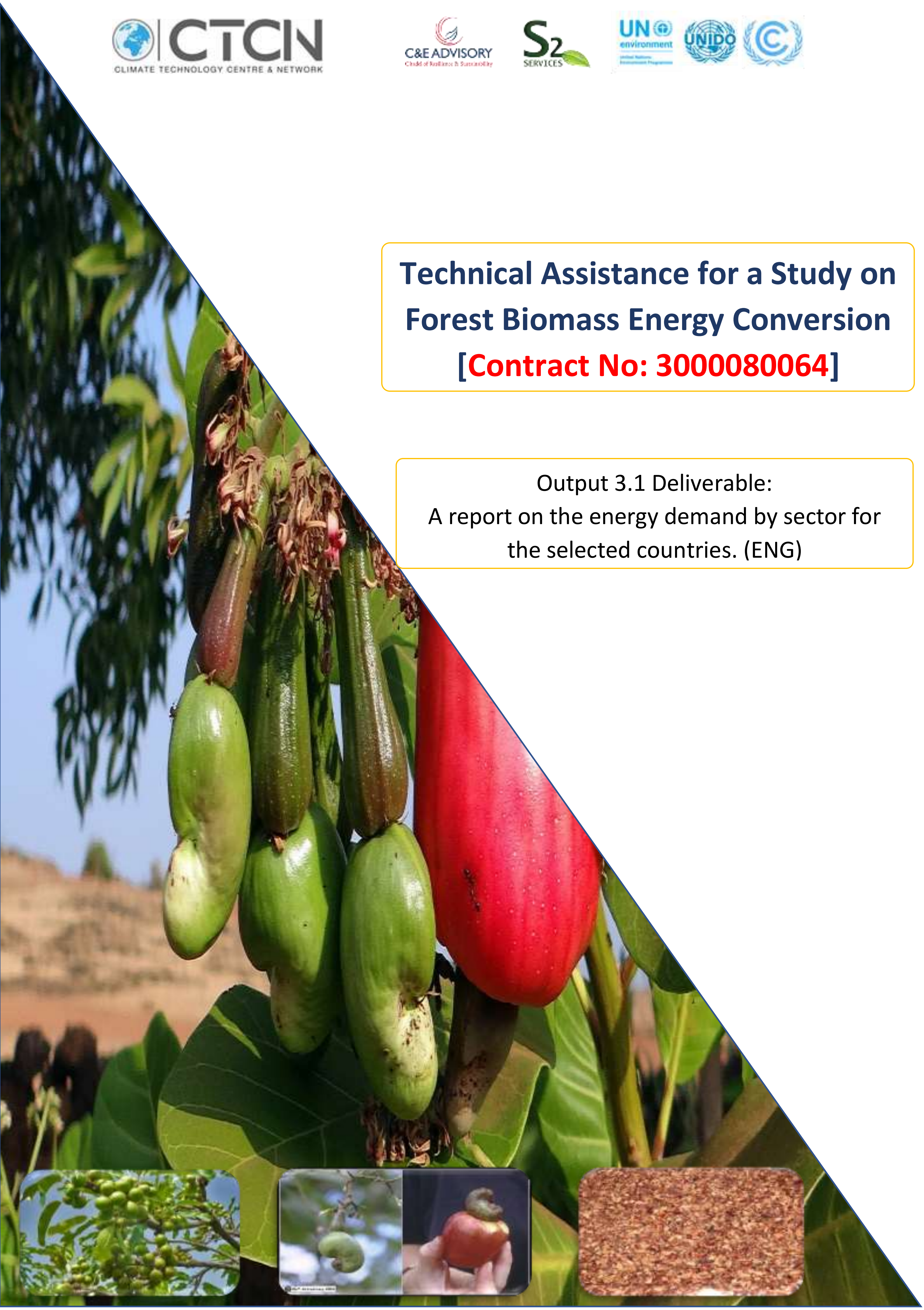

Technical Assistance for a Study on Forest Biomass Energy Conversion [Contract No: 3000080064]

Output 3.1 Deliverable:
A report on the energy demand by sector for the selected countries. (ENG)

A report on the energy demand by sector for the selected countries

Executive Summary

This output 3.1 report is part of the third deliverables (others include output 3.2 and 3.3) of the six deliverables of the CTCN commissioned study on biomass energy conversion in 15 countries in Central, West and East Africa whose objective is to:

- Assess the bioenergy potential from sustainable biomass sources such as wood waste from forest harvesting operations and industry.
- Improve afforestation and forest sector residues energy conversion, and
- Identify market opportunities for the private sector that will bypass the exploitation of traditional biomass sources.

The CTCN technical assistance is intended to promote projects that establish a sustainable industrial chain for forest biomass energy conversion using planted forest including agroforestry as raw material and forestry biomass and sawmill waste. It is anticipated to bring about the following impacts and co-benefits and contribute to country obligations to the Paris agreement through the Nationally Determined Contributions (INDCs) and Sustainable Development Goals

The main objective of output 3.1 was to identify the energy demands by sector for the selected countries in Central, East and West Africa and propose those sectors the forest biomass energy conversion potential can contribute, considering the current problem of traditional biomass consumption. As such output 3.1 report deals with the energy demand by sector for seven Central African countries, two East African countries, and six West African countries.

Chapter 1, which forms the background of the report elaborates on the current trends in the energy industry. Energy assessment of the countries has been carried out to ascertain the future energy demand so as to design projects that will sufficiently, and sustainably supply reliable energy in the medium to long term. This has involved estimating the current needs based on historical trends and the future applications that may be included as the population increases, community continues to grow economically in size and complexity. The report used the Nationally Determined Contributions (NDCs) for each country as the main reference with regards critical sectors of the economy that will contribute to low carbon development while ensuring community resilience in the face of climate change. The energy sector being an enabler of sustainable development is a critical component of the NDC as it contributes about a third of greenhouse (GHG) emissions in a country.

Chapters 2 to 4 outlines the energy demand by sector for each country in the three regions – Central, East and West Africa. Energy resources available and potential in each country are reviewed focusing on the potential, quantity, and installed capacity. Key economic sectors include agriculture, mining, forestry, industry, transport, and domestic/institutional sectors, though there is some variation from one country to another. The purpose of investigating key economic sectors as per NDCs was to assess the potential contribution of biomass energy in mitigating GHG as part of low carbon development in most energy intensive economic sectors.

In **Central Africa**, **Cameroon** accounts for the largest biomass energy source consumed at 73%, followed by oil and gas (20%) and electricity (7%) as per 2011 statistics. The Rural Electrification Agency identified 37 sites with high potential for biomass energy production in the country. Cameroon's energy potential from biomass sources is 1 GWh. The country is the third largest biomass giant in Sub-Saharan Africa with biomass from wood waste in the Eastern region and from rice fields in Ndop, respectively. Cameroon's agricultural sector relies on biomass from animal dung and compost. Very few areas convert forest biomass to energy. The domestic/institutional sector is the greatest consumer of biomass energy. In 2010, forest biomass, mostly in the form of wood energy, contributed 72.6% of energy used in 2010, which was estimated to be 13,163 ktoe. Since the country has large biomass potential in its forests, biomass plants can be set up in sites which lack electricity but are areas of high population. The biomass plant sites in this area can manufacture valorised charcoal, bioethanol, and electricity to serve the surrounding population for their agricultural and household needs.

Democratic Republic of Congo 99% of its electricity is generated from hydropower sources, about 2410 MW being produced. Firewood remains the dominant source of energy. Biogas, biofuel and geothermal remain to be largely unexplored sources of energy. The largest consumers of energy in the country are the household and light industrial sectors. Together they account for over 75% of the energy consumed in the country. Biomass accounts for the largest share of household energy consumption at 93%, and then followed by hydroelectricity at 4%. Oil and others account for 3% and 1% respectively. Biomass is also the major source of cooking energy in DRC. It is mostly used in the form of charcoal and firewood. The annual demand for biomass in the country is 45million cubic metres per year. Bioenergy plants can be set up in most places in the country which can be used to generate power for village uses, production of ethanol for the transport and for cogeneration in industries. The sites proposed for the construction of biomass plants due to the presence of large amounts of residue are Kinshasa, Kisangani and Mbuji-Mayi.

The Republic of Congo has forest covers about 60% of the land area. Biomass, hydropower and solar are the energy resources with the greatest potential in Congo. Wood energy accounts for 80% usage in households. Hydropower has the largest energy potential in the country, at 1400MW, but only 209 MW is generated. The country also has large oil and gas reserves in its offshore fields. Biomass use accounts for over 80% of the energy used in households. This is followed by natural gas at 11%, and petroleum products at 75%. Cogeneration of electricity from logging is generated in Pokola, North West of the country by the Congolese Wood Industry Company. Four megawatts of electricity are generated of which 2MW are distributed to the surrounding population for free as part of corporate social responsibility. Biofuel, such as ethanol, is generated from the country's sugar cane sector, while biodiesel is manufactured from oil palm plantations. Most biomass energy projects in the country are running on obsolete machines. On a positive note, most biomass-based factories are transitioning to second-generation machines which are more efficient. Biomass has the potential to supply energy to run the activities in the logging sites and domestic uses in households.

The Gabonese Republic is rich in hydropower, biomass and fossil fuel reserves and the high precipitation levels and topography contribute to the nation's large hydropower potential. Biomass resources are also in large quantity, a fact attributed to the country's extensive and dense forest cover. The country has the fifth largest oil reserves in the continent. Hydropower potential of the country is estimated to be 10 billion kilowatts/hour per year and contributes 51.7% of the total electricity generated. The forestry sector represents the greatest niche where biomass can be used as an alternative energy source, especially in the running of logging machinery. The report recommends the logging factories in the concession sites to generate electricity using cogeneration from their wood residues.

Republic of Chad: It is estimated to have 312 million hectares in the 1970s but due to deforestation, over 20 million hectares have been lost. The country has higher potential in developing solar and wind energy technologies compared to hydropower. Insolation intensities range from 4 to 6kWh/m^2/hr per day over most of its landscape while windspeeds range from 3 to 9m/2 with the fastest speeds in the northern region. Chad has significant oil reserves and an oil refinery in the capital, N'djamena. This has made the country less reliant on its neighbours for oil, but production rates have been declining in the past few years due to technical problems and instability. In 2011, biomass accounted for 93% of the energy used in the country. The niches where biomass can contribute are in cogeneration of electricity, and production of biofuels for the transport sector. Most of the energy demand is situated south of the capital, N'djamena and which hosts most of the country's industries. This area also has the largest forest cover and is thus able to provide residue for cogeneration from logged wood.

Republic of Equatorial Guinea has one of the largest reserves of oil and gas in the continent. However, biomass contributes over 80% of the household energy needs while petroleum products and water contribute 18% and 2%, respectively. About 58% or 1626 million hectares of the country is covered under dense rainforest. Most of the biomass for household uses is collected from agricultural harvest (70%) while a lesser amount is collected from standing tree canopy (30%). Only 8% of the population uses Liquified Petroleum Gas (LPG). The country has significant potential to generate more power from hydroelectric solar and wind sources. The latter two are due to the equatorial climate and high wind speeds south of the country. The country was estimated to have 1,100 million barrels and 36.8 billion cubic metres of recoverable oil and gas reserves, respectively. The country generates only about 327MW of electricity as most of the households in rural areas rely on biomass. Because of

Equatorial Guinea's conducive environment for forestry and agricultural purposes, the country has enough potential for biomass conversion to electricity. The proposed methods for the country to use at large scale are conventional steam cycle, gasification, and cogeneration. An area that produces significant amounts of wood residue is the area of Bata.

Central African Republic is rich in uranium, a raw material for nuclear energy which is exploited mainly by foreign firms. Hydropower is the only developed energy resource in the country, with an estimated potential of 2000 MW though the current installed capacity falls short of this. Despite the various natural resources that could be harnessed for large scale electricity production, the country relies on biomass for 98% of its energy needs. Electricity supply in the country is unreliable and therefore the few large industries in the country rely alternative sources such as diesel and biomass. For example, the IFB Batalimo and Ngobo sugar factory use wood waste and bagasse for cogeneration, respectively. Industries use less than 1% of the total energy produced in the country. A large share of energy is consumed by households, but mostly from biomass (98%). The country has potential for biomass energy from the forest and agricultural residues which can be sufficiently supplied from the Ouaka, Laboye and Ngakobo regions.

In **East Africa**, **Republic of Burundi,** hydroelectric power is the nation's major supplier of electricity. The installed capacity is around 300MW but most households, which account for 94% of the energy consumption, rely on biomass. Firewood is the main energy source for both artisanal and household use. The country, however, has a number of sources for wood and agricultural residues. The country has potential to develop solar energy with insolation intensities ranging between 4 to 5kWh/m^2 per day while average wind speeds in the country are 4 to 6m/s. The country also has the one of the largest peat reserves in the continent. However, only 0.5% of the total 6 million peat reserves have been exploited. The industrial and domestic/institutional sector are the major users of biomass. The tea industry is one of the largest consumers of firewood. The sawmilling sites transform wood to various products for sale or for use by carpentry associations. Because of the existence of various forms of biomass at varying scales in the country, there are a number of recommendations to improve contribution of biomass energy to the economy. Some of these are:

- Use of pyrolysis to generate energy from rice and coffee husks
- Extracting biogas from palm oil substrate in the Kireka-Muzazi mini-plant in Bujumbura
- Exploitation of the country's peat reserves to generate electricity. The existing National Peat Office (ONATOUR) is mandated with the development of the peat industry
- Increase the capacity of industries using cogeneration so as to generate more electricity. For example, Société Sucrière du Moso (SOSUMO), the leading sugar company, can only generate electricity during the sugar season because of technical inefficiencies
- Gasification of wood waste to generate electricity for large scale industries. Conversely, wood pellets can be used to provide energy needs at the household level

Republic of Djibouti has limited power for biomass and hydropower energy but has considerable potential for solar, geothermal and wind energy. The first two are of limited viability because of lack of sufficient forest cover, wood and agricultural residue. Djibouti, unlike most countries discussed in the report, has limited opportunities for biomass energy. The country's forest cover occupies less than 1% of the total area, and the country has less than 4% of arable land from which agricultural residues can be sourced from. The only viable source of biomass energy is from the exploitation of *Prosopis juliflora* to manufacture pellets.

In **West Africa, Republic of Benin**, the Communauté Électrique du Bénin (CEB) is the national distributor of electricity in Benin. It is a bi-state organ headquartered in Togo, but its management is shared by both countries on a 50-50 basis. Apart from the Nangbéto hydroelectric dam in Togo which generates most of the electricity (65.6 MW), each of the two countries has a 20 MW gas turbine each. To fill the deficit that CEB cannot supply, Benin imports electricity from neighboring Ghana. Biomass is used by household and small-scale industries in the country. As an example of biomass use in industries, the Nocibé cement factory buys agricultural residues, especially cashew hulls to burn in its stoves. Cashew processing plants use 15% of their cashew hulls to fuel their boilers. Biomass has a variety of uses in Benin. The domestic sector is the largest consumer at 83% (1559 ktoe/year in total), followed by the commercial sector at 17% (311 ktoe/year) and industry at 1%(32ktoe). The main large industrial consumer of biomass is the cement industry. Biomass constitutes 15% of the energy in its processes. Biomass in industries, however, is used because it is very cheap compared to electricity, otherwise the latter is still the best option. The biomass reaching the cement factory arrives in a variety of forms such as corn stems, cashew nut shells, peanut hulls etc. For Benin, cashew nut shells, according to this report, have more potential for biomass energy compared to firewood. The cashew hulls can be transformed to briquettes or valorised to produce electricity.

Burkina Faso is energy deficient and imports most of its supply from neighbouring Côte d'Ivoire and Ghana. The country's forests are a source of household energy in the form of firewood and charcoal. A total of 34MW of hydroelectric power is produced from the country's rivers. Only agricultural residues are viable to contribute to the industrial sector's energy needs while in the transport and agricultural sector there is little opportunity available for the use of this resource. Businesses, institutions and households rely on firewood for most of their uses. The report mentions that most cashew industries are located within a 100km zone. This means that cashew shells can be amassed at a single collection point from where they can be transported to a single site for valorisation. Cashew hulls have a supply potential of 17, 200 tonnes/year in Burkina Faso.

Republic of Côte d'Ivoire has large oil, gas, and additionally, large potential for solar and hydroelectric power. In addition, it has large biomass reserves. In 2017, it produced 19,000 kilotonnes of firewood and 1500 kilotonnes of charcoal. The country's hydroelectric potential from its rivers is estimated to be over 1600MW. The household sector is the largest consumer of electricity in the country at 60%, transport comes second at 23%, third are commercial services at 11%, while industry and other uses trail at 4% and 1%, respectively. Household and commercial sector are the largest consumers of biomass at 4254 ktoe/year (88%) and 790 ktoe/year (12%). Use of biomass in the industrial sector is very low. However, for those that use biomass as fuel in their boilers, residues of palm, cocoa and cashew nuts are the main raw materials. Though the country has many areas from where biomass can be sourced from, the areas are scattered all over the country. It is recommended for a decentralized approach for their collection. In addition to valorisation of palm and cashew hulls, the report also recommends for the trial of cacao residues as raw materials for biomass energy. This is because most cacao waste in the country's producing areas is left idle in the plantations.

Republic of Mali energy comes from biomass (66%), oil products (31%), imported electricity (2%) and hydroelectricity (1%). Biomass comes from the country's shrinking forests, while agricultural residues are from rice and cotton husks, and oilseed hulls. The country also produces biofuel from Jatropha. In 2016, 740, 000 litres of biofuel were produced but this production seemed to stop. The northern areas of the country have significant solar irradiance potential of 6 kWh/m^2 per day. The northern areas also experience wind speeds of above 5m/s which are viable for large wind infrastructure investments. Biomass is mostly used in the household, commercial and industry sectors. The first two mostly rely on firewood and charcoal while the third, industries, mostly use agricultural residues such as bagasse, shea cakes and cashew hulls for their energy needs. Little biomass is used in the transport, agricultural and forestry sectors.

Republic of Senegal relies on crude oil and hydropower for most of its national energy needs. Solar and wind energy contribute less than 1% to the overall energy production. The country experiences a solar irradiance of $5kWh/m^2$ per day and wind speeds of upto 6m/s at high altitudes along the coast. Senegal imports 1172 kilotonnes of crude oil, 1220 kilotonnes of oil products and 615 kilotonnes of coal every year. Fuelwood is consumed more compared to charcoal at 1500 kilotonnes for the former and 200 kilotonnes for the latter. A variety of agricultural residues are used for energy purposes from groundnut shells, cereal straws, and sugar bagasse. Industries, commercial services and households are the major users of biomass. From these three economic sectors, industries consume the least biomass at 8.94 ktoe. Households consume almost 200ktoe of biomass annually while commercial services consume 75ktoe every year. For industries, large amounts of wood would be needed to generate any usable form of electricity. Since this is not possible, the industries can further develop the biomass conversion technologies of cashew hulls currently existing in the country. Non-wood and non-forest residues such as shells and husks can be processed to briquettes and biochar. These two products can be used as alternatives to firewood and traditional charcoal for household uses. It will not be easy for biomass sources to replace the use of oil in the agricultural and forestry sectors unless the material is intensively value added. Only biofuel is a promising example.

In **Togolese Republic,** biomass and hydroelectricity are the main energy sources. Biomass use is dominated by wood waste and to a lesser extent plant waste. Over 3000 ktoe of biomass were used in 2017. Hydroelectric power, at Nangbéto dam produces less than 70MW of power. Solar and wind energy systems are few in the country. Only businesses and the household sector use biomass at large scale. Apart from the agriculture sector which does not have any energy consumption statistics, the industry and transport sector majorly rely on refined oil and its products for their energy needs. The report recommends that agricultural residues have the greatest potential to contribute to biomass energy in the country.

In conclusion, the greatest energy niches that biomass energy can fill in the 15 countries are in the household, commercial and industry sectors. For the industrial sector, however, both sophisticated technology and sufficient biomass supply (in space and quantity) is needed to generate enough electricity or fuel for the industrial processes. Biomass can only make inroads in the transport sector in form of biofuel. The study has shown that most household still consume firewood in its natural form using traditional cooking devices. Wood fuel sustainability is therefore challenged by unsustainable harvesting and inefficient methods of converting wood into energy. The use of inefficient cook stoves contributes to wood wastage and smoke exposure associated with severe illnesses. Using briquettes or wood pellets stoves can reduce health risks associated with cooking fuel due to increased fuel efficiency. However, the development of these innovations will need for a multi-disciplinary approach to increase awareness of the benefits of cooking fuel innovations, encourage further research on product quality enhancement and standardization, to understand cultural and behavioral issues influencing adoption, and integrate innovations into bioenergy policy frameworks. The study recommends wood and agricultural residues to be valorised through processes such as pyrolysis and gasification to generate electricity for community and industries where applicable. Regionally, countries with the largest potential for biomass energy are those in Central and West Africa. This report should be read together with outputs 3.2 and 3.3 reports. Output 3.2 summarizes the most appropriate conversion technologies, including pre-treatments and treatments of biomass to produce the final energy use for potential sectors identified in priority countries, whereas output 3.3. gives description of identified pilot projects for each sector, and discusses site design, logistics, biomass suppliers including budget.

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List of Abbreviations

NDC	**Nationally Determined Contributions**
GHG	Greenhouse Gases
GWh	Gigawatt hours
MW	Megawatts
LPG	Liquified Petroleum Gas
CEB	Communauté Électrique du Bénin
SOSUMO	Société Sucrière du Moso
UNDP	United Nations Development Program
GDP	Gross Domestic Product
CTCN	Climate Technology Centre & Network
AFREC	African Energy Commission
CERD	*Centre d'Etudes et de Recherche de Djibouti*
SE4ALL	Sustainable Energy For All

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Background

This output 3.1 report is part of the third deliverables (others include output 3.2 and 3.3) of the CTCN commissioned study on biomass energy conversion in 15 countries in Central, West and East Africa whose objective is to:

- Assess the bioenergy potential from sustainable biomass sources such as wood waste from forest harvesting operations and industry.
- Improve afforestation and forest sector residues energy conversion, and
- Identify market opportunities for the private sector that will bypass the exploitation of traditional biomass sources.

The CTCN technical assistance is intended to promote projects that establish a sustainable industrial chain for forest biomass energy conversion using planted forest as raw material and forestry biomass and sawmill waste. It is anticipated to bring about the following impacts and co-benefits and contribute to country obligations to the Paris agreement through the Nationally Determined Contributions (INDCs) and Sustainable Development Goals

In output 2 reports, the sources of forest residues in the forest supply chain were identified and sites where the largest amount of waste is generated mapped. The report also outlined in detail the process by which wood waste is generated from both forest and agroforestry woody trees until it reaches the final customer.

In this output 3.1 report an assessment of the energy demand by sector for the selected countries has been carried out with a view to determining sectors where biomass energy residues obtained from output 2 can be used to supply clean energy. This is consistent with the main objective of output 3, which is to determine the requirements for and availability of technologies for converting the identified biomass resources in Output 2. There are three deliverables in output 3 which are described below.

- Output 3.1 whose deliverable is a report on the energy demand by sector for the selected countries
- Output 3.2 whose deliverable is a report on the most appropriate conversion technologies, including pre-treatments and treatments of biomass to produce the final energy use for each sector identified.
- Output 3.3. whose deliverable is a report on the identified pilot projects for each sector, including budget, site design, logistics and biomass suppliers

This report focuses on output 3.1 whose main activities entailed identification of the energy demand by sector in the selected countries and a determination of which sectors the forest biomass potential can contribute, considering the current problem of traditional biomass consumption. Biomass energy is becoming an increasingly popular choice for providing an alternative fuel source to many sectors including the energy, agriculture, infrastructure and industry sectors. This is driven by the need to steer dependency away from fossil fuels towards a cleaner, more environmentally friendly source of energy. A sector focused assessment aimed at identifying the actual/potential demand of energy in each of the country's main economic sectors were carried out using the countries NDC report as the main reference. The result of an energy demand assessment is an important factor in deciding:

- If adequate renewable energy resources (biomass in this instance) are both available and adapted
- How much energy systems need to be able to produce?
- If other fuel sources would be needed.

In carrying out this study the characteristics that were taken into account in predicting energy demand included macro-socio-economic factors and community energy needs.

Socio-economic factors

These factors are changing the way the energy consumer baseline and consumer preferences evolve over long periods of time. Contextual factors include:

Demographic factors. These include projections of increased demand due to population growth and income growth. Projections are based on historical trends and incorporate variations in the types of fuels used as households become richer, the so-called "energy stacking."

Geographical factors. Geographical variations considering climate impacts as well as social and cultural practices. Variations affect demand and use of different types of fuel while shaping the types of resources available.

Economic factors. These included forecasts of expected trends in economic statistics such as GDP, consumer price indices, national income and income distribution. These statistics are solid indicators of likely growth in household consumption and productive use, as well as industrial energy consumption and its distribution among segments of society.

Political factors. These considerations assessed the impact of government policy and regulation, including taxes and subsidies. Although it is difficult to accurately assess, trends expressed through long-term government planning show priorities to support different aspects of the energy sector.

Community energy needs

Community needs assessment will reveal the amount of energy required for productive use, as energy demand increases. New businesses and their productive use needs will also need to be included. The energy needs of a community were understood as referring to uses/services such as:

- **Basic and lifestyle**: home cooking, lighting, entertainment, cooling/heating, appliances and communication). Most households have the same basic energy needs for cooking and lighting. End-use energy needs, on the other hand, aim to improve the measured quality of life in terms of convenience, entertainment and improved access to information and communication. Consumption levels vary by income and affordability. Household choices about the use of energy resources provide information on accessibility
- **Social and productive** (public lighting and electrification of schools or health centers as well as uses for services, industry and agriculture): Public services and facilities include evening street lighting, water pumping and energy for schools, health centers and social centers. Since the entire community uses these public services and facilities, the associated costs are borne by all households through village funds or local government budgets or grants. Public uses are not directly related to the income level of each household, but to the overall income of the community. Population growth and incomes are two macroeconomic factors that are behind the growth in demand for public energy.
- **Productive uses**. Productive uses of energy have a cumulative effect on income generation, livelihoods, employment opportunities and subsequent energy demand. In other words, funds invested in productive uses can create other benefits that, in turn, lead to increased use of energy services. For this reason, programs should assess the socio-economic impacts of productive uses of energy in a community.

Taking into consideration the above factors, this report made reference to the countries Nationally Determined Contributions (NDCs), which are the main instruments for implementing the Paris Agreement. NDCs carries the aspirations of the countries commitment to tackle climate change, including emissions mitigation pledges, and adaptation through various actions and investments that align with their development priorities. The energy sector is central to NDCs as the sector is responsible for nearly a third of global greenhouse gas (GHG) emissions. It is for this reason that CTCN working with central and West Africa countries focused on biomass energy conversion using forest residues as part of meeting increasing energy demand as African countries seek to harness synergies between development strategies and NDCs (Merrill, et al., 2017).

Below is a review of the energy demand by sector for the selected countries in Central African countries that include Cameroon, Chad, Equatorial Guinea, Central African Republic, Congo, Gabon, Democratic Republic of Congo.

1 Central Africa Countries

1.1 Cameroon

1.1.1 Energy resources

The main source of energy used in Cameroon is biomass. For cooking and heating, the majority of Cameroonians still depend on biomass, which is abundant and, in some cases, renewable and affordable. Electricity and gas are still very little used, mainly due to unavailability and lack of accessibility, especially in rural areas. According to Cameroon's Energy Situation (SEC) in 2011, the energy consumption mix was 73% biomass, 20% oil and gas products and 7% electricity totaling about 6000 Ktoe (kilo tons oil equivalent) for the whole country and converted to about 0.3 toe (tons of oil equivalent) per capita (Djouedjom & Zhao, 2018).

Biomass

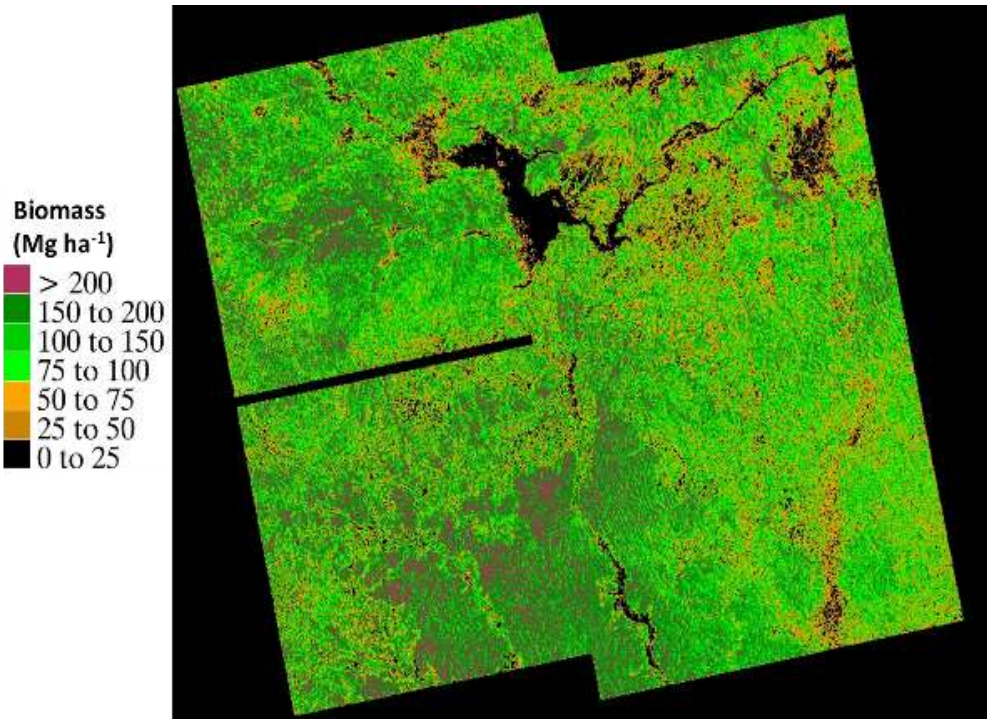


Figure 1: Map of biomass in Cameroon

Cameroon has the third largest biomass potential in Sub-Saharan Africa (Djouedjom & Zhao, 2018). Biomass sources can be classified as woody, agricultural, forest and animal sources. Waste streams from wood mills in the eastern region are sources that can be used to generate electricity. Rice paddies in Ndop in the Northwest Region are potential areas that can provide straw and waste to use in a biomass plant. Tree branches in the forest are forest sources of biomass. Cameroon's potential to generate electricity from biomass residues is estimated at about 1 GWh. A recent study by the Rural Electrification Agency identified 37 sites in 9 regions where energy can be produced from biomass (Djouedjom & Zhao, 2018).

Hydropower

Cameroon has the second largest hydroelectric potential in Africa after the Democratic Republic of Congo (DRC). The gross theoretical potential of Cameroonian hydropower is 294 TWh/year. Of this value, 115 TWh/year are considered technically feasible while 103 TWh/year are economically feasible. However, only 5.5% of the technically feasible capacity has been developed (Djouedjom & Zhao, 2018). In terms of the number of hydroelectric power plants, three main power plants are currently in operation in Cameroon. These are the hydroelectric power plants of Edea, Songloulou and Lagdo. The Edea hydroelectric plant has an installed generating capacity of 263 MW; Songloulou has an installed capacity of 387 MW while Lagdo on the Benue River has an installed capacity of 72 MW. Three large-scale hydroelectric projects are currently in various stages of development: Lom Pangar (30 MW), Memeve'ele (210 MW), Nachtigal (420 MW).

Solar

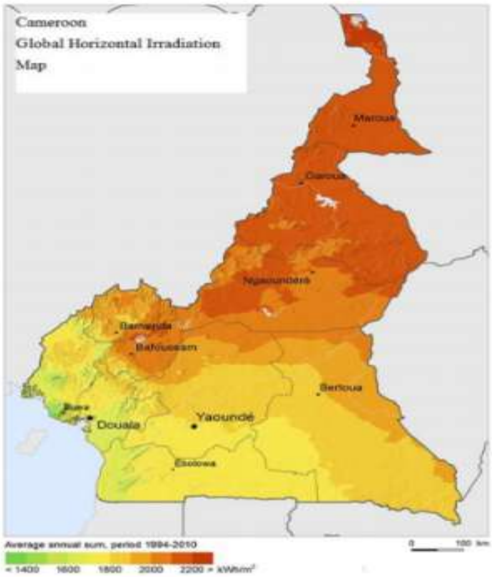


Figure 2: Map of Solar radiation in Cameroon

Solar radiation is important in the northern part of the country (5.8 kWh/day/m^2) (Djouedjom & Zhao, 2018) and to a lesser extent in the wet southern part of the country (4.5 kWh/day/m^2). Solar technology will see growing opportunities. In 2015, Cameroon signed a Memorandum of Understanding (MoU) with its first Independent Power Producer (IPP), Green quest Solar Corporation, to develop a 500 MW photovoltaic solar installation. This project will be located in the northern region of Cameroon and will be piloted with a 72 MW photovoltaic plant (Djouedjom & Zhao, 2018).

Wind turbine

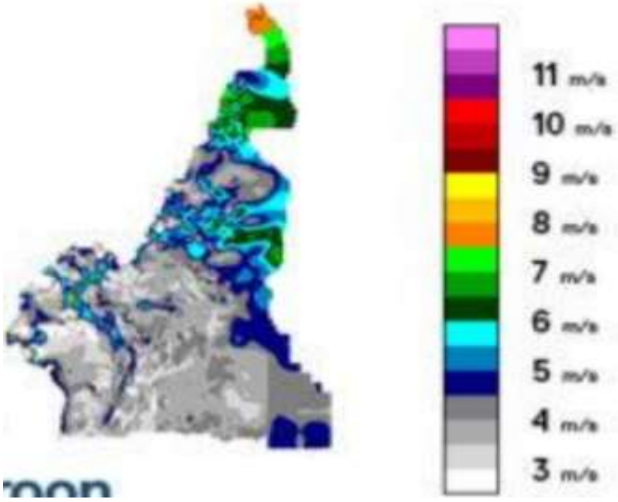


Figure 3: Map of wind speed variation in Cameroon

Wind potential exists in northern Cameroon and coastal areas with an average wind speed of 5 to 7 m/s at some favourable sites. In most areas, the average wind speed is only about 2 to 4 m/s at a height of 100 meters. Currently, two fast wind turbines are being installed in Douala and feasibility studies for a 42 MW wind project (extendable to 80 MW) are underway in the Bamboutos Mountains in western Cameroon (Djouedjom & Zhao, 2018).

Geothermal

Geothermal energy is one of the areas with the least literature in Cameroon. Even in the few documents that exist, the data is often contradictory, making it difficult to conclude about Cameroon's geothermal potential. There is mention of existing hot points in Ngaoundere in Adamawua, Mount Cameroon and Lake Moundou in Manengoumba (Abanda, 2012).

Oil and gas

Cameroon began producing offshore oil in 1977 (Encyclopedia of the Nations, 2020). Annual production has gradually declined since 1985, and the decline is expected to continue with the depletion of existing reserves. according to the Energy Information Administration (EIA) Cameroon is the sixth largest producer of crude oil in sub-Saharan Africa, with production in 2003 at 67,000 barrels per day (10,700 m^3 /d), and reserves estimated at 400 million barrels (64 × 106 m^3) as of 1 January 2004. The country has large reserves of liquefied petroleum gas, which are largely untapped. According to the EIA, Cameroon's natural gas reserves amounted to 3.9 billion cubic feet (110 × 106 m^3) as of January 1, 2004, with unknown production in 2002.

Tidal energy

Globally, ocean energy is in its infancy and knowledge about this energy resource is lacking. It is therefore difficult to find a detailed and comprehensive study of the global potential. Recent studies by the US Department of Energy indicate that only 40 sites in the world have tides with significant potential to generate electricity. As far as Africa is concerned, South Africa is the only country that has previously considered tidal energy, while Cameroon has so far hired MRS Power Cameroon, a subsidiary of MRS Holding Ltd., a fast-growing energy group in sub-Saharan Africa, to conduct a feasibility study on tidal energy potential (Abanda, 2012).
The table below gives the statistics of total energy (production and consumption) in Cameroon.

Table 1: Total Energy Statistics in Kilotonnes of Oil Equivalent (Ktoe)

Category / Catégorie	Unit	2000	2005	2013	2014	2015	2016	2017 P	2018 P
Production of Coal* Production de Charbon*	kt	-	-	-	-	-	-	-	-
Production of charcoal Production de charbon du bois	kt	372	381	457	477	477	486	486	506
Production of crude oil, NLG and additives Production du pétrole brut, LGN et additives	kt	5 783	4 531	3 367	3 814	4 726	4 673	3 894	4 063
Production of natural gas Production de gaz naturel	TJ	0	0	17 816	11 631	19 176	20 710	20 710	22 454
Production of electricity from biofuels and waste Production d'électricité par les biocarburants, déchets	GWh	0	0	68	72	3	4	4	4
Production of electricity from fossil fuels Production d'électricité avec combustibles fossiles	GWh	38	232	1 613	1 518	3 581	3 753	3 798	3 850
Production of nuclear electricity Production d'électricité d'origine nucléaire	GWh	0	0	0	0	0	0	0	0
Production of hydro electricity Production d'électricité d'origine hydraulique	GWh	3 092	3 913	4 231	4 562	4 359	4 611	4 787	4 975
Production of geothermal electricity Production d'électricité d'origine géothermique	GWh	0	0	0	0	0	0	0	0
Production of electricity from solar, wind, Etc. Production d'électricité d'origine solaire, éolienne, Etc.	GWh	0	0	64	68	71	74	77	81
Total production of electricity Production électrique totale	GWh	3 130	4 145	5 976	6 220	8 014	8 442	8 667	8 910
Refinery output of oil products Production de produits pétroliers en raffineries	kt	1 543	1 815	2 372	1 683	1 613	1 596	1 625	1 654
Final Consumption of Coal* Consommation finale de Charbon*	kt	-	-	-	-	-	-	-	-
Final consumption of oil Consommation finale de pétrole	kt	874	880	1 225	1 317	1 221	1 297	1 386	1 485
Final consumption of natural gas Consommation finale de gaz naturel	TJ	0	0	0	0	0	0	0	0
Final consumption of electricity Consommation finale d'électricité	GWh	2 718	3 306	5 214	5 485	6 071	6 425	6 694	6 991
Consumption of oil in industry Consommation industrielle de pétrole	kt	62	58	127	134	75	77	84	91
Consumption of natural gas in industry Consommation industrielle de gaz naturel	TJ	0	0	0	0	0	0	0	0
Consumption of electricity in industry Consommation industrielle d'électricité	GWh	1 516	1 485	2 842	3 011	3 408	3 582	3 665	3 754
Consumption of Coal* in industry Consommation industrielle de Charbon*	kt	0	0	0	0	0	0	0	0
Consumption of oil in transport Consommation de pétrole dans les transports	kt	587	666	970	1 052	1 017	1 032	1 110	1 197
Consumption of electricity in transport Consommation d'électricité dans les transports	GWh	-	-	-	-	-	-	-	-
Net Imports of Coal* Importations Nettes de Charbon*	kt	-	-	-	-	-	-	-	-
Net imports of crude oil, NGL, Etc. Importations nettes de pétrole brut, Etc.	kt	-4 154	-2 655	-995	-2 126	-2 853	-2 868	-2 798	-2 729
Net imports of oil product Importations nettes de produits pétroliers	kt	-571	-838	-356	228	285	296	288	281
Net imports of natural gas Importations nettes de gaz naturel	TJ	0	0	0	0	0	0	0	0
Net imports of electricity Importations nettes d'électricité	GWh	0	0	0	1 507	60	55	60	66

- Data not applicable / Données non applicables

0 Data not available / Données indisponibles

(P) : Projected / Projetées

Source: (AFREC, 2018)

1.1.2 Keys economics sectors according to Nationally Determined Contributions (NDC)

Table 2: Final energy consumption in Cameroon excluding biomass

Residential Tertiary Agriculture		Residential		Tertiary		Agriculture		Non-energy		2008
Mtoe	%	Mtoe	%	Mtoe	%	Mtoe	%	Mtoe	%	Unit
0,273	19,9	0,208	15,1	0,061	4,5	0,004	0,3	0,015	1,11	Cameroon

Source : (Gabriel, 2014)

Table 3: Cameroon's final energy consumption by production sector

2008	Population	Final energy consumption		Industry		Transport	
Unit	**Million**	**Total**	**By hab**				
		Mtoe	Tep	Mtoe	%	Mtoe	%
Cameroon	19	5,86	O.31	0,923	15,7	0,73	12,5

Source : (Gabriel, 2014)

Table 4: Final energy consumption by energy product

Coal		Biomass		Electricity		2008
Mtoe	**%**	**Mtoe**	**%**	**Mtoe**	**%**	
		4,5	**76,5**	**0,4**	**6,9**	**Cameroon**

Source : (Gabriel, 2014)

Table 5: Cameroon's energy balance

electricity	**total**	**Cameroun**
		for capita
Consummation	6.41 bn kWh	247.75 kWh
Production	8.11 bn kWh	313.34 kWh
Import	55.00 m kWh	2.13 kWh
Crude	**Barrel**	
		Cameroun
		for capita
Production	69,000.00 bbl	0.003 bbl
Import	36,480.00 bbl	0.001 bbl
Export	96,370.00 bbl	0.004 bbl
Natural gas	**Put cube**	
		Cameroun
		for capita
Consumption	906.10 m3	35.02 m³
Production	910.40 m3	35.18 m³

Source : (Data, n.d.)

Table 6: Structure of final energy consumption in Cameroon in 2010 (in Ktoe)

No	Sector	Oil product	Biomass	Electricity	Total	%

1	Industry	116,4	0,0	239,1	355,4	6,2
2	Transport	896,3	0,0	0,0	896,3	15,6
3	Other sectors	18,2	387,4	94,2	499,8	8,7
4	Residential	125,1	3785,6	84,8	3995,5	69,5
5	Total General	1155,9	4173,0	418,1	5747,0	100
6	%	20,1	72,6	7,3	100	

Source : (Ngoubou, 2013)

Table 7: Liquified Petroleum Gas (LPG) production statistics for Cameroon

Designation	LPG production by SNH (associated gas)	Predictable production of LPG by SONARA	GPL's predictable national offer
Unit	TM	TM	TM
2015	20 000	28 000	48 000
2020	200 000	28 000	228 000
2025	200 000	28 000	228 000
2030	200 000	28 000	228 000
2035	200 000	28 000	228 000

Source : (Gabriel, 2014)

Table 8: Energy Consumption Bill in 2010

No	**Energy**	**Final Consumption in Ktoe**	**Bill**	
			Million de CFA	**%**
	Firewood	3 981		**0%**
1	**Bought**	1 393	59 221	**13%**
	Not bought	2 587		**0%**
2	**Charcoal**	87	21 416	**2%**
3	**Sawdust and copuls**	106	530	**0%**
4	**Other biomass**	-	-	**0%**
5	**Total biomasse**	4 173	185 167	**16%**
6	**Oil**	1 156	647 924	**54%**
7	**AES Sonel (ancestor of ENEO)**	210	143 000	**12%**
8	**Auto production**	208	215 436	**18%**
9	**Total**	5 747	1 191 527	**100%**

Source : (Gabriel, 2014)

Public sector electricity demand (low voltage and medium voltage consumers), which is increasing by an average of 6% per year, is estimated at 4,700 GWh in 2015 and will grow to 7,600 GWh by 2025 (Republic of Cameroon, 2008).

Electricity demand is expected to continue to grow rapidly, with estimation of 750,000 connections by 2021. The government's plan to add 5,000 MW of generating capacity by 2020 was on a national and regional basis in response to demand (Ossono, 2014). But that plan has not been implemented.

Agriculture sector

The main challenges facing Cameroon's agriculture sector are the search for self-sufficiency, food security, the development of agribusiness and improved productivity and competitiveness. In Cameroon's NDC, four directions are well defined for developing the agricultural sector:

- Consistency in the planning and development of rural areas to develop agriculture while limiting deforestation/degradation.
- The intensification of environmentally friendly agricultural, animal and fisheries production to limit deforestation/degradation.
- Promoting practices to improve agricultural production capacity and enhance environmental resources.
- The energy development of rural resources with the use of waste as an energy source.

Energy demand in the sector: The use of energy in the agricultural sector has not been extensively studied, complicating attempts to project the future energy demand in agricultural sector in Cameroon.
Percentage of biomass used in the sector: The use of biomass in agriculture relies mainly on decomposition of dead biomass in compost and droppings in the fields. The use of energy from the conversion of biomass into agriculture in Cameroon is still in its infancy. Few studies have been done on this area and percentage data on bioenergy use in agriculture on this sector according to the energy demand in agriculture sector. Thereby, the best data is not available of our knowledge.
Contribution of forest bioenergy in the sector: Farmers especially in rural areas should be informed and trained on different energy sources, particularly renewable energy sources and energy efficiency options available to agricultural enterprises. In addition, farmers need to explore the renewable energy sources available to them. Thus, energy companies can outline the various options and possibilities on the exploitation of biomass as an energy source for the development of agriculture. As mentioned in report 2.1, biomass is the most abundant source of energy in Cameroon. In Report 2.2, several technologies can be adopted for the conversion of biomass into clean energy. In the agricultural sector biomass power plants can provide enough energy for pumping water for irrigating plants in arid areas, use for smart agriculture (in greenhouses), the operation of cold rooms allowing food preservation and limiting post-harvest losses, etc. Similarly, biomass can be used for biogas production and waste from it can be used as biofertilizer.

Mining and industry

The mining and industrial sector is one of the 12 economic sectors that were included in Cameroon's INDC. In 2012, the Ministry of Mines mentioned several mining projects under implementation in Cameroon. This includes the five mining licenses granted to Geovic for nickel, cobalt and manganese mining in Nkamouna (Lomié) and the five licences granted to C and K Mining Inc for the exploitation of diamonds and related substances in Mobilong (Yokadouma). In addition, three mining permits have been granted for the exploitation of limestone and marble. These include Cam Iron, a subsidiary of the Australian Sundance Resources for the exploitation of Mbalam iron and Cameroon Alumina Limited, which will develop the bauxite deposits of Mini Martap and Ngaoundal (Adamaoua). The Implementation of these projects requires an increase in the demand for energy in the beneficiaries' communities (MEW, 2006)
Energy demand in the mining sector: Industrial demand is highly conditioned by the energy needs of the aluminium industry, which currently is 1,315 GWh (or 150 MW). With the implementation of the Edea aluminium plant expansion project, this demand will grow up to around 500 MW by 2015. The implementation of the ambitious Bauxite-Aluminium development plan envisaged by the Government with its partners through the Greenfield project and the prospects for the development of the industrial zone of the future deep water port of Kribi will result in additional energy needs of more than 13,000 GWh (1500 MW) by 2016 by 2025. Industrial demand for high voltage electric energy will increase very strongly (aluminum) as well as demand for medium voltage for industries directly dependent on large projects (Republic of Cameroon, n.d). This additional demand will be calculated specifically and independently of the rate of GDP growth. In 2025, the electricity needs will be in the order of 25 TWh for the whole sector.

Table 9: Electricity demand forecast for the "Bauxite-Alumina-Aluminium" sector to 2030

Phases de développement de l'aluminium au Cameroun	Prévisions de la demande Filière « Aluminium»	Site d'Edéa : Passage de 145/185 à 450MW + Socatral (2MW) +2MW (HFO°			Sur le Site de Kribi			TOTAL			MW+
		Énergie (GWh)	Puissance (MW)	FC (%)	Énergie (GWh)	Puissance (MW)	FC (%)	Énergie (GWh)	Puissance (MW)	FC (%)	
1	2004	1 335	175	87%				1 335	175	87%	-
	2005	**1 335**	**187**	**81%**				**1 335**	**187**	**81%**	**12**
	2006	1 433	187	87%				1 433	187	87%	0
	2007	1 433	187	87%				1 433	187	87%	0
	2008	1 750	204	98%				1 750	204	98%	17
	2009	1 750	204	98%				1 750	204	98%	0
	2010	**3 975**	**454**	**100%**				**3 975**	**454**	**100%**	**248**
	2011	3 975	454	100%				3 975	454	100%	0
	2012	3 975	454	100%				3 975	454	100%	0
	2013	3 975	454	100%				3 975	454	100%	0
	2014	3 975	454	100%				3 975	454	100%	0
2	**2015**	**3 975**	**454**	**100%**	**6 517**	**800**	**93%**	**10 493**	**1 254**	**95%**	**800**
3	2020	3 975	454	100%	13 850	1700	93%	17 825	2 154	94%	**900**
4	2025	3 975	454	100%	20 774	2550	93%	24 750	3 004	94%	**850**
	2030	3 975	454	100%	20 774	2550	93%	24 750	3 004	94%	**0**

Source: (MEW, 2006)

Cameroon has significant potential for the production of cotton-based products with higher added value, particularly in the spinning, weaving and clothing manufacturing segments. Based on the local processing of half of cotton-fibre, consideration should be given to the provision of about 20 MW of electricity for industrial units engaged in such activities.

Percentage of biomass used in the sector: The energy consumed in the industrial sector is mainly supplied by petroleum and hydroelectric products. Biomass is not used in Cameroon as an energy source in the mining and industrial sector (Ngoubou, 2013).

Contribution of forest bioenergy: The ratio of energy demand to energy production in Cameroon is more than 1. This reflects the fact that the amount of energy provided does not fully meet the need. This deficit is more evident in mining industries. However, Cameroon is full of a large amount of biomass. According to the Ministry of Water and Energy, the rational consumption of Cameroonian biomass can enable the production of 420 MW via biomass power plants. This excess energy would fill the energy deficit in the industry and mining sector.

Table 10: Synthesis of energy demand for industrial projects other than the aluminium sector

Projet industriel	Demande en puissance (MW)
Industrie lourde	
Développement d'un complexe sidérurgique à Kribi	80 / 160
Industrie légère	
Mise en valeur de la vallée de la Bénoué	50
Raffinerie de pétrole	35
Filière « Coton-textile-confection »	20
Filière « bois »	50
Fabrication d'engrais, d'urée et d'ammoniac	20 / 30
Deuxième cimenterie	4 / 5
Sous-total industrie légère	180 / 190
Grand Total	**260 / 350**

Source : (MEW, 2006)

Forestry sector

As described in Cameroon's NDC, the forestry sector faces major challenges. The main challenge is to ensure the sustainable management of forests and the enhancement of productive forests under management plans, contribution to economic growth and the fight against poverty through the return of part of tax revenues to communities, job creation, Conservation of biodiversity through the strengthening of the national network of protected areas, consistency of the land system through zoning plans. Energy consumption in the forestry sector is dominated by wood forest processing industries.

