Economic Community of
West African States

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ECOWAS ENERGY OUTLOOK
Focus on biomass energy

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DISCLAIMER:
This report expresses the authors' results and analyses. It does not necessarily reflect the views of ECOWAS.
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FOREWORD

A community with access to modern, affordable, reliable and sustainable energy services to improve living standards and socio-economic development. This is the ECOWAS vision for the energy sector. This vision is fully consistent with the revised ECOWAS Treaty, the Sustainable Development Goals, international agreements on climate change, ECOWAS Vision 2050, the African Union's Agenda 2063, and the various national, regional and international commitments of ECOWAS and its member states. The new vision of ECOWAS energy policy is in line with the Revised ECOWAS Treaty, ECOWAS Vision 2050, the Sustainable Development Goals, international agreements on Climate Change, Agenda 2063 of the African Union and the various national, regional and international commitments of ECOWAS and its member states.

Sédiko DOUKA
Commissioner for Infrastructure, Energy and Digitization, ECOWAS Commission

Until 2021, biomass energy represented the main source of primary energy consumption (59% of energy supplies), but the implementation of the ECOWAS Regional Energy Policy will involve a structural transition from traditional biomass to clean energies. Strategic objective 6 of the ECOWAS Energy Policy aims to increase people's access to modern, clean energy for domestic cooking. This will involve strengthening infrastructure and popularizing the use of Liquefied Petroleum Gas (LPG), as well as promoting the development of alternative clean cooking fuels.

The implementation of the energy transition scenario, through which the dynamics of rural and urban cooking fuel use will move towards cleaner use of these fuels, will have a significant positive impact on the environment, especially in these times of climatic upheaval.

Indeed, by increasing the use of LPG by 6.6% per year and decreasing that of firewood and charcoal by 4.5% per year in urban households between 2021 and 2050; and by doubling LPG consumption (0.2 ktoe in 2021) and decreasing firewood consumption in rural households by 7% annually, we will reduce firewood consumption by 681 million tonnes equivalent between 2021 and 2050.

This represents an avoided emission of more than 3,500,000 Gigagrams (Gg) of CO2, while the level of CO2 emissions in the ECOWAS region was around 190,142 Gg in 2021.

I trust that this document, which aims to provide an energy outlook, particularly for political decision-makers, stakeholders and investors, will further motivate us to redouble our efforts to facilitate the sustainable integration of clean energies into the region's energy system.

PRE-READING STATEMENT

Bayaornibè DABIRE
Director of Energy and Mines of the ECOWAS Commission

Since July 2023, the 40-year-old ECOWAS Energy policy was updated. In fact, since the adoption of the Energy Policy in 1982, many significant economic, social, technological and political changes have taken place that have significantly altered the energy issues of the 15 ECOWAS Member States.

This Policy is intended to be ambitious and transformative. Ambitious, because it aims to provide the region's 810 million citizens with universal access by 2050 to modern and clean energy (electricity, natural gas, butane for cooking, biogas, etc.) at a reasonable cost. Transformative, because it aims to achieve an energy mix based on renewable energies, natural gas, a significant improvement in energy efficiency and, above all, a very significant reduction in wood fuels (wood and charcoal).

ECOWAS Energy Outlook is based on historical series from 2010 to 2021, made available through the ECOWAS Energy Information System. It provides a vision and trajectories for sustainable and equitable energy transition in the ECOWAS region up to 2050.

The first edition of this document is focused on biomass energy, as it accounts for most of the region's final energy consumption in 2021. However, the entire ECOWAS energy system is presented and analysed. The present Outlook is in line with the Strategic Objective 6 of the ECOWAS Energy Policy which aims to increase the population's access to modern and clean energy for cooking. Indeed, the Policy stipulates that "Very ambitious targets for access to clean energy for cooking and substitution of solid biomass energy are retained by the Member States This substitution to modern (LPG, biogas, electricity) and clean energies will have a particularly significant positive impact on curbing deforestation (by reducing pressure on the resource) and climate change, as well as on the health of the population (children and women in particular)".

The main results and conclusions will enable us to define trajectories between the 2021 reference year and the 2050 horizon, with analyses for intermediate stages, notably 2030 and 2040.

The ECOWAS Directorate of Energy and Mines hopes that the member states and all its partners will see this as an affirmation of a strong regional commitment and determination to provide access to sustainable energy for All in the ECOWAS region.

ECOWAS DEPARTMENT FOR INFRASTRUCTURE, ENERGY AND DIGITALIZATION

Institutional framework

The Department of Infrastructure, Energy and Digitization is one of the 5 departments of the ECOWAS Commission. It comprises three Directorates including the Directorate of Energy and Mines. The Directorate is responsible for the coordination and harmonization of Member States' energy policies and programmes as enshrined in Article 28 of the revised ECOWAS Treaty.

The Directorate is working closely with the specialized ECOWAS energy agencies. These are

(i) the West African Power Pool (WAPP), created in 1999 and based in Cotonou, Benin. It is in charge of developing regional power generation and transmission facilities, as well as the electrical interconnection of West African states.

(ii) the ECOWAS Regional Electricity Regulatory Authority (ARREC), based in Accra, Ghana, which was created in 2008 to regulate cross-border power trade and promote the development of a competitive regional electricity market.

(iii) The ECOWAS Centre for Renewable Energy and Energy Efficiency (CEREEC) is based in Cape Verde. It was created in 2010 to promote the deployment of renewable energy and energy efficiency technologies in West Africa. It provides technical assistance, capacity building and policy support to ECOWAS member states to accelerate the transition to sustainable energy systems and mitigate climate change.

The Directorate also collaborates with the West Africa Gas Pipeline Authority (WAGPA), established in 2003 in Abuja (Nigeria) as part of the West Africa Gas Pipeline (WAGP) project, which plays a regulatory and representative role for the States involved. WAGP is a major regional infrastructure initiative aimed at transporting natural gas from Nigeria to Benin, Togo and Ghana, thereby promoting energy cooperation and economic development in West Africa.

Regulatory framework

Since 1982, ECOWAS has defined its energy policy and strategy through a series of evolving documents. Chronologically, we cite:

1. the Regional Energy policy which was adopted in 1982 by Decision A/DEC.3/5/82;

2. the ECOWAS Energy Observatory, established by Decision A/DEC.2/01/03 in January 2003;

3. the ECOWAS Energy Protocol adopted on January 17, 2003 by Decision A/DEC. 17/01/03 and which provides the legal basis for energy cooperation among ECOWAS Member States and establishes principles for market liberalization, cross-border trade, and regulatory harmonization;

4. the ECOWAS/UEMOA White Paper on access to energy services for populations in rural and peri-urban areas was adopted in January 2006;

5. The ECOWAS Renewable Energy Policy and the ECOWAS Energy Efficiency Policy were adopted by Additional Acts in July 2013;

6.the ECOWAS Bioenergy Policy and the ECOWAS Policy on Gender Mainstreaming in Energy Access were adopted by Additional Act in June 2017

7. the ECOWAS Hydrocarbon Development Policy and its implementation matrix was adopted in December 2019 by Additional Act A/SA.2/12/19.

8. the ECOWAS Regional Strategy for the Popularization of Liquefied Petroleum Gas (LPG) as a Domestic Cooking Energy was adopted by Regulation C/REG.2/9/20 in September 2020;

9. The ECOWAS Energy Policy was updated and adopted in July 2023 alongside with the ECOWAS Green hydrogen Policy and Strategy Framework.

These policy documents reflect ECOWAS's commitment to promoting sustainable energy development, enhancing energy security, and fostering regional cooperation and integration in the energy sector.

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SUMMARY

The ECOWAS region is confronted with significant energy challenges marked by a heavy reliance on traditional biomass sources like wood and charcoal for various purposes such as cooking, heating, and income generation. This dependence not only accelerates deforestation but also worsens health conditions due to indoor air pollution. Moreover, there exists a pronounced gap between urban and rural areas in terms of accessing clean energy within the ECOWAS region.

To tackle these pressing issues, in July 2023, Energy Ministers from ECOWAS Member States adopted the ECOWAS updated Energy Policy, marking a crucial step towards transitioning to clean and modern energy sources. This policy aims to deploy viable alternative energy solutions to address these challenges while promoting sustainable social and economic development. Notably, Strategic Objectives 4 and 6 of the ECOWAS energy policy focus on diversifying the energy mix and enhancing access to modern and clean cooking energy.

Understanding the socio-economic dynamics, particularly the urban-rural divide, is imperative for an effective energy transition. Factors such as population growth, urbanization trends, income levels, and cultural practices influence energy consumption patterns and the feasibility of accessing modern energy services, necessitating an inclusive transition process.

The inaugural edition of the **ECOWAS Energy Outlook 2024** aims to analyze the key hurdles hindering the region's transition to clean energy on a large scale, encompassing both urban and rural areas. By identifying these challenges, the study aims to provide insights, particularly for policymakers, stakeholders, and investors, to facilitate the sustainable integration of clean energy into the region's energy system.

The Outlook comprises three interconnected chapters:

The first chapter presents updated facts and figures on the ECOWAS energy system up to 2021, providing a comprehensive overview, including primary energy production, foreign trade, energy transformation processes, and final energy consumption broken down by sectors. This chapter also includes sustainable development indicators, maps, and diagrams illustrating the ECOWAS energy systems and those of its member states.

The second chapter delves into various biomass energy forms and levels of utilization, aiming to ensure a sustainable and environmentally friendly energy supply for cooking and other applications, particularly for income-generating activities. The chapter analyzes factors contributing to the current energy usage and establishes disparities in energy forms and utilization levels across different sectors of member states' economies. Relevant country-specific case studies are presented to draw lessons for policy implementation and develop sustainable biomass energy in the ECOWAS region.

This chapter examines the main challenges to be met to enable ECOWAS member countries to transition to a more sustainable biomass energy system, including the application of biomass fuels for transport and the productive sector. Beyond biomass, this chapter also addresses challenges and pathways to increase access to LPG and electricity for cooking with some innovative dissemination strategies.

The focus of **the third chapter** lies in depicting and quantifying the ECOWAS biomass energy system. The imperative shift from traditional biomass to clean fuels holds paramount importance for enhancing health, safeguarding the environment, advancing gender equality, and nurturing sustainable development on a global scale. Nevertheless, within the ECOWAS context, this transition lacks comprehensive long-term pathways to assess its feasibility, particularly considering the urban-rural divide.

Addressing this challenge necessitates a rigorous methodological approach in modeling transition pathways from the baseline year to 2050. To accommodate uncertainties, two scenarios have been developed. The first scenario serves as a reference, analyzing the current trends in biomass production and consumption within ECOWAS to formulate appropriate strategies. In contrast, the second scenario, TRANSECOWAS, aligns with principles of accessing clean, efficient, and modern energy, striving for equity between rural and urban areas. It assumes ECOWAS countries' access to international financial resources, such as commitments under the Conference of Parties (COPs) or requests for technological and financial support in their Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC).

Comparison between the TRANSECOWAS and reference scenarios reveals significant biomass savings in both urban and rural areas. **In urban areas**, over the period 2021-2050, charcoal savings are estimated to be approximately 166 Mtoe compared to the reference scenario, with significant reductions anticipated from 2035 onwards. Over the period 2021 to 2050, LPG consumption is projected to be 2.9 Mtoe higher than the reference scenario, while natural gas usage is expected to reach about 5.5 Mtoe between 2040 and 2050, a resource not introduced in the reference scenario.

In **rural areas**, the TRANSECOWAS scenario forecasts approximately 466 Mtoe of firewood savings between 2021 and 2050, accompanied by a cumulative increase of 10.65 Mtoe in LPG consumption during the same period. This increase, relatively high, is due to the current low level of LPG consumption in rural areas.

Short and medium-term alternative solutions, including improved stoves and a shift towards cleaner energy sources such as LPG, electric cooking, and to a lesser extent, natural gas in urban areas from 2040 onwards, hold promise in alleviating pressure on biomass resources and mitigating environmental impacts and contributing towards the objective of universal access to clean, efficient and modern energy.

1 CURRENT ENERGY SYSTEM: FACTS AND FIGURES

Primary energy production

The primary energy production[1] of the ECOWAS region reached 239,810 kilotons[2] of oil equivalent (ktoe) in 2021. This production is dominated by the production of crude oil and biomass energy, which accounts for almost 80% of energy production.

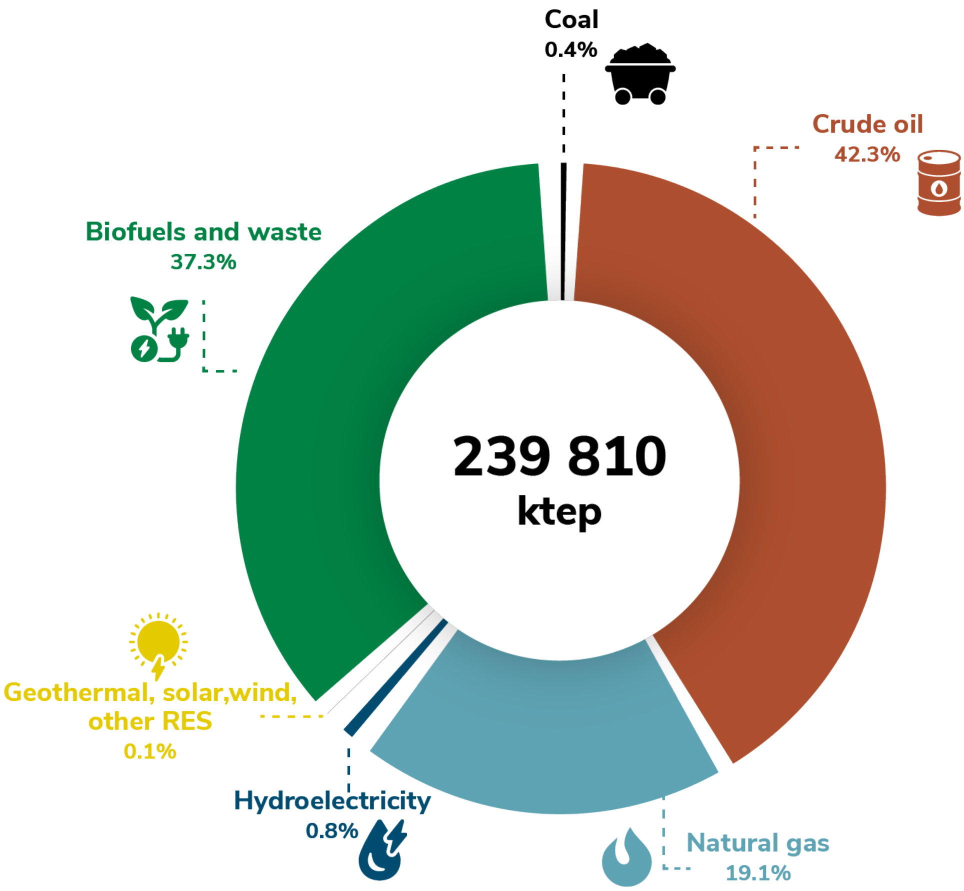

Figure 1: Structure of ECOWAS Primary Energy Production in 2021

[1] The total amount of energy collected that has not undergone any transformation.
[2] In the ECOWAS Energy Key Figures, 2023 Edition, primary production was estimated at 283,982 ktoe; This difference is due to the updating of previous estimates with more recent data made available to the regional database by countries.

Renewable and clean energy accounts for only 1% of the region's primary energy production. This is equivalent to an energy production of **24 treawatt-hour (TWh)**, 94% of which comes from hydropower.

Per capita energy production varies between 0.11 tonnes of oil equivalent (toe) and 0.85 toe in member states. As at the regional level, primary energy production in Nigeria and Ghana is dominated by crude oil. In all other countries, biomass energy is the main source of primary energy production. Its share in the primary energy production of these countries varies between 69.42% (Niger) and 99.95% (Benin).

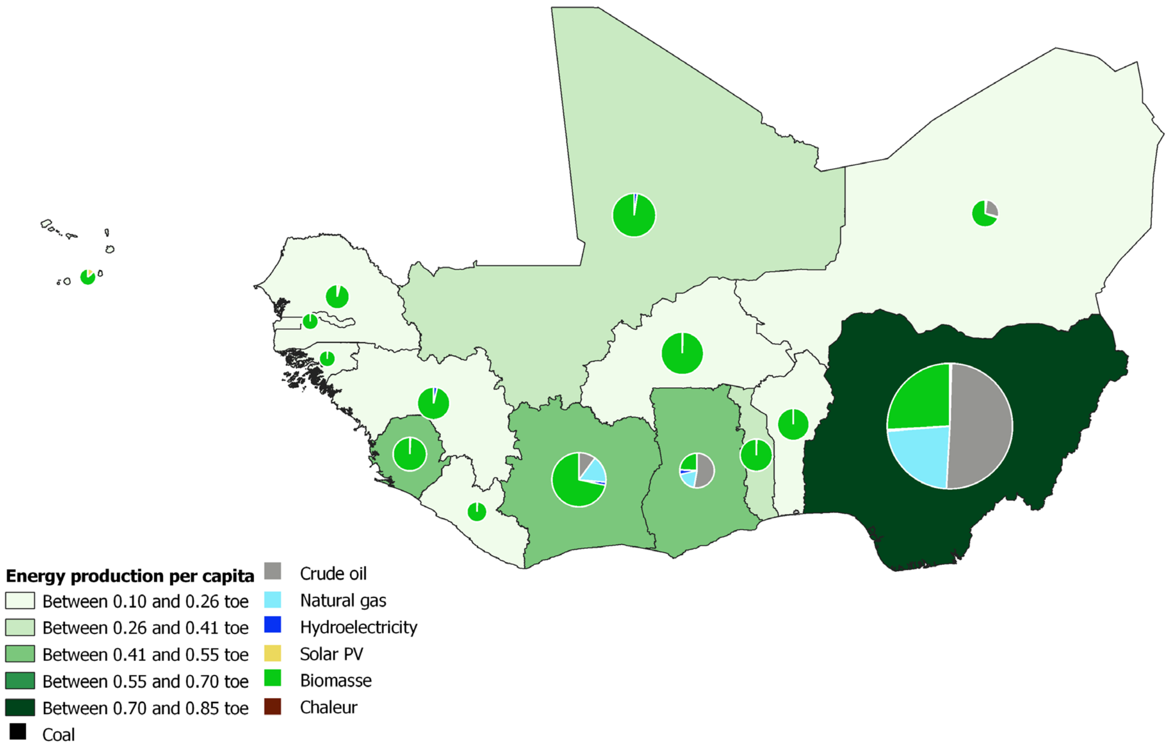

Figure 2: Mapping of primary energy production in the ECOWAS region in 2021 (toe/capita)

Cabo Verde and Senegal are the countries with the lowest levels of primary energy production per capita (0.11 toe). This could be explained by the fact that these countries, in addition to Niger, have the lowest levels of biomass energy production in the region, at 0.7 kilograms of fuelwood per capita per day. This is confirmed by non-biomass mapping.

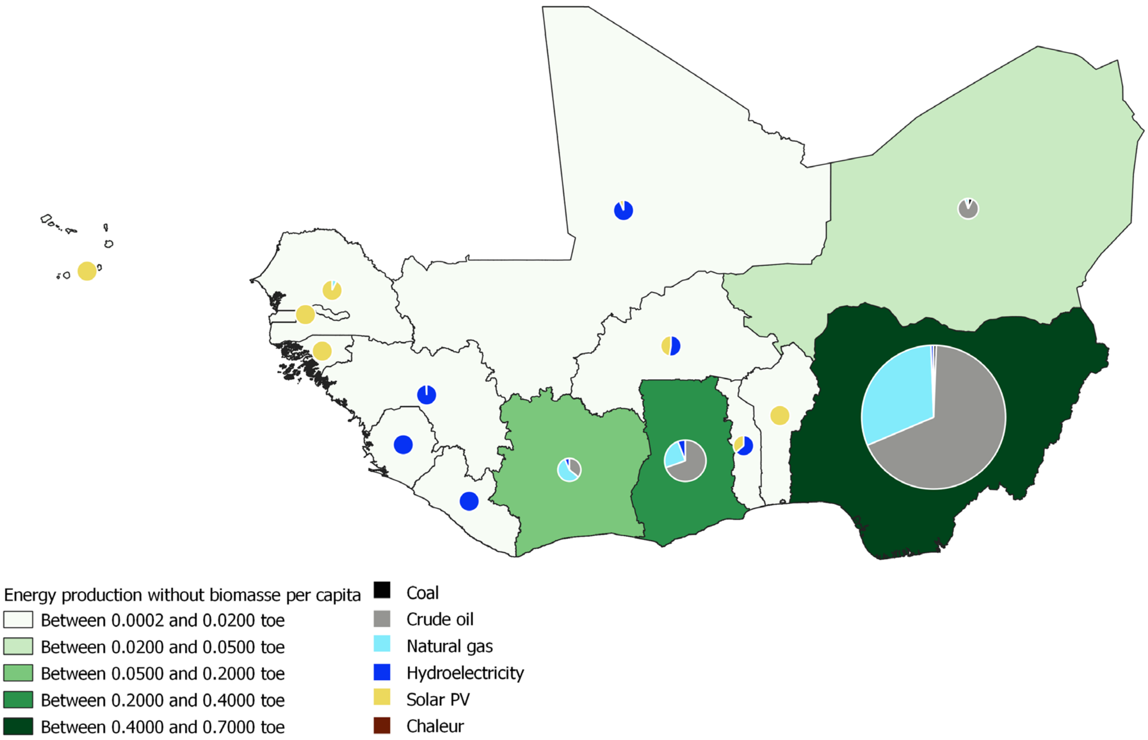

Figure 3: Mapping of primary energy production, excluding biomass in the ECOWAS region in 2021 (toe/capita)

Since 2010, West Africa's primary energy production has increased by an average annual growth rate of 0.77%. This production increased from 220,397 ktoe in 2010 to 239,810 ktoe in 2021.

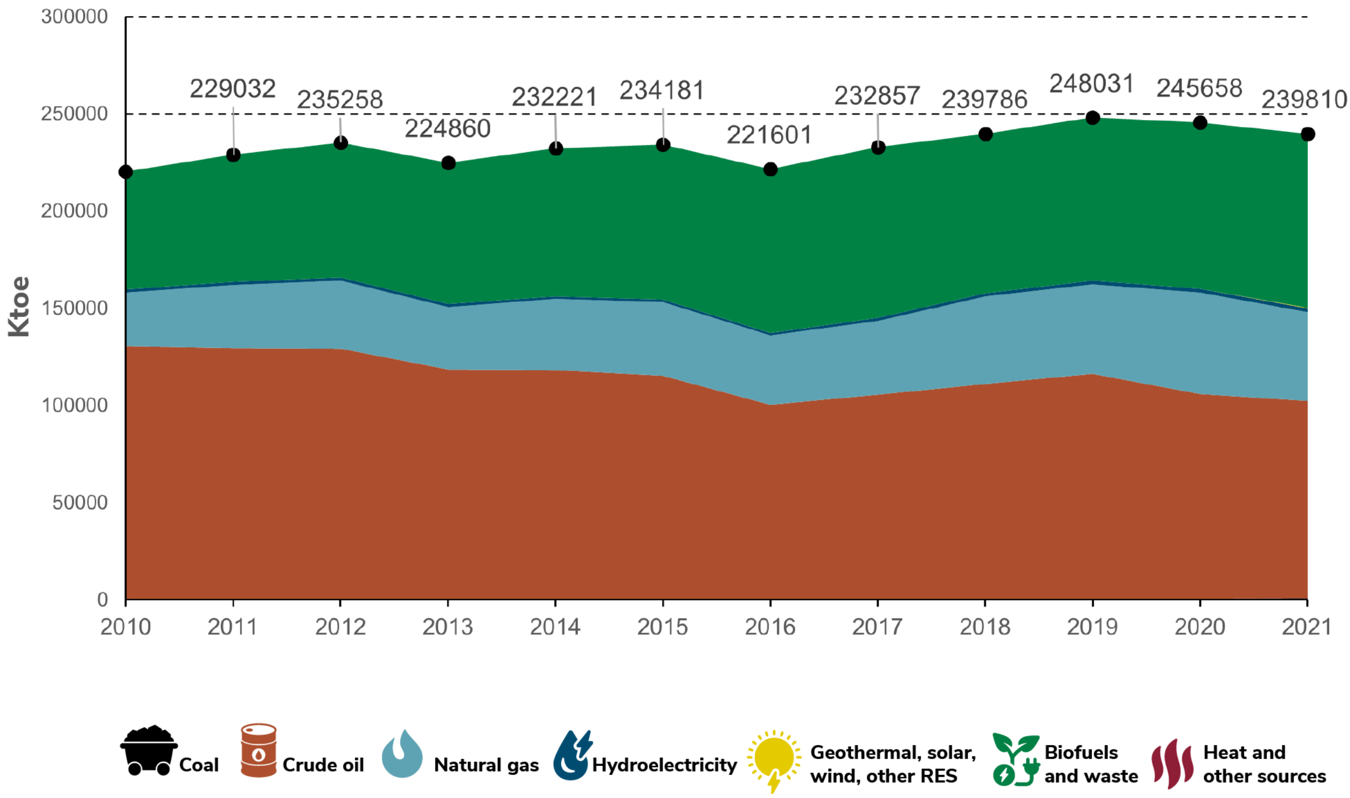

Figure 4: Trend of primary energy production in the ECOWAS region, 2010-2021

Crude oil remains the main source of primary energy production in ECOWAS, however its production has declined since 2010. Indeed, crude oil production has fallen from **130,325 ktoe** in 2010 to **101,482 ktoe** in 2021, representing an average annual decrease of 2.3% over the period 2010-2021. Natural gas production, on the other hand, has increased on average by 4.6% per year over the same period, from **27,806 ktoe** to **45,815 ktoe**.

Only 5 ECOWAS countries produce crude oil or natural gas, namely Côte d'Ivoire, Ghana, Niger, Nigeria and Senegal.

Nigeria is the largest producer of crude oil and natural gas in the region. It accounts for 90% of the region's crude oil and natural gas production. Ghana, the region's second-largest producer of crude oil and natural gas, accounts for 8% of the region's crude oil production and 6% of natural gas production. Côte d'Ivoire contributes 1% of crude oil production and 4% of natural gas production.

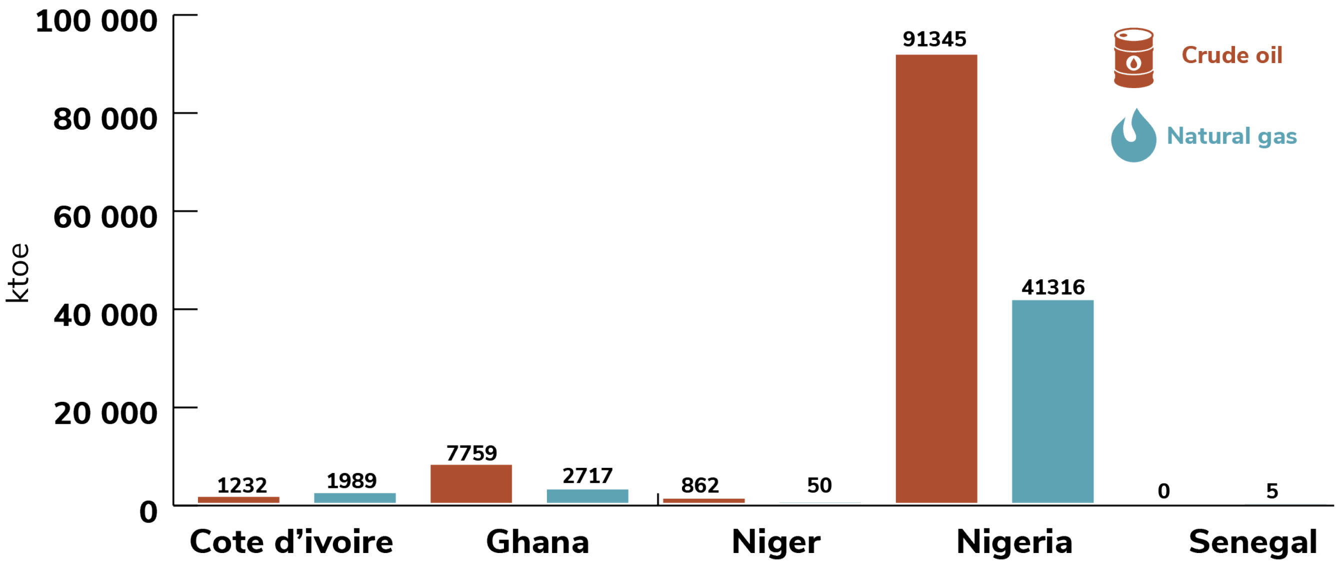

Figure 5: Crude Oil and Natural Gas Production of ECOWAS Member States in 2021

Hydropower remains the predominant renewable energy source in the region's electricity mix. Hydropower generation increased by an average of 2.7% between 2010 and 2021; it increased from 17 TWh to 23 TWh. In 2021, Nigeria (40%), Ghana (33%) and Côte d'Ivoire (12%) were the main producers of hydropower in the region.

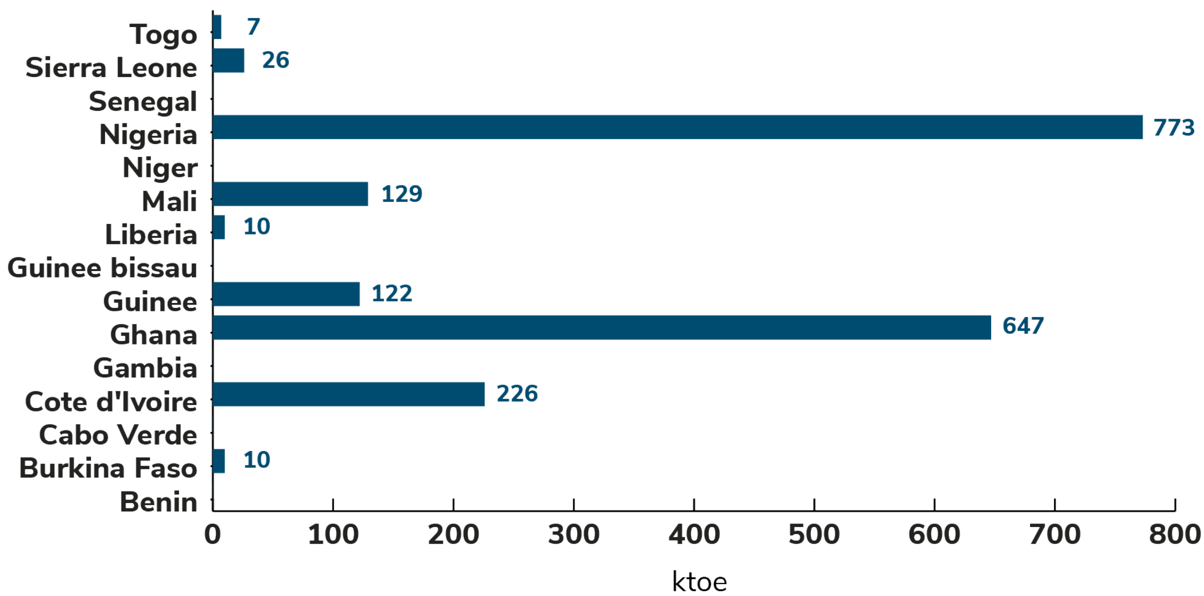

Figure 6: Hydropower Production of ECOWAS Member States in 2021 (ktoe)

Even if countries such as Benin and Senegal have no hydroelectric production on their territory, it is important to emphasise that these countries have a counterpart in the respective productions of Togo and Mali. Indeed, through the Benin Electricity Community (CEB) and the Organisation for the Development of the Senegal River (OMVS), Benin and Senegal hold part of the production of the power plants in Togo and Mali.

As far as solar photovoltaic (PV), wind and geothermal (PvWG) energy are concerned, their contribution to total primary energy production remains marginal. (0.1% in 2021). However, these energy sources experienced very high growth rates over the period, from 18 GWh in 2010 to 1,547 GWh in 2021, representing an average annual growth rate of approximately 50%. Senegal, with nearly 56% of the region's PvWG energy production in 2021, has strongly contributed to the development of these renewable energies in the region. Followed by Ghana with 9.2%; Mali 8.1% and Burkina Faso 7.9%.

The Organisation pour la mise en valeur du fleuve Sénégal (OMVS) is an intergovernmental development organization created on 11 March 1972 in Nouakchott by Mali, Mauritania and Senegal to manage the Senegal River watershed and headquartered in Dakar. Since the start-up of the first unit of the Manantali hydroelectric power plant in Mali in October 2001, OMVS has supplied the electricity companies of the three Member States with clean and cheap energy to the tune of 53% for Mali, 33% for Senegal and 15% for Mauritania, thanks to two high-voltage lines. Since 2013, the Félou hydroelectric power plant has boosted OMVS's production capacity with an average annual production of 335 GWh. Shared among Mali with 45%, Mauritania with 30% and 25% for Senegal.

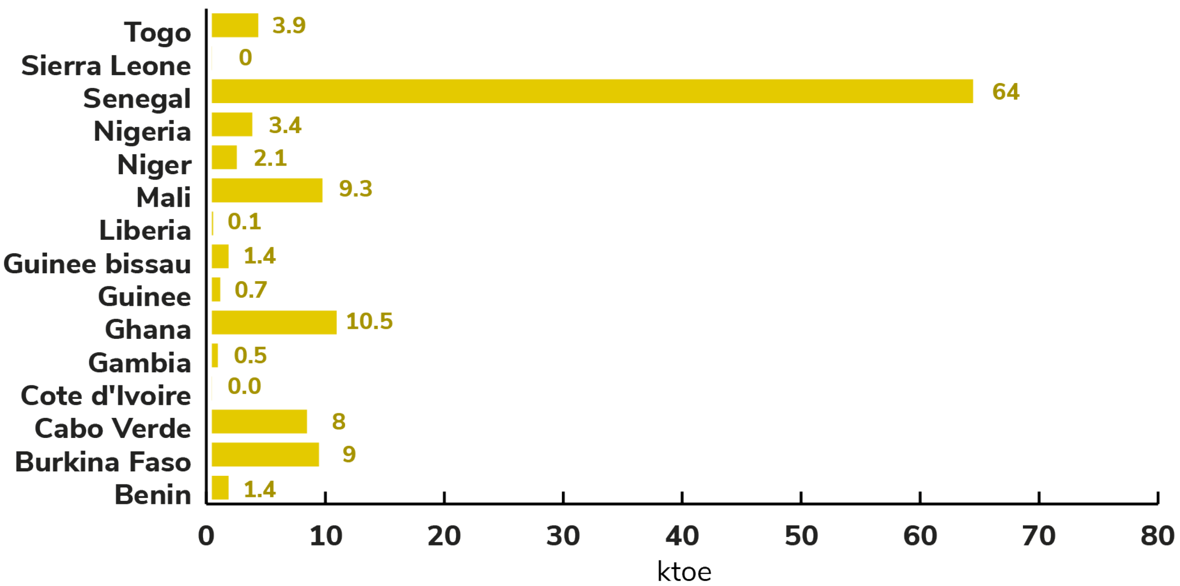

Figure 7: Solar PV, Wind and Geothermal Production of ECOWAS Member States in 2021 (ktoe)

Biomass energy production (mostly fuelwood) increased from **60,673 ktoe** in 2010 to **89,534 ktoe** in 2021. This corresponds to an average annual increase of 3.6%. It is important to note that over the same period, the region's population grew by an average rate of 2.7% per year. This reflects the dependence of households, particularly rural households, on biomass, especially traditional ones, and the failure of existing of policies to increase access to clean forms of energy. **This is a strong signal for the development of more ambitious energy policies for access to clean energy, particularly for the residential sector.**

Wood energy consumption remains high in West Africa. In 2021, the region's firewood production is estimated at 265049 kilotons (46 816 ktoe), 53% of which comes from Nigeria.

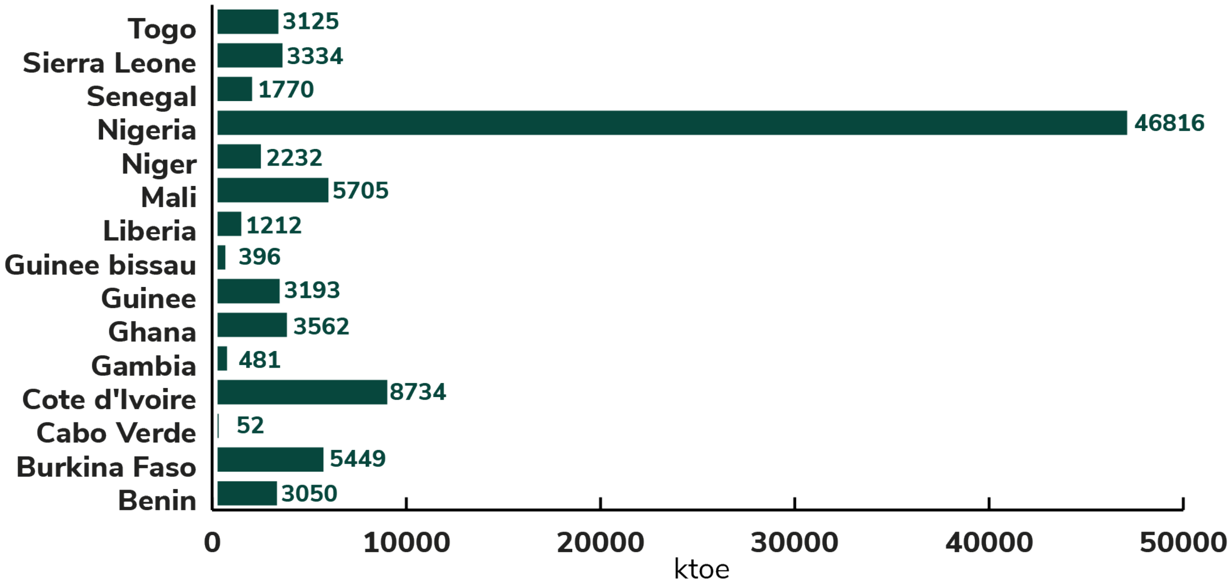

Figure 8: ECOWAS Member States' Firewood Production in 2021 (ktoe)

Foreign trade in energy

The West African region could be considered energy self-sufficient. Indeed in 2021, the indicator of the energy self-sufficiency rate (ratio of energy production to total energy supply) was 158%. However, this overall rate is not significant enough, as all forms of energy are aggregated, including biomass. It is important to emphasize that the region is highly dependent on imports of petroleum products to satisfy domestic demand for all sectors (transport, residential, industrial) and uses.

In 2021, only 13% of petroleum product requirements came from refineries in the ECOWAS region. New refineries in the region (Ghana to be commissioned in 2024 and Nigeria commissioned late 2023), with a cumulative refining capacity of 690,000 barrels per day, will increase the region's refining capacity by 51% and thus reduce imports of petroleum products.

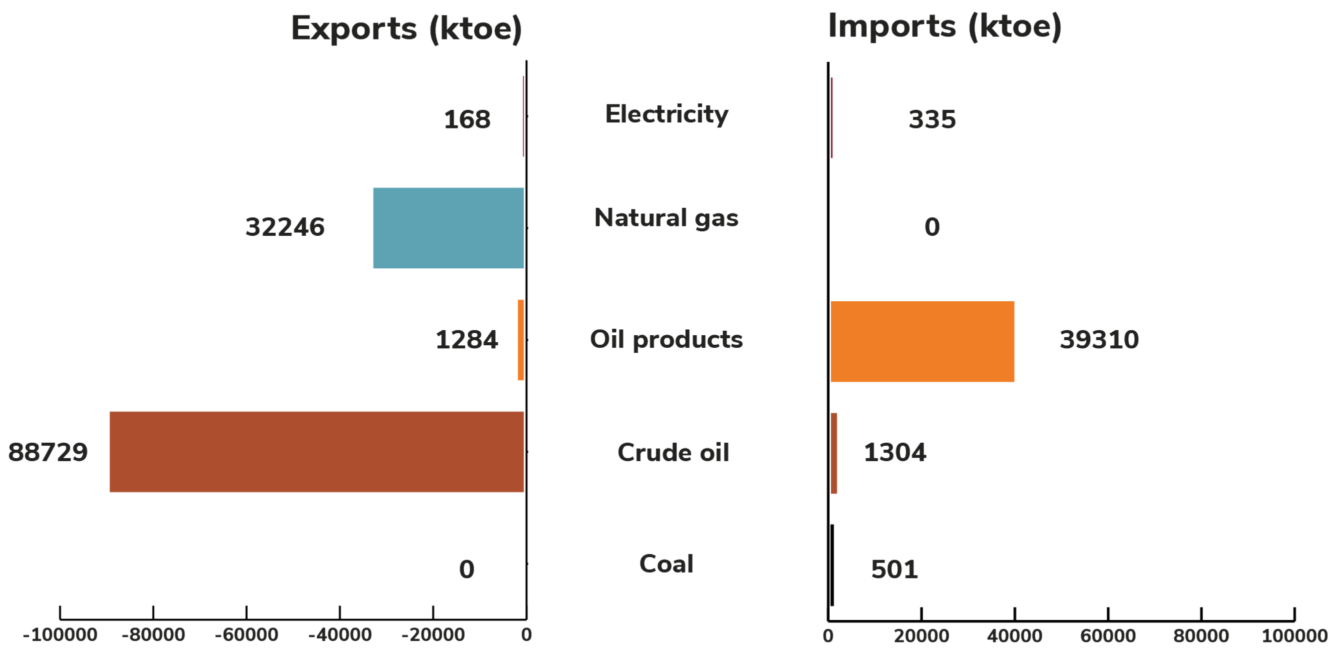

Figure 9: ECOWAS foreign energy trade 2021

Figure 10 shows the level of ECOWAS dependence on petroleum products in 2021 and shows the level of external dependence of the main petroleum products used in the region. Thus, in 2021, the main petroleum products mainly imported were petroleum coke (100%), kerosene/paraffin (97%) and motor gasoline (93%).

When it comes to clean cooking, 88% of the LPG[3] consumed in the region comes from outside the Region.

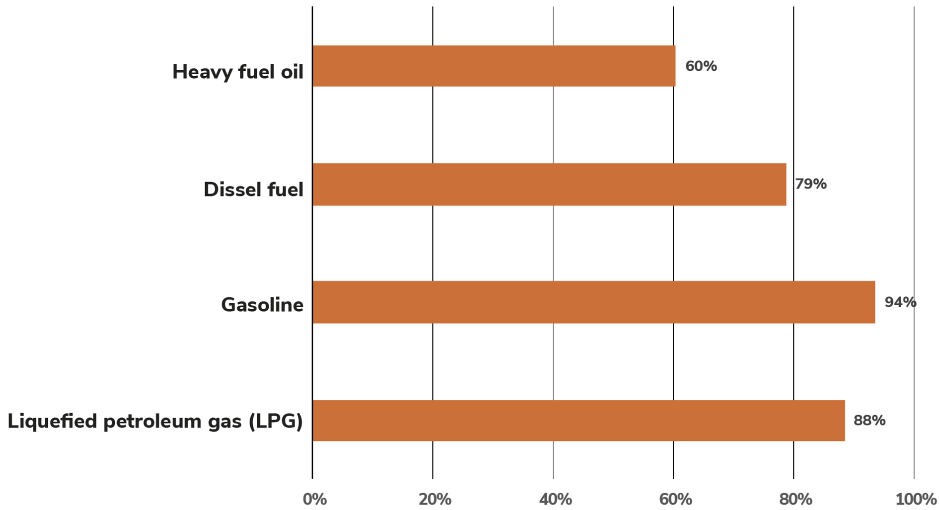

Figure 10: ECOWAS level of dependency for the main Petroleum Products in 2021

With regards to electricity, the reported import quantity for 2021 in the region (335 ktoe or roughly 3.9 GWh) is attributed to the lack of precision regarding the countries of origin. Indeed, exchange of electricity between Member States cannot be considered as imports or exports at regional level.

The main energy importers and exporters are Nigeria, Ghana and Côte d'Ivoire. With the exception of Côte d'Ivoire, all countries in the region import significant petroleum products due to insufficient or non-existent refining capacity. In 2021, petroleum products accounted for only 13% of Côte d'Ivoire's energy imports. For the other Member States, petroleum products accounted for between 61% and 100% of energy imports.

Depending on the country, energy exports at national level are largely made up of:

- Crude oil: Nigeria and Ghana;
- Petroleum products: Côte d'Ivoire, Niger and Senegal;
- Electricity: Benin and Mali.

Niger's landlocked location and the recent discovery of oil have resulted in the construction of a small refinery to process local crude oil for domestic needs but also for the export of petroleum products. In 2021, Niger's net exports of petroleum products reached 397 ktoe. Since November 2023, a pipeline about 2000 km long has linked the oil fields of Niger and Benin.

In 2021, natural gas was only exported by Nigeria and accounted for 28% of the country's energy exports.

[3] Liquefied petroleum gas used for cooking.

