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THE ROLE OF SUSTAINABLE ENERGY ON WEST AFRICAN ECONOMIC GROWTH:

Case study: Côte d'Ivoire, Mali, Senegal

Presented on the 23rd September 2025 by
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DEDICATION

"To my beloved family,

This work stands as a testament to the unwavering support, love, and guidance you have bestowed upon me throughout my journey. Your sacrifices and encouragement have been the driving force behind my accomplishments. With profound gratitude, I dedicate this work to you, as a small token of my love and appreciation.

With all my love,

Mahamadou Kamite"

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ABSTRACT

In the context of climate change and fossil fuel depletion, west Africa must reconcile its growing energy demand with environmental sustainability. This study assesses the role of renewable energy in supporting long-term economic growth and reducing CO_2 emissions in Côte d'Ivoire, Mali, Senegal. The datas for this research was collected from world bank, scientific papers and some international websites. A quantitative scenario-based approach was applied, combining population and GDP projection (2024-2050) with a global regression model linking historical GDP per capita to historical electricity consumption per capita (2011-2024). Future electricity demand was estimated under pessimistic, medium, and optimistic growth scenarios and compared to the technically exploitable potential of solar, wind, and hydropower in each country.

Results indicated that Mali and Senegal possess renewable energy potentials far exceeding future demand, enabling full decarbonization by 2050 under all scenarios. In contrast, Côte d'Ivoire's exploitable renewable potential can cover only 60% of the projected 2050 needs in medium scenario and 33% for optimistic scenario, requiring complementary solutions such as biomass, storage and regional interconnections. Renewable energy transition plans were modelled for each country, progressively replacing fossil fuels with optimal mixes of solar, wind and hydro. CO_2 avoidance calculations show substantial mitigation potential: up to 61 million tons avoided in Mali,54 million in Senegal, and 17 million in Côte d'Ivoire by 2050.

The findings confirm that renewable energy can simultaneously enhance energy security, foster economic growth, and reduce emissions in west Africa, provided that public policies priorities infrastructure investment and regional energy cooperation.

Keywords: Sustainable energy, Economic growth, West Africa (Côte d'ivoire, Mali, Senegal)

RESUME

Dans le contexte du changement climatique et de l'épuisement des combustibles fossiles, l'Afrique de l'Ouest doit concilier sa demande énergétique croissante avec la durabilité environnementale. Cette étude évalue le rôle des énergies renouvelables dans le soutien à la croissance économique à long terme et la réduction des émissions de CO_2 en Côte d'Ivoire, au Mali et au Senegal. Les données utilisées pour cette recherche ont été recueillies auprès de la Banque mondiale, dans des articles scientifiques et sur certains sites web internationaux. Une approche quantitative basée sur des scénarios a été appliquée, combinant les projections démographiques et du PIB (2024-2050) avec un modèle de régression global reliant le PIB historique par habitant à la consommation historique d'électricité par habitant (2011-2024). La demande future en électricité a été estimée selon des scénarios de croissance pessimiste, moyen et optimiste, puis comparée au potentiel techniquement exploitable de l'énergie solaire, éolienne et hydraulique dans chaque pays.

Après cette étude de scénarios, les résultats montrent que le Mali et le Sénégal disposent d'un potentiel énergétique nettement supérieur à la demande à l'horizon 2050, ce qui leur permettrait de décarboner complètement leur économie d'ici 2050 dans tous les scénarios. En revanche, le potentiel estimé pour la Côte d'Ivoire ne peut couvrir que 60 % des besoins prévus à 2050 dans le scénario moyen et 33 % dans le scénario optimiste. Il est donc nécessaire de prendre en compte des solutions complémentaires telles que la biomasse, le stockage et les interconnexions régionales intelligentes. Des plans de transition verte pour les énergies renouvelables ont été modélisés pour chaque pays, visant à remplacer progressivement les combustibles fossiles par un mix optimal d'énergie solaire, éolienne et hydraulique. Les calculs d'évitement de $CO2$ montrent un potentiel d'atténuation considérable : jusqu'à 61 millions de tonnes évitées au Mali, 54 millions au Sénégal et 17 millions en Côte d'Ivoire d'ici 2050.

Les résultats obtenus confirment que les énergies renouvelables peuvent simultanément renforcer la sécurité énergétique, favoriser la croissance économique et réduire les émissions en Afrique de l'Ouest, à condition que les politiques publiques privilégient les investissements dans les infrastructures et la coopération énergétique régionale.

Mots clés : Énergie durable, Croissance économique, Afrique de l'Ouest (Côte d'ivoire, Mali, Senegal)

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LIST OF ABBREVIATIONS AND ACRONYMS

CF: Capacity factor.

CO_2: Carbon dioxide emissions.

CLSG : Côte d'Ivoire-Liberia-Sierra Leone-Guinea interconnector

ECREEE: ECOWAS Centre for Renewable Energy & Energy Efficiency.

ECOWAS: Economic Community of West African States

EC per capita: electricity consumption per person

FDI: Foreign Direct Investment

FMOLS: Fully Modified OLS

GDP per capita: gross domestic product per person

IEA: international energy agency

IRENA: International Renewable Energy Agency.

MSW: Municipal solid waste

OECD: Organization for Economic Co-operation and Development.

OLS : Ordinary Least Squares

OMVS : Organisation pour la Mise en Valeur du fleuve Senegal.

RE: Renewable Energy

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GENERAL INTRODUCTION

GENERAL INTRODUCTION:

In a world marked by climate change and the depletion of fossil fuels, the transition to sustainable energy becomes urgent and a strategic priority. The increase in global temperatures, extreme weather events, and the degradation of our environment highlight the deep need for our energy systems. This transformation is particularly vital for developing countries that are the most vulnerable to the effects of climate change while being the least responsible for historical greenhouse gas emissions (Okesanya et al., 2024).

The energy challenge is especially critical in west Africa. Despite having abundant renewable energy resources, the region suffers from some of the lowest electrification rates in the world. According to the *World bank* (2023) over 220 million people in West Africa live without access to electricity. Energy costs remain among the highest in sub-Saharan Africa, creating a significant barrier to both social development and economic progress. These challenges are compounded by population growth, urbanization, and the urgent need for climate resilience. Yet, West Africa holds a renewable energy potential estimated at over 2,000 Gigawatts (GW) particularly in solar, wind, hydro, and biomass enough to meet and exceed the basic energy needs of its population (*Pwc*, 2023). However, this potential remains largely untapped due to infrastructure deficits, unstable energy policies, and continued reliance on fossil fuels. Fossil energy sources, while currently dominant, are finite and environmentally damaging. In contrast, renewable energy sources are clean, locally available, and sustainable.

Climate objectives and the energy need for development can be addressed simultaneously through the promising paths offered by renewable energies. Several studies mentioned the positive impact of renewable energy on economic growth. For instance, Dogan et al., (2020) show that renewable energy consumption contributes significantly to long-term growth in developing countries. Similarly, Koçak & Şarkgüneşi (2017) confirm the stabilizing effect of clean energy integration in the Black Sea and Balkan regions.

Problem Statement:

West Africa has a double challenge: growing energy demand driven by population growth and economic development (World bank group, 2025a), and the need to cut greenhouse gas emissions in the context of global climate change (IRENA, 2023a). Despite considerable potential in renewable energy sources such as solar, wind, hydro (WAPP, 2019), Côte d'Ivoire, Mali and Senegal still rely heavily on fossil fuels and traditional biomass, which are often inefficient and polluting (IRENA, 2023a).

A transition to sustainable energy sources could not only meet future energy demand but also promote inclusive economic growth while reducing CO_2 emissions (World bank, 2025a). However, this transition raises questions about feasibility, economic efficiency and medium- and long-term environmental impacts, issues that remain largely unexplored in these three countries (WAPP, 2019).

Scope of the study:

This thesis takes a forward-looking and strategic approach, aiming to assess the role those renewable energies can play in the economic transformation of three key countries: Mali, Senegal and Côte d'Ivoire. By combining demographic and economic projections with rigorous modelling of electricity consumption and the exploitable potential of renewable resources, this study offers an integrated view of the energy, economic and environmental challenges specific to each of these countries.

Beyond the technical analysis, this work can shed light on the debate on public policies to adopt to achieve a fair, inclusive and resilient energy transition. It shows different possible scenarios for 2050, quantifies the expected benefits in terms of economic growth and reduction of CO2 emissions. Finally, it is to show that sustainable energy is not only a response to the climate challenge but also a driver of development and energy sovereignty for West Africa.

To manage well, it is imperative to ask oneself questions in order to achieve specific objectives on the following:

Main question:

To what extent can renewable energy meet future energy demand while supporting economic growth and reducing CO_2 emissions in Senegal, Mali, and Côte d’Ivoire?

Research Sub-questions:

- What is the exploitable renewable energy potential in Côte d'Ivoire, Mali, and Senegal?
- How these renewable energy potentials can meet future energy demand under economic growth scenarios in these countries?
- To what extent can the development of renewable energy contribute to reducing CO_2 emissions in the medium and long term?

Main objective:

To assess the role of renewable energy in supporting economic growth, meeting future electricity demand and reducing CO2 emissions in Côte d'Ivoire, Mali et Senegal.