Energy demand in the forestry sector: The estimated energy in the forestry sector in Cameroon is that used in the extraction and processing industries of wood and non-wood forest products. Primary energy is mainly used for wood logging and processing activities. A study conducted by SFID shows that the transformation of one cubic meter of wood requires about 15 liters of diesel. The exploitation of non-wood forest products in Cameroon is limited to extraction, conservation and sale. The low processing rate is linked to low access to energy and a lack of transportation of products from harvest sites to potential processing sites. In this context, the functioning of all the timber industries would result in an additional need of at least 50 MW over the next five to ten years as part of a proactive policy to promote the timber sector, based on incentives to attract private investors to the subsector (GTZ, n.d).

Percentage of biomass used in the sector: The use of biomass in Cameroon is mainly traditional. The use of biomass as an energy source in the forestry sector in Cameroon is almost nil. Biomass is used in the forestry sector in Cameroon for minimal heat needs.

Contribution of forest bioenergy in the sector: With more than 2 million tons of waste produced in Cameroon per year, several cogeneration systems can be installed and exploited. The production of heat and electricity by these cogeneration systems will not meet the energy needs of logging companies.

Transportation sector

As mentioned in Cameroon's INDC (Intended Nationally Determined Contribution) (Republic of Cameroon, 2015), the transport sector should:

- Limit constrained mobility and promote low-carbon transport

- Promote an integrated approach to the sector and the development of low-carbon transport through a National Transport Infrastructure Scheme
- Incorporate an energy/climate dimension into territorial planning documents in an attempt to limit distances, work on functional mix and propose efficient transit policies
- To assist the State and local authorities in the development of low-carbon intra- and intercity public transport development plans (formerly the Yaoundé and Douala trams)
- Promote the purchase of low-emission vehicles and the disposal of the most polluting vehicles through standards, incentives or obligations

Oil is the main source of energy used in the transportation sector. The energy demand is steadily rising.
Energy demand: Cameroon's oil production in 2010 was about 3.3 million tons. TOTAL Exploration-Production remains the largest producer with 61% of the shares. This production continues the downward trend that began in 1985, when Cameroon peaked oil. Between 2001 and 2010, Cameroon's oil production fell by more than 40%. However, the intensification of oil exploration, propelled in recent years by the National Hydrocarbon Company (NHC), augurs an inflection of this downward trend. According to the study on the optimization of the supply of petroleum products (CSPH, 2005), consumption of petroleum products would double over the next 20 years, from 983,409 to 1,732,202 tons from 2005 to 2025. The supply situation in relation to the evolution of consumption indicates increasing deficits on the horizon (MEW, 2006).

Percentage of biomass used in the transport sector: The use of biomass energy in Cameroon's transport sector is in an embryonic state. The percentage of biomass used is almost null. The few cases observed concern the production of bioethanol from biomass. The biomass produced is not enough to sufficiently serve the transport sector.

Contribution of forest bioenergy in the transport sector: The development of an economically viable process for producing liquid biofuels from cellulose could lead to the widespread use of forest biomass in the transport sector. As most of the growth in demand for liquid biofuels is expected in developed countries, trade flexibility is the main factor affecting development plans in most developing countries (FAO, 2008).

Institutional and domestic sector

According to the 2008 Ministry of Water Resources and Energy Survey on Domestic Energy Consumption, 60% of firewood is purchased while the rest is acquired through non-commercial channels. By bringing the final consumption and energy bills closer together, it appears that biomass, which accounts for more than 73% of the energy consumed in Cameroon, accounts for about 16% of national energy expenditure. On the other hand, commercial energy, which accounts for less than 27% in volume, covers 84% of the national energy bill.

Energy demand: The study's long-term consumption projections (15 years) projected a potential consumption of between 78,000 and 166,000 tons, depending on the scenarios. These projections are based on the continuation of the historical series observed, i.e. the continuation of consumption in urban areas, combined with an increase in consumption in rural areas, in line with the policy of poverty reduction. We believe that the high hypothesis is the most likely, and that the total consumption potential is probably greater. In fact, there is considerable potential in northern Cameroon, where the development of LPG can effectively help to curb the phenomenon of deforestation caused by the massive and harmful use of biomass (firewood and charcoal) to meet domestic needs.
Taking the estimated ratio in the study for the specific consumption of the tertiary sector (7%), there is still about 155,000 tons left for the residential sector. Considering that the development of the LPG market will be in favour of an increase in the number of households that have access to it, and by estimating, a doubling in 15 years of the number of households (about 1 million in 2020), the unit consumption per household would increase to 155 kg per year, or about one bottle per month. Although well above the 2002 average, this figure remains modest and is at the lower end of the range compared to unit consumption in other countries with similar levels of development (between 1 and 2 bottles per household per month).

In Cameroon, where nearly 80% of energy consumption is non-domestic and more than 70% is directly related to economic activities, it is mainly the growth of high-consumption industries that will determine future demand. Domestic consumption, which in 2004 represented only 20% of total demand, will remain relatively unimportant on the growth of demand in the medium term.

Percentage of biomass used: Wood-energy, both in rural and urban areas, remains the main energy resource in Cameroon. In 2010, it accounted for 72.6% of total energy consumption, compared with 20.1% for oil and gas products and 7.3% for electricity in households. This can be explained by the accessibility of this form of energy and the importance of its use. The energy balance for 2010 shows that energy wood production was estimated at 13,163 Ktoe, slightly up from 13,118 Ktoe in 2009 and distributed as shown in Figure 4 in 2010 (Gabriel, 2014).

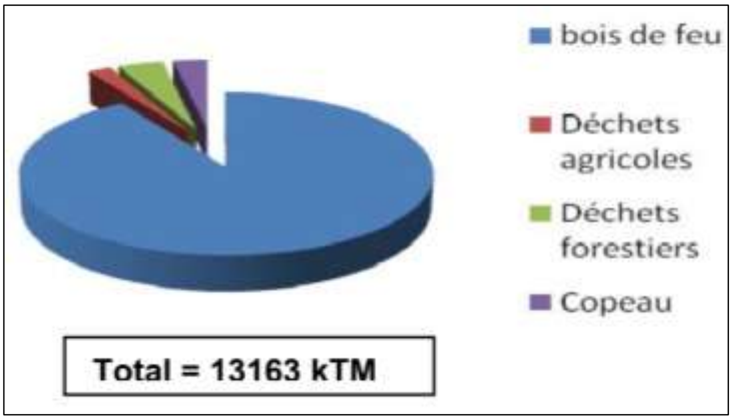


Figure 4: Distribution of wood energy production by nature

Contribution of forest bioenergy in the sector: Implementation of various biomass technologies in Cameroon would make it possible to better exploit biomass potential with better efficiency.

- The construction of isolated biomass power plants in off-grid rural areas would increase access to electricity to households
- The construction of bio-digesters would allow for both domestic gas for cooking and heating and electricity to power electronic devices and lighting in households.

1.1.3 Conclusion and Recommendation

The total energy supply in the Republic of Cameroon may in future not be able to sufficiently meet the demand of a rapidly rising population. This is one of the reasons why the energy produced in Cameroon is directed towards urban areas where the industrial sector is in perpetual growth, without forgetting the rate of residence in urban areas which increases with the rural -urban migration. These arguments justify the poor access to energy in rural areas.

Thus, the industrial sector and the residential sector are the most energy consumer sectors in Cameroon. The demand for energy is in these sectors is very high. Cameroon in his INDC wants to reduce its GHG emissions by -32%. To achieve this, the use of renewable sources is one of the solutions. The conversion of biomass which is a source of renewable energy into a form of sustainable energy can help to fill the deficit observed in the electricity grid of Cameroon and thus increase the rate of access to energy in both urban and rural areas.

The East and South Region, for example, are home to the largest forest concessions and an abundance of Wood Processing Units (WPU). These are therefore the two regions with large forest biomass hot spots and also regions with poor access to energy.

Combustion technology used in biomass power plants can be implemented in these regions to generate electrical energy. This waste can be valorised by the production of ecological charcoal for cooking and heating;

the fermentation of the wood waste also can allow the production of biogas, bioethanol used in several sectors, the resulting compost may be used in agriculture sector.

1.2 Democratic Republic of Congo (DRC)

1.2.1 Energy Resources

Electricity production in 2015 was 676 Ktoe (kilo tons oil equivalent), of which 99.7% was generated from hydroelectric sources. The final electricity consumption in the same year was 613 Ktoe.

Biomass

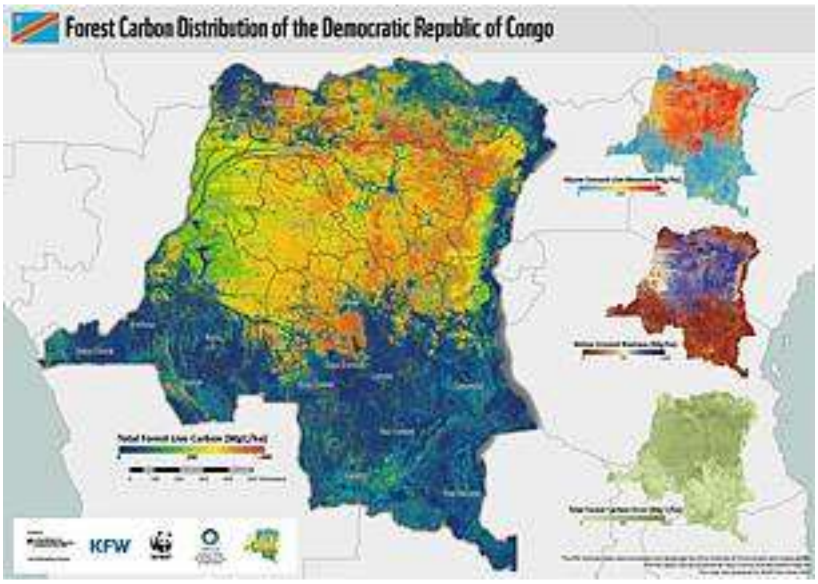


Figure 5: Map of biomass in the Democratic Republic of Congo

Source : (WWF, 2017)

The different categories of biomass that can be used for energy production in the DRC are presented below.

Firewood

The DRC has about 125 million hectares of forest representing 67.9% of the country's area (Kusakana, 2016) The biofuels used are mainly firewood and charcoal. These fuels provide most of the energy used by households, especially for cooking. According to 1985 data, the consumption of these eco-banks amounted to 8.5 million toes (tons of oil equivalent), or 86% of the total energy used in the DRC (Kusakana, 2016).

Biogas

It is a renewable energy source and can be used as fuel for heating, cooking and generating electricity. The raw materials used for biogas generation are plants, animal waste and landfills (where municipal solid waste is dumped). The list of raw materials that can be used to produce biogas is enormous. Studies have shown that the use of landfill gas for energy production is a viable option for the DRC. Currently, biogas production in the DRC is in an experimental phase due to the high cost of biogas plants and the lack of training of users and maintenance technicians (Kusakana, 2016).

Biofuel

The DRC has great potential for biofuel, particularly ethanol, from the sugar industries and molasses distilleries. The main use of ethanol is fuel for engines and fuel additives. (Kusakana, 2016).

Hydropower

Figure 6: A hydro power plant Source: World Wind Map

The DRC has a very large hydroelectric potential, estimated at 774 GWh, corresponding to nearly 65% of the potential of Central Africa, 35% of Africa's potential and 8% of the world's annual potential. This important hydroelectric resource is the result of the country's geographical location in the Congo River watershed. Hydropower is the main source of electricity in the DRC and there is enormous potential to develop micro-scale hydropower plants with an estimated minimum operating capacity of 88,400 MW and an export capacity of 51.9 TWh/year (WEC, 2005). The current level of operation represents about 3% of the economically exploitable capacity. The national electricity organization has 17 hydroelectric plants with a total nominal capacity of 2,410 MW. The two largest are Inga 1 (351 MW) and Inga 2 (1424 MW) with new Inga 3 (4320 MW) and Inga 4 plants in the planning phase (Kusakana, 2016; UNEP, 2017).

Solar

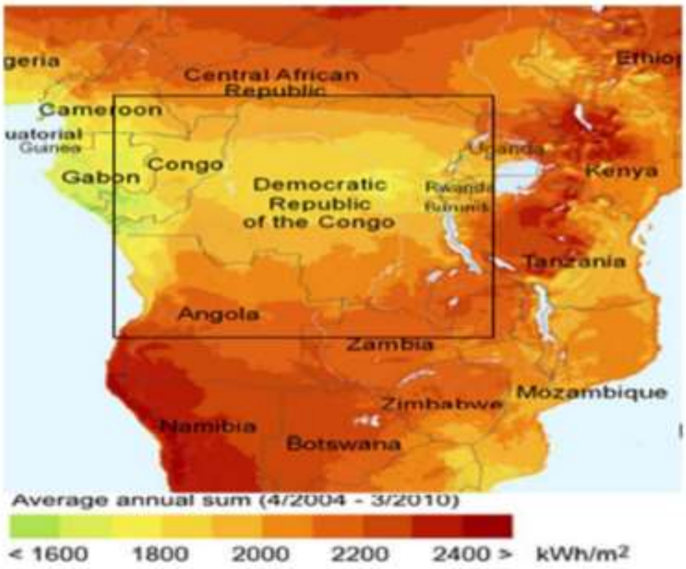


Fig. 5 DRC solar map

Figure 7: Map of solar variation in Africa with Democratic Republic of Congo at the inset

The DRC is located in a very insolated region with radiation levels between 3.25 and 6.0kWh/m2/day, making the implementation of photovoltaic (PV) solar panels viable throughout the country. Currently, only 836 photovoltaic solar systems with a total capacity of 83 kW are in service. There are also 148 Caritas network systems, with an estimated capacity of 6.31 kW. We note that the penetration of solar PV systems is very low in relation to the size of the country and in relation to the availability of this energy resource (Kusakana, 2016).

Wind turbine

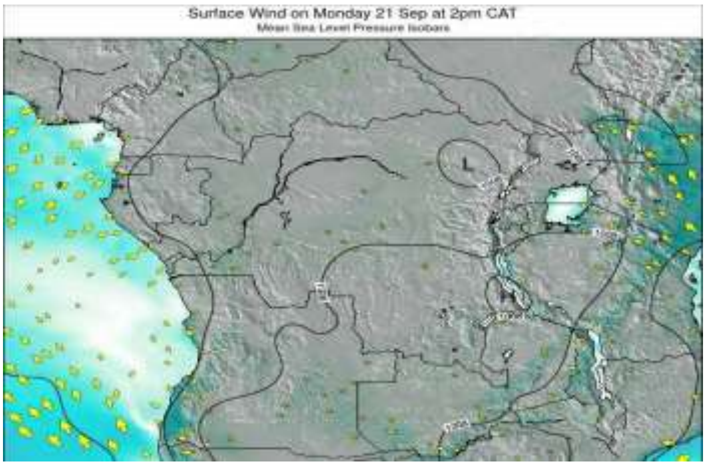


Figure 8: Map of wind speed variation in the Democratic Republic of Congo

The DRC generally has a low wind speed potential ranging from 1.5 m/s to Matadi, 1.7 m/s to Gimbi and 1.8 m/s to Kalemie and Goma. Ugoma makes the difference with wind speed ranging from 6 to 6.6 m/s. Wind energy is not commonly used in the DRC except in a few isolated cases where it is used for windmills to pump groundwater or for small lighting systems. The country's potential wind energy is estimated at about 77,380 MW. However, further studies are needed to determine how much of this potential can be economically exploited (Kusakana, 2016).

Geothermal

The eastern regions of the DRC are part of the East African Rift System, which is one of the largest tectonic structures in the world, where the thermal energy of the Earth's core crosses the surface. As a result, the DRC has significant geothermal energy potential. Two suitable sites, Nyangezi and Uvira/Kinanira/Kavimvira, which have maximum temperatures hot spots of up to 90 degrees Celsius and an average flows ranging from 11 to 162 L/s, have been identified in the eastern part of the country.

Oil and gas

The DRC has oil reserves in the western coastal basin (offshore and onshore) and two virtually unexplored sedimentary basins. In 2009, the country's crude oil reserve of about 180 million barrels was the second largest in southern Africa after Angola. The DRC has a significant production capacity for crude oil. However, the country does not have refineries and must therefore export all production and import refined products for local use.

Lake Kivu (which is shared with Rwanda) contains methane gas reserves of 65 billion m^3, the equivalent of 50 million tons of oil, which are at depths above 300 meters, and remain untapped. The methane reserve in Lake Kivu is the only case of gas dissolved in water in the world. Studies on Lake Kivu have shown that the amount of methane in the bottom of the lake has increased by 30% over the past 30 years due to volcanic activity in the region, as well as the introduction of sardine fish into the lake (Kusakana, 2016).

Nuclear energy

The DRC has a reserve of approximately 1,800 tons of unexploited high-concentration Uranium deposits mainly around seven sites in the southern region of Katanga province: Shinkolobwe, Kalongwe, Lwambo, Mindigi, Kalongwe, Kasompi and Samboa. The DRC's nuclear energy is managed by the Office of the General Atomic Energy Commissioner (CGEA), which is mandated to develop the country's Uranium sector by exploring and exploiting uranium deposits. However, the current activities of the CGEA are limited in terms of research, oversight and regulation. Two research reactors were built in 1958 and 1972 (Atomic Energy Centre), but both were closed in 1998 at the request of the International Atomic Energy Agency (IAEA) for safety reasons (Kusakana, 2016).
The table below shows energy production and energy consumption in the DRC.

Table 11: Total Energy Statistics for the Democratic Republic of Congo in Kilo tonnes of Oil Equivalent (Ktoe)

D.R.of Congo / R.D. du Congo

Category / Catégorie	Unit	2000	2005	2013	2014	2015	2016	2017 P	2018 P
Production of Coal* Production de Charbon*	kt	106	132	0	0	0	0	0	0
Production of charcoal Production de charbon du bois	kt	283	615	3 674	3 803	3 841	4 074	4 129	4 185
Production of crude oil, NLG and additives Production du pétrole brut, LGN et additives	kt	1 169	1 269	1 129	1 061	1 048	996	946	957
Production of natural gas Production de gaz naturel	TJ	0	0	0	0	46	14	0	0
Production of electricity from biofuels and waste Production d'électricité par les biocarburants, déchets	GWh	0	0	0	9	21	22	23	24
Production of electricity from fossil fuels Production d'électricité avec combustibles fossiles	GWh	19	23	9	11	16	14	14	14
Production of nuclear electricity Production d'électricité d'origine nucléaire	GWh	0	0	0	0	0	0	0	0
Production of hydro electricity Production d'électricité d'origine hydraulique	GWh	6 001	7 396	8 231	8 820	8 916	9 099	9 770	10 516
Production of geothermal electricity Production d'électricité d'origine géothermique	GWh	-	-	-	-	-	-	-	-
Production of electricity from solar, wind, Etc. Production d'électricité d'origine solaire, éolienne, Etc.	GWh	0	0	5	7	7	8	8	8
Total production of electricity Production électrique totale	GWh	6 020	7 419	8 245	8 847	8 960	9 143	9 815	10 562
Refinery output of oil products Production de produits pétroliers en raffineries	kt	-	-	-	-	-	-	-	-
Final Consumption of Coal* Consommation finale de Charbon*	kt	0	0	0	0	0	0	0	0
Final consumption of oil Consommation finale de pétrole	kt	269	404	1 096	1 467	863	626	658	693
Final consumption of natural gas Consommation finale de gaz naturel	TJ	0	0	0	0	0	0	0	0
Final consumption of electricity Consommation finale d'électricité	GWh	4 533	4 883	7 252	7 899	7 376	7 001	7 224	7 457
Consumption of oil in industry Consommation industrielle de pétrole	kt	14	42	41	41	20	26	27	29
Consumption of natural gas in industry Consommation industrielle de gaz naturel	TJ	0	0	0	0	0	0	0	0
Consumption of electricity in industry Consommation industrielle d'électricité	GWh	1 890	3 094	3 243	4 342	3 994	3 848	3 979	4 115
Consumption of Coal* in industry Consommation industrielle de Charbon*	kt	0	0	0	0	0	0	0	0
Consumption of oil in transport Consommation de pétrole dans les transports	kt	250	351	1 045	1 423	841	599	630	663
Consumption of electricity in transport Consommation d'électricité dans les transports	GWh	0	0	0	0	0	0	0	0
Net Imports of Coal* Importations Nettes de Charbon*	kt	0	0	0	0	0	0	0	0
Net imports of crude oil, NGL, Etc. Importations nettes de pétrole brut, Etc.	kt	-1 186	-1 269	-1 129	-1 061	-1 048	-996	-984	-973
Net imports of oil product Importations nettes de produits pétroliers	kt	344	563	1 247	1 697	985	743	795	850
Net imports of natural gas Importations nettes de gaz naturel	TJ	0	0	0	80	46	38	38	38
Net imports of electricity Importations nettes d'électricité	GWh	-4 540	-5 507	-8	1 069	-402	-400	-392	-384

- Data not applicable / Données non applicables
0 Data not available / Données indisponibles
(P) : Projected / Projetées

Source : (AFREC, 2018)

1.2.2 Key economic sectors as per the Nationally Determined Contributions (NDCs)

The DRC's INDC refers to four priority areas of activity that are more vulnerable to climate change. It is the transport sector (civil aviation, road transport), energy, industry (the most important being the cement production industry), agriculture and the waste sector. The GHG adaptation, mitigation and reduction plan requires the implementation of new technologies in new processes that would also, to some extent, increase the country's GDP and consequently the country's economic and social growth. However, access to energy is one of the priorities to achieve this goal. The DRC's energy demand since 2005 has been increasing. Energy demand is not limited to these four sectors.

2.2.2.1. Forestry

Energy demand: In the DRC, industry, transport and the residential sector together account for more than 99% of final energy consumption, with the remainder less than one per cent coming from agricultural, livestock, fishing and agroforestry sectors. This is an indicator of the low mechanization of Congolese agriculture in general (agricultural machinery) and the low use of technologies for processing and conserving agricultural products in the broadest sense (agriculture, forest, fishing and livestock).

The supply of electricity includes domestic production, which mainly makes up hydroelectric, thermal and imports from the DRC. The significant investments made by the Congolese Government in recent years have led to a nearly seven-fold increase in national energy production capacity from 89 MW in 2001 to 600 MW in 2011 (excluding the oil and forestry sector). The available supply covers the potential demand for the interconnected electricity grid, which is estimated at 360 MW (Ngoubou, 2013).
In the wake of the DRC's population growth and reconstruction, there is no doubt that energy demand will be resolutely on the rise. Table 11 below presents a simulation carried out by the Ministry of Energy following the Energy Demand Analysis Model (MAED) developed by the International Atomic Energy Agency (IAEA). This model assesses future energy demand on the basis of several parameters and factors such as socio-economic, demographic and other specificities of the country (Esseqqat, 2011).

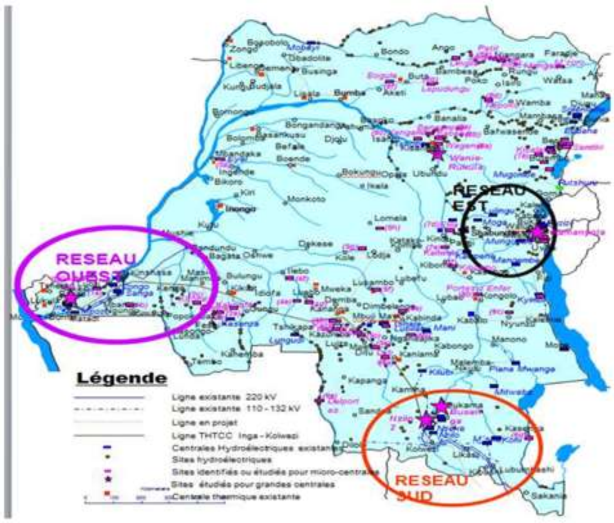


Figure 9: Map of the Democratic Republic of Congo

Table 12: Electricity demand summary following three growth scenarios

Item	Unité	2005	2010	2015	2020	2025	2030
Industrie							
Faible croissance	GWh	2'490'326	3'449'192	5'742'639	9'800'528	17'141'430	30'947'732
Croissance de base	GWh	2'490'326	4'441'712	8'348'222	15'984'283	31'904'305	62'529'135
Forte croissance	GWh	2'490'326	5'031'886	10'166'710	21'847'773	49'918'929	121'220'333
Transport							
Faible croissance	GWh	2'487	14'961	44'722	148'947	242'313	335'643
Croissance de base	GWh	2'487	15'298	45'392	150'215	244'812	341'333
Forte croissance	GWh	2'487	18'470	52'391	160'687	279'111	385'590
Ménages							
Faible croissance	GWh	2'201'082	4'135'048	11'480'187	18'497'992	28'155'558	48'781'342
Croissance de base	GWh	2'201'082	4'925'434	11'640'764	22'809'205	39'462'932	68'740'595
Forte croissance	GWh	2'201'082	7'515'363	23'185'713	32'525'276	50'672'589	80'958'709
Services							
Faible croissance	GWh	760'311	994'743	1'496'818	2'341'350	3'581'715	5'754'518
Croissance de base	GWh	760'311	1'052'135	1'569'774	2'455'302	3'988'379	7'238'945
Forte croissance	GWh	760'311	1'089'438	1'734'297	2'813'328	5'076'088	8'930'258
Total							
Faible croissance	GWh	**5'454'205**	**8'593'944**	**18'764'365**	**30'788'816**	**49'121'016**	**85'819'235**
Croissance de base	GWh	**5'454'205**	**10'434'579**	**21'604'153**	**41'399'006**	**75'600'428**	**138'850'007**
Forte croissance	GWh	**5'454'205**	**13'655'157**	**35'139'112**	**57'347'064**	**105'946'717**	**211'494'890**

Source : (Esseqqat, 2011)

Universal access to electricity by 2030 would mean that the DRC will move to an electrification rate:

- From 9% in 2011 to 100% in 2030 at the national level,
- From 35% in 2011 to 100% in 2030 in the urban area,
- From 1% in 2011 to 100% in 2030 in the rural area.

But to achieve this goal of universal electrification in the DRC by 2030, the final electricity consumption would then be in the order of 149,528 Gwh in 2030 (or 12,858 Ktoe), a 23.8-fold increase in the total final electricity consumption level of 2011; or by 11.25 times the average final electricity consumption per capita increase from 0.008 toe per capita (or 1,394 kWh/year/hbt) in 2011 to 0.09 toe per capita (or 15,685 kWh/year/hbt) in 2030.
The capacity required to meet such demand, with the assumption of improvements in the energy efficiency of the electricity subsector, would be in the order of 32,965 MW, an increase of about 23.8 times the capacity required in 2011 (1,387 MW) or by 12.7 times the capacity already installed in 2011 (2,589 MW). These 32,965 MW will be divided between domestically produced hydropower, electricity imports within interconnected networks through sub-regional energy cooperation, public and private thermal production, and new and renewable power plants (solar, wind biofuels, etc.) (UNDP, 2013).

Percentage of biomass in energy production in DRC: Primary energy production in 2011 is estimated at approximately 23,434 Ktoe, of which 22,781 Ktoe (97.2%) are 653 Ktoe in electricity (2.8%). Net supply for national energy needs (gross primary consumption) is estimated at 24,116 ktoe in 2011, of which 94.5% is biomass (22,781 ktoe), 3.1% of petroleum products (746.Ktoe) and 2.4% is electricity (589.Ktoe).
The DRC's energy consumption (total final consumption) in 2008 was 21.7 million Mega tons of oil equivalent, of which about 75% for domestic use, 22% for industrial use and 1% for transport (IEA 2011). Biomass (including wood energy) is estimated to cover 93% of the country's energy consumption, followed by hydropower with 4%, oil with 3% and mineral coal with 1% (Ministry of Energy, 2009). More than 90% of the demand for this form of energy is in the household sector.
Biomass remains the main source of energy for cooking for more than 93% of the DRC's population. Households and street food vendors rely heavily on coal (or firewood) for daily cooking (77% in Kinshasa). Businesses, such

as bakeries, breweries, restaurants, bricklayers and aluminum smelters, also depend on firewood or charcoal for their daily work (REDD+ International, 2015).
According to the latest Energy Information System 2010 report by the CNE, biomass accounts for 95% of the DRC's overall energy balance. The DRC's demand for domestic energy biomass is 45 million cubic metres of wood per year (UNDP, 2013).

Contribution of forest bioenergy in the sector: In the DRC, yields on the use of traditional fuels through "three-stone fireplaces" or "metal braziers" are very low, between 5 and 7% and between 12% and 15% energy efficiency, respectively. The biomass-energy sectors contain several important areas of application of technologies and know-how to improve the energy efficiency of energy production and consumption methods. Like most African countries, energy efficiency programmes are still in their infancy in the DRC, with the exception of more than 30 years of action to promote improved fireplaces (wood and charcoal) and wood carbonization technologies. In addition to these improved technologies, the implementation of biomass power plants with large capacities would be all the more effective in filling the gap in the country's energy mix. The energy produced from biomass power plants could thus be used in the agriculture and livestock sector (feeding water pumping systems, irrigation, cold rooms, etc.), the transport sector (biofuel production), the industrial sector. The implementation of cogeneration systems allows the production of energy that would feed not only companies operating in the forestry sector (wood processing) but also households close to forest waste production sites. Biogas produced from forest biomass would increase the production of gas for cooking food and heating homes and electricity for lighting and powering electronic devices (UNDP, 2013).

1.2.3 Conclusion and Recommendation

DRC is a country marked by its richness in natural resources due to its large forest area. However, it is one of the poorest countries in Central Africa. Like other countries in the sub-region, the population growth of the DRC continues to increase, and the direct consequence is the rise in energy demand. Hydroelectric power is the main source of energy that feeds the country's electricity grid. On the other hand, bioenergy is the most widely used source of energy in rural areas. The other sources of energy like gas, charcoal, oil is used mainly in urban areas for cooking and also in industry. The cleaner fuels, such as gas and oil are mainly used in urban areas for purposes such as cooking, industry among others. The percentage of biomass in the DRC's energy mix justifies the observed deforestation rate.
The residential sector and the industrial sector are the most energy intensive sectors in thecountry. However, we see that the development of these sectors is not enough. The ratio between supply and demand shows that there is a large energy deficit. Considering the context of the fight against climate change, reducing GHG emissions is essential. To achieve this, the DRC in its INDC plans to look at the use of renewable energy sources such as biomass.
Kinshasa, Kisangani, Mbuji-Mayi are the main localities which are home to the majority of logging companies. Therefore, these are the great hot spots of biomass residues in the DRC. Wood waste in these localities are in significant quantities and can be exploited to fill the energy deficit observed in the DRC.
Combustion and fermentation are the main technologies easily implemented for the production of bioenergy. The combustion used in biomass power plants makes it possible to produce electricity and feed it into the electricity grid. Biogas, biofuel and compost from the fermentation of wood waste can contribute to the development of several activities in the DRC.

1.3 The Republic of Congo

1.3.1 Energy Resources

Congo has significant energy resources of hydropower, oil, natural gas and firewood. The total supply of primary energy in Congo is estimated at 2637 ktoe, while the total final consumption amounts to 1769 ktoe[1]

2.2.2.2. Biomass

Congo is largely covered by forest (60% of the national territory) which accounts for 10% of all tropical rainforests. They are divided into three main massifs: the Mayombe (2 million ha) the Challu (3 million ha) and the North Congo (15 million ha). The potential biomass productivity in Congo's tropical forests is among the highest in the world. Wood-energy is the fuel par excellence of households (more than 80% of total energy consumption). Large consumption centers are fed by informal channels. Charcoal is produced from traditional low-yielding millstones (10-15%) (Ngoubou, 2013).

2.2.2.3. Hydropower

The Republic of Congo has a dense water system that is organized around two main river basins: the Congo River basin, which occupies about 72% of the country's total area, and the Kouilou-Niari basin, covering about 16%. To these two basins it is necessary to add smaller coastal basins: the basins of the Loémé, upper Nyanga, upper Ogooué, and Chilango. Despite the importance of Congo's water system, the hydraulic potential for electricity generation is not yet fully exploited. Out of an estimated hydroelectric potential of 14,000 MW, the installed capacity is 209 MW. Only the Moukoukoulou hydroelectric sites (74 MW) in the department of Bouenza, Djoué (15 MW) in Brazzaville and Imboulou (120 MW) in the Department of the North Pool are operational (Ngoubou, 2013).

2.2.2.4. Solar

In gross terms, the average sunshine in Congo represents a potential of 4.5 kWh/m^2/day, compared to only 3 kWh/m^2/day in the European temperate zone. This important sunshine and the real prospect of reducing the costs of photovoltaic technology lead to a very significant contribution of solar energy to rural people's access to a basic energy service (Ngoubou, 2013).

2.2.2.5. Wind

The only wind measurements available come from the Agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA) synoptic stations (measures at 10-12 m). These measurements indicate that the potential is not appreciable and wind speeds, in the order of 2 m/s, are not constant throughout the year. At such wind speeds, wind energy is currently not viable.

2.2.2.6. Oil and gas

According to the EIA, which cites the Journal of Oil and Gas as a source (January 2016), Congo has large oil reserves of up to 1.6 billion barrels. Indeed, the most influential oil companies operate in the country, including the French Total and the Italian Eni, present in Congo since 1968. The Moho Bilondo offshore oil field, for example, between the end of 2008 and 2010 was the oil reserve that contributed the most to oil production.

[1] *RAPPORT ANNUEL SIE-CONGO 2013*

Another major offshore oil field, between Congo and Angola, whose two countries have agreed to share its profits, is Lianzi, with reserves of about 70 million barrels (Louvel et al. 2017)

Natural gas is also present in considerable quantities, but the absence of a distribution network does not allow for real commercial exploitation. For these reasons, much of the associated gas is re-injected into oil wells (About Energy, n.d.).

The table below shows energy production and energy consumption in Congo.

Table 13: Total Energy Statistics for Republic of Congo in Kilo tonnes of Oil Equivalent (Ktoe)

Congo / Congo

Category / Catégorie	Unit	2000	2005	2013	2014	2015	2016	2017 P	2018 P
Production of Coal* Production de Charbon*	kt	-	-	-	-	-	-	-	-
Production of charcoal Production de charbon du bois	kt	147	171	200	206	210	213	217	221
Production of crude oil, NLG and additives Production du pétrole brut, LGN et additives	kt	13 609	12 594	12 754	13 539	12 605	12 760	14 919	15 116
Production of natural gas Production de gaz naturel	TJ	0	2 093	8 584	9 166	9 410	9 923	9 845	10 237
Production of electricity from biofuels and waste Production d'électricité par les biocarburants, déchets	GWh	0	0	0	0	0	0	0	0
Production of electricity from fossil fuels Production d'électricité avec combustibles fossiles	GWh	1	73	543	788	806	794	817	843
Production of nuclear electricity Production d'électricité d'origine nucléaire	GWh	-	-	-	-	-	-	-	-
Production of hydro electricity Production d'électricité d'origine hydraulique	GWh	298	355	971	952	925	959	1 012	1 073
Production of geothermal electricity Production d'électricité d'origine géothermique	GWh	-	-	-	-	-	-	-	-
Production of electricity from solar, wind, Etc. Production d'électricité d'origine solaire, éolienne, Etc.	GWh	0	0	0	0	0	0	0	0
Total production of electricity Production électrique totale	GWh	299	428	1 514	1 740	1 731	1 753	1 829	1 916
Refinery output of oil products Production de produits pétroliers en raffineries	kt	398	430	775	791	738	746	791	839
Final Consumption of Coal* Consommation finale de Charbon*	kt	-	-	-	-	-	-	-	-
Final consumption of oil Consommation finale de pétrole	kt	157	252	673	728	739	722	748	777
Final consumption of natural gas Consommation finale de gaz naturel	TJ	0	0	0	0	0	0	0	0
Final consumption of electricity Consommation finale d'électricité	GWh	254	344	802	798	807	805	825	847
Consumption of oil in industry Consommation industrielle de pétrole	kt	1	7	32	56	60	58	59	61
Consumption of natural gas in industry -Consommation industrielle de gaz naturel	TJ	-	-	-	-	-	-	-	-
Consumption of electricity in industry Consommation industrielle d'électricité	GWh	137	165	375	373	372	376	385	395
Consumption of Coal* in industry Consommation industrielle de Charbon*	kt	0	0	0	0	0	0	0	0
Consumption of oil in transport Consommation de pétrole dans les transports	kt	134	227	601	634	650	637	661	687
Consumption of electricity in transport Consommation d'électricité dans les transports	GWh	0	0	0	0	0	0	0	0
Net Imports of Coal* Importations Nettes de Charbon*	kt	-	-	-	-	-	-	-	-
Net imports of crude oil, NGL, Etc. Importations nettes de pétrole brut, Etc.	kt	-13 210	-12 042	-12 126	-12 342	-11 799	-11 944	-11 796	-11 650
Net imports of oil product Importations nettes de produits pétroliers	kt	-209	-209	-21	-11	40	16	16	16
Net imports of natural gas Importations nettes de gaz naturel	TJ	0	0	0	0	0	0	0	0
Net imports of electricity Importations nettes d'électricité	GWh	262	418	37	-4	-4	-4	-4	-4

- Data not applicable / Données non applicables

0 Data not available / Données indisponibles

(P) : Projected / Projetées

Source : (AFREC, 2018)

2.2.3. Keys economics sectors according to Nationally Determined Contributions (NDC)

As mentioned in the INDC of the Republic of Congo, forest management and reforestation, forest conservation, agriculture, mining and industrial sector, energy sector, household and transport have a strong impact on the climate and contribute to the country's economic growth. These sectors at the same time are the most vulnerable sectors to climate change. Thus, the adaptation and mitigation plan foresee an increase in energy demand for better development of these sectors of activity.

Forestry

Energy demand: In Congo, the structure of energy demand is made up of biomass, hydropower, petroleum products and gas. The main segments of the energy market are residential (households), industries - SMEs, transport, agriculture and government. Biomass is the country's most popular source of energy, accounting for 81% of Congo's energy supply. In the oil subsector, despite the high intensity of oil activity, petroleum products account for just 7% of energy demand. Petroleum products are mainly composed of fuels (petrol, diesel and fuel) for transport (maritime and river, road and air) and kerosene for lighting and cooking in households. Finally, demand for natural gas accounts for 11% of energy demand (Constantine, n.d)
Energy consumption includes consumption of LT (Low Voltage) and HT/MT (High voltage/Medium voltage), respectively, for households and industries.
Considering Scenario 1 with an energy access rate of 45% between 2015 and 2025, an increase in the total number of households according to the current population growth rate (2.6%), total energy demand would then be estimated at 4,604,944.72 MWh in 2020 to 5,934,571.36 MWh in 2025 (Constantine, n.d).
Considering Scenario 2 with a gradual change of 45% to 60% between 2015-2020 and 90% in 2025 in the rate of access to electricity, demand will evolve in two (2) phases: between 2015 and 2020, it will increase from 2,055,309 MWh to 3,073,604 MWh, an increase of 1,018,295 MWh (49.5%). From 2021 to 2025, consumption will increase from 3,332,091 MWh to 4,296,289 MWh, an increase of 964198 MWh (28.9%) (Constantine, n.d).

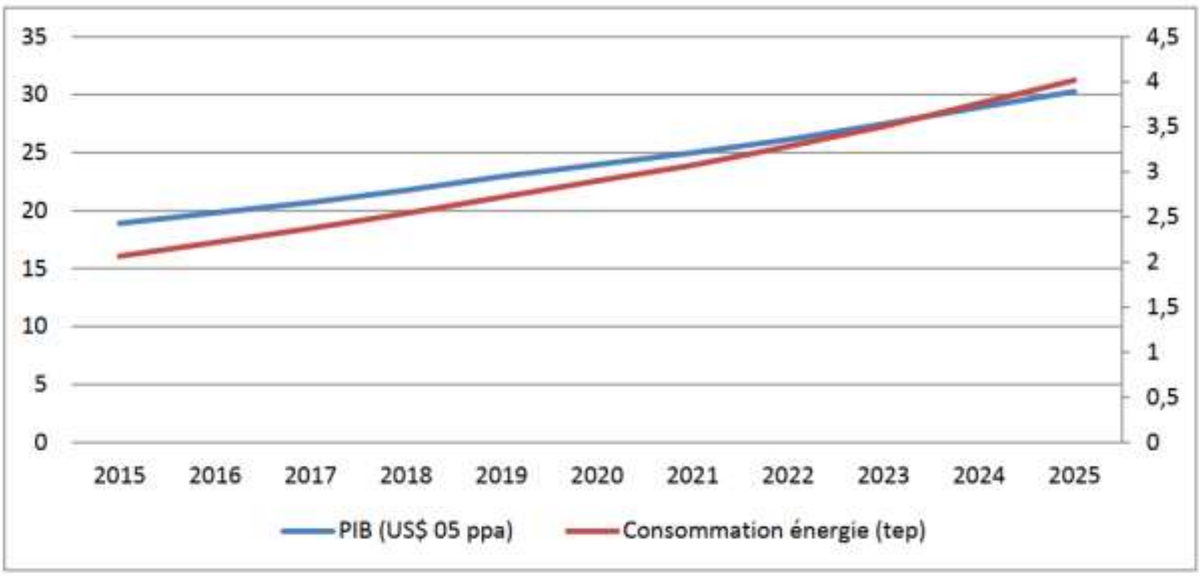
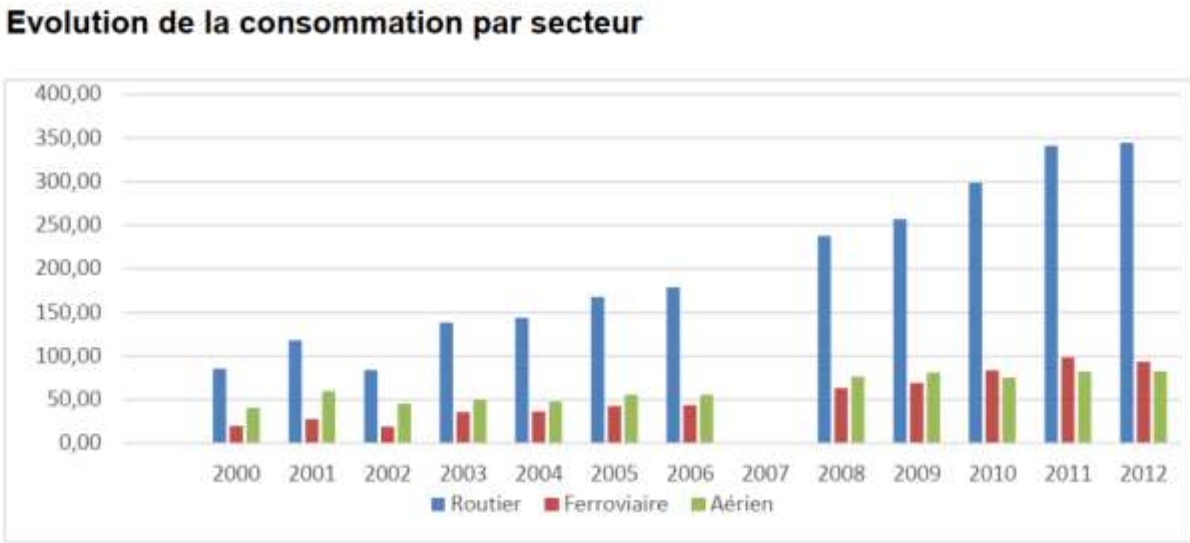


Figure 10: Cross evolution of GDP and energy consumption
Source: OECD library **2014**



Source : INS-MHC-MEH

Figure 11: Changes in the consumption of petroleum products by sector

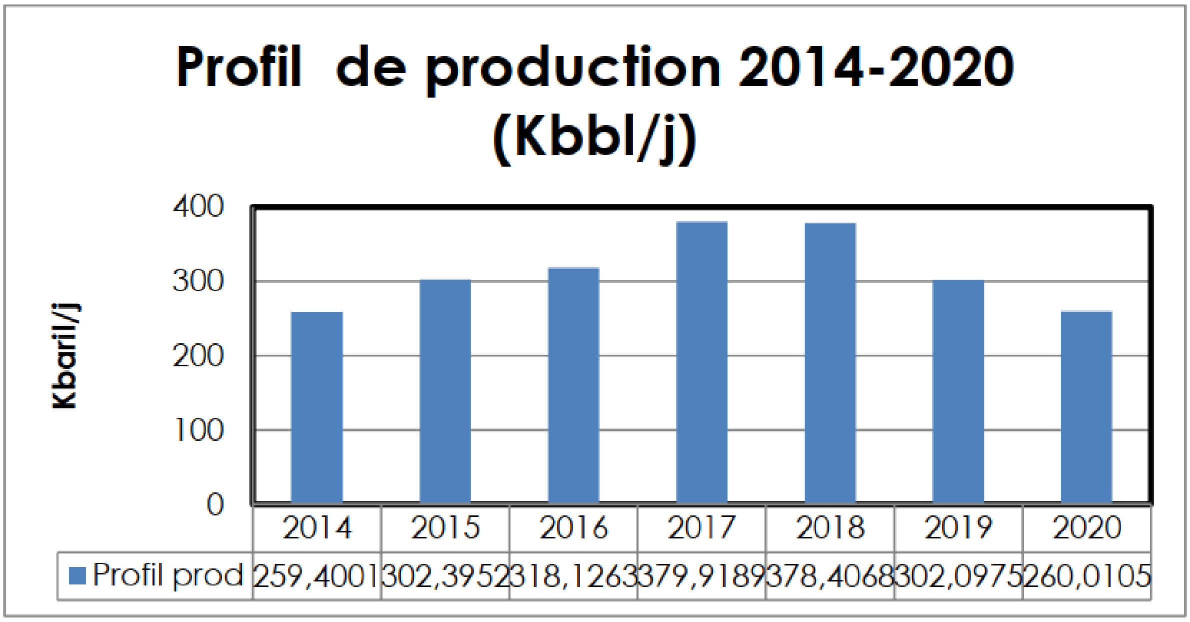


Figure 12: Production profile for 2014 to 2020
Source: MHC, 2014

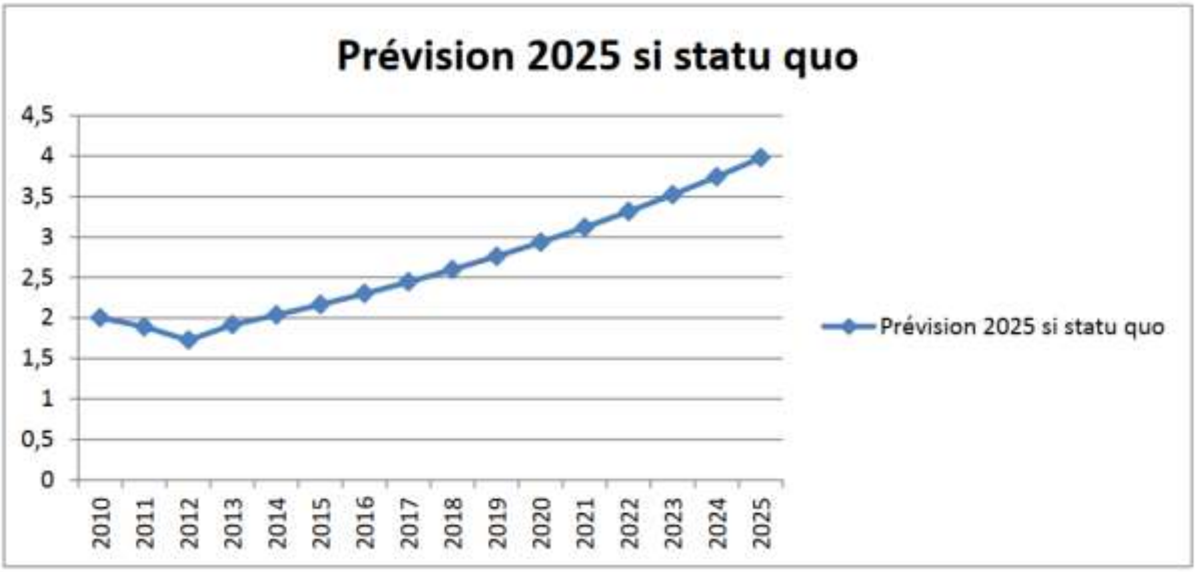


Figure 13: Forecast according to status quoSource : (Constantine, n.d)

Percentage of biomass: Biomass accounts for between 4% and 10% (Loemba, 2008) of Congo's energy supply. In 2008, biomass production was 0.72 Mtoe, primary consumption was 0.72 Mtoe and final consumption of was 0.46 Mtoe (ADEME, 2008). The resources are made up of forests included in the concession of the Congolese Wood Industry Company (CIB) in Pokola in the department of Sangha, in the north-west of the country. Cogeneration is only a secondary activity fuelled by the recovery of by-products from wood waste operations to generate electricity. Electricity generation at this cogeneration is estimated at about 4MW, of which 2MW is self-consumption and the other 2MW are distributed free of charge to the surrounding population as part of the Corporate Social Responsibility (CSR).

Contribution of forest bioenergy: Different bioenergy sectors that are the subject of research and industrial development can lead to structuring industrial investments in multiple sectors.

- Bioelectricity and bio-based cogenerations involve a variety of technologies (small steam turbines, Sterling engine, Rankine turbine, generator gases) that can adapt to the agro-industrial sectors concerned (cotton, rice, wood, palm, sugar)
- biofuels come from two sectors: ethanol fuel, linked to the cane sugar sector; biodiesel, made from agro-industrial or peasant oil plantations. Both are preparing for the advent of second-generation biofuels, which are making rapid progress in industrialized countries
- Industrial biofuels, produced from fast-growing plantations around factories, can power industrial furnaces (cement plants, for example), to replace a few percent of heavy fuel or coal
- Industrial biogas produced by methanizing wet waste reduces the cost of processing it
- Energy crops on agro-forestry perimeters with dual food and energy purposes can increase farmers' incomes and enable them to acquire inputs (Louvel & Gromard, 2017).

1.3.2 Conclusion and Recommendation

The large forest area of the Republic of Congo, like other countries of the Congo Basin, contains important natural resources. Their exploitation has the capacity to significantly improve the country’s local economy. Among these natural resources, many are those allowing a sustainable production of energy. We note hydropower, solar, biomass, gas, oil and many more. Hydropower and gas are the main sources supplying Congo's electricity grid. Bioenergy is the most important energy source in the rural areas, but the use of this biomass is uncontrolled and contributes to deforestation. Thereby, the low rate of access to energy shows that energy supply is much lower than demand.

The areas of Bouenza, Ouesso, Pokala are the areas where the production of biomass is important. Biomass is mainly sourced from the areas of Bounza, Ouesso, and Pokala.As mentioned in Congo's INDC, biomass comes from renewable energy sources. Its use as an alternative source will allow a reduction in GHG emissions. The quantities of this biomass are sufficient in these areas for bioenergy production. This dual energy could make it possible to fill the deficit observed in the electricity sector of the Congo.

As in other countries, fermentation and combustion are the main technologies that can be implemented for energy production. Combustion is best exploited in biomass power plants for the production of electricity; Ecological charcoal, briquettes, pellets (used in households for cooking and in boiler industries, for example) can also be obtained from the combustion of biomass. At the end of fermentation, biogas, biofuel and compost can be obtained and used for the development of several business sectors.