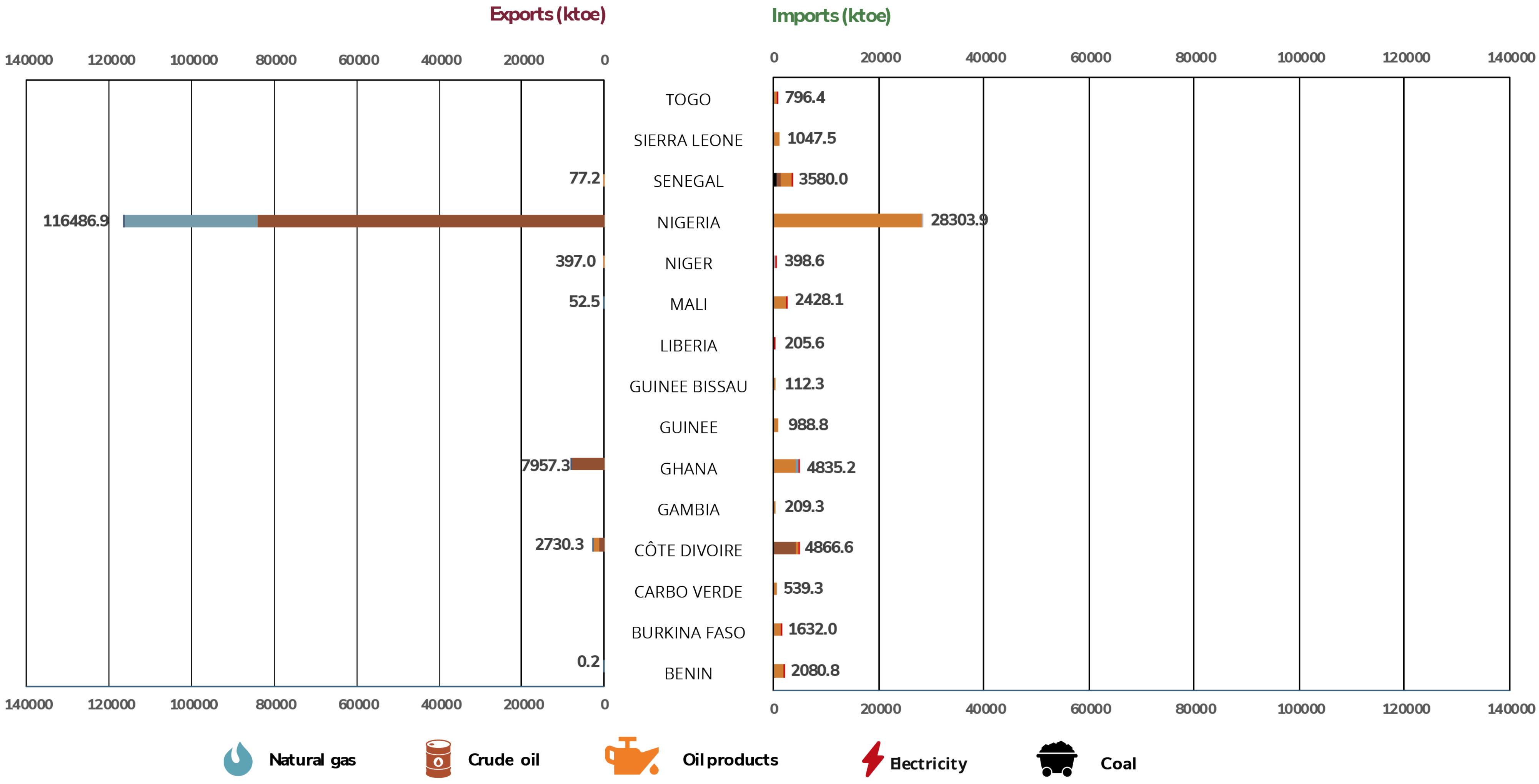

Figure 11: Foreign Trade of ECOWAS Member States in 2021

Since 2010, the region's energy imports have increased by **2.7% per year**, from **30,722 ktoe** to **41,450 ktoe**. Throughout the period, petroleum products were the largest form of imported energy.

With an average annual increase of 9.6%, mineral coal, imported by Benin and Senegal for use in the industrial sector in particular, is the energy source that has seen the strongest increase in imports. The decline in imports of petroleum products between 2017 and 2020 was more pronounced between 2019 and 2020, when the annual decrease was **-8.1%**. This decrease in imports in 2020 compared to 2019 could be explained by the containment measures linked to the Covid-19 pandemic which have slowed economic activity.

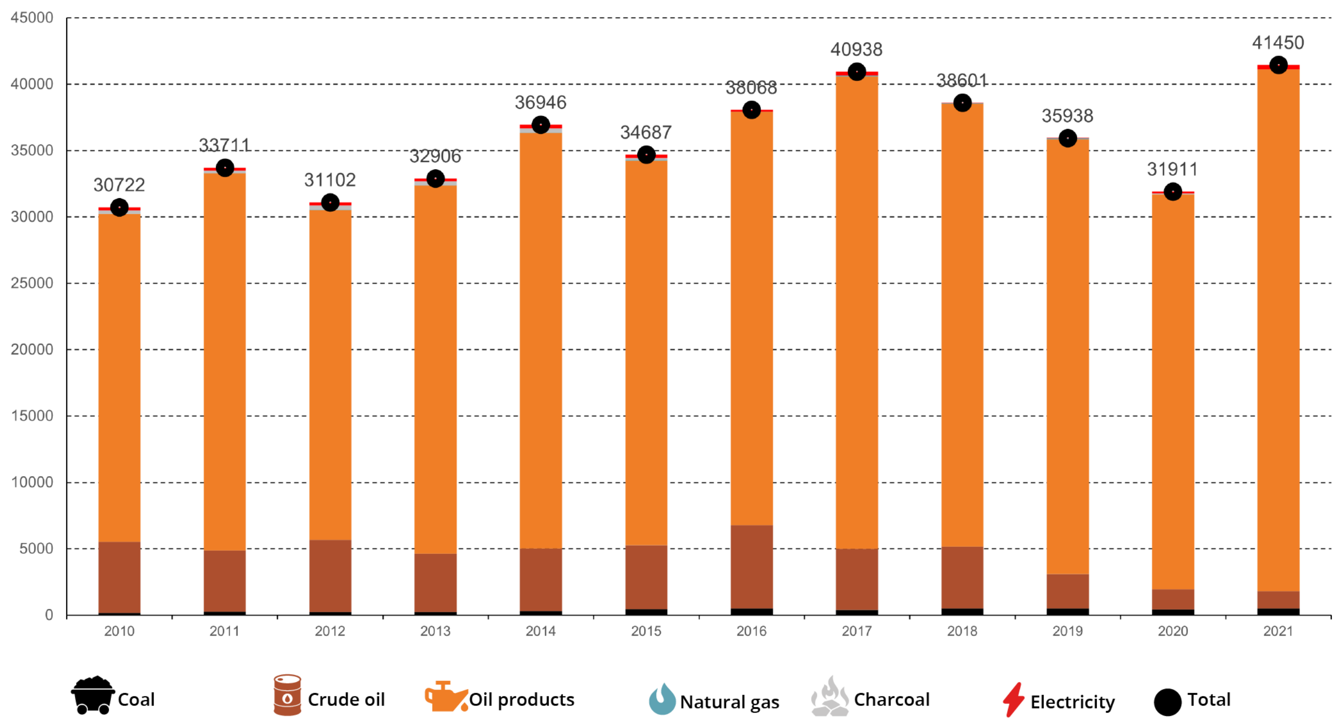

Figure 12: Trend of energy imports in the ECOWAS region, 2010-2021

The region's energy exports decreased from 146,762 ktoe in 2010 to 122,428 ktoe in 2021, an average annual decrease of 1.6% per year over the period. Along with crude oil production, crude oil exports declined. In contrast, natural gas exports increased by 5.6% per year from 17,677 ktoe to 32,246 ktoe between 2010 and 2021.

The significant 13.6% decline in crude oil exports between 2019 and 2020 could also be explained by lower demand from importing countries due to pandemic-related restrictions.

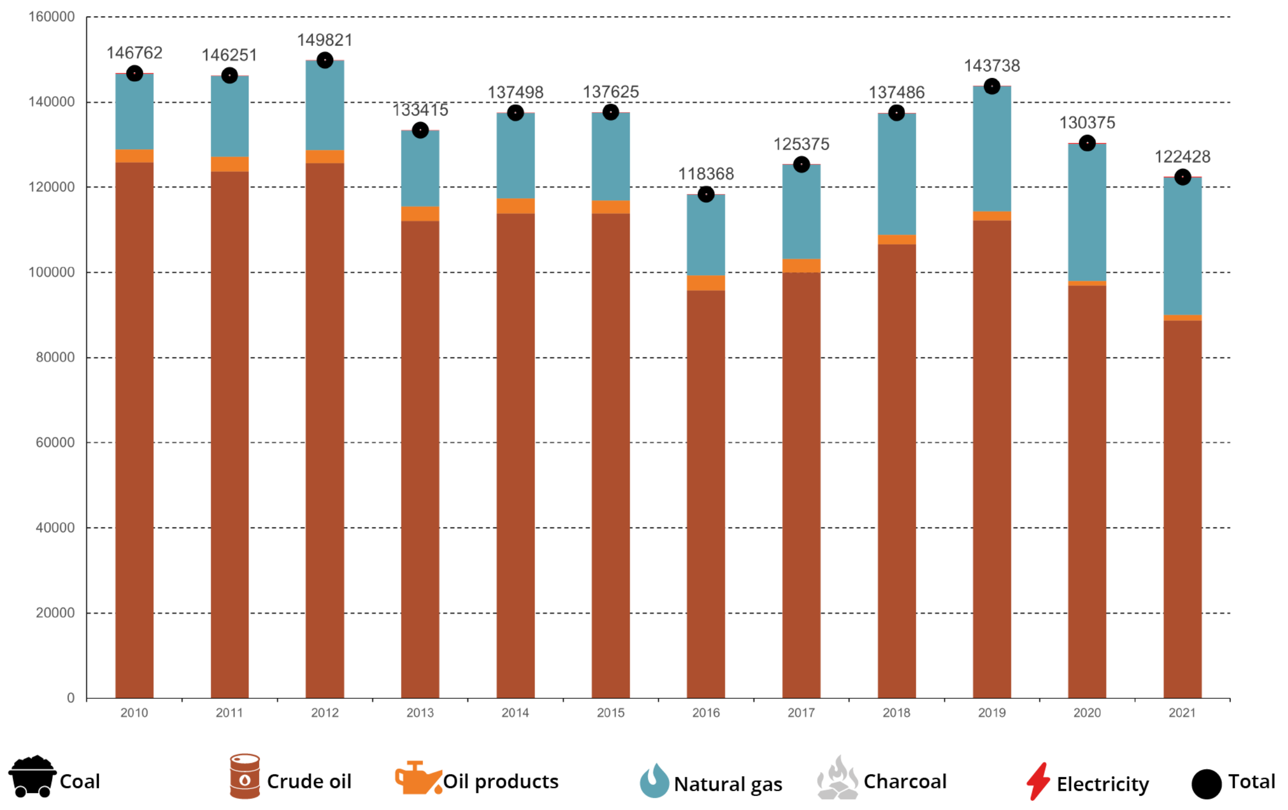

Figure 13: Trend of energy exports in the ECOWAS region, 2010-2021

Total Energy Supply

In 2021, ECOWAS total energy supply (TES)[4] is estimated at 151,320 ktoe. Biomass energy is the main source of energy supply in the region and accounts for almost 59% of the total supply. Crude oil, the region's main source of energy production, accounts for only about 5% of the total supply. This is due to the importance of crude oil exports and refining levels below the region's needs.

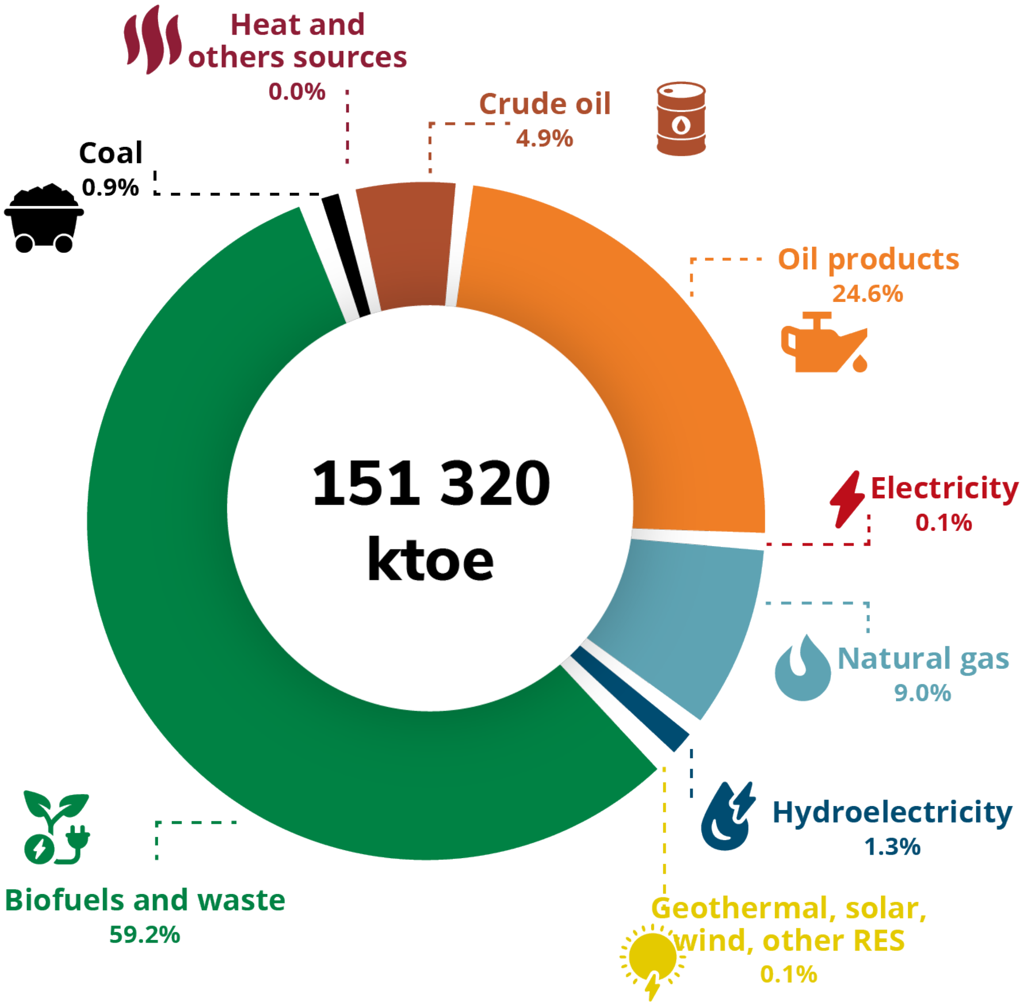

Figure 14: Structure of ECOWAS Total Energy Supply in 2021

Even though renewables (including biomass) account for about 61% of the region's energy mix, this is mainly attributed to biomass energy, as other renewable energy sources account for only 1% of the mix, mainly from hydropower.

[4] The total energy supply is obtained by:
production + imports – exports – net international bunkers + net stock.

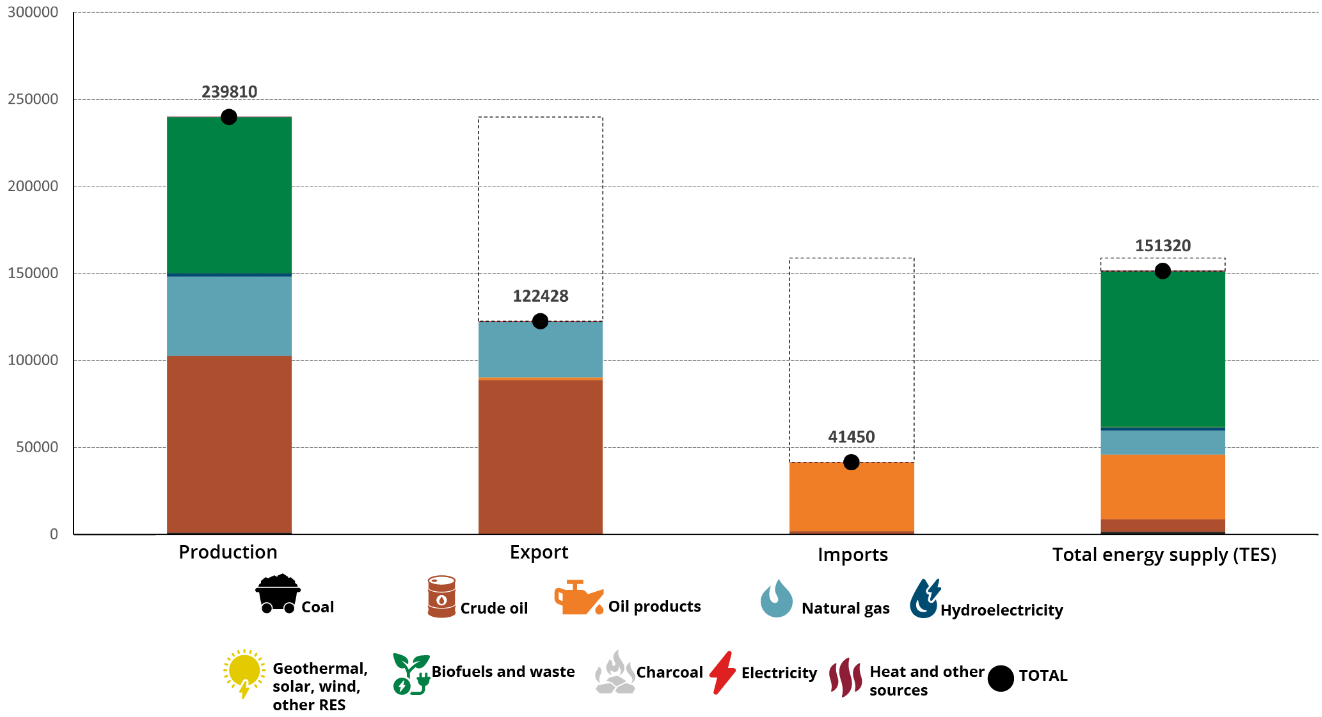

Figure 15: ECOWAS Production, Foreign Trade and Total Energy Supply in 2021 (ktoe)

In 2021, ECOWAS' energy exports represented 52% of its primary energy production. Almost 27% of the total energy supply is imported, mainly petroleum products, to meet the demand of 151,320 ktoe.

The balance of 7,512 ktoe obtained from the difference between total energy supply and Production - Exports + Imports represents the quantity of energy that goes into energy storage and/or international bunkers.

Given the disparity in populations, the supply of absolute values varies considerably between countries. For example, the total energy supply in Nigeria, the most populous country, is 237 times greater than that of Cabo Verde. The Total Energy Supply per Capita indicator removes the effect of population from energy demand and improves comparative analysis.

The total energy supply per capita in ECOWAS is **0.37 toe** (in 2021). Niger has the lowest total energy supply per capita in the region (0.13 toe/capita) and Cabo Verde has the highest ratio (0.65 toe/capita).

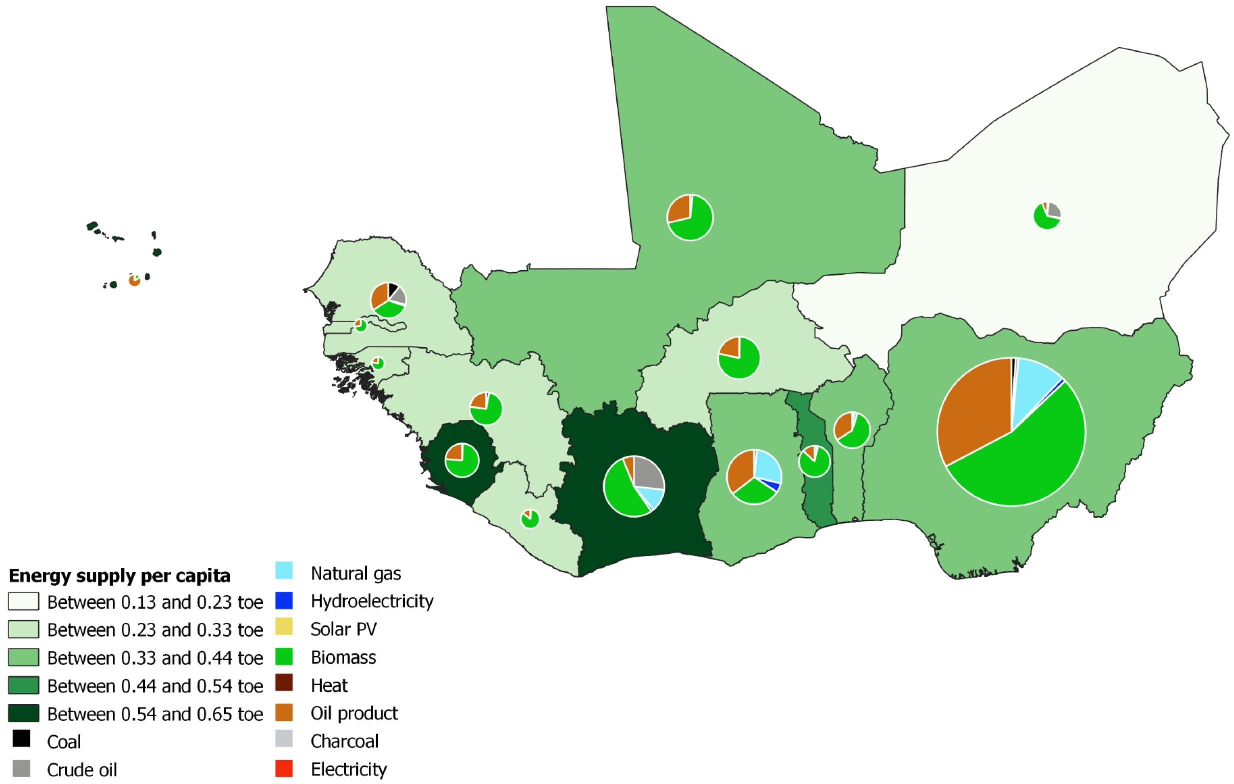

Figure 16: Mapping energy supplies in the ECOWAS region in 2021

The energy supply map (figure 16) shows the energy mix of ECOWAS Member States. Only three countries in the region have an energy mix in which biomass energy is not predominant, namely Cabo Verde, Ghana and Senegal with biomass energy shares in the energy mix of 14%, 31% and 36% respectively.

Between 2010 and 2021, ECOWAS' total energy supply increased by an average rate of 3.5% per year (47% between 2010 and 2021) **from 103,199 ktoe to 151,320 ktoe.**

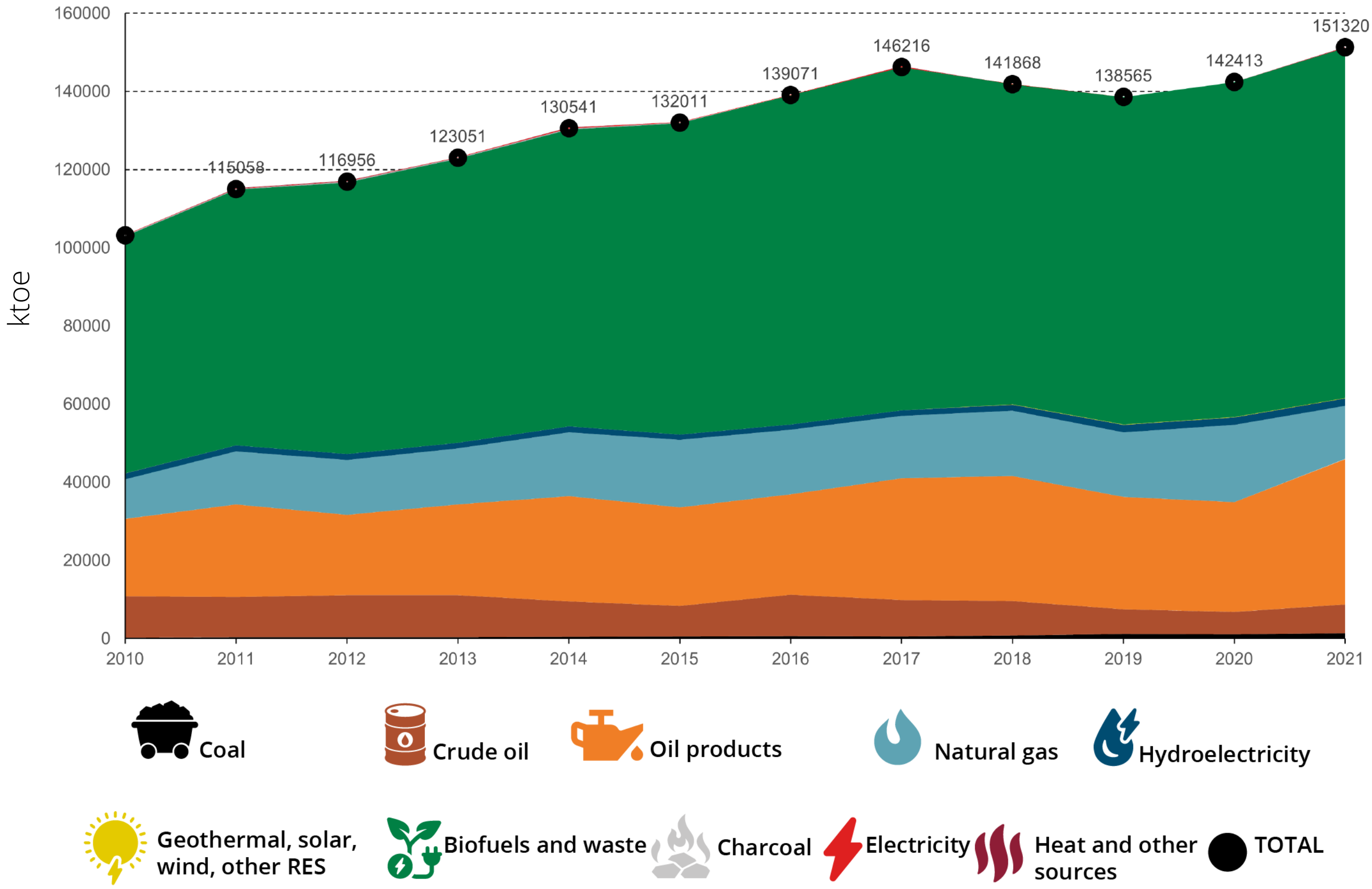

Figure 17: Trend of the total energy supply of the ECOWAS region, 2010-2021

Throughout theperiod 2010-2021, ECOWAS' energy mix has changed very little. It remains dominated by biomass energy. The notable change in the energy mix between 2010 and 2021 is the proportion of petroleum products, which increased from 19% in 2010 to 25% in 2021, while that of crude oil fell from 10% in 2010 to 5% in 2021. These statistics confirm the low access to clean energy and the high dependence on fossil fuels. In 2021, the share of renewable energies, **excluding hydropower**, in energy supply remained marginal.

Energy transformation

In 2021, about 35% of the total primary energy supply (53,170 ktoe) was transformed into secondary products (charcoal, petroleum products, electricity) in the ECOWAS region. The main energy transformation processes identified in the ECOWAS region, in 2021, are carbonization, power generation and refining. The yields of the different transformation processes differ depending on the type of transformation (carbonization, power plants, refining) and the technologies used.

Carbonization

Carbonization is the main process of transformation of biomass energy in the ECOWAS region. Still very rudimentary, carried out in an artisanal way, carbonization in the ECOWAS region has an average energy efficiency of around 42% in 2021.

Burkina Faso is the country with the highest carbonization efficiency (25%) and Guinea the country with the lowest yield (11%). In Guinea, the production of 1 kg of charcoal requires the use of 9 kg of firewood; in Burkina Faso, 4 kg of firewood is enough for the production of 1 kg of charcoal.

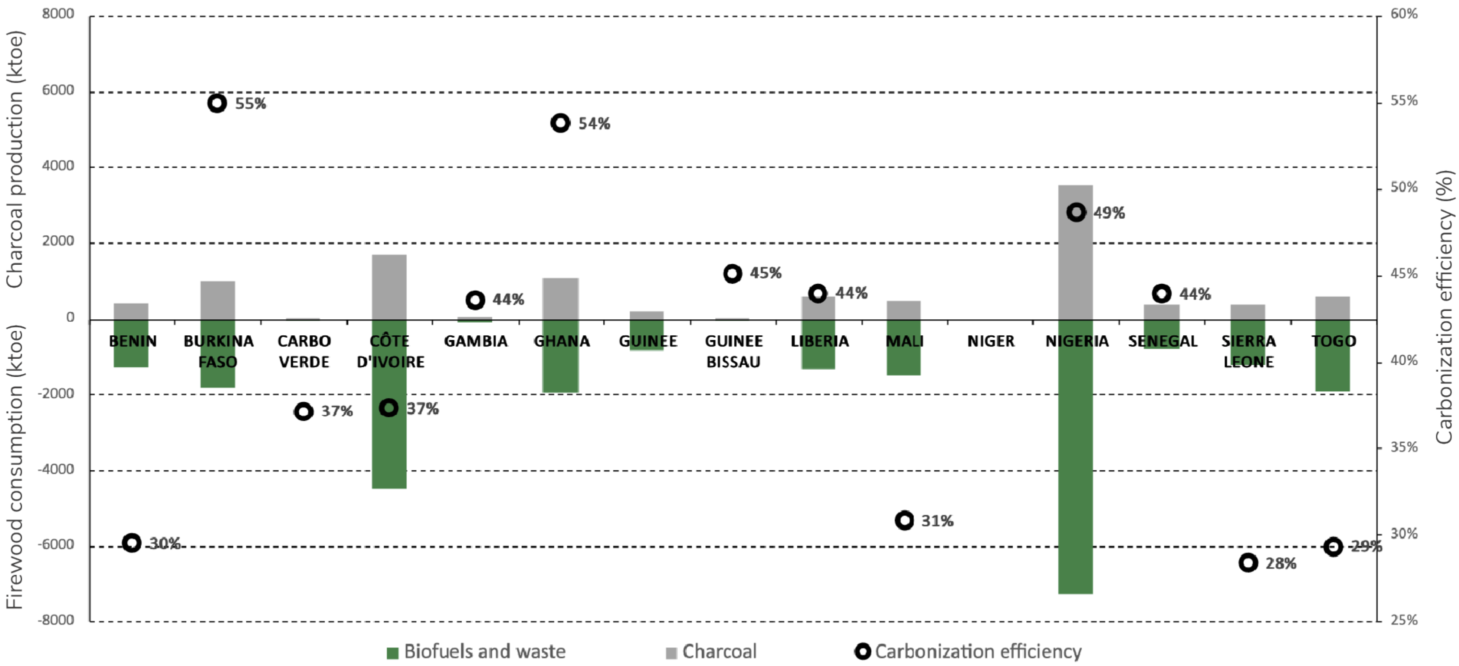

Figure 18: Energy efficiency of carbonization according to ECOWAS Member States, 2021

It should be noted that there are margins of uncertainty, sometimes quite large, in the yields of carbonization units. Regular surveys with representative samples are needed in order to better estimate this indicator.

Power Generation

Power generation is the second largest energy transformation process in the region. In 2021, 40% of the energy used in processing was used to generate electricity. Electricity production takes place from two types of producers: the producer whose main activity is electricity production (75% of electricity production) and the self-producers (25% of electricity production) who produce electricity mainly for their own needs.

Electricity producers, due to the use of natural gas as the main source of electricity generation, have twice the efficiency of electricity generation (62%) than self-producers (32%), who mainly use petroleum products. **The region's overall electricity generation efficiency was 50% in 2021.** These efficiency rates particularly for natural gas are relatively high and must be confirmed by further investigation.

About 38% of the electricity generated in 2021 was produced from petroleum products, particularly by self-producers, which account for 66% of electricity production from petroleum products. Natural gas, the main source of electricity generation in 2021 (42%), grew by an average annual growth of 7% between 2010 and 2021.

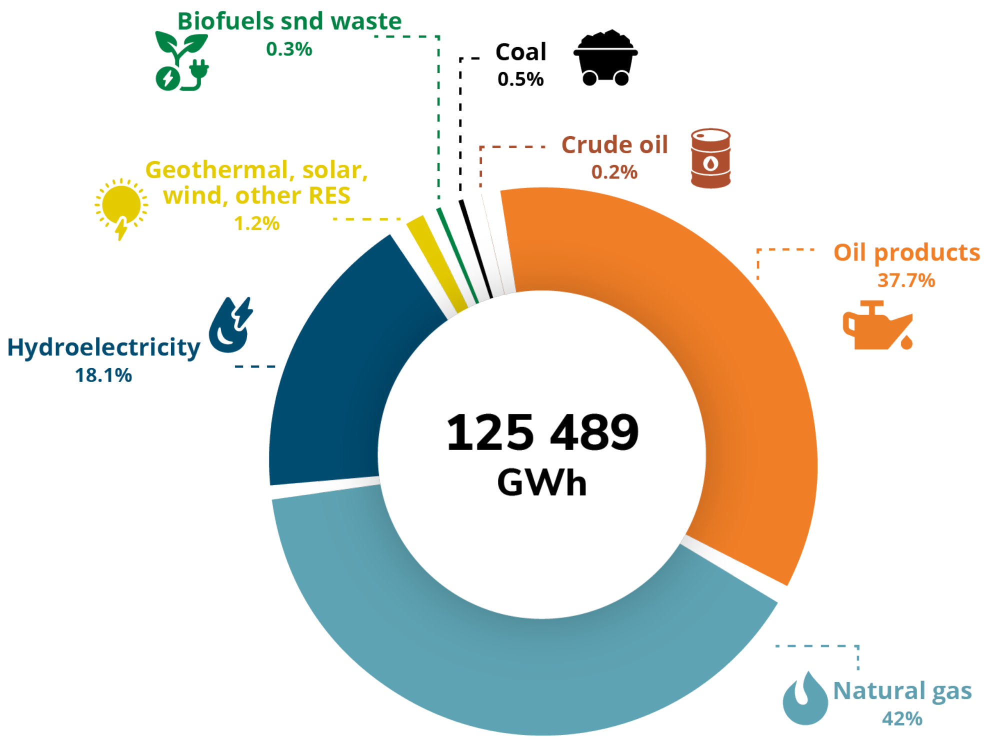

Figure 19: Electricity production mix in ECOWAS, 2021

Renewables account for about 20% of the region's electricity generation. Hydropower accounts for 92% of ECOWAS' renewable power generation. In 2021, the share of renewables in the ECOWAS power generation mix varied between 1% (Benin) and 80% (Liberia). This is mainly due to the contribution of hydropower in these countries.

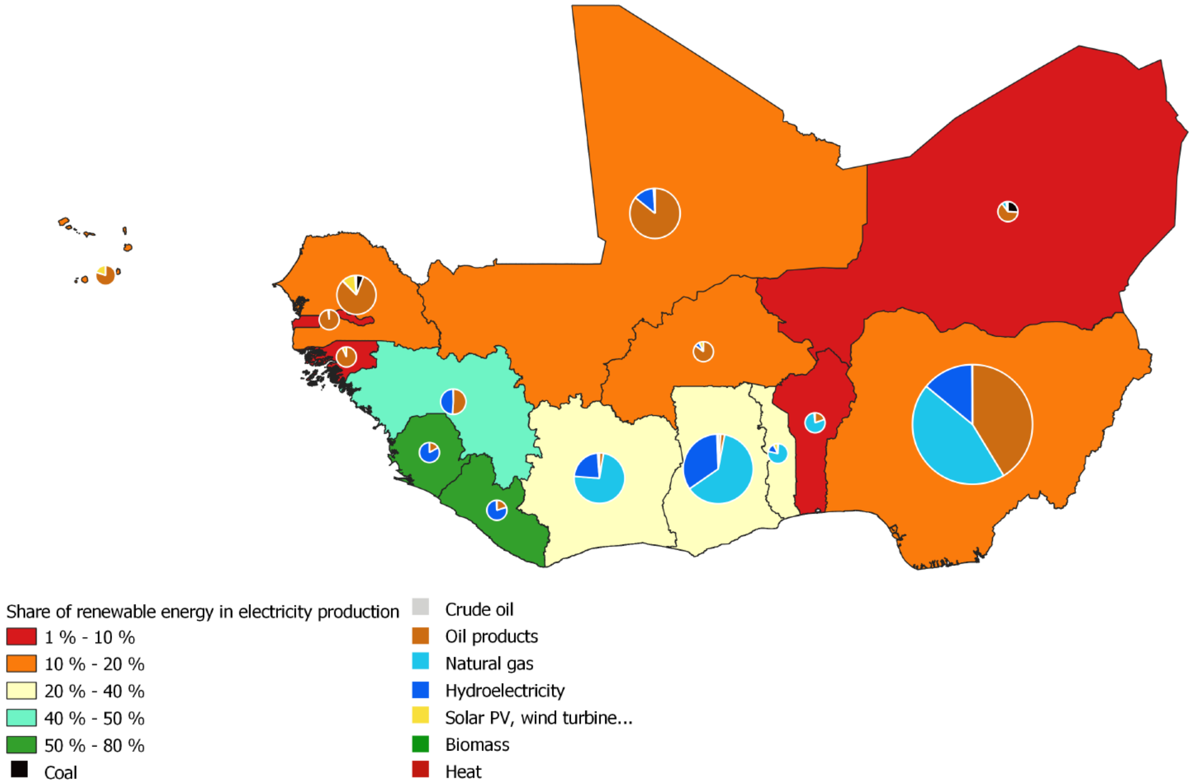

Figure 20: Mapping the Electricity Generation Mix in the ECOWAS Region, 2021

Refining

Crude oil refining is the third largest energy transformation process in the region. In 2021, the share of refined crude oil production was only 6%, showing the region's dependence on imported petroleum products and the offshoring of added values and jobs due to the export of primary resources. Only five (5) countries in the region have one or more refineries.

Table 1: Refining capacities of refineries installed in the ECOWAS region in 2021

Name	Country	Year of in-service	Refining Capacity (Million tonnes per year)
The African Refining Company	Senegal	1963	1,2
Tema Oil Refinery	Ghana	1963	2,0
Ivorian Refining Company	Côte d'Ivoire	1965	3,8
Port Harcourt Refining Company Limited (PHCR)	Nigeria	1965	7,5
Multunational Bitumen Society	Côte d'Ivoire	1978	0,3
Warri Refining & Petrochemicals Company Limited (WRPC)	Nigeria	1978	6,3
Kaduna Refining and Petro-chemical Company (KRPC)	Nigeria	1980	0,03
Eleme petrochemicals Company Limited (EPCL)	Nigeria	2006	0,02
Niger Delta Petroleum Refinery	Nigeria	2010	0,01
Zinder Refining Company (SORAZ)	Niger	2011	1,0
		TOTAL	22,2

Despite being the third largest crude oil producer in the region, in 2021, Côte d'Ivoire with only 19% (4.1 million tonnes per year) of ECOWAS refining capacity, contributes to 67% of 2021's petroleum product production. Diesel is the main product from crude oil refining in the region. In 2021, 43% of the production of petroleum products was diesel and around 63% comes from refineries located in Côte d'Ivoire.

In 2021, the efficiency of the crude oil refining process in the ECOWAS region was 97%. Niger, Côte d'Ivoire and Ghana had refining efficiencies of 97%, 96% and 95% respectively. These yields appear to be somewhat higher than the international average. For example, in Canada, refinery yields are just over 90%[5]

The yields obtained from the Nigeria and Senegal refineries are are above 100%. Further investigation related to the outputs (refined products) and inputs (feedstocks, mainly crude oil) is needed to refine these statistics.

LPG production is still very low in the region. In 2021, LPG accounted for only 5% of petroleum product production. However, it is important to note that between 2010 and 2021, LPG is the refinery product that has seen the largest increase (7.3% per year), from a production of 138 kilotons in 2010 to 300 kilotons in 2021.

[5] Refining Economics (canada.ca)

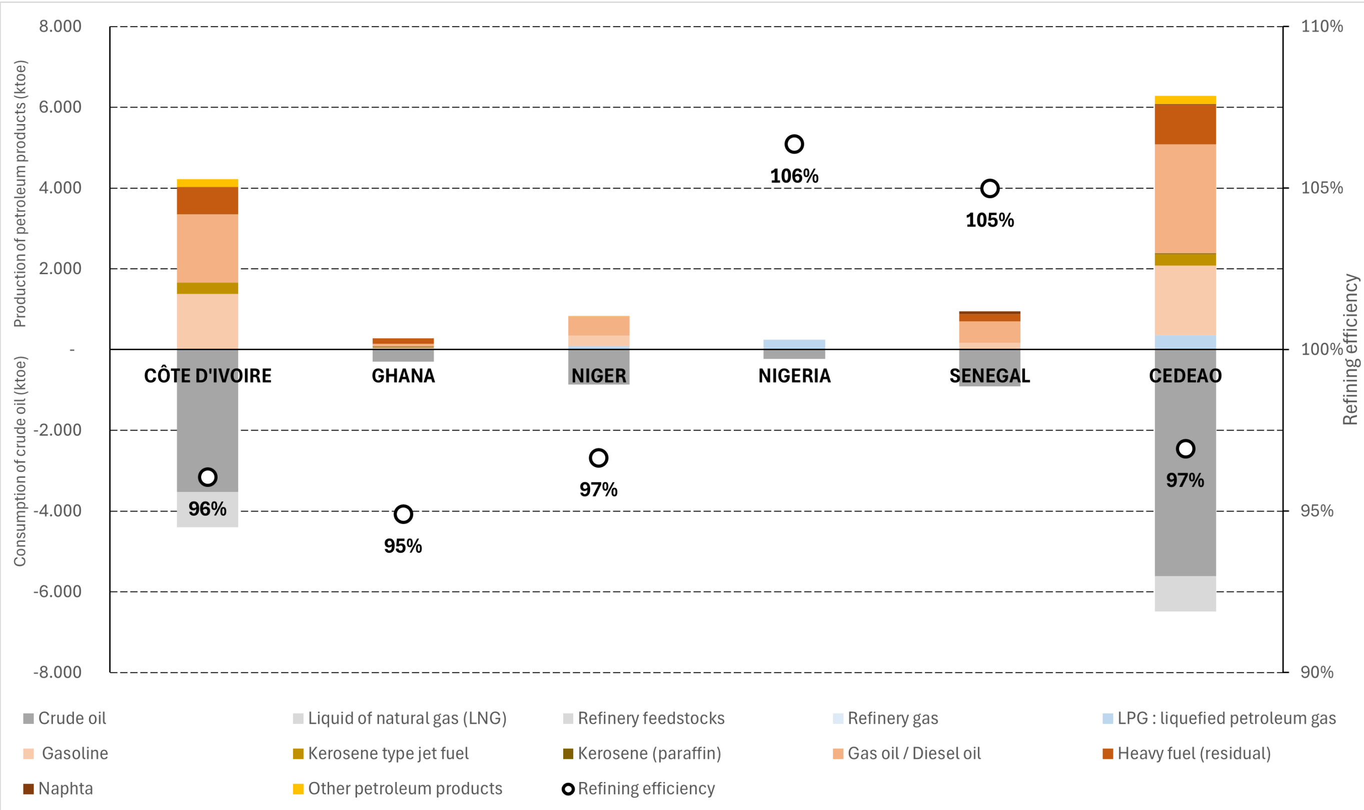

Figure 21: Production of petroleum products and refining energy efficiency according to ECOWAS Member States, 2021

Figure 22 summarizes the transformation processes identified in the ECOWAS region. Due to the high consumption of charcoal in the region, biomass and waste account for nearly 48% of processing inputs. The differences between processing inputs and outputs can be explained by the particularly large losses in the carbonization process due to the low yields of the technologies currently in use. An increase in yields combined with substitution would make it possible to significantly reduce the consumption of wood energy, which is one of the aggravating factors of deforestation.

Petroleum products (especially diesel and petrol) are mainly used by self-producers of electricity. Natural gas has grown significantly since 2010 as an input for electricity generation. In 2021, the share of natural gas for electricity generation is higher than that of petroleum products. Mineral coal, mainly in Niger and Senegal, contributes only marginally to electricity generation. This is due to relatively low economically viable reserves and global trends in greenhouse gas reductions. Southern Africa, which has considerable coal reserves, has a very different electricity mix, with mineral coal still making a significant contribution to electricity production.

The share of renewable energies, excluding hydroelectricity, remains very low despite the commissioning of a few large-scale power plants from 2017 onwards, where renewable capacity excluding hydropower increased from 125 MW in 2016 to 438 MW in 2021. It is highly likely that this share will increase sharply over the period 2024-2050 given ongoing projects and global trends in this area.

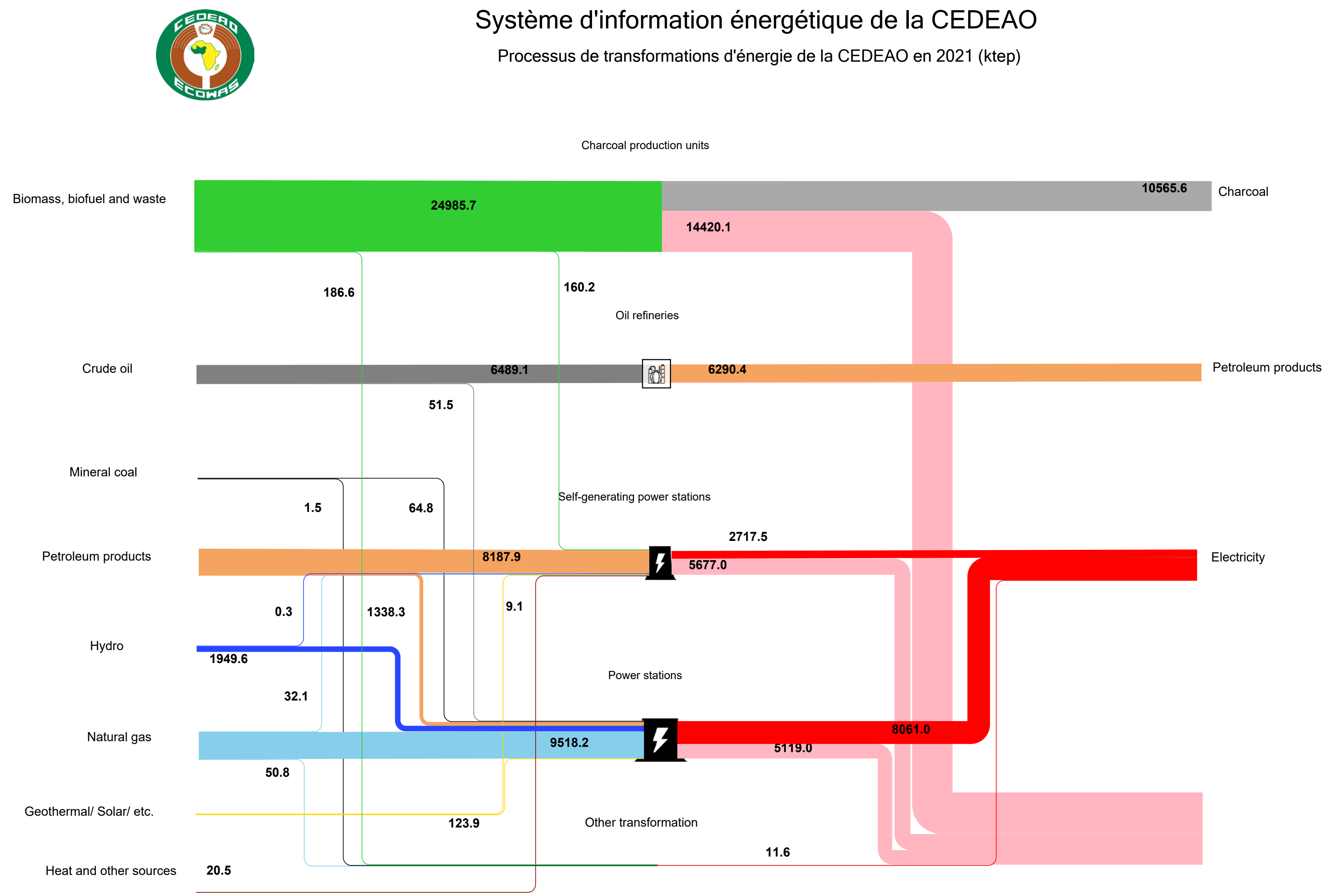

Figure 22: ECOWAS Energy Transformation Flow Diagram, 2021 (ktoe)

Final energy consumption

In 2021, ECOWAS' final energy consumption was estimated at **122,600 ktoe**. This was dominated by wood fuels, which accounted for 60% of consumption, including 51% for fuelwood and other biomass energy and 9% for charcoal. Electricity accounts for only 7% of final energy consumption and petroleum products for 31%, indicating limited access to clean forms of energy.

