote you, we go to your village and help you set up a marketing event. And when you sell, you get commissions, and when you would like to install them to - because it is basically plug-and-play, you can install them to and get commission. […]”	The agent business model gives employment and further education opportunities to people living in rural areas.	employment
Etienne Darveau (AUMN)	„In the last 10 years you felt the climate change and over-farming in the Senegalese agriculture a lot. The water level decreases from year to year and villages have to quit agricultural activity, because they cannot reach water to water their fields anymore. “	Climate change affects the agricultural activities in Senegal and therefore the employment sector.	employment

Etienne Darveau (AUMN)	“A lot of the kids we see here, they do not go to school, they are working on the field. If they have a functioning irrigation system, they would not need the kids on the field, it can bring mature changes to those kids.“	An irrigation system can replace young work labor force and improve the education.	employment / impact
Etienne Darveau (AUMN)	„Solar pumping is a more responsible, more sustainable way to do agriculture. It might not be as efficient at first, but the technology did and will improve. “	Solar irrigation is at this moment not financially attractive.	impact / future
Youssouf Diallo (PRACTICA Foundation)	“Solar irrigation systems are helping the farmers to become less vulnerable to droughts resulting of climate change, because solar pumps are not physically limited.”	Solar irrigation systems are giving independence to farmers.	impact / future
Min Gnom (woman entrepeneur and distributor of LittleSun)	“A family I sold a solar light to in the Tambacounda area, reported that their child fell asleep with a candle next to the bed. The candle fell over and enlightened the foam mattress and after that the hole room. Many families made direct experiences with the insecurity of open fire.”	Villages, which have direct experience with the insecurity of open fire have a higher social acceptance for solar power.	effect
Samuel Dansette (LittleSun)	“Many lights are sold to higher educational jobs on the village, like nurses or midwives. Advantages are for example, that they can enlarge their business hours and their phone can be charged regularly. When their phone is charged, they are reachable all time and can work more, than they could before.”	Solar lights are sold to higher educational jobs like midwives or nurses. They can enlarge their working hours and working quality due to more reachability and reliable light.	employment

Annex H: Interview Guideline

Links between Renewable Energies and Employment in Senegal

Research question: What is the effect of renewable energies on the employment sector in Senegal?

The following guideline for interviews based on quantitative research logic linked to generalized assumptions, but is also open for new categories and perspectives which are used in qualitative research designs. The research method and the deductive categories are described below.

1 Research Method:

A qualitative research method has been selected due to the approaches of the *Sustainable Livelihood Approach* (SLA), which concentrates on people as active actors in their livelihood situation. The main focus of the interview is on the understanding of the subjective reality of people's livelihood and their perspective on it. The interviewed are considered as experts in their situation and will be given enough space to present their circumstances. The interview aims to understand the subjective perspective on the living environments of the interviewed. The results are intensively underlining existing research and investigating the impact and effect on people's livelihood.
A qualitative method of social researching has been chosen, because general statements are based on individual cases as part of an inductive approach. Subsequently the qualitative results are monitored by quantitative methods. [2]

2 Deductive categories:

The categories are derived partly deductively from the research question and partly inductively from the material of the interviews.

- **effects** of RE to the population
- variety in RE **employment** sector
- **impact** of RE in rural areas
- **purpose** RE are used for
- **future** plans for RE

Not all categories are used in every interview, they do not apply to all the interviewees, therefore the interviewees are assigned into groups.

3 Interviewed groups:

The interviewees are divided in government, NGOs, companies and individuals. Two companies, two NGOs, one governmental institution and three individual farmers and distributors of solar products have been conducted
In each group, questions are semi standardized and adjusted to the interviewee.

4 Questions:

The questions are mainly text generating and ongoing questions [96], S.10. The last question aims to give the opportunity to summarize the interview. The level of language is adapted to the interviewees. The phrases are mostly designed to spawn honest long answers, for that indirect, structuring and interpreting questions are asked and answers are recorded.

5 Transcription:

The transcript is a semantic content analysis transcript, so it is a literal transcription with partial elimination of grammatical errors, which would otherwise affect the understanding. [96], S.21ff

6 Conversation continuers:

Conversation continuers can be used during the interview, here are some examples:

- “Can you give me an example of what you mean?”
- “Please tell me more about that.”
- “What you are sharing is relevant. Can you tell me more about that?”
- “How does your experience before that time compare to your experience now (after implementing the product)?”
- “Tell me more about that experience.”
- “How do you see that in the future?”
- “If you could change anything about that experience, what would it be?”

7 Evaluation:

The quotes, which are considered to be the most important to answering the research question, are arranged in grids and restricted to their content. They are assigned a category and reduced to their essential content.

8 Further Notes:

Personal related questions were not asked to members of the ministry, because according to their statement, they were loyal to the government and did not want to publish any other information.
The questions were asked in basic English to assure that they were understood. In cases of unclarity the questions and answers were translated to French, Wollof, Seri, Spanish or German.