1.4 Gabon

1.4.1 Energy Resources

In terms of proven and recoverable oil reserves, the country is considered to be one of the richest in sub-Sharan Africa, ranking 5th largest in the continent. It also ranks as the 3rd largest oil producer in sub-Saharan Africa, following Nigeria & Angola. The country's two main energy sources are fossil-fuels and hydropower. 51.7% of Gabon's total produced electricity in 2015 were generated from hydro, and 48.2% were from fossil fuels. Gabon relies heavily on oil for both its export revenues & its domestic energy production. The other major energy source is hydropower, from which the country's government aims to produce up to 1200 MW by 2020 (World Bank, 2020; Nachmany, et al., 2015).

Hydropower

Gabon has high potential for hydro-electric generation due to its topography and high-precipitation conditions (UNEP 2017). Gabon has an extremely dense and extensive hydraulic network that feeds two major rivers: the Ogooué and the Nyanga. With the existence of powerful rapids on these rivers, the country has considerable hydroelectric potential. Some sites are of great interest, such as those at the Okanda gates, where the Ogooué is engulfed in a series of powerful rapids and whose productivity has been estimated at 10 billion kilowatts per hour per year. According to the Ministry of Energy, the overall hydroelectric potential is estimated between 40,000 and 50,000 gigawatts per year. This is an important asset for its development (Lawson, n.d.).

Oil and Gas

Energy in Gabon comes from two main sources, fossil fuels and hydraulics. Gabon also relies heavily on oil for its export earnings. In terms of oil reserves, the country is one of the richest in sub-Saharan Africa, ranking 5th after Nigeria and Angola among others. Although Gabon's proven oil reserves have increased from 1,300 million barrels in 1996 to 2,500 million barrels in 2004, the government is concerned about the long-term depletion of resources. Total crude oil production increased from a peak of 371,000 barrels per day (59,000 m3/d) to about 289,700 barrels per day (46,060 m3/d) in 2003 (Energypedia, 2019) (UNEP 2017)

Gabon's total electricity production in 2015 was 199 kilotons of oil equivalent (ktoe), of which 51.7% came from hydroelectric sources and 48.2% from fossil fuels. The country's final electricity consumption was 169 ktoe.

Solar, wind

Gabon has an average of 300 sun-shining days per year, with an average daily solar insolation of approximately 4 kWh/m2. Yet, as mentioned earlier, the country is heavily forested, which stands in the way of connecting remote communities to the country's main grid. Therefore, with such solar conditions, stand-alone solar systems would be the ideal solution for power generation for these communities in Gabon.

Biomass

Gabon's forests cover a huge portion of the land area and supply an equally large proportion of the country's energy needs (IEA, 2016). Biomass is the predominant energy source used by 80 per cent of the domestic sector (REEEP, 2012). The country has collaborative ventures at international and regional levels for sustainable forest management and energy use through the Central African Forest Initiative and the International Centre for Carbon Sequestration and Biomass Energy. As the formal wood sector grows, there is also potential to use waste from the timber industry to produce energy (UNEP 2017).

Table 14 : Total energy statistics for Gabon

Gabon / Gabon

Category / Catégorie	Unit	2000	2005	2013	2014	2015	2016	2017 P	2018 P
Production of Coal* / Production de Charbon*	kt	-	-	-	-	-	-	-	-
Production of charcoal / Production de charbon du bois	kt	15	18	21	21	22	22	23	23
Production of crude oil, NLG and additives / Production du pétrole brut, LGN et additives	kt	13 797	13 477	11 608	11 607	11 147	9 993	10 014	10 137
Production of natural gas / Production de gaz naturel	TJ	3 134	3 917	11 755	56 334	20 750	20 900	20 778	21 022
Production of electricity from biofuels and waste / Production d'électricité par les biocarburants, déchets	GWh	7	7	10	10	11	12	13	14
Production of electricity from fossil fuels / Production d'électricité avec combustibles fossiles	GWh	331	559	1 320	2 409	2 503	2 148	2 168	2 191
Production of nuclear electricity / Production d'électricité d'origine nucléaire	GWh	-	-	-	-	-	-	-	-
Production of hydro electricity / Production d'électricité d'origine hydraulique	GWh	809	819	932	795	862	930	1 013	1 104
Production of geothermal electricity / Production d'électricité d'origine géothermique	GWh	-	-	-	-	-	-	-	-
Production of electricity from solar, wind, Etc. / Production d'électricité d'origine solaire, éolienne, Etc.	GWh	0	0	4	6	2	2	2	2
Total production of electricity / Production électrique totale	GWh	1 147	1 385	2 266	3 219	3 378	3 092	3 196	3 310
Refinery output of oil products / Production de produits pétroliers en raffineries	kt	599	706	797	774	762	826	886	951
Final Consumption of Coal* / Consommation finale de Charbon*	kt	-	-	-	-	-	-	-	-
Final consumption of oil / Consommation finale de pétrole	kt	311	350	761	741	728	753	771	791
Final consumption of natural gas / Consommation finale de gaz naturel	TJ	56	66	93	110	114	116	125	136
Final consumption of electricity / Consommation finale d'électricité	GWh	989	1 184	1 736	1 997	2 104	2 017	2 133	2 259
Consumption of oil in industry / Consommation industrielle de pétrole	kt	156	171	374	364	376	380	389	399
Consumption of natural gas in industry / Consommation industrielle de gaz naturel	TJ	56	66	93	110	114	116	125	136
Consumption of electricity in industry / Consommation industrielle d'électricité	GWh	268	321	394	487	502	546	567	589
Consumption of Coal* in industry / Consommation industrielle de Charbon*	kt	-	-	-	-	-	-	-	-
Consumption of oil in transport / Consommation de pétrole dans les transports	kt	101	116	265	260	253	256	260	265
Consumption of electricity in transport / Consommation d'électricité dans les transports	GWh	4	5	7	8	8	9	9	10
Net Imports of Coal* / Importations Nettes de Charbon*	kt	-	-	-	-	-	-	-	-
Net imports of crude oil, NGL, Etc. / Importations nettes de pétrole brut, Etc.	kt	-13 177	-12 643	-10 770	-11 096	-10 652	-9 446	-9 337	-9 229
Net imports of oil product / Importations nettes de produits pétroliers	kt	808	20	315	256	253	255	258	261
Net imports of natural gas / Importations nettes de gaz naturel	TJ	0	0	0	0	0	0	0	0
Net imports of electricity / Importations nettes d'électricité	GWh	0	0	184	388	337	344	369	403

- Data not applicable / Données non applicables
0 Data not available / Données indisponibles
(P) : Projected / Projetées

Source: (AFREC, 2018)

1.4.2 Keys economics sectors according to Nationally Determined Contributions (NDC)

The INDC of the Gabonese Republic (Government of Gabon, 2015) refers to several sectors of activity that have a significant influence on the country's GDP. These sectors, while vulnerable to climate change, contribute to the increase in atmospheric GHG concentration. The functioning of these sectors depends mainly on access to energy in the country. A better development of these sectors thus requires an increase in energy demand.

Forestry sector

Energy demand: Gabon in its National Infrastructure Director Scheme plans to develop electrical infrastructure to meet the additional needs of the forest sector, of about 100 MW by 2025 (Government of Gabon, 2013).

Percentage of bioenergy in this sector: Gabon's forest biomass is mainly represented by waste from logging. However, the energy from the conversion of this forest biomass is used in other sectors of activity. The contribution of bioenergy in the forestry sector is almost nil.

Contribution of forest bioenergy: The recovery of the millions of tons of biomass generated by the logging industries can enable Gabon to implement technologies of cogeneration, biomass power plants, biofuel production and biogas. This energy provided will have to feed forestry companies and households that are close to the production sites of large quantities of waste. The biogas produced should allow food to be cooked and houses to be heated. The biofuel produced will have to supply the transport machinery of forest products.

Industrial sector (wood industries, agribusiness, mining industry)

Energy demand: The estuary province, home to the capital Libreville and the SEZ (Special Economic Zone), is the most industrialized in the country. Its energy demand alone rises to more than 115 MW. In the emerging strategic plan document, Gabon plans to meet this demand by building the 70 MW Gas-fired Power Plant and the Ngoulmendjim Dam (45 MW) as well as the extension and modernization of the north electricity grid of Libreville.

The economic hub of Lastoursville-Koulamoutou with the infrastructure available and projects planned need more than 90 MW for its development. In the emerging strategic plan Gabon has planned the Ngoulmendjim hydroelectric dam to meet this demand. About 10.6 MW will meet the demand of the wood industry and various agricultural and mining activities.

The economic hub of Port-Gentil through its infrastructure and projects will need a capacity of about 117 MW.

At the Belinga pole where Gabon plans to exploit iron, manganese, gotha, its energy needs are estimated at 240 MW.

Lambaréné's economic hub for the development of its activities in the wood industry needs 25.8 MW and various agricultural, agro-industrial and mining activities need 25 MW for manganese production in Ndjolé.

The development of this energy potential will enable to meet the energy needs of industrial Gabon. Gabon, with the support of its partners, will set up a production fleet with a capacity of 1,200 MW in 2020 and 3,000 MW in 2030. This offer will consist of 80% hydroelectric power and 20% thermal energy produced from gas (Government of Gabon, 2013).

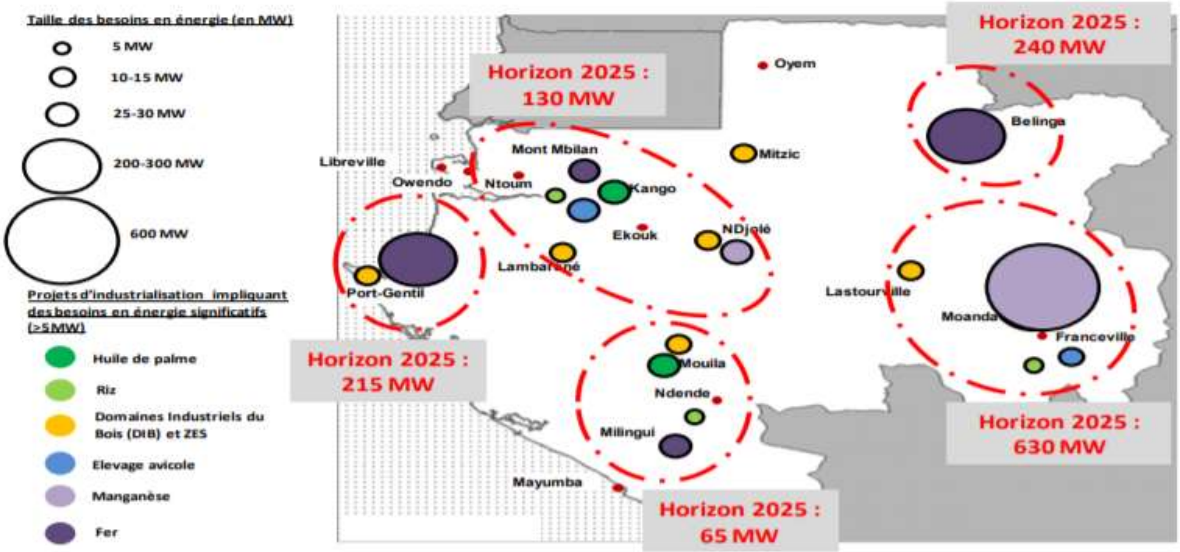


Figure 14: Energy needs maps by pipeline, project and deadline (2016, 2020 and 2025)
Source: (Government of Gabon, 2013)

Percentage of biomass: Gabon has a hydrocarbon-rich subsoil, which explains its choice to use mostly fossil fuel (60.1%) to meet the growing needs of the population. The renewable sources that provide the additional share are represented at 98.7% by the hydraulics sector and 1.3% by biomass (EDF, 2013).

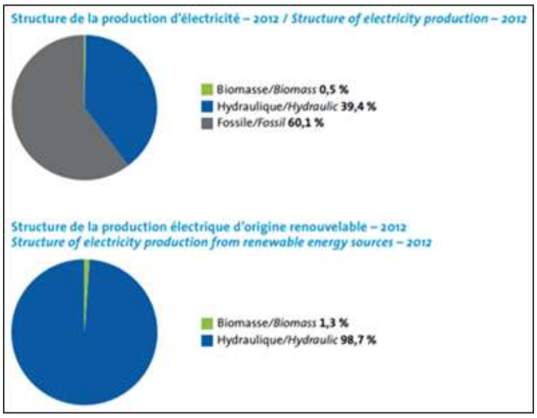


Figure 15: Structure of energy production and production from renewable energy sources

Contribution of forest bioenergy: Different bioenergy sectors that are the subject of research and industrial development can lead to structuring industrial investments in multiple sectors.

- Bioelectricity and bio-based cogenerations involve a variety of technologies (small steam turbines, Sterling engine, Rankine turbine, generator gases) that can adapt to the agro-industrial sectors concerned (cotton, rice, wood, palm, sugar),
- Biofuels come from two sectors: ethanol fuel, linked to the sugarcane sector; biodiesel, made from agro-industrial or smallholder oil plantations. Both are preparing for the advent of second-generation biofuels, which are making rapid progress in industrialized countries,
- Industrial biofuels, produced from fast-growing plantations around factories, can power industrial furnaces (cement plants, for example), to replace a few percent of heavy fuel or coal,
- Industrial biogas produced by methanizing wet waste reduces the cost of processing it,
- Energy crops on agro-forestry perimeters with dual food and energy purposes can increase farmers' incomes and enable them to acquire inputs (Louvel & Gromard, 2017).

1.4.3 Conclusion and Recommendation

The Gabonese Republic, like other countries in Central Africa, has enormous potential in natural resources (hydropower, solar, gas, oil, mines, biomass, etc.) offered on the one hand by its large forest area that covers 85% of its territory. The exploitation of these resources enables to rank Gabon among the most electrified countries on the African continent with an energy access rate estimated at around 97%. However, access to energy is not homogeneous across the country. Rural areas, mainly isolated ones, still experience electrification

issue. This is justified by the priority given to urban areas which are home to the industrial sector (energy intensive) and SMEs. In addition, the residential sector is very important in urban areas and their energy demand is quite high. The populations of these rural areas for basic energy needs use fuelwood and charcoal in an uncontrolled way. As mentioned in its INDC, Gabon through many actions wants to reduce its greenhouse gas emissions. The priority of its actions is focused on the fight against deforestation and the use of renewable energy sources like biomass.
The Nzok Specialized Economic Zone is the area that is home to important forestry companies. This is probably the area where forest waste is found in significant quantities. However, this waste is not ecologically recovered. The production of electricity by combustion in a biomass power plant is one of the technically implementable technologies to supply rural areas. Ecological charcoal, briquettes are products that can be obtained from the combustion of wood waste. Along with combustion, fermentation enables the production of biofuel, biogas, electricity and compost. These products can be used in various sector and industries.

1.5 Chad

1.5.1 Energy Resources

Biomass

In the case of biomass, particularly ligno-cellulosic, the country is home to important sources estimated in the 1970s at 312 million hectares, but today the area has dropped by 23 million hectares. This decline is due to its anarchic and abusive exploitation and repeated droughts (Richard, n.d).

Hydropower

The pre-identified hydroelectric sites are: Am Dam on Batha, Goré, Baibokoum, and Gauthiot Falls. Hydroelectric potential is unevenly distributed over the year (Richard, n.d).

Solar

From the north to the south of the country, the sun shines from 2,750 to 3,250 hours per year. This averages 4 to 6 kilowatts per hour per square meter per day (Xinhua, 2013).

Wind

Wind power, based on the results of satellite measurements, shows that Chad has a very large deposit in the northern regions (where there are two mountain ranges), as well as in the central and southern regions (3 to 9 m/s) (Richard, n.d).

Oil and gas

The country has 7 oil basins, but only the Doba basin is in operation with several fields in production: Miandoum and Komé (since October 2004), Bolobo (August 2004), Nya (July 2007) and Rônier and Mimosas (in April 2011). Oil production began in 2003 and peaked in 2004 at 8.7 Mt (megatonne/million tonnes) (Republic of Chad, 2016; Constantine, n.d). It has declined steadily since 2006 to for example 5.7 Mt in 2011, despite the starting of new fields. This decrease is due to technical difficulties and upwellings which have caused production to stop on several fields. Production stabilized in 2010 with 6.1 Mt. The Djermaya refinery can produce 700,000 t of gasoline and kerosene, 20,000 t of diesel and 60,000 t of LPG per year. In 2007, Chad and China National Petroleum signed a 60/40 partnership agreement for the construction and operation of the refinery. Until then, the country was totally dependent on imports from neighbouring countries including Cameroon, Nigeria, Libya and Sudan (Republic of Chad, 2016)[2].

Table 15: Total energy statistics for Chad

Total Energy Statistics / Statistique Energétique Total

Chad / Tchad

Category / Catégorie	Unit	2000	2005	2013	2014	2015	2016	2017 P	2018 P
Production of Coal* Production de Charbon*	kt	-	-	-	-	-	-	-	-
Production of charcoal Production de charbon du bois	kt	311	355	434	446	457	468	468	486
Production of crude oil, NLG and additives Production du pétrole brut, LGN et additives	kt	0	8 742	4 877	5 490	6 185	6 554	6 954	6 990
Production of natural gas Production de gaz naturel	TJ	-	-	-	-	-	-	-	-
Production of electricity from biofuels and waste Production d'électricité par les biocarburants, déchets	GWh	0	0	0	0	0	0	0	0
Production of electricity from fossil fuels Production d'électricité avec combustibles fossiles	GWh	92	100	269	286	290	294	299	303
Production of nuclear electricity Production d'électricité d'origine nucléaire	GWh	-	-	-	-	-	-	-	-
Production of hydro electricity Production d'électricité d'origine hydraulique	GWh	-	-	-	-	-	-	-	-
Production of geothermal electricity Production d'électricité d'origine géothermique	GWh	-	-	-	-	-	-	-	-
Production of electricity from solar, wind, Etc. Production d'électricité d'origine solaire, éolienne, Etc.	GWh	0	0	0	0	0	0	0	0
Total production of electricity Production électrique totale	GWh	92	100	269	286	290	294	299	303
Refinery output of oil products Production de produits pétroliers en raffineries	kt	0	0	453	420	652	661	672	683
Final Consumption of Coal* Consommation finale de Charbon*	kt	-	-	-	-	-	-	-	-
Final consumption of oil Consommation finale de pétrole	kt	47	72	231	410	391	398	406	415
Final consumption of natural gas Consommation finale de gaz naturel	TJ	0	0	0	0	0	0	0	0
Final consumption of electricity Consommation finale d'électricité	GWh	57	62	167	177	178	184	191	198
Consumption of oil in industry Consommation industrielle de pétrole	kt	5	11	32	31	30	31	31	32
Consumption of natural gas in industry Consommation industrielle de gaz naturel	TJ	-	-	-	-	-	-	-	-
Consumption of electricity in industry Consommation industrielle d'électricité	GWh	26	28	75	80	80	83	87	91
Consumption of Coal* in industry Consommation industrielle de Charbon*	kt	-	-	-	-	-	-	-	-
Consumption of oil in transport Consommation de pétrole dans les transports	kt	36	59	161	362	336	341	346	351
Consumption of electricity in transport Consommation d'électricité dans les transports	GWh	-	-	-	-	-	-	-	-
Net Imports of Coal* Importations Nettes de Charbon*	kt	-	-	-	-	-	-	-	-
Net imports of crude oil, NGL, Etc. Importations nettes de pétrole brut, Etc.	kt	0	-8 787	-4 181	-4 719	-6 458	-6 142	-5 836	-5 544
Net imports of oil product Importations nettes de produits pétroliers	kt	72	126	-23	-10	-5	-5	-5	-6
Net imports of natural gas Importations nettes de gaz naturel	TJ	-	-	-	-	-	-	-	-
Net imports of electricity Importations nettes d'électricité	GWh	-	-	-	-	-	-	-	-

- Data not applicable / Données non applicables
0 Data not available / Données indisponibles
(P) : Projected / Projetées

Source: (AFREC, 2018)

1.5.2 Keys economics sectors according to Nationally Determined Contributions

The INDC of the Republic of Chad mentions agriculture, energy, livestock and waste sectors as most vulnerable to climate change (Republic of Chad, 2015). These sectors have a strong impact on the country's GDP. Thus, the

[2] *EnerdataJanuary, January 2013*

improvement of its business sectors to meet the needs of the rapidly growing population is conditioned by access to energy. As a result, since 2009 the Chadian government through public-private partnerships has evaluated the energy forecasts that are well detailed in its master plan for the energy sector. As indicated in the master plan for energy, Forest biomass can be used for the development of several sectors of activities. It can be operated collectively in residential sector (50 000 to 100 000 inhabitants), in agricultural sector using fermentation to produce biofuel, biogas, electricity; industrially using various technologies as combustion, fermentation, etc. (EU, 2012).

Forestry

Energy demand: Based on the public inquiry and data provided by the SNE, the demand for energy in Chad was established. This request does not cover the industry sector because of their low presence in the country and the fact that they are not connected to the urban network (EU, 2012). [3]

Nombre d'habitants	Demande quotidienne	Type de commune	Caractéristiques de la demande actuelle en énergie
100 habitants	10 kWh	a. Habitats dispersé et villages	Besoin principal en soirée pour l'éclairage Energie principalement sous forme primaire pour la cuisson. Mini groupes électrogènes individuels. Pas de petites industries
1.000 habitants	100 kWh	b. Villes petites et moyennes sans réseau électrique	Problème de l'approvisionnement en eau potable Groupes électrogènes individuels répandus Pas ou très peu de petites industries. Quelques bâtiments sociaux et publiques équipés ou éclairage public.
10.000 habitants	1.000 kWh	c. Villes moyennes avec électrification limitée ou sans réseau	Réseau MT/BT avec distribution en matinée et en soirée Eventuel pompage de l'eau PME existantes mais groupe électrogènes nécessaires.
100.000 habitants	10.000 kWh	d. Villes principales avec électrification continue	Réseau MT/BT mais sous-dimensionnement, vétusté et délestage. Pompage de l'eau nécessaire et gourmand en énergie PME existantes mais groupe électrogènes nécessaires
1.000.000 habitants	> 100.000 kWh	e. N'djamena	Parc de production et réseau insuffisants Electricité chère et non fiable. Grosses entreprises non raccordées ou ayant leur propre groupe

Figure 16: Schematization of energy demand in Chad

Source : (EU, 2012)

The Ministry of Energy in March 2009 carried out a forecast of electricity demand for Chad based on the elasticity of the country's GDP trajectory relative to the current electricity demand (EU, 2012).

Table 16: Electric demand forecast[4]

[3] *Chad's Energy Master Plan*

[4] *Chad's energy master plan*

Année	Population (million)	Demande en électricité (GWh)
2015	12,267	2.801
2020	13,989	4.095
2025	16,027	5.840
2030	18,409	8.193
2035	21,087	11.376
Source : Ministère du Pétrole et de l'Energie, Direction de l'Energie : „Analyse de la demande énergétique 2010-2035", Rapport final, mars 2009, page 60		

Source: (EU, 2012)

The last energy demand study was conducted in 2012 with three envisaged scenarios. The basic scenario, the high scenario and the low scenario.

Basic scenario - demand is based on the development of the number of different consumers, the realistic development of specific consumption, and the realistic development of GDP. Technical losses remain at the same level as today, electrification programmes will be carried out as planned, demand will increase as population and household size increases in different regions of Chad; and the results of the survey are considered.

Top Scenario - compared to the basic scenario, the following changes are considered: The number of subscribers increases more strongly than for the base scenario; the elasticity of demand vis-à-vis GDP is stronger than for the basic scenario; the electrification of the country is carried out in an expected way; the population is growing faster than for the basic scenario.

Low Scenario - compared to the basic scenario, the following changes are considered: The number of subscribers increases less strongly than for the base scenario; the elasticity of demand vis-à-vis GDP is less strong than for the basic scenario; the electrification of the country is carried out in a predicted way; the population is growing less rapidly than for the basic scenario.

The following table includes electricity demand and the rate of increase in electricity demand. The data in the table relates to demand in Chad's 22 regional capitals (N'Djamena, Moundou, Sarh, Abeché, Bongor, Doba, Faya Largeau, Mongo, Oum Hadjer, Biltine, Am Timan, Ati, Mao, Bol, Moussoro, Fada, Bardai, Massakory, Koumra, Kélo, Pala, Lai).

Table 17: Forecasting demand and the rate of increase in electricity demand

Forecasting demand and rate of increase in electricity demand										
	2011		**2015**		**2020**		**2025**		**2030**	
	MW demand	**Rate of increase (%)**	**MW demand**	**Rate of increase (%)**	**MW demand**	**Rate of increase (%)**	**MW demand**	**Rate of increase (%)**	**MW demand**	**Rate of increase (%)**
N'Djamena										

Forecasting demand and rate of increase in electricity demand										
	2011		2015		2020		2025		2030	
	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)
Basic scenario	118,8	-	153,33	29%	200,78	31%	252,6	26%	308,66	22%
Top scenario	118,8	-	163,589	38%	226,31	38%	296,57	31%	374,34	26%
Low scenario	118,8	-	138,953	17%	167,85	21%	197,17	17%	230,23	17%
Moundou										
Basic scenario	6,697	-	8,782	31%	11,388	30%	13,995	23%	16,601	19%
Top scenario	6,697	-	9,337	39%	12,637	35%	15,937	26%	19,237	21%
Low scenario	6,697	-	8,225	23%	10,135	23%	12,045	19%	13,955	16%
Sarh										
Basic scenario	4,102	-	5,309	29%	6,819	28%	8,328	22%	9,837	18%
Top scenario	4,102	-	5,65	38%	7,585	34%	9,52	26%	11,455	20%
Low scenario	4,102	-	4,97	21%	6,055	22%	7,14	18%	8,225	15%
Abeché										
Basic scenario	3,543	-	4,751	34%	6,261	32%	7,771	24%	9,281	19%
Top scenario	3,543	-	5,047	42%	6,927	37%	8,807	27%	10,687	21%
Low scenario	3,543	-	4,455	26%	5,595	26%	6,735	20%	7,875	17%
Bongor										
Basic scenario	1,062	-	1,291	22%	1,577	22%	1,864	18%	2,151	15%
Top scenario	1,062	-	1,382	30%	1,782	29%	2,182	22%	2,582	18%
Low scenario	1,062	-	1,202	13%	1,377	15%	1,552	13%	1,727	11%
Time										
Basic scenario	2,807	-	3,766	34%	4,963	32%	6,161	24%	7,359	19%
Top scenario	2,807	-	3,999	42%	5,489	37%	6,979	27%	8,469	21%
Low scenario	2,807	-	3,531	26%	4,436	26%	5,341	20%	6,246	17%
Faya										

Forecasting demand and rate of increase in electricity demand										
	2011		**2015**		**2020**		**2025**		**2030**	
	MW demand	**Rate of increase (%)**	**MW demand**	**Rate of increase (%)**	**MW demand**	**Rate of increase (%)**	**MW demand**	**Rate of increase (%)**	**MW demand**	**Rate of increase (%)**
Basic scenario	460	-	552	20%	666	21%	781	17%	895	15%
Top scenario	460	-	588	28%	748	27%	908	21%	1,068	18%
Low scenario	460	-	516	12%	586	14%	656	12%	726	11%
Mongo										
Basic scenario	2,105	-	2,564	22%	3,137	22%	3,71	18%	4,284	15%
Top scenario	2,105	-	2,745	30%	3,545	29%	4,345	23%	5,145	18%
Low scenario	2,105	-	2,385	13%	2,735	15%	3,085	13%	3,435	11%
Oum Hadjer										
Basic scenario	1,499	-	1,825	22%	2,233	22%	2,641	18%	3,049	15%
Top scenario	1,499	-	1,954	30%	2,523	29%	3,093	23%	3,662	18%
Low scenario	1,499	-	1,698	13%	1,947	15%	2,196	13%	2,445	11%
Biltine										
Basic scenario	856	-	1,043	22%	1,276	22%	1,509	18%	1,742	15%
Top scenario	856	-	1,117	30%	1,442	29%	1,767	23%	2,093	18%
Low scenario	856	-	970	13%	1,113	15%	1,255	13%	1,397	11%
Am Timan										
Basic scenario	2,105	-	2,564	22%	3,137	22%	3,71	18%	4,284	15%
Top scenario	2,105	-	2,745	30%	3,545	29%	4,345	23%	5,145	18%
Low scenario	2,105	-	2,385	13%	2,735	15%	3,085	13%	3,435	11%
Ati										
Basic scenario	1,872	-	2,29	22%	2,813	23%	3,335	19%	3,858	16%
Top scenario	1,872	-	2,455	31%	3,185	30%	3,914	23%	4,644	19%
Low scenario	1,872	-	2,127	14%	2,446	15%	2,765	13%	3,084	12%
Mao										

Forecasting demand and rate of increase in electricity demand										
	2011		2015		2020		2025		2030	
	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)
Basic scenario	1,203	-	1,472	22%	1,808	23%	2,144	19%	2,48	16%
Top scenario	1,203	-	1,578	31%	2,047	30%	2,516	23%	2,985	19%
Low scenario	1,203	-	1,367	14%	1,572	15%	1,777	13%	1,982	12%
Bowl										
Basic scenario	821	-	1,004	22%	1,234	23%	1,463	19%	1,692	16%
Top scenario	821	-	1,077	31%	1,397	30%	1,717	23%	2,037	19%
Low scenario	821	-	933	14%	1,073	15%	1,213	13%	1,353	12%
Moussoro										
Basic scenario	1,132	-	1,385	22%	1,701	23%	2,018	19%	2,334	16%
Top scenario	1,132	-	1,485	31%	1,927	30%	2,368	23%	2,809	19%
Low scenario	1,132	-	1,287	14%	1,48	15%	1,673	13%	1,866	12%
Fairy										
Basic scenario	3,008	-	3,68	22%	4,519	23%	5,359	19%	6,199	16%
Top scenario	3,008	-	3,945	31%	5,117	30%	6,289	23%	7,461	19%
Low scenario	3,008	-	3,418	14%	3,931	15%	4,443	13%	4,956	12%
Bards										
Basic scenario	106	-	130	22%	160	23%	189	19%	219	16%
Top scenario	106	-	139	31%	181	30%	222	23%	263	19%
Low scenario	106	-	121	14%	139	15%	157	13%	175	12%
Massakory										
Basic scenario	1,353	-	1,656	22%	2,034	23%	2,412	19%	2,789	16%
Top scenario	1,353	-	1,775	31%	2,303	30%	2,83	23%	3,358	19%
Low scenario	1,353	-	1,538	14%	1,769	15%	2	13%	2,23	12%
Koumra										

Forecasting demand and rate of increase in electricity demand										
	2011		2015		2020		2025		2030	
	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)	MW demand	Rate of increase (%)
Basic scenario	2,557	-	3,128	22%	3,841	23%	4,555	19%	5,269	16%
Top scenario	2,557	-	3,354	31%	4,35	30%	5,346	23%	6,342	19%
Low scenario	2,557	-	2,905	14%	3,341	15%	3,777	13%	4,213	12%
Kélo										
Basic scenario	2,557	-	3,128	22%	3,841	23%	4,555	19%	5,269	16%
Top scenario	2,557	-	3,354	31%	4,35	30%	5,346	23%	6,342	19%
Low scenario	2,557	-	2,905	14%	3,341	15%	3,777	13%	4,213	12%
Shovel										
Basic scenario	1,504	-	1,84	22%	2,26	23%	2,68	19%	3,099	16%
Top scenario	1,504	-	1,973	31%	2,559	30%	3,145	23%	3,731	19%
Low scenario	1,504	-	1,709	14%	1,965	15%	2,222	13%	2,478	12%
Lai										
Basic scenario	1,507	-	1,844	22%	2,265	23%	2,686	19%	3,107	16%
Top scenario	1,507	-	1,977	31%	2,565	30%	3,152	23%	3,739	19%
Low scenario	1,507	-	1,713	14%	1,97	15%	2,227	13%	2,484	12%

Source : (EU, 2012)

In terms of demand for wood-energy, the following table gives the values for the next 20 years based on the expected increase in population. This value is also expressed in terms of cubic metres of wood and the area needed for products with an average rate of 0.9m^3/ha corresponding to the estimated production of tree savannas.[5]

Table 18: Forecasting energy wood demand[6]

Tonnes	2011		2015		2020		2025		2030	
Basic scenario	5.776.000	-	6.612.000	14%	7.658.000	16%	8.703.000	14%	9.748.000	12%
Top scenario	5.776.000	-	6.946.000	20%	8.233.000	19%	9.519.000	16%	10.805.000	14%
Low scenario	5.776.000	-	6.317.000	9%	7.159.000	13%	8.002.000	12%	8.845.000	11%

[5] *Chad's Energy Master Plan*
[6] *Chad's Energy Master Plan*

Percentage of biomass used: In 2002 wood and charcoal and other biomass (mostly rural and urban households) amounted to 1,763,000 tons of oil equivalent (96.5%) about 5,289,000 tons of wood equivalent.

In 2010, based on consumption data from the 2005 survey, N'Djamena's theoretical domestic energy consumption would be 137,000 t of wood, 93,000 t of charcoal and 3,000 t of gas. The 93,000 t of charcoal represents in primary energy an amount of 652,000 t, but also a usage value of 240,000 t when one takes into account the difference in calorific power and cooking efficiency.

Table 19: Final energy consumption by industry and energy type

Final consumption								
		1990	2000	2007	2008	2009	2010	2011
Total	Mtoe	0,71	0,87	0,97	0,98	1	1	0,99
By energy								
Oil	%	4	5	6	6	6	6	6
Gas	%	0	0	0	0	0	0	0
Coal, lignite	%	0	0	0	0	0	0	0
Electricity	%	1	1	1	1	1	1	1
Heat	%	0	0	0	0	0	0	0
Biomass	**%**	**98**	**95**	**93**	**93**	**94**	**93**	**93**
By sector								
Industry	%	13	13	13	14	15	13	13
Transport	%	3	3	4	4	4	4	4
Tertiary residence	%	85	84	82	82	81	83	83
Non-energy use	%	0	0	0	0	0	0	0

Source : (Richard, n.d)

Contribution of forest bioenergy: Applications for biomass exploitation in Chad:

- Incineration for cogeneration (heat and electricity)
- Fermentation in biogas production for cooking in households, and other productive activities.
- Biofuels (with or without processing: ethanol, biodiesel and jatropha) for usetransport sector[7]

1.5.3 Conclusion and Recommendation

The Republic of Chad is much diversified in natural resources offered by its large forest area. It contains wood resources, hydraulics, solar, oil, and gas. However, hydraulics, gas and oil are the main sources that supply Chad's electrical grid. A majority of Chad's population has no access to electricity, especially in the rural areas. Several studies have shown that 80% of the energy produced by Chad is used to supply the N'Djaména capital. The demand for energy is higher in the Southern part of the capital, where most of the country's industries are situated. Excluding industries, energy demand is also important at household level for basic energy needs. The ratio between supply and demand is very low, which shows a large deficit in the country's electricity network. Chad's INDC indicates that Chad wants to fight climate change by reducing its GHGs. The use of renewable energy sources like biomass is an action to be implemented.

[7] *Chad's Energy Master Plan*

The southern part of Chad is the part that contains a large quantity of forestry and agricultural waste. These wastes in Chad nowadays can be recovered. However, the sustainable use of this waste will make it possible to fill the deficit observed in the energy mix in Chad.
Fermentation and combustion of this waste are easily applicable technologies to produce bioenergy to power off-grid areas.

1.6 Equatorial Guinea

1.6.1 Energy Resources

Equatorial Guinea has vast energy potential, the bulk of which is oil and natural gas. Electricity consumption in Equatorial Guinea in 2015 was 36 kilotons of oil equivalent (ktoe). The energy consumed is totally produced by the country. In 2012, renewable energy accounted for 29.2% of the final energy mix. Most of its renewable energy comes from hydroelectric power plants.
Equatorial Guinea's main sources of energy supply are biomass (80%), petroleum products (18%) and water resources (2%) despite the country's strong hydroelectric potential. The country's main renewable energy potential lies in biomass and water resources, followed by wind and solar.
Biomass, in the form of firewood and coal, is the most important renewable energy resource used in households for cooking. In rural and suburban areas, households mainly use charcoal or wood for cooking. According to data available for 2012, almost 100% of rural households use firewood exclusively and 20% of urban households use firewood and/or coal for cooking (MEWF, 2019).

Biomass

Equatorial Guinea has about 1626 million hectares of dense rainforest, representing 58.0% of the country's total area There are three main types of vegetation. The first type is composed of medium- and low-rise, moist forests, with high-value wood species. Logging is a large-scale phenomenon, driven by international demand for timber. 61% of the population living in predominantly rural areas faces serious domestic energy problems (DGCE 2001). A small percentage of family units (8%) uses gas to cook. Although most firewood is harvested from subsistence crops after clearing (approximately 70%), there is a strong trend towards fallow logging and in the remaining secondary forests (30%). Biomass consumption is less represented in Equatorial Guinea. The main source of energy in Equatorial Guinea is natural gas. Its natural gas potential ranks it fifth in Sub-Saharan Africa[8].

Table 20: Charcoal consumption in CEEAC countries (tonnes)

Country	2005	2010	2011	2012
Angola	246,612	293,494	303,601	314,056
Burundi	60,000	60,000	60,000	60,000
Cameroon	381,393	429,319	438,493	447,862
RCA		192,223	195,742	199,325
Congo	3,194	3,930	4,082	4,239
RD Congo	1, 704,243	2, 025,055	2, 095,096	2, 167,561
Gabon	17,920	20,168	20,561	20,962
Equatorial Guinea	7,836	9,062	9,297	9,539
Sao Tomé and Principle	8,152	8,836	8,966	9,099
Chad	355,052	402,534	412,871	423,473
Total CEEAC	**2 805 402**	**3 444 621**	**3 548 709**	**3 656 116**

Source: (ECCAS-CEMAC, 2014)

[8] *(Source: NDE (Ministère de l'agriculture, de l'élevage, Les forêts et l'environnement)*

Table 21: Wood consumption in CEEAC countries (m3)

Country	2005	2010	2011	2012
Angola	3, 573,764	4, 009,338	4, 100,538	4, 194,293
Burundi	8, 541,727	9, 259,292	9, 396,845	9, 536,440
Cameroon	9, 485,004	9, 905,983	9, 992,570	10, 080,710
RCA	2, 000,000	2, 000,000	2, 000,000	2, 000,000
Congo	1, 369,000	1, 335,790	1, 357,017	1, 378,601
RD Congo	71, 066,400	76, 602,030	77, 735,602	78, 894,151
Gabon	1, 070,000	1, 070,000	1, 070,000	1, 070,000
Equatorial Guinea	447,000	447,000	447,000	447,000
Sao Tomé and Principle	102,322	107,426	108,310	109,206
Chad	6, 487,646	7, 070,029	7, 183,997	7, 300,182
Total CEEAC	**104 144 868**	**111 808 898**	**113 393 890**	**115 012 595**

Source : (ECCAS-CEMAC, 2014)

Hydropower

Hydropower has significant potential to meet the country's energy consumption needs. The Djibloho dam on the Wele River came online in October 2012 and increased total electricity generating capacity by 120 megawatts (MW). The Sendje River hydropower project is also expected to add 200 MW of capacity upon completion in 2017 (EIA, 2017; UNDP, 2013). Total installed capacity in 2014 was estimated at 200 MW. Electricity generation in 2014 was estimated at 98 million Kwh Electricity is supplied by the national electricity company (CIA, 2020), Sociedad de Electricidad de Guinea Ecuatorial *(*SEGESA).

Solar

Equatorial Guinea has significant potential for solar energy. This potential required the government to carry out a project in Annobon on solar energy as a renewable energy source, which will allow residents of the island of Annobon to have clean energy. The solar complex on which this project is based has a capacity of 5MW, up to 10MW in the future. The project was considered to be the largest self-sustaining solar micro-grid system in the entire African continent and is particularly optimal for the island of Annobon, which will be able to produce sufficient electricity to source, cover the needs of the inhabitants and the future needs of tourism, industrial and commercial activities (MMIE, 2014).

Wind

Wind speeds averaging 6 m/s at heights of 80 m have been measured in the southern area of the mainland. But there are currently no wind power projects in the country (Campos, 2012; REEEP, 2012).

Oil and gas

The proven recoverable oil reserves by the end of 2011 were 1,100 million barrels and oil production at the end of the same year was 91,625 thousand barrels (WEC, 2013). Oil is the country's most important export with exports of crude oil amounting to 318,120 barrels per day (WEC, 2013). By the end of 2011, proven recoverable resources of natural gas were 36.8 bcm (1,299.6 bcf) and natural gas production was 36.8 bcm (WEC, 2013). The natural gas reserves are located off Bioko Island and are mainly in the Zafiro and Alba oil and gas fields. The Alba field was discovered in 1984 and Zafiro began production in 1996. Oil production originates almost entirely from the Zafiro, Ceiba, and Okume fields. Condensate production comes from the Alba field (WEC, 2013).

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Table : Total energy statistics for Equatorial Guinea

Equatorial Guinea / Guinée Equatoriale

Category / Catégorie	Unit	2000	2005	2013	2014	2015	2016	2017 P	2018 P
Production of Coal* / Production de Charbon*	kt	-	-	-	-	-	-	-	-
Production of charcoal / Production de charbon du bois	kt	7	8	10	10	10	11	11	11
Production of crude oil, NLG and additives / Production du pétrole brut, LGN et additives	kt	5 865	17 915	12 855	13 450	11 935	11 115	11 297	11 450
Production of natural gas / Production de gaz naturel	TJ	39	1 802	9 518	9 651	9 922	10 452	11 042	11 698
Production of electricity from biofuels and waste / Production d'électricité par les biocarburants, déchets	GWh	0	0	0	0	0	0	0	0
Production of electricity from fossil fuels / Production d'électricité avec combustibles fossiles	GWh	40	78	396	396	403	411	419	429
Production of nuclear electricity / Production d'électricité d'origine nucléaire	GWh	-	-	-	-	-	-	-	-
Production of hydro electricity / Production d'électricité d'origine hydraulique	GWh	2	7	18	543	567	571	577	586
Production of geothermal electricity / Production d'électricité d'origine géothermique	GWh	0	0	0	0	0	0	0	0
Production of electricity from solar, wind, Etc. / Production d'électricité d'origine solaire, éolienne, Etc.	GWh	0	0	0	0	0	0	0	0
Total production of electricity / Production électrique totale	GWh	42	85	413	939	970	982	997	1 015
Refinery output of oil products / Production de produits pétroliers en raffineries	kt	-	-	-	-	-	-	-	-
Final Consumption of Coal* / Consommation finale de Charbon*	kt	-	-	-	-	-	-	-	-
Final consumption of oil / Consommation finale de pétrole	kt	21	14	84	84	84	88	92	97
Final consumption of natural gas / Consommation finale de gaz naturel	TJ	0	0	0	0	0	0	0	0
Final consumption of electricity / Consommation finale d'électricité	GWh	29	59	361	648	668	728	750	775
Consumption of oil in industry / Consommation industrielle de pétrole	kt	3	2	10	10	10	11	11	12
Consumption of natural gas in industry / Consommation industrielle de gaz naturel	TJ	0	0	0	0	0	0	0	0
Consumption of electricity in industry / Consommation industrielle d'électricité	GWh	9	18	108	194	201	212	227	244
Consumption of Coal* in industry / Consommation industrielle de Charbon*	kt	-	-	-	-	-	-	-	-
Consumption of oil in transport / Consommation de pétrole dans les transports	kt	18	12	55	55	55	57	59	61
Consumption of electricity in transport / Consommation d'électricité dans les transports	GWh	-	-	-	-	-	-	-	-
Net Imports of Coal* / Importations Nettes de Charbon*	kt	-	-	-	-	-	-	-	-
Net imports of crude oil, NGL, Etc. / Importations nettes de pétrole brut, Etc.	kt	-5 703	-17 905	-12 849	-13 369	-12 652	-12 477	-12 305	-12 136
Net imports of oil product / Importations nettes de produits pétroliers	kt	78	58	281	264	287	292	296	301
Net imports of natural gas / Importations nettes de gaz naturel	TJ	0	0	-198 351	-186 745	-	-	-	-
Net imports of electricity / Importations nettes d'électricité	GWh	0	0	0	0	0	0	0	0

- Data not applicable / Données non applicables
0 Data not available / Données indisponibles
(P) : Projected / Projetées

Source: (AFREC, 2018)

1.6.2 Keys economics sectors according to Nationally Determined Contributions

2.6.2.1. Forestry

Energy demand: The main objective of the Electricity Plan of the Republic of Equatorial Guinea 2025 is to establish general guidelines for the development of sufficient electricity infrastructure to meet domestic demand, thus allowing all citizens to have access to electricity services, promoting the use of productive equipment and integrating electricity nationally with the prospect of producing a surplus of energy for export.

According to Cargo Dispatch data, for the island region, currently the peak of demand is about 8.2 MW. Currently, only the installation of the Musola 1 and 2 and Riaba hydroelectric plants, with a capacity of 0.5 MW and 3.8 MW respectively, are underused and out of service (Government of Equatorial Guinea, 2018).

More than 20 major projects in Equatorial Guinea meet energy demand in the fields of production, transport, distribution and marketing:

- Djibloho hydroelectric power plant with a capacity of 120 MW
- Djibloho transmission and processing line
- 60 KV transport network in the city of Malabo
- Turbo-Gas plant expands to 126 MW ISO
- Line 33 KV to Basil Peak and nearby villages
- Remodeling the Ebibeyin and Mongomo electrical facilities
- Adaptation of several power grids in the continental region
- Road lighting on the Ngolo Highway - Port of Bata
- Emergency and assisting generator batteries in Malabo and Bata
- Recovery of the mini-hydropower plants of Riaba, Musola 1 and 2.

The development of these projects should help achieve an installed capacity that will be above the national electricity demand.

Table 22: Annual and cumulative schedule in 2025, 2030 and 2040

Annual Savings In 2025, 2030 and 2040						
	Residential		**Professional**		**Outside**	
	2030	2040	2030	2040	2030	2040
Electricity (Gwh)	1,2	0,1	11	0,9	4,4	0,4
Electricity Bill (Millions of Us$)	0,3	0	2,4	0,2	1	0,1
Hours Accumulated In 2030 And 2040						
	Residential		**Professional**		**Outside**	
	2030	2040	2030	2040	2030	2040
Electricity (Gwh)	15	19	130	170	53	69
Electricity Bill (Millions of Us$)	3,4	4,3	29	38	12	16

Source : U4E 2019

Scenario unchanged

Minimum scenario Ambition

Alta Ambition Scenario

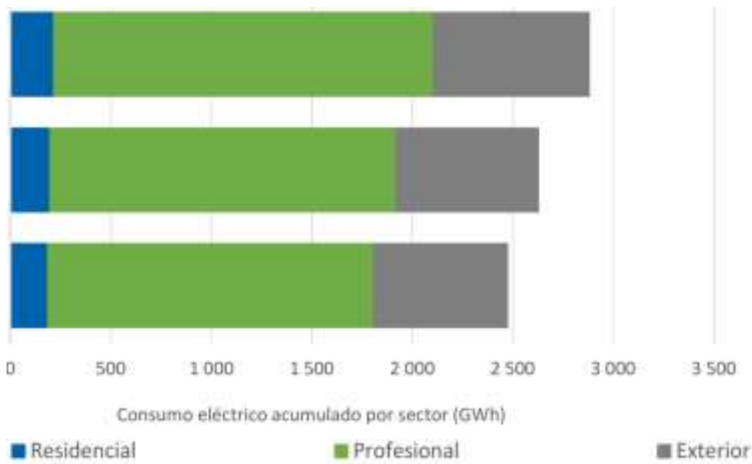


Figure 17: Accumulated electricity consumption per product from 2040
Source: U4E 2019

Percentage of biomass used: The PANDER describes the installed capacity in the country, expressed in megawatts and classified as renewable or non-renewable. Electricity generation capacity is 394 MW, of which 127 MW corresponds to energy production from traditional renewable sources (hydroelectric power plants) and 267 MW from non-renewable sources (156 MW from natural gas thermoelectric power plants and 111 MW from diesel). Biomass is mainly used in the residential sector. The lack of access to the electricity grid in rural areas forces households to use biomass as an energy source for the production of heat and electricity (Republic of Equatorial Guinea, 2019).

Contribution of forest bioenergy: Electrical energy can be obtained by processing biomass from agricultural residues, forest biomass and agricultural industrial residues. The technology applied to obtain electrical energy depends on the type and quantity of biomass available, as well as their physical-chemical characteristics. The main techniques developed for biomass-based electricity generation include the conventional steam cycle based on direct biomass combustion for steam production and turbine drive, the use of synthetic gases from biomass gasification applied to gas turbines, and the use of piston engines that work with synthetic gases or biogas. Biomass production can give rise to cogeneration systems, where steam and gases from biomass combustion are used to generate electricity through combined cycles or are used in industrial processes for heating or cooling. The product obtained from biomass is steam or synthetic gas, which is applied to a steam turbine or a turbine or gas engine system for the production of electricity. In both cases, it is possible to apply a cogeneration system of electrical energy and heat. The heat produced can be used in households for cooking and heating homes, the electricity generated can be used for productive uses, lighting and many other services (Republic of Equatorial Guinea, 2019).

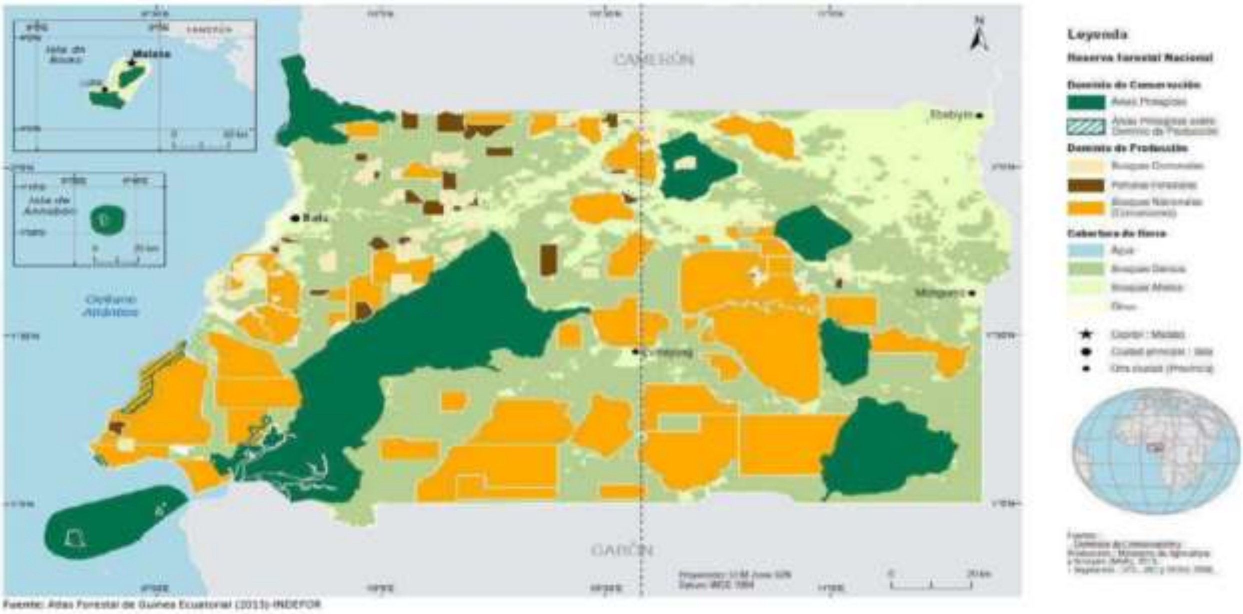


Figure 18: Forest distribution in the Republic of Equatorial Guinea

Source: (INDEFOR, WRI 2016)

1.6.3 Conclusion and Recommendation

Equatorial Guinea has a large variety of natural resources like mining, hydropower, solar, wind, forestry, oil, and gas resources. Like Gabon, the exploitation of Equatorial Guinea's resources makes it possible to classify Equatorial Guinea among the countries with a high rate of access to energy. In addition, Equatorial Guinea is the fifth exporter of oil in Sub-Saharan Africa. Rural areas are characterized by their poor access to electricity. The energy produced by Equatorial Guinea is mainly intended for the industrial sector. The demand for energy by the residential sector shows that it is a sector where the energy consumption is important. Analysis of supply and demand shows that there is an energy deficit. Since the COP 21 summit, Equatorial Guinea has shown its willingness to fight against climate change by drafting its INDC. On the one hand reducing GHG emissions requires the use of renewable energy sources that contribute less GHG emissions.