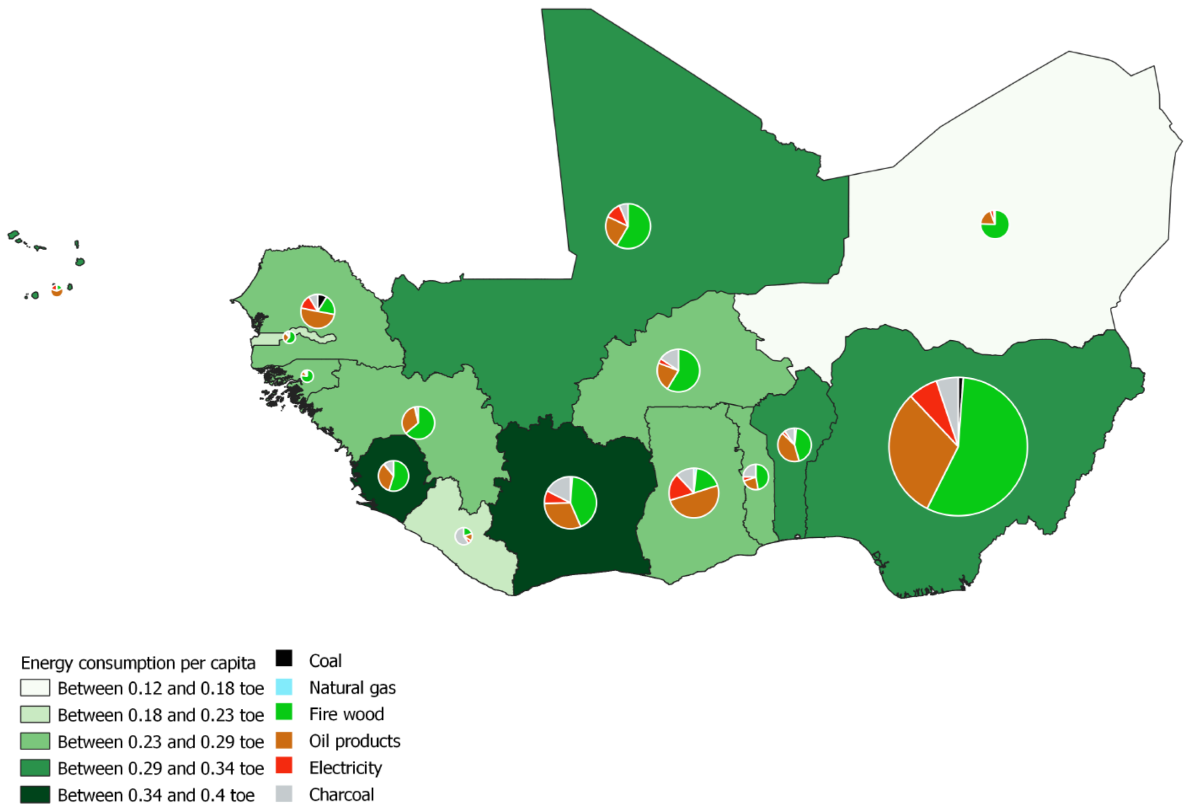

Figure 23: Mapping of final energy consumption in the ECOWAS region in 2021 (toe/capita)[6]

At the regional level, biomass (mainly fuelwood and charcoal) are the primary source of energy in most ECOWAS member states. Only Cabo Verde, Ghana and Senegal have final energy consumption dominated by petroleum products.

The share of electricity in final energy consumption varies from 1% (Sierra Leone) to 20% (Cabo Verde) depending on the country. In addition to Cabo Verde, only 3 countries have a share of electricity in final energy consumption above 10%; these are Ghana (18%), Senegal (13%) and Mali (12%).

[6] The pie charts represent the relative shares of final consumption of different forms of energy by country

ECOWAS' final energy consumption increased from 77,618 ktoe in 2010 to 122,600 ktoe in 2021, indicating an annual average growth rate of 4.2%. Since 2010, the residential sector has remained the largest energy consumption sector. With consump- tion increasing from 49,673 ktoe in 2010 to 74,960 ktoe in 2021, the residential sector experienced the smallest increase over the period 2010-2021, in percentage terms. The most significant increase during this period was in the trade and services sector. Final consump- tion in the retail and services sector in 2021 was 2.4 times higher than in 2010.

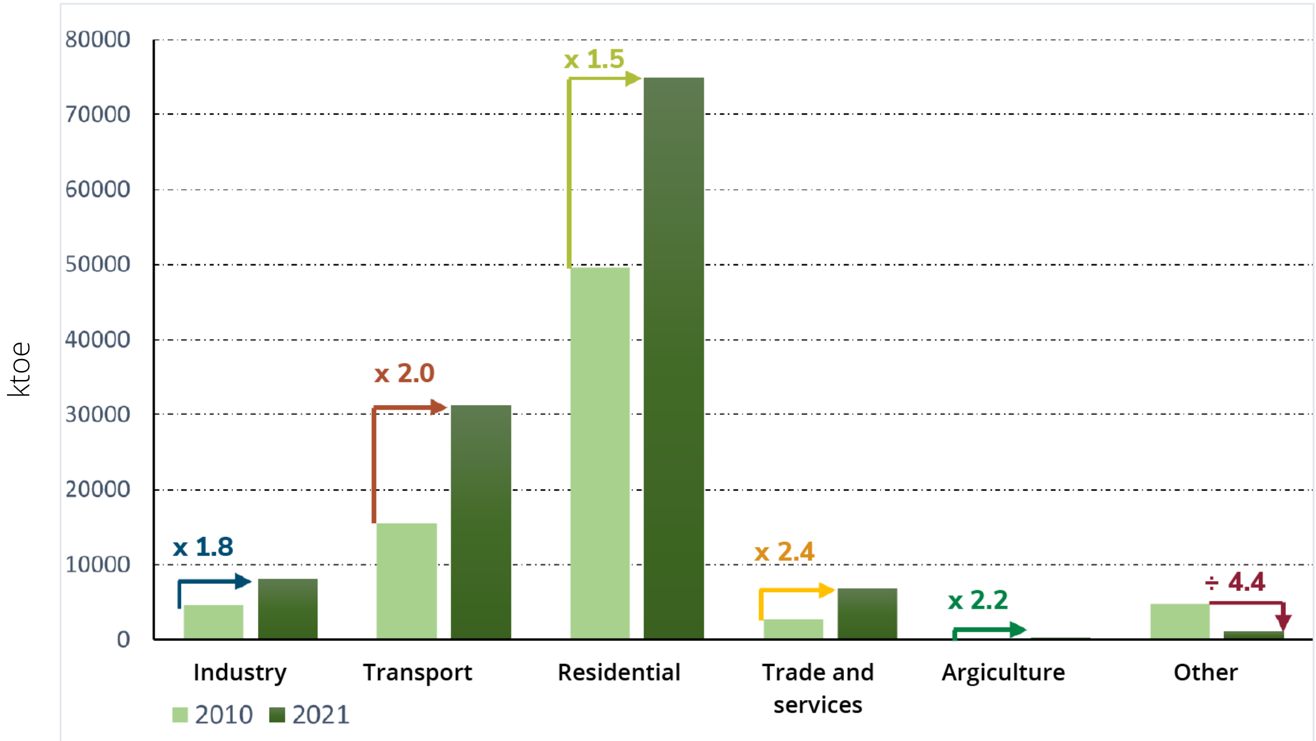

Figure 24 : Growth of final energy consumption by sector of activity in the ECOWAS region, 2010 and 2021

Between 2010 and 2021, consumption in the transport sector doubled from 15,601 ktoe to 31,240 ktoe. The agricultural sector, despite its small contribution to final energy consumption (0.2%), is the second sector of activity whose consumption grew the most between 2010 and 2021. Indeed, the energy consumption of the agricultural sector in 2021 (281 ktoe) is 2.2 times higher than that of 2010 (129 ktoe). In absolute terms, final consumption in agriculture remains very low by international standards. This is due to the fact that agricultural production is still poorly mechanized and uses few energy inputs, particularly for irrigation.

As for the energy consumption of the unspecified sectors (Other), the level of consumption was divided by 4 between 2010 and 2021. This reflects improved data collection in the sense that energy consumption sectors are more accurate.

From 2010 to 2021, the final electricity consumption within ECOWAS rose at an average annual rate of 5%. It increased from 62 TWh to 106 TWh. In 2021, the average annual per capita electricity consumption in ECOWAS was **267 kWh**. This is well below the consumption levels of countries such as South Africa (3,516 kWh/capita/year), Gabon (1,071 kWh/capita/year) or Morocco (971 kWh/capita/year).

In 2021, the residential sector accounted for 47% of final electricity consumption, establishing itself as the primary consumer of electricity. The industrial sector is the second lar- gest electricity consumption sector in the region with 33% of electricity consumed. The industrial sector experienced the highest electricity consumption (12% average annual growth) during the period under consideration. This is an important parameter which measures the industrial progress made in the region.

From a country perspective, the residential sector remains, in most countries, the main sector of electricity consumption. However, it should be noted that in Benin and Burkina Faso, the main sectors of electricity consumption are respectively the trade and services sector and the industrial sector.

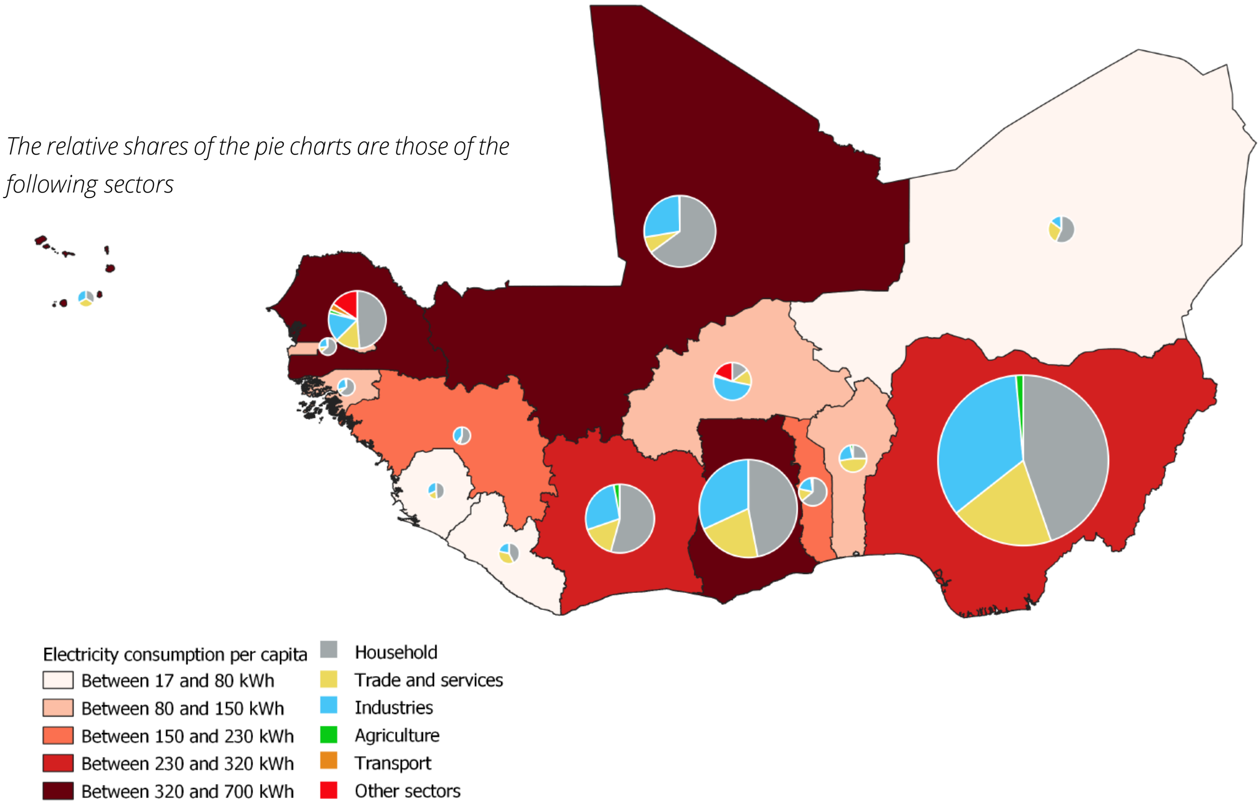

Figure 25: Mapping of electricity consumption per capita of ECOWAS Member States in 2021 (kWh/capita)

Between 2010 and 2021, biomass consumption (firewood, wood residues, agricultural waste and charcoal) increased by an average of 3.4% per year while LPG consumption increased by an average rate of 16% per year. However, these statistics need to be refined. Indeed, a notable surge in LPG usage is likely to lead to a reduction or plateau in the consumption of firewood and charcoal, given that these items serve the same function, primarily for cooking purposes. This can be explained by the methodology used to calculate final consumption of wood and coal, which is based on specific consumption per capita. These specific consumptions are generally derived from surveys carried out several years ago and do not reflect the dynamics of final consumption in the residential sector. **It is therefore necessary to update the specific fuel consumption data in order to refine the statistics of the residential sector, which has a considerable impact on energy systems and deforestation.**

According to the Food and Agriculture Organization of the United Nations (FAO), Africa has the highest **net annual rate** of forest loss between 2010–2020, at 3.9 million hectares[7]. With an estimated 184.6 cubic meters per hectare of standing timber from West and Central African (FAO) forests[8], the consumption of wood fuels between 2010 and 2021 in ECOWAS resulted in **deforestation, covering 4% of the region's** area or 21.4 million hectares of forests.

In 2021, firewood accounted for 93% of the region's final wood fuel consumption in rural areas.

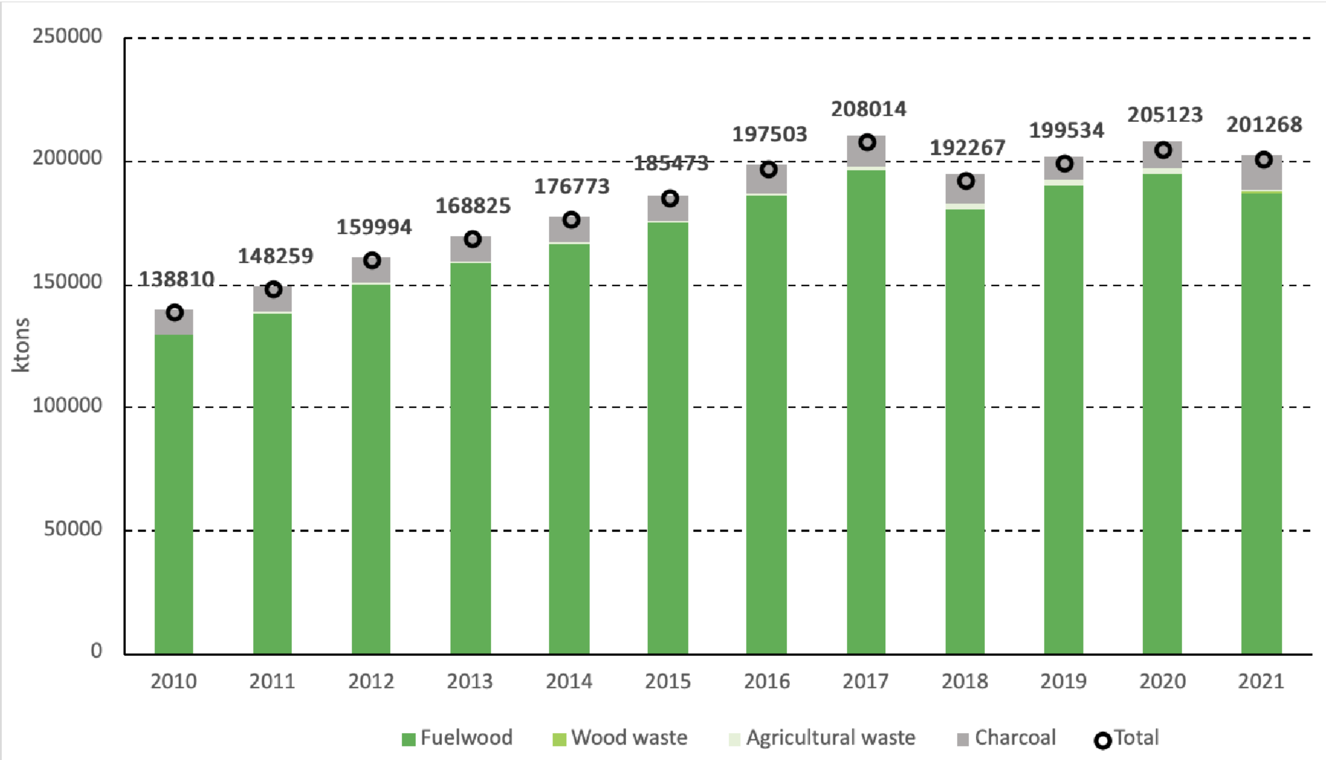

Figure 26: Trend of the final consumption of wood fuel in the ECOWAS region, 2010-2021

In 2021, the average daily consumption of an ECOWAS inhabitant was 1.3 kg of firewood and 0.1 kg of charcoal. Depending on the Member State, this consumption varies between 0.33 kg (Liberia) and 1.79 kg (Sierra Leone) for firewood and between 0.01 kg (Cabo Verde) and 0.44 kg (Liberia). Cabo Verde's extremely low consumption can be explained by the country's very limited forest cover and relatively higher purchasing power allowing for better access to clean forms of energy.

[7] https://www.fao.org/forest-resources-assessment/2020/fr/

[8] Global Forest Resources Assessment, 2020, Page 49

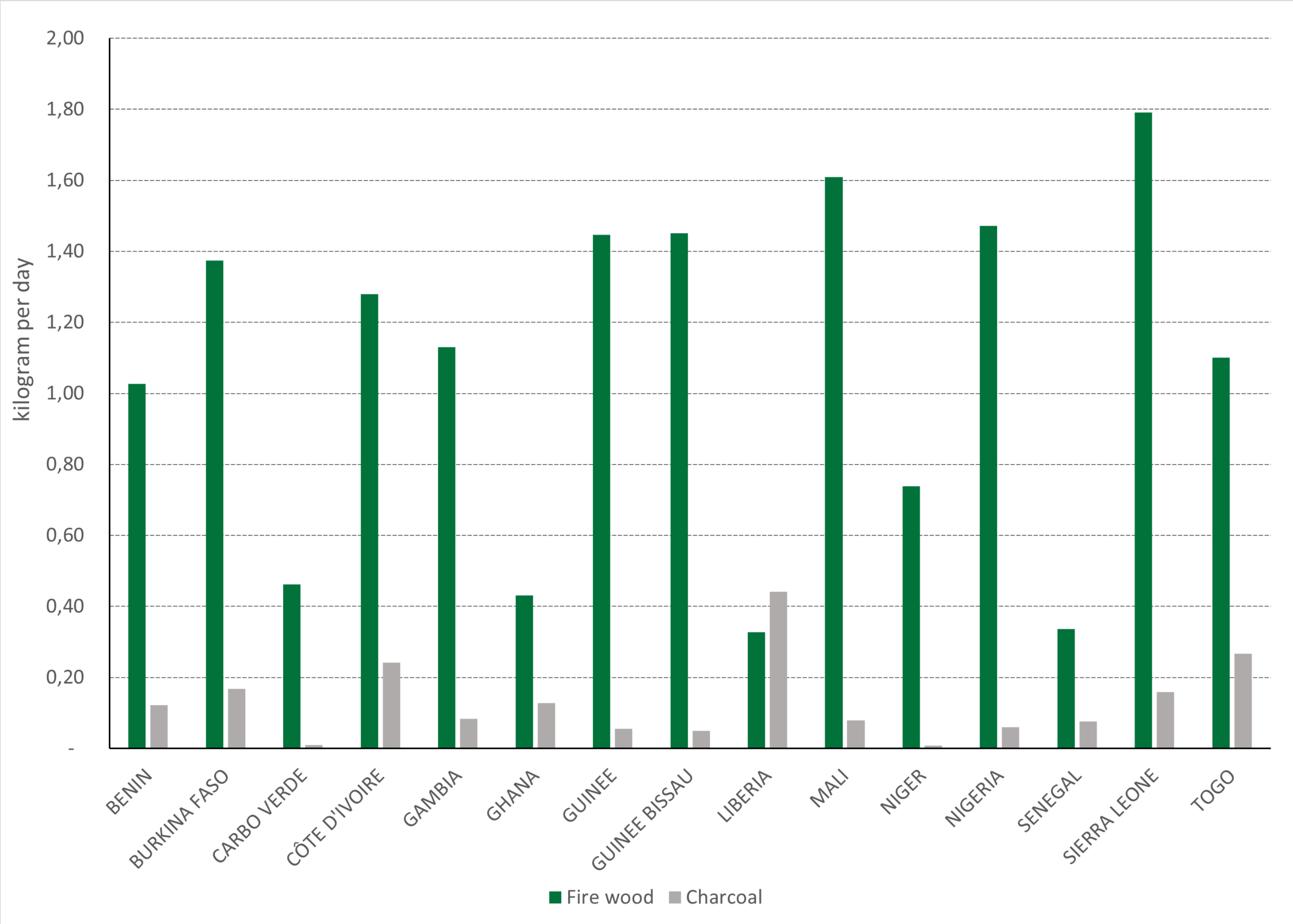

Figure 27: Average daily consumption of firewood and charcoal by ECOWAS Member States, 2021

Sustainable development indicators

In West Africa, the Sustainable Development Goal of **ensuring access to affordable, reliable, sustainable and modern energy for all by 2030** is still far from being achieved.

Access to electricity

Between 2010 and 2021, access to electricity grew at an average annual rate of 2.9%. The percentage of households with access to electricity increased from 41% in 2010 to 56% in 2021. **If this trend continues, only 75% of households will have access to electricity in 2030** with universal access expected by 2040. However, these aggregate statistics do not reflect disparities between countries and between rural and urban areas.

Thus, the Member States that could reach the goal of universal access by 2030 are: Cabo Verde (91% in 2021), Côte d'Ivoire (85% in 2021), Ghana (84% in 2021) and Senegal (76% in 2021).

Although Niger is among the countries in the region with the lowest rate of household access to electricity, it is the second country in the region with the highest rate of increase (7% per year on average). The first country is Togo with an average annual increase in household access to electricity of 10%.

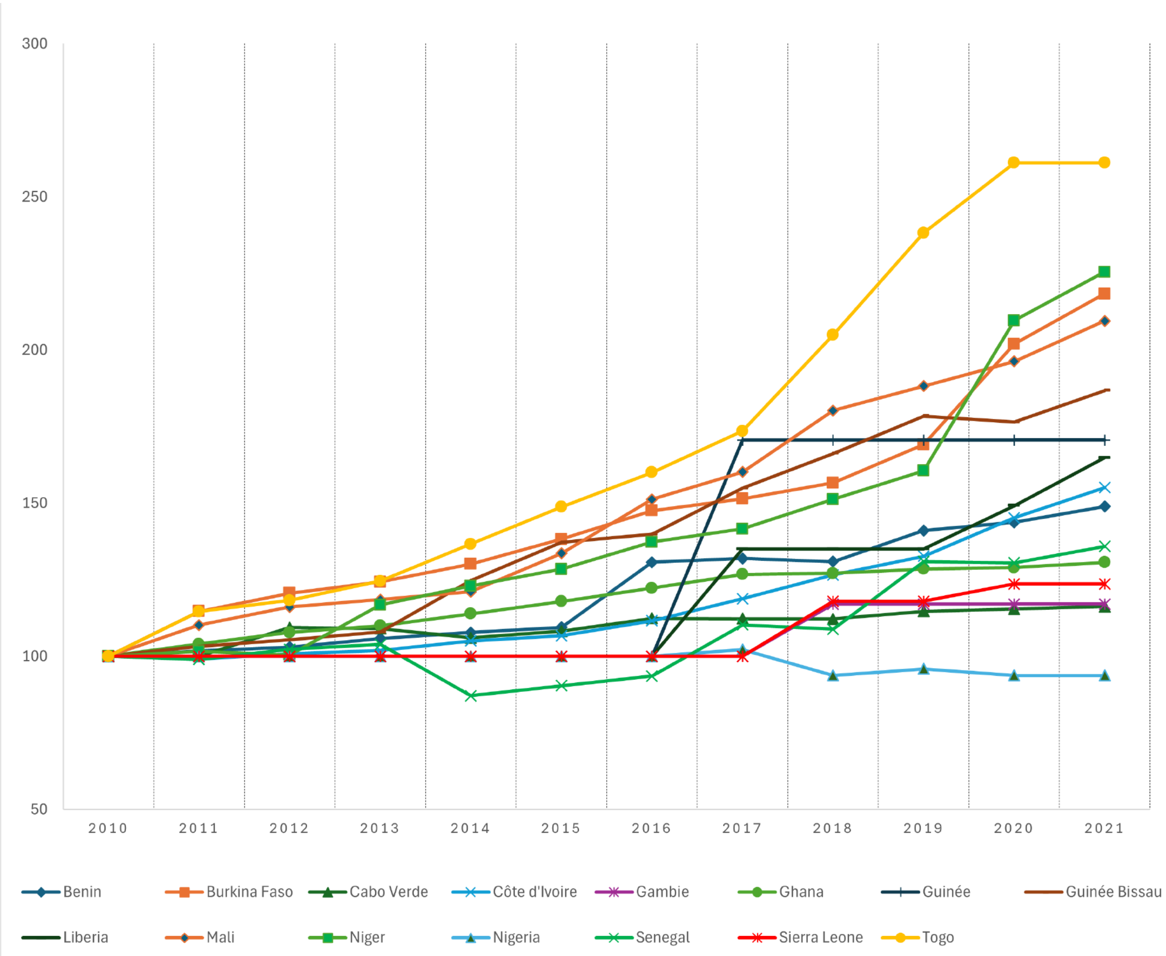

Figure 28: Evolution in base 100 (2010) of household access to electricity in ECOWAS Member States, 2010 - 2021

Clean cooking facilities

The use of clean cooking in the ECOWAS region is still very low. Indeed, in 2021, wood fuels accounted for up to 90% of the final energy consumption of the residential sector in the ECOWAS region with 78% for wood energy and 12% for charcoal. The most recent figures show that 14% of households use LPG for cooking (2017). Within ECOWAS countries, the figure s vary between 1% (Guinea and Sierra Leone) and 78% Cabo Verde. In many countries, this percentage is based on the results of very old surveys,[9] which may be different from the current reality.

With the exception of The Gambia and Niger which have still low LPG usage percentages, for all countries that conducted a recent survey (2018-2020), the percentage of households using LPG is relatively high.

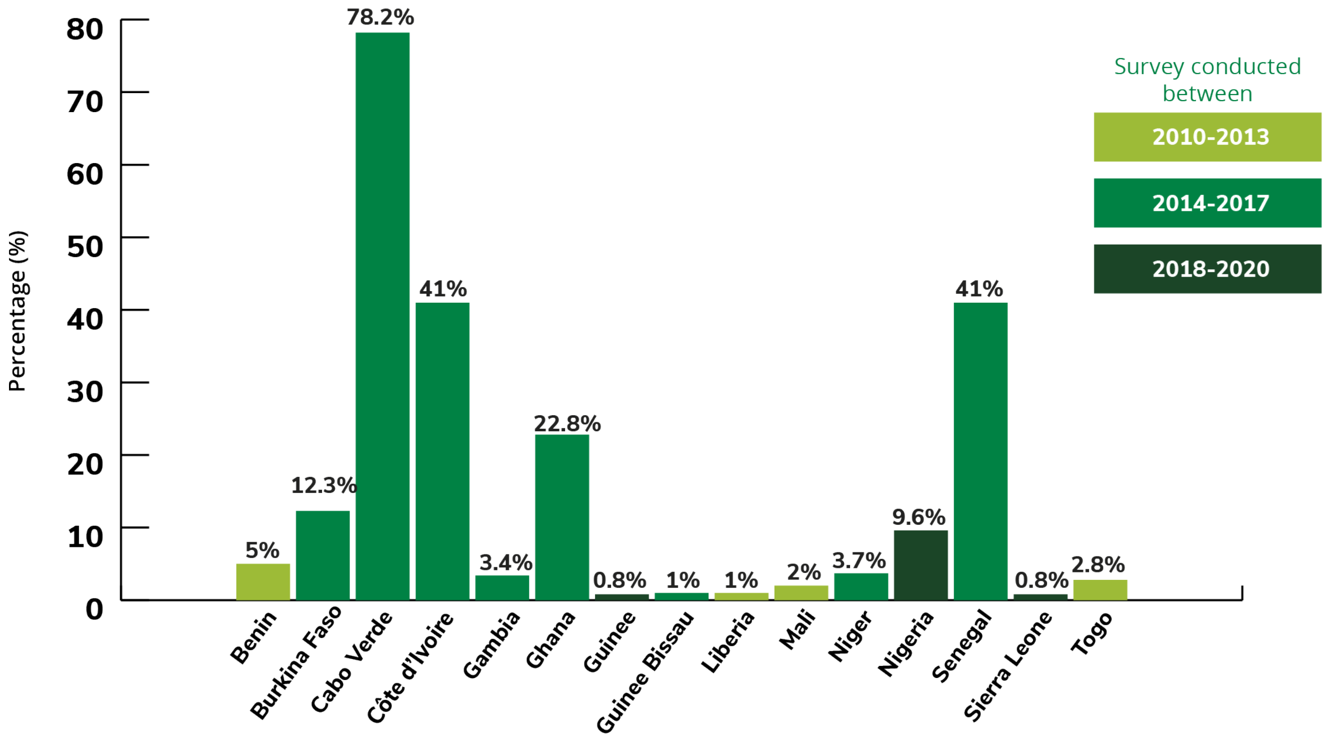

Figure 29: Percentage of households using LPG for cooking in ECOWAS Member States, 2021

[9] The percentage of households using LPG in Liberia and Togo is based on surveys conducted in 2010.

Renewable energy

Due to the significant contribution of biomass to ECOWAS' energy consumption, renewable energy dominates the region's energy consumption. In 2021, the share of renewable energy in the ECOWAS energy mix was 60.5%. This proportion has remained virtually unchanged since 2010, when it was 60.3%. For individual member states, the percentage of renewables in the energy mix varies between 20% (Cabo Verde) and 86% (Liberia). This apparently favourable aggregate statistic does not reflect the structure of the energy forms that make up the energy mix or mix.

Indeed, if biomass energy is excluded, the share of renewable energy in ECOWAS' energy mix will fall from 60.5% to 3%.

Between 2010 and 2021, despite significant progress in electricity production from renewable sources, particularly solar and wind (average increase of 50% per year), the share of renewable energy in the region's electricity production unfortunately fell from 24% to 19%. This is due to the relatively low share of wind and solar PV in the electricity generation mix, but also to the fact that electricity generation from non-renewable sources also increased over the period.

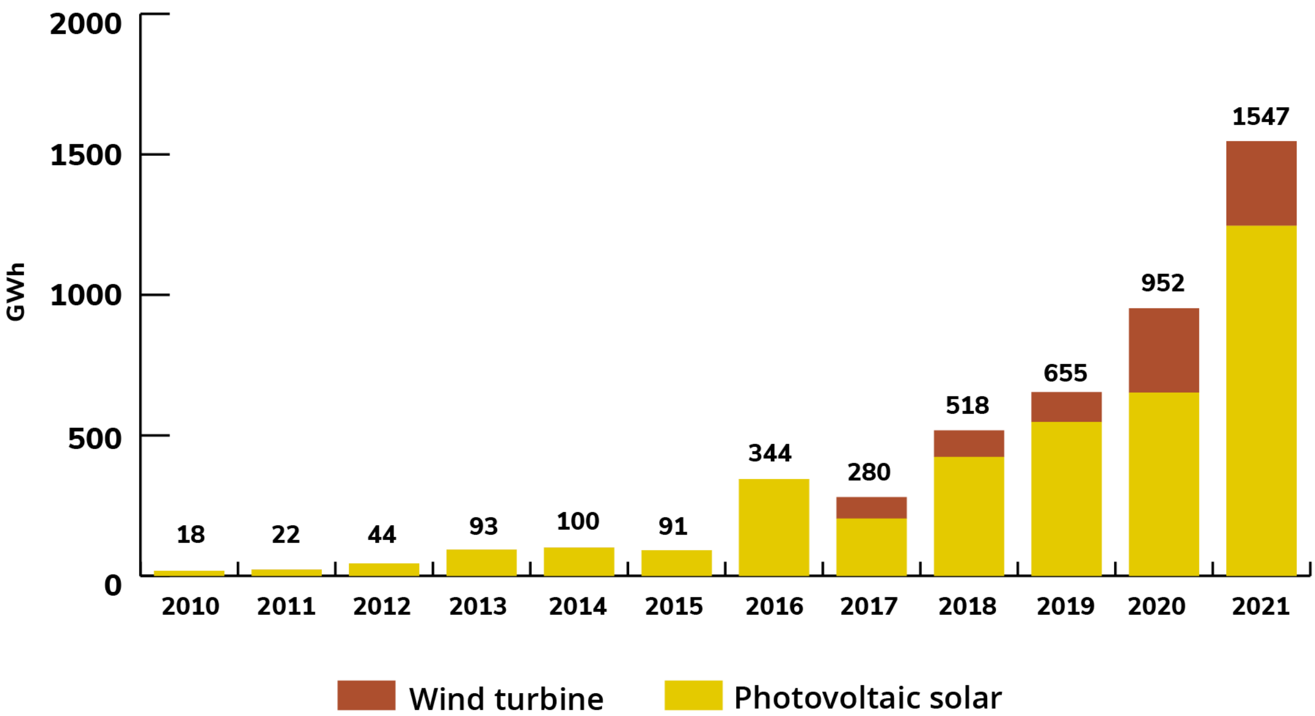

Figure 30: Evolution of electricity generation from renewable energy sources (excluding hydropower) in ECOWAS, 2010 - 2021

Energy Efficiency

At the ECOWAS level, energy intensity[10] improved between 2010 and 2021 by 3.9% (0.36% per year). The largest improvement was observed between 2017 and 2018 when energy intensity improved by 10.7%. Since then, there has been a stagnation between 2018 and 2021.

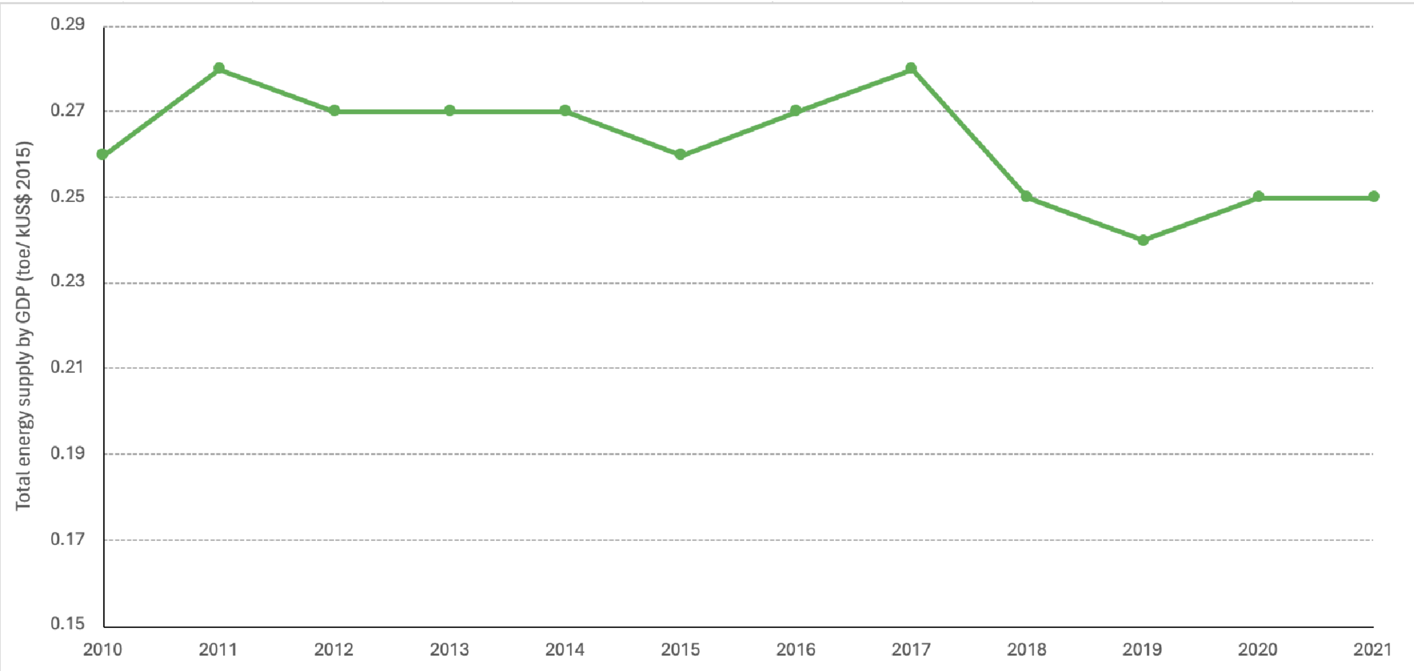

Figure 31: Trend of ECOWAS Energy Intensity, 2010-2021

With the exception of Cabo Verde, Ghana, Nigeria and Sierra Leone, all Member States have seen improvements in energy intensity. Statistics on energy intensity remain indicative given the uncertainties of the calculation parameters, in particular gross domestic product and the weight of biomass. In addition, the calculation of energy intensity by branch would provide a better understanding of the effect of the various factors on energy intensity.

Togo is the country in the region that has seen the highest improvement in energy intensity with an improvement of 87.9% between 2010 and 2021 (8% per year). **It is important to note that the weight of biomass energy in the energy mix is a strong contributor to improvements in energy intensity.**

[10] Energy intensity is an important indicator of primary energy consumption by economic activity. It shows the amount of energy needed to produce one unit of GDP. Low energy intensity means better energy efficiency and better use of energy for the production of one unit of gross domestic product.

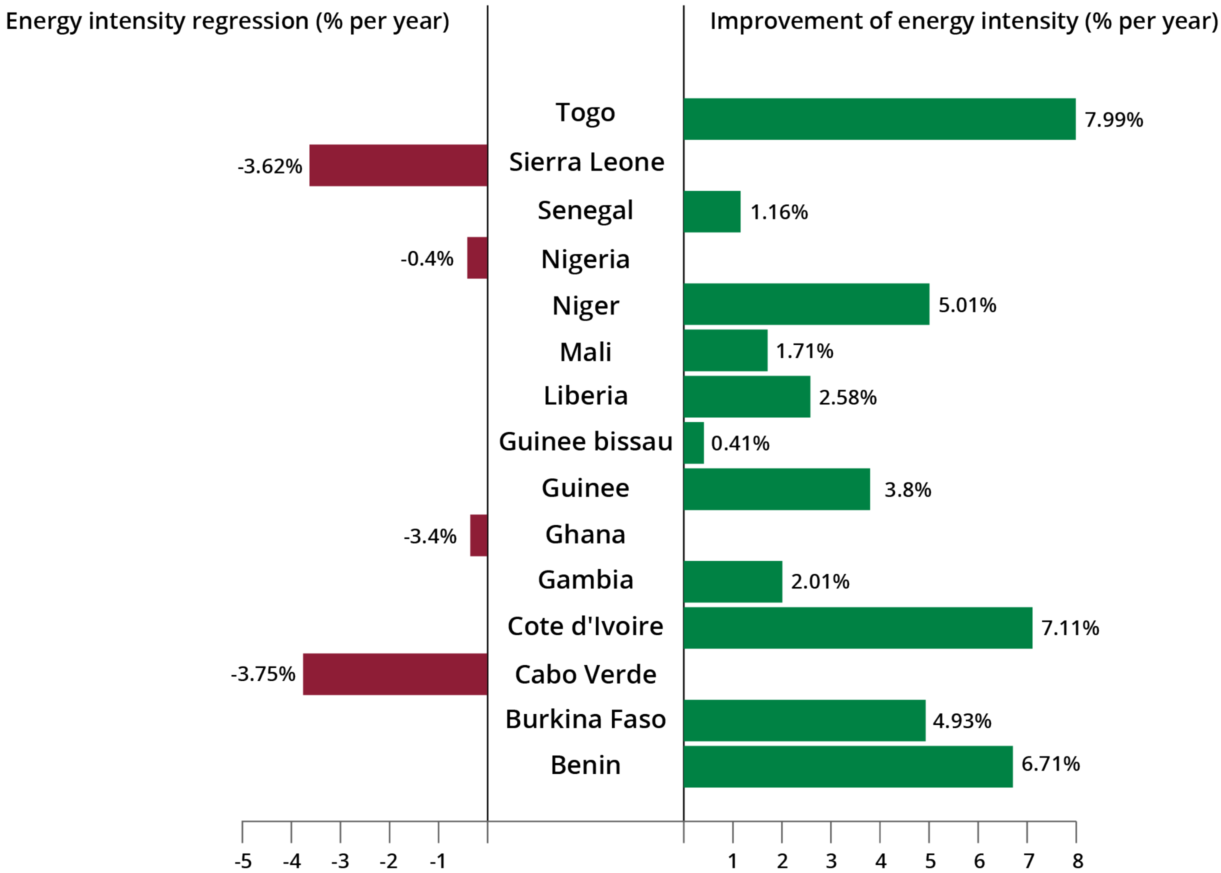

Figure 32: Energy Intensity Improvement in ECOWAS Member States, 2010 - 2021

Installed renewable energy capacity

Between 2015 and 2021, 880 MW of renewable generation capacity was installed in the ECOWAS region, an average of 147 MW per year. This new capacity results from the commissioning of 305 MW of solar PV plants. Senegal, with 47% of the region's solar photovoltaic capacity, has made a major contribution to the development of solar energy in the region.

Hydropower capacity is the main source of the ECOWAS renewable energy installed capacity and production; In 2021, they accounted for 91% of the region's renewable energy capacity. Since 2015, the region's hydropower capacity has increased by 450 MW.

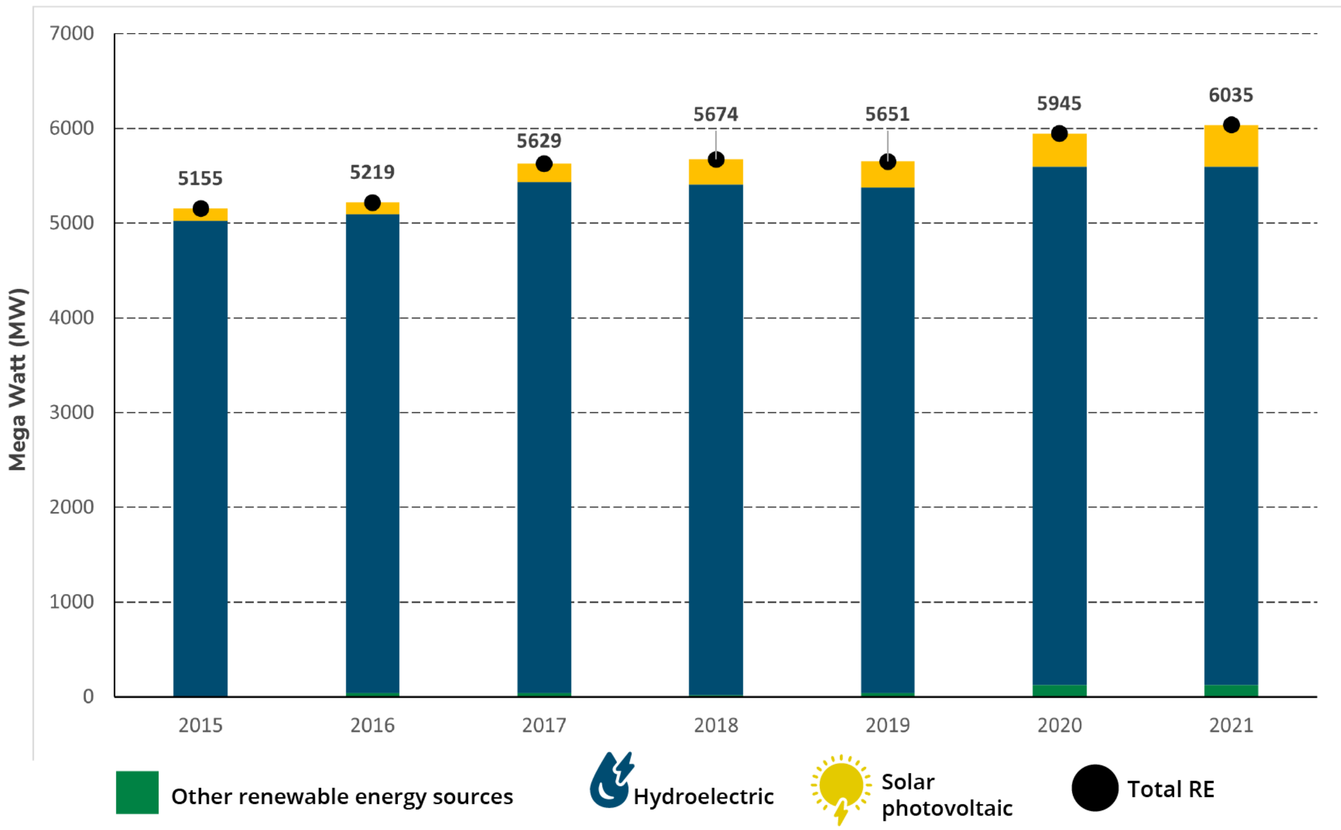

Figure 33: Evolution of the ECOWAS Installed Renewable Energy Capacity, 2015 - 2021

Energy flow diagrams

The energy flow diagram is a graphical representation of energy flows in a country or region. It presents, according to the type of graph, the forms of energy used in the country and their importance according to the thickness of the flow. It is also possible to identify the main sectors of energy production or use.

The various energy flows presented below are graphical representations of the energy balances of ECOWAS Member States in 2021. It shows energy flows from production and imports to energy consumption and transformation processes.

This representation, in addition to giving us a quick overview of the main energy sectors and forms in the region, also allows us to identify the magnitude of process imbalances as well as the level of energy losses.

The results of the analyses of the energy diagrams (presented in Annex 1) of the ECOWAS Member States described below give us for each country a brief summary of the energy landscape of the States in 2021, as well as that of the region.

BENIN

Benin's energy system is characterized by high biomass energy production and high consumption of fully imported petroleum products. The residential sector and the transportation sector are the main sectors of energy consumption. Natural gas, the main source of electricity generation, is imported, as is mineral coal used in the industrial sector, which is the fourth largest energy consumption sector.