Specific objectives:

- To identify and quantify the renewable energy potential (solar, wind, hydro) in Côte d'Ivoire, Mali, and Senegal.
- To evaluate how this renewable energy potential can meet the projected electricity demand driven by economic growth under different GDP scenarios.
- To estimate the extent to which increasing renewable energy use can reduce CO_2 emissions over the medium and long term.

The thesis was organized following the steps below.

After the general introduction, we started with Chapter 1 to show the current state of the countries to be studied in terms of production and the share of renewable energies in the energy mix, as well as to demonstrate the link between electricity consumption and the growth of the country (GDP) through various studies that have been conducted. Chapter 2 discusses how and where the data was collected, as well as the methodology that was adopted to successfully carry out this work. Chapter 3 focuses on the presentation, interpretation, and discussion of the results obtained, and the general conclusion summarizes the main points of the document, especially ensuring that all objectives have been met in order to propose actions to address the issues that led to this work.

CHAPTER I: LITERATURE REVIEW

CHAPTER I: LITERATURE REVIEW

Introduction

This chapter presents the conceptual and theoretical framework underlying this research. It first sets out the definition and scope of sustainable energy, then describes West Africa's renewable energy potential. The advantages and challenges associated with their deployment are then discussed, before examining the current energy situation in the countries studied and the economic theories relevant to analyzing the link between energy and economic growth.

1.1 Definition of Sustainable Energy

According to (Rosen, 2021), sustainable energy is defined as energy "produced and used in a manner that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition, rooted in the Brundtland Report, highlights the dual challenge of ensuring present energy access while safeguarding long-term environmental and economic sustainability (Keeble, 1988).

Furthermore, sustainable energy does not harm the environment (or at most, the risk is minimal), does not exacerbate climate change and is inexpensive. Although the creation and implementation of means to capture sustainable energy come at a cost, the energy sources themselves are generally free. Examples of sustainable energy sources include wind, solar and water (hydropower). All of which can be considered inexhaustible and widely available to almost everyone. Geothermal energy can also be included as a sustainable alternative energy source. Geothermal energy creates usable energy from the planet's internal energy sources, such as geysers (*Routledge Taylor and Francis Group*, 2025).

1.2 Renewable energy potential

In 2023, the exploitable installed power capacity potential differs significantly across Mali, Senegal, and Côte d'Ivoire. According to data from IRENA, Mali has the highest solar potential, estimated at 298.812 GW, as well as 7.962 GW of wind capacity. It also has 1.050 GW of hydropower potential, based on estimates from (Nopenyo et al., 2019). Senegal has a solar potential of 37.223 GW and a wind capacity of 4.531 GW, both based on IRENA assessments. While Senegal has less significant information on hydropower potential within its territory, it shares access to regional hydropower resources through the Senegal River Basin, with most of the strategic sites located in Mali. Through the OMVS project, Senegal benefits from a share of the electricity produced by these shared hydroelectric facilities. Côte d'Ivoire, meanwhile, has 28.919 GW of solar potential and 2.548 GW of wind potential (both from IRENA), along with 2.458 GW of hydropower capacity (Koua et al., 2015).

1.3 Advantages & Challenges of renewable energy in West Africa

1.3.1 Advantages

Table 1: Exploitable installed capacity potential (Côte d'Ivoire - Mali – Senegal)

EXPLOITABLE INSTALLED POWER POTENTIAL (2023)				
Country	Solar (GW)	Wind (GW)	Hydropower (GW)	Sources
Mali	298.812	7.962	1.050	(IRENA, 2018) , (Nopenyo et al., 2019)
Senegal	37.223	4.531	-	(IRENA, 2018)
Côte d'Ivoire	28.919	2.548	2.458	(IRENA, 2018), (Koua et al., 2015)

Abundant renewable resources

West Africa's renewable energy potential exceeds 2,000 GW, driven by world-class solar irradiance, wind corridors and hydropower opportunities. Harnessing even a fraction of this could meet basic energy needs for the entire region (PWC, 2023;IRENA, 2023).

Expanded access through regional integration

Projects like the 1303km CLSG interconnector and the west Africa Power Pool have delivered affordable power to over 2.8 million people, reduced dependance on diesel generators, and cut CO_2 emissions by millions of tons (World bank, 2025)

Economic growth and Job creation

Scaling renewables attracts foreign direct investment, boosts local industry and training programs, and can create millions of jobs. One estimate projects up to 38 million global renewables jobs by 2030, many of which could be in west Africa's rapidly expanding solar and wind sectors (Springer nature, 2024).

Competitive electricity costs

Renewables, particularly solar and wind, are now the cheapest sources of new electricity generation globally, with solar PV costs falling dramatically since 2010. This trend helps lower long-term energy costs in West Africa.

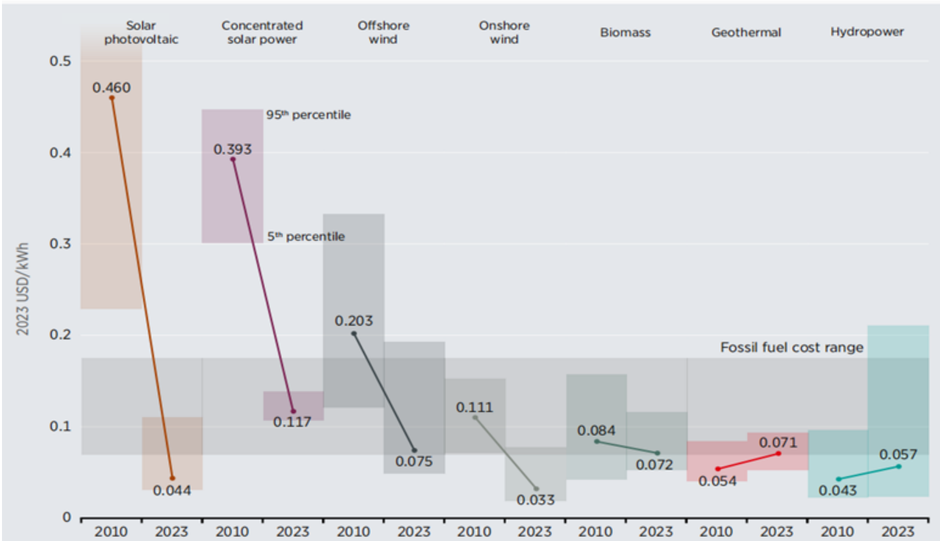

Figure 1: Evolution of the renewable energy cost (IRENA, 2024)

1.3.2 Challenges

Outdated and insufficient grid infrastructure

Integrating variable renewables demands upgraded, automated transmission and distribution networks, as well as widespread deployment of mini-grids, off-grid systems and storage solutions in areas where current investment falls short (PWC, 2023).

Massive financing needs and bankability issues

Achieving a higher renewables share requires over US $540 billion in power-sector investment by 2050. Many West African governments are debt-distressed and public services are limited in terms of liquidity, deterring private capital due to increase credit risk (PWC, 2023).

Policy, Regulatory and Tariff Barriers

Although the production and distribution in several markets has been liberalized , the tariffs are not very competitive and require frequent subsidies, which masks the real cost and amplifies the risks associated with the purchase. The lack of progress on the border project and the security of investments are linked to a lack of harmonized regional regulations.. (IRENA, 2023; PWC, 2023).

Table 2:Total installed costs of different renewable energy technologies

	Total installed costs (2023 USD/kW)		
	2010	2023	Percent change
Bioenergy	3 010	2 730	-9%
Geothermal	3 011	4 589	52%
Hydropower	1 459	2 806	92%
Solar PV	5 310	758	-86%
CSP	10 453	6 589	-37%
Onshore wind	2 272	1 160	-49%
Offshore wind	5 409	2 800	-48%

Source:(IRENA, 2024)

High End-User Costs and Affordability

Electricity prices in West Africa average around US $0.20/kWh, with peaks above US $0.40/kWh in countries like Burkina Faso. High tariffs and limited affordability slow down both residential and industrial uptake of renewables (Res4Africa, 2023).

Limited institutional capacities and skills

The obstacles to the planning, execution and long-term operation of projects may be due to the limitation of local labor force of only about 66,000 workers, the lack of technical and management expertise (Res4Africa, 2023).

Political and Economic Risks

Political instability, currency volatility and weak utility governance remain predominant risks, complicating power purchase agreements and increasing the perceived cost of capital for renewable projects (World bank, 2023).

1.4 Current energy situation

- **Côte d'Ivoire**

Electricity consumption in Côte d'Ivoire in 2023 is primarily dominated by fossil energy sources, with gas accounting for almost the entire fossil contribution at over 7.65 TWh. In contrast, low-carbon energy sources provide a smaller slice of the electricity mix, with hydropower contributing a significant portion of this at 3.35 TWh. Overall, the total electricity production in the country is about 357 kWh per person, which is significantly lower than the global average of 3813 kWh per Person (World bank, 2025a). This disparity highlights a concerning gap in electricity availability, suggesting potential challenges for economic development and quality of life, which rely heavily on stable and abundant electricity supplies. Notably, Côte d'Ivoire's energy mix could benefit greatly from expanding low-carbon sources to reduce reliance on fossil fuels, which are linked to climate change and air pollution (Lowcarbonpower, 2023).