In the Bata area, there is a significant number of enterprises engaged in the processing of forest products. Bata area is one of the areas with large amounts of wood waste.

The transformation of this wood waste into bioenergy could make it possible to fill the deficit observed in the energy mix of Equatorial Guinea. The combustion and fermentation processes are those technically applicable and the resulting products (electricity, biogas, biofuel, ecological coal, etc.) allow the development of several sectors of activity.

1.7 Central African Republic

2.7.1. Energy Resources

2.7.1.1. Biomass

The Central African Republic (CAR) is particularly rich in biomass because of its heavily forested area. Traditional biomass, divided between firewood and charcoal, is the country's main energy resource. About 98% of the energy consumed in the territory comes from traditional biomass. This energy source is intended for heating, cooking food and lighting (Nzango, 2019).

2.7.1.2. Hydropower

CAR has a dense water system and a hydroelectric potential estimated at 2000 MW. Partial inventories have revealed about 40 hydroelectric sites ranging from 5 to 180 MW. Only two sites have been developed: the Boali site on the Mbali River, and the Mobaye site on the Oubangui River (Nzango, 2019).

2.7.1.3. Solar, wind and Geothermal

Due to its type of climate and geographical location, the Central African Republic is conducive to the development of photovoltaic electricity. Its average irradiation rate is estimated at 5 kWh/m2/d. But the exploitation of these solar potentials is still in the embryonic stage: pumping water in rural areas, health centers, lighting etc. In addition, no studies have yet been carried out to enhance the mechanical energy of the wind in the Central African Republic, but some sites have been identified as favourable to geothermal exploitation (Nzango, 2019).

2.7.1.4. Oil and gas

The CAR has oil potential that is still being clarified. The Central African subsoil is rich because of its geological diversity but has not yet been systematically prospected or seriously researched due to political instability.

2.7.1.5. Nuclear energy

Nuclear power generates electricity in nuclear power plants. CAR has a uranium deposit that was identified in the south-east of the country in the early 1960s. Reserves have been estimated at more than 23,000 tons. Its exploitation began timidly in 1975, then in the 2000s by AREVA, a French firm (Nzango, 2019).

2.7.1.6. Uranium

The sedimentary deposit of phosphates of Bakouma (Prefecture of Mbomou) contains known reserves of uranium (metal) amount to approximately 20,000 tons. The production processes of commercial uranium concentrate from ore from this deposit have been defined and the costs for treatment established (Komode, n.d.).

2.7.1.7. Lignite

The existence of a lignite deposit has been recognized in the same region of Bakouma. The importance of this deposit is estimated at approximately 2.9 million cubic meters. This deposit is however insufficiently evaluated (Komode, n.d.).

Table 23: Total energy statistics for Central African Republic

Central African Republic / République Centrafricaine

Category / Catégorie	Unit	2000	2005	2013	2014	2015	2016	2017 P	2018 P
Production of Coal* Production de Charbon*	kt	-	-	-	-	-	-	-	-
Production of charcoal Production de charbon du bois	kt	21	21	13	13	14	14	15	16
Production of crude oil, NLG and additives Production du pétrole brut, LGN et additives	kt	-	-	-	-	-	-	-	-
Production of natural gas Production de gaz naturel	TJ	-	-	-	-	-	-	-	-
Production of electricity from biofuels and waste Production d'électricité par les biocarburants, déchets	GWh	0	0	0	0	0	0	0	0
Production of electricity from fossil fuels Production d'électricité avec combustibles fossiles	GWh	23	28	1	1	1	1	1	1
Production of nuclear electricity Production d'électricité d'origine nucléaire	GWh	-	-	-	-	-	-	-	-
Production of hydro electricity Production d'électricité d'origine hydraulique	GWh	84	134	138	139	141	142	144	146
Production of geothermal electricity Production d'électricité d'origine géothermique	GWh	0	0	0	0	0	0	0	0
Production of electricity from solar, wind, Etc. Production d'électricité d'origine solaire, éolienne, Etc.	GWh	0	0	5	7	7	7	8	8
Total production of electricity Production électrique totale	GWh	107	162	144	147	149	151	153	155
Refinery output of oil products Production de produits pétroliers en raffineries	kt	-	-	-	-	-	-	-	-
Final Consumption of Coal* Consommation finale de Charbon*	kt	-	-	-	-	-	-	-	-
Final consumption of oil Consommation finale de pétrole	kt	40	41	34	40	40	42	43	44
Final consumption of natural gas Consommation finale de gaz naturel	TJ	-	-	-	-	-	-	-	-
Final consumption of electricity Consommation finale d'électricité	GWh	63	76	105	76	63	65	66	68
Consumption of oil in industry Consommation industrielle de pétrole	kt	6	3	5	5	5	5	5	5
Consumption of natural gas in industry Consommation industrielle de gaz naturel	TJ	-	-	-	-	-	-	-	-
Consumption of electricity in industry Consommation industrielle d'électricité	GWh	14	20	17	15	0	0	0	0
Consumption of Coal* in industry Consommation industrielle de Charbon*	kt	-	-	-	-	-	-	-	-
Consumption of oil in transport Consommation de pétrole dans les transports	kt	27	29	27	33	33	34	35	36
Consumption of electricity in transport Consommation d'électricité dans les transports	GWh	-	-	-	-	-	-	-	-
Net Imports of Coal* Importations Nettes de Charbon*	kt	-	-	-	-	-	-	-	-
Net imports of crude oil, NGL, Etc. Importations nettes de pétrole brut, Etc.	kt	-	-	-	-	-	-	-	-
Net imports of oil product Importations nettes de produits pétroliers	kt	38	44	27	53	56	58	61	65
Net imports of natural gas Importations nettes de gaz naturel	TJ	-	-	-	-	-	-	-	-
Net imports of electricity Importations nettes d'électricité	GWh	-	-	-	-	-	-	-	-

- Data not applicable / Données non applicables
0 Data not available / Données indisponibles
(P) : Projected / Projetées

Source : (AFREC, 2018)

2.7.2. Keys economics sectors according to Nationally Determined Contributions

2.7.2.1. Industries

This section is an overview of the energy demand of CAR's main consumption sectors. The sectors are industries, domestic (residential), agriculture and transport. CAR has a national electrification rate of no more than 4%, while average electricity demand is growing by more than 8% per year due to urban growth. The demand for energy in Bangui at peak times ranges from 50 to 80 MW, while the total electricity supply of ENERCA does not even exceed 40 MW. Boali's hydropower plants provide only a cumulative capacity of 18.65 MW; and the Bangui thermal power plant provides 22 MW, making a total electricity production of 40.65 MW. While current demand for energy at peak times ranges from 50 to 80 MW, projections suggest that it can reach 403 MW by 2030. Of the total electricity power distributed by ENERCA, 41% is consumed by commercial activities and utilities, 35% by households, and 24% by existing industries. Electricity consumption by utilities is in most cases free of charge (Nzango, 2019).

CAR's energy supply system pushes industries to produce their own energy from non-renewable sources. The most of these companies use diesel generators. Only IFB Batalimo and the Ngakobo sugar refinery uses biomass (wood waste for IFB and bagasse for Ngakobo) to produce electricity. The table below show the list of companies that produce their own energy (Komode, n.d.).

Table 24: List of independent producing companies

Companies	Activities sector	Type of technology production	Fuel used	Capacity (MW)
Bossongo	Oil mill	Thermal	diesel fuel	0,4
Nzila	Cement plant	Thermal	diesel fuel	4,00
SCAD	Sawmill	Thermal	diesel fuel	0,6
IFB Batalimo	Sawmill	Thermal	Wood wastes	0,6
IFB Ngotto	Sawmill	Thermal	Diesel fuel	0,2
SEFCA	Sawmill	Thermal	Diesel fuel	0,64
TANRY	Sawmill	Thermal	Diesel fuel	0,8
SOFOKAD	Sawmill	Thermal	Diesel fuel	0,672
Nagkobo	Sawmill	Thermal	Bagasse, shell cotton	1,6
Cellule Bambari	Cotton grinning	Thermal	diesel fuel	0,4
Cellule Bossangoa	Cotton grinning			0,4

Source: DGE

Energy demand: The final energy consumption in 2011 is 1120 Ktep. According to the EIS-CAR (Energy Information System of the Central Africa Republic) annual report 2013, by sector of activity, households constitute the highest energy consumption with 91% share. Then come the transport sectors and commerce & public service with 4% consumption each. The industrial sector only represents 1% of final energy consumed in 2011 (Komode, n.d). It should be noted that almost all of the energy consumed by households comes from biomass (firewood and charcoal).

According to the 2013 SIE - CAR annual report, final electricity consumption is split between three sector categories: industry, households and commerce, and public service. Their distribution for the years 2009 to 2011 is given in the table below.

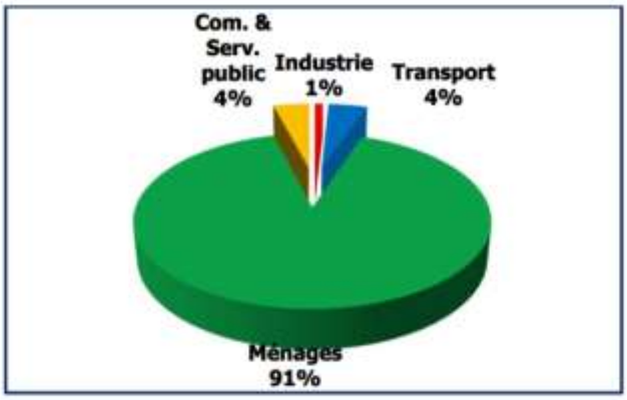


Figure 19: Sectoral distribution of total final energy consumption in 2011

Table 25: Final electricity consumption in MWh, by sector in 2009, 2010 and 2011

Secteur /Année	**2009**	**2010**	**2011**
Industrie	15 131	16 843	18 622
Ménages	26 900	26 345	27 221
Commerce & service public	30 702	31 350	32 248

Source : rapport annuel 2013 SIE-RCA

In CAR, the industrial and residential sectors are ranked at the top of the list as the most energy consumers. It may therefore be a connection between the Central African economy and energy consumption:
Industrial energy consumption and the potential for energy savings
Household energy consumption and the potential for energy savings
The table below regroup the energy consumption in the industrial and household sector.

Table 26: Energy consumption in the industrial and household sector (toe)

Sector /year	**2007**	**2008**	**2009**	**2010**	**2011**
Industry	11 075	11 262	11 756	17 143	14 513
Household	926 301	952 289	968 478	990 772	1 012 216

Source : SIE-CAR

Table 27: Energy strategy and relevant objectives (access, capacity, security of

Indicators	2011	Target 2015	Target 2020	Target 2025	Target 2030
Proportion of localities electrified					
Proportion of household with access to electricity	2,50%	10%	30%	40%	50%
Proportion of household with access to modern cooking systems	0%	2%	5%	8%	10%
Proportion of new and renewable energy in the national energy balance	0%	2%	5%	8%	10%

Source: (Komode, n.d.)

Cooking with charcoal only concerns a small number of wealthy households. Charcoal is also used in many households for ironing. Table 27 below shows an evolution of the demand for wood energy, from 2008 to 2011.

Table 28: Evolution of demand for fuelwood, from 2008 to 2011

	2 008		2009		2 010		2011	
	Firewood	Wood charcoal	Firewood	Wood charcoal	Firewood	Wood charcoal	Firewood	Wood charcoal
Production (1000 t)	2 469	5,9	2 530	6,1	2 594	6,2	2 658	6,4
Wood quantity used for wood charcoal production	40		41		41,8		43	
Consumption (1000 t)	2 429	5,9	2 489	6,1	2 552,2	6,2	2 615	6,4
Exportation (1000 t)								

Source: DGE

Percentage of biomass used: In 2016, energy production reached about 2.86 million tons of oil equivalent. Firewood represents production, electricity from the interconnected system 1%, and charcoal 1% (Bindo, 2017).

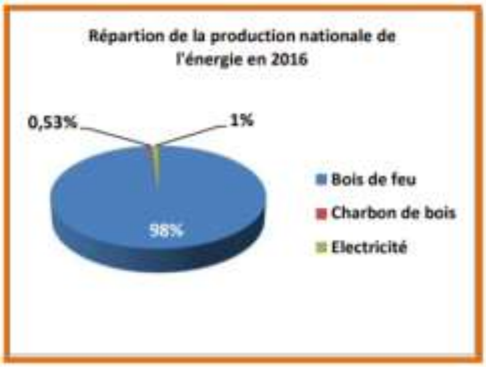


Figure 20: Nature energy production

Contribution of bioenergy: Applications for biomass exploitation in Chad:

- Incineration for cogeneration (heat and electricity).
- Fermentation for biogas production for cooking in households, productive use activities

Biofuels (with or without processing: ethanol, biodiesel and jatropha) for the development of the transport sector.

1.7.1 Conclusion and Recommendation

CAR is a country whose main natural resources are provided by the forest. The CAR has potential in solar, hydropower, wind, thermal and biomass energy. The majority of the oil and gas used in CAR is imported. The electricity sector in CAR is characterized by a mismatch between supply and demand. In fact, the rate of access to electricity is 2.5% nationally, around 20% at Bangui the capital, 1% in electrified secondary centres and almost zero in rural. This situation is so precarious for the economic and social development of the country and is explained by the low installed capacity of production infrastructure correlated with the use of unsuitable technology, the low rate of urbanization of cities. To this is added the monopoly of the public electricity service granted to the state company ENERCA since independence and the limited resources of the state to finance projects electrification.

Ouaka, Lobaye, Ngakobo are home to some forestry companies. These are areas with significant amounts of forest waste. Agricultural waste can also be found there. The recovery of this agricultural and forestry waste can contribute to making up for the deficit observed in the CAR's electricity network.

East Africa Selected Countries

3.1. Burundi

3.1.1. Energy resources of the country

3.1.1.1. Biomass

Households are the main consumers of energy in the country, accounting for 94% of total energy consumption. To a great extent, the consumption relies on biomass. Wood accounts for 97% of the fuel used, which inserts strong pressure on Burundi's limited and fragile forests. If industry and transport is included, 94% of all energy consumption relies on biomass, which is composed by around 70% of fuel wood, 18% of agricultural residues, 6% of charcoal, and 1% of bagasse. The current forest coverage of the country is 174, 000 hectares against a forecast consumption rate of 180, 000 ha (UNEP, 2017) which means that there is a deficit of wood supply. Firewood is the main energy source for most artisanal or industrial activities and for cooking fuel for majority of the population. The total sustainable firewood biomass supply from all sources was an estimated 6,400,000 m^3 in 2007. One of the main challenges is to develop a sustainable firewood supply. There exist several available sources of waste biomass and agricultural residue in different forms in Burundi, which can be sustainably harvested and transformed into energy sources.

3.1.1.2. Hydropower

Hydro power provides the majority of the country's electricity power supply. Burundi's energy supply depends on 95% hydro from 7 hydroelectricity plants, which has a combined installed power capacity of 30.6 MW (International Business Publications, 2018). However, there is considerable potential for further development, including micro, mini and small hydro power. Burundi's theoretical hydropower capacity is 1,700 MW, however, roughly 300 MW is seen as economically viable, and only 52 MW has been functionally installed (International Business Publications, 2018). The focus of the energy policy is on rehabilitation of existing (hydropower) plants and distribution grids, as well as the development of new hydroelectric sites. Furthermore, a rural electrification program is planned, mainly by grid extension, and by providing information on alternative energy sources affordable for low-income households (Se4All, 2020).

The average consumption of electricity in Burundi is 23 kWh/cap/year which is one of the lowest in the world (Fortune of Africa, n.d). Burundi is one of the least electrified countries globally currently at 7% overall, with 49% of the urban and only 1% of the rural population connected to electricity (Se4All, 2020). The electricity sector in Burundi is underdeveloped and the electrification rate is 11% (World Bank). Table 1 shows the electricity status as of 2013 according to the Burundi's National Energy Report (2017) (Karangwa, 2017). The energy situation is characterised by insufficient power supply to meet the demand, which inhibits economic growth.

Table 29: Electrification status in Burundi, 2013

Without electricity	95 %
With electricity	5 %
Urban electrification rate	2.8 %
Rural electrification rate	2 %

Source: (Karangwa, 2017)

3.1.1.3. Oil and Gas

Oil: In the period 2011 – 2015, 2.5% of the energy demand in Burundi was from petroleum (Burundi National Energy Report, 2017). Most of these petroleum sources are used to run household generators. Burundi has no known fossil fuel reserves. As a result, all of its thermal power is run from imported oil. The use of non-renewables is predominant at the household level. As of 2017, only 9% of Burundi's energy was sourced from diesel generators (Hafner, Tagliapietra, Falchetta, & Occhiali, 2019). The remaining 91% was from hydroelectric generation which makes Burundi a country heavily reliant on renewable energy. Out of the 35.5 Megawatts (MW) of electricity generated in Burundi, about 14% or 4.97MW of electricity is generated from diesel. Most of this diesel is imported from Kenya and Tanzania (Bazex & Antoine, 2019). Per capita consumption of energy is 219 kilogrammes (kg) of oil per year, which is the lowest in the world.

The Burundian Government has for the past 10 years leased a gas-fired power generation of 30 MW capacity located at Bujumbura, the capital city. This lease aims at bringing an immediate emergency electricity supply, but this solution has both an environmental and financial cost: around 160,000 litres of fuel is consumed each day and Régie de Production et Distribution d'Eau et d'Electricité (REGIDESO), the national electricity utility company required to pay around EUR 3.8 million per month. The lease has been entered into with Interpetrol, a company already operating in Burundi for the quasi-monopoly of oil importation (Barba, 2018).

LPG and Kerosene: The use of LPG and kerosene as sources of cooking fuel is impaired by low purchasing power of the citizens, poor infrastructure for delivery, and high cost of imports and transport of the product(s) (UNIDO, n.d).Most of the households that use kerosene or LPG are mostly located in Bujumbura and its environs. There has been an increase in the number of people using LPG and kerosene as alternatives to firewood and charcoal, but their numbers constitute a very small percentage of the total population.

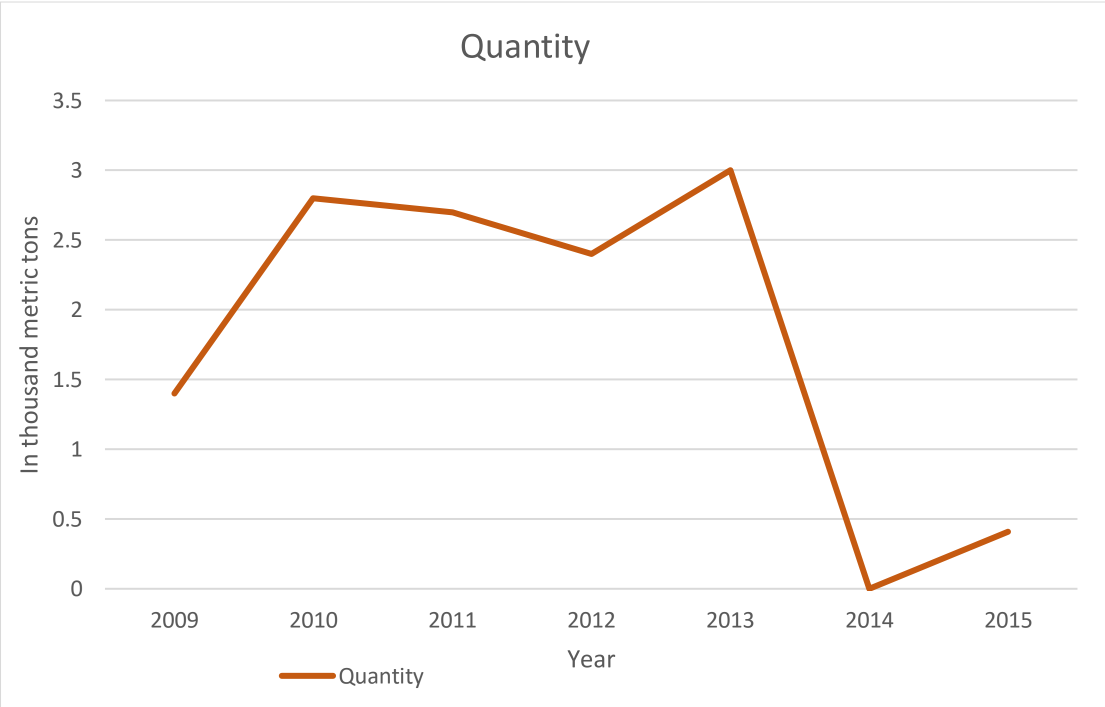


Figure 21: Statistics on total consumption of kerosene in thousand metric tonnes
Source: (United Nations Statistic Division, 2018)

3.1.1.4. Biogas

Biogas is a form of energy adapted well to the needs for Burundi. The current government's plan is to produce energy by means of digesters. According to the World Development Indicators, there is no data on biogas as well as all forms of cooking fuel (Liquified Petroleum Gas (LPG), natural gas) for Burundi. This does not mean that there are no biogas installations in Burundi, but that the statistics on the installations and capacities are not available.

The biogas industry in Burundi flourished in the 1980s and 1990s, with 320 – 1100 units installed in 1993, but data after this date remains scanty. In 1992, there were 206 small-scale biogas installations, and 84 institutional plants with digester volumes of over 100m^3 (Sacranie & Lausten, 2017). Ever since the beginning of the 2000's, biogas use has been decreasing steadily even though there is widespread knowledge and skills on the use of this technology, which was facilitated by international organizations in the '80s and '90s such as the German Technical Cooperation (then GTZ, but now GIZ), French Technical Cooperation (FTC), Belgian Technical Cooperation (BTC) and others (UNIDO, n.d).

3.1.1.5. Solar, Wind & Geothermal

Solar energy: Burundi has natural conditions favourable to the sustainable use of solar energy. The average annual power received is around 2000 kWh / m² per year, equivalent to the best European regions which are found in the Southern Mediterranean (Se4All, 2020). Average solar insolation stands at 4-5 kWh/ m^2/day (insert ref). There is a large potential for solar PV electricity generation in rural parts of Burundi since most regions are still yet to be connected to the main electrical grid. Solar energy is being investigated as a potential provider for off-grid electrification in rural areas. Institutions such as the Solar Electric Light Fund have also invested in small solar systems for public buildings, such as health centres.

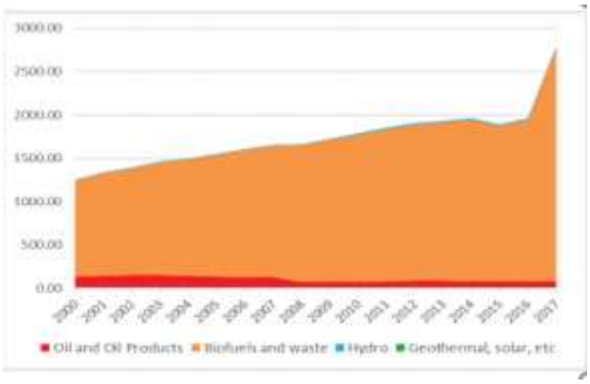
Wind energy: Data on wind patterns has been recorded by the Institute for Agronomic Sciences of Burundi (ISABU). Though primarily for agricultural purposes, the mean wind speed for the country oscillates between 4 and 6 m/s. More potential sites probably exist in the higher elevations. To date, no feasibility studies on wind power have been carried out in Burundi.

Geothermal energy: Geothermal resources have been identified in the West Rift Valley region in the neighbouring Democratic Republic of Congo to the east. Several geothermal indicators exist in Burundi, but there is little available data to-ascertain their commercial viability.

Peat: Peat resources in Burundi amount to about 323 km^2 (WEC, 2013). Of the country's known peatlands, the most extensive is located beneath the Akanyaru swamp complex to the north, an area of about 123 km^2 with an estimated 1.42 billion m^3 of peat in situ (Joosten, 2010). Peat production in 2008 was 20,000 tonnes which was entirely consumed in the same year. This constituted the entire production and total consumption total for all of Africa (WEC, 2013) (UNEP, 2017). As an alternative to wood, the use of peat would help in reducing pressure on Burundi's forests. Commercialisation of this resource, for use in agriculture and industry is being driven by the National Peat Officer (ONATOUR). ONATOUR was established in 1977 and in Africa, is the only facility that produces turf or dried-out peat sods using mechanical means. So far, only 0.5% of the 6 million tonnes peat reserves have been processed. Most of this (90%) has been used by the military and prisons. With the rehabilitation of the processing facilities, peat production is expected to rise (WEC, 2013).

3.1.2. Energy demands by economic sectors

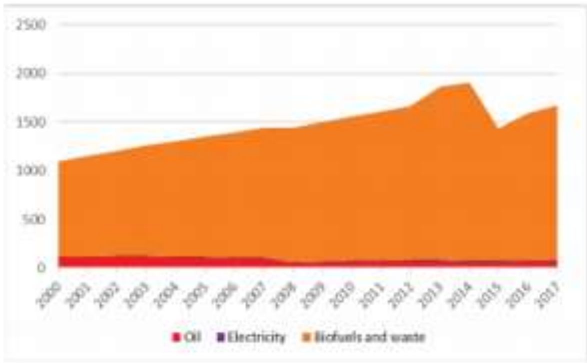
The primary energy supply and consumption at household level in Burundi is dominated by biomass (biofuels and wastes)(Figures 2a, Figure 2b, Figure 3a, Figure 3b). Most of Burundi's energy supply is from hydroelectric sources. As of 2017, the electricity produced outweighed the amount consumed. Ironically, part of the excess energy supplied is imported from outside the country.



a)

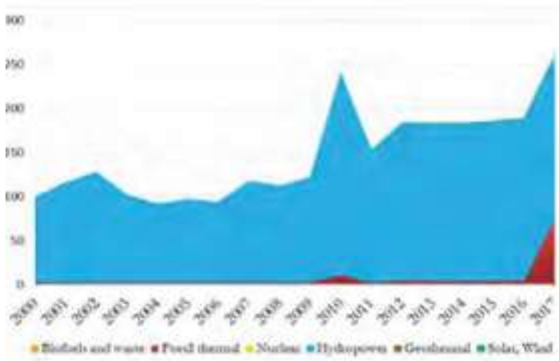
Figure 22: Total primary energy supply in Ktoe

Source: ?



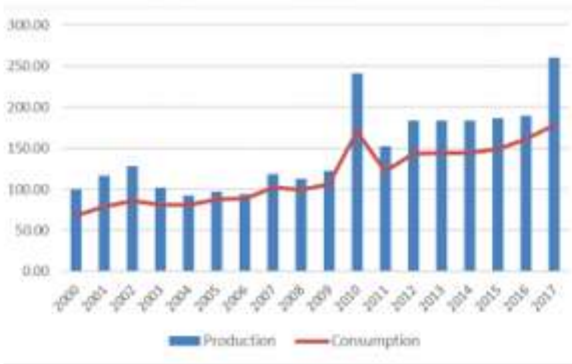
b)

Figure 23: Total final energy consumption in Ktoe



a)

Figure 24: Electricity Generation by source (GWh)



b)

Figure 25: Electricity Production and Consumption (GWh)

Source: ?

Burundi's energy sector is under-developed, which means that there exist considerable opportunities for investors, especially in the electricity sector which is mostly handled by the national water and electricity utility REGIDESO. REGIDESO has an installed capacity of 35.8 MW, of which 30.8MW are from hydropower plants and 5.5MW from thermal units. Both sources constitute 97% of the national installed capacity as per 2012 statistics. Burundi's national production is lower than consumption, hence the increasing need to import energy. This phenomenon is a consequence of under-investment in the energy sector over the last 20 years. Thus, there clearly is a need to increase national electricity production.

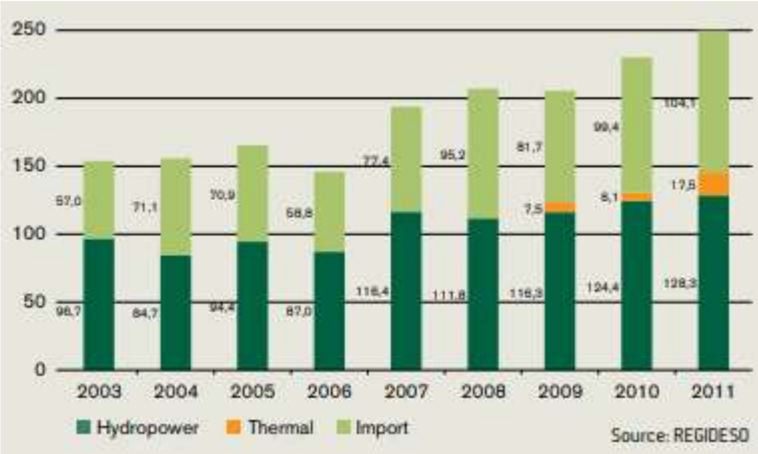


Figure 26: Sources of electricity production according to REGIDOSO (2003 to 2011)

Source: (Ministry of Energy and Mining, 2012)

Table 30 below shows the energy balance for Burundi. It shows that most of the energy consumption in the industry and transport sector comes from oil products. Most households, however, rely on biomass. The graph also shows that the agriculture and forestry sectors have limited energy consumption as represented by their nil figures.

Table 30: Energy balance for Burundi

2017 — Thousand Tonnes of Oil Equivalent (ktoe)		Crude Oil[2]	Oil Products	Coal[2]	Natural Gas	Nuclear	Hydro	Wind/ Geother./ Solar	Biofuels / Waste	Electricity	Total
PRIMARY SUPPLY	Production	0.00	-	0.00	0.00	0.00	15.95	0.09	2702.06	-	2718.10
	Imports	0.00	73.92	0.00	0.00	-	-	-	0.00	9.67	83.59
	Exports (-)	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
	Int. Marine Bunkers (-)	-	0.00	-	-	-	-	-	-	-	0.00
	Int. Aviation Bunkers (-)	-	0.00	-	-	-	-	-	-	-	0.00
	ΔStock (+ draw, - build)	0.00	3.86	0.00	0.00	-	-	-	-	-	3.86
	TPES[3]	**0.00**	**77.78**	**0.00**	**0.00**	**0.00**	**15.95**	**0.09**	**2702.06**	**9.67**	**2805.55**
	Transfers	0.00	0.00	-	-	-	-	-	-	-	0.00
	Statistical Difference	0.00	-5.19	0.00	0.00	0.00	0.00	0.00	370.51	-0.01	365.31
TRANSFORMATION	**Transformation**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-15.95**	**-0.09**	**-723.88**	**22.39**	**-717.53**
	Electricity Producers	0.00	0.00	0.00	0.00	0.00	-15.95	-0.09	0.00	22.39	6.35
	Petroleum Refineries	0.00	0.00	-	-	-	-	-	-	-	0.00
	Charcoal Plants	-	-	-	-	-	-	-	-723.88	-	-723.88
	Gas-to-Liquids	0.00	-	-	0.00	-	-	-	-	-	0.00
	Coal-to-Liquids	0.00	-	0.00	-	-	-	-	-	-	0.00
	Blast Furnaces	-	-	0.00	-	-	-	-	-	-	0.00
	Other Transformation	0.00	0.00	0.00	0.00	-	-	-	0.00	-	0.00
	Own Use	0.00	0.00	0.00	0.00	-	-	-	0.00	-0.25	-0.25
	Losses	0.00	0.00	0.00	0.00	-	-	-	0.00	-16.51	-16.51
FINAL CONSUMPTION	**TFC**	**0.00**	**72.59**	**0.00**	**0.00**	**-**	**-**	**-**	**2348.69**	**15.29**	**2436.57**
	Industry	0.00	22.14	0.00	0.00	-	-	-	0.00	2.99	25.13
	Transport	-	50.16	0.00	0.00	-	-	-	0.00	0.00	50.16
	Households	-	0.23	0.00	0.00	-	-	-	2046.22	8.34	2054.79
	Com. & Public	0.00	0.06	0.00	0.00	-	-	-	302.47	3.96	306.49
	Agriculture/Forestry	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
	Others (Non Specified)	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
	Non-Energy Use	0.00	0.00	0.00	0.00	-	-	-	-	-	0.00

Source: ?

3.1.3. Main economic sectors and their energy demand

3.1.3.1. Agriculture Sector

The Burundian economy is dominated by the agriculture sector, which accounts for nearly half of its gross domestic product (GDP) and close to 80% of its export revenues (Republic of Burundi, 2015). The current economic structure, dominated by subsistence farming, is very vulnerable and fragile due to its dependency on climatic conditions (Republic of Burundi, 2015). There are many opportunities in the agriculture sector that could benefit from improved energy sources such as bioenergy. For example, fisheries in Lake Tanganyika need cooling systems to conserve the fish. Photovoltaic power generation could be a potential solution. In the agriculture sector processing and conservation of fruits, vegetables or milk in rural areas is a way of achieving economic development. The installation of photovoltaic generators could be a solution to the energy problems the agro-processing sector is facing (Republic of Burundi, 2015).

3.1.3.2. Mining

The scale of the Burundian mining sector is minor compared to its neighbours. Burundi is home to an estimated 10,000 artisanal miners. Two thirds of the artisanal miners are engaged in gold mining. In 2012, mining accounted for less than 1% of the country's Gross Domestic Product (GDP) while subsistence agriculture accounted for more than 40%. Fiscal revenues from the mining sector represent a mere 0.3% of national fiscal revenues despite gold being Burundi's largest national export. In 2013, 2.8 tonnes worth more than USD 100 million were exported, most of which ends up in Dubai in the United Arab Emirates–(Matthysen, 2015). Furthermore, extraction is often carried out with rudimentary techniques and tools such as pickaxes, hammers, chisels, shovels and pans. Efficiency can already be increased considerably with the introduction of quite simple techniques, such as water pumps, compressors and automatic crushing machines, some of which require electricity. Burundi's Vision 2025 aims at providing energy in quantities sufficient for the industrial, artisanal and mining activities.

3.1.3.3. Forestry

Most state forest plantations were established in the 1980s. However, it is not clear how much and which forest plantations are still standing after the long political crisis. Support for updating forest inventory in Burundi, the last of which was carried out in 1976 and collection of accurate forest statistics in Burundi is urgently needed. For example, the area and usable volume of wood of several different species remains unknown in Burundi. The statistics on the energy demands from the forestry sector are not available, though a number of actors involved in wood processing business sector mainly characterised by individual businessmen and informal groups exist. However, there is limited industrial scale processing and hence the energy demands in the forestry sector are low. With the exception of major towns like Bujumbura where there are few wood working machines, wood processing is mainly carried out with hand tools. Some of the large companies and sawmillers involved in primary and secondary processing in some of the big forest plantation estates in Burundi include: Wood perfect, Participatory Management Group (PMG), Coopérative INEZA des menuisiers du Marché de Mutanga Nord (INEZA), Cooperative of carpenters - Mutanga North Market and different carpenters associations working at the artisanal training centre of Jabe (Centre de Formation Artisanal (CFA).

3.1.3.4. Industry

In Burundi, Industry and handicraft represents just 17-18% of GDP. BRARUDI brewery is one of the largest electricity consumers in Burundi and is reported to have produced 2.8% of its own electricity consumption in 2011 and is interested in investment opportunities in alternative solutions such as renewable self-production. According to earlier scenarios for economic growth, the energy needs in 2020 with industrial consumption included were estimated at 100 MW. However, a number of industrial activities require additional capacity that is estimated to be at least 100 MW. Consequently, the energy demand was estimated at around 250 MW in 2020, excluding the energy needs of the nickel mines, which would need around 280 MW in peak hours (Figure 27). There are also other mines projects, like MUSONGATI and MUREMERA nickel projects that require electricity. The commercial and handicraft sector also has a considerable need for electricity (welding, preservation of milk etc) (Fortune of Africa, n.d).

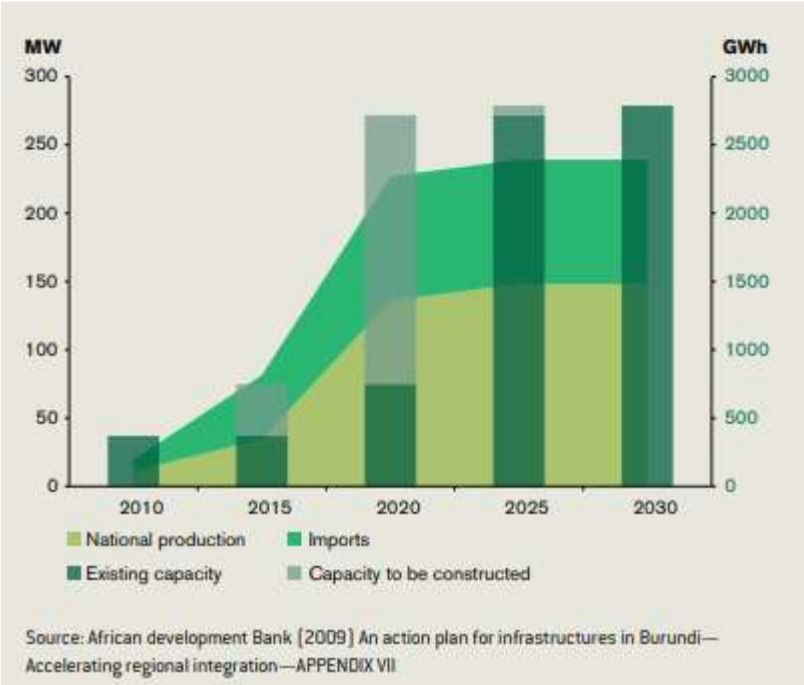


Figure 27: Electricity power and consumption

Source: ?

3.1.3.5. Transport

The transport sector is one of the most vital sectors in Burundi as other sectors depend on it for the movement and delivery of their goods. The sector in Burundi is undergoing improvements following destruction of infrastructure as a result of civil wars. Because of the landlocked nature in Burundi road is the most dominant mode of transport. The road transport system in Burundi comprises about 14,480kilometres of road network and only about 7 percent of them remain open in all weather, the rest are considered as local roads or local tracks. The sector is affected by high fuel prices since it imports most of the petroleum products. Burundi does not possess any railway infrastructure, although there are proposals to connect it to neighbouring countries via railway. The country’s Bujumbura International Airport is the only airport people can use for international air travel. One of the focus areas of Burundi’s Vision 2025 is on improvement and the development of the infrastructures of transport, communication and energy. Concerning the infrastructures for transport, Burundi’s vision 2025 plans to turn Burundi into a transit and a major hub for the Great Lakes subregion, and to function as a service economy.

3.1.3.6. Domestic/Institutional Sector

Households are the main consumers of energy in the country, accounting for 94% of total consumption. Their needs are almost exclusively met by traditional biomass (99%). Burundi’s Vision 2025 has as a principal objective to ensure that by 2025 both the rural and urban populations have access to reliable, clean sources of energy and at competitive prices. Given the large dependency of Burundi’s households and communities on wood fuel and charcoal, with firewood consumption accounting for 96 % of total consumption (rural—76 %; urban—24%), there is a severe fuel wood deficit.

3.1.3.7. Other sectors

Health, education and tourism sectors in Burundi are other sectors that have considerable demands for energy. 20% of the rural hospitals and 70% of the health centres do not have access to energy. There is a considerable public health challenge in supplying hospitals and health centres with a minimum level of energy for lighting, refrigeration, and sanitation services. The vast majority of schools in rural areas do not have electricity. Although many buildings have been equipped with solar energy, a needs and resources analysis should be carried out to increase access and identify which energy source would be most suitable. Access to solar energy or small-scale hydropower for remote tourism destinations would improve the quality of accommodation and also promote the development of ecological tourism in Burundi (Republic of Burundi, 2012).

3.1.4. Sectors with high potential of bioenergy

Industry and mining sectors: These two sectors have high potential. Vision 2025 requires that both the rural and the urban population have access to reliable, clean and competitive energy sources and provide sufficient energy for industrial and mining activities. As a result of the existing energy deficit in Burundi, Burundi's industries are currently internally generating their own energy either by using costly solutions or solutions that pose a threat to the environment, such as using firewood for the processing of tea. These industries have an interest in supporting and consuming renewable energy both for environmental purposes but also to reduce costs (Republic of Burundi, 2015) calls for the expansion of hydroelectric power stations and investment in renewable energy, improvement in wood-energy sector while safeguarding the environment, and promotion of renewable energies (solar, ethanol and wind). Currently, search for new and use of existing renewable energy sources, in particular, fuels of biological origin – biomass has now intensified in the world energy sector driven by the rising prices for fossil fuel.
Domestic /Institutional sector: This sector is very important since more than 90% of the population of cities and almost 100% of secondary urban centres use charcoal or firewood as a source of energy mainly for cooking food ((Ministry of Energy and Mining, 2012). As noted above, Burundi's Vision 2025 has as a principal objective to ensure that by 2025 both the rural and urban populations have access to reliable, clean sources of energy and at competitive prices, and bioenergy offers a good opportunity to realise this objective.

1.7.2 Conclusions and Recommendations

There are many opportunities and potential for bioenergy in Burundi derived from the following:

1. A growing power supply-demand gap notably due to a rapidly increasing power demand in the capital city of Bujumbura and (ii) a huge energy resource (notably renewable, with hydro, estimated to 1,7 GW, and solar, estimated to 2,000 kWh/m²/year).
2. Burundi is also very densely populated compared to other neighbouring countries such as Tanzania or Kenya. The country has a population density of 350km^2 and is populated by 10 million people, a figure similar to that of Rwanda.
3. It has a huge demand for small and medium scale energy projects which may match to its agricultural needs (mechanization and food-conservation), the global welfare of the local population (schools and hospitals) and the potential mineral extraction in the region.
4. Burundi possesses large deposits of peat in the order to of 50 million tonnes. Household energy needs could be met by carbonising peat with agricultural waste in small, cost-efficient, and widely distributed stoves (GIZ, 2011).

Successful exploitation of biomass reserves in the Republic of Burundi will partially solve the country's energy problems. In addition to minimizing consumption of diesel fuel the use of biogas and pyrogas will improve the thermodynamic and economic efficiency of the existing diesel-electric generators of the "REGIDESO". One solution is the use of pyrolysis on peat, wood waste, agricultural biomass, household and industrial waste in order to obtain from them secondary energy resources - pyrolysis and biogas, diesel fuel, coke, charcoal, heating oil. Studies on the pyrolysis processing of both peat and solid agricultural waste from rice, sorghum, peas, beans, maize, as well as biogas from solid and liquid waste from the Kirekura-Muzazi mini-plant in the city of Bujumbura for the production of palm oil were carried out in 2019. The main types of biomass with promising results if upscaled for commercial use are Burundi palm sawdust, local peat, rice and coffee straws and husks. Some of the conclusions made from this study are:

- Fast and high-temperature pyrolysis allows one to preserve the energy capacity of rice, coffee straw and husk, as well as Burundian palm trees, and thereby increase the yield of volatile gases for a longer time during high-temperature conversion.
- Biogas obtained from a palm liquid substrate in the Kirekura-Muzazi mini-plant in the city of Bujumbura, contains: CH_4 - more than 70%; H_2S - about 0.1%; CO_2 - about 30%. This indicates that the resulting biogas, with methane content of more than 70%, may well be used as fuel for generating electricity in diesel generators, and for domestic purposes.
- Considering the amount of gas produced every day at the operating mini-plant that processes 6.0 tons per day of palm raw materials, it can be concluded that with full automation and intensification of the cooking process it becomes possible to increase productivity by several times and thus to approach the production of biogas to the existing industrial plant in Europe, which will at least partly solve the energy problem in the Republic of Burundi.
- The results of the reconstruction of diesel generators of the industrial group "REGIDESO" to the use of biomethane as fuel will increase their engine life, as well as reduce the consumption of diesel fuel by 55-60%, and thereby reduce the cost of electricity supplied by 2.0-2 5 times (Manigomba, Chichirova, Gruzdev, Ndikumana, & Lyapin, 2019).

In Burundi, the following biomass activities could be explored (Ministry of Energy and Mining, 2012):

- Electricity production based on waste by direct burning or by methanisation.
- The use of household and/or industrial waste for incineration and methanisation.
- Peat-based electricity production. Burundi possesses a peat potential estimated at 600 million tons. The exploitable potential would be around 47 to 58 million tons. The management of the peat is the responsibility of the National Peat Office (ONATOUR).
- The use of sugar cane residues (bagasse) to produce electricity. The country's leading sugar company, Société Sucrière du Moso (SOSUMO) has a biomass power plant. The plant is a 2 x 2 MW cogeneration unit that is fuelled with bagasse (sugar cane residues) and is operational during the entire sugar season. Unfortunately, this turbine is linked only to the SOSUMO factory and its administrative buildings. Eventual surplus production is not injected to the REGIDESO grid. The absence of a steam condenser prevents the factory from being productive outside the sugar season, despite the stocks of bagasse waste. The French cooperation is currently analysing how to help SOSUMO connect to the national grid and also to resell its surpluses to REGIDESO.
- The use of peat in combination with forest biomass residues or agricultural waste to produce briquettes.
- Gasification of wood waste from wood industries to produce wood pellets and distribution of efficient cookstoves.

3.2. Djibouti

3.2.1. Energy resources of the country

3.2.1.1. Biomass

Total Primary Energy Supply in Djibouti is dominated by biomass, accounting for about 67%, with the remaining share from oil products (Singh, Nouhou, & Sokona, 2015). Biomass use has progressively decreased in urban areas as a proportion of the total. Kerosene has replaced biomass in Djiboutian homes, and renewables account for negligible amounts of energy consumed across the whole country. However, better data are needed to improve the assessment of the biomass contribution to the overall energy mix. With the majority of the country being semi desert, Djibouti's potential for large-scale power production from biomass is expected to be of limited feasibility since both wood waste and agricultural residues are lacking. However, no formal assessment has yet been made into the country. Predominant use of traditional biomass resources for domestic purposes is inefficient and potentially harmful, particularly the household use of charcoal and firewood. World Bank has made recommendations to the government of Djibouti to promote the use of bottled LPG as an alternative, which will likewise improve home energy efficiency.

3.2.1.2. Hydropower

Djibouti has no hydropower sources of its own. The country imports its energy from Ethiopia's hydropower production through a 150MW electrical transmission line (Republic of Djibouti, 2015). Prior to 2011, 100% of Djibouti's energy was generated from heavy fuel oil and diesel thermal power plants. From that year onwards, however, some 65% of Djibouti's electricity has been supplied through a 150-MW interconnection line from Ethiopia. Local power production, which now accounts for around 35% of the energy supply, continues to be generated through local heavy oil and diesel thermal power plants, with a total power generation capacity of 126 MW, distributed between four generation plants: Boulaos (108.2 MW), Marabout (14.4 MW), Tadjoura (2.2 MW) and Obock (1.2 MW), according to a 2013 Djibouti market brief by the Africa-EU Energy Partnership. Djibouti vision 2035, mentions improving access to energy and energy security as a primary strategic focus and envisaged a power sector transition from 100% fossil thermal in 2010 to 100% renewable energy by the year 2020.The electricity sector in Djibouti has not seen much progress for several decades and the electrification rate is 55% (Singh, Nouhou, & Sokona, 2015). Most demand is from the city of Djibouti and it has been growing at a rate of 5% a year. Forecasts put the maximum energy demand for 2025 at 810 GWh/yr.

3.2.1.3. Oil and gas

Djibouti has no oil reserves and no refining capacity so far. Djibouti relies entirely on imported fossil fuels and electricity to meet its energy needs and, therefore, remains exposed to fluctuating oil prices. Figure 28 shows the Total Primary Energy Supply between 2000-2010 of oil when compared to bioenergy.

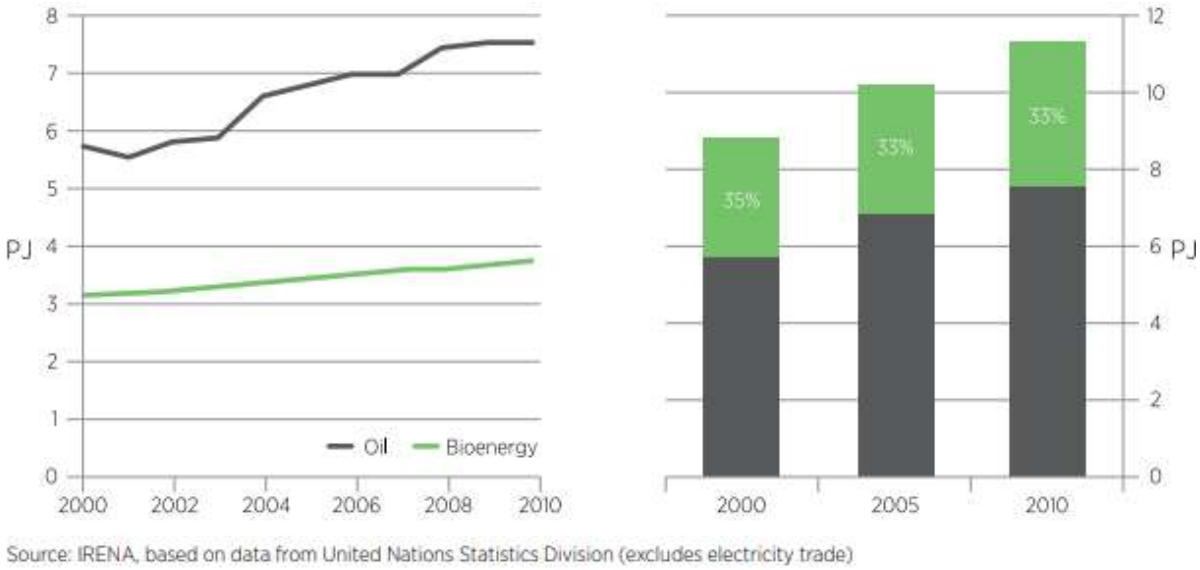


Figure 28: Total primary energy supply from 2000 to 2010

Source: (Singh, Nouhou, & Sokona, 2015)

Petroleum product consumption has been on the rise since 2005, particularly diesel and kerosene (Figure 29). This rise in consumption is due to increased demand from the transport and household sectors. In 2012, Djibouti imported nearly 390 000 tonnes of oil equivalent. Fuel oil consumption has reduced since 2011 as a result of the interconnection with Ethiopia.