BURKINA FASO

In Burkina Faso, the energy system is largely dominated by locally produced biomass, which is mainly used in the residential and service sectors, but also to a lesser extent at the level of self-producers to produce electricity. Fully imported petroleum products are widely used by the transportation sector. The industrial sector is the largest sector in terms of electricity consumption.

CAPE VERDE

Cabo Verde's energy system is largely dominated by petroleum products, which are entirely imported. They are mainly used by the transport sector and by the power generation energy industry where processing losses are significant. Locally produced electricity is used in almost all sectors of activity. Biomass energy use is low across the country, but biomass energy is the main source of energy for the residential sector.

CÔTE D'IVOIRE

In Côte d'Ivoire, the energy system is dominated by biomass energy and mainly imported crude oil. Biomass energy is the main source of energy for the residential sector. Petroleum products, used mainly by the transport sector and to a lesser extent by households, are produced mainly by the country's refineries. Electricity is mainly produced by public power plants, which largely use natural gas, but also hydroelectricity.

GAMBIA

As in most countries in the region, The Gambia's energy system is dominated by biomass energy. Fully imported petroleum products are used mainly in the transport and industrial sectors, but also for electricity generation. Electricity is mainly consumed in households and in shops and services.

GHANA

Ghana's energy landscape is marked by high production of crude oil, much of which is exported. The vast majority of imported petroleum products are used, particularly in the transport sector, which is the country's largest energy consumption sector. Natural gas is the main source of electricity generation, but it is also used in the industrial sector. Although biomass energy remains the primary source of energy for households, electricity plays an important role in their consumption.

GUNIEA

The energy system is dominated by biomass energy, which is used entirely by the residential sector. Fully imported petroleum products are mainly used in industry and transportation. It is important to note that there is a gap between imports and uses, which represents a level of improvement in the country's statistics. Electricity generation, too, has a gap between the amount of energy that goes in and out of the transformation process.

GUNIEA BISSAU

In Guinea Bissau, the energy system is dominated by biomass energy, which is used mainly in the residential and industrial sectors. Fully imported petroleum products are mainly used in the transportation sector and for electricity generation. Electricity used mainly in households and services has a gap between production and consumption.

LIBERIA

Liberia's energy system predominantly uses biomass energy which is mainly processed into charcoal. Charcoal is the main form of energy consumed in the country, especially by households. There is a lack of energy used as inputs to the electricity production process of self-producers and needs to be collected more.

MALI

Mali's energy system is dominated by biomass energy. Produced locally, it is the main form of energy used in the residential sector. The electricity made available to consumers is mainly produced locally from petroleum products, hydroelectricity, solar photovoltaic energy and biomass energy. Petroleum products, which are entirely imported, are mainly used in the transport sector.

NIGER

Niger is the only country in the region where the carbonization of biomass, especially firewood, is not permitted. However, the country's energy system is still dominated by biomass energy, which is the main source of household energy. The petroleum products used in the country come mainly from the local refining of crude oil produced in the country. Much of the production of petroleum products is exported, and the rest is used for transport, industry, commerce and households.

NIGERIA

Nigeria's energy landscape is marked by high production and export of crude oil and natural gas. Petroleum products, consumed in the country in particular for transport and electricity production by self-producers, are largely imported. The residential sector is the largest sector in terms of energy consumption and it mainly consumes biomass energy. Natural gas is the country's main source of electricity generation.

SENEGAL

Senegal's energy system is marked by a diversity of forms of energy. Electricity generation in the country is from biomass energy, mineral coal, natural gas, solar photovoltaic, wind and petroleum products. A third of the petroleum products used in the country are produced locally from imported crude oil. Biomass energy is the main source of energy consumption in the residential sector, but electricity and petroleum products have a significant share.

SIERRA LEONE

In Sierra Leone, the energy landscape is dominated by locally produced biomass, which is the main source of household energy, far ahead of electricity and petroleum products. Fully imported petroleum products are used mainly in the industrial and transportation sectors. Electricity, which is produced entirely locally and in particular from hydroelectric dams, has a gap between the quantities entering and leaving the production process.

TOGO

Togo's energy system is characterised by the high use of biomass energy and significant carbonization losses. Charcoal from the carbonisation process is the second most consumed energy product in the country. Wholly imported petroleum products are widely used by the transportation sector and very little in the residential sector. A significant portion of the electricity consumed in the country is imported, and the rest is produced mainly with natural gas.

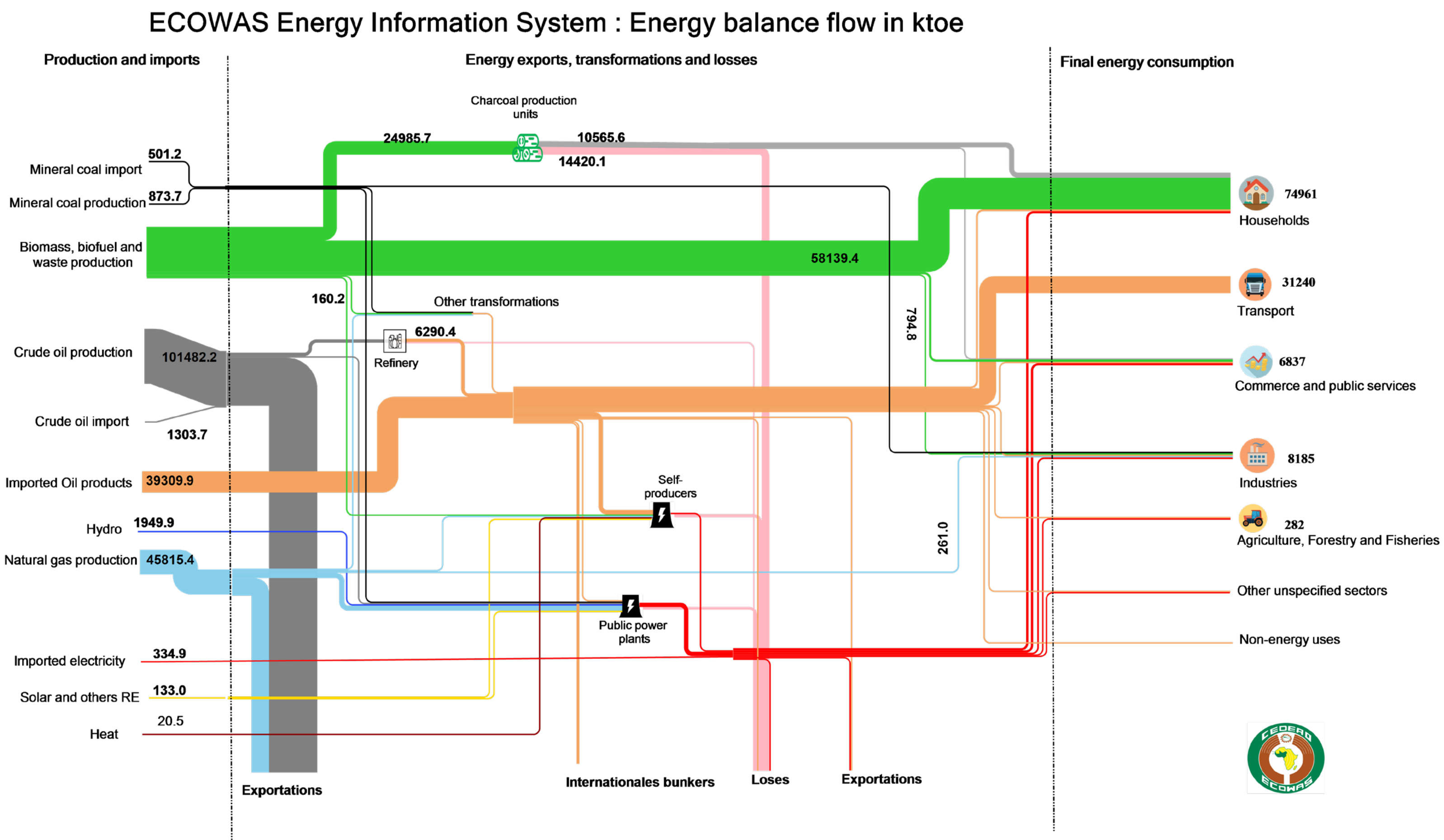

Figure 34 : ECOWAS Energy Balance Flow in Ktoe, 2021

ECOWAS

The region has a fairly varied energy mix that is dominated by crude oil, biomass energy, and natural gas. The residential sector is the main sector of energy consumption and it mainly consumes biomass energy. Significant gaps can be observed in petroleum products and electricity.

2 BIOMASS ENERGY SUBSYSTEM AND SUSTAINABLE ACCESS TO CLEAN AND EFFICIENT FORMS OF ENERGY

Introduction and approach

Biomass remains a major energy source for most countries in the ECOWAS region. According to the ECOWAS Updated Energy Policy adopted in 2023, about 62.6% of the total final energy consumption in the ECOWAS region in 2019 came from wood and charcoal. In eight out of the fifteen ECOWAS countries, the share of biomass in final energy consumption exceeds 70%. Over 90% of the wood consumed in the region is in rural communities, showing a wide disparity in energy consumption sources for rural and urban communities. This, coupled with the low efficiency of the biomass value chain, is worrying.

Accordingly, the updated ECOWAS Energy Policy promotes a "transformation of the energy sector towards modern, clean energy (from wood fuels to renewable energies, natural gas and other gaseous fuels), as well as a significant improvement in energy efficiency". Strategic objective 6 of the policy "**Increase access to modern cooking energy**" calls on member states to set ambitious targets for access to clean cooking energy and for the substitution of solid biomass energy, in order to curb deforestation and climate change and safeguard the health of the region's populations, particularly children and women.

This chapter explores the various biomass energy forms, quantities and levels of utilisation to ensure a sustainable and environmentally friendly energy supply for cooking and other applications particularly for income generating activities in the ECOWAS region. The factors contributing to the use of current energy types are analysed. The emphasis is to establish the disparities between the available energy forms, quantities and levels of utilisation across the various sections of member states' economies. Relevant data was gathered from various government and regional institutions, scientific publications, and ECOWAS energy statistics on biomass fuel availability, quantities, and consumption. Interesting country-specific case studies are further presented to understand approaches for successfully implementing biomass energy systems, draw lessons for policy implementation and set the path for developing sustainable biomass energy in the ECOWAS region. This chapter concludes by briefly examining the key issues that must be tackled to enable ECOWAS member countries to transition to a more sustainable biomass energy system, including the application of biomass fuels for transport and the productive sector.

Overview of biomass availability and usage in rural and urban areas

The ECOWAS region has significant biomass resources that provide energy for cooking and other applications. In 2021, biomass (classified as biomass and biofuels) contributed 58.1% to Total Final Energy Consumption (TFEC) in the region. Generally, not much change has occurred over the years, as shown in Figure 1. The share of biomass in TFEC has reduced only marginally from 2010 to 2021, from 65% to 58%. Absolute consumption has increased though, from 51,000 ktoe in 2010 to 82,000 ktoe in 2021, in line with population and other growth indicators. There are notable differences in biomass availability and utilisation patterns across rural and urban areas in ECOWAS countries.

For example, Ghana's 2021 census showed that whereas only 39% of urban households use biomass as the main source of fuel for cooking, 78.5% of rural households rely on biomass (mainly firewood and charcoal) as the main source of fuel for cooking. Also, urban households tend to use more charcoal than firewood (28% use charcoal against 11% for firewood), whereas rural households tend to use more firewood than charcoal (62% use firewood against 16% charcoal). This rural-urban disparity is similar across the ECOWAS sub-region (de la Sota et al., 2018).

Table 2 shows the share of biomass in TFEC in the 15 ECOWAS countries for the latest data published in the ECOWAS Energy Information System. Biomass usage is lowest in Cape Verde, Ghana, and Senegal (see Section 2.5). Only 20.5% of Cape Verde's TFEC in 2019 was provided by biomass. Ghana had 33.6% in 2022. The reasons for low biomass usage in these countries include unavailability of the biomass resource, as well as plans and policies to promote alternative fuels. In Cape Verde for instance, biomass potential is low, prompting the use of alternative cooking fuels in the country. In the case of Senegal, efforts to transition to LPG for cooking has been ongoing since the 1970s, using a number of policy instruments. Details of Senegal's LPG journey is further presented in Section 2.5.1. Ghana has also made substantial efforts at promoting LPG for cooking, with a policy in place to have at least 50% of the population using LPG as main cooking fuel by 2030. On the contrary, Liberia, Sierra Leone, and Guinea Bissau have more than 80% of TFEC from biomass. Guinea Bissau is the highest, with 85% in 2020 (ECOWAS Energy Information System, 2024).

Low access to affordable energy and heavy reliance on traditional biomass fuels have significant social and economic implications for the region. The combustion of these fuels in poorly ventilated spaces can lead to indoor air pollution, which poses significant health risks highlighted by the World Health Organization (WHO, 2023). Prolonged exposure to indoor air pollution can cause respiratory diseases and other health issues, particularly among women and children who spend more time indoors and near cooking areas. As shown later, these countries are also making efforts towards transitioning to modern fuels for cooking.

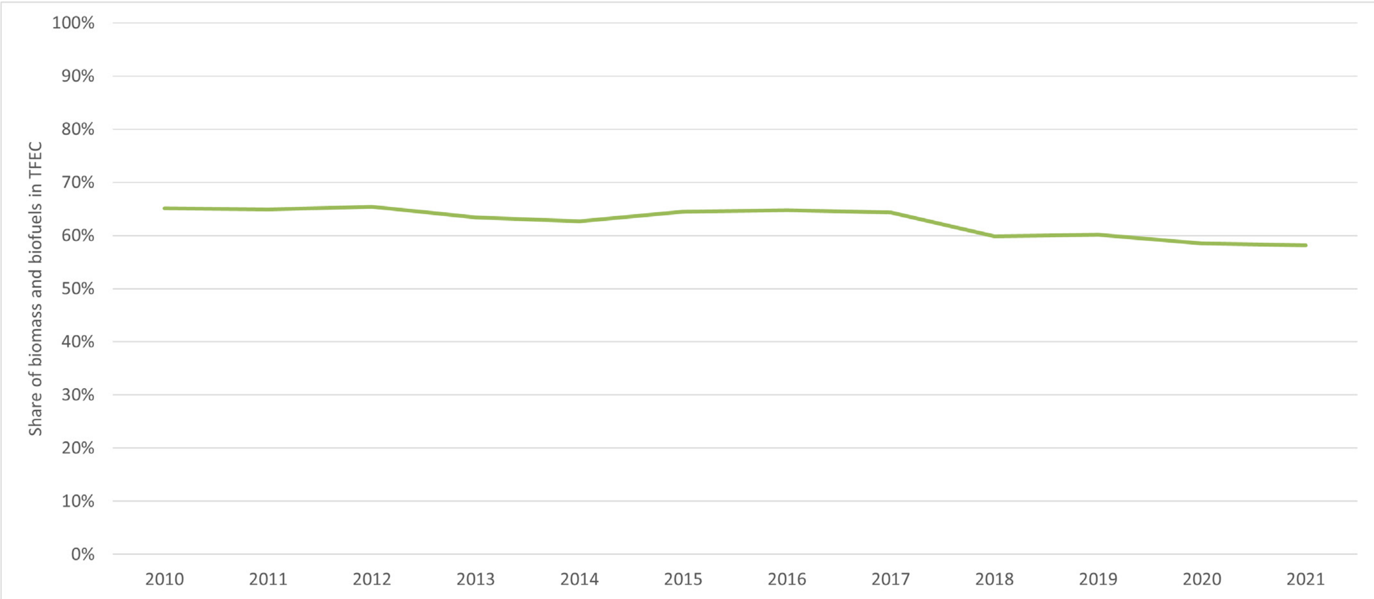

Figure 35: Share of biomass in TFEC in the ECOWAS region

Table 2: Share of biomass in TFEC of ECOWAS countries

Country	Share of biomass in TFEC
Benin	53.5% as at 2021
Burkina Faso	73.6% as at 2020
Cape Verde	20.5% as at 2019
Côte d'Ivoire	56.5% as at 2020
Gambia	71.2% in 2018
Ghana	33.6 % as at 2022
Guinea	73.4% in 2018
Guinea Bissau	85.0% in 2020
Liberia	81.0% in 2019
Mali	68.5% in 2020
Niger	73.6% in 2022
Nigeria	59.7% as at 2019
Senegal	40.3% in 2020
Sierra Leone	80.8% in 2019
Togo	71.7% in 2022

Source: Data from ECOWAS Energy Information System (2024)

A significant portion of the population in ECOWAS resides in rural areas with livelihoods closely tied to biomass resources (see graph in Chapter 3). Fuelwood and charcoal from woodlands satisfy most households' energy needs for cooking in these rural areas. Woodlands and trees outside forests are the primary source of fuelwood and charcoal. Large tracts of communal forests, woodlands, and fallow lands exist in rural areas, providing the main resource base.

Agricultural residues also provide a key biomass resource in rural areas as they are often used as complementary household fuels and provide raw materials for small-scale enterprises. The main agricultural residues utilised in rural areas as biomass energy feedstock are cereal crop residues, coconut shells, groundnut husks, and sugarcane bagasse. These residues often provide supplementary household fuels and could also serve as feedstock for small-scale bioenergy technologies like gasifiers that provide electricity and motive power.

Urban households depend primarily on charcoal and liquefied petroleum gas (LPG) as the main cooking fuels (ECREEE, undated) in some ECOWAS countries such as Senegal, Ghana and Cape Verde. The charcoal consumed in urban areas is produced mainly in rural and peri-urban areas and transported to urban markets for sale. The raw materials are sourced from trees and shrubs, sometimes unsustainably. Urban demand for charcoal has led to lands close to cities being denuded of woody biomass. This has necessitated sourcing charcoal from more distant rural areas, increasing end-user costs. Figure 36 shows the flow of biomass across rural and urban communities in the region.

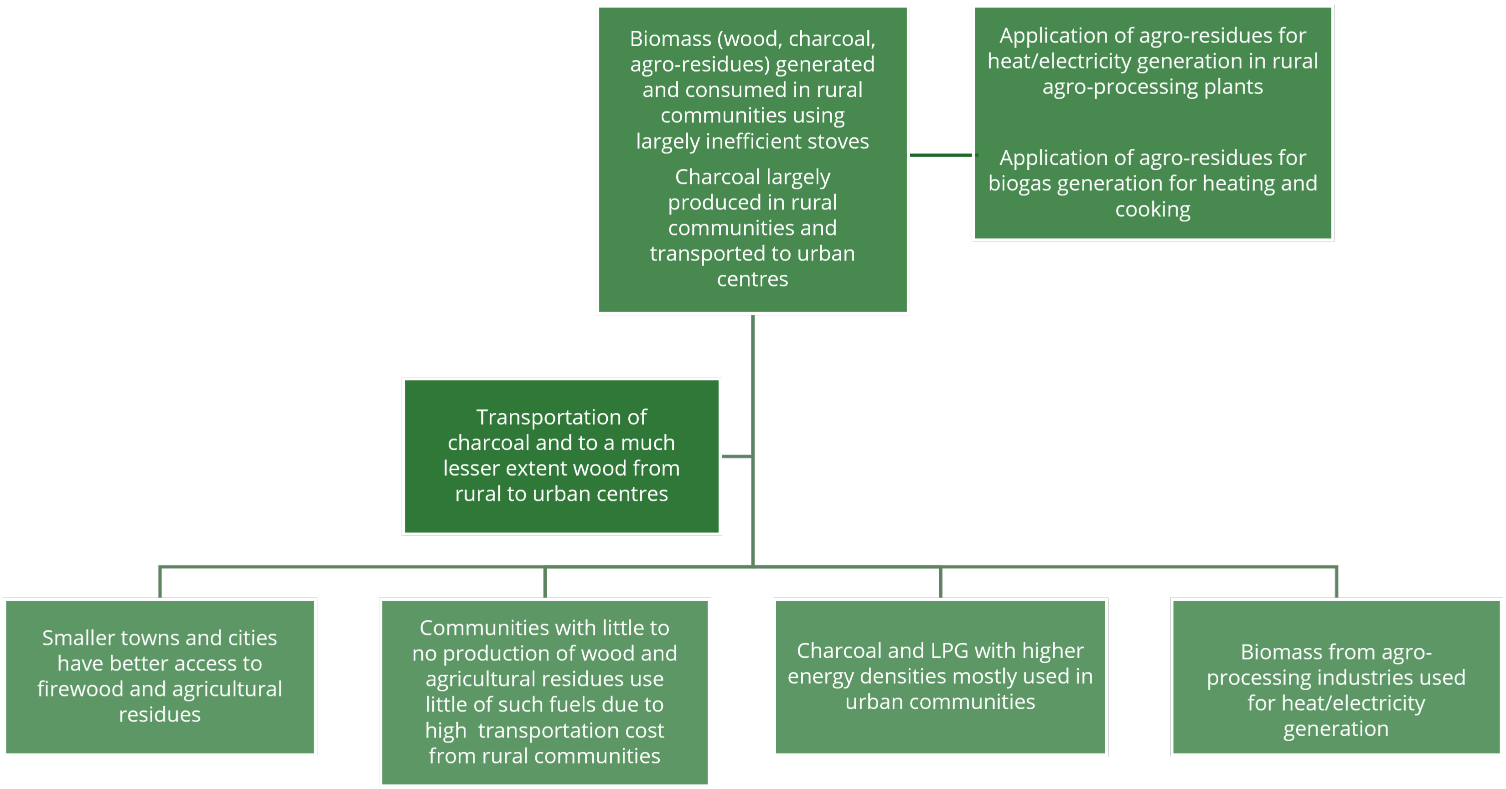

Figure 36: Biomass flow in rural and urban communities

The opportunities for urban households to use fuelwood or agricultural residues directly are limited since most urban areas lack easy access to such raw biomass resources. Fuelwood and crop residues must be transported over long distances from surrounding rural regions to meet urban energy demands. This significantly increases costs, making fuelwood unattractive for urban consumers who favour charcoal and LPG with higher energy densities, especially when available.

The availability and use of biomass resources differ markedly across urban areas based on size, administrative capabilities, and proximity to rural biomass sources. Smaller towns and cities tend to have better integration with surrounding rural areas and easier access to agricultural and wood residues that can meet local energy demands. Larger cities have greater challenges in meeting biomass energy needs solely from nearby resources and require an extensive sourcing network, which pushes up fuel costs.

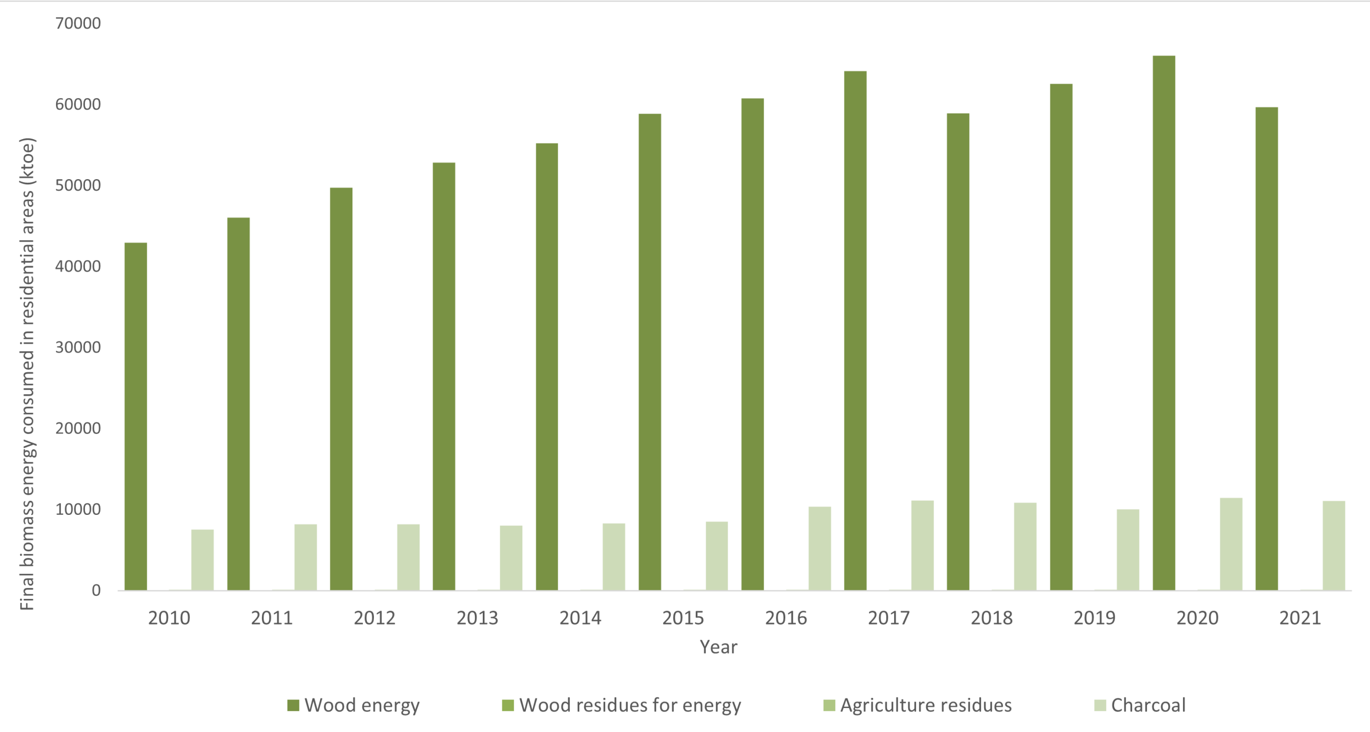

Figure 37: Total energy supply from biomass sources in ECOWAS

Table 3 shows the final biomass energy consumption for residential applications, commercial and public services, and agricultural activities in the region between 2010 and 2021. Wood energy dominates energy supply sources, followed by charcoal. There has been a general increase in the biomass energy supplied for all biomass sources and all sectors between 2010 and 2021. The residential sector is the highest consumer of both wood and charcoal, followed by the commercial and services sector.

Table 3: Final biomass consumption in industrial, residential, commercial and agricultural Sectors

Sector	Biomass type (ktoe)	2010	2015	2021
Industrial Sector	Wood	1516	2202	2429
	Agriculture residues	4	15	324
	Charcoal	-	-	5
Residential Sector	Wood	42960	58856	59680
	Wood residues	-	-	19.5
	Agriculture residues	66	79	86
	Charcoal	7524	8519	11046
Commercial and Public Service	Wood	1424	1683	13166
	Agriculture residues	17	17	27
	Charcoal	573	5094	1514
Agriculture/forestry/ fishing	Wood	573	238	-
	Wood residues	-	-	13
	Charcoal	453	238	10

Source: ECOWAS Energy Information System (2024)

Drivers of fuel use in the ECOWAS region

Globally, and particularly in sub-Saharan African countries, biomass-dependent households have rapidly grown due to rapid population growth, high fuel costs of alternative options and interruptions in fuel supply (World Bank, 2014). Identifying the factors contributing to biomass utilisation is essential to formulate and implement appropriate policies and measures. Some factors have been identified to influence the consumption of biomass.

Generally, it has been established that household income and socio-demographic factors contribute to using biomass as an energy source for rural and urban areas. A study in China found that off-farm income has a positive and significant impact on expenditures on clean energy, such as electricity and gas, but exerts a negative and significant impact on expenditures on non-clean energy, such as biomass (Ma et al., 2019). Generally, as off-farm income expenditures on clean energy increase, that on non-clean energy such as biomass decreases. Similarly, household income has been identified as the major factor that can contribute to biomass utilisation in India (Farsi et al., 2007).

Several factors have been identified to contribute to the choice of energy for cooking and other heat applications in rural and urban areas in the ECOWAS region. It has been reported that household income or wealth is a key factor influencing households' choice of cooking energy and, in essence, using firewood or charcoal as energy sources (Dongzagla and Adams, 2022). However, for a particular country, the factors contributing to biomass use may differ depending on unique socio-economic, cultural, and demographic factors. Overall, household income has been established to be the main determinant factor in using biomass as an energy source (Dongzagla and Adams, 2022). It has also been established that non-income factors, such as characteristics of the head of the household, which include gender, occupation, and educational level, among others, also contribute to the use of charcoal and firewood (Dongzagla and Adams, 2022).

Several studies have focused on the rural situation, examining the determinants of rural households' choice of cooking energy consumption across various countries in the region. Non-income factors such as access to roads, markets, the cost of technology, sociocultural settings, and location-related variables also contribute to the use of biomass and a particular biomass type in rural areas (Dongzagla and Adams, 2022). Adeyemi and Adereleye (2016) found that higher education level of household heads could help trigger fuel switching and abandonment of the use of unclean cooking energy. They also found income level and nature of household heads' occupations to greatly influence the reduction in biomass consumption and a switch to modern cooking fuels. Twumasi et al. (2020) also conducted a study that concluded that access to credit may influence a switch to modern cooking fuels.

Other factors reported include household income, consumption expenditure, household size, age of household head, marital status, sex and education levels of household heads, occupation, ownership of dwellings, nature of housing (modern or traditional), and accessibility to energy sources in terms of availability and price (Adeyemi and Adereleye, 2016; Wassie et al., 2021). Large household size has been reported to affect the use of biomass energy. An increase in household size is likely to increase biomass consumption and the probability of households adopting unclean cooking fuel (Dongzagla and Adams, 2022). Bisu et al. (2016), in an assessment of urban household cooking energy choice in Nigeria, reported that dwelling ownership status and seasonal changes were key factors influencing households' choice of cooking energy and biomass as an energy source. Kitchen location, educational level of household heads, household income, alternative energy sources, convenience of energy, distance to energy source, and effect of energy source were also identified by Amoah (2019). Dongzagla and Adams (2022) reported that household wealth is the main determinant factor of urban households' choice of clean cooking fuel because clean cooking fuel and equipment are expensive compared to unclean cooking fuel. A study by Sana et al. (2020) in Ouagadougou (Burkina Faso) also reported that cooking fuel choice is strongly influenced by socio-economic status, family size, and also by the woman's educational attainment, age and the main cooking fuel used in her parents' house.

Other important factors include availability, tradition and culture, and underdeveloped energy infrastructure. Biomass resources like fuelwood, charcoal, and agricultural residues are abundantly available across rural areas of most ECOWAS countries. Harvesting fuelwood and producing charcoal provide livelihoods for many low-income households. Biomass is often perceived as 'free' or very cheap for rural communities. Biomass fuels can also be adapted to traditional cooking needs and preferences relatively easily compared to modern fuels, further reinforcing continued usage and dependence (Dongzagla and Adams, 2022). Cooking with fuelwood and charcoal is deeply ingrained in food cultures across the region. Traditional stews and methods of preparation often rely on the use of wood-based cooking fuels. Such cultural preferences have sustained biomass usage for household cooking in several countries.

Efforts to transition to modern cooking fuels like LPG and electricity face distribution challenges in reaching many rural areas. In urban areas, electricity supply can be unreliable. Where available, high upfront costs of transitioning to LPG or electric stoves are often unaffordable for poorer households, compared to biomass stoves with minimal fuel costs, providing energy access for lower-income groups. The lack of infrastructure locks many households into biomass usage.

Rising urbanisation and charcoal demand have spurred its commercial production, often illegally, enlarging the charcoal industry across ECOWAS. Traders play a key role in supplying charcoal. In addition to governance gaps and lack of enforcement of forest, land, and energy regulations, this has enabled unsustainable biomass harvesting in some areas and uncontrolled urban charcoal markets.

Biomass conversion and utilisation technologies in the ECOWAS region

Cookstoves

According to the ECOWAS Updated Energy Policy , the technologies used for 'burning' biomass in the region are inefficient and thus place a heavy toll on forestry resources. Traditional cookstoves, which are basic three-stone rudimentary stoves, and other forms using fuelwood and charcoal for cooking in households and small-scale enterprises, are ubiquitous across the region. They contribute the largest share of cooking stoves as efforts are ongoing to introduce more efficient cookstoves in the region. Improved biomass cookstoves, often modified versions of the traditional stove designs, incorporating insulated combustion chambers, chimneys, and reduced fuel needs through better heat transfer, have been introduced over the years. These enhance fuel efficiency and reduce harmful emissions.

Several improved cookstoves have been developed and utilised across the region. The cookstoves are categorised based on the type of construction materials, the draft system utilised (natural or forced draft) and the biomass type (either charcoal or firewood) (Boafo-Mensah et al., 2021; World Bank, 2014). A category of these cookstoves uses ceramic insulation materials to improve energy efficiency, with either a forced or natural draft system, with charcoal as fuel. Examples include Cook Mate Ceramic, Holy Cook, and Toyola, which use a natural draft system and Ahibenso, Teri, and ACE, which apply a forced draft system. This category of stoves has a thermal efficiency of 20 to 29% (Boafo-Mensah et al., 2021). Other improved cookstoves, such as Cook Mate and Envirofit, use aluminium, mild steel, and stainless steel as construction materials to improve efficiency. These improved cookstoves are either manufactured locally within the region or imported. For example, Toyola (see Figure 38) is manufactured in the region while Envirofit is imported. Some improved stoves have been introduced and tested for commercial activities as well.

a[11]

b[12]

Figure 38:
(a) Toyola improved cookstove; (b) Envirofit stove

[11] https://toyola.energy/our-products/
1[2] https://envirofit.org/product/cookstoves/supersaver-charcoal/

Several efforts are underway in the region to increase access to improved cookstoves and other modern fuels to reduce biomass usage per unit of cooking and heating. Some countries in the region that have advanced in promoting improved cookstoves include Senegal, Benin, and Cote d'Ivoire, with lessons that can be learned and replicated in other countries.

Senegal is one of the countries in the region that have managed to reduce the share of biomass in their TFEC by introducing improved cookstoves, and the use of LPG (Fabrice et al., 2023). These initiatives aim to reduce reliance on biomass fuels and improve health by reducing indoor air pollution. Some improved cookstoves in the country can reduce biomass use by up to 45% compared to traditional stoves (Sow, 2022). The Senegalese government started the National Improved Stoves Program in the 1980s to promote more efficient wood-burning stoves. This included training local artisans on stove construction and subsidising the cost. Senegal was one of the first countries to partner with the Global Alliance for Clean Cookstoves, which was launched in 2010. This brought more funding and attention to clean cooking solutions in Senegal. Several NGOs like Energy 4 Impact and Groupe Energies Renouvelables, Environnement et Solidarités (GERES) have projects in Senegal to market improved biomass cookstoves, especially in rural areas. Despite the availability of cleaner-burning stove alternatives, traditional open-fire stoves remained pervasive, possibly due to their ability to meet practical needs such as large cooking capacity and rapid heat generation (Diouf and Miezan, 2018).

In Benin, the Ministry of Environment and Climate Change has been actively involved in programs to expand access to improved cookstoves since the 1990s. The government removed tariffs and taxes on imported stoves and materials to make improved cookstoves more affordable. A national cookstove program launched in 2007 focused on locally-made stoves from clay and metal. Stove artisans were trained in production. Cote d'Ivoire also established a national program for household energy management in 1989, which included improved stoves. NGOs like GERES and Envirofit have distributed tens of thousands of efficient biomass stoves in rural Cote D'Ivoire. The government has partnered with the European Union (EU) and others on programs to subsidise improved stoves for lower-income households. Radio and television awareness campaigns have promoted improved stoves' benefits to drive adoption.

Charcoal kilns

Currently, charcoal kilns commonly used in the region for converting wood into charcoal are largely traditional earth mound kilns with poor efficiency and higher environmental pollution. The lower efficiencies translate to a higher wood usage per unit of charcoal produced, with higher emissions. Control of the carbonisation process in traditional earth mound kilns is not always easy and often results in low-grade charcoal contaminated with soil crumbs. According to the ECOWAS Energy Information System, charcoal consumption in 2021 was 14.3 Mtoe (equivalent to approximately 18 million tonnes of charcoal). Based on historical trends, demand is expected to continue to rise in the years ahead. In view of such high anticipated demand, an improvement in the carbonisation efficiency of charcoal production will significantly impact the amount of wood required to produce charcoal. Ongoing activities to improve kiln efficiencies have resulted in the development of several improved charcoal kilns to increase process efficiency and reduce greenhouse gas emissions in the process. In recent times, improved kilns such as Casamance kiln, drum kiln, portable metal kilns, brick kilns, steel kilns and the Retort kiln have been introduced, which significantly increase charcoal conversion efficiency when compared to the traditional earth mound kilns (Wondmagegn et al., 2023). While there is no proper data, these improved kilns' usage is minimal. Some of the improved kilns can reduce fuel wood consumption by up to 60% compared to the traditional system, which automatically reduces emissions of gases such as carbon dioxide, carbon monoxide, and methane (Adio et al., 2022).

Biodigesters

Bio-digesters are air-tight chambers where organic matter like animal dung or crop residues are anaerobically digested to produce methane gas for cooking and lighting. Biodigester technology ranges from simple plastic bags on beds of straw to produce small amounts of gas for cooking to complex systems such as Upflow Anaerobic Sludge Blanket (UASB) digesters used in large farming installations capable of producing several megawatts of electricity. Many bio-digesters have been developed over the years, but digesters mainly implemented in ECOWAS member countries include floating domes, fixed domes and bag-design digesters, especially at the domestic level (Kranert et al., 2012). The principal constituents of biogas are methane and carbon dioxide, plus other minor gases such as ammonia and hydrogen sulphide. Biogas can be used directly for heat applications, e.g., cooking. It can be used in internal combustion engines for electricity generation and transport when upgraded by removing carbon dioxide, hydrogen sulphide, and other constituent gases. In the ECOWAS region, gas from domestic plants is mostly used for cooking. The by-product of the bio-digestion process, referred to as 'digestate', is also utilised as organic fertiliser for soil enrichment (Arthur and Baidoo, 2011). Despite the significant reported benefits of small-scale domestic biodigesters and the potential availability of feedstock for biogas production, biodigesters penetration in the ECOWAS region has been relatively low (Kemausuor et al., 2018).

Aside from domestic plants using biogas for cooking in ECOWAS member countries, some institutional and large-scale biogas plants generate electricity for electricity and heat applications, with some connected to the national grid (See Figure 39).

For example, in Ghana, there is currently one commercially available biogas plant (Safisana Biogas) with a capacity of 0.1 MWp that produces electricity for the national grid (Ghana Energy Commission, 2023). Details of the Safisana biogas plant and other small-scale biogas to electricity plants in Ghana are presented in Box 1.

BOX 1: Small-scale biogas for electricity generation in Ghana

The Safisana biogas plant generates 685 MWh of electricity annually (Safisana, 2024) and operates in a densely populated urban community near the national capital. The main feedstock used includes food waste, market waste, industrial waste and faecal matter generated from the community. The main products include electricity (which is sold to the national grid) and organic fertilisers produced from the digestate. The company has been successfully operated over the years, and its model can be replicated in other urban communities to use available biomass resources for sustainable energy generation.

In 2022, a new 400 kW hybrid PV-Biogas-Pyrolysis plant was commissioned at Gyankobaa in the Ashanti Region of Ghana. The 400-kW production facility is a hybrid of solar PV, biogas, and pyrolysis plants. The biogas component of the facility converts 12 tonnes of municipal solid waste into biogas and bio-fertiliser daily. A 100-kW electricity generator is connected to the biogas plant, though electricity production has not started yet (Bioenergy Insight, 2022). In 2014, the SIAT group installed two large-scale anaerobic digestion plants. Details of this plant can be found in the Ghana case study in Box 3.

Recognising that 'biodigester technology, thanks to its multiple advantages, is one of the most appropriate responses to food, nutritional and energy insecurity, to poverty to environmental degradation as well as to the adaptation of agriculture to the effects of climate change when the dissemination of the technology reaches a critical mass', Benin , Burkina-Faso, Côte d'Ivoire, Guinea, Mali, Niger, Senegal and Togo founded in 2018 **the Alliance for Biodigester in West and Central Africa (AB. AOC).** AB.AOC is a young regional institution, an instrument for policy dialogue that aims to put in place, through multifaceted support, the conditions necessary to (i) activate a solvent demand, (ii) strengthen the technical and financial capacities of the private sector, and (iii) improve the institutional, regulatory and fiscal environment to facilitate large-scale dissemination of biodigester technology through the market approach.

The ECOWAS region has a technical potential of more than **12,250,000** biodigesters (SNV, 2018), of which only around 25,000 have been built to date, mainly in Burkina Faso, Senegal, Mali and Guinea. The most widespread biodigester technology is the fixed-dome continuous-feed biodigester, with a capacity of between 4 and 10 cubic metres, whose biogas is mainly used for domestic cooking.

The biodigester sector therefore represents an investment opportunity for the private sector and will make a significant contribution to achieving the target objectives of the National Clean Cooking Action Plans (PANCP) and the National Bioenergy Action Plans (PANBE) for achieving universal access to clean cooking. In order to make the most of the potential available, the AB.AOC is currently engaged in the process of drawing up its 2025-2029 Strategic Plan to accelerate and judiciously manage the rate of deployment of biodigesters in its member countries and to develop carbon projects there.

Similarly, FasoBiogaz SARL in Burkina Faso has a 275-kW grid-connected biogas-to-electricity plant in Ouagadougou, the capital city. The power plant is located in a municipal area between a municipal slaughterhouse in Ouagadougou and the country's leading brewery. Waste streams from those companies are used to generate biogas whilst transforming them into valuable organic fertiliser. The proximity of feedstocks to the plant ensures a sustainable feedstock supply, which is crucial for biobased plants.

The Songhaï Regional Centre in Benin, created in 1985, is an original centre for integrated development that puts human capital and bio-energy development at the centre of the pyramid of primary, secondary, and tertiary production. The Songhaï Centre in Porto-Novo produces an average of 1,300 m3 of biogas per month, supplying two generators with a total power capacity of 75 kW to produce electricity (WABEF, 2017). Western Africa Bio-wastes for Energy and Fertilizer (WABEF) has developed and tested operational tools to promote anaerobic digestion and recycle bio-wastes to produce energy and fertilisers in Bénin, Mali, Sénégal, and Cape Verde. Selected actors have been trained in using these tools and are responsible for further uptake and dissemination. In 2021, EDF, Meridiam, and SIFCA laid the foundation stone for the largest biomass power plant in the region. The proposed 46 MW plant will be located in the Aboisso municipality, East of Abidjan, Côte d'Ivoire, and will use agricultural waste as feedstock. See details this plant in Box 2.

a

b

Figure 39:
a) Safisana Biogas to Electricity Plant in Ghana
b) 275 kW biogas to electricity plant in Burkina Faso

Sources: Safisana (2024); FasoBiogas (2024)

BOX 2 Large scale biogas power plant in Abidjan

Located in the Aboisso municipality, around 100 km East of Abidjan in Côte d'Ivoire, the 46 MW power plant will use agricultural waste and will produce enough electricity for 1.7 million people a year. It forms part of the 2014-2030 National Action Plan for Renewable Energy established by Ivory Coast, which has set a 45% target of renewable sources in its energy mix by 2030 (MPS, 2023).

The project is based on the circular economy and will have major social spin-offs: the plant construction works will create at least 500 local jobs. There will also be the equivalent of over 1,000 direct full-time jobs during plant operation, giving rise to significant economic benefits and creating many steady indirect jobs.

The purchase of the biomass required for plant operation will generate new income for nearly 12,000 farmers in the region, over a period of 25 years, helping improve the standard of living of the rural population.

A major technological and industrial innovation, the project will save 4.5 million tons of CO2 emissions over the 25-year operating period and will enhance the reliability of the Ivorian electricity system.

The Ivorian company BIOVEA ENERGIE, EDF (40%), Meridiam (36%) and SIFCA (24%) have co-developed this pilot project, which will benefit from the long-term commitment of financial partners such as the Agence Française de Développement (AFD) through its subsidiary Proparco, and the Private Infrastructure Development Group (PIDG) operating under its subsidiary, the Emerging Africa Infrastructure Fund (EAIF), which is administered by Ninety One, the appointed fund manager. This power plant is due to be commissioned at the end of 2025. The consortium is already intending to replicate it in other agricultural production areas in Côte d'Ivoire.

Source : https://biovea-energie.com/

Briquetting and pelleting technologies

The production and utilisation of pellets and briquettes is one of the options that could be used to reduce reliance on traditional biomass sources sourced from trees. Agricultural by-products such as groundnut husks, maise stalks and cobs, rice husks, millet husks, and sorghum husks have been considered as feedstock for pellet and briquette production (Bappah et al., 2022). These by-products fulfil the requirements for non-woody pellets and briquettes and can be used as good feedstock for production. Pellets and briquettes produced from these resources have been characterised as medium to high quality in terms of burning and cooking characteristics, less smoke generation, and environmental friendliness (Ofori and Akoto, 2020). The pelletisation and briquetting of cocoa pod husks and their mixtures have been mentioned as an alternative fuel source in the region. The abundance of cocoa pod husks in the region, which boasts the two largest producers of cocoa globally, presents a good opportunity to explore alternative fuel options presented by pellets and briquettes.

Ghana and Cote d'Ivoire could be leading the way in taking advantage of this opportunity. Ghana is also said to have the potential to produce 2.7 million tonnes of pellets from wood waste (Mawusi et al., 2023). Abellon Clean Energy Limited started wood waste pellet production that serves business-related customers in Ghana and abroad, though production has been suspended. Abellon's production facility in Ghana, a 72,000 tonnes per year plant, operated for a few years and suspended operations. In Nigeria, there are opportunities to produce pellets and briquettes from wood waste, with production potential in the tens of thousands of tonnes per year (Akhator et al., 2023). Nigerian sawmills generate an estimated 5.2 million tonnes of wood waste annually, usually burnt in the open air or disposed of (Akhator et al., 2023). Though production data is limited, Cote d'Ivoire has the potential for pellet and briquette production from cocoa husks and coconut shells (Dutch Ministry of Foreign Affairs, 2021). Other countries in the region have similar potentials due to their suitable agro-ecological situations. However, despite the growing need for a sustainable solid fuel, they have not fully embraced briquette and pellet fuels for residential use. Factors limiting the commercialisation of biomass briquetting in the sub-region include limited capacity to develop pelleting and briquetting machines and limited market development (Ichu et al., 2020). Overall, there is an opportunity to maximise pellet and briquette production in the region to meet fuel demand in households and local industries. More investment in production facilities, supply chains, and capacity-building efforts are needed to realise the full potential.

Liquid biofuel technologies

The production of liquid biofuels in the region is still in its early stages, with some countries exploring the potential of various feedstocks. However, there are challenges related to infrastructure, technology, and investment that need to be overcome. In July 2022, ANADER, Scania, and Total Energies signed an agreement to develop a pilot project in Abidjan. The project aims to produce 3,500 litres of biodiesel from rubber seeds and test its effectiveness. Over the past year, Scania has delivered 400 biodiesel-compatible standard buses and 50 biogas-compatible articulated buses to SOTRA, as part of its Sustainable Transport Project with the Côte d'Ivoire Ministry of Transport (SCANIA, 2023).