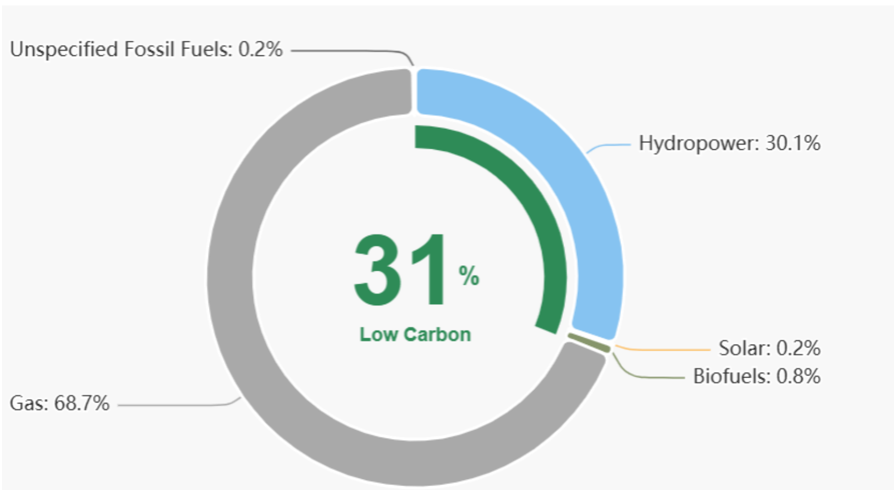

Figure 2: Côte d'Ivoire renewable Energy Share (2023)

Source: (Lowcarconpower, 2023)

As of 2023, Côte d'Ivoire had made notable progress in expanding access to electricity across the country. According to the *World bank* (2023) , approximately 72.4% of the national population had access to electricity. However, a significant gap persists between urban and rural areas. In urban regions, electrification reached an impressive 92%, reflecting strong infrastructure and grid connectivity in cities. In contrast, rural areas had an electrification rate of only 48%, as reported by (*Tradinge Conomics*, 2025), underscoring the challenges of extending the national grid to remote communities.

- **Mali:**

  In 2023, Mali's consumption shows a strong dependence on fossil fuels, representing approximately more than half of the electricity produced (2.5 TWh). At the same time, low-carbon energies contribute nearly 1.9 TWh, with hydroelectricity playing a very important role with approximately 1.64 TWh. This shows that Mali has a considerable share of clean energy in its energy mix, but that the country is heavily dependent on fossil fuels. Electricity consumption per capita is 193 kWh, which is significantly lower than the world average of approximately 3,813 kWh/capita (World bank, 2025a). Economic growth and access to modern equipment could be limited by this level of electricity production and industrialization, and an improvement in living conditions would be difficult. (Lowcarbonpower, 2023).

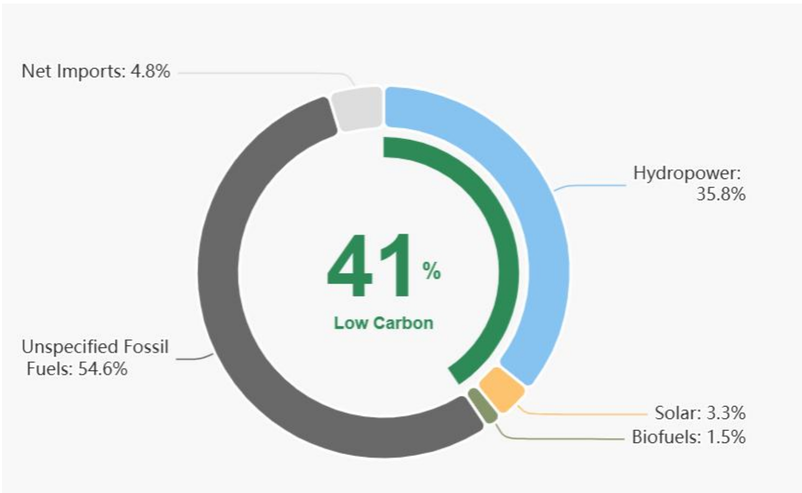

Figure 3: Mali renewable energy share (2023)

Source: (Lowcarbonpower, 2023c)

Mali is determined to improve its energy situation by relying on reliable, accessible, and cheaper energy sources, which is essential for economic growth and industrial development, particularly in the agricultural sector. As of 2023, the electrification rate is 56%, with a disparity between urban areas (87%) and rural areas (31%). The country still faces serious challenges in meeting the growing demand. Although there have been improvements, many localities, especially rural areas, remain without a stable energy supply (*AFRICA DEVELOPEMENT BANK*, 2025).

- **Senegal:**

Senegal's current electricity consumption paints a picture of reliance primarily on fossil fuels, with more than 70% of the electricity generated from these sources. Within the low-carbon category, which comprises approximately 20% of the electricity generation, wind and solar energies serve as the main pillars, cumulatively accounting for nearly 16%. Hydropower and biofuels contribute modestly to the low-carbon share, with around 3.6% and a little over 1% respectively. Net imports and coal together make up about 11% of the total electricity consumption. The dominance of fossil fuels indicates a significant area of improvement for Senegal to boost its clean energy footprint (Lowcarbonpower, 2023d).

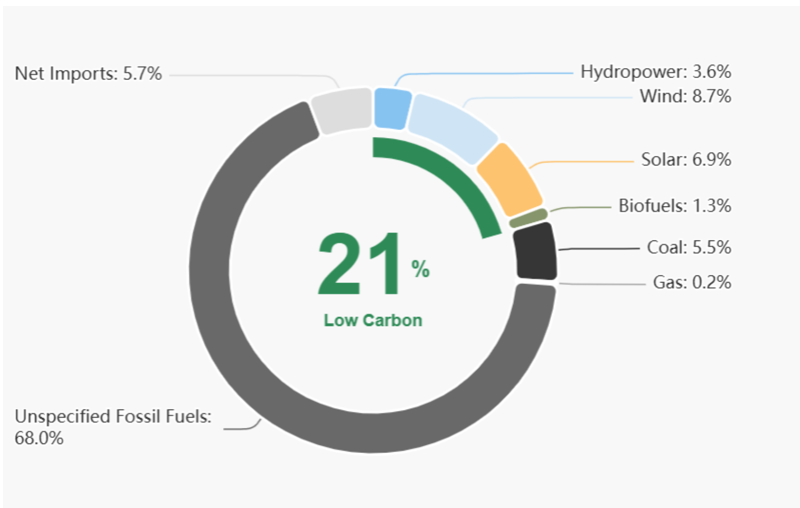

Figure 4: Senegal renewable energy share (2023)

Source: (Lowcarbonpower, 2023d)

Senegal is aiming for universal access to clean, affordable, and reliable energy by 2025. With a population of 17.7 million, the country already has one of the highest electrification rates in West Africa. As of 2023, 84% of the population has access to electricity, with 97% in urban areas and 64% in rural areas. Despite these improvements, many rural communities still lack stable electricity (*AFRICA DEVELOPEMENT BANK*, 2025).

1.5 Relevant economic theories

1.5.1 Endogenous growth theory: Innovation and Energy as drivers of economic Growth

The Endogenous Growth Theory emphasizes the role of technological advancement and innovation as internal factors in driving long-term economic growth. Within this framework, renewable energy is considered not only a cleaner alternative but a catalyst for innovation-led growth. According to Raihan et al. (2025), the expansion of renewable energy infrastructure often necessitates technological innovation and foreign direct investment (FDI), which can stimulate job creation, improve energy security, and enhance productivity. This dynamic is especially important in emerging economies such as those in West Africa, where traditional energy systems are often underdeveloped and unreliable. They argue that clean energy transitions represent a dual opportunity, meeting rising energy demand while simultaneously fostering innovation and sustainable development through energy diversification and efficiency improvements.

Similarly, Apergis & Payne (2010) find that in OECD countries, economic output when integrated into an endogenous production framework could be positively affected by renewable energy consumption, alongside capital and labor inputs. Their panel FMOLS estimates show that renewable energy has a significant and positive coefficient in the long-run production function, indicating its role as a growth factor, alongside physical and human capital.

Riti et al. (2022), who studied 28 Sub-Saharan African countries from 1990 to 2019, found that higher use of renewable energy increases real GDP, boosts investment in infrastructure, and improves energy efficiency over time. Their study shows that energy plays an important role in supporting long-term, sustainable economic growth.

In Ghana, Gyimah et al. (2022) showed that energy policies can contribute to national development because in their study they found that the use of renewable energy has a strong positive impact on economic growth, even if its indirect effects are weak, the direct relationship is strong.

According to Hirsh & Koomey (2015), economic growth causes an increase in energy consumption when a country is developing, i.e., undergoing rapid industrialization with clear visions in place, but at a certain level of development, it no longer automatically implies a proportional increase in electricity consumption.

1.5.2 Bidirectional Link Between Energy Consumption and Economic Growth

Several empirical studies identify a bidirectional relationship: economic growth leads to an increase in energy demand, while the expansion of energy capacity stimulates growth. Riti et al.(2022) confirm this circular dynamic in Sub-Saharan Africa through Granger causality tests. Similarly, in a study on Ghana, Master et al., (2025) observe a feedback effect between renewable energy consumption and GDP growth.