Figure 8. Petroleum product consumption over time

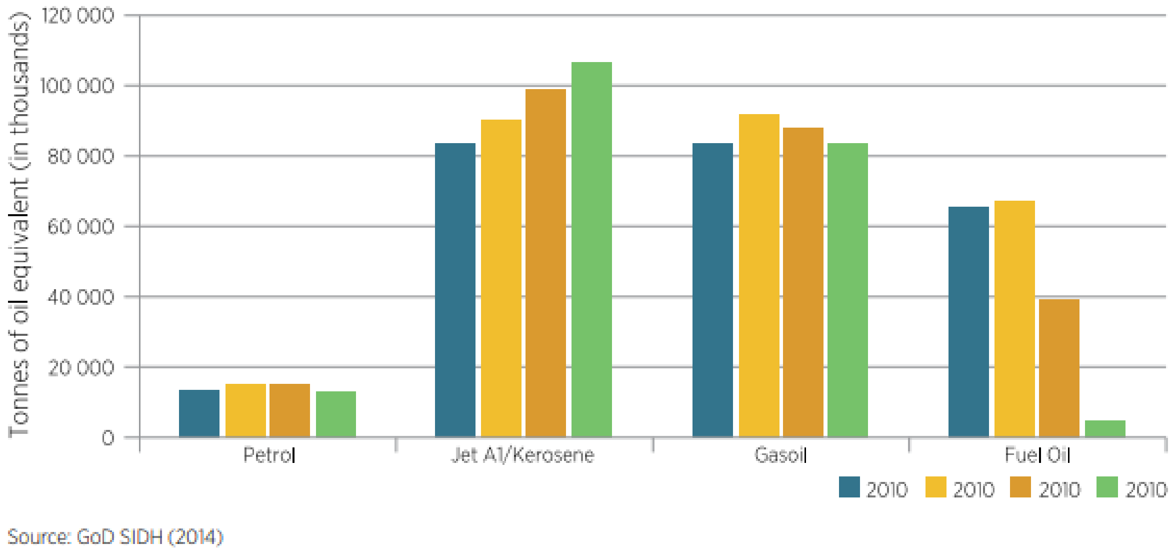


Figure 29: Petrol product consumption over time

Source: (Singh, Nouhou, & Sokona, 2015)

There is currently no available data on biogas in Djibouti or the industries that use this resource. According to a 2015 Djibouti report, the production of electricity using household waste has a potential of generating 10MW. However, this assessment was considered a non-priority by the government since no funds were available to finance biogas projects and further study was needed to assess the viability.

3.2.1.4. LPG and kerosene

Clean fuels for cooking are Biogas, Liquified gas, electricity, and natural gas (BLEN).Kerosene continues to be a key source of heat energy in Djiboutian households and has been on a rising trend compared to biomass use in the past few years. According to the World Bank ranking of 2016 (World Bank, 2020) only 11.5% of the total Djiboutian population in 2016 had access to clean cooking fuels.

3.2.1.5. Solar, wind and geothermal

Solar: Djibouti has high potential for solar energy due to its high temperature seasons that provide Global Horizontal Irradiance (GHI) of 4.5-7.3 kWh per square metre per day (m2/day). Djibouti had set a target of achieving electrification of 30% of the rural population by solar photovoltaics by 2017. A solar park of an area of 5200m^2set up by the Japanese government in 2012 produced 508MWh for the entire year. The site of the solar plant is at *Centre d'Etudes et de Recherche de Djibouti (CERD).* Surplus power is fed to the Djibouti Electricity Company (*Electricité de Djibouti (EdD)*). The solar park has 1440 solar panels (Hassan Daher, Gaillard, Ménézo, & Amara, 2015) that have a combined output of 304 Watt Peaks (Wp)(Ibid). Watt peak is the maximum power output of a solar panel under ideal conditions. The government also plans to set up three more solar plants at Petit Bara, Ali Sabieh and Goubet. The commissioning of these plants is expected to be done in 2025. These three solar plants are expected to provide a combined output of 250MW of photovoltaic electricity (Republic of Djibouti, 2015). The country aims to set up other solar plants that will be used to desalinize sea water for both domestic and industrial use.

Wind: Studies conducted in the 1980s indicated that average wind speeds across Djibouti peak at 4 m/s, indicating a moderate potential for wind energy. The potential of wind energy in Djibouti is 390MW.Djibouti is planning to set up an onshore wind farm with an electric generation of 60MW (Republic of Djibouti, 2015). The site of the proposed windfarm will be at Goubet. The power plants are set to be commissioned in 2025 (Republic of Djibouti, 2015). Other places identified for the construction of wind farms in the country are:

- Ali Sabieh
- Bada wein
- Egralyta
- Djibouti city

Geothermal: Geothermal exploration in the Djibouti fields began in the 1970's in the Assal Rift Zone (Singh, Nouhou, & Sokona, 2015). Due to the country's inefficient thermal plants. Out of the 120MW installed, the country only generates 67MW of electricity (The World Bank, 2017; Republic of Djibouti, 2015). The exploitable potential of the country's geothermal energy is 330 – 650 Megawatts Electricity (MWe), the capable electric output from a plant.The sites having geothermal potential in Djibouti and which exploratory drilling has already been done are (Republic of Djibouti, 2015):

- Lake Asal
- NorthGoubhet
- Lake Abhe
- Obock
- SakalolAlol
- Gaggadé
- Hanlé
- Arta

None of these geothermal sites have been developed but the most recent available literature states that funding of $24.73 million for development of Lake Asal geothermal site was given to the Djibouti government in 2018 (Africa Energy Portal, 2020). In addition, the government plans to build a 30MW plant on Lake Asal (UNEP, 2017).

3.2.1.6. Other sources of energy

Tidal Energy: Blue shark energy, a French firm, is planning to build a 120MW tidal farm off the coast of Djibouti. The tidal farm will be harnessing the tidal waves off the coast to generate electricity.

3.2.2. Energy demand by economic sectors

Data for primary energy supply by Energy Africa Commission is not available but data for total energy consumption shows that Djibouti heavily relies on oil and biomass (biofuels and wastes) (Figure 30). The economic sectors in Djibouti especially transport and household rely on imported oil products (Figure 31).

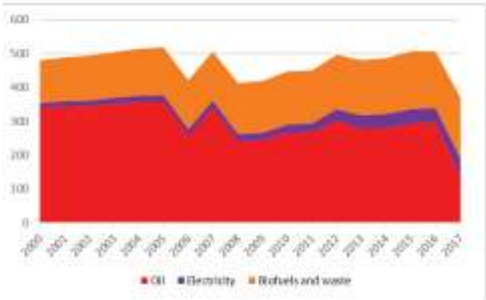


Figure 30: Total final energy consumption in Ktoe

Source: ?

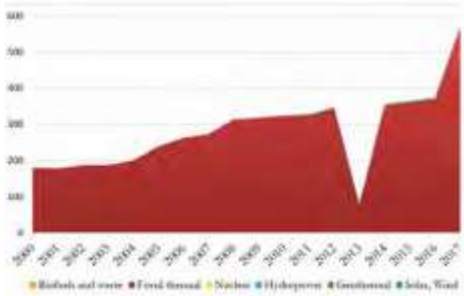


Figure 31: Electricity production and consumption in GWh

Source: ?

Table 31: Energy consumption by source and sector in 2017

	2017	Crude Oil[1]	Oil Products	Coal[2]	Natural Gas	Nuclear	Hydro	Wind/ Geother./ Solar	Biofuels / Waste	Electricity	Total
		Thousand Tonnes of Oil Equivalent (ktoe)									
PRIMARY SUPPLY	Production	0.00	-	0.00	0.00	0.00	0.00	0.02	249.85	-	249.87
	Imports	0.00	157.14	0.00	0.00	-	-	-	0.00	43.70	200.84
	Exports (-)	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
	Int. Marine Bunkers (-)	-	0.00	-	-	-	-	-	-	-	0.00
	Int. Aviation Bunkers (-)	-	0.00	-	-	-	-	-	-	-	0.00
	ΔStock (+ draw, - build)	0.00	0.00	0.00	0.00	-	-	-	-	-	0.00
	TPES[3]	**0.00**	**157.14**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**249.85**	**43.70**	**450.71**
	Transfers	0.00	0.00	-	-	-	-	-	-	-	0.00
	Statistical Difference	0.00	0.01	0.00	0.00	0.00	0.00	0.00	75.31	-47.68	32.64
TRANSFORMATION	**Transformation**	**0.00**	**-15.81**	**0.00**	**0.00**	**0.00**	**0.00**	**-0.02**	**-144.41**	**48.98**	**-111.26**
	Electricity Producers	0.00	-15.81	0.00	0.00	0.00	0.00	-0.02	0.00	48.98	33.15
	Petroleum Refineries	0.00	0.00	-	-	-	-	-	-	-	0.00
	Charcoal Plants	-	-	-	-	-	-	-	-144.41	-	-144.41
	Gas-to-Liquids	0.00	-	-	0.00	-	-	-	-	-	0.00
	Coal-to-Liquids	0.00	-	0.00	-	-	-	-	-	-	0.00
	Blast Furnaces	-	-	0.00	-	-	-	-	-	-	0.00
	Other Transformation	0.00	0.00	0.00	0.00	-	-	-	0.00	-	0.00
	Own Use	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
	Losses	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
FINAL CONSUMPTION	**TFC**	**0.00**	**141.34**	**0.00**	**0.00**	**-**	**-**	**-**	**180.75**	**50.00**	**372.09**
	Industry	0.00	0.00	0.00	0.00	-	-	-	0.00	10.33	10.33
	Transport	-	126.35	0.00	0.00	-	-	-	0.00	0.00	126.35
	Households	-	14.99	0.00	0.00	-	-	-	146.36	23.30	184.65
	Com. & Public	0.00	0.00	0.00	0.00	-	-	-	34.39	11.98	46.37
	Agriculture/Forestry	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
	Others (Non Specified)	0.00	0.00	0.00	0.00	-	-	-	0.00	4.39	4.39
	Non-Energy Use	0.00	0.00	0.00	0.00	-	-	-	-	-	0.00

Source: ?

3.2.3. Main economic sectors and their energy demands

3.2.3.1. Agriculture Sector

The primary sector (agriculture and fisheries) contributes to about 3% of the GDP. Annual estimates indicate a growth rate of 7.7% for year 2020 (World Bank, 2019).Unreliable rainfall and less than 4% arable land limits crop production to small quantities of fruits and vegetables, and most food must be imported. The contribution of agriculture to the national GDP is expected to increase from 3.7% in 2012 to 4.1% in 2022 and 5% of GDP by 2035, according to government plans stated in the Djibouti Vision 2035 strategy document. The sector is currently made up of small plots and subsistence farming techniques – which is perhaps no surprise given the arid climate. The government is hoping to increase the amount of locally cultivated products and seafood, but also establish agro-industrial production units to add value to production, with an eye to exports to the Gulf states. Due to the limited agricultural production, energy demand from the agriculture sector is therefore low.

3.2.3.2. Mining

Djibouti's key natural resources include salt, petroleum, gold, clay, marble, pumice, gypsum and diatomite. At 155 m below sea level, Lake Assal is believed to have the largest unexplored salt reserves in the world, totalling around 100 Mt. A nationwide survey of the country's mineral resources in 2015 found new deposits of sandstone, limestone and ornamental stones in Ali Sabieh in the south; corallian limestone, clay and pumice in Tadjourah; and ilmenite sand, corrallin limestone and ornamental stones in Obock in the north. These industrial minerals and rocks are necessary for the development of sectors like construction, public works, agriculture and the ceramics industry. The country's first gold mining operation located near the Port of Djibouti has a huge potential. At present, mining accounts for between 1% and 3% of Djibouti's GDP, according to estimates from the World Bank and the African Development Bank. Government efforts to improve the mining investment environment are part of a concentrated effort to diversify the economy and improve the broader investment climate – a central part of the Djibouti Vision 2035 strategy for economic development and inclusive growth. Mining therefore has a huge energy demand potential in Djibouti and energy assessment demands would provide more insight on the magnitude of energy needed for this important sector.

3.2.3.3. Forestry

Djibouti has very few forest resources. The forested area of Djibouti is just 0.3% of the country's total land area (Butler, 2016). The Food and Agriculture statistical database (FAOSTAT) estimates the total area under forestry in the country to be 56 km^2 (FAO, 2019).Because the country does not have industrial plantations and the natural forests are not for exploitation, the energy demand for wood products has to be substantiated from other sources.

3.2.3.4. Industry

The industrial and manufacturing sector accounts for 17% of the GDP. There are currently just over 30 formal, large-scale, commercial manufacturing enterprises operating in the country. The firms are largely focused on the domestic market as opposed to exports, with a number of companies operating in the building materials, beverage and mineral water, industrial gas, and plastic and paper production segments. A central part of Djibouti's government's Vision 2035 strategy for economic development is facilitating industrial growth in the country. The growth curve of the industrial sector's energy demand is expected to rise in the near future and especially from the agro-processing, shipping and processing industries.

3.2.3.5. Transport

The structure of the economy is dominated by the service sector - transport, communications, commerce, and tourism. These contribute to more than 80% of Djibouti's GDP, and employ about 60% of the active population (IMF, 2013). Transport and related logistical services remain the backbone of the economy. The government launched a programme to increase port activity in 2012 by building two ports as well as road corridors. Much of this is intended to meet the needs of the growing Ethiopian economy. The construction of the Port of Doraleh, expected to increase the port's annual cargo handling capacity to 10 million tonnes by 2022. The 759km Addis Ababa–Djibouti Railway, the first all-electric inter-country railway system in Africa, completed in 2017 and inaugurated in 2018, is a major transport infrastructure in Djibouti. The railway has a total capacity of 24.9 million tonnes of freight annually, although the current haulage is about 5m tonnes. However, the haulage is expected to increase to 6 million tonnes by 2023. Meanwhile, development of the airline sector is also underway. The national carrier, Air Djibouti, was relaunched in 2015 and there are two new airports, the Ahmed Dini Ahmed International Airport near the Sept-Frères archipelago, and the Hassan GouledAptidon International Airport at Bicidley. The two airports are expected to increase the country's air transport capacity by eight times from the current 900, 000 passengers. Investments in port infrastructure have contributed to the recorded rise in commercial activity in Djibouti in 2019, and this is expected to increase the energy demand of the industrial sector in Djibouti.

3.2.4. Sector with high potential of bioenergy

Like Burundi, the industry and mining sectors of Djibouti have the highest potential for bioenergy use. Growth in these sectors is currently being driven by infrastructural development. The industrial sector for example will also remain strong as the nascent import-substitution manufacturing industry (mainly food processing and construction materials) develops. Annual estimates indicate a growth rate of 7.7% for the year 2020 (World Bank, 2019).

1.7.3 Conclusions and Recommendations

There is no bioenergy that can be derived from forest biomass since there are no forests exploited for commercial purpose in Djibouti. There is also no agricultural waste since most of the crops grown are for consumption purposes, and little or none at all are grown as raw materials for bioenergy production. However, there is potential of using *Prosopis Juliflora*, an invasive species for bioenergy which can be processed to briquettes or used as feedstock for electricity generation. The *Prosopis Juliflora* tree has successfully been used as feedstock at energy generation plants in India and there were attempts by the Cummins Cogeneration Kenya Ltd intends to do the same in Kenya in 2014. In Kenya's case, this was not successful because the area's Prosopis species had a lot of moisture hence incompatible with the gasification technology which would have been employed to produce the biomass.

2 West Africa

4.1. Benin

4.1.1. Energy resources

From the graph below it is clear that Benin produces very little energy on its soil. Total primary energy production in 2017 is largely dominated by biomass, mainly wood energy. Although producing hydroelectricity and having solar photovoltaic plants, the part of these two forms of renewable energy is marginal in the total primary energy production balance.

The data in the graph come mainly from the Energy Information System (EIS) of the Republic of Benin for 2017. The only missing information in the EIS concerns hydropower production on the national territory[9] and was taken from the AFREC balance sheet (2019). [10]This production is very low, since it only concerns the Yéripao dam, with 0.5 kW installed in the country.

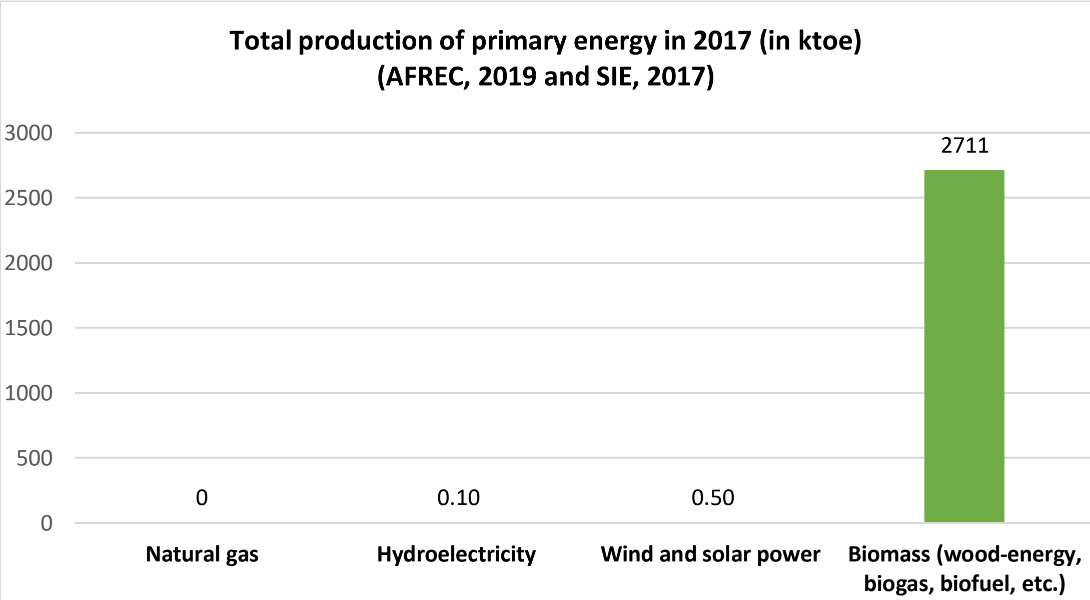


Figure 32: Total primary energy production in 2017 in Benin (in ktoe)
Source: (AFREC, 2019)

The data in the graph below are again mainly from the EIS 2017, with the addition of hydroelectricity production from AFREC (2019).

According to this graph, Benin imports almost as much oil products as it does biomass. It also shows that the country imports 87 ktoe of electricity. All imported natural gas (50 ktoe) as well as 40 ktoe of oil products are transformed into electricity. Together, these two fossil fuels produce 28 ktoe of electricity, or 24% of the total (power plants and autoproducers, see Figure 33).

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[9] Since the hydropower production given in the EIS includes the production of the Nangbéto dam in Togo under the CEB (see 4.1.1.2).

[10] The data in these two reports largely overlap. There are a few differences, however: for example, the SIE reports 64 ktoe of industrial energy consumption, the AFREC 45.88. An error has also been found: AFREC has counted the import of natural gas as own production in its balance sheet.

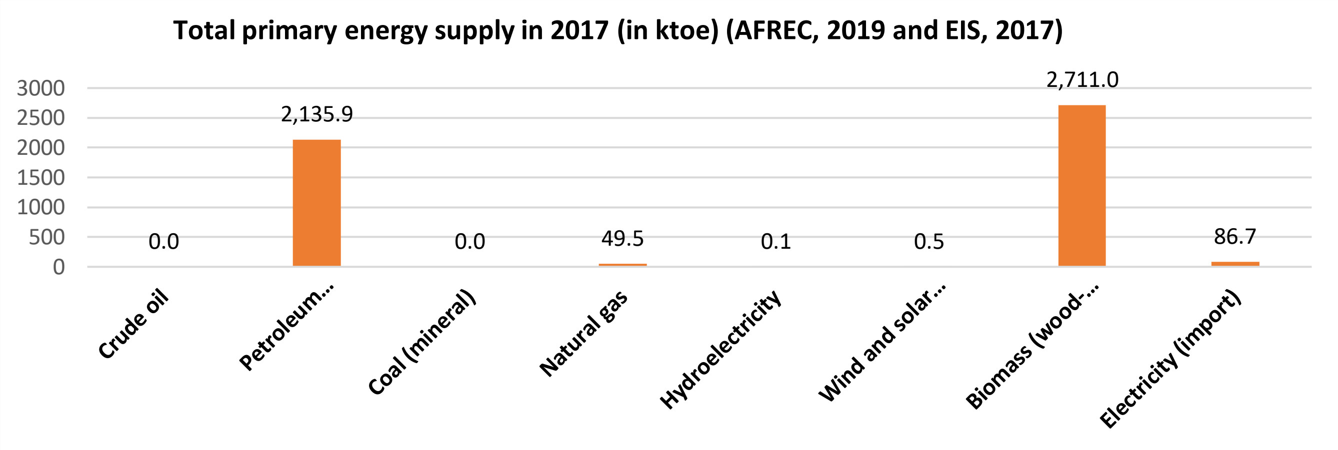

Figure 33: Total primary energy supply in 2017 in Benin (in Ktoe)

Source: (AFREC, 2019)

Particularity of Benin: Benin-Togo bi-state electricity network and strong external dependency

Together with Togo, Benin forms the Communauté Électrique du Bénin (CEB), a bi-state body with headquarters in Lomé (Togo). CEB makes it possible to pool energy resources, namely the Nangbéto hydroelectric dam in Togo and two gas turbines of 20 MW each, one located in Benin and the other in Togo. The production of these facilities is shared 50-50 between Togo and Benin. It is also CEB that imports electricity for both countries.

In 2017, 70% of the electricity distributed in Benin was imported by the CEB (56% from Nigeria, 10% from Ghana and 4% from Côte d'Ivoire). Since 2019 and the inauguration of the Maria Gleta II power plant, imported electricity has fallen to around 50% of national consumption. This electricity comes from Ghana, as Benin no longer obtains its electricity from Nigeria (Benin Government, 2019).

16% of the electricity is produced by thermal power stations, including CEB's gas turbines. The 7% of hydroelectricity in figure 1 is produced almost exclusively by the Nangbéto dam in Togo (65.6 MW). Benin has a dam at Yéripao, but this only has an installed capacity of 0.5 MW[11]. Self-production is entirely based on the production of oil products[12].

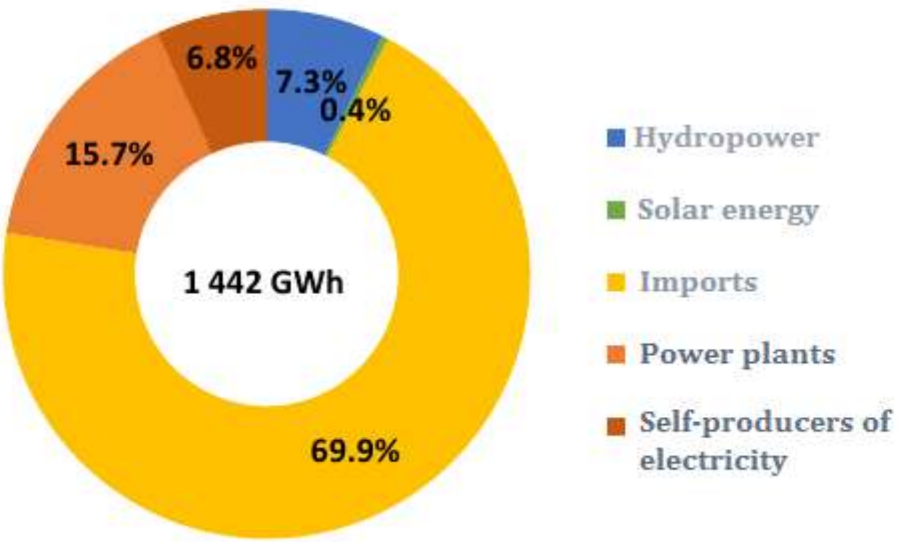

Figure 34: Structure of electricity supply in Benin in 2017.

[11] *Personal communication of the author with Mr. Salim CHITOU, head of the EIS at the General Directorate of Energy Resources of Benin.*
[12] *Ibid.*

4.1.1.1. Biomass [13]

A study carried out within the framework of the Bois de Feu project (phase II) (Bois de Feu II, 2007) considered that 90% of biomass production in Benin (excluding plantations) is potentially usable as fuelwood. The annual production of fuelwood in 2007 was estimated at 5,700,000 tonnes (8,134,460 m^3). This value is not very far from that of the 2015 EIS report of the General Directorate of Energy of the Republic of Benin. This report estimates that the total amount of fuelwood harvested from the forest amounts to 7,125,996.4 tonnes (equivalent to 2,711 ktoe). This productivity is determined on the basis of values of 5 tonnes/ha for dense forests, 1.2 tonnes/ha for open forests and wooded savannas and 0.6 tonnes/ha for wooded savannas, weighted with the percentage represented by each type of forest formation according to CENATEL's estimates of forest formation areas in 1998 (giving an average forest productivity of 0.81 tonnes/ha).

All of Benin's wood energy is used to meet the thermal needs of the population (cooking, water heating) and small-scale industry. Some industrialists also use residual biomass, which they produce themselves or recover from third party industrialists, to meet their thermal energy needs. We have the following information at our disposal:

- The Nocibé cement plant (there are 4 cement plants in Benin) buys residues from agro-industrials, cashew nut hulls in particular, to supply its stoves.
- The oil mills SHB and Fludor (cotton oil) use part of their waste for energy purposes.
- Cashew processing plants use a portion (about 15%) of their cashew hulls as fuel for their boilers.

The PDEHR study (2017) also cites oil palm leaves, cotton stems and rice husks as potentially energy-generating biomass. The mobilization of these resources raises questions. While rice husks are already frequently used for litter in poultry farms, cotton stems are left on the field and then burnt, while palm leaves are left at the foot of the palm trees in the case of peasant plantations, and burnt in the case of industrial plantations. The collection of this biomass should be organised in order to envisage a valorisation of the biomass.

Finally, there are recent initiatives to convert residual agricultural biomass into electricity (for cashew nut processing units in particular). However, these projects have not yet taking shape and are at various stages of implementation.

4.1.1.2. Hydropower

Under CEB, the country benefits from about 50% of the electricity generated by the Nangbéto hydroelectric dam in Togo. It has an installed capacity of 65.6 MW. Benin has a hydroelectric power plant in Yéripao, but this has an installed capacity of only 0.5 MW. In 2017, the cumulative supply of these two dams reached 7% of final electricity consumption, or 101 GWh (9 ktoe, compared with the 0.1 ktoe that the Yéripao dam alone would have produced in 2017 according to AFREC). (AFREC, 2017).

[13] *This part is taken from the report of Outcome 2 for Benin of this study.*

Table 32: Potential for hydropower generation

Theoretical Hydropower Potential of Rivers in Benin	
Pico/micro/mini HPP	5 MW
Small HPP	90 MW
Medium/large HPP	239 MW
No attractive potential	415 MW
Total of all rivers in country	749 MW
Total of rivers with attractive theoretical potential for pico/micro/mini, small, or medium/large HPP	334 MW

The following table summarises the potential for hydropower generation in Benin, as estimated by the Off-Grid Electrification Master Plan (PDEHR, 2017).

Source :(PDEHR, 2017)

4.1.1.3. Solar

While the EIS for 2015 did not mention solar energy, the EIS for 2017 reports 0.4% of electricity produced by solar energy (6 GWh).

The Off-Grid Electrification Master Plan document (PDEHR, 2017) states that photovoltaic solar energy is central to off-grid electrification (OGE) policies. It mentions that in 2017, "5% of localities in Benin [had] been the subject of an EHR project, part of which only electrified community centres (schools, health centres, etc.), without deploying the service to the population. In detail:

-2% (83) of the localities [had] mini-grids and a 100% PV power plant.

-3% (101) of localities [were] receiving individual PV kits

-1% (30) of localities [were] benefiting from community PV kits.

77 micro-solar power plants (each with a capacity of around 50 kW) have been built across Benin to supply off-grid locations. Only 4 (financed by UEMOA) are now connected, as contracts for the management of the plants have not yet been awarded for the 73 others (financed by the government). The solar energy given in the 2017 EIS also takes into account the savings in electricity consumption for public lighting induced by the installation of solar streetlamps.

The PDEHR (2017) estimates the solar potential for electricity production in Benin depending on the regions in:

-North: 1560 kWh/kWp installed per year

-Central part: 1460 kWh/kWp installed per year

-South: 1400 kWh/kWp installed per year in wetlands.

4.1.1.4. Oil and derivatives

Benin imports 100% of the hydrocarbons it consumes. The country's situation is marked by informal importation of petrol and diesel from Nigeria, where oil products, which are heavily subsidised, are much cheaper. In 2017, uncontrolled imports have been estimated at 56% of total hydrocarbon supplies (EIS, 2017).

75% of this hydrocarbon supply concerns petrol and diesel. The remainder is made up of 14% paraffin, 7% fuel oil (heavy gas oil), and 3% butane gas.

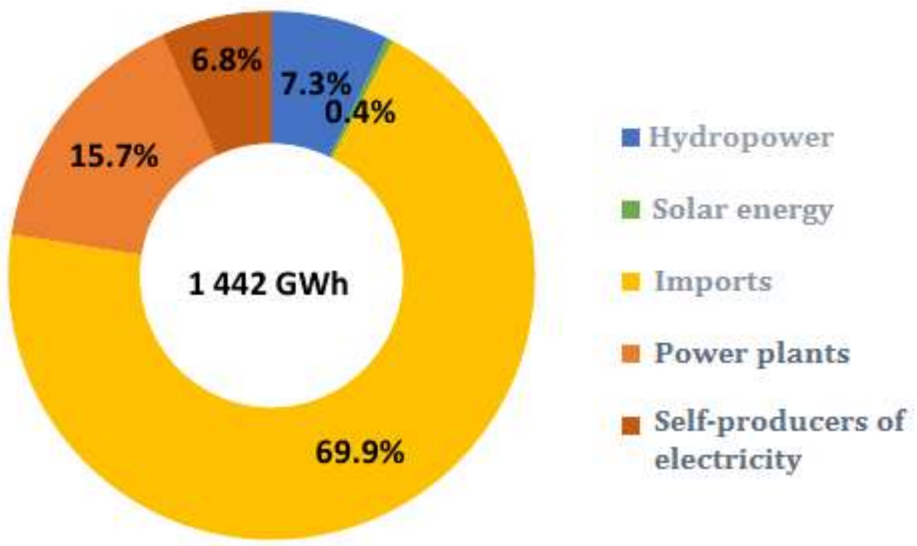

Figure 35: Structure of electricity supply in Benin in 2017

4.1.2. Key economic sectors according to NDP

The transport sector is the country's main energy consumer (49% of the total), followed by the household sector (40%). The commercial and public service sector accounts for 9% of the total. Industry accounts for 2%. Only 0.3% is consumed by agriculture and forestry.

Biomass (4254 ktoe/year in total) is mainly used for domestic purposes (1559 ktoe/year or 83% of this total). 17% of the remaining biomass is consumed by the commercial and public service sector (311 ktep/year). 1% of the biomass is consumed by the industry sector (32 ktep/year)

Oil products are consumed mainly in the transport sector (2015 ktoe/year). They are consumed in all other sectors but in comparatively negligible proportions: 32 ktoe by industry, 32 ktoe by households, 13 ktoe by agriculture and forestry and finally 4 ktoe by commerce and public services.

Electricity consumption is very similar to the commercial and public service, household and industrial sectors (43, 32 and 22 ktoe respectively). Agriculture and forestry consume 1 ktoe.

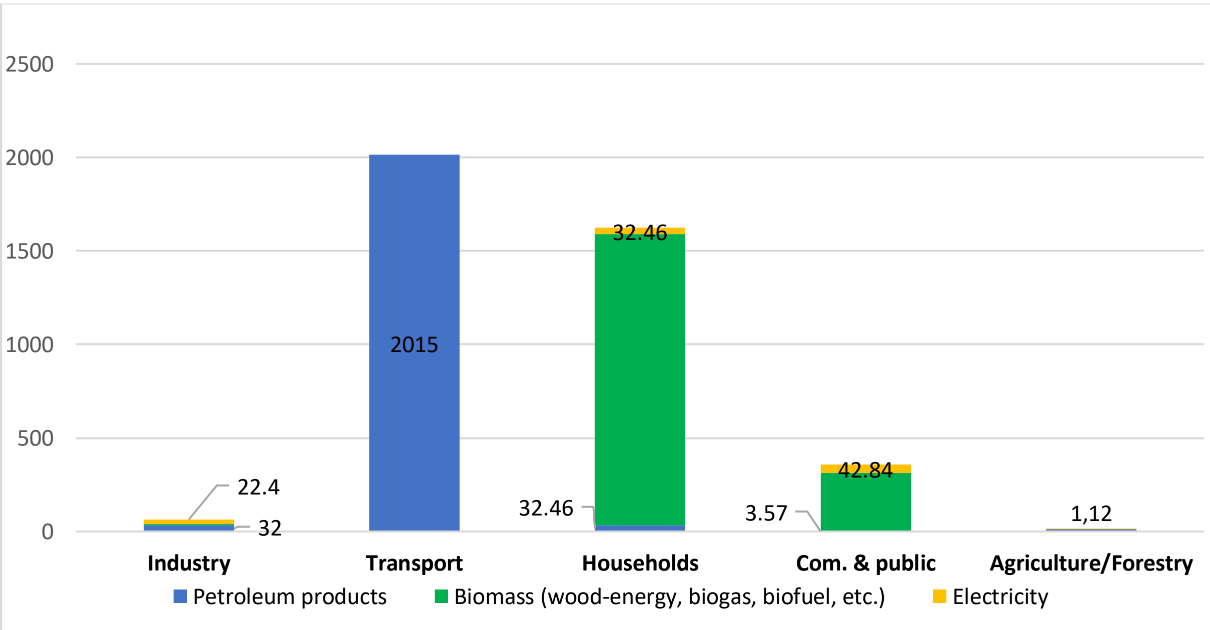

Figure 36: Final consumption by sector in 2017 (in ktoe)

Source: (SIE, 2017)

4.1.2.1. Industry

Energy demand: In 2017, the energy consumption of industry was 64 ktoe, i.e. less than 2% of the total final consumption, which reflects the weakness of the country's industrial fabric.

The two forms of energy mainly consumed by industry are electricity (35%) and oil coke (32%, used in cement industries). The part of biomass energy in industrial consumption is also quite significant, accounting for almost 15% of the total final energy consumption (Figure 36, see Section 4.1.2 above).

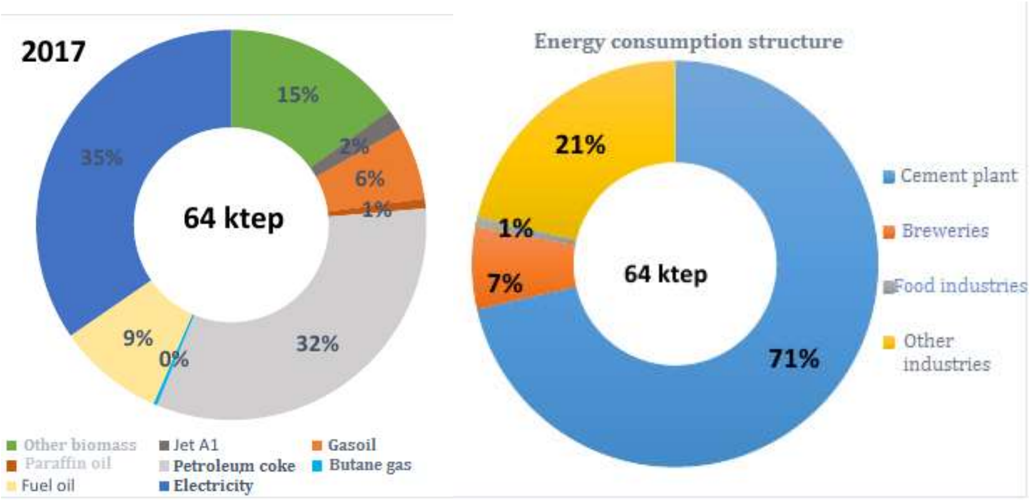

Figure 37: Structure of energy consumption in the industrial sector in 2017

Percentage of biomass used in the sector: As stated, oil coke (mineral coal) is used mainly for thermal purposes. But agricultural residues can also be used. This is particularly the case with cashew nut Shells. Some cashew nut processors in Benin already sell their cashew nuts (for very modest sums) to cement factories.

Other processing industries have thermal needs: cotton oil mills and cashew nut processors in particular. Oil mills and cashew nut processors already use their waste to meet their thermal energy needs **Error! Reference source not found.**). The part of recovered agro-industrial waste could be increased through the promotion of appropriate technologies (**Error! Reference source not found.**).

Contribution of forest bioenergy in the sector: Benin's cement factories (there are 4 in 2020), consumed 71% of the total energy in 2017. This energy is in the form of electricity and heat. As an energy-consuming activity, cement plants producing clinker have significant heat requirements in their stoves. This may explain the 15% part of biomass use. Indeed, these cement plants are supplied with solid biomass from different sources: corn stems, cashew nut shells, peanut hulls, etc., in order to supply their process with cheaper energy (compared to oil coke or fuel oil, which would be the alternatives).

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4.1.2.2. Transport

Energy demand: Transport mobilised 2015 ktoe of oil products in 2017, at a rate of 64% petrol and 36% diesel[14]. Since the end of rail transport in 2018, all of this consumption is destined for road transport.

[14] Paraffin is not counted in the domestic consumption of the transport sector, as this product is consumed by aircraft whose destination is outside Benin's borders. It is taken into account under the heading "international air bunkers".

Percentage of biomass used in the sector: There is no realistic scenario today to envisage a contribution of forest biomass to the transport sector. However, CNSL (Cashew Nutshell Liquid), the oil contained in cashew nut shells, has been considered as a natural source of fuel for aviation (similarities with paraffin). After distillation, cardanol is obtained, which is used in the chemical industry as a raw material for various polymers and composites.
Contribution of forest bioenergy in the sector: There are no biofuels consumed in Benin.

4.1.2.3. Residential (households)

Energy demand: As elsewhere in the West African sub-region, the vast majority of Benin's household energy consumption is in the form of wood energy consumption (Figure 3). Broadly speaking, in rural areas it is mainly firewood that is consumed, since the resource is within easy reach, whereas the larger the town and the further away the population is from rural areas, the greater is the consumption of charcoal.
From the 2017 EIS figures presented in Figure 3, the relative part of consumption of coal seems undervalued while that of firewood seems overvalued. Indeed, these data are based on a 2012 study (SIEP, 2012). The population of urban centres has increased over the last 10 years in favour of rural areas, and the part of charcoal today should be higher. If we take the proportions indicated by the EIS of 2017, the energy delivered by firewood at the national level was about 4 times the energy equivalent of charcoal. Together, energy from wood accounts for 93% of total household final energy consumption. To this must be added 3% corresponding to various biomasses such as coconut husks or corn stems that are occasionally used as fuel; and an additional 1% to count the contribution of butane gas (LPG) to the household energy mix. In total, 97% of domestic energy consumption meets the thermal energy needs of households.
Only 3% would be used for lighting and other miscellaneous uses: through paraffin and electricity. The low participation of the electricity component in the energy balance of families is a sign of the poor access to electricity in this sector (national electrification rate 29% in 2018).

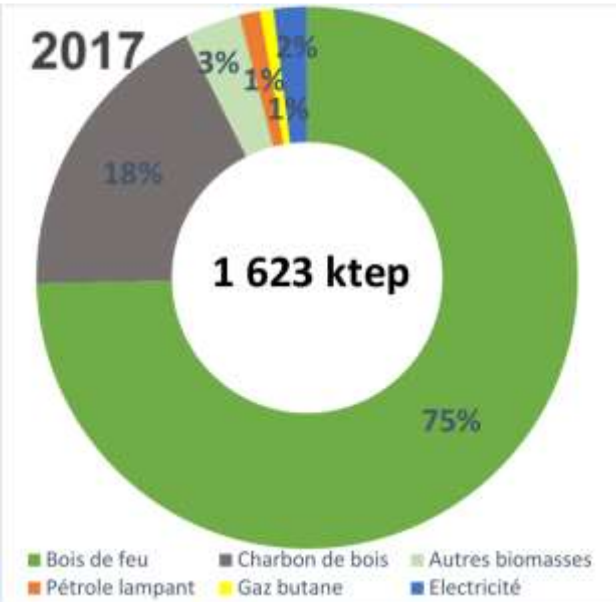
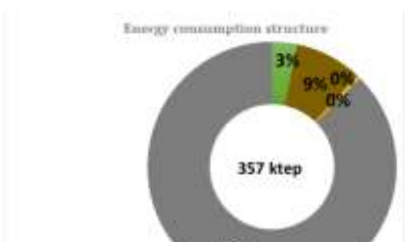


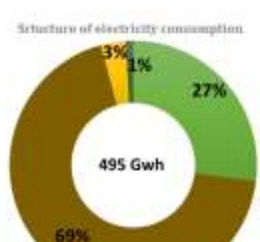
Figure 38: Household energy consumption in 2017

Contribution of forest bioenergy in the sector: Green coal briquettes (or clean coal), produced from the carbonisation of agricultural residues, could replace a proportion of commercial coal consumption. In the case of forest biomass, briquettes can for example be produced from carbonised cashew nut hulls. Other resources can be used more systematically, such as corn stems, for example

4.1.2.4. Businesses and public services

Energy demand: Energy consumption in the commercial and public service sector in 2017 reached 357 ktoe, of which 68% was firewood, 16% charcoal, 12% electricity, 3% other biomass and 1% butane gas (Figure 4). Most of this energy is consumed by small units such as shops, supermarkets, bakeries and small food processing units ("other tertiary" in the graph).
Restaurants, school canteens and bakeries, for example, use firewood because of the large amounts of thermal energy they require. Some sectors have a special need for coal, such as ironmongery, dyeing or the dry-cleaning trade (irons). (Espace_réservé29).





Contribution of forest bioenergy in the sector: Green coal briquettes (or clean coal), produced from the carbonisation of agricultural residues, could replace a proportion of commercial coal consumption. In the case of forest biomass, briquettes can for example be produced from carbonised cashew nut shells. Other resources can be used, such as corn stems, for example.

4.1.2.5. Agriculture/Forestry

Energy demand: Consumption in the agricultural and forestry sector represents only a marginal part of the total final energy consumption: 14 ktoe in 2017, i.e. 0.3% of the total. 88% of this energy is in the form of diesel, 8% in the form of electricity and 4% in the form of paraffin.

It should be noted that "as of 2017, the consumption of cotton ginning plants has been transferred to the agricultural sector, in order to comply with the INSAE nomenclature, which now classifies these industries in this sector, since they are an integral part of the agricultural process" (SIE, 2017). The ginning plants would have a marginal consumption of diesel compared to the consumption of the sector (0.62 ktoe for a total of 13), but would be the main consumers of electricity among the consumers listed in this balance sheet (1.02 ktoe out of a total of 1.04).

Contribution of forest bioenergy in the sector: The agriculture and forestry sector can contribute to making the wood energy sector more sustainable through reforestation programmes of fast-growing species for wood energy. Until now, reforestation policies in Benin have mainly concerned species used for timber (teak and melina). However, some reforested species can also be exploited for fuelwood (Eucalyptus, Acacia and Khaya). The Khaya species is an indigenous species used for energy wood.

2.1.1 Conclusions and recommendations

As indicated in Result 2.1, the main residual forest biomass that can be mobilized in Benin is cashew nut shells, a waste product from processing plants. This potential has been estimated at 17,640 tonnes of cashew nuts (corresponding to the volumes transformed in 2018), or 1,270 GWh annually, to be potentially converted into various energy products.

Indeed, hulls can be valorised in the following ways:

- Thermal energy: to supply boilers on site (direct combustion with gas washing or use of H2CP pyrolysis stoves developed by Nitidæ[15]) or for the needs of other industries (cement factories for example, as is already done today).

- Electrical energy: with {gasification unit + gas turbines/motors} or {boiler + steam turbines} systems. The first option is more profitable for units below 5 MW and is promoted by Nitidæ. A first project for the installation of a power generation system with gasification is underway in Benin (GAZEL project). A second project to convert hull residues into electricity has recently been developed in the country but its implementation has not yet started.

[15] *H2CP (High Calorific Cashew Pyrolyser) ovens, degrade the shells into gas. It is then the gas and not the raw cashew that is burnt in the boiler furnace. This eliminates much of the pollution associated with the direct combustion of the hulls in cashew processing plants. About 15% of the initial mass of the hulls is recovered as coal.*

- Coal: after carbonisation of the hulls, obtained either as a by-product of a pyrolysis or gasification operation for energy purposes or in a dedicated carbonisation stove.

The thermal and electrical energy resulting from the valorisation of cashew nut shells would supply the industrial sector, and hulls charcoal could be used by households as a substitute for charcoal.

Recommendations

As noted in the report on Outcome 2.1, in terms of access to energy from residual biomass, the most promising sectors would be cashew nuts and shea butter.

As far as cashew nuts are concerned, for factories with sufficient processing capacity (> 5000 tons of nuts processed per year), the self-production of electricity from cashew nut shells can be a very interesting operation. The GAZEL project in which Nitidæ is involved in consortium with the IED group and CIRAD should demonstrate its relevance. The country has two industrial units that meet the minimum capacity requirements.

For low capacity factories (< 5000 tonnes of nuts processed per year), H2CP pyrolysis stoves are indicated to reduce pollution linked to the combustion of the hulls and improve the working conditions of the workers. Both options can be combined with the marketing of biofuel briquettes from residual cashew nut hulls coal. Stoves specifically designed for the carbonisation of cashew hulls could also be envisaged, the main product sought would then be coal (with an efficiency of 20 to 25% against 15% for H2CP stoves and 10% for gasification units). Alternative fuels to charcoal could then be placed on the local market.

In the case of shea, the crab produced at the end of the process has an interesting energy potential. It is moreover commonly used by artisanal processors themselves as a source of fuel. The main obstacle to its use by a wider public is the non-centralised nature of this waste. Solutions adapted to the scale of production of this waste could be put in place, in order to make this biomass more accessible to potential buyers (households, small businesses, industry). Indeed, shea crab can be packaged in the form of balls or even logs and has fuel characteristics very similar to wood.

4.2. Burkina Faso

4.2.1. Energy resources

The country's energy resources

Burkina Faso is a landlocked country with very limited energy resources. The country produces neither oil and gas nor coal and uranium. Its main natural energy source is the sun. Indeed, like most Sahelian countries, Burkina Faso benefits from an average daily sunshine of 5.5 kWh/m^2 , which is very favourable for the operation of solar systems (Burkina Faso Government, 2016). However, like its neighbours, in Burkina Faso, biomass is the country's most widely used energy resource.

For a long time, hydropower has been the most exploited renewable resource to produce electricity. It is only recently that solar photovoltaic electricity has surpassed the contribution of hydropower. By 2017, solar PV had produced 62 ktoe, while domestic hydropower contributed only 11 ktoe (**Error! Reference source not found.**).

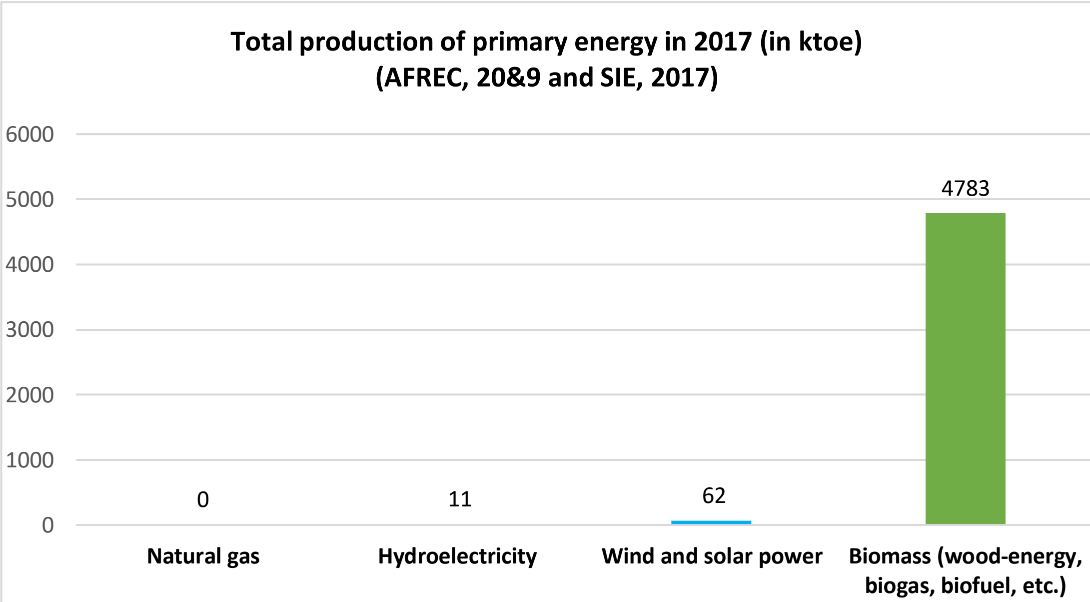


Figure 40: Total primary energy production in 2017 in Burkina Faso (in Ktoe)

Source: (AFREC, 2019)

Table 33: Burkina Faso's energy resource production between 2000 and 2019.

Years	2000	2005	2014	2015	2016	2017	2018*	2019*
Charcoal production (kt)	196	404	795	490	884	410	932	984
Natural gas production (TJ)	-	-	-	-	-	-	-	-
Electricity production from biofuels, waste (GWh)	6	0	0	0	0	0	0	0
Electricity generation with fossil fuels (GWh)	302	390	722	1710	1801	1448	1542	1643
Hydropower generation (GWh)	98	99	64	93	102	124	136	149
Electricity production from solar, wind, etc. (GWh)	0	0	5	0	0	725	755	814
Total electricity production (GWh)	406	489	791	1804	1903	2297	2433	2606
Imports of oil products (ktoe)	313	507	889	1046	1110	1549	1656	1170

Source: (AFREC 2019) **projection*

Despite all this, Burkina Faso is far from being an energy-sovereign country, and imports much of its primary energy. **Error! Reference source not found.** shows the total primary energy supply, where Burkina Faso has to procure 1328 ktoe of oil products and 56 ktoe of electricity (from its neighbours Côte d'Ivoire and Ghana).