Whereas small-scale ethanol production (as beverage) in the region is quite common, ethanol for transportation is not widespread. Sierra Leone is reported to be exploring and producing from sugarcane syrup. The Addax bioethanol plant began operations in 2016, produces 85,000 m3 of bioethanol annually (Praj, 2016). In recent years, the Italian company, Eni, has taken significant steps towards establishing biofuel supply chains in Africa. The company has planned agricultural investments to facilitate large-scale production, with a goal of increasing bio-refining capacity in Africa to over 5 million tonnes annually by 2030 (MRC, 2023; Transport & Environment, 2024).

Other technologies

Apart from cooking and heating technologies, some modern biomass conversion technologies for producing fuels, heat and electricity from biomass resources are being piloted in the region, mainly on university campuses and some communities. These include pyrolysis and gasification systems aimed at contributing to sustainable waste management.

Gasifiers can convert wood, charcoal, or agricultural residues into combustible producer gas (syngas) through thermo-chemical processes. Syngas can be used directly for heat applications such as cooking and drying crops. Gasifier stoves for cooking are common in some developing countries, particularly in Asia. Feedstock for gasifier stoves includes rice husk, corn cobs, and sawdust. When syngas is appropriately cleaned to remove tar and carbon dioxide, it can be used in combustion engines, micro-turbines, fuel cells, or gas turbines. Syngas can power smaller electricity generators and irrigation pumps for productive activities in the region. A typical commercially established gasifier plant varies between 100-400 kWe. However, plants as small as 10 kW and as large as 2 MW have been established (Ramamurthi et al., 2016). Among biomass conversion technologies, gasification is one of the best for reusing waste biomass. It is considered one of the most efficient ways of converting the energy embedded in biomass, as it provides the opportunity for small-scale electricity and heat generation applications with lower greenhouse gas emissions (Akolgo et al., 2019; Pereira et al., 2012).

Despite the development of gasifier technology worldwide, the technology is not widespread among ECOWAS countries. Four gasifier plants for institutional heat and electricity operations with a total capacity of 174.8 kW have been identified to be currently installed in Ghana. These include a 120 kWe throated downdraft gasifier at Asueyi Gari Processing (see Figure 6), 24.8 kWe system in Papasi in the Offinso North District, 20 kW ferrocement downdraft gasifier at the Kwame Nkrumah University of Science and Technology, Kumasi and 20 kW system at Modern Star School Complex located in Tamale in the Northern Region of Ghana (Osei et al., 2021; Akolgo et al., 2019). The feedstock types used in the gasifiers in Ghana are mostly rice husk, maise cobs, cassava peels, or wood processing residues (e.g. sawdust, offcuts) (Osei et al., 2021). Nigeria commissioned a 100 kVA refuse-derived fuel (RDF) gasification plant at the University of Nigeria to power the campus and nearby communities (Africa Energy Portal, 2019). Feedstock for the plant include corn husks and wood chips. Researchers at the Nigerian Federal University of Agriculture have also designed and fabricated a laboratory-scale gasifier for testing, with wood chips and sawdust as feedstock (Olayanju et al., 2020).

Some challenges and barriers have been identified to hamper the development of gasification technologies in the ECOWAS region. These challenges have been categorised into socio-technical and economic (Akolgo et al., 2019; Kontor, 2013; Osei et al., 2021; Owen and Ripken, 2017). Technical challenges include feedstock availability and supply challenges, ash handling, gas cleaning, tar minimisation, cleaning and moisture content reduction, and lack of tailor-made technology to suit locally available residues. Generally, the lack of funds to conduct repairs, maintenance, and modification are the major economic challenges and one of the stumbling blocks of the gasification projects.

a *b*

Figure 40:
a) 20 kW gasifier plant at Papasi and
b)120 kW gasifier plant at Asueyi

Source: Ghana Energy Commission (2016)

Beyond biomass: LPG and the emergence of electric cooking

Promotion of LPG for cooking

Due to the challenges of using biomass, efforts are being made across the region to increase access to LPG and electricity for cooking with some innovative dissemination strategies. Senegal started a 'butanization' programme in 1974. It exempted LPG-related equipment and appliances from import duties and promoted cooking appliances consisting of a stove mounted on top of a 2.7-kg cylinder (World Bank, 2021). The government shifted from promoting the stove-cylinder package to a price subsidy for LPG sold in 2.7-kg cylinders, which was later extended to LPG sold in 6-kg cylinders (World Bank, 2021). These subsidies were meant to help the poor access LPG for cooking. Subsidies have been intermittent in Senegal as the country's LPG policy has undergone several reforms. Over the years, there were concerns that subsidies were not benefiting low-income people. In line with the intermittent nature of the subsidy programmes, the share of households using LPG as the primary cooking fuel has fluctuated in recent years, falling sharply from 2010 to 2013 and not beginning to recover until 2016 (World Bank, 2021). The share of households using LPG as primary cooking fuel was 31.6% in 2010, reduced to 23.5% in 2014, rose to 31.2% in 2018 and reduced again to 27% in 2019. However, in most urban areas and particularly the capital, LPG is the main cooking fuel.

Notwithstanding these up-and-down movements, Senegal is one of the countries with the region's highest share of households using LPG. The government has partnered with organisations like the Clean Cooking Alliance to distribute subsidised LPG kits with stoves, tanks, and connectors to low-income households as part of efforts to reduce deforestation and indoor air pollution. It has also launched public awareness campaigns on the benefits of LPG for health and the environment.

Benin has been trying to transition households from traditional biomass to LPG for cooking. The promotion of increased use of LPG for cooking in Benin was achieved through various measures. One approach was to analyse the determinants of domestic LPG use in Benin (Adanguidi, 2021), which found that important factors for adopting domestic LPG included the residence department and the level of education. The government was urged to implement policies that promote the physical and financial accessibility to domestic LPG, such as subsidies, to the population still dependent on traditional biomass sources (Lokonon, 2020). Another study identified factors associated with adopting modern cooking fuels, including having a female household head, a household head with at least secondary formal education, per capita expenditures, access to electricity, and economic shocks (Diouf and Miezan, 2019). These findings suggest that promoting the use of LPG for cooking in Benin involved addressing socio-economic factors and improving accessibility. These factors are essential for the entire region. The government eliminated VAT on LPG in 2003 to reduce consumer costs (Adanguidi, 2021). The National Office for Petroleum Products partnered with LPG companies to run marketing campaigns promoting LPG usage. A micro-credit scheme was launched by the government and private partners in 2008 to provide small loans to purchase LPG equipment. Despite these efforts, most people still rely on wood/charcoal for daily meals. Access and cost remain key barriers, especially for poorer rural households.

Like Senegal and Benin, Cote d'Ivoire has actively encouraged a transition from traditional charcoal and woodfuels to LPG for cooking. The government has recommended the use of butane and has been promoting 'clean' cooking (Berte and Adou, 2023). The use of LPG for cooking is expanding rapidly in urban areas, with 92% of households in Abidjan equipped with LPG stove, although it is not always the main fuel used (Giordano et al., 2018). The aim is to switch from traditional sources to cleaner and more modern fuels (Diouf and Miezan, 2019). The government has reduced taxes and duties on LPG imports to make bottled LPG more affordable. It has also invested in import and storage infrastructure to improve supply logistics. Awareness campaigns have promoted the health and environmental benefits of switching to LPG for cooking in urban and rural areas. Cote d'Ivoire hosted the 4th West Africa LPG Expo in 2023 to promote regional LPG adoption. Like Senegal and Benin, charcoal remains widely used despite these efforts, especially in rural areas where LPG distribution is limited, and fuel switching is constrained by a purchase power much lower than in urban areas. Many urban low-income families also still rely on charcoal. Key challenges include the upfront cost of LPG cooking equipment and safety concerns. The challenges confronting Senegal, Benin, and Cote D'Ivoire are widespread in the region and must be addressed in efforts to transition from traditional biomass sources to modern fuels.

Emergence of electric cooking

Apart from developing and adopting improved cookstoves across the ECOWAS region, electric cooking is being promoted across member countries. The promotion has become necessary due to the region's low adoption of electric cooking. Ghana, for instance, boasts the highest electrification rate (87% as of 2022) in the region after Cape Verde. But, data from the 2021 census shows that only 0.4% of households use electricity as the main fuel for cooking. This section looks at promoting electricity for cooking, especially programmes supported by Modern Energy Cooking Services and Clean Cooking Alliance.

The Modern Energy Cooking Services (MECS) is a programme funded by UK Aid which aims to spark a revolution by rapidly accelerating the transition from biomass to clean cooking on a global scale. MECS has been very active in Africa and has conducted extensive research into clean cooking technologies in the region. The key research areas are the viability, cost-effectiveness, and user satisfaction of efficient electric cooking devices.

Some studies have been conducted in ECOWAS member countries. For example, studies have been conducted in Ghana to explore the effectiveness of using electric cooking methods to prepare popular Ghanaian foods using modern energy-efficient devices. The convenience of using electric cooking was also explored. The electricity consumption of the preparation of some common dishes and its comparison to primary cooking fuels (charcoal and LPG) in urban Ghana were also explored. Charcoal was the most expensive fuel, with LPG coming in a little cheaper and electricity over 50% cheaper overall (Sarpong et al., 2023). The study demonstrates that efficient electric cooking can be used to prepare Ghanaian favourite dishes at less cost without any variation to the food taste. The study recommended that commercial and domestic cooks should use modern electrical devices given the energy efficiency and potential to save time cooking with electricity. The dissemination of the outcomes of such a study can significantly contribute to changing people's mindset on electric cooking and encourage them to accept it as a primary energy source for cooking and other heat applications. MECS also has liaised with appropriate stakeholders and agencies to promote electric cooking in Ghana. These include Ministry of Energy, Ghana Energy Commission, Ghana Clean Cooking Alliance, Netherlands Development Organisation, GIZ, and Global LPG Partnership (GLPGP). Such studies must be done in other parts of the region as there may be unique cases with the cost of electricity and other fuels in different countries.

MECS provided technical support and partnered with other stakeholders to conduct research in Nigeria on controlled cooking tests using an electric cooker. The study investigated the cost and time of cooking and the energy required to cook food using an electric cooker compared to charcoal and firewood. The study sought to provide reliable data to back up the inclusion of electric pressure cookers as a clean cooking technology that is cost-effective, fast, and clean. The study outcomes were consistent with the findings of other cooking tests. Using an electric cooker is faster, more reliable, and more convenient than using firewood, charcoal, and LPG (Akpasoh and Edeminam, 2023). Therefore, this forms the basis for promoting electric cooking as a cost-effective clean cooking option.

In Cote d'Ivoire, initiatives to promote electric cooking and, in general, the development and adoption of improved cookstoves have been undertaken. Using electrical energy-efficient appliances for cooking can reduce cooking costs for consumers, release time that can be used for productive use or leisure and mitigate household air pollution's impact on families' health. Therefore, initiatives from MECS must be expanded to other ECOWAS member countries to ensure a wider use of electric cooking. However, adopting electric cooking is tied strongly to the reliability of existing grid infrastructure across respective countries, requiring resiliency in national electricity grid systems across member countries.

The Clean Cooking Alliance (CCA) also promotes clean cooking, including electric cooking. CCA complements partners' work to build a dynamic, inclusive, and financially sustainable cooking industry to achieve universal access to clean cooking by 2030. They aim to reduce the demand for firewood and charcoal, encouraging new forest growth.

Worldwide CCA approaches clean cooking activities as part of the wider conversation on climate action, systemic approaches, and financing for sustainable and just energy transitions. Across ECOWAS member countries, some initiatives have been implemented to promote electric cooking. CCA established its Venture Catalyst program in 2020 to help clean cooking companies innovate and scale up. Since then, the program has carried out 83 projects with 26 companies in 19 countries. In 2022, the Venture Catalyst added five new companies based in Ghana and Nigeria to its portfolio (CCA, 2022). CCA has also supported clean cooking weeks across ECOWAS countries. A typical example is the support of Nigeria's Clean Cooking Forum and a Ghana-specific convening following the Clean Cooking Forum. CCA also supported the development of Nigeria's Clean Cooking Strategy and the work of several national clean cooking associations (CCA, 2022), with electric cooking forming one of the strategies being promoted.

Notwithstanding the efforts mentioned above, electric cooking uptake is very low in the region. Access to reliable and affordable electricity remains the most immediate barrier to electric cooking for households without clean cooking in the region. For starters, many countries in the region have low access to electricity, with access rates worse in rural communities. In ECOWAS, access to electricity is characterised by very strong disparities between countries. Within the countries, similar disparities exist between urban and rural areas. In rural areas, access to electricity remains low despite some progress. In addition, the quality of service (frequent outages, fluctuating voltage levels, among others) is below international standards. At the regional level, the rate of household access to electricity in 2021 was around 56.34%, according to the ECOWAS Energy Information System. Of the 15 ECOWAS countries, only three have a rural electricity access rate of more than 35%. Where electricity is available, it is often not reliable, either due to regular generation shortfalls, or transmission and distribution challenges. Also, in many countries in the region, there is a widespread perception that electricity is expensive, compared to other cooking fuels (Leary et al., 2021), affecting its adoption for cooking. In view of this, more studies such as those presented above, as well as awareness creation on the outcomes of these studies, must be pursued while improving the general availability and reliability of electricity in the region. There are also mixed perceptions regarding the safety of electric cooking. These perceptions are likely, due to the abundance of poor-quality devices, which may cause serious injuries. Poor quality wiring is also a safety concern, especially for low-income households, as electric cooking appliances can easily overload thin cables designed for lighting (Leary et al., 2021). These challenges must be addressed if the region is to increase access to clean cooking.

Country Case Studies on biomass for productive purposes

Ghana (Heat and Electricity from Oil Palm Waste)

The production and consumption of woodfuels in Ghana are widely recognised for their contribution to the national energy supply and their significance for rural livelihoods. According to a World Bank study (Hooda et al, 2022), although the percentage share of woodfuels in the national energy mix fell from 70% to 35% between 1990 and 2019, demand for woodfuel is still increasing in absolute terms because of population growth. Firewood and charcoal are the main cooking fuels for 4.5 million households (HHs), and woodfuels are also widely used for institutional and commercial catering, industrial processing, and small enterprises. Figure 41 shows woodfuel consumption in residential, industrial, and commercial sectors. The increased absolute demand has led to concerns about impacts on forestry and wood resources. According to the report, 39% of charcoal producers surveyed declared that they source wood from natural forests. When juxtaposed with almost 7 million tonnes of wood used for charcoal production in 2022, it calls for serious measures to deal with the challenge. The report recommended focusing on four key areas to maximise the sustainability of woodfuel value chains, including increasing the supply of woody biomass, supporting cleaner and more efficient woodfuel use, promoting alternative energy sources, and strengthening the enabling framework for sustainable woodfuels.

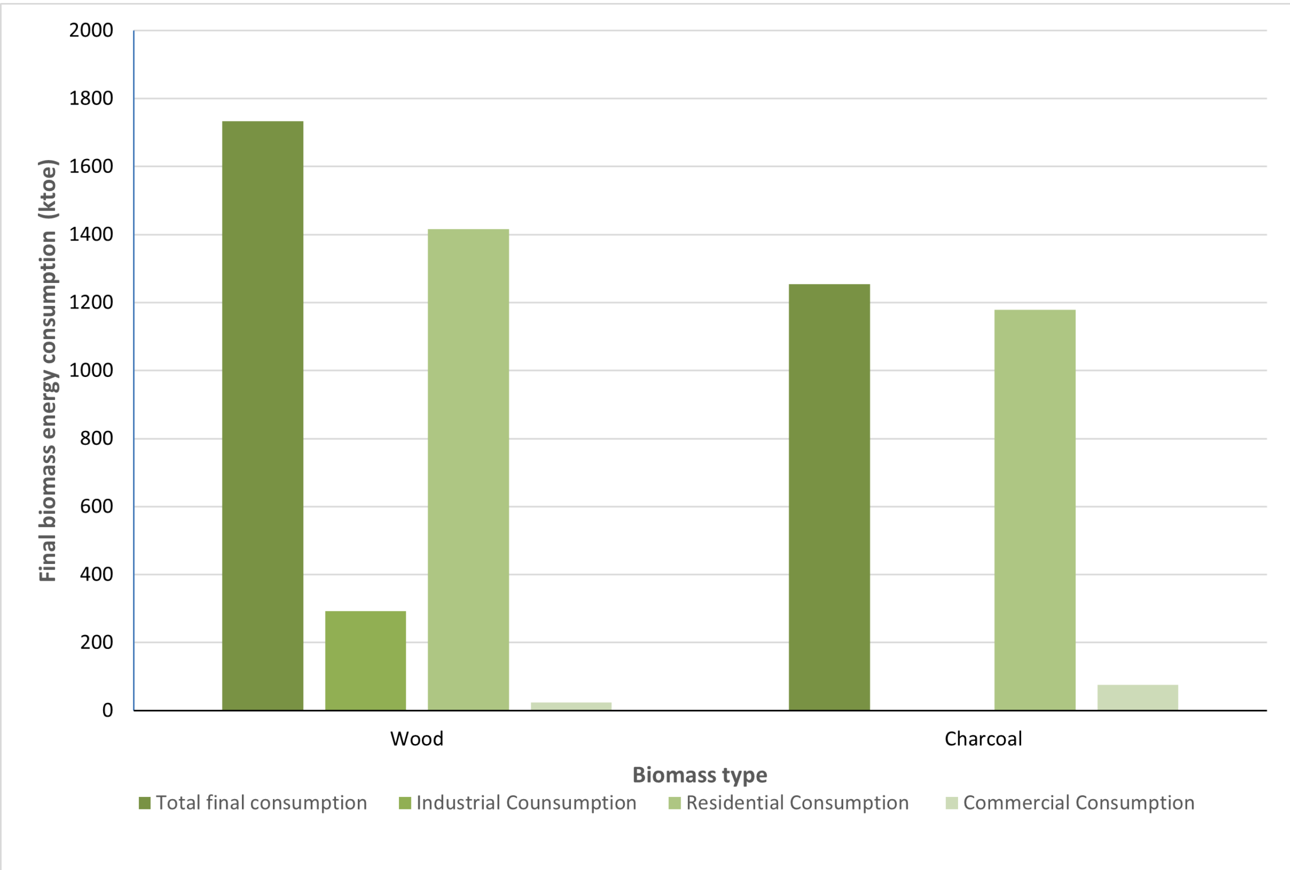

Figure 41: Final biomass energy consumption in Ghana

Source: Data from ECOWAS Energy Information System (2024)

The oil palm milling industry is leading the way towards promoting alternative energy sources in Ghana and could serve as a lesson for processing facilities in the region. The production of heat and electricity is a prominent activity in Ghana's oil palm processing sector. All the medium/large-scale oil palm processing plants produce heat and/or electricity from solid residue generated from the processing activities (See Table 4). The Ghana Oil Palm Development Company (GOPDC) utilises the liquid effluent to generate biogas in addition to the utilisation of the solid waste. GOPDC is the largest oil palm mill in Ghana and is owned by Société d'Investissement pour l'Agriculture Tropicale (nv Siat sa) of Belgium. Details of the GOPDC process are presented in Box 3.

Table 4: Small to medium-scale modern biomass plants in Ghana

Name of plant	Biomass feedstock	Technology type	Capacity of plant	Product
HPW Fresh and Dry	Fruit waste	Anaerobic digester (AD)	2 *450m^3	Heat
Benso Oil Palm Plantation	Oil palm waste	Combustion plant	500 kW	Heat/Electricity
Twifo Oil Palm Plantation	Oil palm waste	Combustion plant	1200 kW	Heat/Electricity
Ghana Oil Palm Development Company (GOPDC)	Oil palm waste	Combustion plant & AD	2500 kW and 2*10,000m^3	Heat/Electricity
Safisana	Faecal matter, industrial waste, and market waste	AD	100 kW	Electricity

Source: Ghana Energy Commission, 2016

BOX 3 Heat and electricity generation from oil palm waste at GOPDC

The Ghana Oil Palm Development Company (GOPDC) is Ghana's largest oil palm mill with a production capacity of 130,000 tonnes per annum 'fresh fruit bunch' palm oil mill and a 100 tonne/day refinery and fractionation plant. To promote sustainable biomass use, GOPDC utilises all its solid and liquid biomass residues to generate electricity and heat for its processing operations and provide the company's residential community with power.

View of GOPDC mill with plantation in the background

The solid wastes, which include empty fruit bunches and palm kernel shells, are used to produce heat and electricity in a combined heat and power (CHP) plant. The 2.5 MW CHP plant utilises all the solid wastes, with additional palm kernel shells sourced from adjoining communities to the mill. The power plant can supply about 90-95% of the company's power needs, including the residential areas. However, this may vary throughout the year, depending on production fluctuations. The rest of the company's power needs are met from the national grid.

Biomass combustion furnace at GOPDC

The liquid effluent from the mill is fed to an anaerobic digestion (AD) system. The AD system consists of two balloon digesters, each with a capacity of 10,000 m3. The plants operate at a temperature of between 30 to 35 degrees Celsius, with no external heating. During peak production season, biogas production is 300 to 400 m3 per day per reactor, reducing to about 55 to 200 m3 per day per reactor during the lean production season. Daily mixing is done using agitators, with the methane content of the biogas at about 56%. The biogas produced is used for steam production at the refinery. The boilers at the refinery consume virtually all the gas the biogas plants produce. Minor gas flaring occurs during the peak production season to reduce pressure in balloons. GOPDC's case is an interesting learning case for industrial processing units in the region producing large amounts of solid and liquid waste but not utilising these for modern biomass energy generation. When large amounts of waste are generated on-site, it serves as a free raw material for generating cheaper and more reliable energy sources, especially compared to the cost of other management and disposal systems.

A view of one of GOPDC's biogas plants and agitator

Aerial view of GOPDC biogas plants

Source: GOPDC[13]

[13] https://www.gopdc-ltd.com/latest-news/siat-wins-biogas-industry-award-for-best-agricultural-plant/

Guinea Bissau (Heat and Electricity from Cashew Nut Shells)

Biomass plays a critical role in the overall energy consumption in Guinea-Bissau. It contributed 85% to the final energy consumption in 2020 (see Table 5). Woodfuel is the most dominant among biomass types, constituting about 84% of final biomass energy consumption. Unlike other ECOWAS countries, residential biomass energy consumption is mostly dominated by fuelwood, with charcoal contributing just 8.3% of the final energy consumption in the residential sector (see Figure 42).

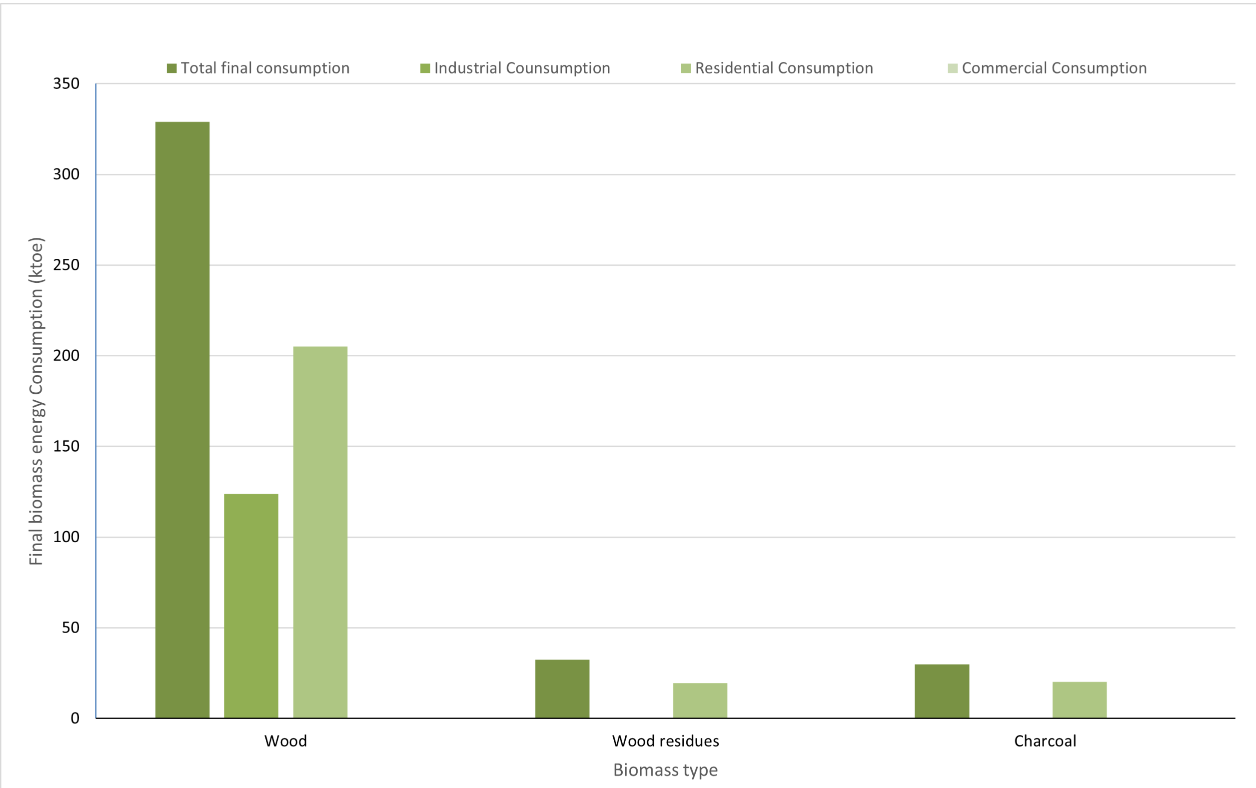

Figure 42: Final biomass energy consumption in Guinea Bissau

Table 5: Biomass energy production and utilisation in Guinea Bissau

	Wood (ktoe)	Wood residues (ktoe)	Charcoal (ktoe)
Production	389.52	32.4	29.92
Total Supply	389.52	32.4	29.92
Statistical difference	1.44	0.3	-
Transformation of which:	61.92	0.3	-
Charcoal production units	61.2	-	-
Other transformation	0.72	0.3	-
Total final consumption	329.04	32.4	29.92
Industry Sector:	123.84	-	-
Food, beverage & tobacco	7.92	-	-
Construction	16.2	-	-
Other industries not specified	99.72	-	-
Other Sectors:	205.2	32.4	29.92
Residential	205.2	19.5	20.24
Commercial & public services	-	-	-
Agriculture/forestry/fishing	-	12.9	9.68
Non specified	-	12.9	9.68

Source: ECOWAS Energy Information System (2024)

Despite the wider use of traditional biomass as fuel for cooking and other heat applications, Guinea Bissau has implemented some efficient and environmentally benign bioenergy technologies, particularly biomass combustion for electricity generation. The technologies are mostly installed in communities and industries with abundant biomass, with some specific cases discussed in this section. Cashew is by far the most important cash crop produced in Guinea-Bissau and contributes biomass waste that can be used for energy generation (see Table 6). Cashew is grown nationwide, mostly at family-scale plantations: most families are involved in cashew production (Pachero de Carvalho and Mendes, 2015). Total cashew production reached approximately 182,000 tonnes in 2013; official exports reached 132,000 tonnes that year, but large quantities were also exported to neighbouring countries without registration. Cashew apple, Cashew nutshell (CNS) and Cashew nutshell liquid (CNSL) are the main biomass by-products generated from cashew processing. Table 6 presents some details on its electricity production potential.

Table 6: Biomass resources in Guinea Bissau

Primary Product	Production (t/year)	By-product	Production (t/year)
Raw cashew nut	180,000	Cashew apple	504,000
	Processed 6,000	Cashew nutshell	3,675
		CNSL	750
Rice	Gross 200,000	Rice husk	26,400
	Net 120,000	Rice straw	120,000
Palm fruit	80,000	Solid waste	44,000
		Palm wastewater	80,000
		Palm kernel shell	30,000
Peanut	46,000	Shell	22,080
		Straw	105,800
Aguardente	2,750	Bagasse	30,000
		Cane trash	5,000
		Vinasse	15,000
Cattle (heads)	1,600,000	Dung	1,176,000
Logging/sawmilling (m^3)	6,400	Forest residues	4,103
		Wood chips	4,014
		Sawdust	1,338

Source: Frederiks et al. (2017)

Table 7: Electricity production and shell consumption for different conversion routes

	Unit	Steam engine [a]		Steam turbine [b]	
Net output	kWe	50	200	50	200
Net efficiency	%	5%	5%	3%	6%
Electricity production [c]	MWh/a	135	540	135	540
Annual shell consumption [d]	t/a	442	1767	690	1473
Specific shell consumption [d]	Kg/kWh	3.3	3.3	5.1	2.7
Annual shell consumption [e]	t/a	512	2046	799	1705
Specific shell consumption [e]	Kg/kWh	3.8	3.8	5.9	3.2

Notes: a based on Benecke boiler/steam engine (16/1.2 bar (a) steam pressures) (b) back pressure turbine (17/1 bar(a) steam pressures) (c) based on 3600 h/a at 75% capacity (d) steam cooked shell (e) oil cooked shell
Source: Frederiks et al. (2017)

Combustion of sugar cane bagasse and sugarcane thrash produced in the distillery sector represent the largest immediate potential (5.1 GWh/year), followed by wood chip gasification (2.3 GWh/year), biogas from cattle dung (1.5 GWh/year) and cashew shell gasification (1.4 GWh/year). Others, such as rice straw combustion, biogas from cashew apple, and gasification of palm kernel shells and rice husks, also show good theoretical potential. The main practical barrier to deploying these resources is their small-scale and dispersed production. Some biomass electricity plants have been implemented over the years. These systems make use of available biomass resources within companies or communities. Notwithstanding the successful implementation of some of these systems for a while, they experienced varying technical and economic challenges. Two such interesting case studies are discussed in Box 4 and Box 5.

BOX 4: SAFIM Biomass to Electricity Power Plant

The biomass power plant in Safim was originally conceived by FUNDEI (Guinean Foundation for Industrial Business Development / Fundação Guineense para o Desenvolvimento Empresarial Industrial) in 2007. The plant was constructed and started in 2012 with financial support from UEMOA. The plant has a horizontal fixed grate biomass boiler with a capacity of 1 MWth, an asynchronous AC alternator 82 kVA, and 415V with turbine-rated shaft power of 60 kW. The feedstock is cashew nut shell with a consumption of 201 kg/h (4.8 t/d).

The power plant was started up and tested in 2013. According to Frederiks et al. (2017), the plant operated for several days during the testing phase, but it was unknown whether it ever reached full power. During the testing phase, there were problems with the operation of the boiler: the cashew nutshell liquid coming out of the shells mixed with fuel and ashes and caused blockages in the grate. This prevented ash disposal and air supply through the grate. Operating the boiler required constant raking to clear the grate, making it impossible to operate the boiler with the furnace doors closed. Also, smoke production was excessive, covering the plant's immediate surroundings in smoke. After the testing phase, the plant operation was discontinued, with 45 kWh of energy generated.

BOX 5: SICAJU Power Plant

Another pilot project of interest is the 75 kWe SICAJU plant. The plant produced electricity and processed steam for the cashew plant, using waste cashew shells. The equipment functioned satisfactorily until 2009; the cashew processing plant was closed temporarily, and when it was started up again, the boiler still worked, but the steam engine malfunctioned. The maximum load of the SICAJU factory is some 30-40 kVA, and the power plant supplied this load without problems. There was always an excess of cashew shells available while running the power plant – SICAJU processing capacity is approx. 1200 t/year, but this could be increased by adding shifts.

The challenges and lessons from these biomass plants can be used to ensure successful implementations of such projects across ECOWAS member countries. For example, the Safim Biomass plant's main technical barrier is the steam engine's malfunction, which requires a specialist's assessment and resolution. As the plant has functioned well for two years, and the equipment has been well-kept, it is expected that no major refurbishment is required. As noted by Federiks et al. (2017), there is limited knowledge and experience in developing biomass-to-electricity projects in Guinea Bissau. It was reported that in-depth technical knowledge on biomass properties, selection of appropriate technologies, efficiencies and biomass-to-energy conversion rates, and plant scaling are lacking. In the case of the Safim power plant, this has led to poor technology selection, underestimation of fuel consumption, selection of a site at a distance far from potential biomass suppliers, and disregard for existing electricity supply concession. Therefore, replications of such projects across ECOWAS countries require in-depth technical analysis to ensure the selection of the appropriate technology based on the biomass feedstock available and, most importantly, the plant's siting at an appropriate location to ensure the sustainable feedstock supply. Local workforce development is critical if such plants are to function properly and be sustainable.

Burkina Faso (Biomass for Productive Activities)

Biomass plays an important role in energy production in Burkina Faso. In 2020, biomass constituted 73.6 % of the total final energy consumption in Burkina Faso (see Table 8). Among the biomass types, woodfuel is the most consumed fuel, constituting 76.2 % of the final biomass energy consumed in the country. Residential use of biomass dominates the biomass landscape, as shown in Figure 43.

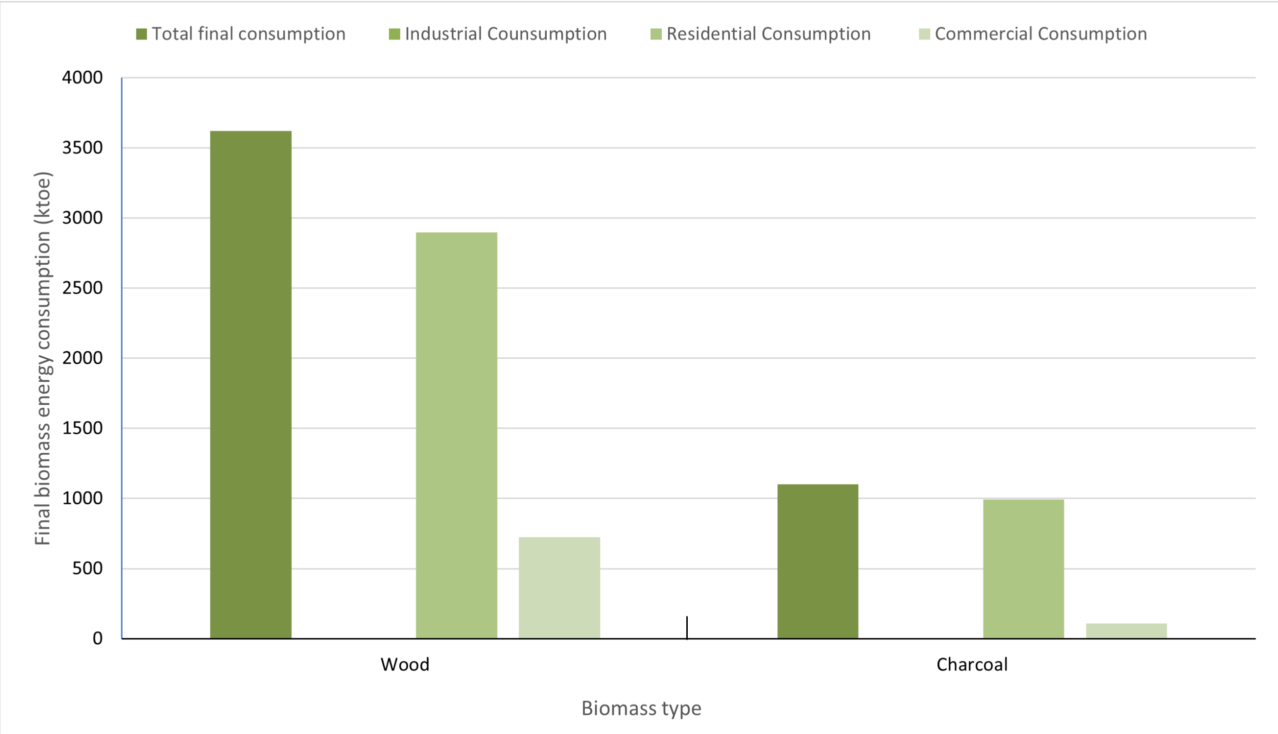

Figure 43: Final biomass energy consumption in Burkina Faso

Table 8: Biomass energy production and utilisation in Burkina Faso

	Wood (ktoe)	Agriculture residues (ktoe)	Charcoal (ktoe)
Total Supply	5425.2	27.2	1102.64
Transformation of which:	1804.68	-	-
Charcoal production units	1804.68	-	-
Total final consumption	3620.16	27.2	1102.64
Residential	2896.2	27.2	992.64
Commercial & public services	723.96	-	110

Source: ECOWAS Energy Information System (2024)

After residential usage, commercial use for productive activities is the next most important application of biomass fuels in Burkina Faso. An example of such productive use of biomass is the BioStar project, which is developing sustainable bioenergy solutions for small agrifood enterprises in rural parts of Burkina Faso (and Senegal). Sixteen Burkina Faso and Senegal SMEs are involved in the project as pilot enterprises. The first bioenergy equipment, which produces dried mangoes, was installed at AgroBurkina (see Figure 44). The company uses a dryer using heat generated by burning cashew nut shells (Cirad, 2023). AgroBurkina is convinced of the technology's merits and plans to install another, larger-capacity bioenergy-fuelled dryer made by local manufacturers. Identical equipment will also be produced locally and installed at three other pilot mango drying units in Burkina Faso and Senegal.

Figure 44: Drying of Mangoes using heat produced from the combustion of cashed shells

Source: Cirad (2023)

One other productive use of biomass in Burkina Faso is the use of firewood for brewing beer. In Burkina Faso, beer brewing is the third most important livelihood, after farming and wage labour. The country's two major cities, Ouagadougou and Bobo-Dioulasso, have around 2,380 and 1,144 breweries, respectively, producing the local dolo beer (GIZ, 2013). Beer production consumes significant quantities of firewood. The FAFASO (Foyers Améliorés au Burkina Faso) project supports the dissemination of efficient stoves for beer production. The project introduces large stoves to millet beer brewers, particularly in the big cities. The improved mud stove Foyer dolo Roumdé for local beer production (Figure 45), disseminated by FAFASO, saves more than 60% on fuel in comparison to older stove models and even more than 80% in comparison to the traditional three-stone fires, which are still often used in rural areas, even for beer brewing (GIZ, 2013).

Figure 45: The use of Firewood in improved cookstoves for Beer Brewing in Burkina Faso

Source: GIZ (2013)

COP28 and the way forward for modern biomass usage in the ECOWAS region

At COP 28, 118 governments pledged to triple renewable energy capacity by 2030. However, Civil Society Organisations (CSOs) frowned upon biomass for large-scale electricity generation, fearing the dangers of grazing down forests for biomass electricity production and the impact it may have on communities and farmlands, especially in Africa. This stance by CSOs may affect funding going into large-scale biomass power solutions in the region, especially if the feedstock is not waste-based. However, it creates an opportunity for ECOWAS member countries to concentrate on smaller solutions, such as those on clean cooking and other productive purposes.

According to the Stockholm Environment Institute (SEI, 2024), international donors have committed to investing billions of dollars into clean cooking at COP28. It is expected that about USD 4.5 billion a year could be available to support clean cooking. The African Development Bank also pledged to direct about 20% of their energy sector investments to clean cooking, making an additional USD 2 billion available for clean cooking initiatives over ten years. ECOWAS countries must be well placed to unlock some of these funding opportunities to support the transition to clean cooking in the region. Key issues that must be addressed include increasing access to improved cookstoves, promoting improved wood carbonisation technologies, promoting the production of pellets and briquettes from waste-based resources that would otherwise be discarded, and promoting a wider and faster transition to LPG and electricity for cooking. This is also in line with the ECOWAS bioenergy policy and the Updated ECOWAS Energy Policy.

Improved biomass cookstoves have been promoted in the region for many years, but most households still use less efficient biomass stoves for cooking. Availability, affordability and cooking methods are among the challenges hindering widespread adoption. These issues must be appropriately addressed, in line with recommendations from the ECOWAS Bioenergy Policy and ECOWAS Renewable Energy Policy. Reducing the amount of wood used for energy in ECOWAS countries will not be achieved with improved cookstoves alone. The region must also emphasize the promotion of improved charcoal kilns for the efficient production of charcoal, which is a major cooking fuel for urban communities in the region. In addition to creating awareness of the benefits of improved carbonisation technologies, there must also be capacity building to localise the construction of kilns and make improved kilns affordable in rural communities where charcoal is mainly produced.

Biomass briquettes and pellets from solid biomass can replace fuelwood and reduce deforestation. They can be used for both domestic cooking and small-scale commercial activities. These must be promoted as part of the overall strategy to transition towards clean cooking.

At the top of the cooking energy ladder for every country is LPG and electricity. Transitioning to LPG and electricity for cooking should be the ultimate aim for clean cooking in the region. Innovative approaches are needed to complement existing efforts to increase access to LPG and electricity for cooking. Research is needed to promote electric cooking technology that uses less electricity, including induction stoves, because electric cooking is one of the surest ways to decarbonise cooking in the region. More evidence of the affordability of electric cooking is also needed to convince households to switch to electric cooking technologies.

Beyond household cooking, it is also important for the region to look strongly into the promotion of biomass for productive purposes, such as is done by existing small-scale processing industries in the region. Case studies have been provided of ongoing efforts in Burkina Faso to promote sustainable biomass use for productive purposes. Initiatives such as those in Burkina Faso are needed in other countries where biomass is used in large quantities for productive ventures, to ensure sustainable use. Design and fabrication of improved biomass application devices that suit processing needs and cultures of respective countries and their localities is needed, as well as training of businesses in sustainable practices in the use of biomass.

As shown in the Ghana Oil Palm Development Company (GOPDC) case study, there are also opportunities to use agricultural and process waste from the processing plants scattered across the region for captive heat and electricity production to supplement supply from the grid. GOPDC's case shows an example that can be replicated across the region, especially with the advancement of biomass conversion technologies that are able to utilise a plethora of biomass waste sources to generate heat and electricity. The ECOWAS region abounds in primary and secondary agricultural activities that generate large amounts of biomass waste that should be sustainably utilised for energy purposes.

With regards to liquid biofuels, some countries in the region have acknowledged the potential benefits of developing domestic biofuel industries to enhance energy self-sufficiency for transportation, and rural development. However, it is essential to balance economic aims and social and environmental priorities and establish clear governance frameworks to promote sustainable growth of the liquid biofuels sector. To increase biofuel production in the region, public-private collaboration, community-level scaled projects, public enlightenment, tax incentives, and sustainable technology adoption are recommended. If done responsibly, biofuels could become an increasingly important fuel in the region's transportation energy mix in the coming years. Sustainable liquid biofuels production should avoid conflicts between that could likely results from competitive use of land for food and fuels. Efforts must be made to sustain food production activities while promoting biofuels production for transportation.

Ultimately, policy coherence and long-term effects will be best realised under a regional context, which require harmonising approaches in line with Strategic Objective 6 of the Updated ECOWAS Energy Policy which aims to increase access to modern, clean energy for cooking in the region.

3 TRANSITION TO MODERN FORMS OF ENERGY FROM THE BIOMASS SUBSYSTEM

The approach and methodology adopted fall within the framework of the strategies and guiding principles of the ECOWAS updated energy policy adopted in May 2023. This policy is characterized by a long-term energy mix that is less dependent on fossil fuels and compatible with the objectives of economic, social, and environmental development as well as energy security.

An approach based on the needs of both rural and urban areas is essential to align with a logic of economic, social, and environmental development. To address these constraints, it is imperative to rely on a model that meets these criteria (demand-based approach, compatibility with national energy balances), while being sufficiently flexible to accommodate the complexity of the country's energy system, particularly regarding final consumption of both rural and urban areas.

What does universal access to energy mean: credible alternatives?

In ECOWAS countries, traditional energies or biomass (firewood and charcoal) still play a significant role in household consumption, mainly for cooking purposes. However, there are significant disparities between rural and urban areas and among countries. For example, in Cape Verde, traditional energies are only minimally used while they are predominant in countries such as Guinea Bissau or Mali.

Universal access implies reducing the share of the traditional biomass, which will be replaced by clean energy sources. In the case of ECOWAS countries, this primarily involves LPG (liquefied petroleum gas) and potentially natural gas in urban areas starting from around 2040.

ECOWAS biomass energy system[14]

In ECOWAS as well as in many sub-Saharan Africa countries, biomass, mainly firewood and charcoal, accounts for the bulk of the total final consumption particularly to meet the cooking needs for urban and rural households. In 2021, biomass in ECOWAS countries including charcoal accounted for 60% of the final consumption with sharp differentiations between urban and rural areas.

The pattern of production and consumption of biomass is linked with a combination of adverse environmental, health, social, and economic impacts. As far as environment and climate change are concerned, the use of traditional biomass, such as wood and charcoal, contributes to deforestation and environmental degradation. Burning biomass for cooking releases greenhouse gases, contributing to climate change although this is controversial if biomass is used in a sustainable way.

Gender impact: Traditional biomass for cooking often requires collecting firewood or other biomass fuels, which can be time-consuming and physically demanding, particularly for women. Indeed women, who are traditionally responsible for cooking in many societies, often are the most impacted with traditional biomass use.

Transitioning to clean cooking solutions may dramatically positively impact climate change and improve the livelihoods of households who heavily rely on traditional biomass. The transition to clean cooking aligns with several Sustainable Development Goals (SDG), including those related to health and well-being (SDG3), gender equality (SDG5), affordable and clean energy (SDG7), and climate action (SDG13). Access to clean fuels and efficient technologies, particularly for cooking, produce fewer or no greenhouse gas emissions, thus helping combat climate change. Furthermore, efficient technologies and clean fuels can empower women by improving their health, reducing their workload, and giving them more time for education and income-generating activities. These benefits however imply a comprehensive understanding and quantification of the current and future biomass sub energy systems which is not yet the case in most sub-Saharan African countries.

[14] In this report biomass encompasses firewood and residues on one hand and charcoal on the other hand

Should emissions from biomass be accounted for, and what methodology should be used?

There is a fundamental difference between combustion from fossil fuels and biomass combustion. The combustion of fossil fuels releases carbon that has been locked in the Earth for millions of years, while biomass combustion emits carbon that is part of the biogenic carbon cycle. The use of fossil fuels increases the total carbon quantity in the biosphere-atmosphere system, whereas bioenergy systems operate within this system. Carbon from biomass combustion simply returns to the atmosphere and is absorbed during plant growth.