This relationship has been found to be bidirectional in many cases, meaning that economic growth contributes to energy consumption and vice versa. This reciprocal causality is consistent with the feedback hypothesis described by Koçak & Şarkgüneşi (2017), who studied Black Sea and Balkan countries and found mutual causality in several cases, particularly when renewable energy was integrated into national grids. This implies that investment in renewable energy can have self-reinforcing effects on economic development.

Apergis & Payne (2010) also observed a similar causality of both directions in a panel of 20 OECD countries. Using Granger's causality cointegration test, they were able to show that economic growth and energy consumption influence each other, that is, mutually. This shows that the expansion of renewable energy could boost the country's development and the country's development could also push more towards renewable energy.

For developing economies like Mali, Senegal, and Côte d'Ivoire, the bidirectional nature of this relationship suggests that renewable energy initiatives can both benefit from and contribute to economic expansion. As these nations seek to modernize their economies, integrated energy policies could unlock productivity gains and attract foreign investment, thereby reinforcing the growth cycle.

1.5.3 Growth and Pollution Dynamics

According to the Environmental Kuznets Curve (EKC) hypothesis, economic growth initially causes environmental degradation, but once a certain income threshold is reached, structural changes, increased environmental awareness, and cleaner technologies lead to environmental improvement.

This model is indirectly corroborated by Raihan et al. (2025), who demonstrate that Egypt, a fast-growing country, is implementing a national strategy to reduce its carbon emissions and ensure its long-term sustainability, including by switching from fossil fuels to renewable energy. According to their empirical findings, the use of renewable energy not only slows environmental degradation but also boosts GDP in the long run.

Energy demand increases pollution from the early stages of development, but policy-driven clean energy transitions can eventually decouple economic activity from its environmental impact. This is consistent with the EKC hypothesis.

Similarly, Koçak & Şarkgüneşi (2017) stress the environmental and economic co-benefits of renewable energy in transitioning economies. They found that in countries with high fossil fuel dependency, a shift to renewables contributes to sustainable economic growth by reducing reliance on imported fuels and lowering emissions, a dynamic relevant to West African countries where energy access is often linked to diesel generators and biomass.

The transition toward renewable energy is increasingly regarded as a strategic pathway to sustainable development, allowing emissions to decline without compromising productivity. This perspective highlights the energy transition as a vital instrument for balancing economic growth with ecological sustainability, as noted by Gyimah et al. (2022).

1.5.4 Research gap

In light of all that has preceded, most studies on the relationship between energy and economic growth in sub-Saharan Africa have adopted a regional approach, which tends to overlook national specificities that are very important for an analysis. When the subject is generalized, it becomes difficult to understand the dynamics of countries like Côte d'Ivoire, Mali, and Senegal, which have different energy, economic, and ecological situations (Hafner & Raimondi, 2022). However, little study has been done on the link between how renewable energies can simultaneously respond to the growth in demand caused by demographic and economic growth and their impact on the environment.

This shortcoming is particularly worrying in a context where these countries are discovering new gas resources while committing to decarbonization and inclusive growth targets (IRENA, 2023a). The lack of integrated analysis limits the formulation of public policies adapted to local realities and long-term challenges. Regional initiatives such as the West African Power Pool or cross-border interconnections (OMVS, CLSG) have certainly improved access to electricity, but they are not enough to inform national choices on energy transition (World bank, 2025). It is therefore imperative to develop integrated national analyses capable of articulating the energy, economic, and environmental issues specific to each country in order to guide coherent and sustainable public policies in the context of the energy transition in West Africa.

Partial conclusion

To summarize, we can say that literature has emphasized that many studies have shown a strong link between economic growth and energy growth. Others also show that West Africa has vast potential in renewable energy, but its exploitation remains a problem due to technical, financial, and institutional limitations. This highlights the relevance of conducting studies on the impact of renewable energy in supporting the economic development of selected countries.

CHAPTER II: METHODOLOGY AND DATA

CHAPTER II: METHODOLOGY AND DATA:

Introduction

This chapter details the methodological approach adopted to achieve the study's objectives. It presents the analytical framework used, the data sources mobilized, and the processing steps used to estimate future electricity demand and the exploitable potential of renewable energies.

2.1 Research approach

This study uses a quantitative, forward-looking, and scenario-based approach to assess the role of renewable energy in supporting long-term economic growth and meeting electricity demand in three West African countries: Senegal, Mali, and Côte d'Ivoire. The main objective is to project electricity needs under different economic growth trajectories and compare these projections with each country's exploitable renewable energy potential. This comparison makes it possible to assess the feasibility of a sustainable energy transition by 2050, while estimating the volume of CO_2 emissions that could be avoided through the deployment of renewable energy.

The approach involves several key steps. First, population and GDP projections for the period 2024–2050 were developed using World Bank data, with three economic scenarios (pessimistic, medium, and optimistic) constructed based on historical growth trends and adjusted for their standard deviations. Next, the relationship between GDP per capita and electricity consumption per capita was modeled using a global linear regression based on data from countries at different stages of development. Third, total future electricity demand was calculated by multiplying projected per capita consumption by the estimated population for each year. The analysis then estimated the annual production potential of solar, wind, and hydropower resources using capacity factors and technical parameters, before comparing these values to projected demand. Finally, the study developed renewable energy transition pathways for the three countries and quantified the corresponding CO_2 emission reductions.

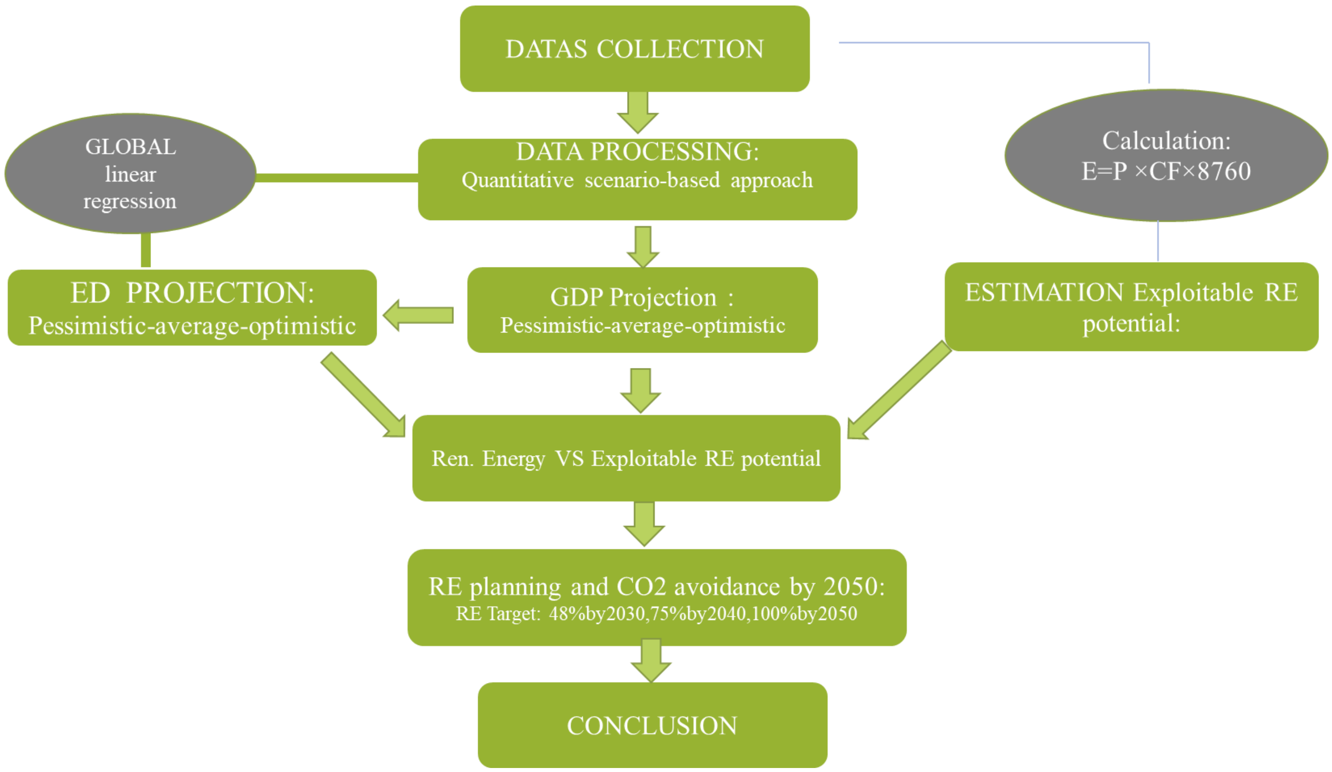

Figure 5: Overall Work chart

2.2 Data collection

All of the secondary data used in this study was gathered from reliable worldwide databases, peer-reviewed scientific journals, websites and technical reports.