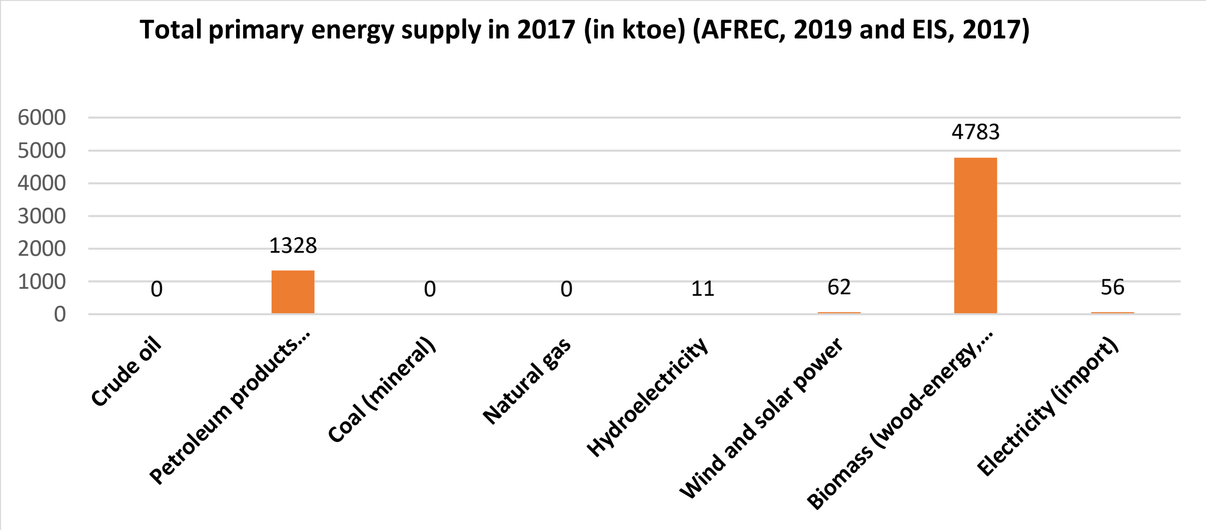


Figure 41: Total primary energy supply in 2017 in Burkina Faso (in ktoe) Source: (AFREC, 2019)

4.2.1.1. Biomass

Forest biomass, which is a limited resource, is mainly used for the wood-energy sector. On the other hand, biomass, particularly agricultural biomass, is abundant and is the subject of energy interest in certain areas. However, the current level of recovery remains modest in view of the quantity of potentially exploitable residues.

While wood and charcoal are mainly used in households, agricultural residues such as rice husks and bagasse, cotton stems are also an interesting source of potentially valuable energy. Apart from these residues, others are currently of interest to industry as an important source of energy. This is the case of sugar cane bagasse, cashew nuts or cotton seed husks, which can be used to produce heat or even electricity. This is the case of the larger agro-industries, which produce their electrical energy for self-consumption. Only one biomass cogeneration unit is connected to the grid, the Faso biogas plant in Ouagadougou. It produces biogas from the waste from the refrigerated slaughterhouse in the capital of Burkina Faso. The gas turns an electric generator which exports to the grid, and the refrigeration circuit removes heat which is then recovered by the neighbouring brewery.

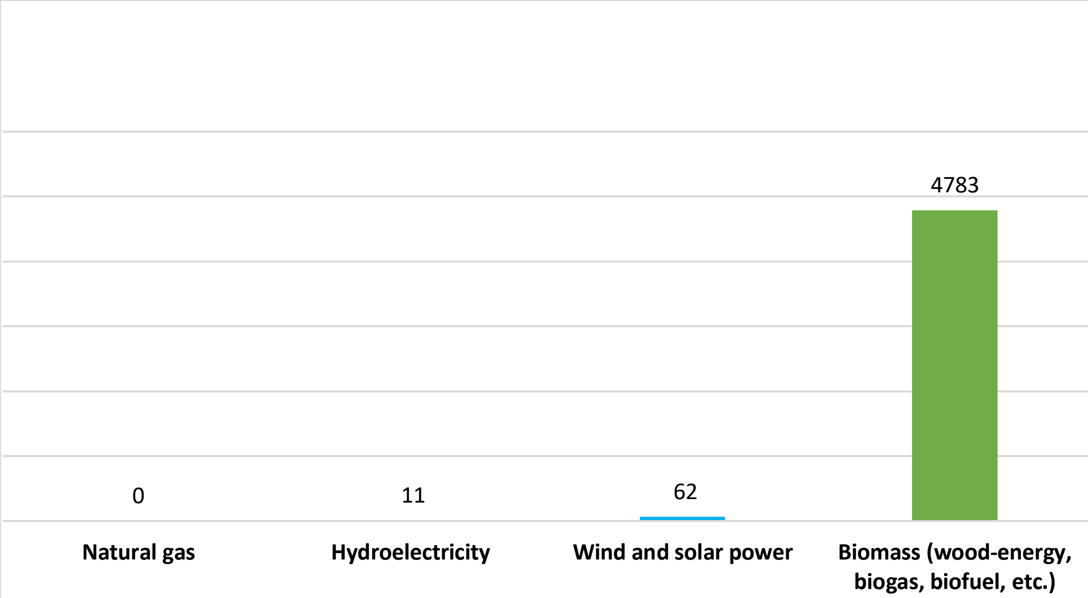


Figure 42: Total primary energy production in 2017 (in ktoe) Source : (SIE, 2017; AFREC, 2019)

4.2.1.2. Hydropower

The power of Burkina Faso's rivers is exploited in electricity production at the Bagré (16 MW), Kompienga (14 MW), Niofila (1.5 MW), Tourni (0.5 MW) and Samandéni (2.56 MW) power stations.

The total hydroelectric power (34.56 MW) contributes 10% of the total installed capacity and the contribution of the hydroelectric production of the National Interconnected Network (RNI) averaged 100 GWh per year. Unfortunately, the guaranteed hydropower capacity during the peak period represents only 38% of the total installed capacity.

Table 34: Burkina Faso's energy resource production between 2000 and 2019.

Years	2000	2005	2014	2015	2016	2017	2018*	2019*
Charcoal production (kt)	196	404	795	490	884	410	932	984
Natural gas production (TJ)	-	-	-	-	-	-	-	-
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Electricity generation with fossil fuels (GWh)	302	390	722	1710	1801	1448	1542	1643
Hydroelectricity generation (GWh)	98	99	64	93	102	124	136	149
Electricity production from solar, wind, etc. (GWh)	0	0	5	0	0	725	755	814
Total electricity production (GWh)	406	489	791	1804	1903	2297	2433	2606
Imports of oil products (ktoe)	313	507	889	1046	1110	1549	1656	1170

**projection*

Source : (AFREC, 2019)

4.2.1.3. Solar

Burkina Faso has significant solar energy potential. The solar deposit, although evenly distributed throughout the country, provides an average daily sunshine of 5.5 kWh/m^2, for 3,000 to 3,500 hours/year. However, this resource remains very little or not enough exploited. The incentive policy of exemption from customs duties and VAT on solar equipment aims to change this trend and make this resource more economically attractive. Nevertheless, there is a growing number of installations of solar kits (individual or collective), small photovoltaic or hybrid power plants (photovoltaic coupling and generators).

In 2015, autonomous solar systems were the most widespread with an installed capacity of around 4 MWp. From 2019, the Zagtouli power plant will be the first solar power plant connected to the grid with 50 MWp. Since then, several other power plant projects have been under development and, together with the recent inauguration of a solar panel manufacturing plant, demonstrate the country's commitment to transforming itself into solar power.

4.2.1.4. Oil and derivatives

Burkina Faso has neither deposits nor refining facilities. And for this, the country is totally dependent on imports. Three types of actors are involved in the import, storage and distribution of oil products: the state playing its regalian role in regulation and regulation through its involved ministries, specialised state bodies supporting the implementation of government policy, and private operators involved in marketing. The volume of imports tripled between 2005 and 2017.

Table 35: Burkina Faso's energy resource production between 2000 and 2019.

Years	2000	2005	2014	2015	2016	2017	2018*	2019*
Charcoal production (kt)	196	404	795	490	884	410	932	984
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Electricity production from biofuels, waste (GWh)	6	0	0	0	0	0	0	0
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Imports of oil products (ktoe)	313	507	889	1046	1110	1549	1656	1170

**projection* Source : (AFREC, 2019)

4.2.2. Key economic sectors according to NDP

The country does not consume coal or natural gas. On the other hand, although it does not also produce oil, it does consume it. This consumption is mainly due to the transport sector and, to a lesser extent, to the power generation and industrial sectors, as can be seen in **Error! Reference source not found.**.

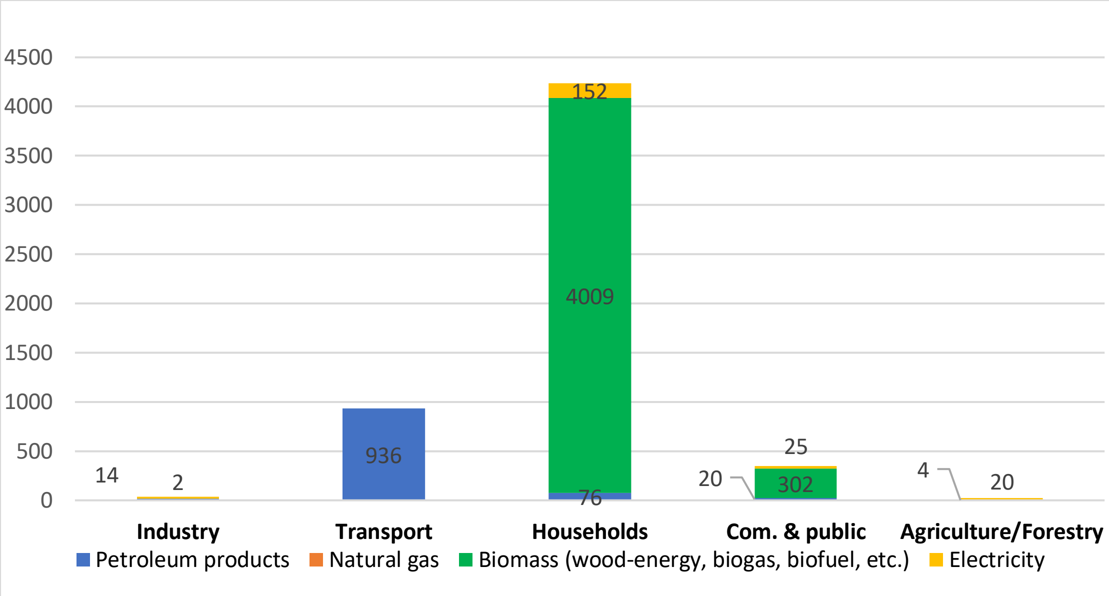

Figure 43: Total final energy consumption by sector in 2017 in Burkina Faso (in ktoe)

Source: (AFREC, 2019)

4.2.2.1. Industry

Energy demand: The following **Error! Reference source not found.** presents the energy consumption in industry in Burkina Faso.

Table 36: Evolution of energy consumption in the industry sector from 2000 to 2019

Years	2000	2005	2014	2015	2016	2017	2018*	2019*
Industrial oil consumption (ktoe)	2	4	6	11	11	14	17	20
Industrial electricity consumption (ktoe)	12	17	61	38	39	23	24	24

**projection*

Source : (AFREC, 2019)

An analysis of the table shows a tenfold increase in oil consumption over 15 years (between 2005 and 2019). Indeed, from 2014 Burkina Faso will start to export gold from its industrial mines. It is this emerging sector which is driving the growth in the consumption of oil and derivatives. By generating their own electricity from their own generators, the first mines that initially (2014) relied on the national electricity grid have gradually gained independence from the unreliable and pressurised grid. However, the overall consumption of energy resources remains very low compared to the country's total consumption of oil products (1050 ktoe in 2017 against 14 ktoe of industrial consumption, i.e. 1.3% of final consumption).

Electricity consumption in industry, on the other hand, rose significantly between 2005 and 2014 before falling from 2015 onwards. This is, in part, the phenomenon just mentioned: the mining sector consumed electricity from the grid in its early days, and more recently it has decided to supply itself with its own facilities.

Percentage of biomass used in the sector: Faced with the national problem of an energy deficit, the industrial sector, which is highly dependent on energy, is beginning to explore or even exploit other energy sources. Bioenergy in the form of agro-industrial residues is increasingly attracting industries, especially those of the agro-food industry, which can access this resource quickly and at lower cost. Indeed, for certain industrial units installed in areas with high agricultural potential or those which transform agricultural products into commercial products, agricultural residues represent valuable energy sources. Some industries such as SN SOSUCO and SN

CITEC are already active in the production of combined heat and electricity (cogeneration) from the daily use of about 1,200 tonnes of sugar cane bagasse and cotton seed cake respectively.

Other residues such as cashew nut hulls or shea cakes are real energy sources that are intensively exploited in the industrial sector, but only for thermal purposes at the moment.

Contribution of forest bioenergy in the sector: Forest biomass, considered as waste from the wood-energy sector, cannot contribute to this sector. The country itself is not forested and the exploitation of wood for energy purposes is largely dominated by domestic consumption. Although the use of wood by small and medium sized industries is observed in the field, such uses should be prohibited or at least accompanied by energy efficiency measures in order to minimize the contribution of this fuel, which is currently overexploited in the country.

On the other hand, the forest biomass from non-timber forest products currently exploited in Burkina Faso has a real potential to contribute to this reduction or even disappearance of the use of wood energy in the sector. The two main forest products processed by the industry are cashew nuts and shea butter. It has been estimated that the current potential for cashew nut hull waste is 17,200 tonnes/year at present, with a forecast of around 50,000 tonnes/year by 2030. The shea industry also offers an interesting potential (around 30,000 t of potentially recoverable oilcake). However, for the latter, prior negotiations will be necessary to dispose of this cake, a large quantity of which is sent to Ghana.

The cashew nut hull is emerging as an untapped source of biomass, widely available in industrial centres. Some links are beginning to develop between cashew nut processing plants and consumers of these shells for energy purposes (mostly small and medium industry). It would be interesting to build on this dynamic to initiate a real transition towards the full conversion of the cashew nutshell, which would benefit the industrial sector by being a source of renewable energy.

4.2.2.2. Transport

Energy demand of the sector: The following table shows energy consumption in transport in Burkina Faso.

Table 37: Evolution of energy consumption in the transport sector from 2000 to 2019

Years	2000	2005	2014	2015	2016	2017	2018*	2019*
Oil consumption in transport (kt)	142	230	403	685	705	992	1027	1067
Electricity consumption in transport (GWh)	-	-	-	-	-	-	-	-

Source : (AFREC, 2019) *projections

The table shows that energy consumption in transport is entirely dominated by oil. The country is therefore not yet in the era of electric vehicles. The railway sector does not run on electricity either, but on fossil fuels. Conventional energies therefore dominate this sector entirely.

Percentage of biomass used in the sector: No contribution of biomass energy to the transport sector has been identified.

Contribution of forest bioenergy in the sector: Bioenergy can help reduce dependence on conventional energy. To this end, the bioenergy path that can be explored is that of biofuels. Indeed, within the framework of the Sustainable Energy For All (SE4ALL) initiative, two options have been retained in the biofuels action plan: the production of bioethanol allowing the use of E10 fuel (10% incorporation into petrol) and the production of vegetable oil to be incorporated into diesel up to 30%. (Gouvernement Burkina Faso, 2015).

4.2.2.3. Residential (households)

Energy demand of the sector: Household energy consumption in Burkina Faso, as in most sub-Saharan countries, is still dominated by wood energy. About 90% of households use wood as their main source of energy according to a 2015 report. According to this report, existing validated statistical data dates back to 2002 with an estimated consumption of 4,280,941 tonnes of fuelwood and 217,137 tonnes of charcoal. However, the report indicates that an extrapolation of the growth rate of charcoal consumption (5.4%/year) resulted in the following values in 2012: 7,243,448 tonnes of fuelwood and 367,401 tonnes of charcoal. Charcoal consumption therefore represented 2,296,254 tonnes of wood in 2012, taking into account average carbonisation yields estimated at 16%, i.e. approximately 6 kg of wood for 1 kg of charcoal.

But as can be seen in Table 37, the general trend in charcoal production is upward.

Since 2009, a major programme of bio-digester construction has been implemented by the National Bio-digester Programme with a target of 100,000 units by 2030. According to this programme, 13,000 biodigesters have been built for households throughout the country. The beneficiaries of this programme are families with one to several heads of livestock. A realistic scenario of 38,000 units of biodigesters by 2030 would have been adopted (PNB, 2020).

However, the promotion of butane gas (LPG) is a priority action in the promotion of modern alternative fuels for cooking. Butane gas, whose total consumption remains marginal, is nevertheless steadily increasing. In 2002, butane gas represented less than 1% of the country's energy balance. (MEPRED, 2008) . But with the State's exemptions to encourage its use, this rate has risen to 1.4%. Urban households are the ones that use this resource more.

Percentage of biomass used in the sector: Biomass accounts for 96% of the final energy consumed in the residential sector. It is mainly firewood, charcoal and, to a lesser extent, other biomasses (cow dung, peanut hulls, rice husks, etc.), mainly used for cooking.

Although not very widespread at the national level, it should be noted that biogas, produced from cow dung or slaughterhouse waste, also provides cooking energy for a few thousand households (domestic biodigesters produced as part of the National Biogas Programme), as well as electricity at the Faso biogas plant.

Contribution of forest bioenergy in the sector: It was found during the work felled for result 2.1 that the exploitation of forest biomass in the strict sense leaves little residue from which a value chain would make sense. Thus, the main possibility for the sustainable energy use of forest biomass, including residues of non-wood forest products, would be the creation of schemes to integrate them into the commercial supply of biofuels (fresh or carbonised).

Agricultural (non-forest) biomass should also be taken into account as the potential is still untapped.

4.2.2.4. Businesses and public services

Energy demand of the sector: Consumption in the commercial sector in Burkina Faso is dominated by wood energy, particularly for heating and cooking. In public services, electricity consumption remains predominant with the use of lighting, air conditioning, lifts and the supply of electronic equipment.

Percentage of biomass used in the sector: Biomass contributes 87% of the final energy consumed in this sector. This is mainly firewood and charcoal used in the country's many restaurants and hotels. Professional uses (ironing, dyeing, traditional metallurgy, pottery) also need biomass, as well as small-scale agro-food processing activities, which are often confused in the service sector and therefore the commercial group (fish smoking, manufacture of shea butter...).

Contribution of forest bioenergy in the sector: With an energy consumption profile quite similar to that of households, the conclusions that can be applied are the same as in section 2.3 above.

4.2.2.5. Agriculture

Energy demand of the sector: Agriculture in Burkina Faso is still traditional. Production techniques and tools remain basic. Mechanisation exists in some places, but motorised equipment mainly uses oil.

Percentage of biomass used in the sector: No biomass has been identified as being used in this sector.

Contribution of forest bioenergy in the sector: Biomass is not an energy source that can replace the energy resources currently used in agriculture: electricity and fossil fuels, as the latter provide mechanical energy most often (tractors, pumping, etc.).

On the other hand, it is the sector that produces the largest amount of biomass (cereal stems, hulls, ears, raffles, etc.). This biomass from agricultural residues is an important untapped bioenergy potential.

2.1.2 Conclusions and recommendations

From the above, it can be noted that the country lacks conventional energy resources (oil, gas, coal, etc.). On the other hand, it has abundant biomass from agriculture and the agro-food industry (cashew nut hulls, shea, mango, cotton, rice waste, etc.). Today, some industries operate 100% from their own biomass for energy needs, which is already commendable. But efforts remain to be made to encourage all industries to move in this direction. And to do this, a better organisation of the actors could facilitate the supply of biomass to those who do not have it locally, so that the industrial sector is energy self-sufficient, if only for steam production. For at present, industry still consumes firewood (although this resource has not been identified), whereas in most cases this wood can be replaced by agro-industrial biomass waste.

As mentioned above, the agriculture sector has a high potential for residues that can be used for bioenergy. The real problem here is the dispersal of this biomass on the field and often far away from use areas such as cities. Also, the problem of storing this potentially valuable biomass remains a challenge, to which must be added the mentality of the populations who immediately think of selling it as soon as their residue becomes a source of covetousness.

As noted in the report on Outcome 2.1, in terms of access to energy from residual biomass, the most promising sectors would be cashew nuts and shea butter.

As far as cashew nuts are concerned, for plants with sufficient processing capacity (> 5000 tonnes of nuts processed per year), self-production of electricity from cashew nut hulls can be envisaged. The country has at least one industrial unit that meets the minimum capacity requirements and is interested in the option with a view to becoming a fully sustainable factory.

Given the relative proximity of different cashew processing units in Burkina Faso (most of them are located along a 100 km long axis), it would be conceivable to implement a system of centralisation of the cashew hulls in a single site, for their energy conversion. The conversion method can take several forms:

- Extraction of the oil from the hull then valorisation of the two materials (oil and scrab) separately.
- Energy recovery without separation,
- As a direct fuel in industrial uses (and using the h2cp pyrolysis stove).
- In carbonization and then briquetting, to be used in the residential and commercial sector.

It is interesting to note that Burkina Faso is a pioneer in the conversion of cashew nut hull by means of pyrolysis stoves, and it has been demonstrated that several industrial sectors other than cashew nuts can benefit from this technology and thus eliminate the consumption of conventional fuels or firewood. This is the case of several cotton oil mills, using cashew nut hulls, or mango drying units.

4.3. Ivory Coast

4.3.1. Energy resources

Côte d'ivoire, a West African country rich in resources, has been experiencing years of remarkable economic growth since 2010. On the energy front, the government has set itself the objective of achieving 95% electrification on a national level by 2020 and 98% by 2030, with a part of renewable energy in the production mix of 42% of electrical energy by 2030 (including 26% from hydroelectricity), and 57% of the installed capacity of the park.

Total primary energy production in Côte d'Ivoire was about 11,000 ktoe in 2017. 65% of this energy is biomass, notably wood energy (firewood and charcoal). Côte d'Ivoire is an oil and natural gas producing country, with *1648 and 1881 ktoe respectively (16 and 18 per cent of total supply).* The country also produces hydroelectricity (2050 GWh, or 1.7%).

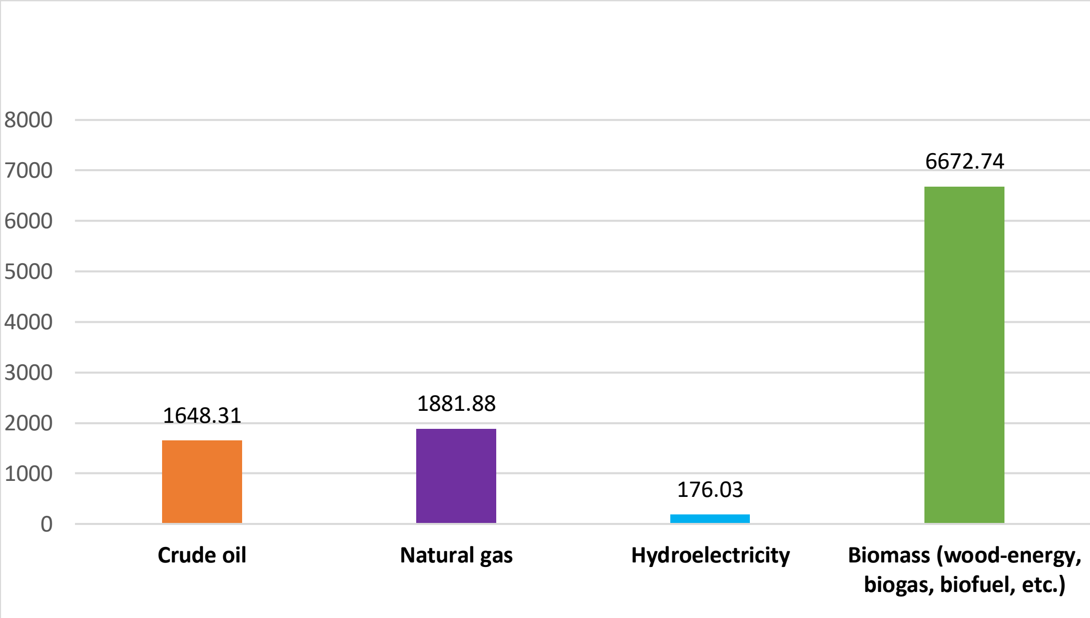

Figure 44: Total primary energy production in 2017 (in ktoe)
Source: (AFREC, 2019)

4.3.1.1. Biomass

In 2017, the country produced 19,000 kt of firewood against 1,500 kt of charcoal. Agricultural and agro-industrial residues represent the other biomass deposit of the country, a deposit particularly interesting for the industrial sector and the production of electricity. The National Action Plan for Renewable Energies (CEDEAO / République Côte d'ivoire, 2016) estimates the national biomass potential at more than 12,000,000 t/year. According to the BEFS-RA report (FAO, 2018), which announces volumes of the same order of magnitude, vegetable waste[16] falls into the following categories:

- Agricultural residues potentially available from processing industries: about 2,000,000 tonnes
- Agricultural residues in the fields: around 11,500,000 tonnes (of which around 1,500,000 t/year of cocoa waste)
- Logging residues in the logging plots: around 400,000 t/year
- Wood processing residues (sawdust, slabs and chips): approx. 130,000 t/year

[16] *Excluding therefore the waste produced by the livestock sectors, also listed in the BAFS-RA.*

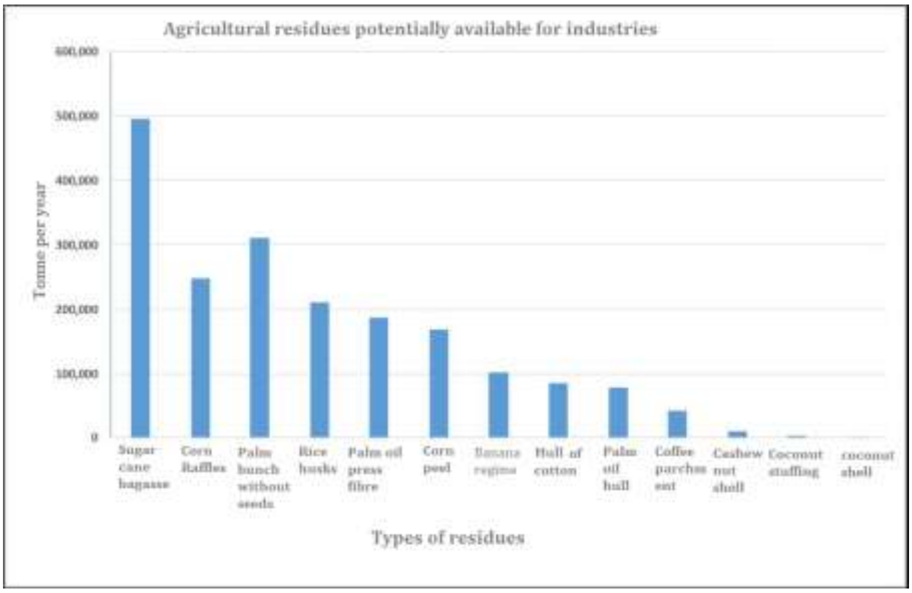

Figure 45: Distribution of agricultural residues potentially available from local processing units.
Source: (RA, 2016)

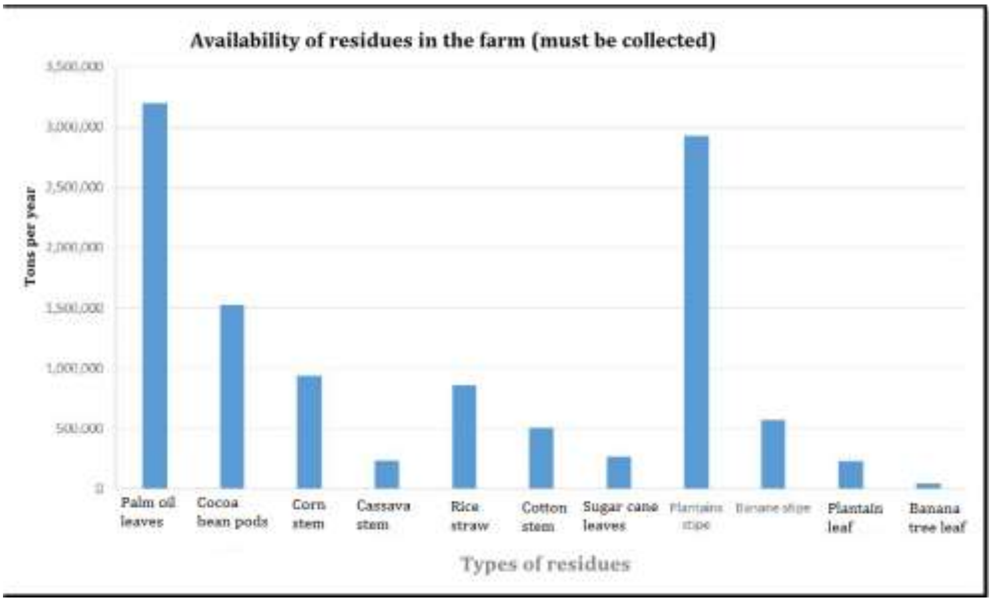

Figure 46: Distribution of potentially available agricultural residues in agricultural production plots.
Source: (RA, 2016)

There are several biomass-based combined heat and power (CHP) plants. These are the Sucrivoire (bagasse) and Sania (palm oil) plants. These plants are managed for self-consumption by industrialists, who use their waste. In 2017, 46 ktoe of biomass were used in the production of electricity.

At least five other projects are in the pipeline, all aiming to be connected to the electricity grid. Power ratings range from 1MW to 123MW, bringing the projected total to 241MW. All these plants will start up at the earliest in 2023. All of the power plants are based on the biomass resources of the major agricultural sectors in Côte d'Ivoire: cocoa, rubber, palm, cotton and cashew nuts (the first three of which can be considered as forest resources).

Côte d'Ivoire's energy strategy is ambitious in terms of using bioenergy as a source of electricity. It was announced in 2016 (PANER, 2016) 225 MW installed biomass capacity for 2020, a capacity reaching up to 485 MW until 2030. The capacity installed on the grid in biomass should therefore slightly exceed the capacity in solar PV.

4.3.1.2. Hydroelectricity

Hydroelectricity is a priority in Côte d'Ivoire in the promotion of renewable energies. The country intends to increase the part of medium and large hydropower to 26% of the energy mix by 2030. The objective is for small hydropower to reach 16% of the energy mix by the same date. The national potential of hydroelectric production is estimated at 1680 MW (PANER, 2016). For the time being, in 2017 hydroelectricity contributed to 9.5% of the resources invested in the country's electricity production.

4.3.1.3. Solar

The duration of sunshine varies between 2,000 and 2,700 hours per year depending on the region of the country (the north of the country is sunnier than the south, which has a humid climate). The average annual sunshine on a horizontal plane is estimated at 5.25 kWh/m^2/day. (PANER, 2016).
However, solar is not the preferred renewable resource for access to electricity given its intermittent nature, and the mismatch between the solar irradiation profile and the load profile of Côte d'Ivoire (which has a peak load in the evening) does not favour a massive development of solar PV. However, the NREAP notes that both biomass and solar PV have the advantage that they can be deployed in a decentralised manner, particularly in the north of the country, and will thus make it possible to supply electricity demand locally and avoid major losses on the transmission grid. Indeed, 6 IPP projects in solar PV have been approved to date, for implementation in the northern half of the country.
Here again, the objectives of the NAPER 2016 are slightly behind schedule, as the country was forecasting an installed capacity of 25 MW in 2020 and an increase to 424 MWp by 2030. However, the first grid-connected solar power plant, 37.5MW, is expected in 2021 (PANER, 2016).

4.3.1.4. Natural gas

The country consumes all of its natural gas production for electricity generation. Electricity production from natural gas reached 515 ktoe in 2017. The efficiency is therefore 32%. Côte d'Ivoire does not import natural gas.

4.3.1.5. Oil

Côte d'ivoire is an oil producer, with a production of 1648 ktoe in 2017. However, in 2017, the country exported practically the same amount (1500 ktoe) and imported twice as much (3000 ktoe). This perpetuates its dependence on oil prices.
Only 2.30 ktoe of oil products are burned in thermal power plants. The remaining 3150 ktoe are refined for export (1240 ktoe) and for domestic consumption excluding electricity production. 335 ktoe of imported refined oil products are also imported for the needs of the same national consumption excluding electricity production.

4.3.2. Key economic sectors according to NDP

A small part of the oil products leaving Ivorian refineries, corresponding to 157 ktoe of oil products, is consumed in various sectors for non-energy uses, such as the manufacturing sector (paints, surface coatings, polymers, cosmetics...).
The predominant energy source in the total final energy consumption in 2017 (7069 ktoe/year) is biomass, accounting for 60% of the total. This is followed by the consumption of oil products, which accounts for 31%. This is followed by the consumption of electricity and natural gas, accounting for 8% and 1% of total consumption respectively. It should be noted that the natural gas supply has been entirely transformed into electricity: 515 ktoe, which is added to the 176 ktoe of hydroelectricity. The total of 570 ktoe of electricity is obtained after subtracting 180 ktoe of losses.

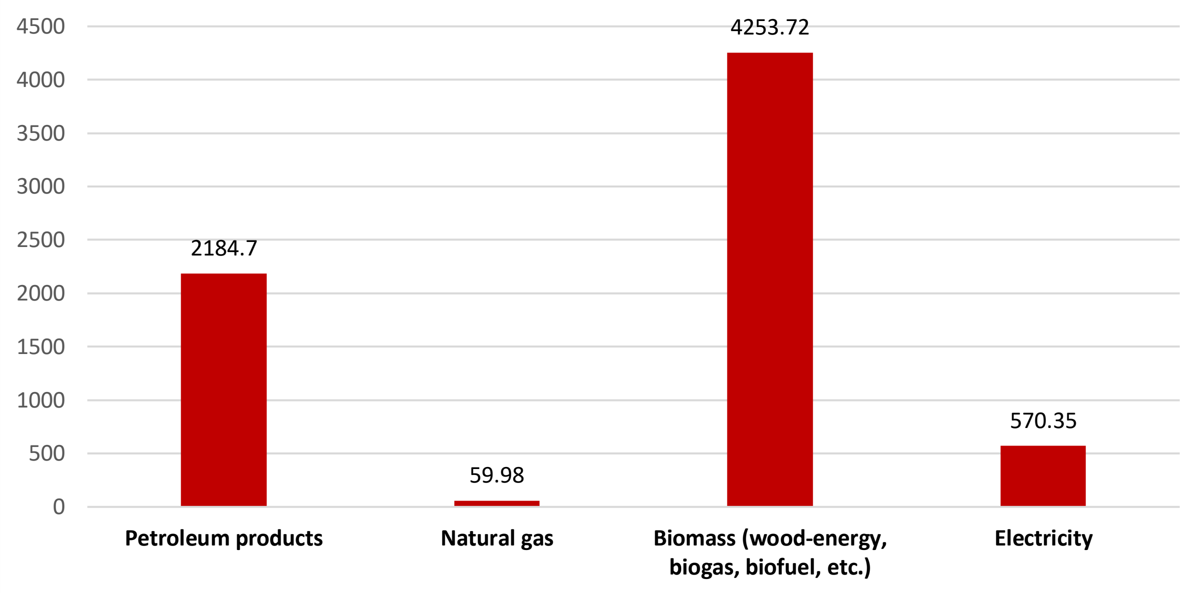

Figure 47: Total final energy consumption in 2017 in Côte d'Ivoire (in ktoe)

Source: (AFREC, 2019)

As shown in **Error! Reference source not found.** below, the household sector is the country's main pole of energy consumption (60% of the total), followed by transport (23%). The commercial and public service sector accounts for 11% of the total. Industry accounts for 4%. Finally, 2% are consumed for non-energy use.

Biomass (4254 ktoe/year in total) is mainly used for domestic purposes (3754 ktoe/year, or 88% of this total). The remaining biomass (12%) is consumed by the commercial and public service sector (790 ktep/year).

Oil products are consumed mainly in the transport sector (1623 ktoe/year), to a lesser extent by households (294 ktoe/year). 157 ktoe are consumed for non-energy use, 90 ktoe for trade and public services and 20 ktoe in industry.

Natural gas, on the other hand, is used almost exclusively in the industrial sector (60 ktoe/year). It should be remembered that most of the natural gas in Côte d'Ivoire is transformed into electricity.

Electricity consumption is almost equally distributed between the commercial and public service, household and industrial sectors (194, 191 and 183 ktoe respectively).

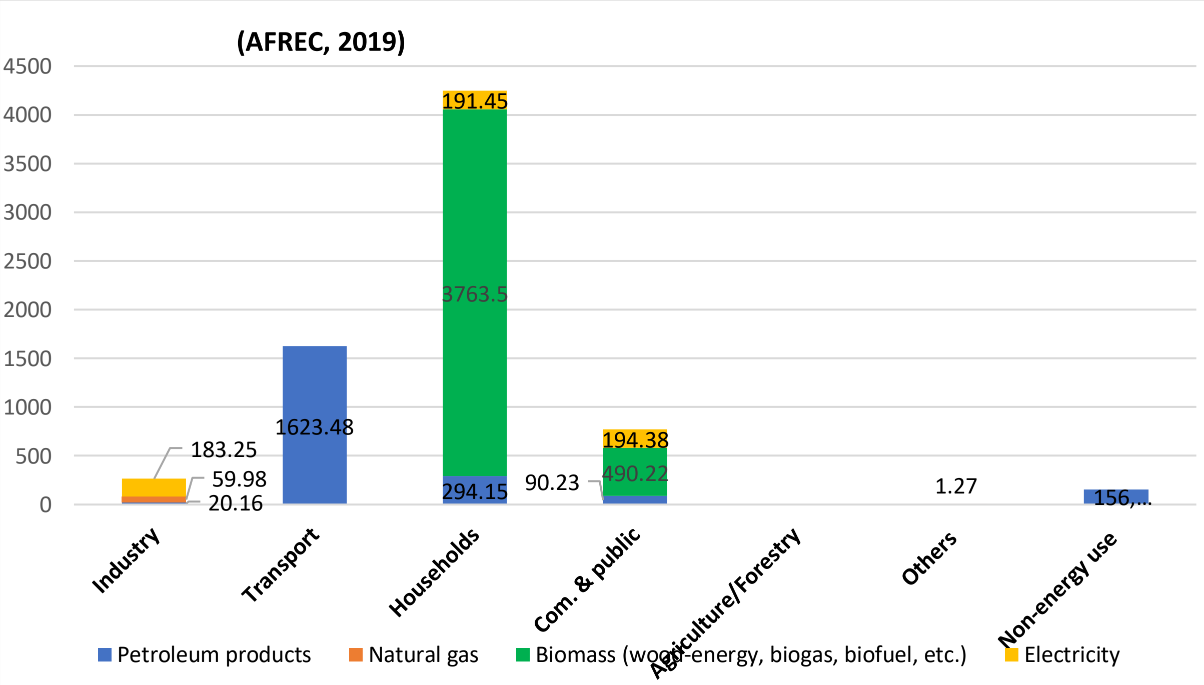

Figure 48: Final consumption by sector in 2017 (in ktoe) Source: (AFREC, 2019)

4.3.2.1. Industry

Energy demand: Industry is the fourth most energy-consuming sector in the country, accounting for 4% of the country's final energy consumption. The Ivorian industrial sector is very much centred on consumer goods and more specifically the agro-food industry: production and refining of palm oil (Côte d'Ivoire is the leading producer in West Africa), grinding and production of cocoa paste (leading world producer), cashew nut processing (leading cashew nut producer in the world, and growing capacities for processing)... Not forgetting non-food products: fabric manufacturing, materials and polymer industry, cosmetics.
There is also a mining sector, but its part in the energy balance is not the largest.
Large industries have important thermal needs and therefore consume natural gas. This is the only sector in the country to use this resource, which is produced domestically and is also converted into electricity (as mentioned above). The rest of the sector's consumption would be in the form of electricity.

Percentage of biomass used in the sector: Biomass seems to have been neglected in this balance sheet, as the industrial sector does use biomass for its own energy needs. More and more factories are adopting biomass to power their boilers. This biomass comes from the remains of crops, whether perennial or annual: hevea, palm, cocoa, cashew nuts are the main crops.
The few plants that produce their own electricity have been mentioned in the balance sheet at the level of the electricity transformation line, i.e. upstream of industrial use, so that biomass has not been considered as a final energy resource.

Contribution of forest bioenergy in the sector: The trend has begun, but the use of biomass for industrial purposes is not yet systematic. Residual biomass should first benefit each of the sectors from which it originates. Starting with the wood industry, where it would be possible to convert the waste generated by the largest sawmills into electricity, which would be self-consumed in order to power the processing equipment. Then, the other sectors (not only cocoa, palm, cashew nuts, but also breweries and other non-food production) could benefit more systematically from this waste, primarily for thermal purposes, by adapting existing boilers and stoves to use biomass, replacing natural gas or oil derivatives. Some plants could also produce their own electricity, in cases where the available biomass deposit is large enough (and the current situation of access to the network is rather unfavorable.

4.3.2.2. Transport

Energy demand: Transport mobilized 1623 ktoe of oil products in 2017. At present, bioenergy does not contribute to the energy supply of the transport sector at the national level.
Contribution of forest bioenergy in the sector: There is no realistic scenario today to envisage a contribution of forest biomass to the transport sector. However, CNSL (Cashew Nutshell Liquid), the oil contained in cashew nut shells, has been considered as a natural source of fuel for aviation (similarities with paraffin). After distillation, cardanol is obtained, which is used as a solvent in the chemical industry.

4.3.2.3. Residential (households)

Energy demand: As elsewhere in the West African sub-region, the vast majority of energy consumption by Ivorian households is in the form of wood energy (88% of consumption). 7% of oil products and 5% of electricity complete the energy consumption of Ivorian households.
The country aims to achieve 100% access to modern cooking energy by 2030, through the promotion of coal produced with efficient techniques (16% of the coal produced in the country by 2030), and the promotion of improved stoves, but above all the promotion of butane gas as an energy source (reaching 90% of the population by 2030, according to the NREAP). Several awareness-raising actions on the use of improved stoves and butane gas (LPG) have been undertaken for several years and will continue to be undertaken in Côte d'Ivoire.

Contribution of forest bioenergy in the sector: As indicated above, the country envisages that 16% of coal will eventually be produced using efficient techniques, and this includes biochar (or green coal, from agricultural biomass or waste). The production of green coal and biogas is listed in the objectives of the National Renewable Energy Action Plan (NREAP, 2016). Green charcoal can indeed be produced from residues from agriculture in forests, such as those from cocoa fields. Cocoa waste, which is abundant and under-exploited in the form of pods and old plants, could contribute to the energy balance in both carbonised and fresh form.

4.3.2.4. Businesses and public services

Energy demand: Energy consumption in the trade and public service sector in 2017 reached 775 ktoe, of which 63% is biomass, 25% electricity and 12% oil products. Most of the biomass energy is consumed by small and large shops, restaurants, hotels, dry cleaners, supermarkets, bakeries and small food processing units (production of gari and attiéké, fish smoking, transformation of shea butter, etc.).
Contribution of forest bioenergy in the sector: The measures proposed for the household sector (section 4.3.2.3) apply.

4.3.2.5. Agriculture/Forestry

Energy demand: The energy demand of the agricultural and forestry sector is not given in the AFREC reports. The agricultural and forestry sector, itself, requires energy sources that can meet the needs for mechanical work (cutting, ploughing, water pumping, transport of inputs and products) but also thermal (cold chambers, drying for conservation). The fact that these consumptions have not been recorded in the national energy balance sheets shows the low part they represent in the national total. The second handicap of this sector as regards the quantification of energy-consuming activities is its fairly widespread degree of informality, at least on the producers' side. Thus, energy consumption by organised actors (cooperatives, packaging units, sawing units, etc.) has been classified in the industrial sector.
Percentage of biomass used in the sector: Without available data, the part of bioenergy in this sector could not be ascertained. The case of Côte d'Ivoire could be extrapolated from that of neighbouring Ghana, which has a similar agricultural and climatic profile. More than two-thirds of final energy in Côte d'Ivoire is derived from oil products, with the rest coming mainly from electricity and a small part from mineral coal and natural gas. Bioenergy does not appear to contribute to the balance sheet of this sector.

It is certain that in any case Côte d'Ivoire does not use mineral coal or natural gas for any agricultural activity. So, this consumption profile, in which oil derivatives are the most used, ahead of electricity, can be maintained. Bioenergy is therefore not a source used by the sector.

Contribution of forest bioenergy in the sector: Reforestation policies with fast-growing species (teak in particular) are carried out. Like neighbouring Ghana, Côte d'Ivoire is increasingly covered with teak forests, which is a wood appreciated as a fuel, but also a material in demand on the international timber market. Thus, felling during thinning applied to teak plantations often ends up in the fuelwood market and is consumed by the productive sector (bakeries and others) and by households.
A holistic planning of agricultural sectors could find ways of achieving synergies between several sectors, where the residual biomass of some could be used by others to meet heat needs for product conservation reasons (drying, smoking, pasteurisation). Post-harvest losses of cassava, yam and cereals could be reduced by making intelligent use of wood waste from other neighbouring agricultural or forestry sectors.

2.1.3 Conclusions and recommendations

Main sectors with potential for bioenergy

Due to the consumption profile described above, the residential (household), commercial and public sectors and the industrial sector are important consumers of biomass and/or heat, and the volumes consumed are only increasing, due to an increasing population, the standard of living and the industrialisation of the country.

Recommendations

One form of residual forest biomass that can be mobilised in Côte d'Ivoire and which is very abundant is cocoa waste, a waste left at the edge of the plantations.
In particular, the cocoa pod can be valorised in the following forms:

- Thermal energy: as a non-carbonised fuel, after drying of the pod. This fuel can then be used to power industrial sites but can also be used for household applications. The pod can also be carbonized. This is being implemented by the APNFP in Afféry.

- Electrical energy: with small- or large-scale systems. Large scale would seem to be more profitable and there are already some projects developed in this direction.

The great difficulty of this biomass is that it is very scattered in the territory and its access is difficult because it is located in the forests. Decentralised conversion techniques should be recommended.
Although wood waste is present in sawmills, the sustainability of the sector is not assured today and therefore it cannot be said that it is a good idea to consider this deposit, for the time being. Moreover, it is not the largest residual biomass deposit in the country.

4.4. Mali

4.4.1. Energy resources

Like many African countries, Mali's energy situation is characterised by:

- Abusive exploitation of forest resources
- Dependence on oil products imported from abroad
- The high cost of developing the country's abundant renewable energy potential.

The energy sector comprises four main sub-sectors which are (i) hydrocarbons, (ii) traditional energies, (iii) renewable energies and (iv) electricity. Mali's 2014 energy balance sheet reveals that biomass (wood and charcoal) accounts for about 78% of national energy consumption, oil products 17%, electricity and renewable energies (other than hydroelectricity) 5%. The implementation of the various projects and programmes has led to the following main indicators[17] for the energy sector (situation in 2014):

Table 38: Energy Sector Indicators 2012 - 2016

Variables	2012	2013	2014	2015	2016	2017
Electricity production EDM (GWh)	1 276	1 420	1 574	1 594	1768	
Part of non-hydropower RE in Electricity Generation	-	-	7%	7%	N/A*	
Consumption of oil products per year (TOE)	911 839	972 298	1 024 000	1 056 864	1 373 533	
Butane gas consumption (in tonnes)	13 279	12 010	12 228	12 982	14 530	ND

[17] *EIS Report, PDIO-2015*

Biomass consumption	78% of the national energy balance 2014	71,6%	73,2%	
Import of all Hydrocarbon consumption	17% of the balance sheet 2014	24,9%	22,3%	
Electricity consumption	5% of the balance sheet 2014	3,5%	4,6%	

(EIS Report, PDIO-2015 and AFREC 2019) (*ND= not available)

Mali imports all of its fossil fuel needs. Oil products represent 26% of all imports in 2010 and 22% in 2015, making it very sensitive to price volatility. It should be noted that despite this decrease in the part of oil product imports in total imports, the consumption of oil products per year has steadily increased in recent years, as shown in the following graph:

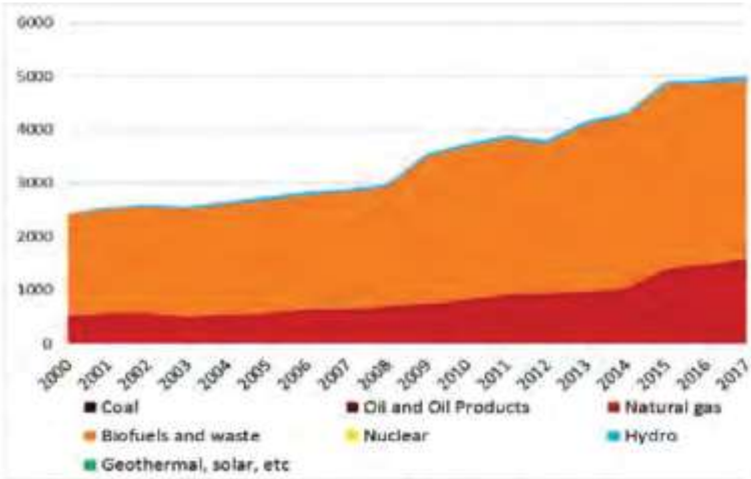

Figure 49: Total primary energy supply in 2017 in Mali (in ktoe) Source: (AFREC, 2019)

The country has no internal fossil or geothermal resources for energy production. Energy production comes mainly from biomass (bioenergy/biofuel); hydroelectricity and imported fossil fuels. The balance of energy production in Mali in 2017 reveals that biomass (wood energy, biofuel...) represents about 97.9% of national energy production, hydroelectricity 2.1% and a small contribution for other renewable energies (solar) (Cf. following graph).

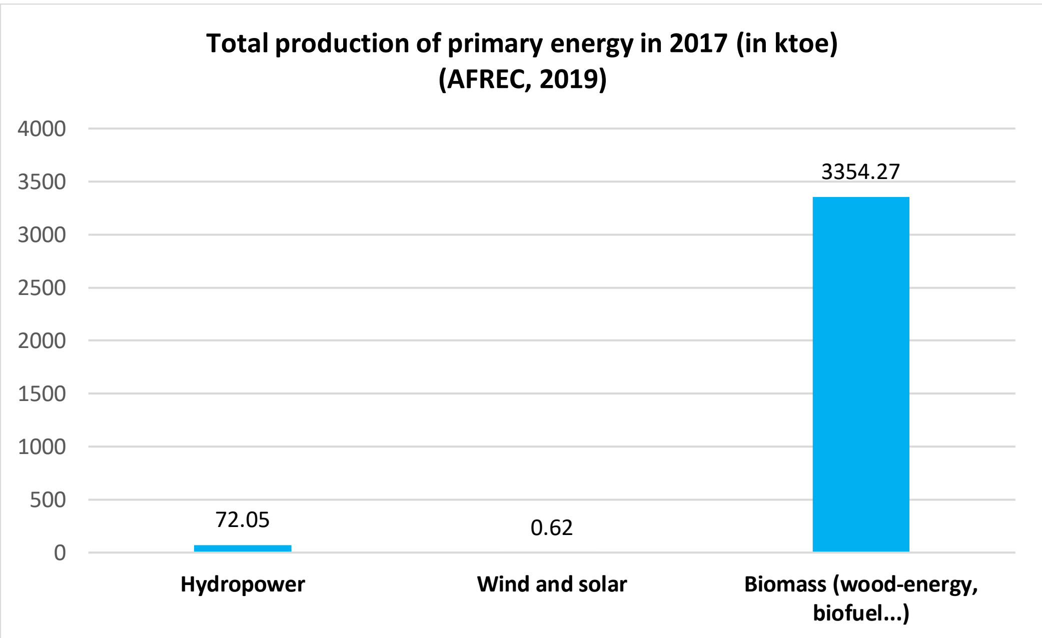

Figure 50: Total primary energy production in 2017 in Mali (in ktoe)

Source: (AFREC, 2019)

Total primary energy supply

Energy supply in Mali concerns four main sub-sectors which are (i) hydrocarbons, (ii) traditional energy, (iii) renewable energy and (iv) electricity. The balance of supply in 2017 in Mali reveals that biomass (wood energy, biofuel, etc.) represents about 66% of the total supply, oil products 31%, imported electricity 2%, hydroelectricity 1% and a low supply for renewable energy (solar and wind) (see Figure 51).