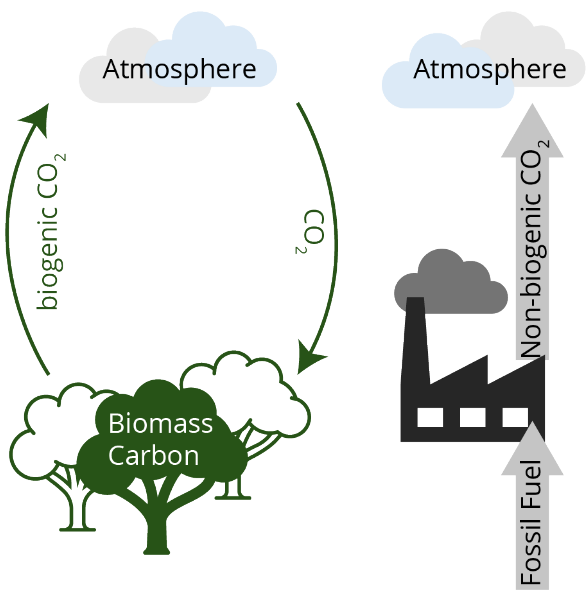

Figure 46: The biomass ecosystem

Source: www.ieabioenergy.com/iea-publications/faq/woodybiomass/biogenic-co2/

The net result of greenhouse gas (GHG) emissions from using biomass for energy is not estimated by calculating emissions at the point of combustion. Biogenic carbon flows and all associated fossil GHG emissions are accounted for by considering the **entire bioenergy system**. This explains why bioenergy is considered a carbon-neutral energy source and is promoted by government policies as a substitute for fossil fuels. For the same reason, no carbon tax is applied to biomass combustion. It must however be highlighted that **unsustainable** exploitation of biomass leads to soil and land degradation, deforestation and in extreme cases desertification, resulting in net additions of greenhouse gas emissions.

Representation and quantification of ECOWAS biomass energy system

The ECOWAS biomass energy system is relatively complex and characterized by its informality. The complexity is influenced by a variety of factors, including socio-economic, technological, environmental, and policy considerations. ECOWAS' supply is sourced from a wide range of biomass resources, including agricultural residues, forestry waste, and animal dung. Part of these primary resources are transformed into charcoal through, in most cases, traditional and non-efficient equipment (see figure 46).

Charcoal is a major source of energy for cooking and heating, particularly in urban areas whereas biomass and waste, mainly firewood, are predominant in rural areas. Furthermore, charcoal production is a source of income for many households in both urban and rural areas providing employment opportunities for those involved in the production, transportation and commercialisation of charcoal.

Charcoal production in sub-Saharan Africa is often characterized by informal and traditional practices relying on traditional and inefficient technologies in the carbonization process. These practices contribute to soil erosion, habitat loss, and long-term environmental damage. One of the significant challenges associated with charcoal production is deforestation. Moreover, traditional cooking methods involving charcoal can lead to indoor air pollution, posing health risks, particularly for women and children who spend significant time near open fires.

Transitioning to modern, clean and sustainable biomass technologies requires overcoming entrenched habits and cultural preferences. In our modelling, we shall be considering firewood and waste one hand and charcoal on the other hand. **The concept of biomass and waste** will encompass all biomass forms, including charcoal. The following diagram summarizes the biomass energy sub system.

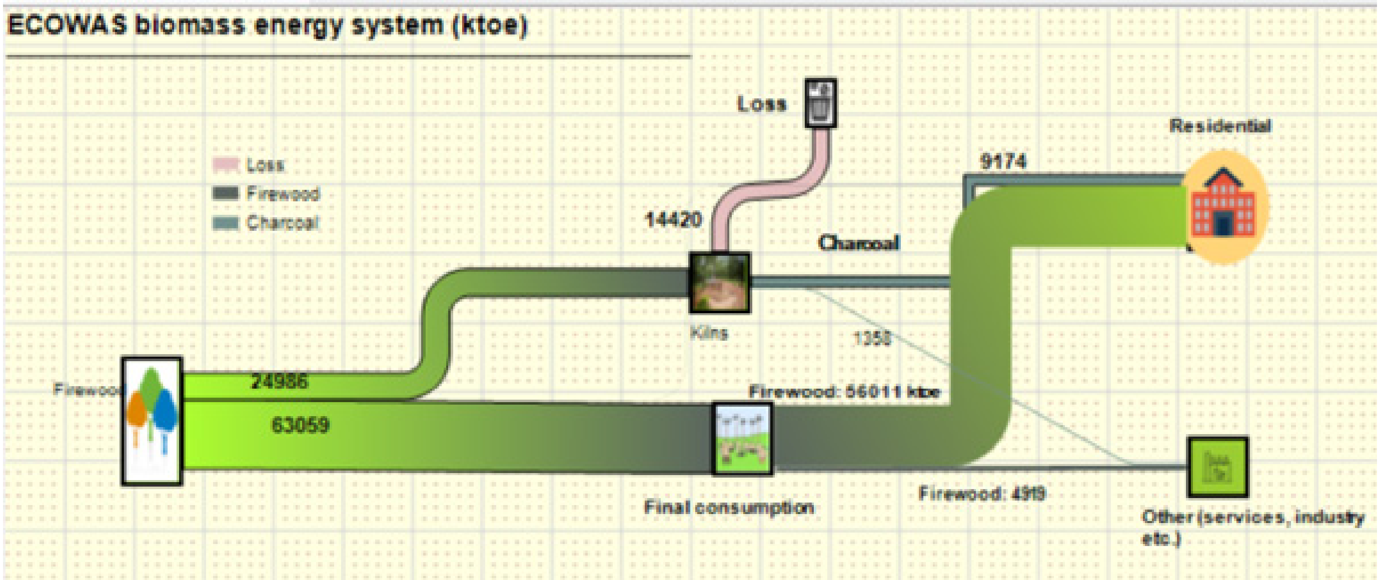

Figure 47: ECOWAS biomass energy system in 2021 (ktoe)

In 2021, almost 89.5 Mtoe of biomass were produced within the ECOWAS region. Part of this primary production, approximately 25 Mtoe, was transformed into charcoal. The remaining biomass was used as cooking fuel mainly in rural areas. The bulk of biomass and charcoal are devoted primarily to meeting the needs of both urban and rural households. A fraction is devoted to services (restaurants for instance) and industry, mainly small-scale traditional industries such as breweries, brick making, ceramics, etc. Given the low efficiency rates of the carbonisation process, there are heavy losses, estimated at 14.4 Mtoe in 2021. Charcoal production is often informally regulated, leading to challenges in monitoring and controlling unsustainable practices.

Criteria for biomass modelling and energy transition

There is now a large consensus on the social, economic and environment benefit of the transition from traditional biomass to modern and clean forms of energy particularly for cooking. Transitioning from traditional biomass to clean fuels is essential for improving health, protecting the environment, promoting gender equality, and fostering sustainable development on a global scale. However, at least for ECOWAS, this is not substantiated with comprehensive pathways over a long-time horizon to assess the feasibility of the transition nor the dichotomy between urban and rural areas. Beyond the principles which are paramount, such an objective requires a rigorous methodological approach encompassing the following steps. The assumptions will encompass rural and urban areas and all fuels according to figure 48.

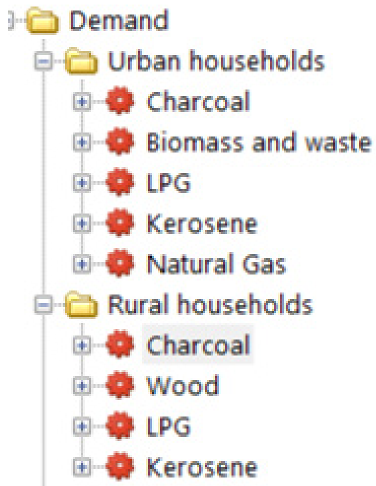

Figure 48: urban and rural households tree

Differentiated scenarios for urban and rural areas

Given the disparities between urban and rural areas, achieving universal access requires different scenarios and hypotheses for urban and rural zones. Furthermore, considering the current low access rates to clean fuels in rural areas, the regional objective of universal access by 2030 is not realistic because it would require a massive penetration of LPG, the only credible energy source by 2030. Current LPG production capacities are insufficient. Significant quantities of LPG will need to be imported, significantly impacting the trade balance of these countries. Besides the budget allocated for imports, current infrastructure (bottling units, transportation trucks, port terminals, etc.) must be considerably developed.

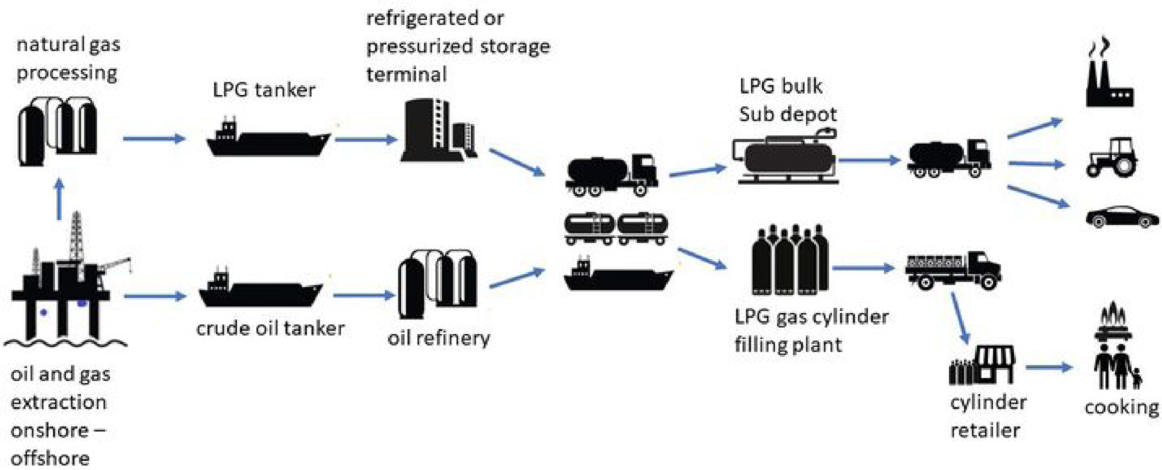

Figure 49: LPG value chain

Source: Ssource energypedia) lpg value chain -

Base year and source of data

The base year is 2021 for which ECOWAS has collected, processed and carried out quality check of data received from most member states. For a limited number of countries who have not yet sent their data to ECOWAS, extrapolation to 2021 was used based on historical data. Furthermore, unlike 2020, the year 2021 can be considered a normal year because it was not marked by cyclic phenomena of high magnitude as was the case during the COVID-19 pandemic.

Database : ECOWAS and member states

The statistical database selected is derived from the ECOWAS energy information system This is a comprehensive and transparent database, accessible online (*https://eis.ecowas.int/*). It encompasses the entire energy system, from production to final consumption. Additionally, most data are available in tons of oil equivalent (toe) as well as in specific or physical units. Key statistics are provided by member states.

Scenarios and Time Horizon

The time horizon extends until 2050 with an analysis of results in 2030, 2035, 2040, and 2050. However, calculations will be available for all years covering the period 2021-2050. Apart from the reference scenario (BAU), a scenario of energy transition (TRANESCOWAS) is developed. This scenario is characterized by a significant decrease in traditional fuels (firewood and charcoal) compensated by a strong penetration of clean and modern energies, especially for cooking, such as LPG.

Model chosen for modelling the biomass sub-sector and justification

The LEAP (Low Emissions Analysis Platform) model has been chosen to develop the scenarios of the biomass subsystem. Several factors justify this choice:

- Numerous studies have highlighted the relevance of LEAP model, particularly its efficiency and alignment with energy balances similar to those established by ECOWAS.
- LEAP is a robust and widely recognized platform that can effectively capture the intricacies of the biomass subsystem while providing transparency and flexibility to adapt to various scenarios and policy frameworks. For instance LEAP has been by several African countries for their Nationally Determined Contribution to the United Nations Framework on Climate Change (UNFCC).
- LEAP also offers the advantage of being an open model, allowing for great flexibility for the user and transparency, particularly in calculations and the selection of assumptions.
- LEAP is categorized as a bottom-up model, meaning it starts from disaggregated demand which form the basis of the model.
- The ECOWAS new regional energy policy has been modelled based on LEAP model.

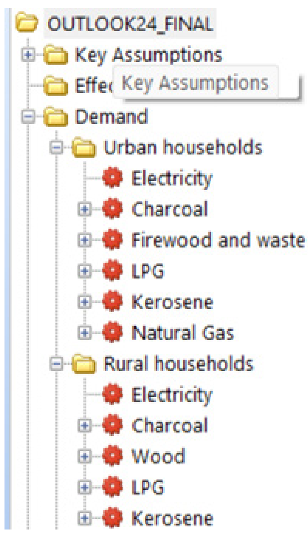

Figure 50: urban and household tree for ECOWAS (Leap model)

Rural and urban households breakdown till 2050: demographic trend

Data collection for annual energy balances produced by member states does not include a dichotomy between urban and rural households. For future trends this dichotomy is essential as the consumption pattern between rural and urban areas is different as well as the demographic trend. The following figure and table show the demographic trend till 2050 of both urban and rural households to model the biomass consumption.

Figure 51: Urban, rural and total population 2021-2050

Table 9: Urban, rural and total population 2021-2050

Branch	2021	2025	2030	2035	2040	2045	2050
Urban population	184,41	232,16	277,95	329,19	385,99	448,65	516,64
Rural population	207,77	225,59	240,50	255,47	269,88	282,57	293,08
Total population	392,18	457,75	518,45	584,66	655,87	731,22	809,72

Source: United Nations database, Population division

Biomass consumption typology in urban and rural areas

The consumption pattern of biomass, firewood and charcoal varies dramatically according to urban and rural areas. Charcoal is predominant in urban areas whereas biomass (firewood) is the main cooking fuel in rural areas. Rapid urbanization has led to a growing demand for charcoal in urban areas, driven by population growth and rural migration. This increased demand often exacerbates environmental issues. However consumption in both areas have impact on deforestation.

Firewood and charcoal are the main biomass fuels to meet households demand in both urban and rural areas. It is assumed that **90% of charcoal and 5% of firewood** are devoted to meeting the demand of urban areas whereas **10% of charcoal and 95% of firewood** are consumed in rural areas. **These assumptions are derived from the regional energy policy.**

Conversion from specific units to tonnes of oil equivalent and default calorific values

The conversion is based on the default calorific values of the respective fuels according to the UN International Recommendations for Energy Statistics (IRES[15]). Default values are used when specific calorific values are not available. Default calorific values, which refer to the energy content of fuels with specific characteristics, are generally applicable to all circumstances (different countries, different flows, etc.). Specific calorific values are based on the specificity of the fuel in question and are measurable from the original data source. Given the diversity of biofuels specifics within ECOWAS and the absence of measurement, default values is the best methodological approach to the conversion issue. In many instances there are sharp differences between the upper and lower values. For instance, for fuelwood and charcoal the calorific values are as follows.

Table 10: Calorific value of the main fuels used for cooking

GJ/metric ton	Default calorific value	Lower calorific value	Upper Calorific value
Fuelwood and residues (firewood and waste)	15,6	7,9	31
Charcoal	29,5	14,9	58
LPG	47,3	44,8	52,2

Source: UN-IRES (2018, table 4.1)

[15] International Recommendations for Energy Statistics (IRES, 2018) , UN ST/ESA/STAT/SER.M/93,

Quantifying urban and rural consumption

In 2021, according to updated ECOWAS energy balances, the total consumption of firewood and waste[16] reached 63,069 ktoe and that of charcoal 10,532 ktoe.

Based on these assumptions and the biomass consumption typology, urban areas consumption is as follows

Table 11: Urban energy consumption in 2021 (ktoe)

Branch	2021 value	Current Account Expression	Unit
Charcoal	9 478	10532*0.9	ktoe
Biomass and waste	3 153	63059*0.05	ktoe
LPG	1 147	1247*0.92	ktoe
Kerosene	128	643*0.2	ktoe
Natural gas	0	0	ktoe

In rural areas, firewood is the main energy source particularly for cooking. The share of clean fuels is relatively small. The following table shows the total consumption and the share of rural consumption and its breakdown among all energy sources.

Table 12: Rural energy consumption in 2021 (ktoe)

Branch	2021 value	Current Account Expression	Unit
Electricity	518	2589*0.2	
Charcoal	1 053	10532*0.1	ktoe
Biomass and waste	59 916	63069*0.95	ktoe
LPG	100	1247*0.08	ktoe
Kerosene	514	643*0.8	ktoe

[16] In this report biomass will encompass all types of biomass (firewood, bioenergy wastes etc.)

The following table summarizes charcoal and biomass consumption in both urban and rural areas.

Table 13: Charcoal and firewood &waste consumption in rural and urban areas in 2021

ktoe	Total consumption	Urban areas	Rural areas
Charcoal	10,532	9479	1258
Firewood and waste	63,069	3153	59,915

Firewood and charcoal consumption trends in urban and rural areas: Reference scenario

Due to significant variations in the types of fuel consumption and disparities in social and economic wealth, the energy transition will fundamentally differ between urban and rural areas. Additionally, the accessibility to clean fuels is contingent upon the urban or rural nature of the respective areas. It is therefore paramount in modelling energy transition to split urban and rural areas.

In order to take into consideration the uncertainties, two scenarios have been developed. The first scenario is the **reference scenario** (which is the business-as-usual scenario (BAU) without significant changes or disruptions. The BAU is a **benchmark** for analysing the current trend of biomass production and consumption within ECOWAS in order to develop appropriate strategies and plans of action.

The second scenario (TRANSECOWAS) is in line with the principles of access to clean efficient and modern forms of energy, and equity between rural and urban areas. It is assumed that ECOWAS countries will have access to international financial resources such as the pledges committed under COPs or the requests to technological and financial support in the Nationally Determined Contribution (NDC) submitted to the UN Framework Convention on Climate Change (UNFCCC)

Assumptions for the BAU scenario

Urban consumption in 2021 is as follows:

Urban population (thousand)	Total firewood and waste urban Consumption (ktoe)	Firewood and waste (kgoe/capita/year)	Total charcoal consumption (ktoe)	Urban charcoal (kgoe/capita/year)
184 411	3153	17.1	9478	51.4

Sources: ECOWAS energy balances, UN Population division

Rural consumption in 2021 is as follows:

Rural population (thousand)	Total firewood and waste urban Consumption (ktoe)	Firewood and waste (kgoe/capita/year)	Total charcoal consumption (ktoe)	Rural charcoal (kgoe/capita/year)
206 903	59915	289	1053	5.1

Sources: ECOWAS energy balances, UN Population division

Dynamic of urban and rural consumption 2021-2050 and alignment with ECOWAS regional energy strategy

The assumptions developed will vary according to urban and rural areas. This is due to different patterns of consumption in the two areas. In order to be aligned with the regional energy strategy, the assumptions are to a large extent derived from the updated energy policy adopted in 2023 by ECOWAS member states. To take into consideration the growth rate dynamics between 2021 and 2050, three periods will be considered with different growth rates.

In the BAU scenario the growth rate of biofuels will be far below the demographic growth rate. This is due to fuel switching from biofuels to LPG. This trend expects LPG growth rates higher than the demographic rate. Such a trend contributes to increasing access to clean cooking. The consumption of kerosene for cooking will decrease in line with the trends observed in ECOWAS countries The growth rates for urban areas are as follows (%):

Table 14: Dynamic of cooking fuels in urban areas in ECOWAS countries 2021-2030: Business as usual scenario

	2021-2030	2031-2040	2041-2050
Charcoal	1.59%	1.89%	1.79%
Wood	1.95%	1.89%	1.79%
LPG	6.1%	7%	7%
Kerosene	-2%	-3%	-3%

Key results in urban areas 2030-2040-2050

Despite partial fuel switching from traditional fuels to LPG and a growth rate of consumption far below the urban demographic growth, charcoal consumption is expected to reach high absolute levels by 2050, significantly impacting on deforestation and greenhouse gas emissions. LPG consumption will reach 8.5 Mtoe, approximately eight times the 2019 level.

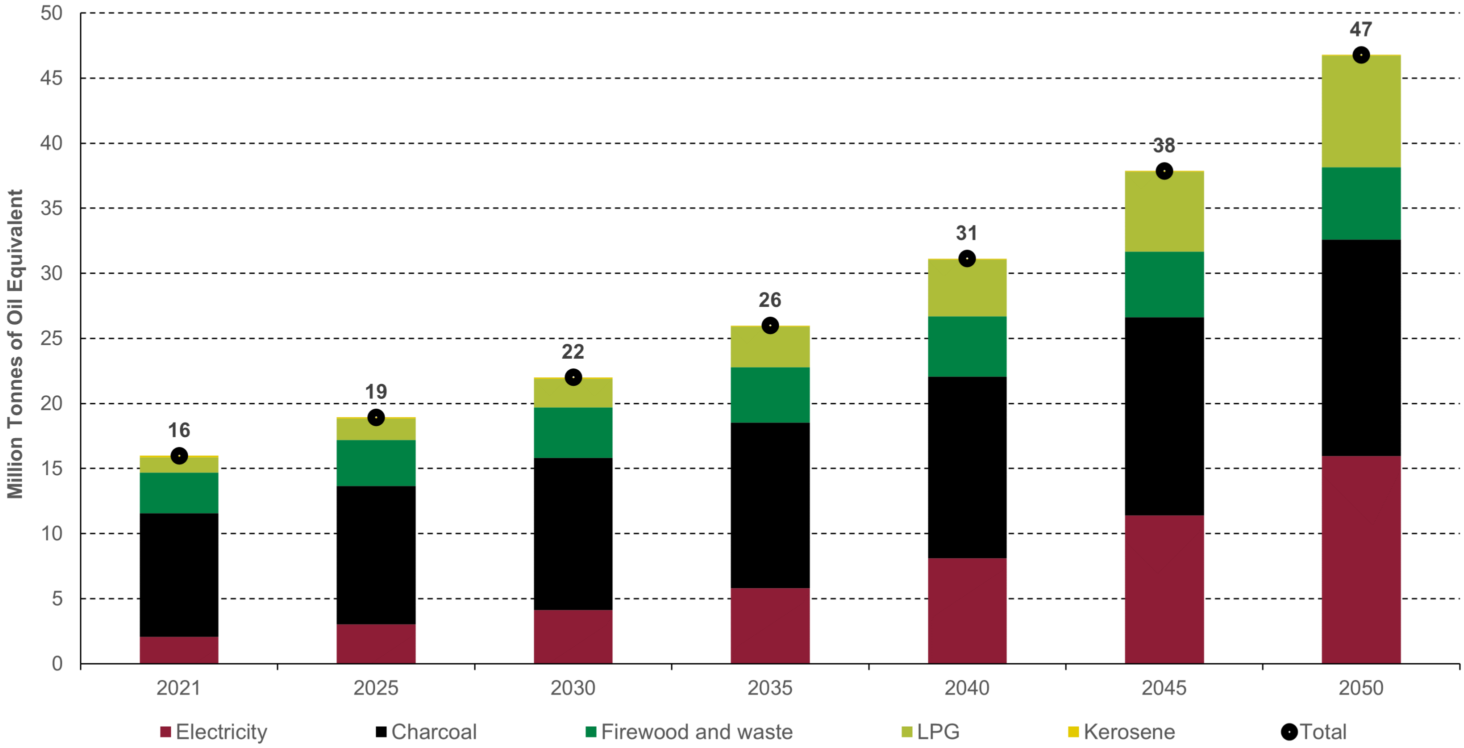

Figure 52: Urban consumption by energy sources

Table 15: Urban household consumption by energy sources 2021-2050 reference scenario (Mtoe)

Branch	2021	2025	2030	2035	2040	2045	2050	Annual Growth rate 2021-50
Electricity	2.1	3.0	4.1	5.8	8.1	11.4	16.0	7.3%
Charcoal	9.5	10.6	11.7	12.8	13.9	15.2	16.6	2.0%
Biomass and waste	3.2	3.5	3.9	4.2	4.6	5.1	5.5	2.0%
LPG	1.1	1.6	2.2	3.1	4.4	6.1	8.6	7.2%
Kerosene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-2.9%
Natural gas	-	-	-	-	-	-	-	-
Total	16.0	18.9	22.0	26.0	31.0	37.9	46.8	3.8%

Assumptions and trends for rural areas

In rural areas the key drivers of the demand for cooking fuels are demographic growth, access to modern fuels for cooking and purchasing power. Unlike urban areas, rural areas are located far from the LPG production and distribution centers which increase the final costs due to higher transportation costs. Even when this component is subsidized it is not always implemented. Based on the findings from the ECOWAS regional policy, the assumptions are as follows:

Table 16: Dynamic of cooking fuels in rural areas in ECOWAS countries 2021-2030: Business as usual scenario

	2021-2030	2031-2040	2041-2050
Charcoal	1.50%	1.89%	1.89%
Wood	0.5%	-1%	-1.5%
LPG	6.61%	7%	7%
Kerosene	-3%	-3%	-3%

In rural areas, despite a decrease of the firewood consumption rate over the period 2021-2050, this fuel will remain the main source of cooking for rural population reaching 56.1 Mtoe in 2040 and 48.2 Mtoe in 2050 against 59.9 Mtoe in 2021. This trend will be driven by population growth and an energy mix for rural populations in which clean forms of energy, mainly LPG, will remain marginal in absolute values despite high relative growth rates.

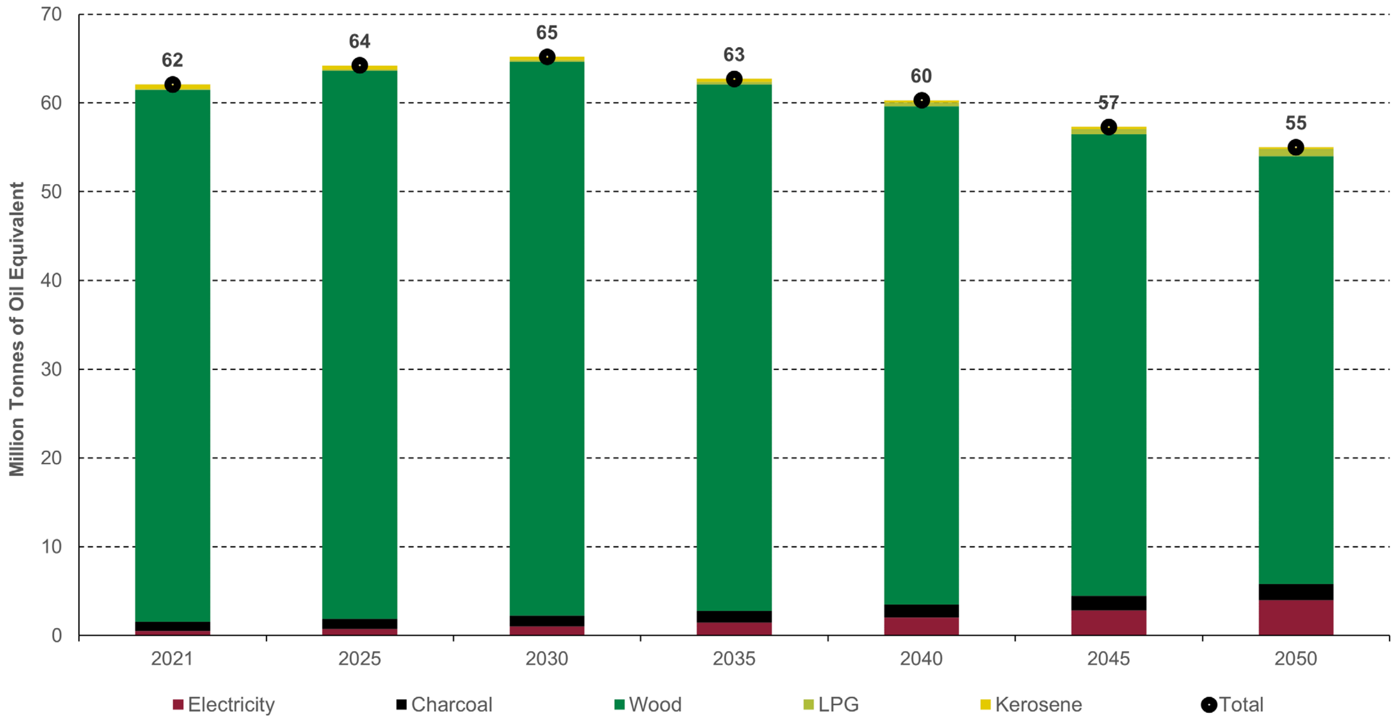

Figure 53: Rural consumption by energy sources 2021-2050 reference scenario

Table 17: Dynamic of cooking fuels in rural areas in ECOWAS countries 2021-2030: Business as usual scenario

Branch	2021	2025	2030	2035	2040	2045	2050	Total	Annual growth rate
Electricity	0.5	0.8	1.0	1.4	2.0	2.8	4.0	53.1	7.30%
Charcoal	1.1	1.2	1.2	1.4	1.5	1.6	1.8	42.1	1.89%
Firewood and waste	59.9	61.7	62.3	59.3	56.1	52.0	48.2	1 724.1	-0.75%
LPG	0.1	0.1	0.2	0.3	0.4	0.6	0.8	10.4	7.37%
Kerosene	0.5	0.4	0.4	0.3	0.3	0.2	0.2	9.7	-3.20%
Total	62.1	64.2	65.2	62.7	60.3	57.3	55.0	1 839.4	-0.42%

This trend will increase the pressure on deforestation. Over the period 2021-2050, more than1.7 billion toe of firewood and 1.8 Mtoe of charcoal will be consumed to meet the needs of rural population for cooking. This trend is not sustainable to maintain the biodiversity and forest resources but also for social equity reasons. The LPG consumption will dramatically increase in relative values (8 times). However, the per capita consumption will remain very low and below the current consumption in some countries in sub-Saharan and North Africa. Such a trend will maintain the sharp disparities in term of access to clean energy between urban and rural areas.

ECOWAS transitioning scenario and acces to clean energy: key results

In the case of ECOWAS, universal access implies a **gradual** reduction in the use of bioenergy between the reference year 2021 and 2030. Post 2030, the share of biomass is expected to decrease **significantly**.

The assumptions of the ECOWAS Transition scenario (TRANSECOWAS) are aligned with the Regional Energy Policy of ECOWAS and adjusted to take into consideration a gradual penetration of natural gas in urban areas from 2040 onwards. Given the concentration of the population in urban areas and the development of natural gas infrastructure, this alternative will be increasingly cost-effective. Furthermore, the life expectancy of natural gas resources in ECOWAS countries is higher than oil resources. We have considered that in 2040, natural gas will account for only 2% of LPG consumption, and 10% in 2050. LPG growth rate consumption is correlated with urban population growth rate and includes transition from traditional fuels to clean cooking fuels to comply with the trend of universal access to clean energy. This trend is realistic and is based on experiences from North African and Latin American countries. As was the case for the BAU, assumptions will be very different according to urban and rural areas.

Biomass consumption in urban areas: key results

Compared with the reference scenario (BAU), the implementation of ECOWAS regional energy policy will imply a structural transition from traditional biomass to clean energy, mainly LPG but also, at a modest level, natural gas from 2040 onwards. Strategic Objective 6 of the ECOWAS energy policy is aimed at increasing the population's access to modern and clean energy for cooking. Two priority actions have been proposed to achieve this strategic objective:

- Priority Action 6.1: Strengthen infrastructure and popularise the use of LPG;
- Priority Action 6.2: Promote the development of alternative clean cooking fuels.

The following assumptions provide the trends towards the implementation of the ECOWAS regional policy (ECOREP) in urban areas.

Table 18: Dynamic of cooking fuels in urban areas in ECOWAS countries 2021-2030 : TRANSECOWAS scenario

	2021-2030	2031-2040	2041-2050
Charcoal	1%	0.5%	-4.5%
Wood	-0.5%	-0.5%	-4.5%
LPG*	7.5%	7.4%	6.6%
Kerosene	-3.5%	-3.5%	-3.5%

The marginal decrease of LPG growth rate after 2031 is due to the decrease of urban population growth rate. Nevertheless, LPG growth rate consumption will remain very high and account for twice the growth rate of urban population.

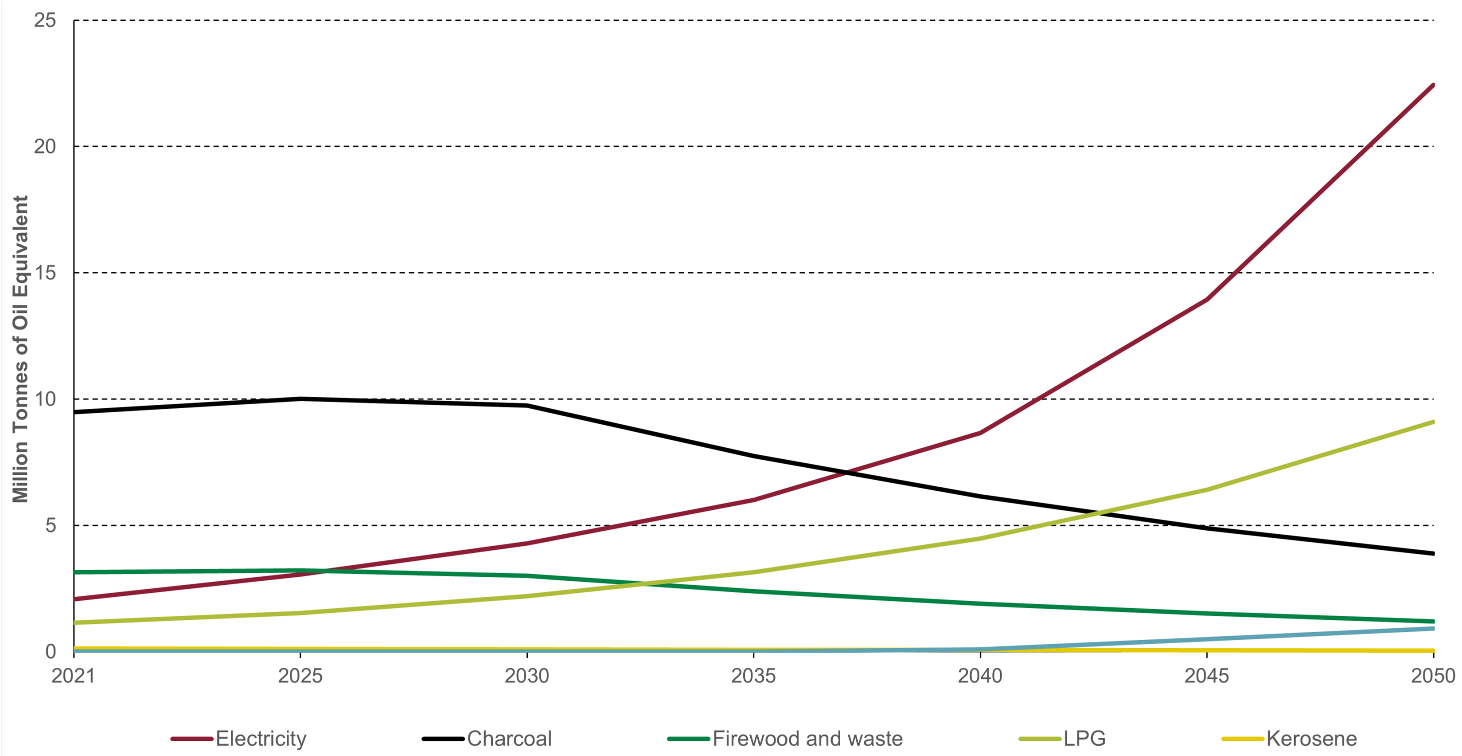

Figure 54: Urban consumption by energy sources 2021-2050: TRANSECOWAS scenario

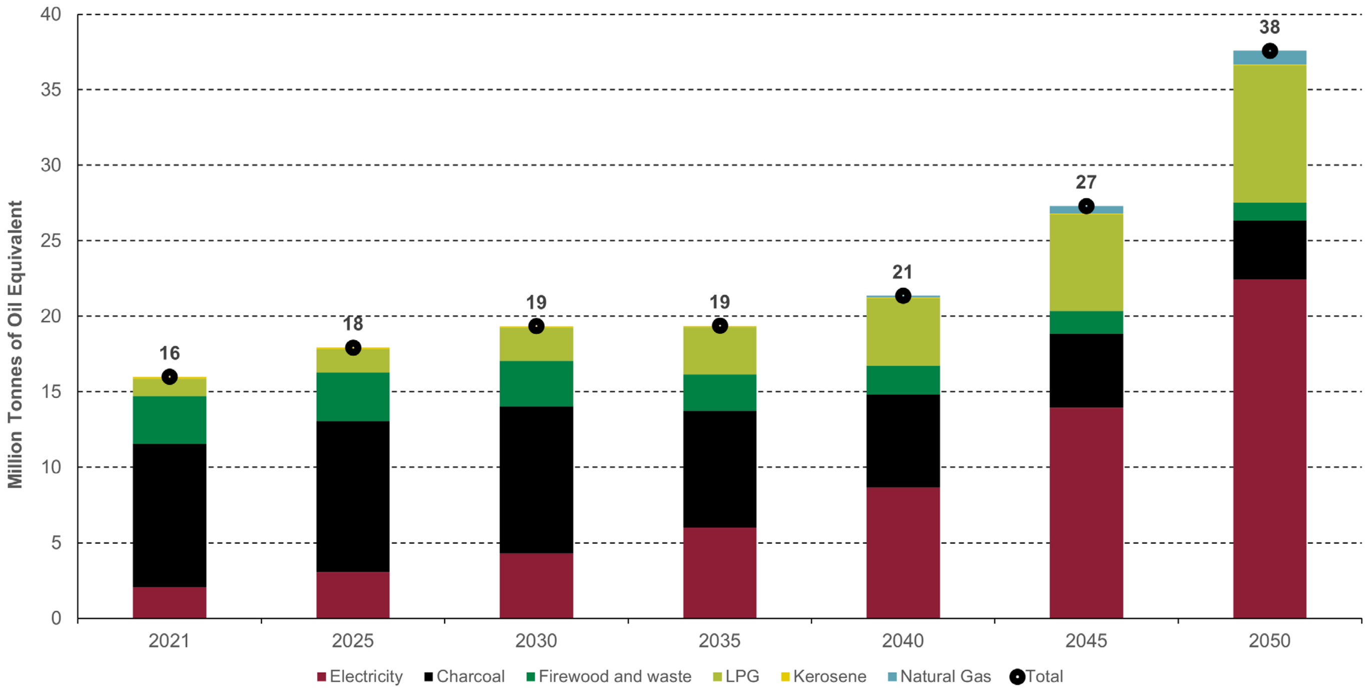

Figure 55: Urban consumption by energy sources 2021-2050: TRANSECOWAS scenario

Table 19: Urban consumption by energy sources 2021-2050 TRANSECOWAS scenario (Mtoe)

Branch	2021	2025	2030	2035	2040	2045	2050	Total	Annual average growth
Electricity	2.1	3.1	4.3	6.0	8.7	13.9	22.4	247.1	8.6%
Charcoal	9.5	10.0	9.8	7.7	6.2	4.9	3.9	224.0	-3.0%
Firewood and waste	3.2	3.2	3.0	2.4	1.9	1.5	1.2	70.2	-3.3%
LPG	1.1	1.5	2.2	3.1	4.5	6.4	9.1	117.2	7.4%
Kerosene	0.1	0.1	0.1	0.1	0.1	0.1	0.0	2.4	-3.5%
Natural gas	-	-	-	-	0.1	0.5	0.9	5.5	
Total	16.0	17.9	19.3	19.4	21.3	27.3	37.6	666.4	3.0%

In 2050 charcoal consumption, which is currently the main fuel, will decrease from 9.5 Mtoe in 2021 to 3.9 Mtoe. The share of firewood (biomass and waste) will be only 1.2 Mtoe in 2050 against 3.2 Mtoe in 2021. The switch from these traditional fuels to LPG will be driven by a high penetration of LPG (on average 7.4% annual growth rate between 2021-2050) and the introduction, at a slow rate, of natural gas from 2040 onwards. The following table shows the share of energy sources in urban areas and the comparative energy mix between the base year and end year

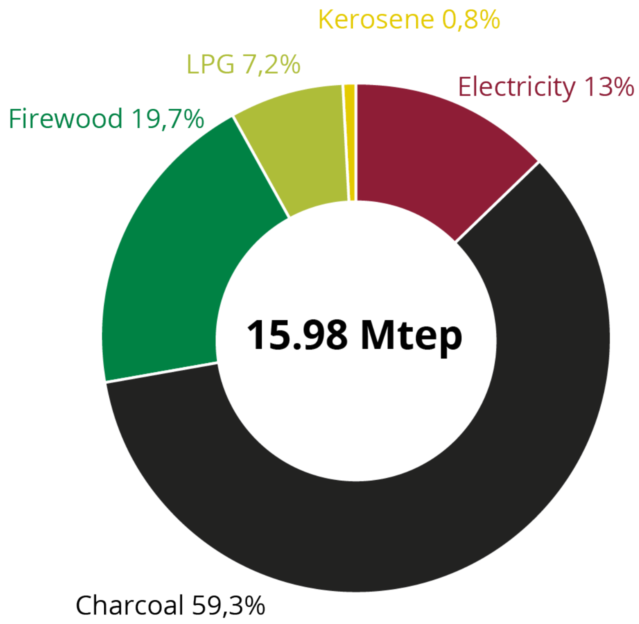

Figure 56: Share of energy sources final consumption in urban areas in 2021

In 2050, the share of biomass (charcoal and firewood) will decrease dramatically from 79% in 2021 to 13% in 2050. LPG, and to a lesser extent natural gas, will contribute to the transition to clean energy fuels. Electricity trend is provided as an illustration as it will mainly contribute to universal access to electricity. Indeed, the role of electricity in transitioning from firewood and charcoal to clean energy will remain relatively small. It must be pointed out that the transition requires building the infrastructure for LPG production and distribution as well the infrastructure for natural gas, particularly the transport and distribution system.

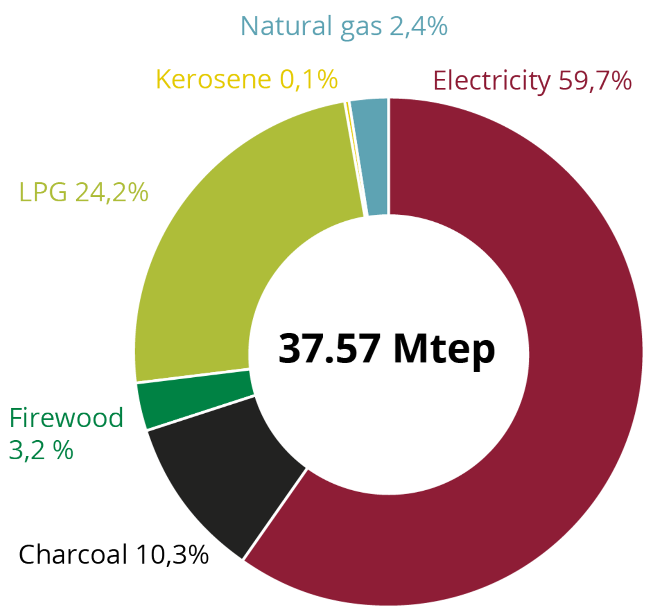

Figure 57: Share of energy sources final consumption in urban areas in 2050

Biomass consumption in rural areas: key results

Biomass, including firewood, crop residues, and animal dung, serves as the primary energy source for cooking and heating in many rural households across ECOWAS countries. Rural communities in ECOWAS countries heavily depend on biomass for meeting their daily energy needs due to limited access to clean energy sources such as liquefied petroleum gas (LPG). Addressing challenges related to biomass consumption in rural areas is crucial.

The following assumptions provide the trends towards the implementation of the ECOWAS regional policy (ECOREP) in rural areas and achieving sustainable development goals, including poverty reduction, gender equality, and environmental sustainability, within the region.

Table 20: Dynamic of cooking fuels in rural areas in ECOWAS countries 2021-2030 : TRANSECOWAS

	2021-2030	2031-2040	2041-2050
Charcoal	2.1%	1%	0.5%
Wood	0.5%	-6%	-7%
LPG*	2 times the consumption in 2021	2 times the consumption in 2021	2 times the consumption in 2021
Kerosene	-3.5%	-3.5%	-3.5%

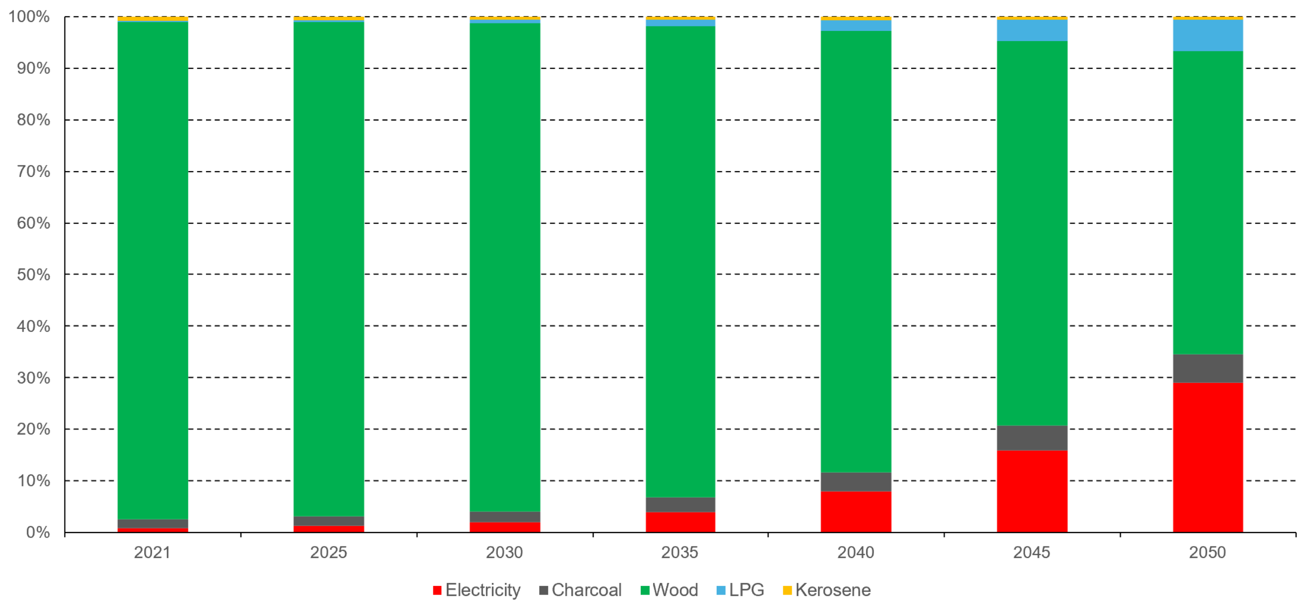

Figure 58: Trends of the structure of energy consumption in rural areas of ECOWAS 2021 - 2050

*LPG consumption is still very low in rural areas. A very high growth rate will only have a marginal impact on the LPG consumption in these areas. It is assumed that LPG consumption will double every 5 years. This is a realistic assumption given the very low of LPG consumption, in absolute values, in rural areas.