- Data on electricity consumption and socioeconomic variables came from the World Bank's open data portal. These are GDP, and electricity consumption per capita data for Senegal, Côte d'Ivoire, and Mali. The World Bank offers data that is well recognized and standardized, which makes it appropriate for long-term trend research and cross-country comparisons. Estimates of renewable energy potential, including solar, wind, and hydropower, were sourced from technical reports and scientific studies. Key sources include the International Renewable Energy Agency (IRENA, 2018), Nopenyo et al. (2019) for Mali, and Koua et al. (2015) for Côte d'Ivoire. These sources assess the technically exploitable renewable energy resources available in each country, based on geographic, meteorological and hydrological data.
- From IRENA publications, capacity factor values for hydropower, wind, and solar technologies were taken. The practical production capacity of each renewable source under

local conditions was estimated using these numbers, which show the ratio of actual energy output to maximum feasible production.

- World Bank predictions used as the basis for population estimates.

Microsoft Excel was used to organize and preprocess all secondary data, whereas Python including the Pandas and Matplotlib libraries was used for statistical analysis and data visualization.

2.3 Data processing

This section presents the analytical methodology used to assess and project the future electricity demand based on different economic development path and the role of renewable energy in west African countries:

2.3.1 Population projection

Population projection (2024-2050) refers to the estimated future population of a country, based on current trends in birth rates, death rates, and migration. These projections are collected from the World Bank, a trusted international source that uses demographic data to predict how populations will grow or decline over time. These datas help in planning for economic development, energy needs, and services.

Table 3:Demographic projections *Côte d'Ivoire*-Mali-Senegal

Demographic projections			
Year	Côte d'Ivoire	Mali	Senegal
2024	31934177	24478551	18501946
2025	32711493	25198773	18931931
2026	33494291	25932224	19366499
2027	34281081	26679120	19807203
2028	35077033	27440568	20254529
2029	35883416	28215470	20706584
2030	36698953	29002822	21163150
2031	37529317	29804488	21623672
2032	38376564	30618840	22085892
2033	39244325	31442766	22548789
2034	40132755	32276631	23011980

2035	41033794	33118293	23476546
2036	41948418	33967842	23942184
2037	42879953	34823406	24407533
2038	43824318	35685521	24872466
2039	44778705	36549440	25335950
2040	45743868	37413583	25797467
2041	46717392	38280810	26257432
2042	47702113	39151230	26716383
2043	48700625	40026268	27174847
2044	49708995	40902454	27632950
2045	50716028	41778937	28089655
2046	51718011	42655598	28546241
2047	52721420	43530804	29001962
2048	53730545	44405666	29457192
2049	54739353	45279723	29911791
2050	55746945	46154032	30364896

2.3.2 GDP per capita projections (2024-2050)

This method is the most used by big institutions such as European central bank to calculate the growth rate of countries with uncertainty about the future (European central bank, 2025).
The objective is to project gross domestic product (GDP) through 2050. To do this, it is important to develop three economic growth scenarios: an optimistic scenario, a baseline (or average) scenario, and a pessimistic scenario. These scenarios are based on the historical trend in GDP growth rates over the period 2012–2024.
The first step is to calculate two fundamental statistical indicators: the mean and standard deviation of GDP growth rates over this period. These indicators describe the overall trend (average growth) and variability (standard deviation) of GDP growth over time.

- **Average growth rate:**

The arithmetic mean of the growth rates is obtained by summing all the annual GDP growth rates and dividing the total by the number of years considered (13 years from 2012 to 2024). The equation (1) is from (European central bank, 2025).

$$\mu = \frac{1}{n} \sum_{i=1}^{n} x_i \qquad (1)$$

where:

x_I: GDP growth rate for year; **n**: total number of years (13 in this case)

μ: the mean (average) of the sample

- **Standard deviation**

The standard deviation measures the dispersion of the annual growth rates around the average. It is calculated using the following sample standard deviation equation (2) from (European central bank, 2025).

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \mu)^2} \qquad (2)$$

where:

x_I: GDP growth rate for year

n: total number of years (13 in this case)

μ: the mean (average) of the sample

A low standard deviation indicates relatively stable growth, while a high standard deviation reflects volatile or irregular growth due to economic shocks or other fluctuations.

Example : Côte d'Ivoire

$$\mu = \frac{1}{13} \sum xi = 6.74 \qquad \sum(\text{xi} - \mu)^2 = 65.72 \qquad \sigma = \sqrt{\frac{65.72}{13-1}} = 2.34$$

- **Building the three scenarios**

Based on the calculated average and standard deviation, three scenarios are defined to estimate the future annual growth rate of GDP:

Optimistic scenario: μ+σ (strong economic performance, high productivity, stable institution and favorable investment climate)

Baseline scenario: μ (continuation of current trends without major shocks)

Pessimistic scenario**:** $\mu - \sigma$ (economic slowdown due to internal and external challenges)

- **Projection of reel GDP**

These estimated GDP growth rates are then applied year by year from 2024 to 2050 to simulate the economic trajectory of each country under the three scenarios. These projections will serve as the foundation for estimating future electricity consumption per capita, as part of the broader analysis linking economic development and electricity demand. The equation (3) is from (Fmi, 2025).

$$GDP_t = GDP_{t-1} \times (1 + g) \tag{3}$$

where:

GDP = Gross Domestic Product; **t** = year (time index); **g** = growth rate

- **GDP per capita calculation**

The projections of population and projections of total GDP have been used to calculate GDP per capita for each country. The total GDP was estimated using expected annual growth rates, while the population was projected using World Bank data from 2023 to 2050.We obtained the GDP per capita by dividing total GDP by total population each year, which helps assess the average economic well-being of individuals. This formula (4) below was taken from (Pib et al., 2018).

$$\text{GDP per capita} = \frac{\text{Total GDP}}{\text{Population}} \tag{4}$$

2.3.3 Electricity consumption projection by 2050:

The projection has been made by making the global linear regression to get our linear regression equation which allowed us to project our selected countries electricity consumption per capita by 2050.

- **Global linear model regression**

To estimate the future electricity consumption (EC) per capita in Mali, Senegal, and Côte d'Ivoire, we used a global linear regression model. This model helps to understand how electricity use is related to income level, using GDP per capita as the main variable (Ibitoye & Adenikinju, 2007). We built the model using data from many countries around the world including developed, developing, and least-developed countries. This mix helps make the model more accurate and useful for countries at different stages of development.

The countries used to do this regression are: Argentina, Brazil, Côte d'Ivoire, Germany, Egypt Arab Rep., Spain, France, Hungary, Israel, Japan, Mali, Nigeria, Portugal, Senegal, South Africa

The model is based on a simple equation (5) from (Nayan et al., 2013):

$$\mathrm{EC}_{\text{per capita}} = a \times \mathrm{GDP}_{\text{per capita}} \tag{5}$$

where:

EC per capita represents electricity consumption per person (in kWh/person),

GDP per capita is the gross domestic product per person (in current USD),

α: 0.23 (This number shows how much electricity use increases when income (GDP per capita) goes up. It tells us how strong the link is between the two).

In this equation, we assume that when GDP per capita is zero, electricity use is also very low or close to zero.

We also used the R-squared (R^2) value to check how well the model works. R^2 tells us how strong the relationship is between GDP per capita and electricity use. A high R^2 means that the model gives a good explanation of how electricity consumption changes with income.

- **Projection of electricity consumption:**

After developing the global equation, we applied it to project electricity consumption per capita for Mali, Senegal, and Côte d'Ivoire from 2024 to 2050. However, before using the model, we first tested its accuracy by comparing the model's estimate for 2023 with the actual observed electricity consumption per capita in each country for that same year. The difference between the estimated and actual value for 2023 was calculated as the initial error margin for each country. We then adjusted the model accordingly.

The final equation (5) used for each country became equation (6) from (Nayan et al., 2013):

$$\mathrm{EC}_{\text{per capita}} = a \times \mathrm{GDP}_{\text{per capita}} + \varepsilon \tag{6}$$

Where: ε is the **error term**

Country	Reel value (2023) (World bank, 2025b)	Estimate value (2023) from equation (6)	Error = Ev- Rv
Cote d'ivoire	324	531	-207
Mali	193	183.89	+89
Senegal	400	360.37	+39.63

The error margin was: −200 for Côte d'Ivoire, +0.89 for Mali, and +39.63 for Senegal. This correction allowed the projections to be more closely aligned with real 2023 data and ensured greater reliability for forecasts up to 2050.

- **Total annual electricity consumption from 2024 to 2050**

After estimating future values of electricity consumption per capita under different GDP per capita scenarios, we now calculate the total annual electricity consumption for each country (Mali, Senegal, and Côte d'Ivoire) from 2024 to 2050.

Electricity consumption was calculated by multiplying each country's electricity consumption by its population projection (Nayan et al., 2013). This step allows us to know how much electricity each country will need to develop an energy plan and make investment decisions.

$$TEC_t = ECPC_t \times POP_t \tag{7}$$

Where:

TEC = Total Electricity Consumption;

ECPC = Electricity Consumption per Capita

POP = Population; **t** = year (time index)

2.3.4 Estimation of the quantity of energy from exploitable renewable Potential

The estimation of annual electrical energy generation from exploitable renewable energy potential capacity (solar, wind, hydropower) is based on converting the installed capacity (expressed in gigawatts, GW) into energy output (in gigawatt-hours per year, GWh/year). This conversion takes into account the capacity factor, which reflects the actual operational efficiency over the course of a year, depending on local and technological conditions.