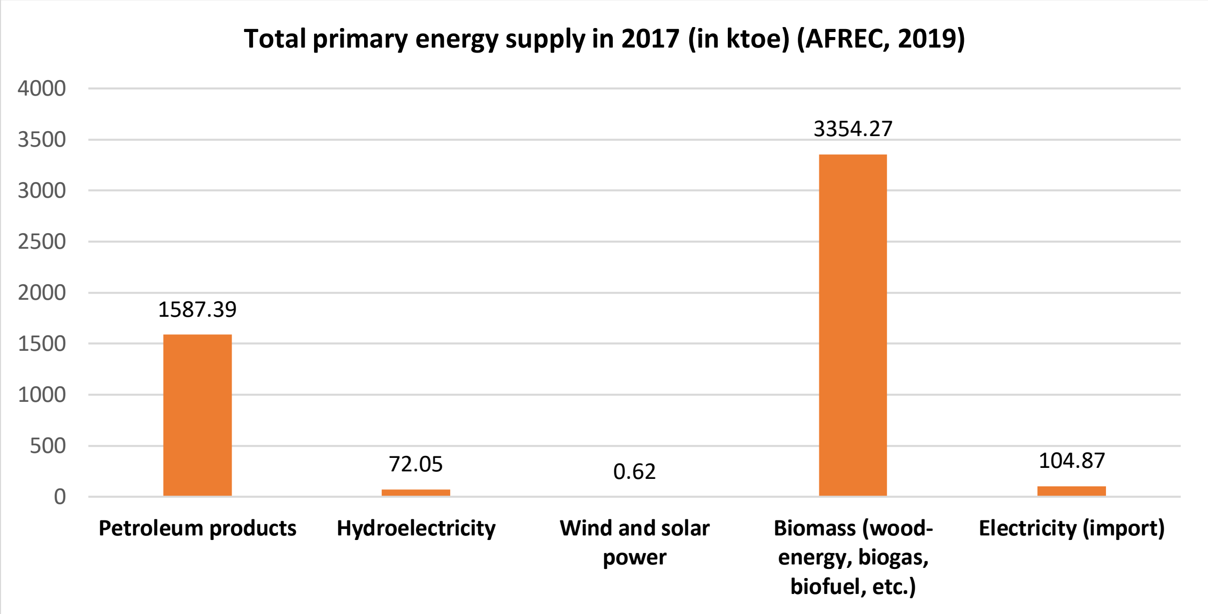

Figure 51: Total primary energy supply in 2017 in Mali (ktoe)

4.4.1.1. Biomass

Forest bioenergy: Wood energy, the main source of energy for Malian households, comes from the country's forests, whose surface area is estimated at nearly 33 million hectares, i.e. about 25% of the country's surface area, with a standing volume of about 520 million m^3 . As explained in the previous report 2.1, although these forests cover large areas, they are not very productive (weighted productivity for the country as a whole of about 0.86 m^3/ha/year) and have been overexploited since the beginning of the decade 2010. Year after year, Malian forests are experiencing a decline in their wood stocks, due to the growing demand for fuel and the clearing of surrounding areas for agricultural purposes. All this has been brought about by a very significant population growth.

In a country exposed to climate change and where land and natural resource degradation is a real problem, wood energy is not an adequate response to growing energy needs.

Agricultural and vegetal waste: Mali has significant potential for energy production from agricultural waste **Error! Bookmark not defined.Error! Bookmark not defined.**:

- 1.5 million tonnes of rice and cotton waste (husks, stems, etc.) in 2010.
- Nearly 3.5 million tonnes in 2018, following an annual growth of 10% in cereal production, mainly around Sikasso (cotton) and Ségou/Mopti (rice).
- Mali is a large regional producer of oilseeds: more than 500,000 tonnes of groundnuts, 370,000 tonnes of cotton seeds and 200,000 tonnes of shea nuts, which leads to the production of large quantities of crabs and hulls.
- As the leading regional producer of livestock, with more than 30% of the total livestock in uemoa and annual growth of around 5%, Mali offers untapped opportunities for the recovery of animal waste.
- In addition, there are aquatic invasive species and household waste estimated at nearly 600,000 tonnes per year.

Energy crops: The conditions are optimal for sugar cane production with abundant sunshine and water for irrigation. Production is concentrated in the Office du Niger area in existing sugar factories (Sukala and Nsukala). The 20,000 hectares cultivated produce 140,000 tonnes of sugar and 11 million litres of ethanol, which are successfully exported.

Jatropha (jatropha) cultivation has long been used in Mali as a traditional fence. Mainly concentrated in the regions of Sikasso, Koulikoro, Kayes and Ségou, 65,000 ha of jatropha allow an estimated production of 5,500 tonnes of seeds in 2016. Four presses and a refinery are currently in operation, and 740,000 litres of jatropha-based biofuel were produced in 2016, with annual growth of 35% since 2010. However, it is noted that this unit has been idle since at least 2018.

4.4.1.2. Hydroelectricity

The electricity sector is dominated by the national company EDM-SA. It also includes a few isolated private systems and several dozen multifunctional platforms managed by local communities. The electricity company EDM-SA, the main and historic operator in the electricity sector, has had a concession since 2000[18] for the production, transmission, distribution, import, export and marketing of electrical energy throughout its perimeter covering 99 localities (including mainly the District of Bamako and the 10 regional capitals).

The identified exploitable hydropower potential is 1,150 MW on some twenty sites with a corresponding average annual production of approximately 5,600 GWh. In 2019 (SEforALL), May), 2019, nearly 840 MW of this potential remains available, undeveloped and divided into 3 major groups: sites at the feasibility study stage (150 MW); sites at the pre-feasibility stage (342 MW); and sites at the reconnaissance stage (150 MW)**Error! Bookmark not defined.**.

The main rivers and their tributaries are the following sites:

- Sites at the feasibility study stage: Taoussa (20 MW; 100 GWh); Sotuba II (6 MW; 30-40 GWh); Kénié (42 MW; 188 GWh); Markala (13 MW; 45 GWh); Félou II (60 MW; 320 GWh); Gouina (140 MW; 560 GWh).
- Sites at the pre-feasibility stage: Labezanga (14-84 MW; 67 GWh); Gourbassi (13 MW; 104 GWh); Moussala (30 MW; 160 GWh); Galougo (285 MW; 1520 GWh); Badoumbé; Dioumbéla; Boudofara; Maréla; Bindougou.
- Sites at the reconnaissance stage: Toubani (35 MW; 134 GWh); Baoulé II (30 MW; 124 GWh); Bakoye II (45 MW; 193 GWh); Salambougou (10 MW; 40 GWh); Kourouba; Banifing.
- Micro hydroelectric power plant sites (feasibility studies): Farako (50 kW); Kéniéba (180 -250 kW); Nimbougou (8 -12 kW); Papara (50-60 kW).

4.4.1.3. Oil and derivatives

The hydrocarbons sector is characterised by a net import of all oil products. The country is therefore totally dependent on oil resources. This should not be interpreted as if the country does not have any hydrocarbon deposits. Oil exploration, undertaken since independence, did not lead to the discovery of hydrocarbon deposits until 2003. However, Mali has five sedimentary basins totalling 750,000 km^2, all located in the northern half of the country, on which hope is based. To date, only four hydrocarbon exploration drillings have been carried out in Mali. All of them have proved negative. As for the gas indices observed during some hydraulic drilling, they are of little interest for a significant energy exploitation.

To date, Mali does not have any significant hydrocarbon resources of its own. Its supply has been ensured almost exclusively by the subsidiaries of large multinationals[19], from Côte d'Ivoire and Senegal. But since then, the country has undertaken to liberalise the sub-sector and diversify its sources of supply. National operators have appeared and occupy a growing part of the market, and new supply centres have been added to the existing ones: Ghana, Togo, Nigeria, Benin, etc.

The country's energy supply depends mainly on oil products (31%), being exclusively imported.

[18] *Decree No. 00-580/P-RM of 22 November 2000 approving the Public Electricity Service Concession Contract.*
[19] *Mobil Oil, Shell - Texaco, Elf, Esso, Total*

4.4.1.4. Solar

The inventory of renewable energies reveals a quantitatively very significant potential throughout the country (with disparities, however, depending on the renewable energy sources). Apart from hydropower, solar energy is the most abundant renewable resource in Mali. Even if they have never been accounted for in energy balances, they could be close to 3% of the conventional electricity produced (about 12 MW). (Duarte, 2012) . This falls short of the National Energy Policy's quantified objectives, which indicate that the part of renewable energies in national electricity production should reach 6% in 2010 and 10% in 2015.
Solar irradiation is very high and is spread throughout the country. It reaches an average of 6 kWh/m^2/day for a daily sunshine duration of 7 to 10 hours. Solar radiation in the country is stronger in the desert areas of the North.
According to the country's energy balance, in 2017 0.62 ktoe of primary energy from solar, geothermal and solar power were produced, or 7.21 GWh. This corresponds entirely to the contribution of solar energy, since the installed wind power capacity is limited to a few individual installations (as shown below) and was certainly not included in this balance sheet.

4.4.1.5. Wind turbine

Wind resources, especially in the South, are not as promising as solar energy. The lower wind speed limit is generally defined at 5 metres/second for an economically reasonable exploitation of wind resources. Wind speeds above 5 metres/second prevail in the part of the country above 16 degrees north latitude, which includes the cities of Timbuktu and Gao. This band is sufficient for pumping applications for irrigation and the supply of drinking water to small localities. However, due to the low population density in these areas, demand will also be low. In addition, the critical political and security context affecting northern Mali will play a determining role in the development of wind projects. For the time being, apart from a few pilot projects and small water pumping stations, wind energy has not yet really taken off. Feasibility studies have been carried out on a 1.1-3 MW wind farm in Timbuktu and a 0.9-2 MW wind farm in Gao (AER-Mali, n.d.)[20].

4.4.1.6. Others

Unlike other neighbours in the sub-region, Mali does not rely on natural gas or mineral coal. The supply figures are 0 for these raw materials.

2.1.4 4.4.2 Key economic sectors according to NDP

Final energy consumption refers to energy products consumed for activities other than conversion or transformation into other energy products. **Error! Reference source not found.** and the following graphs show the final energy consumption of Mali's total and of each economic sector in 2017.

Table 39: Final energy consumption in Mali by source

	Oil products (ktoe)	Biomass (wood-energy, biofuel, etc.) (ktoe)	Electricity (ktep)	Total (ktoe)	% by sector
TOTAL	1084,98	2426,84	247,82	3759,64	100%
	29%	65%	7%	100%	
Industry	192,37	-	104,18	296,55	8%

[20] *Information obtained from EAR-Mali experts*

	65%	-	35%	100%	
Transport	794,96	-	-	794,96	21%
	100%	-	-	100%	
Households	16,48	2190,07	93,28	2299,83	61%
	1%	95%	4%	100%	
Com. & public		236,77	38,67	275,44	7%
		86%	14%	100%	
Agriculture/Forestry	42,33	-	-	42,33	1,1%
	100%	-	-	100%	
Others	38,84	-	11,69	50,53	1%
	77%	-	23%	100%	

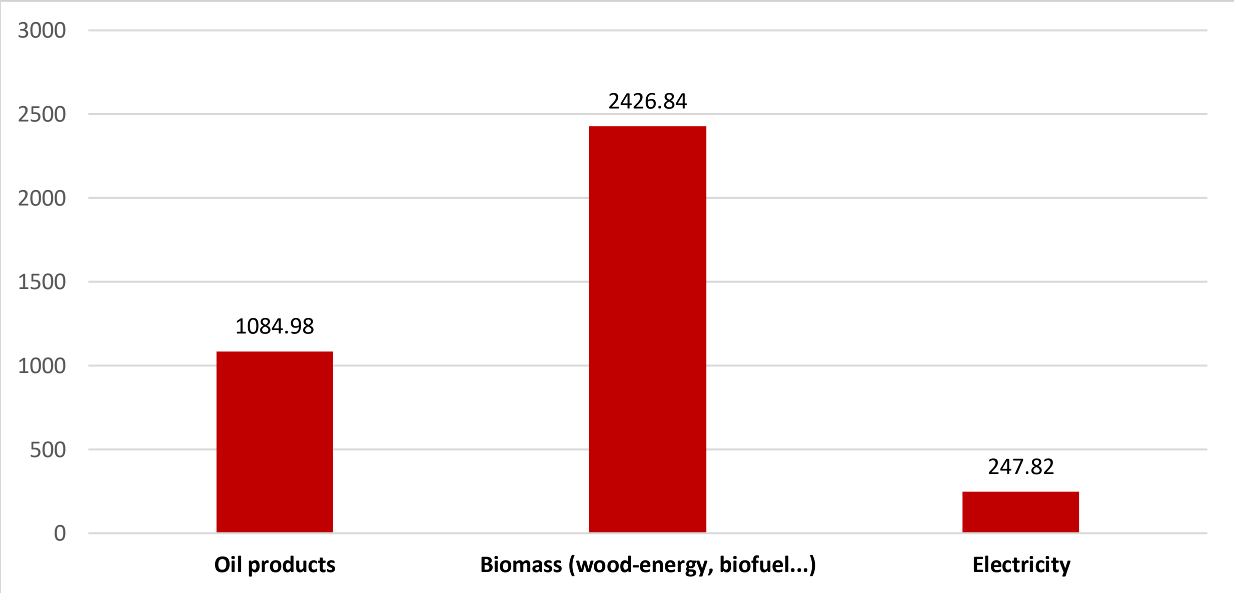

Figure 52: Total final consumption in 2017 (in ktoe)

Source: (AFREC, 2019)

Biomass represents 65% of total final energy consumption in 2017, 29% of consumption is derived from oil products and less than 7% of consumption is from electricity.

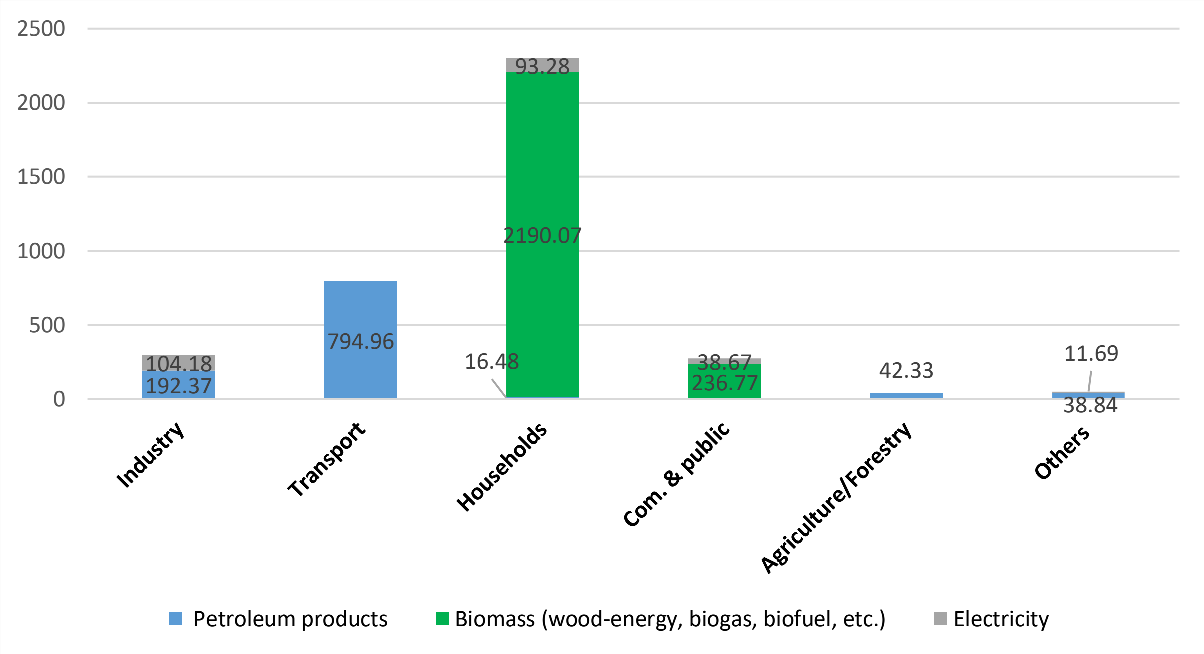

Figure 53: Final consumption by sector in 2017 (in ktoe)
Source: (AFREC, 2019)

4.4.2.1. Industry

Industry in Mali is relatively undeveloped. This industry is essentially composed of agro-industry, spinning mills and food processing industries, SMEs and SMIs. They are mainly concentrated in Bamako and only slightly in the interior, with the exception of the CMDT factories. The mining industry is fairly developed, especially in the field of gold production.

Energy demand: Total energy consumption by the industrial sector accounts for 8% of Mali's total final consumption in 2017 (see Table 39). The main energy consumed in this sector comes from oil products (65%) and electricity, itself produced with fuel oil by EDM (35%) (see Table 39). The extractive industry is by far the largest consumer of these resources. However, most of the factories are not connected to the network, hence the large part of oil products in the balance sheet of this sector.

Percentage of biomass used in the sector: Error! Reference source not found. shows that bioenergy does not participate in the energy consumption of the industrial sector, although there are agro-food industries in the country that consume the waste produced by themselves for energy purposes. This shows the undervaluation of this sector. Some agro-processing plants can use their own waste or other agricultural or agro-industrial waste to produce bioenergy. This is the case of the Sukala sugar factory (bagasse), the MaliShi shea butter factory, which uses part of the crabs in its boiler, and the cashew nut processing agro-industrial platform, which uses cashew nut shells. The jatropha processing plants also use their product (biofuel) and by-products (shells, capsules and cake) to produce their own energy.

Contribution of forest bioenergy to the sector: Given that Mali is exposed to climate change and where land and natural resource degradation is a real problem, conventional forest biomass (wood and derivatives) cannot provide an adequate response to the energy needs of the industrial sector.

On the other hand, non-timber forest products such as shea and cashew nuts are emerging as potential sources of biomass waste. The shea industry counts with the salient example of MaliShi, which should eventually reach 30,000 tonnes of shea kernels processed per year, and thus generate waste crab after extraction of 15,000 tonnes. This waste has the advantage of being concentrated on a single site, which facilitates the supply of biomass waste. The plant is planning to use its crab, in addition to fuel for its boiler, as a raw material for the manufacture of combustible briquettes that could benefit the population by replacing firewood.

4.4.2.2. Transport

Consumption in the transport sector covers all transport activities, regardless of the economic sector concerned: road transport; air transport; rail transport and inland waterway transport.

Energy demand: Energy demand in the transport sector accounts for 21% of Mali's total final energy consumption in 2017 and is 100% dominated by oil products (see Table 39).

Percentage of biomass used in the sector: Oil dominates 100% of consumption in the transport sector. No initiatives to introduce renewable sources in the sector have been identified.

Contribution of forest bioenergy in the sector: Forest biomass at the moment cannot provide a solution to Mali's transport sector. The production of biofuel from jatropha and ethanol from sugar cane would be an alternative to substitute part of the oil consumption in this sector.

4.4.2.3. Residential

Energy consumption in the residential (household) sector concerns three sources of energy: oil products, biomass and electricity.

Energy demand of the sector: Energy demand in the residential sector accounts for 61% of Mali's total final energy consumption in 2017, ranking it as the leading consumer sector. Demand is dominated by biomass (mainly wood energy) which accounts for 95%. Biomass is used for cooking needs and some artisanal activities. Oil products which represent 1% (essentially butane gas and paraffin, at 16.48 ktoe) are used for lighting (in rural areas) and also for cooking (in urban areas). Electricity accounts for 4% of household final consumption and is used for lighting and household appliances (see Table 39).

Percentage of biomass used in the sector: The participation of bioenergy in the residential sector is low. The promotion of domestic bio-digesters to produce biogas could be the solution to the valorisation of household biomass waste, especially among the population with livestock.

Contribution of forest bioenergy in the sector: With the results of the Report 2 of the same study, Mali has no wood processing residues, but the use of charcoal dust for the production of charcoal briquettes would be a solution to substitute part of the consumption of charcoal in the residential sector.

Also, agricultural residues (rice, cotton waste, etc.) and agro-industrial residues (shea, cashew, groundnut waste, etc.) could be compacted into briquettes to replace wood, given its high calorific value; or carbonised to produce biochar and could be used to replace wood energy.

4.4.2.4. Trade and public service

Energy demand of the sector: The energy demand of the commercial and public service sector represents 7% of Mali's total final energy consumption in 2017. The demand is dominated by two energy sources: biomass (mainly wood energy) which accounts for 86% of the energy consumption of this sector and electricity accounts for 14% of the final consumption of the sector (see Table 39).

Percentage of biomass used in the sector: The participation of bioenergy in the commercial sector is notably provided by wood-energy, at the level of the numerous catering and craft or small food-processing businesses, which also carry out processing activities of these products.

It is interesting to note the use of shea tree residues (crab) in bakeries, especially in rural and peri-urban areas, as a substitute for wood.

Contribution of forest bioenergy in the sector: The recovery of charcoal dust for the production of dust briquettes would be a solution for substituting a part of the charcoal consumption and wood in the commercial and public service sector.

The promotion of biodigesters for productive purposes to produce biogas could be the solution to recover organic waste from markets, restaurants, canteens....
Also, agricultural residues (rice, cotton, groundnut waste, etc.) and agro-industrial residues (shea, cashew, etc.) could be carbonised to produce biochar and could be used to replace wood energy.

4.4.2.5. Agriculture and forestry

Consumption in the agriculture and forestry sector concerns exclusively oil products.
Energy demand of the sector: Energy demand in the agriculture and forestry sector accounts for 1.1% of Mali's total final energy consumption in 2017 and is 100% dominated by oil products (see Table 39). This consumption is related to agricultural and forestry machinery.
Percentage of biomass used in the sector: Although oil dominates 100% of consumption in the agriculture and forestry sector.
Contribution of forest bioenergy in the sector: Forest biomass at the moment cannot provide a solution to Mali's agriculture and forestry sector.
Apart from forest biomass, the production of biofuel from jatropha and ethanol from sugar cane would be an alternative to substitute part of the consumption of diesel and petrol in this sector.

4.4.2.6. Other sectors

Consumption in the other sectors concerned is related to oil products and electricity. This consumption represents 1% of Mali's total final energy consumption in 2017. In this consumption, oil products represent 77% and electricity 23% (see Table 39).

2.1.5 Conclusions and recommendations

Main sectors with potential for bioenergy

- The country's energy consumption is dominated by biomass (65%) of total final consumption in 2017, 90% of which is in the residential sector and 10% in the commercial and public service sector. In a country exposed to climate change and where land and natural resource degradation is a real problem, the wood-energy resource cannot provide an adequate response to the growing energy needs.
- Residues in wood-energy supply chain are minimal, and only charcoal dust could be identified in 2.1 as a potentially interesting material for recovery and use as fuel.
- The country's second source of consumption is related to oil products (29%) of total final consumption in 2017 and is dominated by the transport sector (73% of total oil products), industrial (18%); and 9% for other sectors.

In view of the above, the main sectors with potential for bioenergy are grouped in order of priority:

1- Residential and Commercial and utilities.
2- The industrial sector.
3- The transport sector; and agriculture and forestry.

Recommendations
The consumption of wood energy dominates total final energy consumption, particularly in the residential sector, which leads to worrying deforestation and justifies the use of bioenergy and modern/improved means of cooking.
The recommendations for bioenergy here concern the residential sector but also the commercial and public service sector. These recommendations are :

- Recovery of charcoal dust for the production of dust briquettes to substitute a part of charcoal and wood consumption in these two sectors.

- Improved carbonisation to reduce deforestation.
- To produce biochar and biogas from agricultural and agro-industrial residues to replace wood energy in these two sectors.

❖ In the industrial sector, the consumption of oil products must be reduced by using alternative fuels (biomass):
- The agro-food industries can valorise their waste to produce thermal energy necessary for their process by using H2CP technology developed by Nitidæ and which has already proved its worth on the agro-industrial platform in Kita.
- If the quantity of waste is large (as in the case of cashew nut or shea factories: MaliShi), the production of electricity can be envisaged.

❖ Concerning the transport & agriculture and forestry sector, the production of biofuel from jatropha and ethanol from sugar cane would be an alternative to substitute part of the consumption of diesel and petrol in these two sectors.

4.5. Senegal

4.5.1. Energy resources

Primary energy production

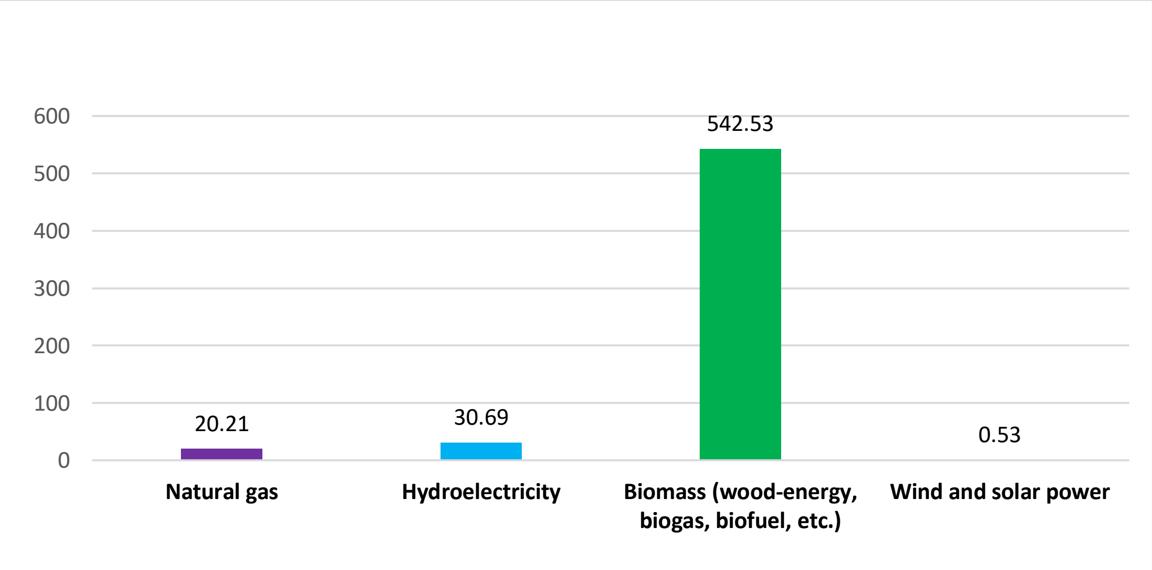

Figure 54: Total primary energy production in 2017 (in Ktoe)

Total primary energy production in Senegal was about 600 ktoe in 2017 and is mainly (over 90%) based on biomass, especially wood energy (fuelwood and charcoal). The country also produces, but to a much lesser extent, hydropower, gas and electricity.
Natural resources (solar and wind energy), representing respectively nearly 0.6% and less than 1% of total primary energy production (see Figure 54).
Unlike some countries on the African continent (Nigeria, Angola, Algeria...), Senegal does not produce crude oil or mineral coal.

Total primary energy supply

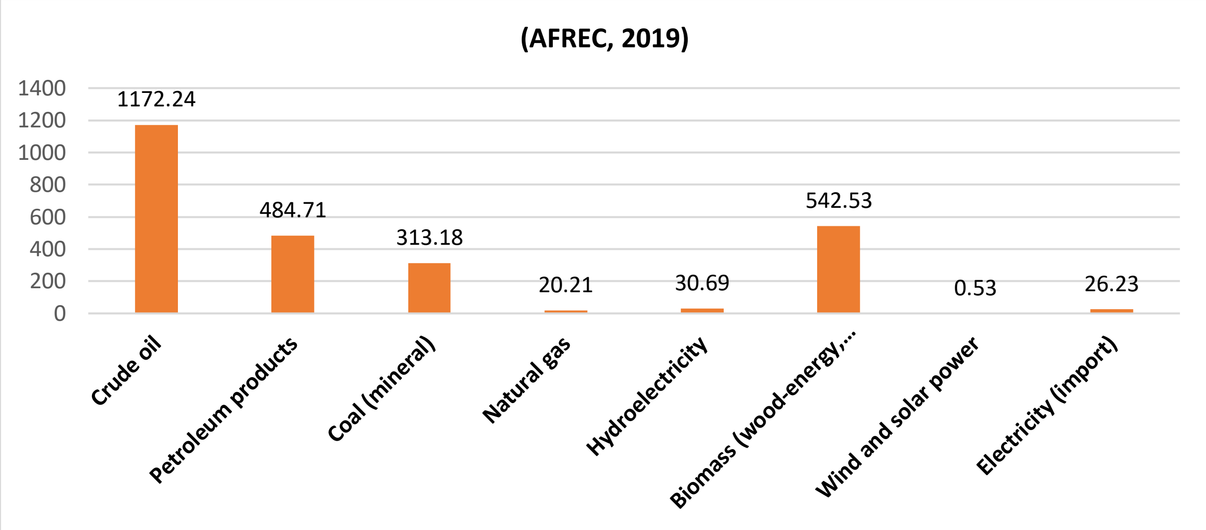

Figure 55: Total primary energy supply in 2017 (in ktoe)

Source: (AFREC, 2019)

To meet all its energy needs, the country imports large quantities of energy based on fossil fuels such as crude oil (1172 kt/year), oil products (1220 kt/year) but also mineral coal (615 kt/year). In 2017, these accounted for more than 75% of the country's total primary energy supply, being estimated at nearly 2600 ktoe, and more precisely 49%, 19% and 12% respectively of this total (see Figure 55).
Biomass, also including biogas and biofuel in addition to wood energy, still accounts for about 20% of this total supply. It should be noted that biomass flows (import and export, especially wood energy with neighbouring countries such as Gambia and Mali) are not taken into account since they are equal to zero in AFREC's energy balance sheet, which suggests an undervaluation of biomass volumes in terms of both supply and consumption. Also, although minimal, it should be noted that the country imports electricity (equivalent to 26 ktoe) at a rate of only 1% of its total primary energy supply.

4.5.1.1. Biomass

Forest bioenergy: In 2017, the country produced more than 1500 kilotonnes (kt) of firewood compared to more than 200 kt of charcoal (see Figure 56).

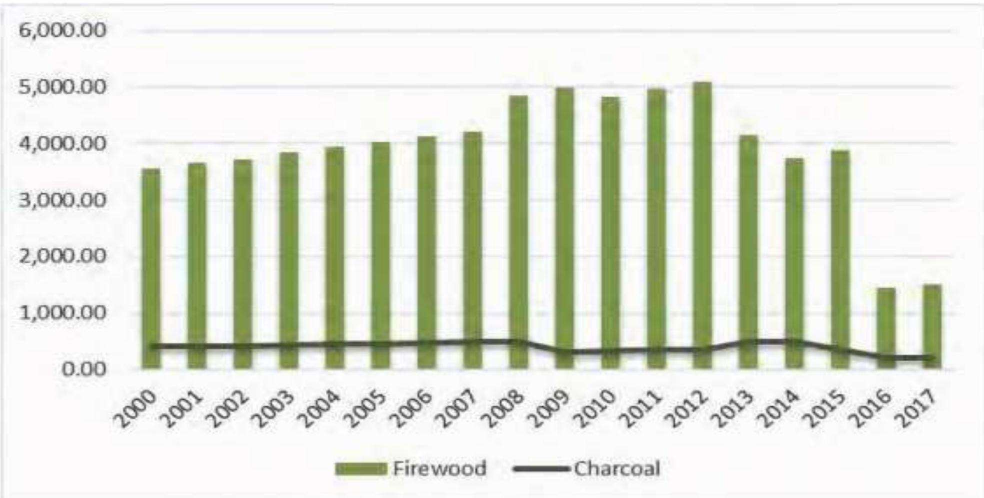

Figure 56: Fuelwood and charcoal production in Senegal (Ktoe)
Source: (AFREC, 2019)

Although charcoal production appears to have been broadly stable between 2000 and 2015, there has been a significant decline in fuelwood production since 2012 (substantially offset by an increase in charcoal production in 2013 and 2014), but especially since 2015, when charcoal production slightly diminished. This decrease is to be understood in the context of measures to ban logging in much of the country, as reported in the previous report 2.1.

Therefore, it is likely that the considerable decline in the production of wood fuels since 2015 has been offset by the increase in the use of LPG (butane gas).

Agricultural and vegetable waste: The country also produces residual agricultural biomass, including residues of groundnuts (shells), cereals (straw), cotton (stems) and sugar (bagasse). Groundnut shells and sugar cane bagasse are now being exploited for various energy purposes. At least bagasse has been accounted in this balance sheet.

There have also been initiatives to produce bio-coal from straw (NEBEDAY, n.d) since 2015.

4.5.1.2. Hydroelectricity

Hydropower is the best established and most commonly used renewable energy technology in West Africa and is the only technology used on a commercial scale in most ECOWAS member states.

According to AFREC, installed hydroelectric capacity in Senegal would have reached 357 GWh in 2017.

The country has six hydroelectric power stations managed by independent power producers according to the Senegalese CRSE (Comission de Régulation du Service Electrique), which publishes a compendium of the different profiles of power producers on its website (CRSE, n.d.). The installed capacity of the two power stations already commissioned since 2002 and 2013 is respectively 66 MW for the Manantali power station (which also supplies Mali with 144 MW) against 15 MW for the Felou power station. That of the four power stations under construction varies from 35 MW to 128 MW, for a total cumulated power of 333 MW.

4.5.1.3. Oil and derivatives

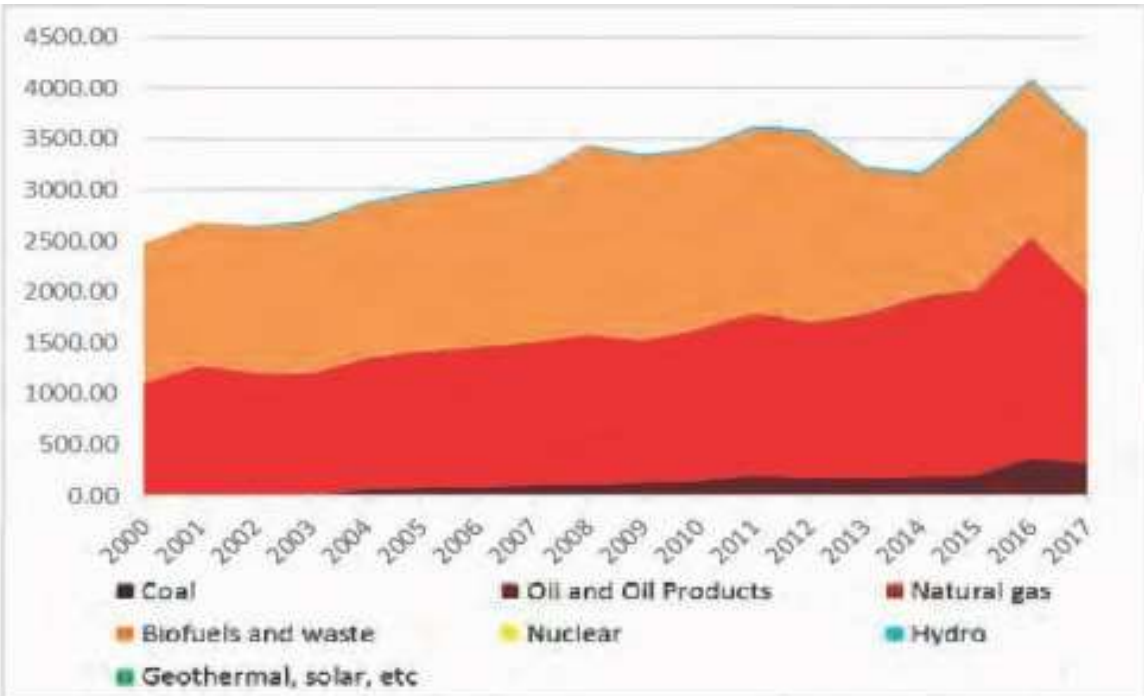

Figure 57: Total primary energy supply in 2017 in Senegal (in ktoe)

Source: (AFREC, 2019)

The country's energy supply depends mainly on crude oil and oil products (64%), being exclusively imported since Senegal is not an oil-producing country.
As with biomass-based energy supplies, imports of oil and its derivatives rose significantly between 2000 and 2016 before falling significantly, in favour of imports of mineral coal (see Figure 56).
All imported crude oil is processed in domestic oil refineries to extract the maximum commercial value and all imported oil products are transformed into electricity in thermal power plants.
According to Senegal's CRSE, the country has five thermal power plants, concerned with independent production, with a total cumulative capacity of about 400 MW. Only one of them, with a capacity of 120 MW, is being implemented in the Thiès region.

4.5.1.4. Solar

The country has significant potential for the use of solar energy for both electrical and thermal purposes, with 3,000 hours of sunshine per year and a total irradiation of 5.8 kWh/m²/day (MEP, 2019). Six solar power plants for independent power generation have already been installed and commissioned between 2016 and 2018. In addition, three more solar power plants are currently being commissioned with a total installed capacity of 83 MW (CRSE, n.d.).

4.5.1.5. Wind turbine

The wind potential is quite important along the Senegalese coasts, especially on the 50 km wide strip from Dakar to Saint-Louis, where the average annual wind speed has been measured at 4m/s at 10m height against more than 6 m/s between 30m and 40m height (MEP, 2019).
To date, there are no wind power plants for commercial energy production.
However, a wind farm with a capacity of 151 MW is being implemented at Taiba Ndiaye in the Thies region. Completion is scheduled for 2021. According to a CRSE publication, this park should include 50 turbines spread over two sites connected by an underground cable and will be linked to the local grid of the Société Nationale d'Electricité du Sénégal (SENELEC).

4.5.1.6. Others

In addition to crude oil and oil products, other types of fossil fuels supply the country's energy needs, namely mineral coal and natural gas.
According to AFREC, by 2017, Senegal would have produced 20 ktoe of natural gas and imported 313 ktoe of mineral coal, representing 13% of total primary energy supply.
All the natural gas produced is transformed into electricity, while about 30% of imported mineral coal is transformed in blast furnace (metallurgy) and 70% is used in other industrial sectors.

4.5.2. Key economic sectors according to NDP

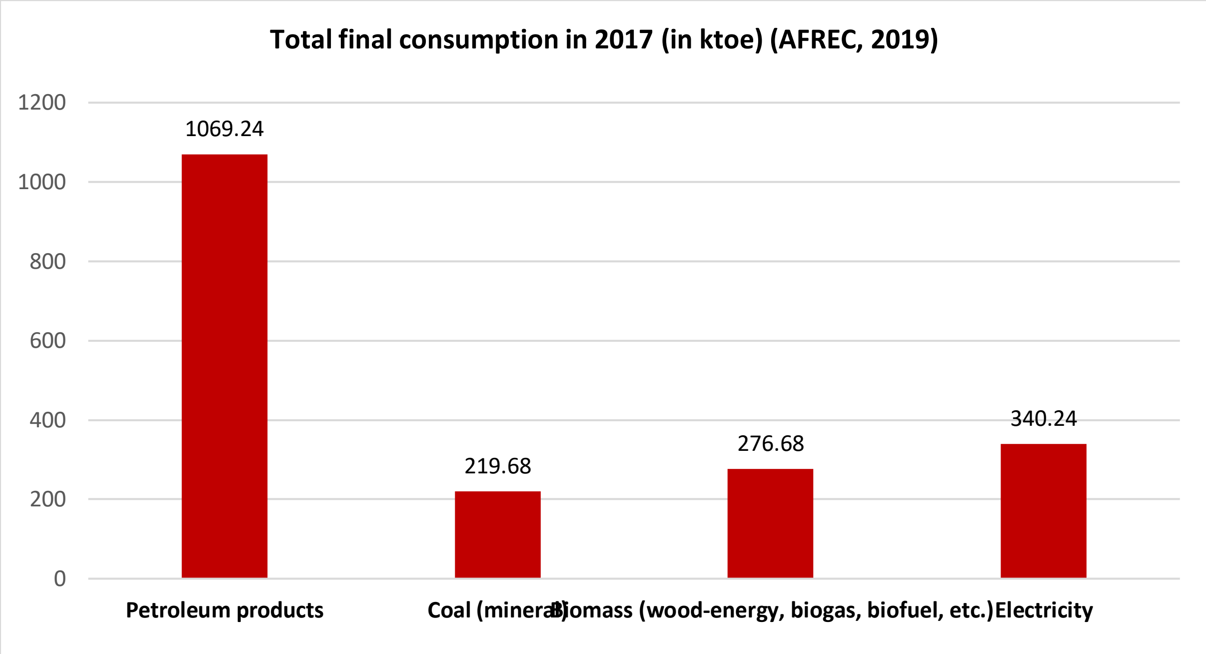

Figure 58: Total final energy consumption in Senegal, 2017 (in Ktoe)
Source: (AFREC, 2019)

The total final energy consumption in 2017 (1906 ktoe/year) of the country's various economic sectors comes mainly from the use of oil products (59% of the total) but also from electricity (18%), biomass (15%) in a broad sense (firewood, charcoal, biogas, biofuel...) and mineral coal (12%) (see Figure 58).

It should be noted that:

(i) All imported and refined crude oil is used to power thermal power plants to produce electricity.

(ii) hydropower, natural gas, solar and wind energy produced at national level, equivalent to about 30 and 20 and 0.5 ktoe/year respectively, are fully transformed into electricity.

The transport sector is the country's main energy-consuming sector (45% of the total), followed by industry and households (23% and 21% respectively), while trade and public services represent only 9% of the total against 2% for other unspecified sectors and less than 1% for agriculture & forestry (see Figure 59).

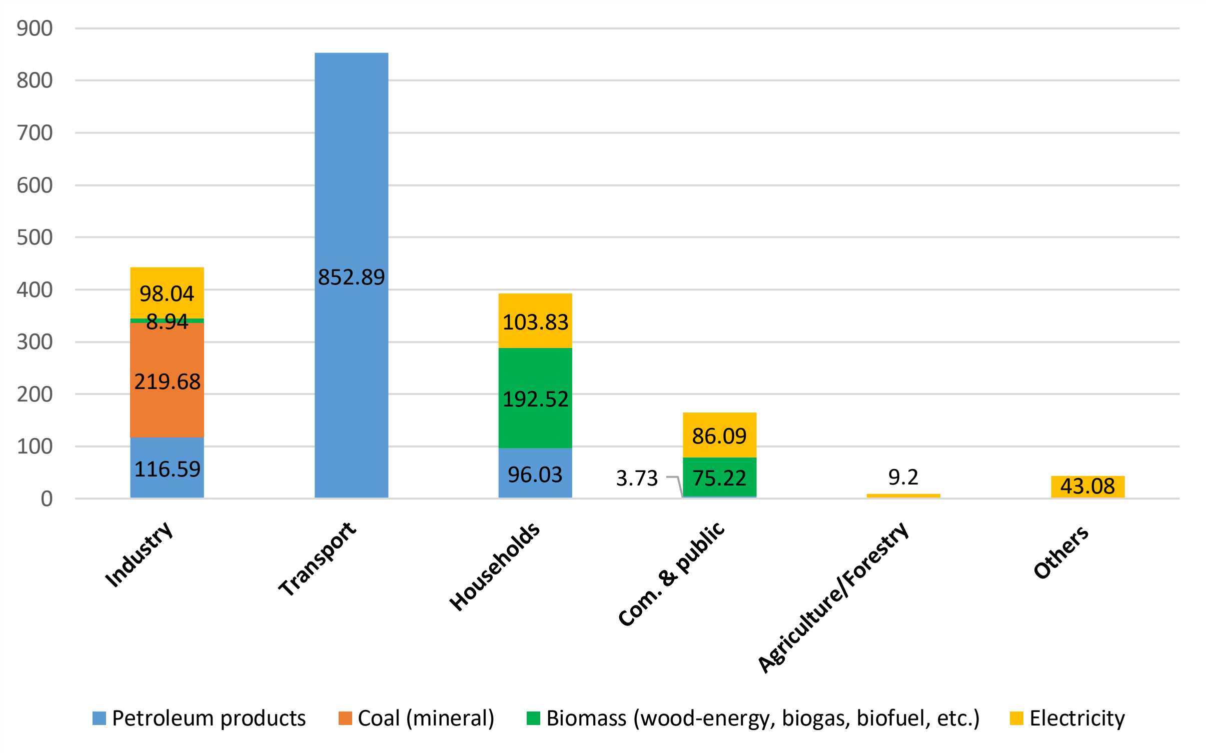

Figure 59: Total final energy consumption by sector in 2017 in Senegal (ktoe)

Source: (AFREC, 2019)

Oil products are consumed mainly in the transport sector (853 ktoe/year), to a lesser extent in industry (117 ktoe/year) and households (96 ktoe/year), and to a relatively small extent in shops and public services.

Mineral coal, on the other hand, is used exclusively in the industrial sector (220 ktoe/year), while imported electricity partially meets almost all the different sectors, from households (104 ktoe/year) to industry (98 ktoe/year), trade & utilities (86 ktoe/year), agriculture & forestry (9 ktoe/year) and other undefined (43 ktoe/year).

Finally, biomass (277 ktoe/year in total) is mainly used for domestic purposes (193 ktoe/year, i.e. 70% of the total) but also in commerce & public services (75 ktoe/year, i.e. 27%) and to a very lesser extent in industry (9 ktoe/year, i.e. 3%).

4.5.2.1. Industry

Energy demand: The industry sector is the second largest energy consumer in the country, equivalent to approximately 443 ktoe/year in 2017, which represents 23% of the final energy used at the national level.

More than 90% of the Senegalese industrial sector is dominated by small and medium sized enterprises (SMEs). In 2015, the Senegalese industrial sector counted nearly 1300 companies (Mansoor, Issoufou, & Sembene, 2019) spread over: (i) 45% in the agro-food sector (peanut industry, sugar production, breweries, processing of food products such as flour, vinegar...), (ii) 36% in the manufacturing sector (production of mattress, foam, tapestries...), (iii) 12% in the chemical sector (production of chemical fertilisers...), (iv) 4% in energy and (v) 3% in extractive activities (extraction of phosphates...).

The energy consumed by this sector is essentially based on hydrocarbons (around 75% of the total), including mineral coal (220 ktoe/year) and oil products (117 ktoe/year), to a lesser extent (22% of the total) on electricity (98 ktoe/year) and very little on biomass (9 ktoe/year) (**Error! Reference source not found.**).

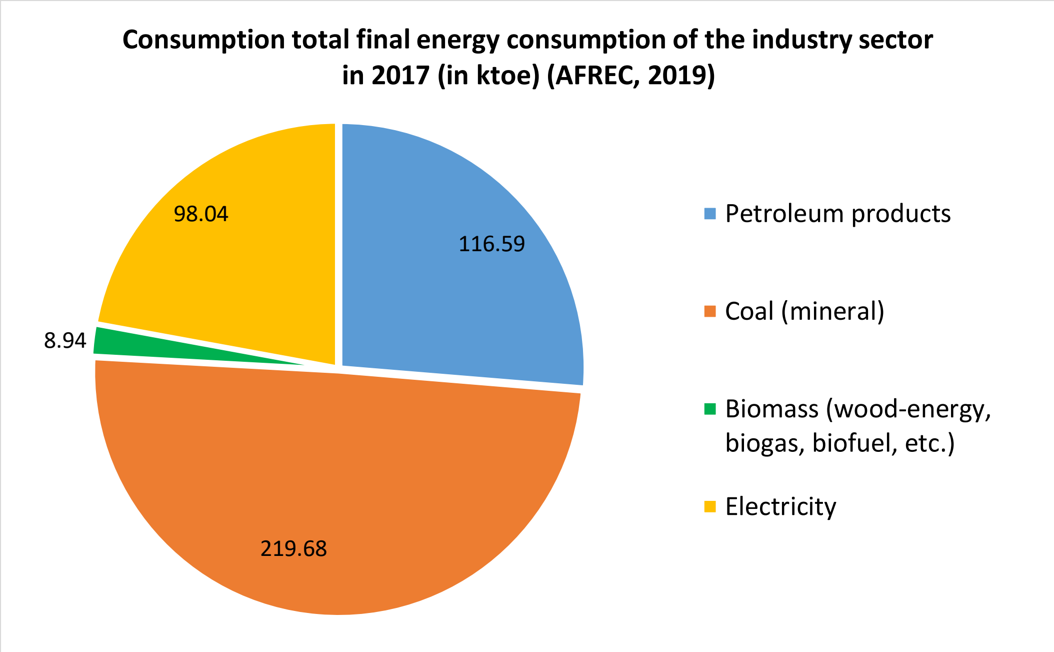

Figure 60: Total final energy consumption of the industry sector in 2017 in Senegal (ktoe)
Source: (AFREC, 2019)

Percentage of biomass used in the sector: The part of biomass consumed in the energy balance of the industrial sector is very low, at 2% of the total.
Among the different experiences in the field of biomass energy recovery for industrial purposes, it can be mentioned the energy autonomy achieved by the Compagnie Sucrière Sénégalaise (CSS). Indeed, this company uses bagasse (cane residues) as fuel in a steam boiler coupled to a tube to provide the energy required to operate machinery and other equipment such as irrigation pumps.
In addition, it should be noted that this company has a distillery, with a capacity of 12 million litres per year, for the production of alcohol for export.

Contribution of forest bioenergy in the sector: Forest biomass could contribute to the supply of thermal energy first, by taking forest residues such as sawdust or wood chips. These would have to be collected from wood processing sites, although, as reported in Report 2.1, the sawnwood sector is difficult to characterize and is currently in decline.
Forest biomass, used on a large scale, would make it possible to supply part of the electricity needs of the industrial sector through the installation of biomass power plants, producing electricity from the water vapour released by burning wood. The resource should, however, come from reforestation, in order to reduce the pressure on the national forest heritage, which is currently protected against this type of exploitation.
Also, it may be envisaged to develop energy self-sufficiency projects in certain factories using non-timber forest products, such as, for example, the pyrolysis of cashew nut shells to produce the thermal energy needed to process cashew nuts and, on a larger scale, the production of electricity from these materials.