Table 21: Structure of energy consumption in rural areas of ECOWAS 2021-2050

Branch	2021	2025	2030	2035	2040	2045	2050
Electricity	0.8%	1.3%	2.0%	3.9%	7.9%	15.9%	29.0%
Charcoal	1.7%	1.9%	2.1%	2.8%	3.7%	4.8%	5.5%
Firewood and waste	96.5%	95.8%	94.7%	91.4%	85.6%	74.6%	58.7%
LPG	0.2%	0.4%	0.6%	1.3%	2.2%	4.1%	6.1%
Kerosene	0.8%	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%
Total	100%	100%	100%	100%	100%	100%	100%

There will be a significant decrease in firewood and waste consumption from over 96% in 2021 to approximately 59% in 2050. The share of charcoal will slightly increase, reflecting the preference for more efficient fuels. However, in 2050, the share will not exceed 5.5%. Kerosene will remain marginal with just 0.6% in 2050. Fuel switching from traditional fuels to clean fuels will be compensated by a sharp increase in the share of LPG (0.2% in 2021, 4.1% in 2050).

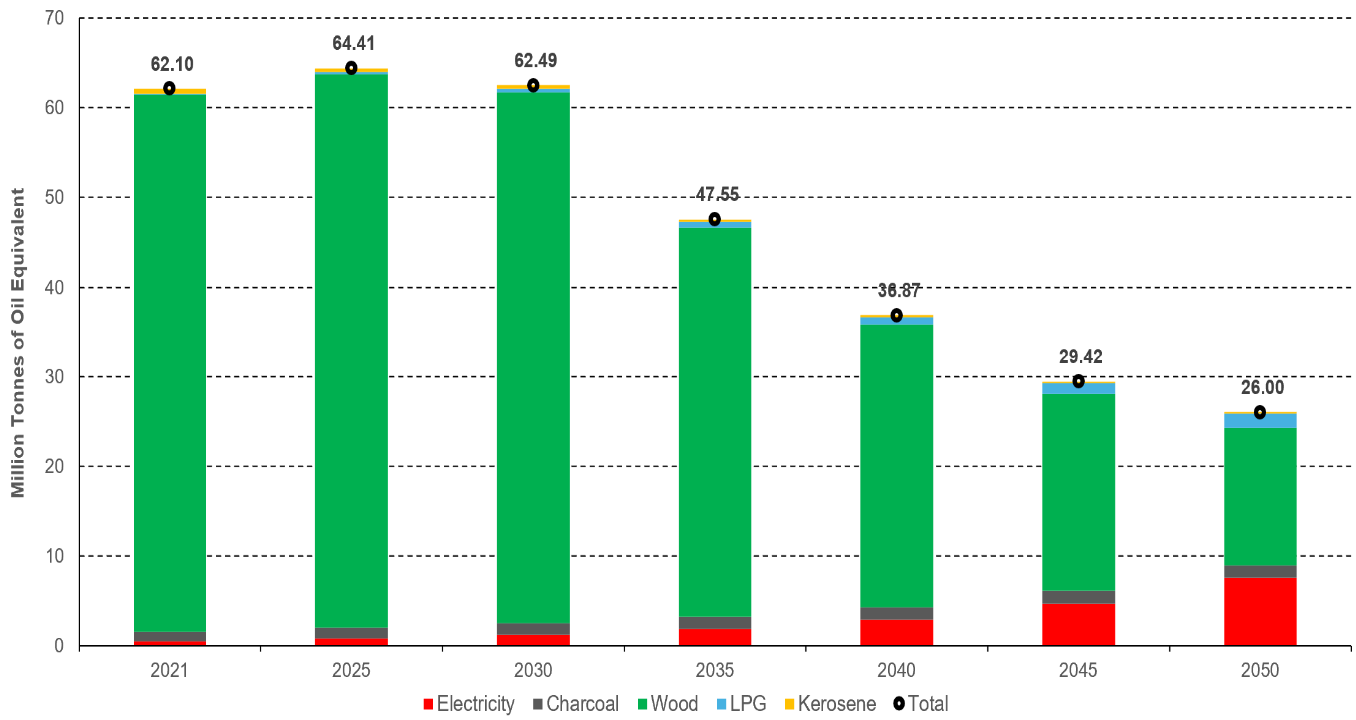

Figure 59: Trends of energy consumption by rural households: Transition scenario

Table 22: Transition scenario in rural areas 2021-2050 (Mtoe)

Branch	2021	2025	2030	2035	2040	2045	2050	Annual average growth
Electricity	0.5	0.8	1.2	1.9	2.9	4.7	7.6	9.7%
Charcoal	1.1	1.2	1.3	1.3	1.4	1.4	1.4	1.1%
Firewood and waste	59.9	61.7	59.2	43.4	31.5	21.9	15.3	-4.6%
LPG	0.1	0.2	0.4	0.6	0.8	1.2	1.6	10.0%
Kerosene	0.5	0.4	0.4	0.3	0.2	0.2	0.1	-4.3%
Total	62.1	64.4	62.5	47.6	36.9	29.4	26.0	-3.0%

Modelling the trend of rural consumption shows that, on average, the annual growth rate of LPG consumption in rural areas sees significant reduction in firewood consumption and sharp increase in LPG consumption. The key results of the transition scenario from biomass to clean fuels in rural areas are as follows:

- The major result is the sharp decrease in absolute value of firewood and residues from 59.9 Mtoe in 2021 to 15.3 Mtoe, i.e., a negative growth rate of -4.6% despite the demographic growth in rural areas. However, this share is still relatively high and should further decrease to reach the broad objective of the Africa Union Agenda 2063

- The share of LPG will dramatically increase, from 0.1 Mtoe to 1.6 Mtoe, i.e., on average an annual growth of 10%. To achieve universal access to clean energy, this trend must be sustained beyond 2050 as firewood and waste will still account for more than 58% of the rural energy mix.

- The share of kerosene, which is already marginal will be non-significant in 2050. This trend is already observed in most ECOWAS countries

Energy transition scenarios impacts

Modelling biomass energy trends (firewood and charcoal) in both urban and rural areas show the impact on the energy mix in both areas as well as on forest resources. The transition scenario (TRANSECOWAS) will lead to huge wood energy savings over the period 2021-2050 and a relatively high penetration of LPG in both areas. Urban areas will experiment the introduction of natural gas from 2040 onwards. The trend will be relatively slow till 2050. Natural gas should play an increasing role in the energy mix after the deployment of natural gas infrastructure for urban consumption from 2040 onwards. The key results are presented for urban and rural areas

Energy transition scenarios impact in urban areas

In urban areas a sharp decrease of the charcoal consumption will be achieved. There will be only a small increase of LPG consumption compared to the reference scenario. This is due to the fact that in both scenarios (reference and TRANSECOWAS) the increased rate of LPG consumption will be relatively high. Natural gas in urban areas will be introduced from 2040 onwards.

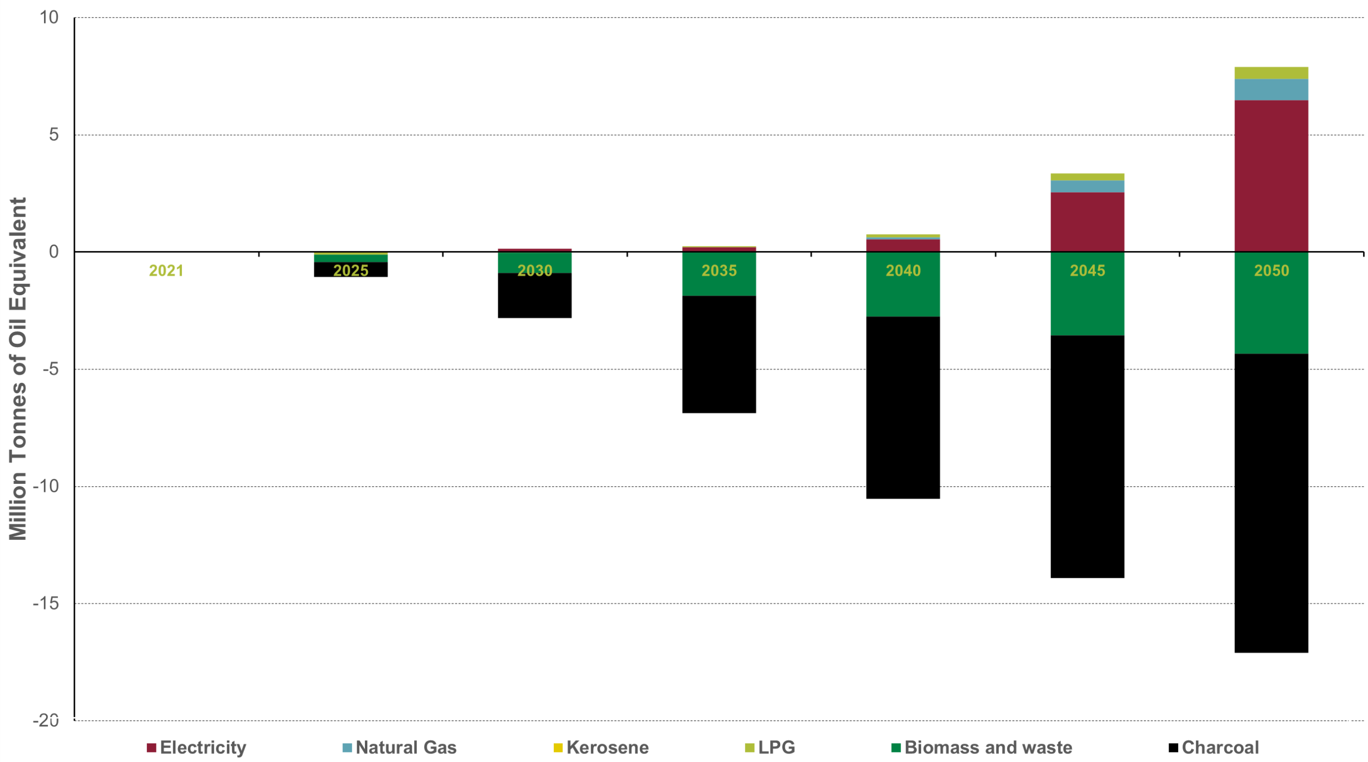

Figure 60: Energy consumption in urban areas: TRANSECOWAS versus reference scenario 2021-2050

Table 23: Energy consumption in urban areas: TRANSECOWAS versus reference scenario 2021-2050

Fuel	2021	2025	2030	2035	2040	2045	2050	Total
Electricity	-	0.04	0.14	0.21	0.54	2.55	6.48	34.79
Natural gas	-	-	-	-	0.09	0.50	0.91	5.49
Kerosene	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.22
LPG	-	-0.10	-0.02	0.03	0.12	0.29	0.51	2.92
Firewood and waste	-	-0.32	-0.87	-1.85	-2.74	-3.56	-4.34	-59.46
Charcoal	-	-0.62	-1.92	-5.00	-7.78	-10.34	-12.76	-165.79

The cumulative savings of charcoal will be close to 166 Mtoe compared with the reference scenario. Significant charcoal savings will be achieved from 2035 onwards. On 2030 charcoal savings will reach just 1.92 Mtoe, against 12.76 in 2050. There will also be firewood savings but at a much smaller scale in absolute values , as firewood is not widely used in urban areas.

Energy transition scenarios impact in urban areas

In urban areas, the implementation of the transition pathway will lead to significant savings in firewood consumption and a relatively high increase in LPG consumption.

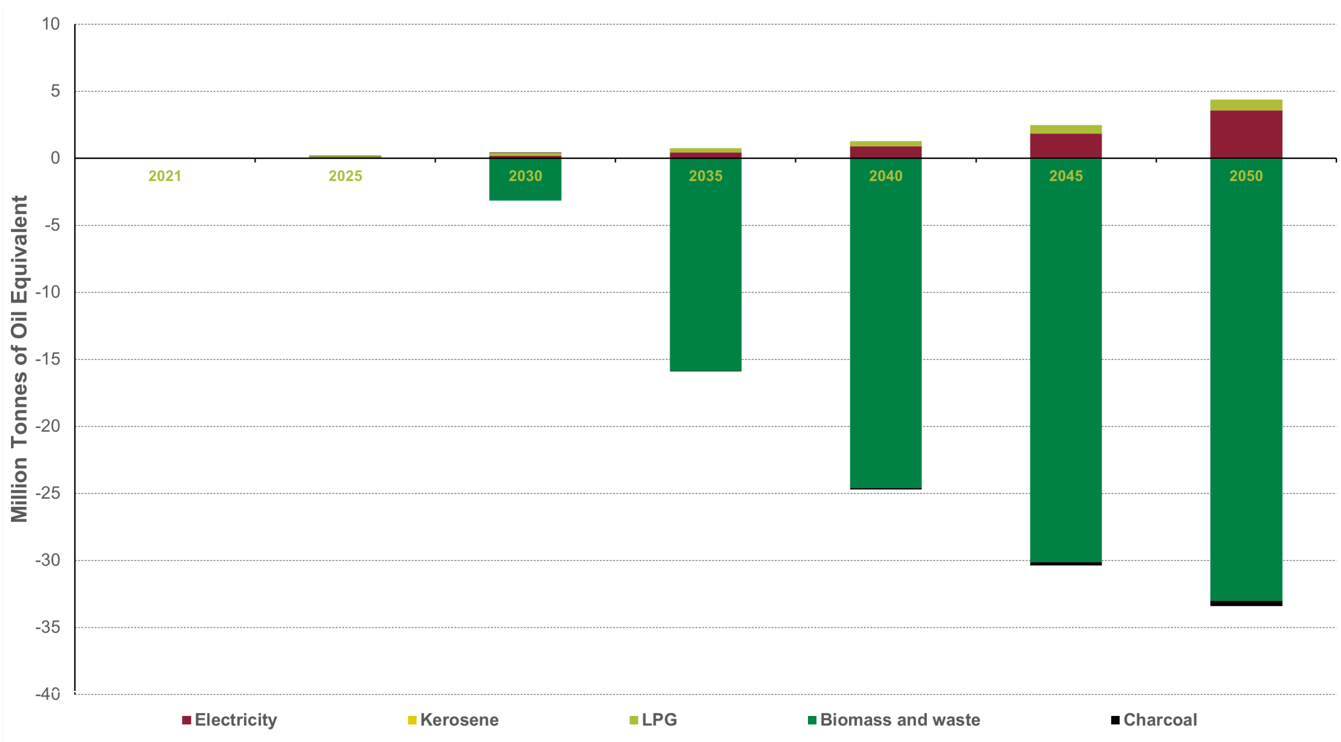

Figure 61: Energy consumption in rural areas: TRANSECOWAS versus reference scenario 2021-2050

In 2050, more than 32 Mtoe of firewood and 0.37 Mtoe of charcoal will be saved under the transition scenario. However there will be an increase of 0.8Mtoe in LPG consumption compared with the reference (BAU) scenario. The impact of firewood savings as a result of the transition scenario will become substantial from 2030 onwards. In 2030, firewood savings will reach 3.15 Mtoe. In 2050 more than tenfold firewood savings (32.9 Mtoe) will be achieved compared with 2030 (3.15 Mtoe).

Table 24: Energy consumption in rural areas: TRANSECOWAS versus reference scenario 2021-2050

Fuel	2021	2025	2030	2035	2040	2045	2050	Total
Electricity	-	0.07	0.18	0.43	0.88	1.84	3.56	26.83
Kerosene	-	-	0.00	-0.02	-0.03	-0.05	-0.06	-0.68
LPG	-	0.09	0.20	0.31	0.40	0.64	0-81	10.65
Firewood and waste	-	-	-3.15	-15.85	-24.56	-30.07	-32.97	-465.98
Charcoal	-	0.04	0.06	-0.03	-0.13	-0.25	-0.37	-2.60

Over the period 2021-2050, approximately 466 Mtoe of firewood will be saved. During the same period, the cumulative increase in LPG consumption will reach 10.65 Mtoe. Although in absolute value the increase is not important for rural population, this trend will contribute to bridging the energy gap with urban population as well impacting on forest resources depletion.

The way forward

The impact of firewood consumption on deforestation is significant and has several interconnected environmental, social, and economic consequences. While biomass will remains a vital energy source in Sub-Saharan Africa for the short and mid terms, there is a critical need for sustainable management practices and the promotion of alternative energy solutions to address the environmental, health, and socioeconomic challenges associated with its consumption. Achieving a balance between energy needs and environmental conservation is essential for the long-term well-being of communities in the region. Indeed biomass consumption on a large scale has detrimental impact on:

- Biodiversity, soil conservation, and water management, affecting agricultural productivity and exacerbating food insecurity.

- Health: Combustion of biomass with inefficient stoves results in indoor air pollution. This, in turn, poses severe health risks, especially for women and children who spend considerable time indoors. Respiratory diseases and other health issues are prevalent in communities relying heavily on biomass for cooking.

- Economic vulnerability: biomass collection, such as firewood, is a time-consuming task, primarily carried out by women and children. This contributes to limiting opportunities for education, income generation, and other activities that could enhance overall well-being. The depletion of forests due to high biomass consumption affects livelihoods dependent on forest resources. Communities relying on these resources become economically vulnerable as their traditional sources of income are diminished.

- Greenhouse Gas Emissions: The burning of biomass releases carbon dioxide and other pollutants, contributing to greenhouse gas emissions. While biomass is considered renewable, its unsustainable production practices can lead to a carbon footprint that exacerbates climate change.

This trend in both urban and rural areas is not sustainable. Implementing and enforcing policies that promote sustainable forestry practices and regulate the harvesting of firewood can help address deforestation issues. Alternative solutions in the short and mid-term such as improved stoves and mainly fuel switching to cleaner energy sources mainly LPG electric cooking and to a lesser extent natural gas in urban areas from 2040 onwards can help reduce the pressure on biomass resources and mitigate environmental and health impacts. Addressing this challenge requires a holistic approach that involves sustainable energy alternatives, , community engagement, effective policies within members states in implementing the ECOWAS regional energy strategic objectives and priority actions.

REFERENCES

Adanguidi, J. (2021). Factors Affecting the Use of Domestic Gas in Benin: A Comparative Study of Artificial Neural Networks and Logistic Regression. Asian Journal of Agricultural Extension, Economics & Sociology, 1–21.

Adeyemi, P. A., & Adereleye, A. (2016). Determinants of household choice of cooking energy in Ondo State, Nigeria. J Econ Sustain Dev, 7(9):131e42.

Adio, A. A., Saliu, A. O., Akanbi-Gada, M. A., & Najeem-deen, B. A. (2022). Effects of Charcoal Production on Soil Physicochemical Properties in Moro Local Government Area of Kwara State, Nigeria. Journal of Environmental Protection, 13(2), Article 2.

Africa Energy Portal (2019). Nigeria launches its first organic waste power plant. Available from https://africa-energy-portal.org/news/nigeria-launches-its-first-organic-waste-power-plant

Akhator, P. E., Bazuaye, L., Ewere, A., & Oshiokhai, O. (2023). Production and characterisation of solid waste-derived fuel briquettes from mixed wood wastes and waste pet bottles. Heliyon, 9(11), e21432. https://doi.org/10.1016/j.heliyon.2023.e21432

Akolgo, G.A., Kemausuor, F., Essandoh, E O. Atta-Darkwa, T., Bart-Plange, A., Kyei-Baffour, N., & Maia, C. (2019). Review of Biomass Gasification Technologies: Guidelines for the Ghanaian Situation. International Journal of Engineering Science and Application, 3, 152-158.

Akpasoh, A. M. & Edeminam, V. B. (2023). Controlled Cooking Test Study for Nigeria. Available from https://mecs.org.uk/wp-content/uploads/2023/08/Controlled-Cooking-Test-draft-Nigeria_Tovero-Energy.pdf

Amoah, S. T. (2019). Determinants of household's choice of cooking energy in a global south city. Energy Build 196:103e11.

Arnold, M., & Persson, R. (2003). Reassessing the fuelwood situation in developing countries. International Forestry Review, 5(4), 379–383.

Arthur, R., & Baidoo, M. F. (2011). Harnessing methane generated from livestock manure in Ghana, Nigeria, Mali and Burkina Faso. Biomass and Bioenergy, 35(11), 4648–4656.

Bappah, M., Bradna, J., Malaťák, J., & Vaculík, P. (2022). Viability of some African agricultural by-products as a feedstock for solid biofuel production. Research in Agricultural Engineering, 68(4), 210–215. https://doi.org/10.17221/74/2021-RAE

Berte, S., & Adou, D. D. F. (2023). Challenges connected with the energy choice and transition in bakeries of Abidjan, Côte d'Ivoire. Energy, Sustainability and Society, 13(1), 7.

Bioenergy Insight. (2022). Hybrid biogas plant is first for West Africa. Bioenergy Insight Magazine. Available from https://www.bioenergy-news.com/news/hybrid-biogas-plant-is-first-for-west-africa/

Bisu, D.Y., Kuhe, A. & Iortyer, H.A. (2016). Urban household cooking energy choice: an example of Bauchi metropolis, Nigeria. Energ Sustain Soc 6(1):15.

Boafo-Mensah, G., Neba, F. A., Tornyeviadzi, H. M., Seidu, R., Darkwa, K. M., & Kemausuor, F. (2021). Modelling the performance potential of forced and natural-draft biomass cookstoves using a hybrid Entropy-TOPSIS approach. Biomass and Bioenergy,150,106106.

Cirad (2023). Biofuel from agrifood waste? A gamble that is paying off in Burkina Faso. Available from https://www.cirad.fr/en/cirad-news/news/2023/biofuel-from-agrifood-waste-a-gamble-that-is-paying-off-in-burkina-faso

Clean Cooking Alliance (CCA) (2022), 2022 Annual Report. Available from https://cleancooking.org/wp-content/uploads/2023/03/CCA-2022-Annual-Report.pdf

de la Sota, C., Lumbreras, J., Pérez, N., Ealo, M., Kane, M., Youm, I., & Viana, M. (2018). Indoor air pollution from biomass cookstoves in rural Senegal. Energy for Sustainable Development, 43, 224–234.

Diouf, B., & Miezan, E. (2019). The Biogas Initiative in Developing Countries, from Technical Potential to Failure: The Case Study of Senegal. Renewable and Sustainable Energy Reviews, 101, 248–254.

Dongzagla, A., & Adams, A.-M. (2022). Determinants of urban household choice of cooking fuel in Ghana: Do socio-economic and demographic factors matter? Energy, 256, 124613.

Dutch Ministry of Foreign Affairs (2021). Study of the biomass potential in Côte d'Ivoire. Available from https://www.rvo.nl/sites/default/files/2021/06/Study-of-the-biomass-potential-in-Cote-dIvoire.pdf

ECOWAS (2023). ECOWAS updated energy policy. Economic Community of West African States

ECOWAS (2024). ECOWAS Energy Information System. Available from https://eis.ecowas.int/

ECREEE, undated. Background on the biomass situation. available from http://www.ecreee.org/sites/default/files/documents/basic_page/ecowas_bioenergy_strategy.pdf

Ghana Energy Commission (2016). Baseline Study of Renewable Energy Technologies in Ghana. Available from https://energycom.gov.gh/rett/documents-downloads?download=173:baseline-study-of-renewable-energy-technologies

Fabrice, O. E., Kamagaté, T., Dagbaud, U., Koné T. (2023). Compost and biogas market in Côte d'Ivoire: Economic impact assessment by CGE model. Res. Sq., pp. 1–11.

Farsi, M., Filippini, M., & Pachauri, S. (2007). Fuel choices in urban Indian households. Environment and Development Economics, 12(6), 757–774.

FasoBiogas (2024). https://www.fasobiogaz.com/

Frederiks, B., Raul A. J., Lugmayr, M., Sema, G., Delgado, J. & Semedo, E. (2017). Baseline Study on the Biomass Electricity Generation Potential in Guinea Bissau. Available from http://www.ecowrex.org/system/files/200617_baseline_study_on_bioelectricity_in_guinea_bissau.pdf

Ghana Energy Commission (2023). National Energy Statistics 2022. Available from https://www.energycom.gov.gh/newsite/files/2023-energy-Statistics.pdf

Giordano, P., Assogba, M., & Rahnema, A. (2018). Fueling the Change: The Journey From Biomass to Modern Source: Situation and Perspectives of Cooking Fuels in Côte d'Ivoire (SSRN Scholarly Paper 3303908).

GIZ (2013). Brewing Beer with Efficient Cookstoves Burkina Faso. Available from http://www.produse.org/imglib/downloads/energy_sources/PRODUSE-Fact-sheet-Burkina%20Faso.pdf

Hooda, N., Bisi-Amosun, O. O., Donyinah, A. K., Francois,Y., Kaushik, I., Kemausuor, F., Owen, M.. Guy, O., Maclean, A. & Verheijen, L. (2022). Ghana - Green Growth PASA : Analysis of the Woodfuels Sector in Ghana. Washington, D.C.: World Bank Group. Available from http://documents.worldbank.org/curated/en/099200001102313104/P1759890f23a9900409192073be0b5c18b4

Ichu, B. C, Nwogu, N.A, Agulanna, A. C, & Nwakanma, H. O (2020). Potentials of biomass briquetting and utilisation: the Nigerian perspective. Pacific Int. J., 3(1), 07–12, 2020.

Kemausuor, F., Adaramola, S.M., & Morken, J. (2018). A Review of Commercial Biogas Systems and Lessons for Africa. Energies, 11(11).

Kontor, S. (2013). Potential of biomass gasification and combustion technology for small-and medium-scale applications in Ghana. Available from: https://core.ac.uk/download/ pdf/38098807.pdf

Kranert, M., Kusch, S., Huang, J. & Fischer, K. (2012). Anaerobic Digestion of Waste. In: Karagiannidis, A. (eds) Waste to Energy. Green Energy and Technology. Springer, London.

Leary, J., Menyeh, B., Chapungu, V., & Troncoso, K. (2021). eCooking: Challenges and Opportunities from

a Consumer Behaviour Perspective. Energies, 14(14).
Lokonon, B. O. K. (2020). Household cooking fuel choice: Evidence from the Republic of Benin. African Development Review, 32(4), 686–698.

Ma, W., Zhou, X., & Renwick, A. Impact of off-farm income on household energy expenditures in China: implications for rural energy transition. Energy Pol 2019;127:248e58.

Mawusi, S. K., Shrestha, P., Xue, C., & Liu, G. (2023). A comprehensive review of the production, adoption and sustained use of biomass pellets in Ghana. Heliyon, 9(6), e16416.

MPS (2023). Construction starts of largest biomass power plant in West Africa. Available from https://www.modernpowersystems.com/news/newsconstruction-starts-of-largest-biomass-power-plant-in-west-africa-11175363

MRC (2023). Eni bets on agri-business in Africa to expand biofuel production. Available from https://www.mrchub.com/news/407862-eni-bets-on-agri-business-in-africa-to-expand-biofuel-production

Ofori, P., & Akoto, O. (2020). Production and Characterisation of Briquettes from Carbonised Cocoa Pod Husk and Sawdust. Open Access Library Journal, 7(2), Article 2.

Olayanju, T. M. A., Dairo, O. U., Sobukola, O., Odebiyi, O., & Dahunsi, S. O. (2020). Development of small-scale downdraft gasifiers for biomass gasification. IOP Conference Series: Earth and Environmental Science, 445(1), 012056.

Osei, I., Addo, A. & Kemausuor, F. (2021). Crop Residues Utilisation for Renewable Energy Generation in Ghana: Review of Feedstocks Assessment Approach, Conversion Technologies and Challenges. Ghana Journal of Technology, 5 (1), 29– 42.

Owen, M. & Ripken, R. (2017). Bioenergy for Sustainable Energy Access in Africa, Technology Country Case Study Report (incorporating Country Scoping Reports). Available from: https://gender.cgiar.org/publications/bioenergy-sustainable-energy-access-africa-technology-country-case-study-report

Pachero de Carvalho, B.R. & Mendes, H.M. (2015) Cashew Chain Value in Guiné-Bissau: Challenges and Contributions for Food Security (A Case Study for Guiné-Bissau). Available from http://centmapress.ilb.uni-bonn.de/ojs/index.php/proceedings/article/viewFile/456/451.

Pereira, E.G., da Silva, J. N., de Oliveira,J. L. & Machado, C.S. (2012). Sustainable energy: a review of gasification technologies, Renewable and Sustainable Energy Reviews, 16 (7), 4753-4762.

Praj. (2016). Sustainable Ethanol Plant for Africa. https://www.praj.net/wp-content/uploads/2017/11/sustainability.pdf

Ramamurthi, P. V., Fernandes, M. C., Nielsen, P. S. & Pedro N. C. (2016). Utilisation of rice residues for decentralised electricity generation in Ghana: An economic analysis. Energy 111(18), 620-629.

Safisana. (2024). Our Circular Solution. Available from https://safisana.org/

Sana, A., Kafando, B., Dramaix. M., Meda, N., Bouland, C. (2020) Household energy choice for domestic cooking: distribution and factors influencing cooking fuel preference in Ouagadougou. Environ Sci Pollut Res Int. 27(15):18902-18910.

Sarpong, A. A., Todd, J. F. & Hoogakker, S. (2023). The Ghana ecookbook, exploring electric cooking. Available from https://mecs.org.uk/wp-content/uploads/2023/08/Ghana-eCookbook-V2.pdf

SCANIA. (2023). Scania launches biodiesel pilot in Côte d'Ivoire, reducing emissions and creating new jobs. Available from https://www.scania.com/group/en/home/newsroom/press-releases/press-release-detail-page.html/4677908-scania-launches-biodiesel-pilot-in-cote-d-ivoire--reducing-emissions-and-creating-new-jobs

SEI (2024). The quiet triumph of COP28: clean cooking. Available from https://www.sei.org/features/cop28-clean-cooking/

Sow, S. (2022). Cookinations: Mechanisms to Decouple Wood Production and Food Preparation in Sub-Urban Areas. In A. Fall & R. Haas (Eds.), Sustainable Energy Access for Communities: Rethinking the Energy Agenda for Cities (pp. 139–146). Springer International Publishing.

Transport & Environment (2024). From Farm to Fuel: Inside Eni's African biofuels gamble. Available from https://www.transportenvironment.org/discover/from-farm-to-fuel-inside-enis-african-biofuels-gamble/

Twumasi, M.A, Jiang, Y., Ameyaw, B., Danquah, F. O. & Acheampong M. O. (2020). The impact of credit accessibility on rural households clean cooking energy consumption: the case of Ghana. Energy Rep 6:974e83.

WABEF. (2017). Integrated development of biogas in West Africa. https://agritrop.cirad.fr/585817/7/ID585817_EN.pdf

Wassie, Y. W., Meley, M., Rannestad, M. M, & Adaramola M. S. (2021). Determinants of household energy choices in rural Sub-Saharan Africa: an example from southern Ethiopia. Energy 221(1):1e13.

Wondmagegn, S., Esubalew, M., Balemual, A., Mhriet, S., Nigusu, T., Adane, W., & Tesfaw, M. (2023). Design and development of a modified biomass charcoal production kiln. Ethiopian International Journal of Engineering and Technology, 1(1).

World Bank (2014). Baseline and feasibility assessment for alternative cooking fuels in Senegal. Available from http://documents1.worldbank.org/curated/en/247331468009985340/pdf/884510WP0REPLA0g0May20140Box385191B.pdf

World Bank (2021). Subsidising Bottled Gas: Approaches and Effects on Household Use. Available from https://documents1.worldbank.org/curated/en/475411626156399447/pdf/Subsidizing-Bottled-Gas-Approaches-and-Effects-on-Household-Use.pdf

World Health Organization (2023). Household air pollution. Available from https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

ANNEXES

Annex 1: Member States' 2021 energy flows

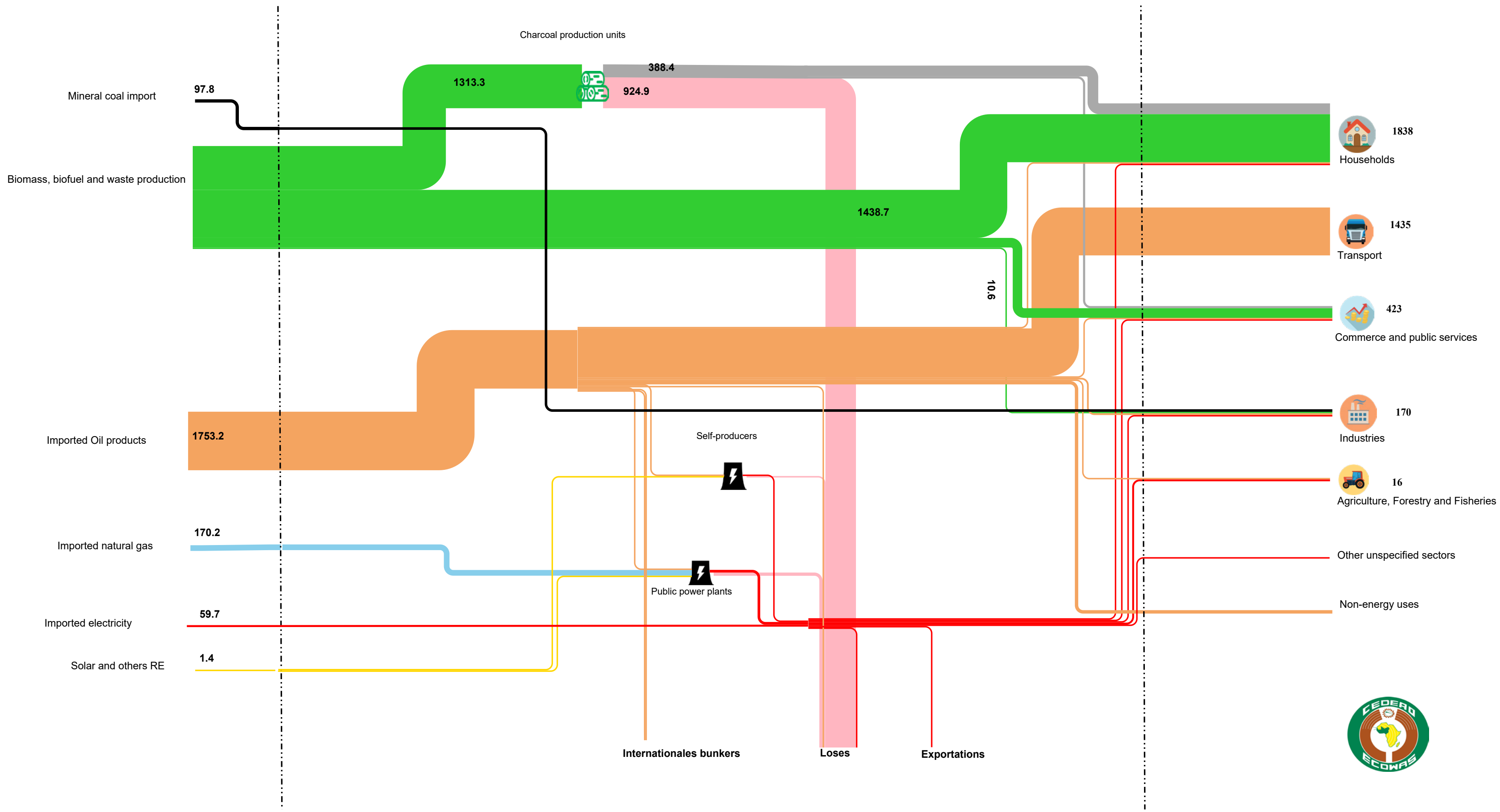

Figure 62: Benin's energy balance flows in ktoe, 2021

Benin's energy system is characterized by high biomass energy production and high consumption of fully imported petroleum products. The residential sector and the transportation sector are the main sectors of energy consumption. Natural gas, the main source of electricity generation, is imported, as is mineral coal used in the industrial sector, which is the fourth largest energy consumption sector.

BURKINA FASO

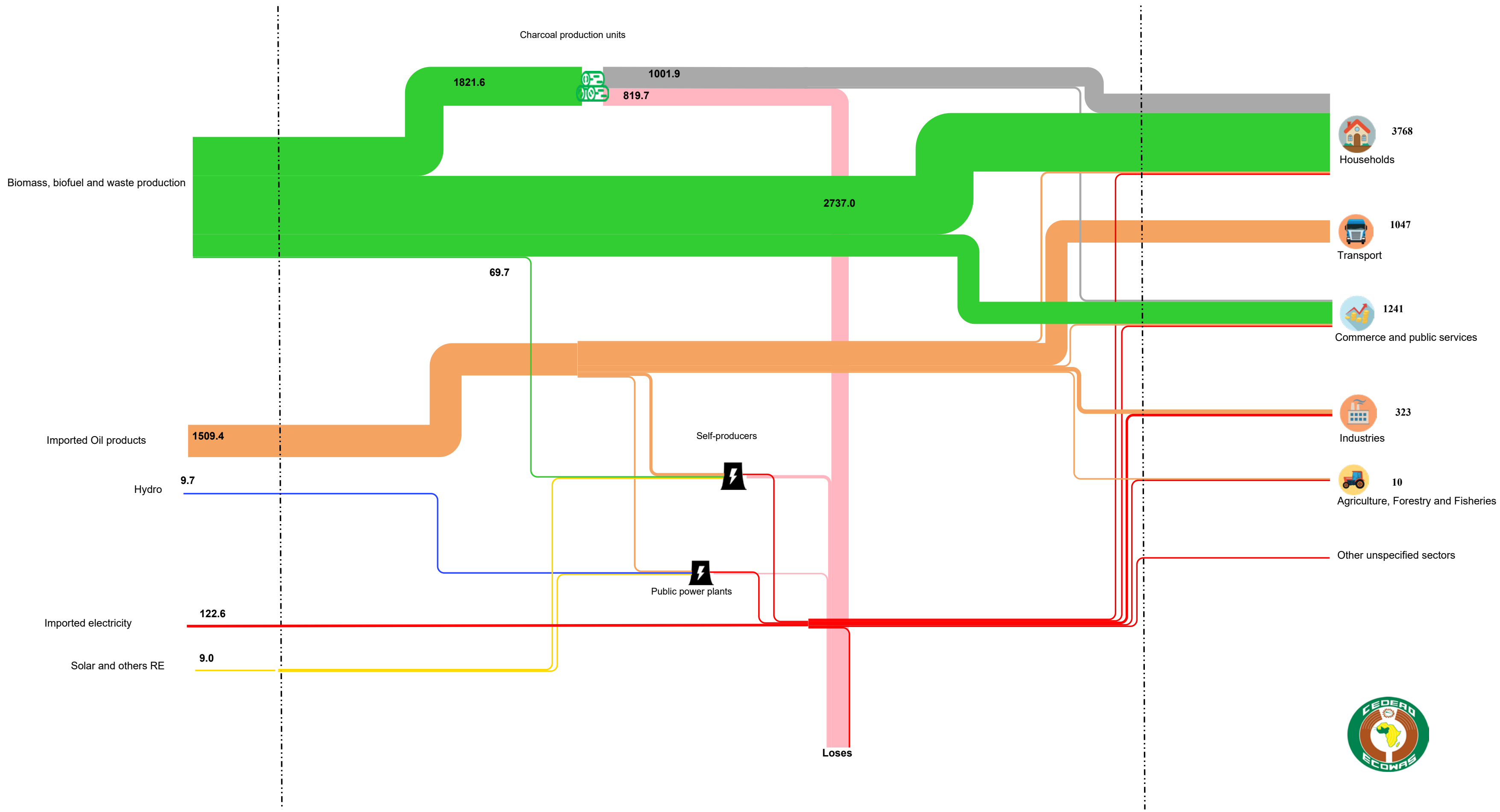

Figure 63: Burkina Faso's energy balance flows in ktoe, 2021

In Burkina Faso, the energy system is largely dominated by locally produced biomass, which is mainly used in the residential and service sectors, but also to a lesser extent at the level of self-producers to produce electricity. Fully imported petroleum products are widely used by the transportation sector. The industrial sector is the largest sector in terms of electricity consumption.

CABO VERDE

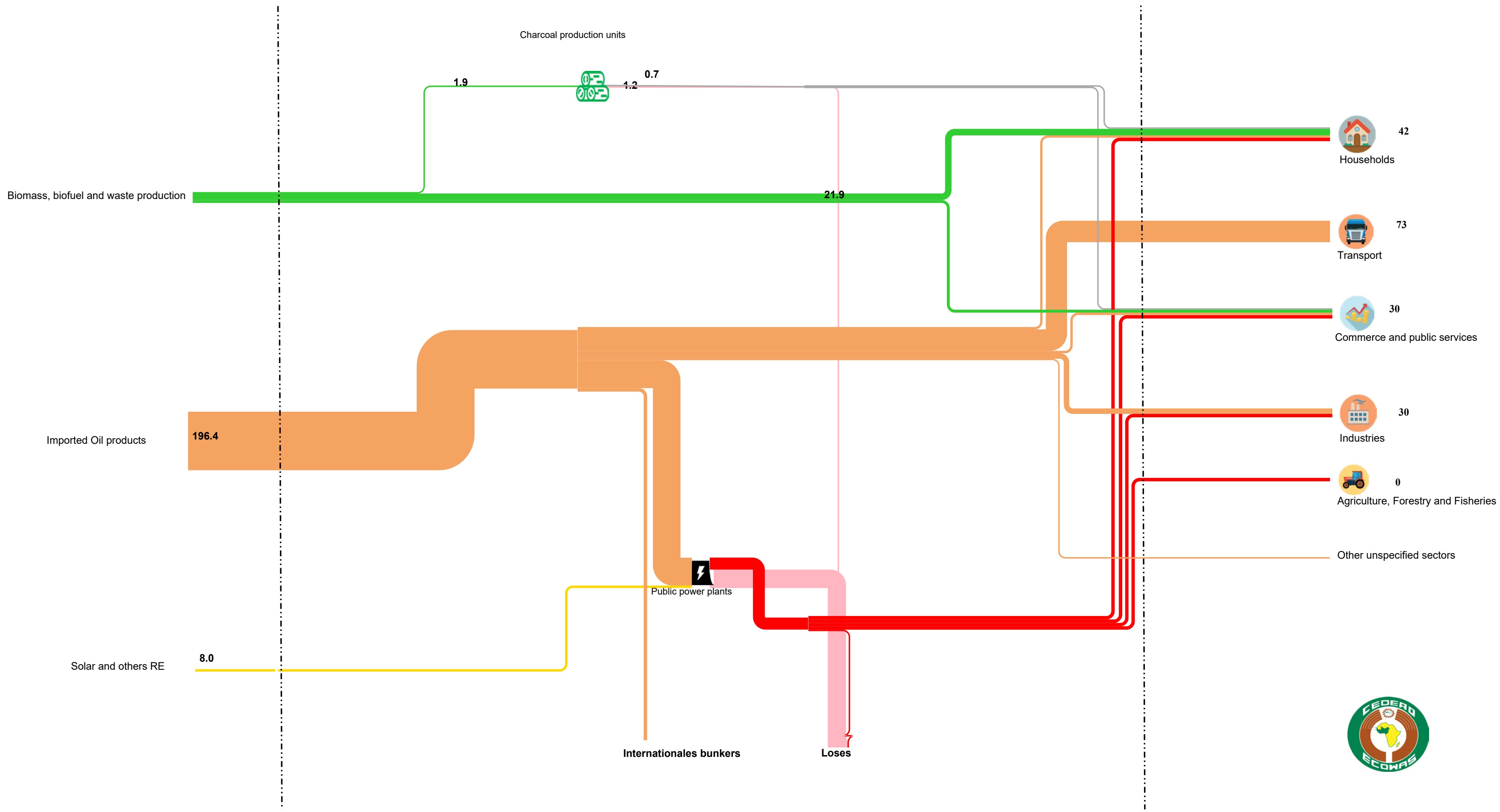

Figure 64: Cabo Verde energy balance flows in ktoe, 2021

Cabo Verde's energy system is largely dominated by petroleum products, which are entirely imported. They are mainly used by the transport sector and by the power generation energy industry where processing losses are significant. Locally produced electricity is used in almost all sectors of activity. Biomass energy use is low across the country, but biomass energy is the main source of energy for the residential sector.

CÔTE D'IVOIRE

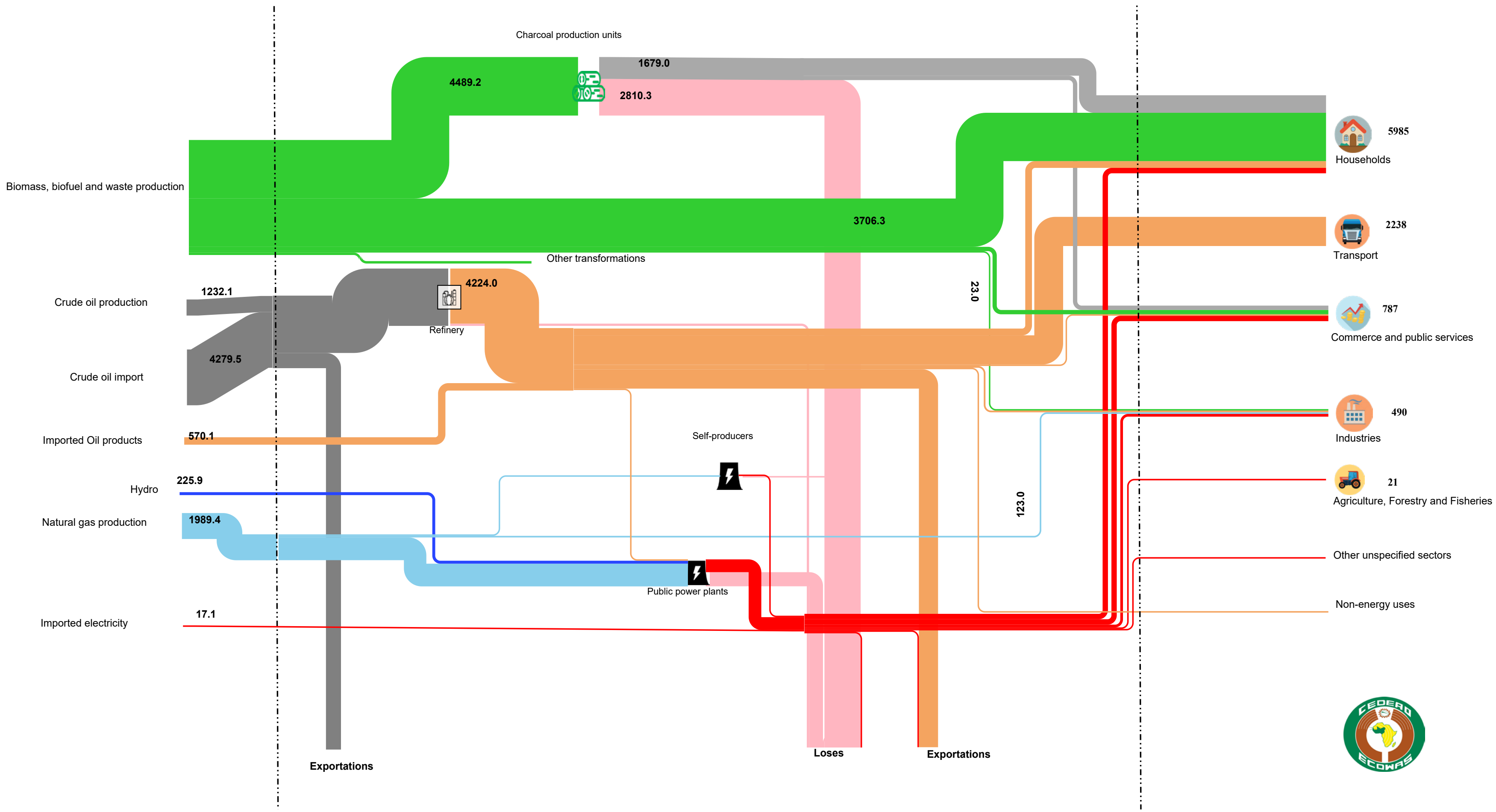

Figure 65: Côte d'Ivoire's energy balance flows in ktoe, 2021

In Côte d'Ivoire, the energy system is dominated by biomass energy and mainly imported crude oil. Biomass energy is the main source of energy for the residential sector. Petroleum products, used mainly by the transport sector and to a lesser extent by households, are produced mainly by the country's refineries. Electricity is mainly produced by public power plants, which largely use natural gas, but also hydroelectricity.