The capacity factor represents the average proportion of time that a facility operates at its maximum rated capacity. It varies depending on the type of energy source.

The table below shows the capacity factors for the main energy sources (hydropower, solar, and wind) in Côte d'Ivoire ,Mali and Senegal.

Table 4: Capacity factor of each technology in each country

Capacity factor (CF)	SOLAR	WIND	HYDRO
Côte d'Ivoire	0.19	0.12	0.33
Mali	0.21	0.22	0.54
Senegal	0.20	0.27	-

Sources: Solar and Wind (IRENA, 2018) hydro (Allington et al., 2022)

The annual energy production for a given technology is calculated using the following formula (8) from (Bolson et al., 2022) :

$$E_{\text{year}} = P \times CF \times 8760$$

Where:

E_{year}: annual energy production (in GWh/year); **P**: installed power capacity potential (in GW)

CF: capacity factor (value between 0 and 1)

8760: number of hours in a year (365 days × 24 hours)

This approach provides a realistic estimation of the amount of energy each country can produce annually from its renewable energy resources, taking into account technical performance and local environmental conditions.

2.3.5 Comparison between future energy demand and renewable Energy Potential:

Based on prior estimations of the exploitable potential of key renewable energy sources namely (hydropower, solar, and wind) as well as projections of national electricity demand by 2050 under three growth scenarios (pessimistic, medium, and optimistic), the following methodology was applied to assess the capacity of renewable energy to meet future demand:

- Estimation of individual coverage rates by source

For each demand scenario, the coverage rate of each renewable source was calculated by dividing its estimated annual electricity production by the projected electricity demand for the year 2050.

$$CR = \frac{AP_s\ (GWh)}{PAD\ (GWh)}$$

The formula used was: (9)

Where:

CR = Coverage Rate;

APs = Annual Production of the source

PAD = Projected Annual Demand

This indicates how many times each source can satisfy the projected demand.

- Calculation of total renewable coverage

The total coverage by renewable energy was obtained by summing the contributions of all considered sources (hydropower, solar, and wind):

2.3.6 Renewable energy planning, C02 avoidance:

- **Renewable energy planning**

This renewable energy transition plan was developed in response to the absence of clearly defined long-term energy strategies (extending to 2050) in countries such as Côte d’Ivoire, Mali, and Senegal. This study aims to assess the potential for an energy transition in three West African countries (Mali, Senegal, and Côte d’Ivoire) by the year 2050, based on projected electricity demand (average scenario), the availability of renewable resources, and international climate objectives. A prospective modelling approach was adopted, using quantitative scenario analysis to evaluate different decarbonization pathways (IRENA, 2023b) . The methodology follows the steps outlined below.

Step1:

The first step involved collecting key technical and statistical inputs for each country:

- Projected electricity demand from 2024 to 2050, based on a medium-growth scenario that reflects national economic and demographic dynamics (tables 8, 9, 10).
- Initial energy mix (2024), showing the share of each source (fossil fuels, hydro, solar, wind), based on the (figures 3;5;7)
- Capacity factors for each technology, used to convert energy generation needs (GWh) into installed capacity requirements (MW). These vary by country (table 3).
- Maximum exploitable potential for each renewable source (in GWh/year), based on technical studies and the calculation made in (tables 11,12, 13).

Step 2: Definition of Renewable Energy Targets

Progressive renewable energy (RE) penetration targets were established by modeling transition pathways:

- In line with ECOWAS regional policy, as promoted by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE);
- Based on IRENA's regional roadmap for the African power sector;
- Reflecting long-term decarbonization goals inspired by the European Commission, used here as a benchmark for full renewable integration.

Table 5: Renewable energy target by 2050

Period	RE Target	Sources
2025-2030	48%	(ECREEE, 2024)
2030-2040	75%	(IRENA, 2022)
2040-2050	100%	(European Commission, 2019)

Step 3: Scenario development

For each country, three transition scenarios were constructed to represent different technological strategies:

Three scenarios have been developed for the countries except Côte d'Ivoire because it has been previously proven that its demand cannot be covered by the exploitable RE potential available in the country, so we maximize all the potential in order to have the maximum possible coverage.

Table 6:Percentage allocated to each source to reach the target by 2050

Country	Year	Solar (%)	Hydropower (%)	Wind (%)
Côte d'Ivoire	Scenario	80%	15%	5%
Mali	Scenario 1	60%	30%	10%
	Scenario 2	40%	30%	30%
	Scenario 3	30%	20%	50%
Senegal	Scenario 1	70%	3.3%	26.7%
	Scenario 2	50%	3.3%	46.7%
	Scenario 3	80%	3.3%	16.7%

In each case, the renewable generation target for a given year is distributed among the three sources, subject to the maximum technical potential available in each country.

Step 4: Energy production and installed capacity modelling

For every year between 2024 and 2050:

- The total electricity demand is multiplied by the RE penetration target for that year.
- The resulting renewable generation is distributed according to the scenario ratio (solar/wind/hydro), and capped if a source exceeds its national potential.
- Fossil fuel generation is calculated as the difference between total demand and total renewable output.
- Required installed capacity (MW) is then computed using the following equation (10) from (Bolson et al., 2022):

$$IC\ (MW) = \frac{AG\ (GWh) \times 1000}{CF \times 8760} \tag{10}$$

Where:

IC = Installed Capacity; **AG** = Annual Generation; **CF** = Capacity Factor

➢ CO_2 emissions avoidance:

To assess the impact of a renewable energy transition plan on greenhouse gas emissions, we estimated the amount of CO_2 emissions avoided by comparing two scenarios:

Reference Scenario (Business-as-Usual):

Assumes that the electricity mix remains unchanged over time. The share of fossil-based electricity generation is held constant at its baseline level (e.g., as observed in the base year). This scenario represents the likely path without the implementation of renewable energy policies.

Planned Scenario (Renewable Energy Plan):

represents the proposed transition plan, which reduces or caps fossil fuel production while gradually increasing the share of renewable energy (such as solar, hydro, and wind).

Calculation Procedures:

- For each target year, calculate the total projected electricity demand (in GWh).

Estimate emissions under the reference scenario by assuming a constant share of fossil electricity using the equation (11) from (Principles & Emissions, 2024).

$$CO_{2_{ref}} = TD \times FS \times EF \quad (11)$$

Where:

CO_2 ref = Reference CO_2 emissions (tCO_2)

TD = Total Demand (GWh)

FS = Fossil Share (%)

EF = Emission Factor (tCO_2/GWh)

- Calculation of emissions under the planned scenario, based on the actual amount of electricity generated from fossil sources using the equation (12) from (Principles & Emissions, 2024).

$$CO_{2_{plan}} = FG \times EF \quad (12)$$

Where:

CO_2 plan = Planned CO_2 emissions (tCO_2); **FG** = Fossil Generation (GWh)

- Compute avoided emissions as the difference between the two using equation (13) from (Principles & Emissions, 2024).

$$CO_{2_{avoided}} = CO_{2_{ref}} - CO_{2_{plan}} \quad (13)$$

Table 7:Emission factor of the grid in Côte d'Ivoire -Mali-Senegal

Country	Emission Factor (g CO_2/kWh)	Source / Year
Mali	1 076	(Breeze, 2022b)
Senegal	840	(Climatiq, n.d.)
Côte d'Ivoire	466	(Breeze, 2022a)

Partial conclusion:

The methodology described above provides a robust basis for comparing future energy needs with the available potential for renewable energy. It also makes it possible to assess the feasibility of a sustainable energy transition in the three countries studied, while taking into account the dimension of CO_2 emissions reduction.

CHAPTER 3: RESULT AND DISCUSSION

CHAPTER 3: RESULT AND DISCUSSION

Introduction

This chapter presents and interprets the main findings of the study. After projecting GDP and electricity demand trends through 2050, the analysis compares these future needs with the exploitable potential of renewable energies. Finally, energy transition scenarios are developed for Mali, Senegal, and Côte d'Ivoire, highlighting the CO_2 emission reductions that could be achieved.

3.1 GDP projection

3.1.1 GDP growth rate

The average growth rate (2012-2024) for Côte d'Ivoire, Mali, and Senegal yielded values of 6.74, 4.33, and 5.11, respectively, with standard deviations of 2.24, 2.05, and 1.78.
This allowed us to identify three scenarios (pessimistic, average, and optimistic) for the three countries.

*Table 8:GDP growth rate scenarios of **Côte d'Ivoire** -Mali-Senegal*

Country	Annual Mean μ (%)	Std. Deviation σ	Reference Scenario (%)	Optimistic Scenario (%)	Pessimistic Scenario (%)
Côte d'Ivoire	6.74	2.24	6.74	8.99	4.49
Mali	4.33	2.05	4.34	6.39	2.28
Senegal	5.11	1.78	5.11	6.9	3.33

For Côte d'Ivoire, our medium scenario (6.74%) is close to recent projections: the IMF indicates 6.3% in 2025 on its country page (International monetary fund, 2025a) and in its most recent announcements, while the World Bank puts average growth at around 6.5% for 2024-2026 (World bank group, 2025b). This alignment reinforces the credibility of our baseline scenario.