4.5.2.2. Transport

Energy demand of the sector: Transport is the most energy-consuming sector in terms of the country's total final energy consumption, with a total of approximately 853 ktoe consumed annually, or 45% of the total.
Oil products provide all the energy consumed by this sector (petrol, diesel, paraffin, etc.). The latter absorbs about 80% of the oil products consumed by the various economic sectors of the country.
Percentage of biomass used in the sector: At present, bioenergy does not contribute to the energy supply of the transport sector at the national level.

Indeed, initially created to reduce energy dependence on oil through the production of biofuel, the CSS ethanol plant finally opted for the production of alcohol for export (first exporter of raw alcohol within the WAEMU in 2015) (GRET, 2015).

Contribution of forest bioenergy in the sector: It is difficult to envisage the energetic valorisation of forest biomass in order to supply the transport sector (availability and access to raw materials, technological barriers, investment constraints...) but rather from non-forest biomass (although the same difficulties can be encountered there).

This sector can effectively be supplied with energy through the production of biofuel based on (i) alcohol such as bioethanol produced from bagasse (or other sugar-rich material such as fruit waste like mango as a non-timber forest product) or (ii) oil such as biodiesel produced from jatropha seeds for example.

Moreover, once treated and compressed, biogas can be used as an alternative fuel to oil for transport, giving it properties similar to compressed natural gas. It can be produced through the methanisation of biomass (agro-industrial and livestock waste, etc.).

4.5.2.3. Residential (households)

Energy demand of the sector: The third largest energy consumer in the country (21% of the total) just after industry (23%), the residential sector consumes an annual total of almost 400 ktoe.

Biomass (firewood and charcoal for cooking...) satisfies almost half of the energy needs of households, i.e. almost 200 ktoe/year, while electricity (for lighting, the supply of domestic electrical equipment...) and oil products (production of butane gas used for cooking, fuel for powering generators in particular) each meet almost a quarter, i.e. 104 and 96 ktoe/year respectively (see Figure 61).

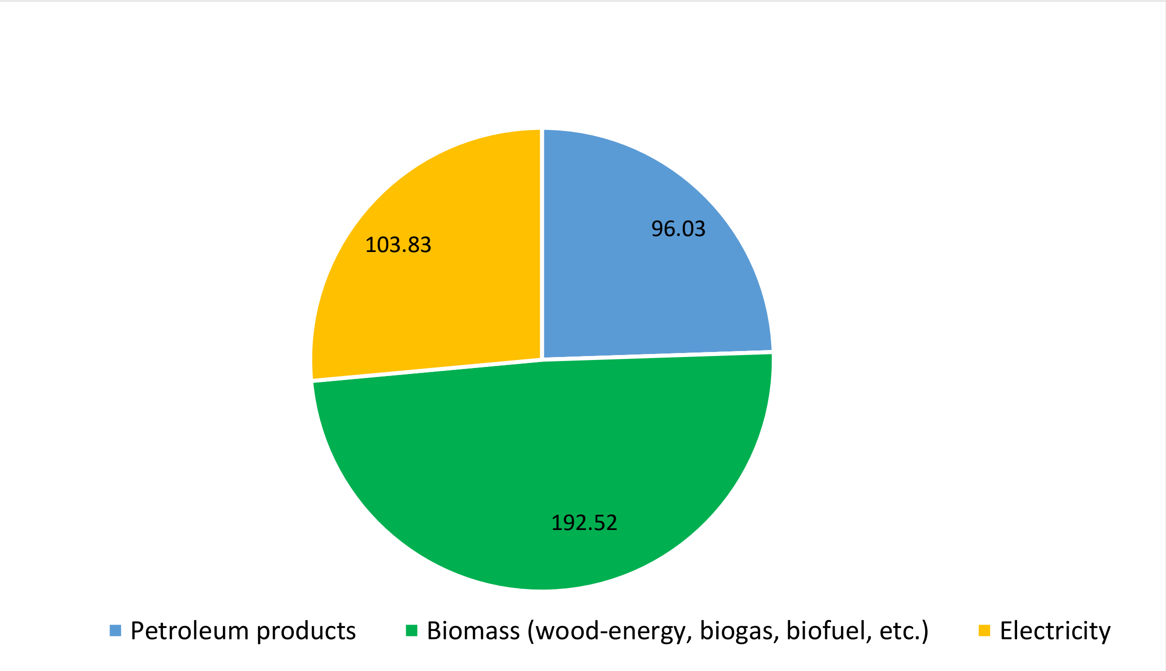

Figure 61: Total final energy consumption of the residential sector (households) in 2017 (in Ktoe)

Source : (AFREC, 2019)

Percentage of biomass used in the sector: Constituting 49% of the final energy consumed in the residential sector, biomass is the type of energy widely used by households.

These are mainly firewood, charcoal and, to a lesser extent, bio-coal (a product made from dust, peanut shells or straw), used mainly for cooking, or even heating (water heating, heating of rooms, etc.) or other specific domestic uses (ironing, for example).

Although not widespread at the national level, it should be noted that biogas, produced from cow dung or slaughterhouse waste, also provides cooking energy for more than 1,300 households (domestic biodigesters produced as part of Senegal's National Biogas Programme and biodigesters from the St-Louis slaughterhouse with a production capacity of 10,000 m^3 per year to supply 12 households with biogas).

Contribution of forest bioenergy in the sector: Beyond the use of firewood and charcoal, in particular as fuel for domestic cooking, there seem to be relatively many possibilities for the use of forest biomass (including residues of non-wood forest products) or non-forest biomass (agro-industrial biomass from non-forest sources) for household energy supply:

- Production of alternative charcoal (biochar) from forest residues (wood dust available in charcoal distribution points in large cities, sawdust and wood chips in sawmills, cashew nut shell or cashew nut shell dust in cashew nut processing plants, etc.) and/or agricultural residues (peanut shell, rice husk, cotton stem... available in the production areas of these crops);
- Production of biogas, from cow dung or other fermentable biomasses (slaughterhouse waste, fruit waste, especially mangoes, etc.) for cooking and lighting purposes, or even for decentralized electrification.
- Electricity production in biomass power plants (wood from reforestation and sustainable management, sawdust and wood chips, agricultural residues, etc.).
- Production of biofuel as an alternative to oil to power household generators (bioethanol from bagasse or other sugar-rich waste, biodiesel from jatropha oil, etc.).

4.5.2.4. Businesses and public services

Energy demand of the sector: The commercial and public services sector represents only a small part of the country's energy consumption, i.e. less than 10% of the total (165 ktoe/year out of the total of 1906 ktoe consumed annually).

Nearly 98% of the energy used by this sector comes from electricity (89 ktoe/year; street lighting, power supply of public buildings, shops and restaurants...) and biomass (75 ktoe/year; firewood and coal used in restaurants...); and only 2% from oil products (butane gas used in restaurants, fuel for generators...) (see Figure 62).

Percentage of biomass used in the sector: Almost half of the energy needs of this sector are derived from biomass (46% of the total) and, more particularly, mainly from the use of firewood and charcoal as cooking fuel for catering. Due to the fact that the informal economy is widespread in the country, especially street catering, it is likely that this energy consumption has been underestimated.

In spite of its very small part in the total electricity consumption of this sector, it is worth highlighting two experiences in the production of biogas for the purpose of "clean" electricity production.

In the field of trade (meat), the Société de Gestion des Abattoirs du Sénégal (SOGAS) in Dakar produces annually 517,000 m^3 of biogas which is energetically recovered thanks to a cogeneration unit (production of 800 MWh/year of electrical energy and 1700 MWh/year of thermal energy (ReCube, 2016).

In the field of public services (sanitation), the Cambérène wastewater treatment plant produces 51,100 m^3 of biogas annually, which is converted into electrical and thermal energy via a cogeneration system. This self-produced clean energy on site reduces the conventional energy used in the plant by 50% (Incatema, 2019).

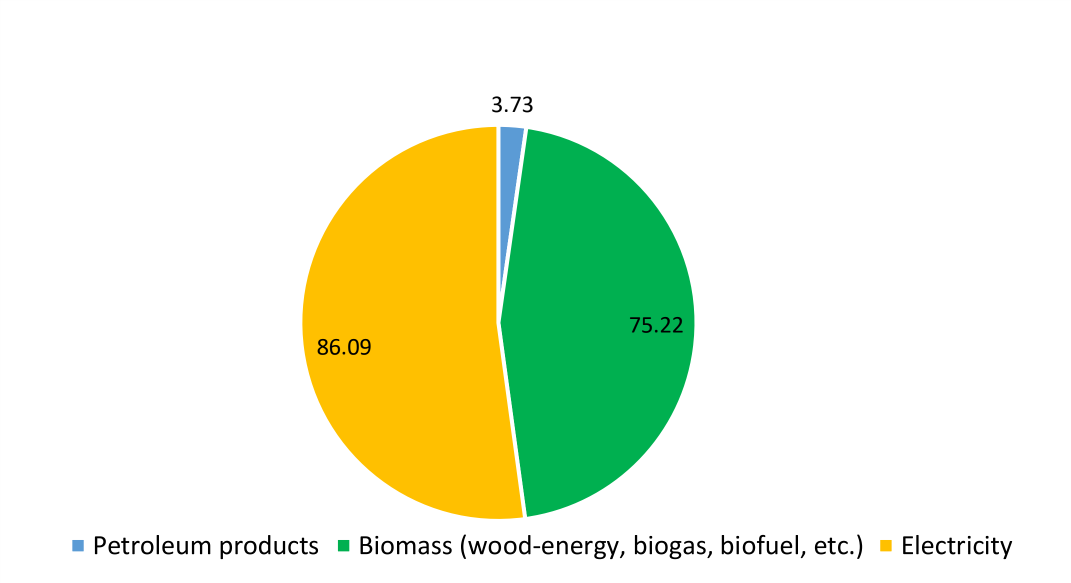

Figure 62: Total final energy consumption of the commercial and public services sector in 2017 in Senegal (in ktoe)
Source: (AFREC, 2019)

Contribution of forest bioenergy in the sector: The proposals made above in chapter "4.5.2.3" concerning households are applicable here, particularly for businesses (restaurants, slaughterhouses, etc.).

4.5.2.5. Agriculture and forestry

Energy demand of the sector: The agriculture and forestry sector consumes less than 1% of the country's total final energy, i.e. only 9 ktoe/year solely from electricity (power supply of cold rooms for the conservation of agricultural products, and possibly also of machinery in wood processing plants).
Percentage of biomass used in the sector: No biomass is used to meet the energy needs of this sector.
Contribution of forest bioenergy in the sector: As mentioned in chapters "1.1.1" relating to the industrial sector and "4.5.2.3" relating to the residential sector, electricity generation in forest biomass plants (wood, sawmill waste, non-timber forest product residues, etc.) could be considered.

2.1.6 Conclusions and recommendations

Main sectors with potential for bioenergy
In a country that is highly dependent on imported fossil fuels to meet its energy needs, but at the same time is seeing its forest resources dwindle due to the ever-increasing demand of wood energy, it is essential to act with measures that will reduce this trend in two ways: firstly, to reduce the consumption of primary resources (energy efficiency), and finally to make the exploitation of the resource sustainable (among other things, by increasing the supply of modern biomass, such as charcoal from managed sources, bio-coal or biogas).
The economic sector with the best potential to act on this use of biomass for energy purposes seems to be households since 70% of biomass is consumed by them. This biomass is used for thermal purposes (mainly cooking) which is the most appropriate use for the type of biomass used (wood fuels from small trees, crop residues and small-scale biogas).
Also, the commercial & public services and industry sectors present a significant potential for biomass use as these sectors (i) consume the remaining 30% of biomass and (ii) depend on the use of electricity to meet their energy needs, respectively up to 52% and 22%.
Recommendations
The fact that :

(i) Biomass satisfies almost half of households' energy needs (around 50%), thus leaving considerable room for improvement (especially since 26% of households' energy needs are met by importing electricity, compared with 24% for importing oil products),

and

(ii) Senegal is characterised by a very young population (average age of the population is 19 years, with an estimated projection in 2020 of 16.7 million) and is experiencing very significant population growth (population growth rate of around 3% between 2017 and 2018) (Ansd, 2012), households a *priori* represent the most promising sector in terms of access to modern biomass-based energy services.

4.6. Togo

4.6.1. The country's energy resources

Primary energy supply

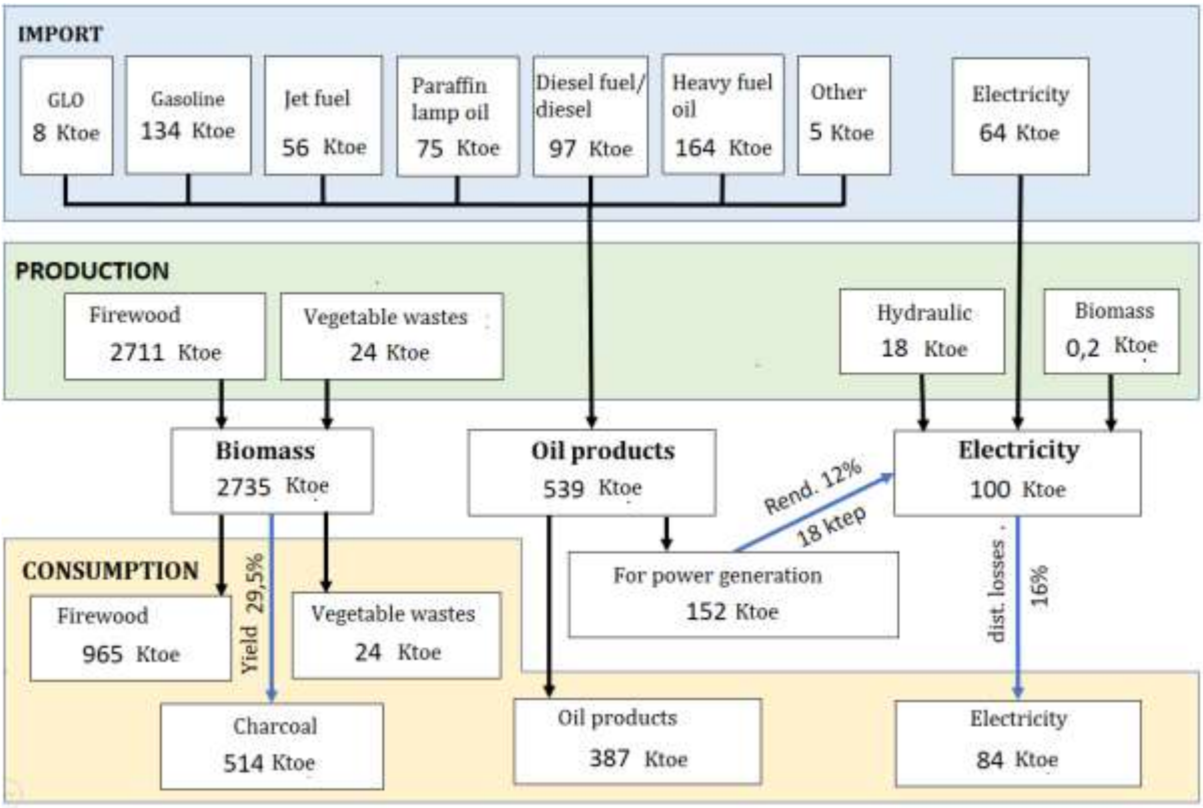

Figure 63: Details of Togo's energy supply in 2016 Source: (SIE, 2016)

Togo's Energy Information System, in its 2016 report (SIE 2016) [21] oil products and electricity.
Data from the African Energy Commission (AFREC) confirms this trend. Indeed, in 2017, biomass, oil products and electricity also constituted the essential of the total primary energy supply (AFREC 2019).

[21] *Where no additional sources are mentioned, the 2016 energy data correspond to the EIS 2016 data.*

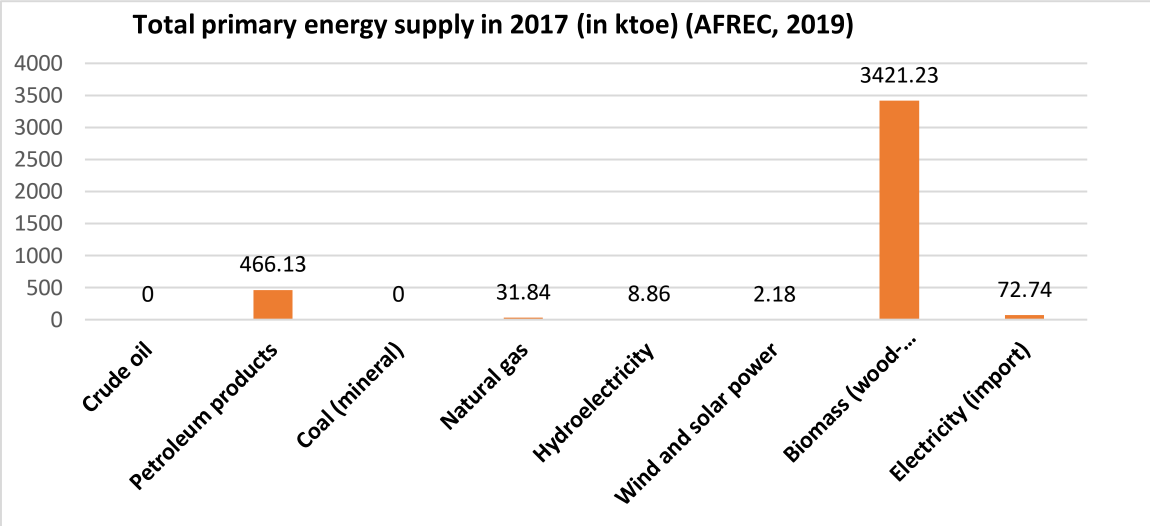

Figure 64: Total primary energy supply in 2017 in Togo (in ktoe)

Source: (AFREC, 2019)

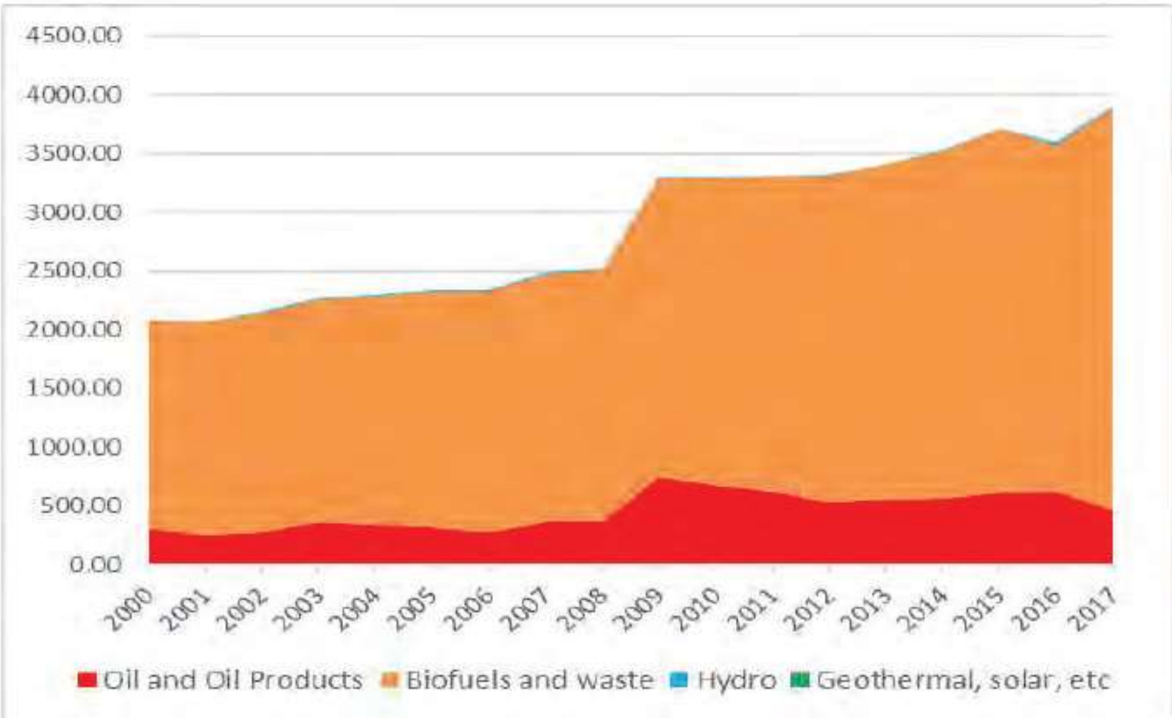

Figure 65: Growth curve of Togo's supply of energy by source

Source: (AFREC, 2019)

Error! Reference source not found. presents the evolution of energy production in Togo between 2000 and 2017 (with projections for 2018 and 2019).

At the level of national energy production, as shown in **Error! Reference source not found.** below, is by far the most important locally produced energy source in Togo. Since 2016, production has been increasing to meet the cooking energy needs of the population. It can also be seen that since 2017, almost 90% of the electricity produced by Togo is dominated by fossil fuels, specifically oil products, 100% of which are imported. On the other hand, the contribution of renewable energies (especially hydraulic) to this electricity production has decreased. The part of other renewable energies (solar, wind, etc.) is marginal (around 3% since 2017).

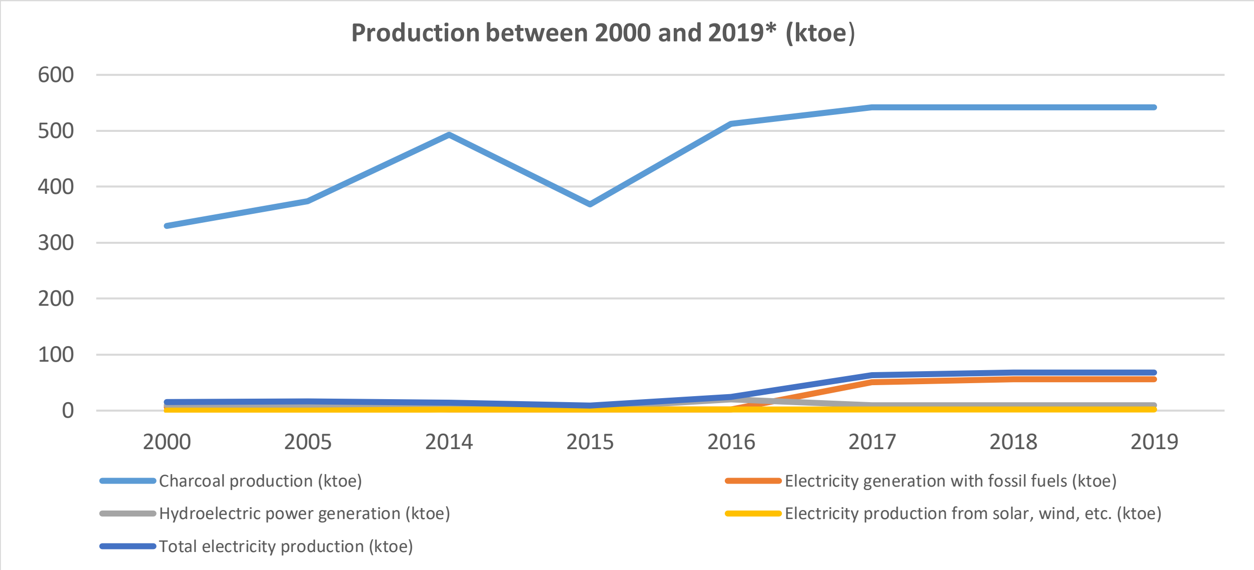

Figure 66: Production in Togo between 2000 and 2019 (Ktoe)

Source: **(AFREC 2019)**

**the years 2018 and 2019 are projections*

Table 40: Trends in energy production in Togo between 2000 and 2019

Years	2000	2005	2014	2015	2016	2017	2018 *	2019*
Coal Production (ktoe)	-	-	-	-	-	-	-	-
Charcoal production (ktoe)	330	374	493	369	513	542	542	542
Production of crude oil, NGL and additives (ktoe)	-	-	-	-	-	-	-	-
Natural gas production (ktoe)	-	-	-	-	-	-	-	-
Electricity production from biofuels, waste (ktoe)	0	0	0	0	0	0	0	0
Electricity generation with fossil fuels (ktoe)	6	10	2	2	2	51	56	56
Hydroelectric power generation (ktoe)	9	6	10	5	20	9	10	10
Electricity production from solar, wind, etc. (ktoe)	0	0	2	2	2	2	2	2
Total electricity production (ktoe)	15	16	14	9	24	63	68	68
Production of oil products in refineries(ktoe)	-	-	-	-	-	-	-	-

Source: (**AFREC 2019**) **projection*

Biomass

Biomass is an important source of energy in Togo. It is dominated by wood energy (firewood and charcoal) and is mainly used by households, and to a certain extent by businesses.
Biomass consumption comes entirely from domestic resources. Total production in 2016 was 2,735 ktoe in primary energy, with 99% (2,711 ktoe) of wood energy and the rest of plant waste (24 ktoe). More than a third (35%) of the wood is used as is, mainly by households (i.e. a consumption of 965 ktoe), and almost all the rest is transformed into charcoal with a mass yield of 15% (i.e. an energy yield of 29.5%), allowing a final consumption of 514 ktoe. In 2017, total biomass production was 3 421 ktoe, an increase of 25% compared to 2016.

Hydroelectricity

Togo's hydroelectric potential is very important thanks to the river network. About forty sites have been prospected on the Mono, Oti and Sio rivers, of which nearly half (23) have a potential of more than 2 MW. Thus, according to the EIS 2016 report, the expected production of all the sites is estimated at about 850 GWh for a power to be installed of about 224 MW.

In 2017, the production of hydroelectric power was 8.86 ktoe, or 103,042 MWh. The best-known dam is that of Nangbéto, a few kilometres from the town of Atakpamè. This dam is operated by the Communauté Électrique du Bénin (CEB) for a total power of 64 MW.

Oil and derivatives

Togo is 100% dependent on imports for its supply of oil products. Since 2009, supplies of oil products have surged and its consumption remains sustained until a decline in 2017 of 13.5% compared to the previous year. In 2016, supply amounted to 539 ktoe. A large majority (72% or 387 ktoe) is consumed as is, mainly by the transport sector, and the rest (152 ktoe) is used for electricity production with an efficiency of 23% for public power plants.

Solar

According to a SE4all (2012) report, new and renewable energies (solar, wind, biofuels, etc.) are marginal (or even insignificant) in Togo's energy balance (SE4all, 2012).
Thus, in 2012, according to this report, the total installed solar power capacity at the national level was 301.92 kWp. It is often used for the electrification of social infrastructures: schools, dispensaries, drinking water pumping, etc. in rural areas.
Togo's 2017 energy balance reports 2.18 ktoe (25,353 MWh) of solar, wind and geothermal energy production. It is legitimate to blame everything on solar energy, as wind power is not yet developed in the country, and the potential for geothermal energy is nil. This energy would come in particular from off-grid solar systems, as the first solar power plant connected to the electricity system is expected in 2021 in Blitta (50MW).

Wind turbine

According to the SE4all report, the installed capacity in 2012 was 5.7 kW. It is used for pumping drinking water in rural areas, precisely in the locality of Atalote (Prefecture of Kéran) by the Sisters for water pumping. However, these sources have not been referenced in the WIS 2016, which is why the production of primary renewable wind energy has been estimated at 0.
The report points out that a project for the construction of wind power plants (24 MW) was announced and could see the first connections to the grid.

4.6.2. Key economic sectors according to NDP

Togo's national final consumption of energy resources is presented in **Error! Reference source not found.**.

Table 41: National final energy consumption of Togo's energy resources between 2000 and 2019

Years	2000	2005	2014	2015	2016	2017	2018*	2019*
Final Coal Consumption (ktoe)	0	0	0	0	0	0	0	0
Final oil consumption(ktoe)	271	286	544	594	617	364	376	376
Final consumption of natural gas (ktoe)	-	-	-	-	-	-	-	-
Final electricity consumption (ktoe)	40	52	99	107	107	155	161	161

(*2018 and 2019: projections)

Oil consumption increased significantly between 2005 and 2016. However, since 2017, this consumption has fallen.

On the other hand, electricity consumption is on the rise. In two decades, electricity consumption has quadrupled from 40 ktoe in 2000 to 161 ktoe in 2019. This could be explained by the increase in the coverage rate and the rise in the number of households with access to electricity.

A comparison of oil and electricity consumption reveals a reversed trend in both since 2016. This could be reflected in the fact that oil consumption is gradually being reduced in favour of electricity.

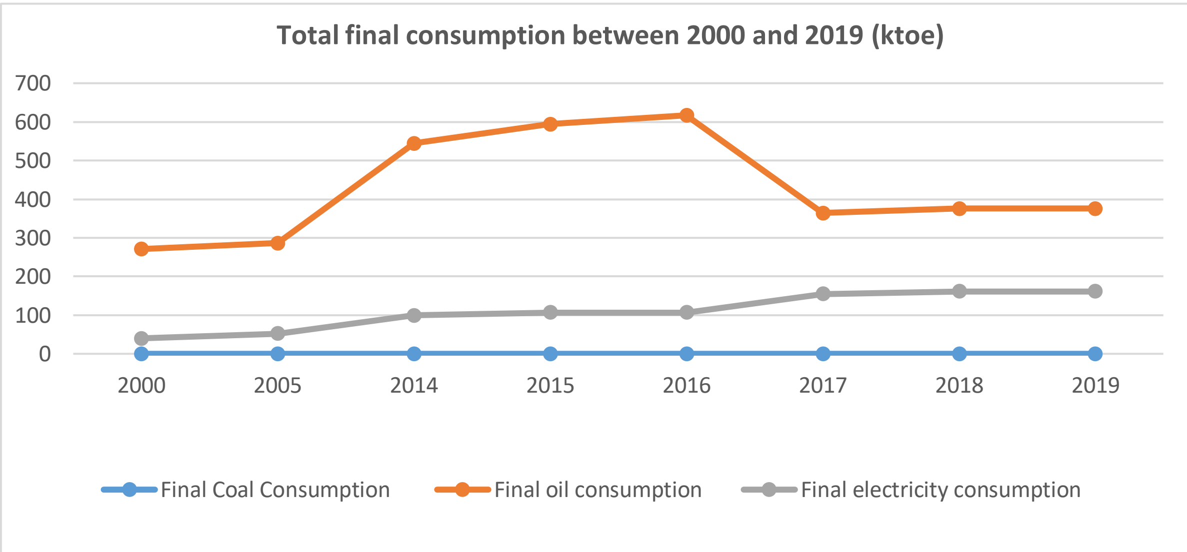

Figure 67: Total final consumption between 2000 and 2019

Even if this is not shown in the above table, it should be noted that the final consumption of energy sources in Togo is dominated by biomass. In fact, in 2016, it accounted for 76% of the country's final energy consumption, mainly wood fuels (wood and charcoal) and some agricultural residues. In 2017, biomass consumption was 1919.15 or 79% of the country's total final consumption.

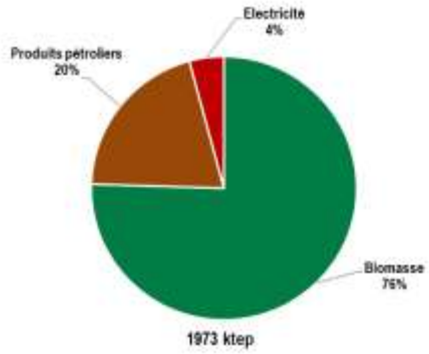

Figure 68: Distribution of final consumption by energy source in 2016

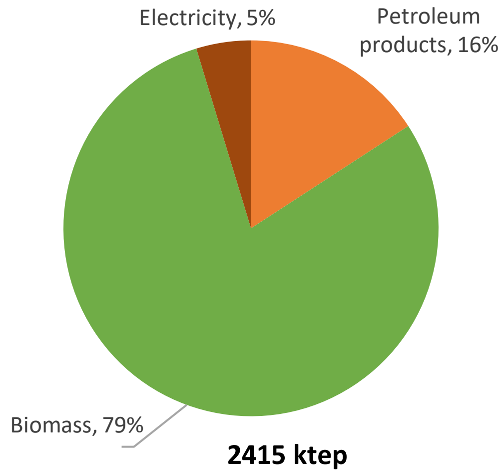

Figure 69: Total final consumption in 2017 in Togo

Source: (SIE, 2016)	Source: (AFREC 2019)

According to the figures above, final energy consumption would have increased by 22% compared to 2016. Indeed, final energy consumption in Togo has jumped since 2015 as reported by the statistics collected by AFREC; biomass taking an increasingly important part in the total energy consumption. Thus, according to EIS 2016, 1499 ktoe of biomass would have been consumed in 2016 against 1919 ktoe in 2017. This may not necessarily correspond to a real leap in biomass consumption, but rather to an increasingly comprehensive energy intelligence system, which the 2017 EIS was able to identify more sources than in previous editions.
The distribution of this consumption in 2017 by sector of activity is as shown in Figure 71.

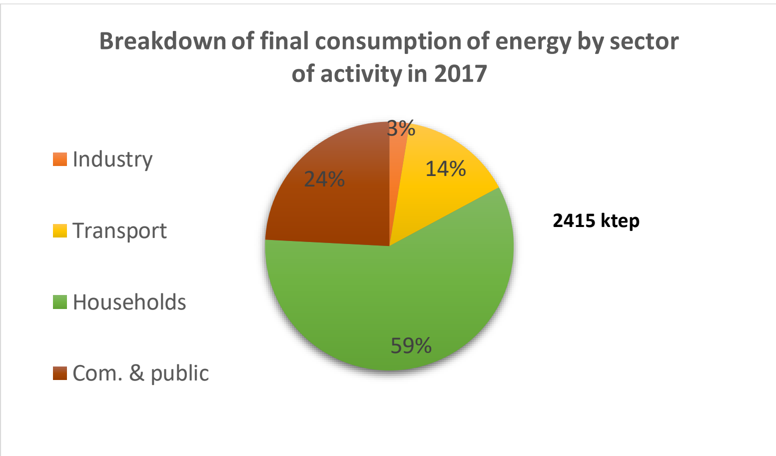

Figure 70: Distribution of final energy consumption by activity sector in 2017

Figure 71: Distribution of final energy consumption by activity sector in 2017

Source: (AFREC 2019)

According to the most recent balance sheet available (2017), households account for the largest part of the final energy consumption (59%), followed by the commercial and public sector (24%) and then transport (14%). Industry would represent only 3% of the total.

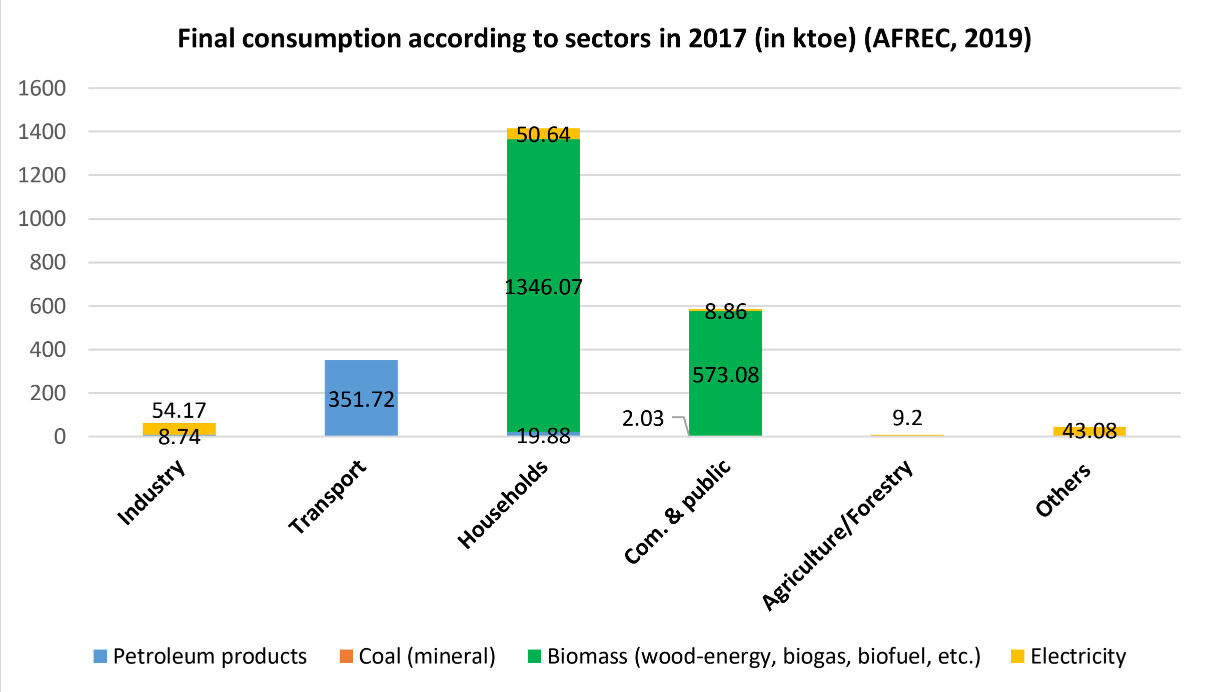

Figure 72: Total final energy consumption by sector in 2017 in Togo (in ktoe)

Source: (AFREC, 2019)

4.6.2.1. Industry

Energy demand: The country is weakly industrialised and the part of this sector in energy consumption is proof of this. The industrial fabric is represented above all by agro-food processing, followed by extractive and mining processing activities (WTO, 2012). The latter weigh heavily in the energy balance of the industry, because they are very energy-consuming activities: extraction of phosphates, production and grinding of clinker, iron ore and marble. In 2016, mining products accounted for around 60% of the country's exports. Among the major food processing industries there is at least one oil mill producing cotton oil and shea butter, based in Lomé.

The following table presents energy consumption in industry in Togo according to AFREC sources.

Table 42: Energy consumption in industry in Togo

Years	2000	2005	2014	2015	2016	2017	2018*	2019*
Industrial oil consumption (ktoe)	85	30	52	57	60	9	10	10
Industrial consumption of natural gas (ktoe)	-	-	-	-	-	-	-	-
Industrial electricity consumption (ktoe)	11	16	28	34	35	54	56	56
Industrial Coal Consumption (ktoe)	-	-	-	-	-	-	-	-

Source: (AFREC 2019) (*projections)

After 2016, the consumption of oil in industries in Togo decreased, unlike that of electricity, which increased more significantly from that date.

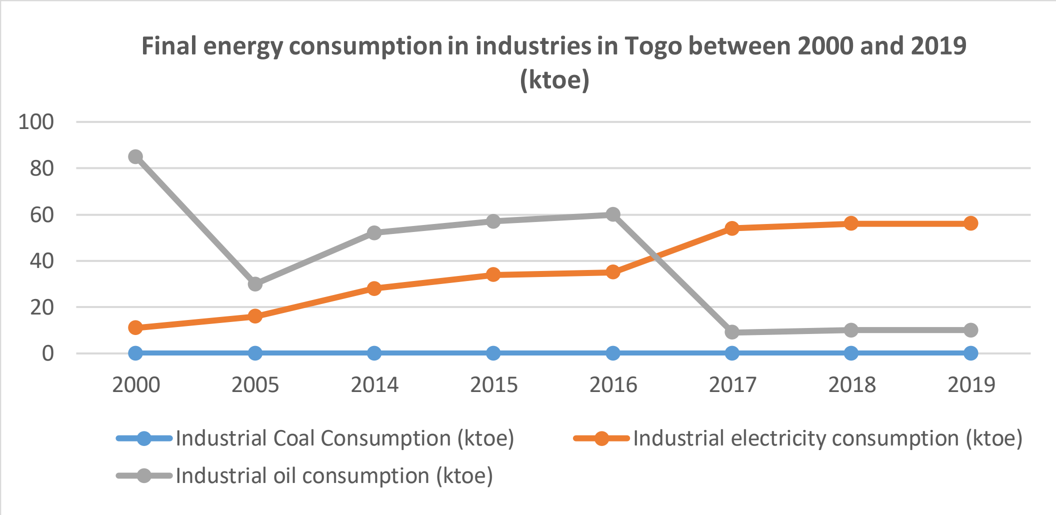

Figure 73: l energy consumption in industries in Togo between 2000 and 2019

Source: (AFREC 2019)

Percentage of biomass used in the sector: Available data show an insignificant or even non-existent part of biomass in industrial energy consumption. Oil and electricity would remain the only sources of energy used in industries in Togo as illustrated in the following figure.

Nevertheless, it has been reported from a good source that the Nioto oil mill in Lomé uses its residual biomass to provide itself with thermal energy (Icilome, 2019). The omission of this contribution suggests that other uses of biomass in industry have also not been identified in the EISs for the moment. The balance sheet would therefore give partial information, although certainly the part of biomass in the final energy is expected to be minimal compared to other energy sources (oil products and electricity).

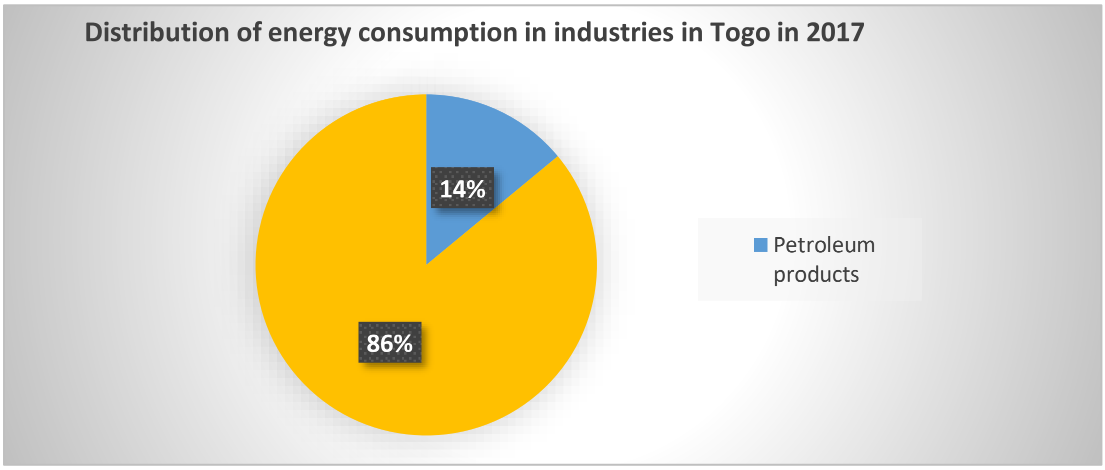

Figure 74: Distribution of energy consumption in industries in Togo in 2017

Source: (AFREC 2019)

Contribution of forest bioenergy in the sector: The low part of industrial energy consumption in total energy consumption (3% in 2016 and 2017 for example) reflects the country's low level of industrialization. In addition, the large part of electricity in this consumption could indicate that these industries use much less calorific energy (heat). Indeed, the processing of the various products of the subsoil requires large quantities of electricity. Grinding, cutting, etc. units require power in the order of MW in order to be able to operate.

That said, forest biomass in the strict sense could not contribute to the sector. The country lacks sufficient forest resources, and the biomass exploited for energy purposes mainly contributes to domestic consumption. On the other hand, biomass from agricultural sources, sometimes non-wood products such as shea and cashew nuts, can still be exploited, at least for thermal purposes given the size of the processing units. As a paradigmatic example, Nioto, as the largest processor of shea butter and cottonseed oil and one of the country's largest industrialists, uses its waste in its boiler and is reportedly studying the feasibility of producing its electricity from these sources (shea crab and cotton husks).

4.6.2.2. Transport

Energy demand: The following table shows energy consumption in transport in Togo.

Table 43: Energy consumption in transport in Togo between 2000 and 2019

Years	2000	2005	2014	2015	2016	2017	2018*	2019*
Oil consumption in transport (ktoe)	137	195	419	461	483	334	345	345
Electricity consumption in transport (ktoe)	-	-	-	-	-	-	-	-

(*projections)

The transport sector remains exclusively dominated by the consumption of oil products, most of which is used in road transport and a small part of it is used as jet fuel in air transport.

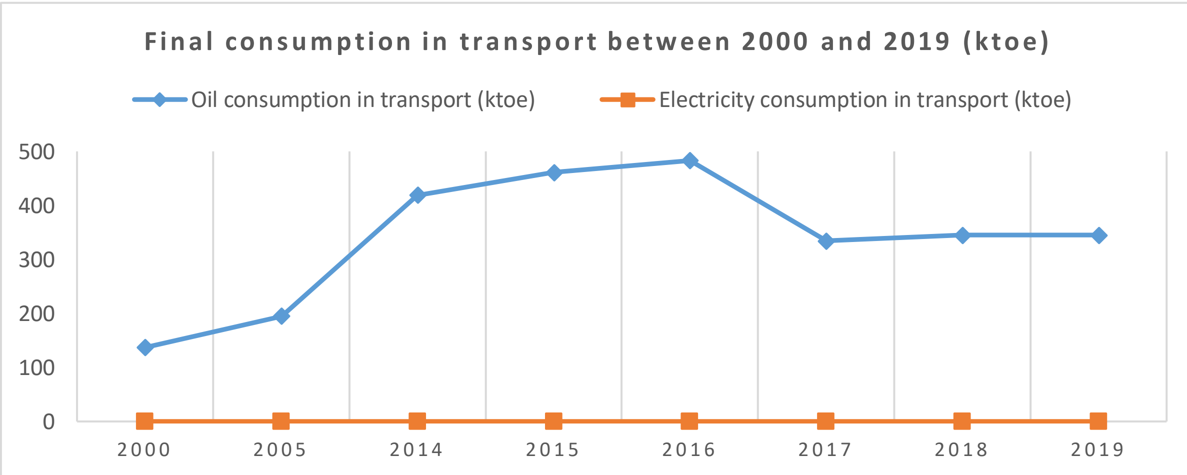

Figure 75: Final consumption in transport in Togo between 2000 and 2019

Source: (AFREC 2019)

Contribution of forest bioenergy in the sector: As stated in these reports, the contribution of bioenergy in this sector could only be through the use of biofuels. But for the time being, this is an area that is far from being developed in Togo. So, it must be admitted that oil products still have a bright future in this sector in Togo.

Residential (households)

Energy demand: Biomass represent the most essential forms of energy consumed in households. In 2016, it accounted for 90%, while in 2017 it accounted for 95% of the energy consumed in households. This biomass consists mainly of firewood and charcoal, the energy of which is used by households for cooking and heating.

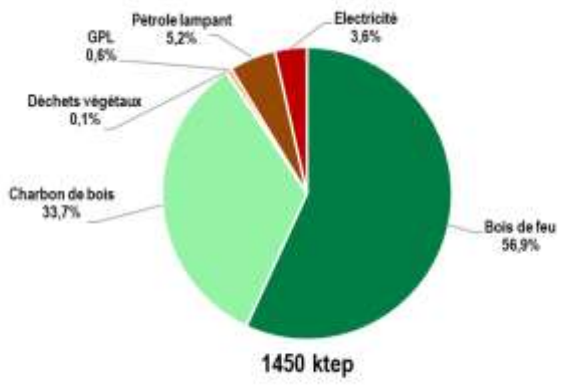

Figure 76: Household energy consumption in 2016

Source: (EIS 2016)

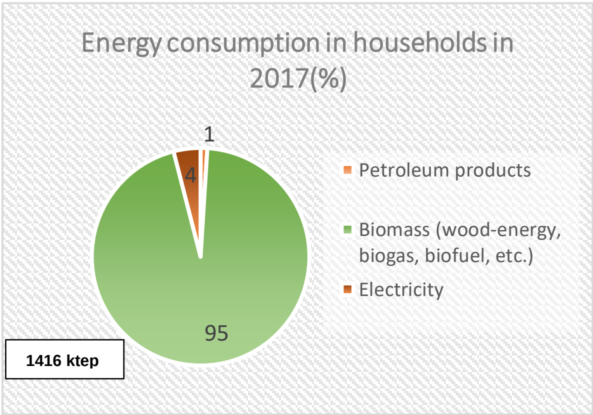

Figure 77: Household energy consumption in 2017

Source: (AFREC 2019)

Businesses and public services

Energy demand: As seen above, the part of shops and public services in consumption is 24%.
According to AFREC data, in 2017, consumption in this sector was dominated by biomass consumption of about 573 ktoe or 98%.

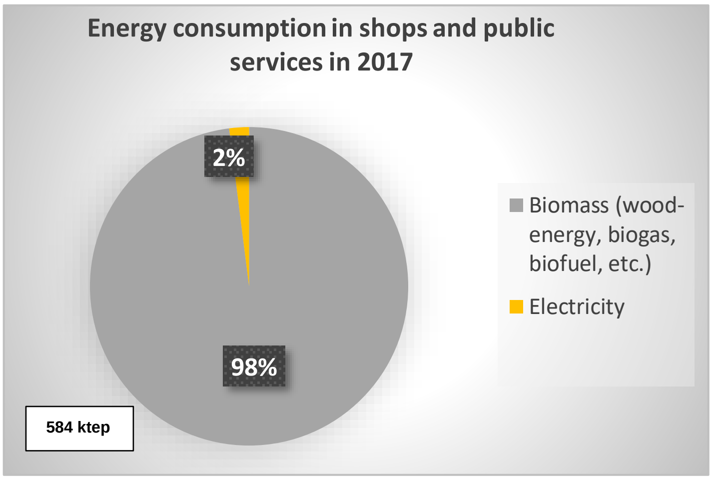

Figure 78: Commercial and utility energy consumption in 2017

Source: (AFREC 2019)

Agriculture

Energy demand: There is very little or no information on energy consumption in this sector. The energy balances drawn up between 2000 and 2016 in Togo's EIS (2016) report do not provide any data on energy consumption in the agriculture sector, either on the consumption of oil products or on the consumption of biomass or electricity. Unless it is assumed that the sector does not consume energy (which seems unlikely), this could be explained by the unavailability of this information. Especially since it is a quasi-informal sector, and occupies a majority of the rural population, which is not always aware of the need for energy data. However, and as the EIS (2016) reminds us, the absence of consumption of oil products and electricity in agriculture could be an indicator of the low level of mechanization in Togolese agriculture (agricultural machinery) and the low use of technologies for processing and conserving agricultural products in the broad sense (agriculture, forestry, fishing and livestock).

However, as in most countries of the sub-region, it is a sector that provides residual biomass (cereal stems, hulls, ears, raffles, etc.) available both in the fields and in processing sites. The latter remain, with a few exceptions, very small in size, so the waste is scattered. This biomass could be an important source of energy but unfortunately not yet sufficiently exploited.

2.6.3 Conclusions and recommendations

Main sectors with potential for bioenergy

In view of the above situation, the main sectors with bioenergy consumption potential are households and commercial and public services, where energy is mainly used for cooking.

Recommendations

The large part of biomass, especially woody biomass (firewood and charcoal) in total household energy consumption could be replaced by bioenergy in the form of biofuel. As noted in Report 2.1, some potential for the valorization of charcoal dust in Lomé can be foreseen. However, the biomass that can be valorized into bioenergy is mainly found in agricultural residues, which are not the subject of this study.

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