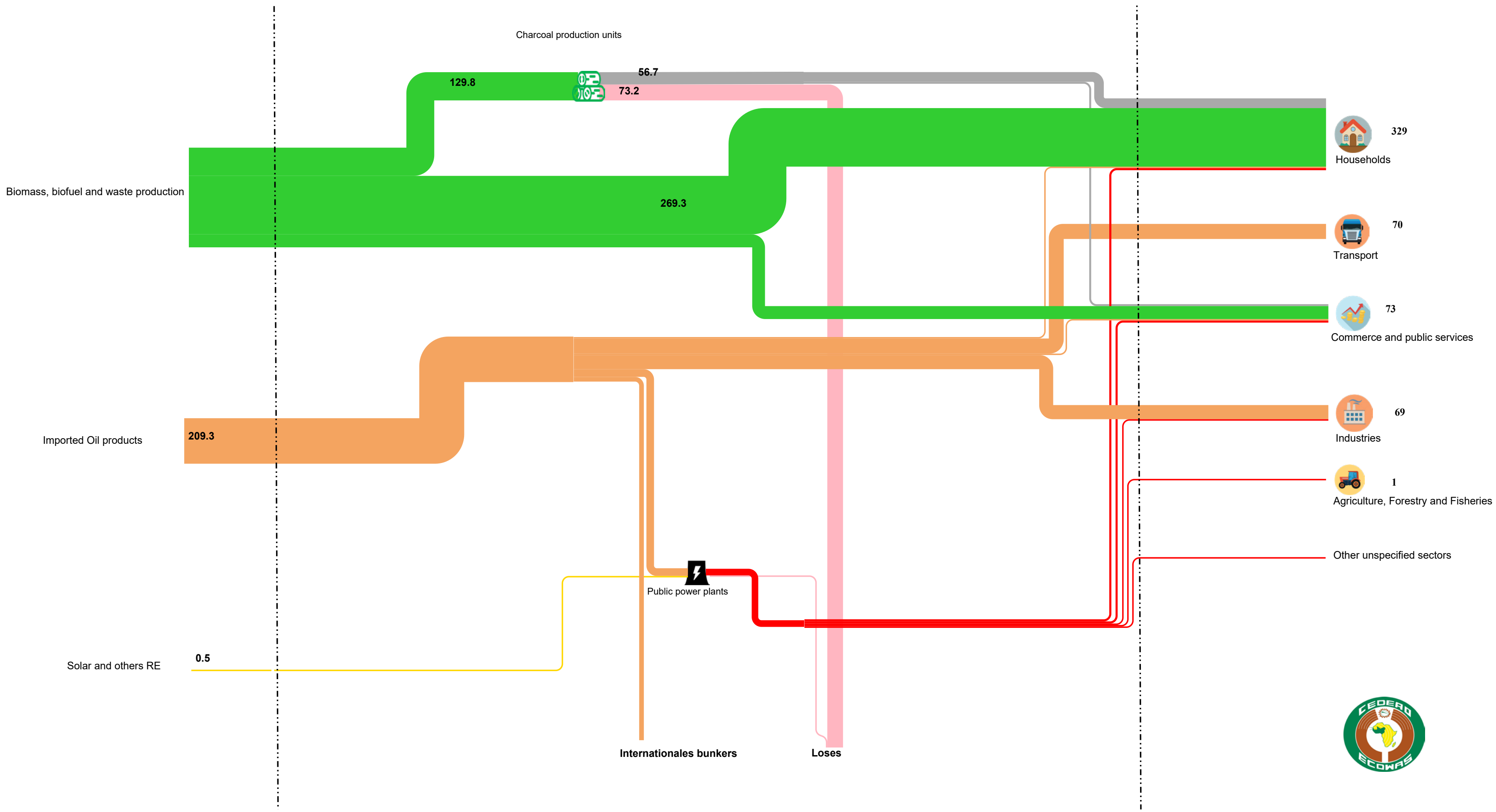

Figure 66: The Gambia's energy balance flows in ktoe, 2021

As in most countries in the region, The Gambia's energy system is dominated by biomass energy. Fully imported petroleum products are used mainly in the transport and industrial sectors, but also for electricity generation. Electricity is mainly consumed in households and in shops and services.

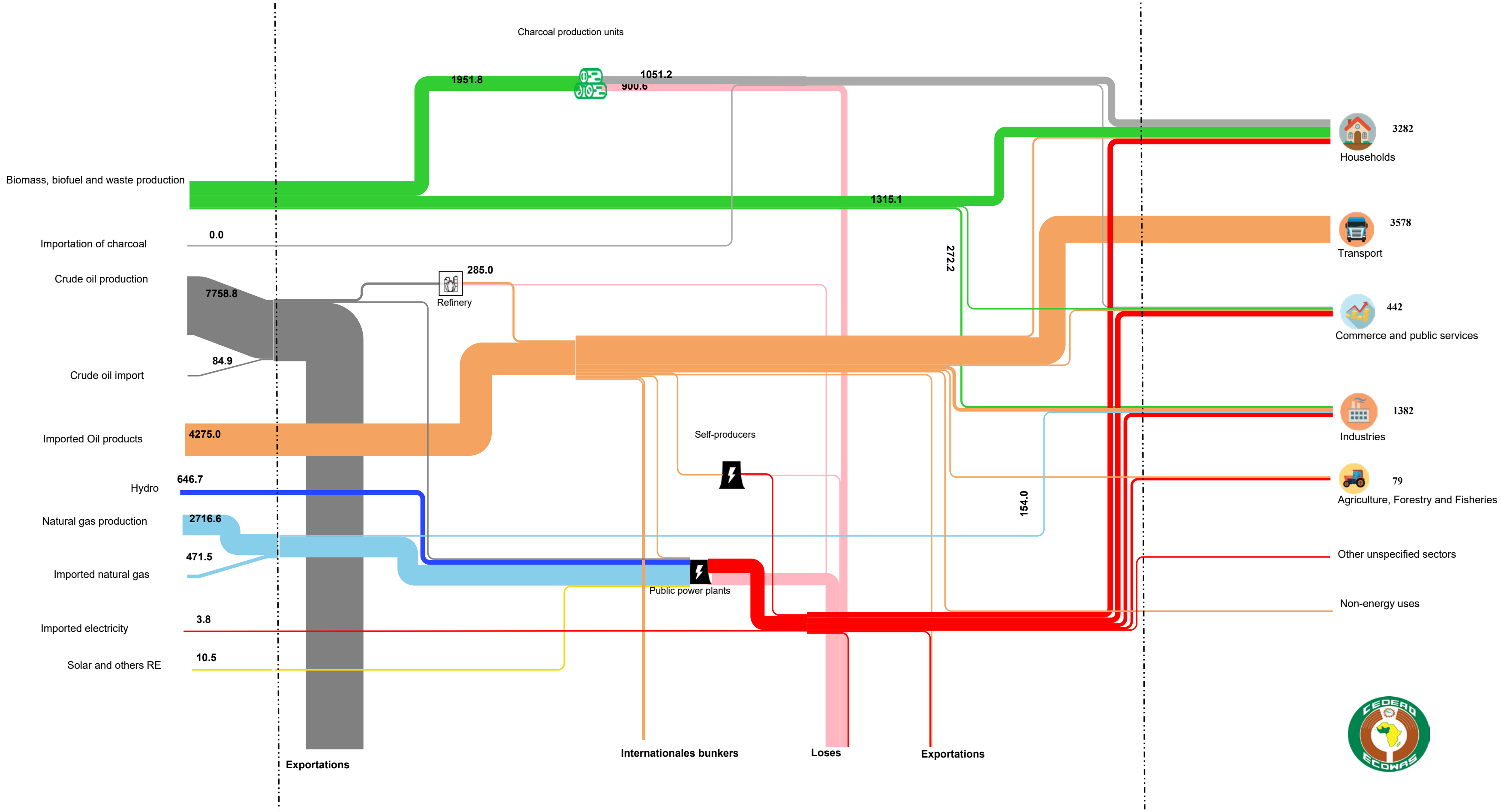

Figure 67: Ghana 's energy balance flows in ktoe, 2021

Ghana's energy landscape is marked by high production of crude oil, much of which is exported. The vast majority of imported petroleum products are used, particularly in the transport sector, which is the country's largest energy consumption sector. Natural gas is the main source of electricity generation, but it is also used in the industrial sector. Although biomass energy remains the primary source of energy for households, electricity plays an important role in their consumption.

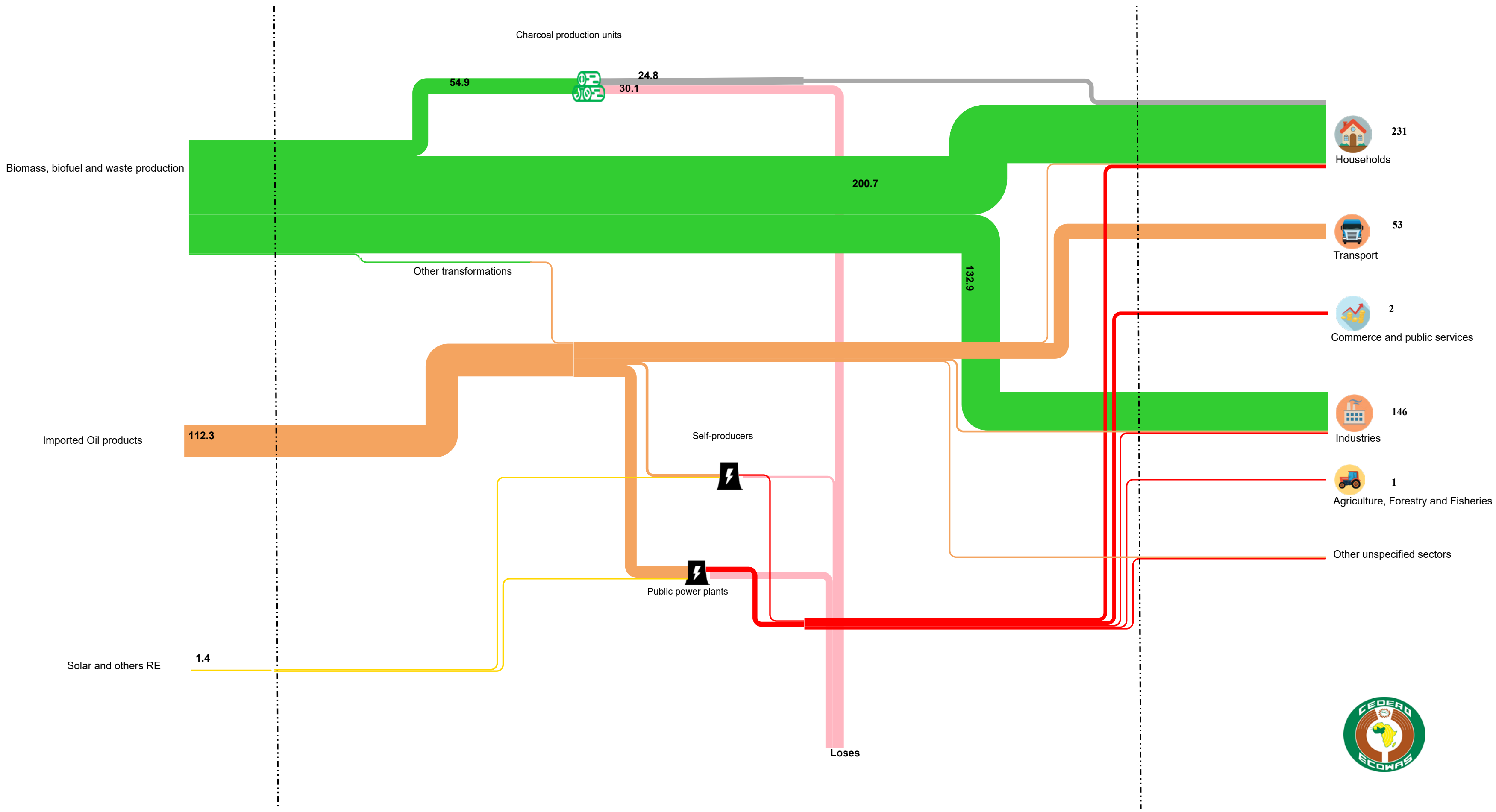

Figure 68: Guinea 's energy balance flows in ktoe, 2021

The energy system is dominated by biomass energy, which is used entirely by the residential sector. Fully imported petroleum products are mainly used in industry and transportation. It is important to note that there is a gap between imports and uses, which represents a level of improvement in the country's statistics. Electricity generation, too, has a gap between the amount of energy that goes in and out of the transformation process.

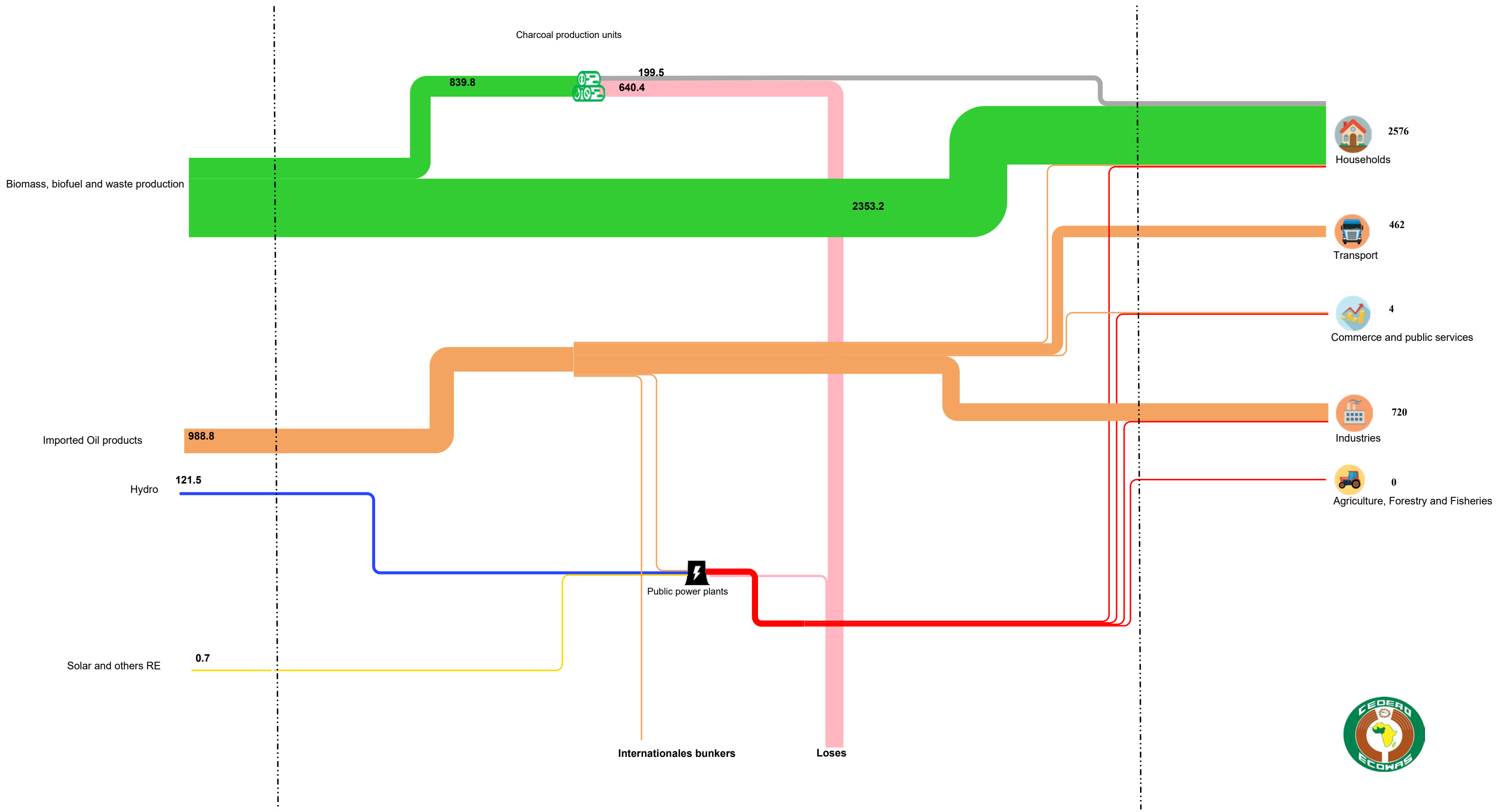

Figure 69: Guinea Bissau's energy balance flows in ktoe, 2021

In Guinea Bissau, the energy system is dominated by biomass energy, which is used mainly in the residential and industrial sectors. Fully imported petroleum products are mainly used in the transportation sector and for electricity generation. Electricity used mainly in households and services has a gap between production and consumption.

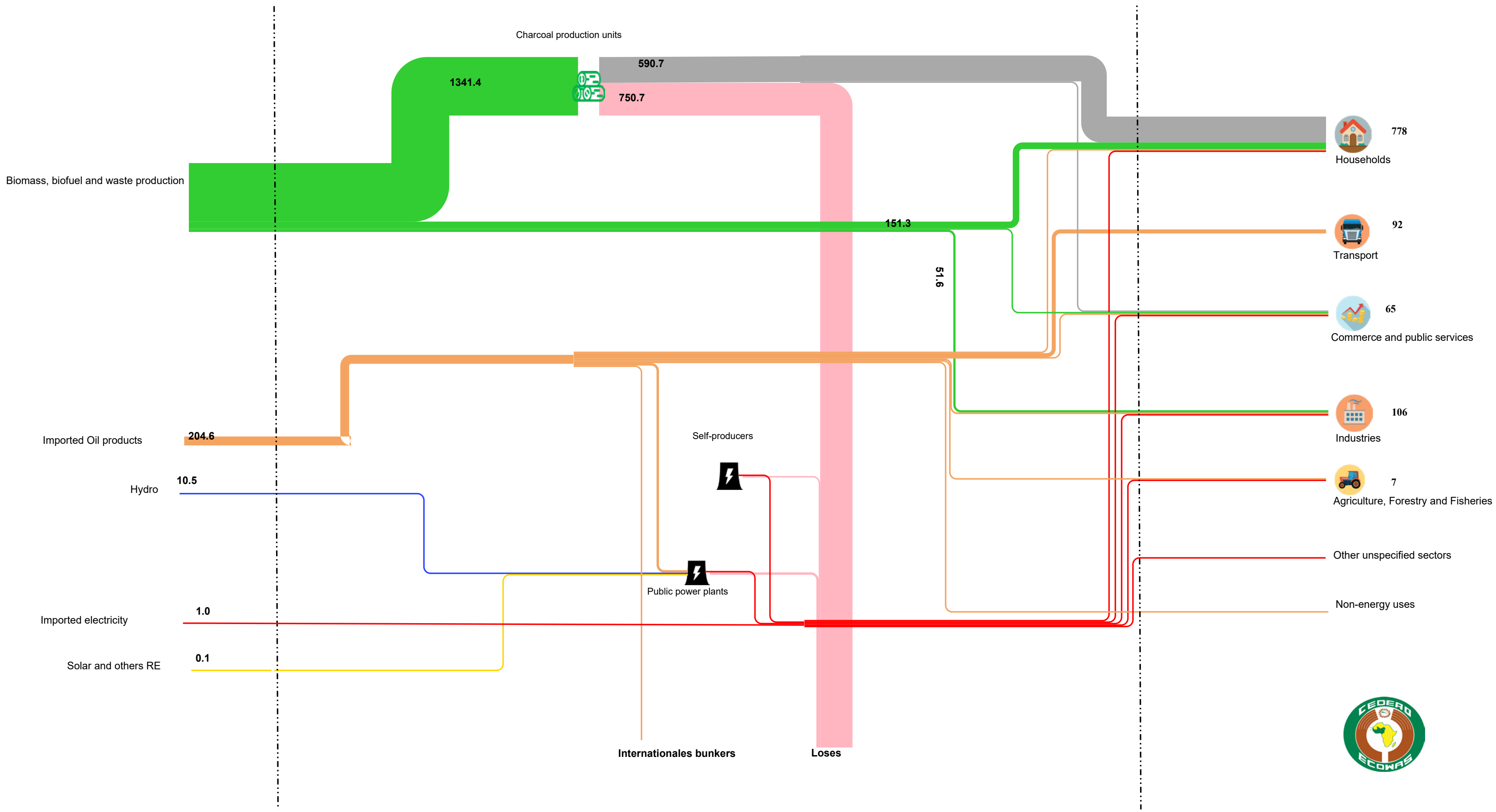

Figure 70: Liberia's energy balance flows in ktoe, 2021

Liberia's energy system predominantly uses biomass energy which is mainly processed into charcoal. Charcoal is the main form of energy consumed in the country, especially by households. There is a lack of energy used as inputs to the electricity production process of self-producers and needs to be collected more.

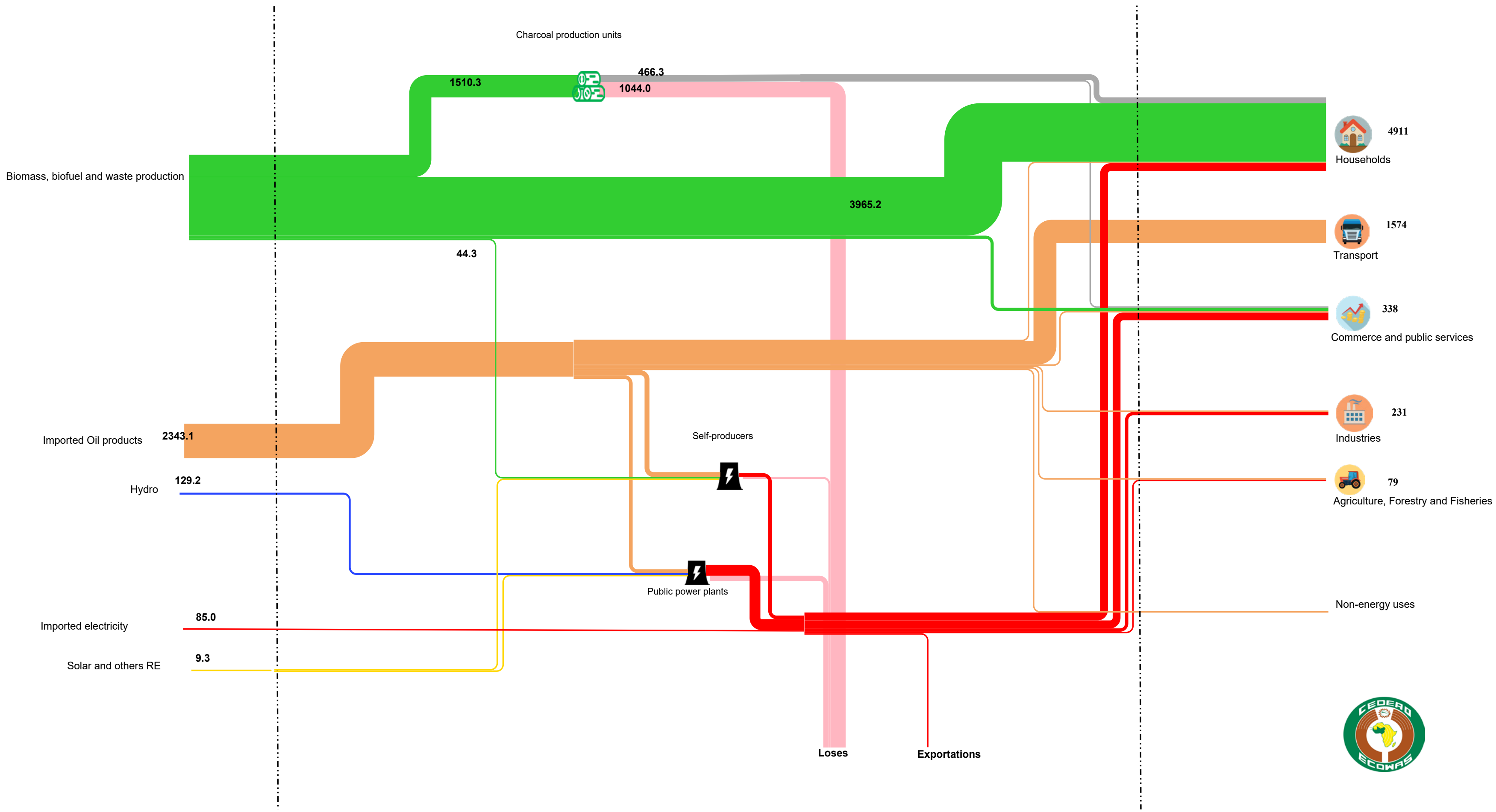

Figure 71: Mali's energy balance flows in ktoe, 2021

Mali's energy system is dominated by biomass energy. Produced locally, it is the main form of energy used in the residential sector. The electricity made available to consumers is mainly produced locally from petroleum products, hydroelectricity, solar photovoltaic energy and biomass energy. Petroleum products, which are entirely imported, are mainly used in the transport sector.

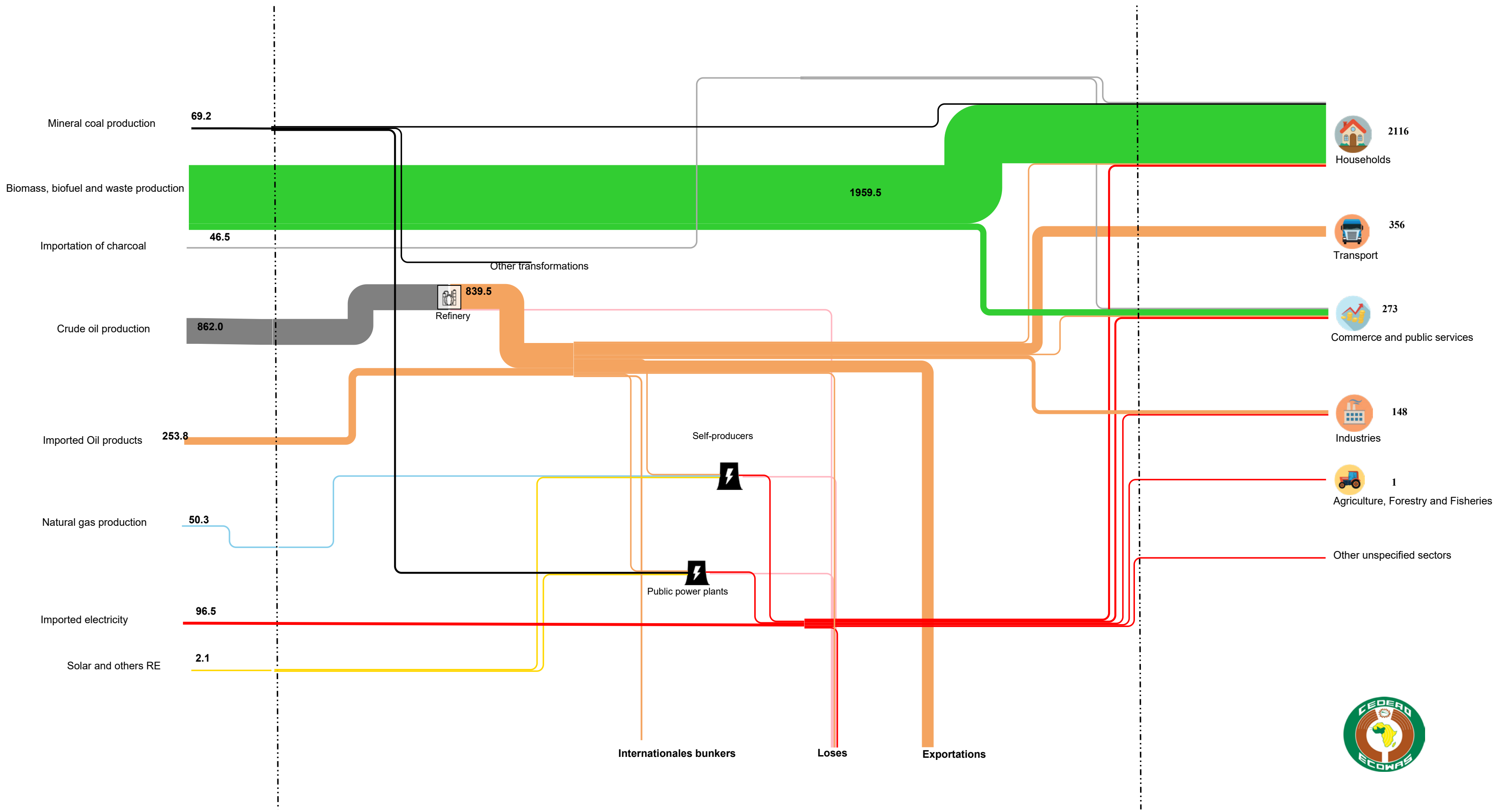

Figure 72: Niger's energy balance flows in ktoe, 2021

Niger is the only country in the region where the carbonization of biomass, especially firewood, is not permitted. However, the country's energy system is still dominated by biomass energy, which is the main source of household energy. The petroleum products used in the country come mainly from the local refining of crude oil produced in the country. Much of the production of petroleum products is exported, and the rest is used for transport, industry, commerce and households.

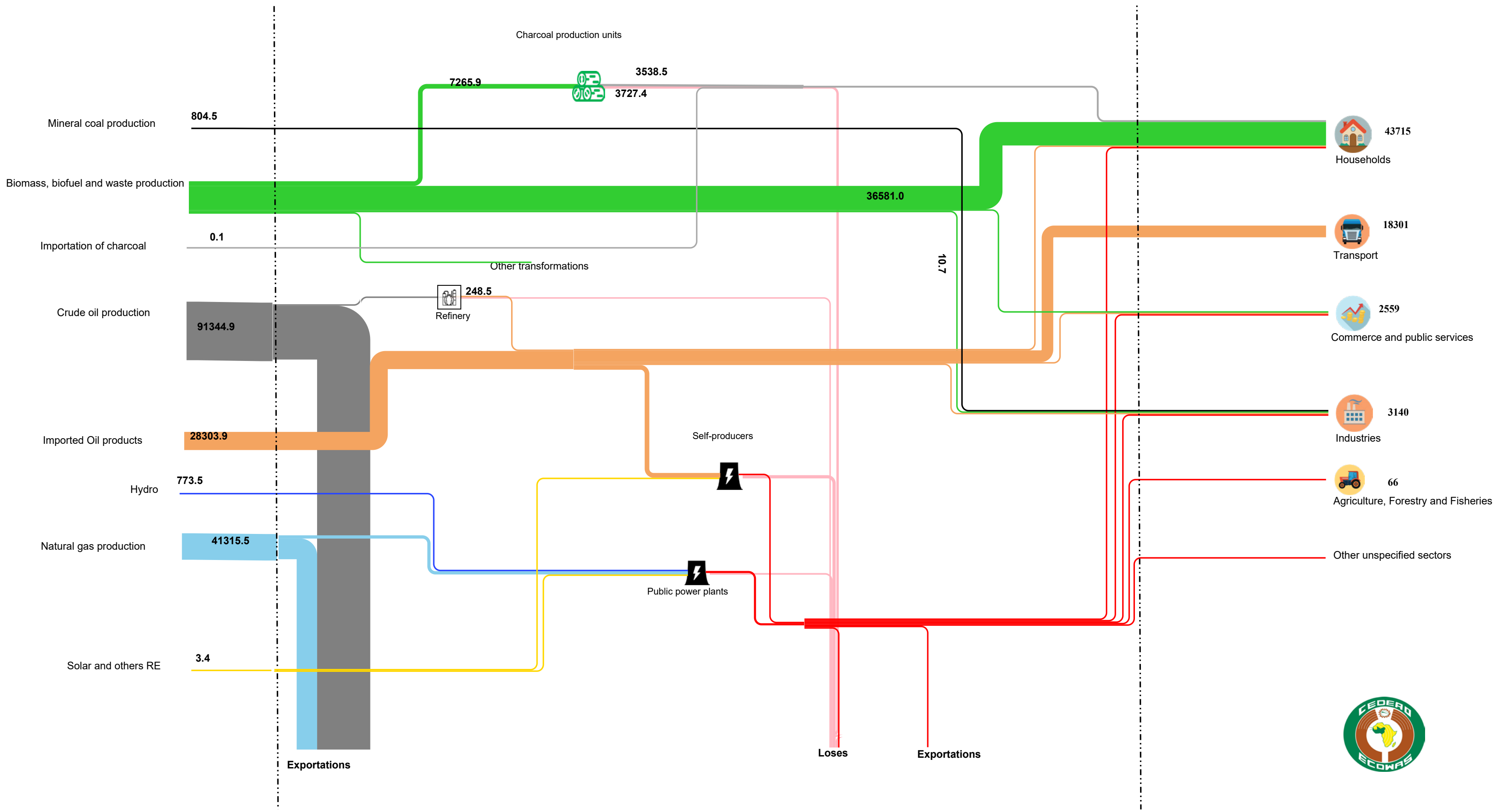

Figure 73: Nigeria's energy balance flows in ktoe, 2021

Nigeria's energy landscape is marked by high production and export of crude oil and natural gas. Petroleum products, consumed in the country in particular for transport and electricity production by self-producers, are largely imported. The residential sector is the largest sector in terms of energy consumption and it mainly consumes biomass energy. Natural gas is the country's main source of electricity generation.

SENEGAL

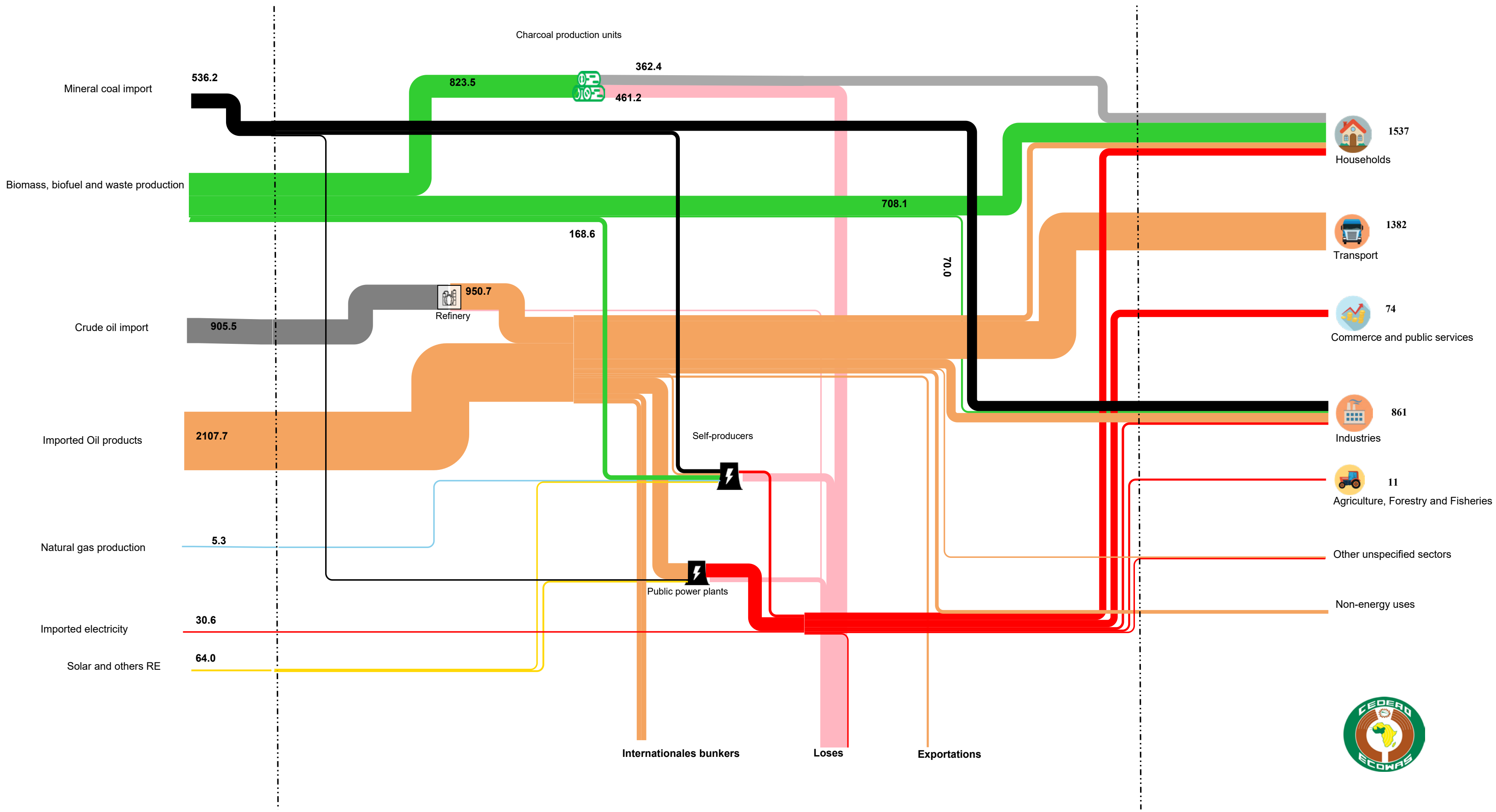

Figure 74: Senegal's energy balance flows in ktoe, 2021

Senegal's energy system is marked by a diversity of forms of energy. Electricity generation in the country is from biomass energy, mineral coal, natural gas, solar photovoltaic, wind and petroleum products. A third of the petroleum products used in the country are produced locally from imported crude oil. Biomass energy is the main source of energy consumption in the residential sector, but electricity and petroleum products have a significant share.

SIERRA LEONE

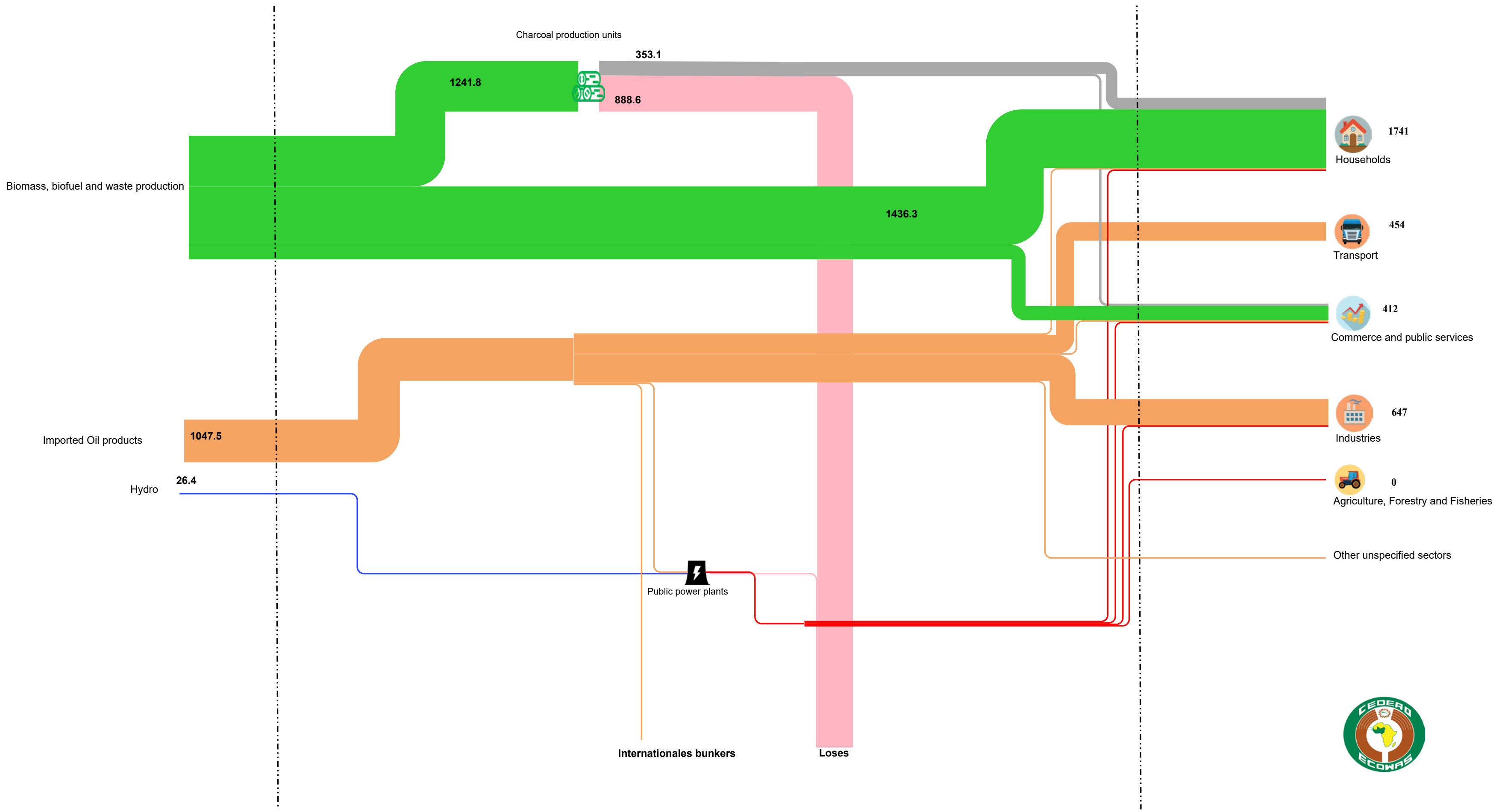

Figure 75: Sierra Leone's energy balance flows in ktoe, 2021

In Sierra Leone, the energy landscape is dominated by locally produced biomass, which is the main source of household energy, far ahead of electricity and petroleum products. Fully imported petroleum products are used mainly in the industrial and transportation sectors. Electricity, which is produced entirely locally and in particular from hydroelectric dams, has a gap between the quantities entering and leaving the production process.

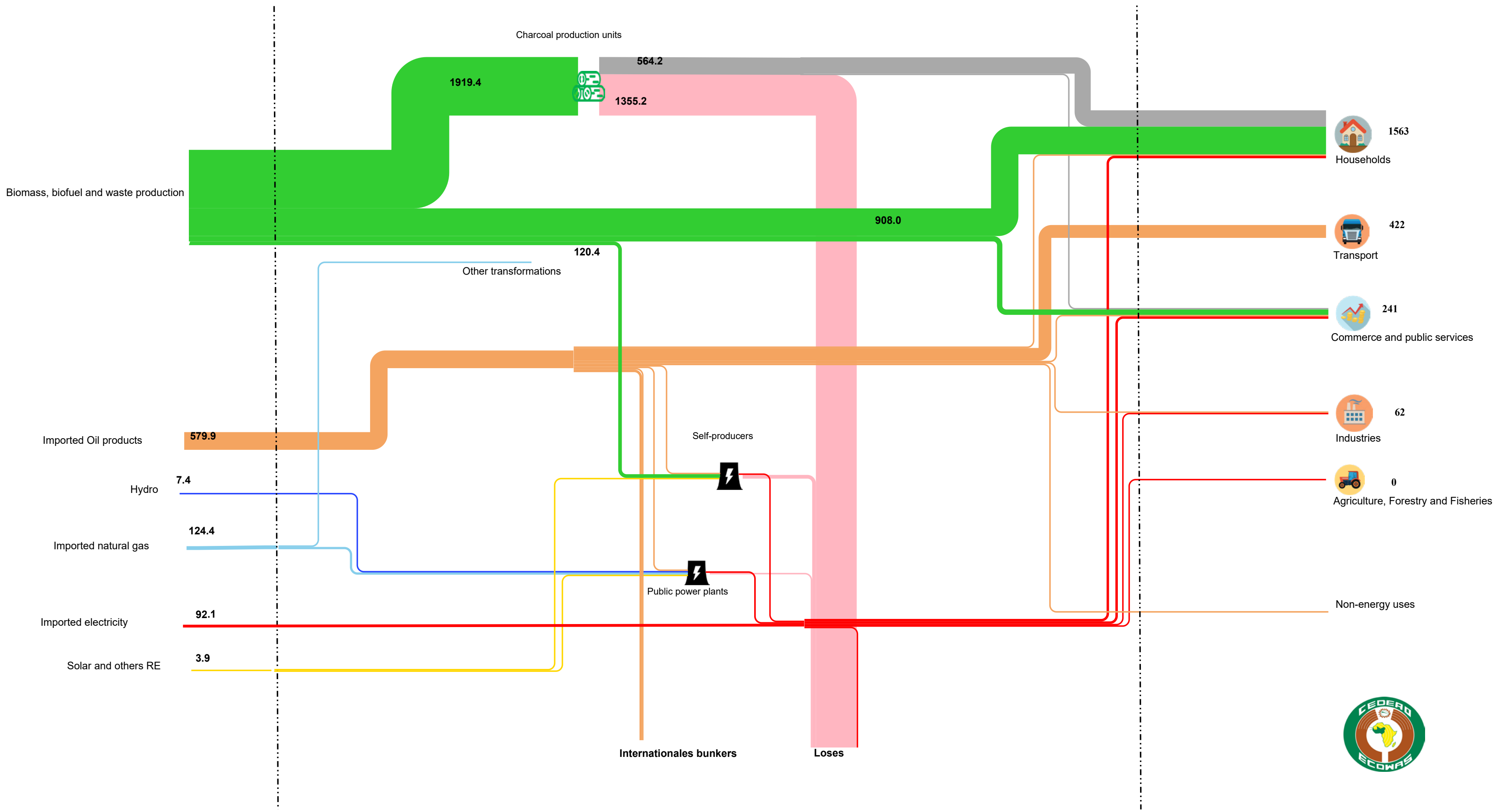

Figure 76: Togo's energy balance flows in ktoe, 2021

Togo's energy system is characterised by the high use of biomass energy and significant carbonization losses. Charcoal from the carbonisation process is the second most consumed energy product in the country. Wholly imported petroleum products are widely used by the transportation sector and very little in the residential sector. A significant portion of the electricity consumed in the country is imported, and the rest is produced mainly with natural gas.