In the case of Mali, our reference (4.33%) compares to 4.9% in recent IMF documents, we are therefore slightly below the international consensus but within our range (2.3-6.4%) in (International monetary fund, 2025b).

Senegal estimates that the growth rate of Senegal will be 5.9% while our estimate shows an average growth rate of 5.11%, which is a bit below.

In fact, the optimistic scenario assumes more favorable conditions such as stronger investments, political stability ,and positive global market dynamics, leading to higher than average growth .In contrast ,the pessimistic scenario reflects less favorable circumstances, including potential economic shocks or instability, resulting in lower than average growth (mean minus standard deviation).These scenarios provide a comprehensive framework to evaluate the potential range of economics outcomes for Côte d'Ivoire ,Mali and Senegal.

3.1.2 GDP per capita projection

This result (figure 9) shows how the GDP per capita will grow by using the projection of Total GDP and population by 2050.

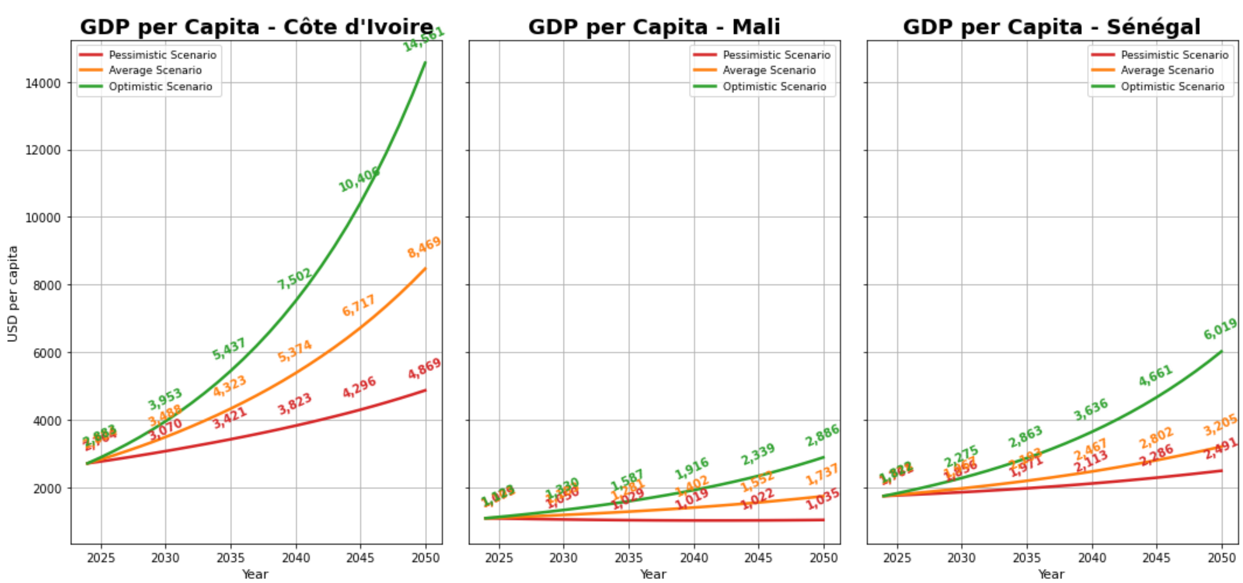

Figure 6: GDP per capita projection (Côte d'Ivoire - Mali -Senegal)

The projections of GDP per capita by 2050 show contrasting trajectories between Côte d'Ivoire, Mali, and Senegal depending on the scenarios considered. In Côte d'Ivoire, the pessimistic scenario indicates a moderate increase of about 80% between 2024 and 2050, while the average scenario projects a rise of nearly 212%, and the optimistic scenario anticipates a spectacular growth of more than 437%, placing the country among the most dynamic in the region. Mali shows a reduction in GDP per capita: -5% in the pessimistic scenario, around +59% in the average scenario, and up to +165% in the optimistic scenario, reflecting strong structural constraints that hinder its development potential. Senegal occupies an intermediate position, with an increase of +42% in the pessimistic scenario, nearly +83% in the average scenario, and about +245% in the optimistic scenario, highlighting a significant growth potential though less pronounced than that of Côte d'Ivoire.

3.2 Electricity consumption:

These results show the global linear regression equation between historical GDP per capita and Ec capita which allowed us to find the different projections of future electricity demand using GDP per capita projection of each selected countries.

3.2.1 Global regression model

The figure 10 shows the relationship between GDP per capita an Ec per capita.

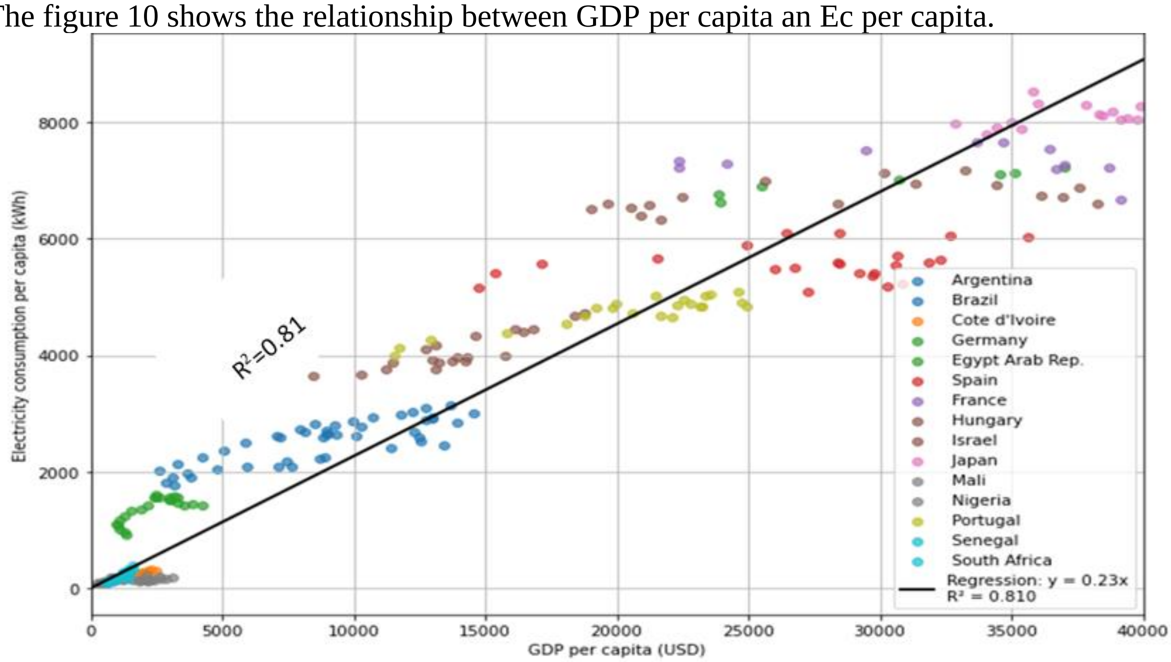

Figure 7: Global linear regression Model

Regression analysis shows a strong correlation between GDP per capita and electricity consumption per capita ($R^2 = 0.810$). The equation obtained shows that a US$1 increase in GDP per capita leads to an average increase of 0.23 kWh of electricity per capita. This result is consistent with the work of Ibitoye & Adenikinju, (2007), who had already identified a quasi-linear relationship between GDP growth and electricity consumption in sub-Saharan Africa. Like them, our study highlights that this link is particularly strong in low-income countries, where access to energy remains limited.

The West African countries included in the sample (Côte d'Ivoire, Senegal, Mali) are located in the lower left part of the graph, with a GDP per capita of less than USD 2,500 and equally low electricity consumption (less than 500 kWh/capita). This level can be explained by a lack of infrastructure and a still limited stage of development.

Conversely, countries such as Brazil, Hungary and Argentina show a more gradual trajectory, with GDP growth accompanied by a steady increase in per capita electricity consumption.

Our results also highlight that beyond a certain threshold of GDP per capita, economic growth does not necessarily lead to a proportional increase in electricity consumption. This is the case for the industrialised countries included in the analysis (France, Germany, Japan, Portugal, Israel), where energy consumption has stabilised relatively despite continued economic growth.

This phenomenon is consistent with the decoupling hypothesis described by Hirsh & Koomey, (2015) : advanced economies tend to stabilise or even reduce their consumption through energy efficiency gains and structural transition to less energy-intensive sectors, such as services.

3.2.2 Electricity demand projection

The results presented (tables 8;9;10) below represent the projected electricity demand based on different GDP and population growth scenarios between 2024 and 2050 in Côte d'Ivoire, Mali, and Senegal:

According to pessimistic projections, it should be noted that electricity demand in Côte d'Ivoire will increase from 13,293 GWh in 2024 to 50,888 GWh in 2050, which is 3.8 times higher than the initial value in 2024; in the medium scenario, it will increase from 13,293 GWh in 2024 to 97,043 GWh in 2050, or 7.3 times higher than the demand in 2024. In the optimistic scenario, there is a 13.2-fold increase, rising from 13,293 GWh to 175,156 GWh in 2050.

Here we note that in the average scenario, electricity demand will increase from 13,293.46 GWh in 2024 to 21,845 GWh in 2030, representing annual growth of 8.4% This is in line with the Ivorian government's electricity demand projection in the World Bank document, which is an increase from 11,425 GWh in 2021 to 24,745 GWh in 2030, representing an increase of 8% (Bank et al., 2022).

Table 9: Côte d'Ivoire future energy demand by 2050

Future energy demand - **Côte d'Ivoire**			
Year	pessimistic Scenario (GWh)	Medium scenario (GWh)	Optimistic Scenario (GWh)
2024	13293.46035	13293.46035	13293.46035
2025	14027.15371	14474.67153	14922.18936
2026	14799.92088	15745.24679	16710.69669
2027	15613.87751	17111.5969	18673.75912
2028	16469.84186	18579.16549	20826.0757
2029	17369.52457	20154.64292	23184.57087
2030	18315.25198	21845.71541	25768.24146
2031	19308.00447	23659.131	28596.32996
2032	20349.60799	25602.92066	31690.66332
2033	21441.66367	27685.35954	35074.7433
2034	22586.59789	29916.051	38774.97191
2035	23788.64805	32306.94864	42821.82844
2036	25050.29657	34868.82913	47246.51225
2037	26373.66007	37612.72297	52082.55967
2038	27762.51449	40551.98414	57368.11756
2039	29220.50402	43700.54659	63144.42326
2040	30750.67315	47072.50732	69455.63232
2041	32356.86624	50683.58038	76350.5405
2042	34041.991	54549.41879	83881.1991
2043	35809.16232	58686.82068	92104.44243
2044	37663.01028	63115.10422	101083.6144
2045	39609.83975	67856.33852	110889.1843
2046	41654.58603	72932.37577	121596.2007
2047	43800.26256	78364.38072	133284.2817
2048	46050.53099	84175.48814	146040.7772
2049	48411.39433	90392.58954	159963.1079
2050	50888.00651	97043.24274	175156.2789

According to the projection, it can be seen that Mali's electricity demand will grow slightly, from 6,137 GWh in 2024 to 11,031 GWh in 2050, i.e., 1.8 times for the pessimistic scenario, from 6,137

GWh in 2024 to 18,482 GWh in 2050, or 3.1 times in the medium scenario, and in the optimistic scenario, we see a 5-fold increase from 6,137 GWh to 30,674 GWh in 2050.

The demand projection for Mali according to the World Bank is estimated at 7273 GWh in 2035, which is below our average scenario projection of 9785 GWh and somewhat closer to the pessimistic scenario of 7866 GWh (World bank et al., 2014).

Table 10: Mali future energy demand by 2050

Future energy demand -Mali			
Year	Pessimistic scenario (GWh)	Medium scenario (GWh)	Optimistic scenario (GWh)
2024	6137.04132	6137.04132	6137.04132
2025	6277.134602	6402.89483	6528.655057
2026	6420.419728	6680.262115	6945.277019
2027	6566.969408	6969.642197	7388.505521
2028	6716.858799	7271.556527	7860.041847
2029	6870.162788	7586.547162	8361.694022
2030	7026.958075	7915.179797	8895.385815
2031	7187.325681	8258.047249	9463.166597
2032	7351.345331	8615.764868	10067.21355
2033	7519.097277	8988.97343	10709.84183
2034	7690.666763	9378.344718	11393.51786
2035	7866.138735	9784.577403	12120.86353
2036	8045.602107	10208.40253	12894.67044
2037	8229.146073	10650.58108	13717.90694
2038	8416.864042	11111.90929	14593.73339
2039	8608.846839	11593.21316	15525.50748
2040	8805.190279	12095.35756	16516.80465
2041	9005.99634	12619.24885	17571.43299
2042	9211.366824	13165.83015	18693.44144
2043	9421.407021	13736.08665	19887.13895
2044	9636.220237	14331.04184	21157.10555
2045	9855.914534	14951.7661	22508.21661
2046	10080.60111	15599.37687	23945.65988
2047	10310.39235	16275.03874	25474.95348
2048	10545.40569	16979.9693	27101.97082
2049	10785.75979	17715.43751	28832.9594
2050	11031.57741	18482.76873	30674.56749

For the pessimistic scenario in Senegal, there will be a 2.3-fold increase in demand between 2024 and 2050, rising from 8,154 GWh to 18,597 GWh. for the medium scenario, demand will increase from 8,154 GWh in 2024 to 23,584 GWh in 2050, approximately 3 times, and for the optimistic scenario, demand will increase 5.3 times between 2024 and 2050.

By 2030, Senelec/MPE projections show electricity demand at around 10 TWh, which is very close to our projection (10413 GWh or 10.4 TWh) , but the pessimistic and optimistic scenarios remain slightly above and below this value (IEA, 2023)**.**

Table 11: Senegal future energy demand by 2050

Future energy demand -Senegal			
Year	Pessimistic scenario (GWh)	Medium scenario (GWh)	Optimistic scenario (GWh)
2024	8154.70054	8154.70054	8154.70054
2025	8418.890587	8493.602509	8683.621787
2026	8691.492839	8846.644922	9248.030622
2027	8972.842936	9214.494702	9850.42375
2028	9263.243361	9597.802746	10493.42355
2029	9562.911749	9997.153061	11179.73766
2030	9872.141861	10413.22462	11912.33204
2031	10191.22417	10846.71285	12694.36445
2032	10520.39208	11298.27682	13529.14448
2033	10859.93875	11768.65708	14420.2652
2034	11210.19374	12258.65332	15371.59555
2035	11571.55611	12769.15861	16387.33041
2036	11944.38194	13301.04802	17471.8962
2037	12328.99763	13855.1932	18629.98351
2038	12725.79116	14432.55482	19866.65911
2039	13135.12769	15034.09951	21187.30366
2040	13557.4063	15660.85806	22597.69219
2041	13993.07704	16313.94377	24104.03643
2042	14442.60925	16994.52242	25712.98029
2043	14906.48679	17703.80899	27431.62405
2044	15385.193	18443.05432	29267.54035
2045	15879.18111	19213.51724	31228.77773
2046	16389.01254	20016.60471	33324.03445
2047	16915.18553	20853.70225	35562.52501
2048	17458.26022	21726.30117	37954.14585
2049	18018.79459	22635.93641	40509.45462
2050	18597.3367	23584.18109	43239.7089

Illustration of the electricity demand from 2024-2050:

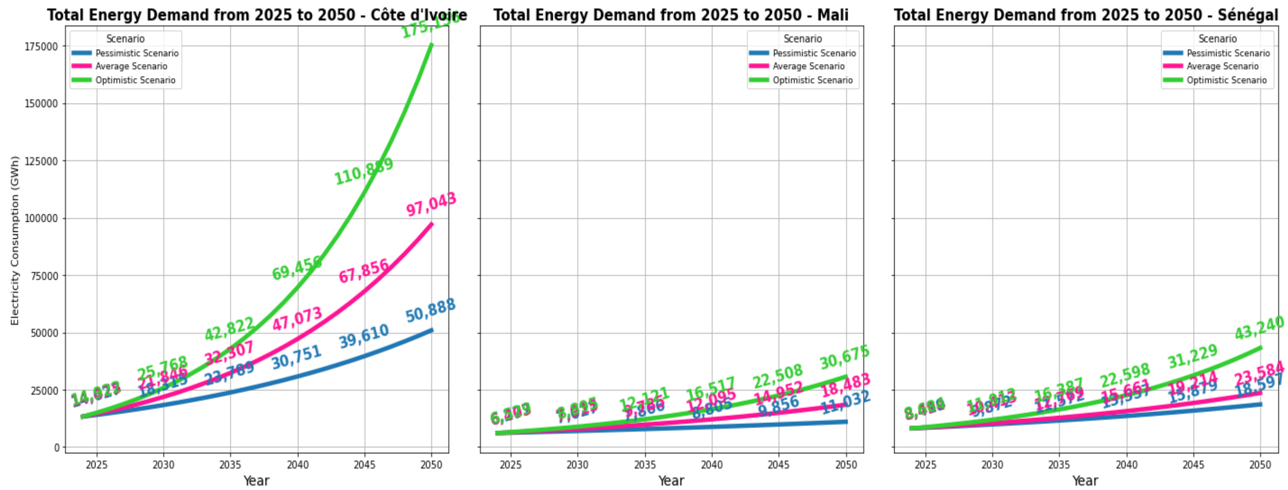

Figure 8: Summary of total energy demand (Côte d'Ivoire -Mali - Senegal)

3.3. Estimation of exploitable renewable energy potential

The tables 11;12 and 13 show the results of calculations of the energy that could be generated by the exploitable potential in terms of installed capacity of each renewable source for each country.

Table 12: Côte d'Ivoire estimation of exploitable renewable energy potential

Côte d'Ivoire				
Energy Source	Capacity Factor (%)	Exploitable Potential (GW)	Hours/Year	Estimated Output (GWh/year)
Solar PV	19%	28.919	8,760	48639.44448
Wind	13%	2.548	8,760	2834.70096
Hydropower	33%	2.458	8,760	7,106
Total exploitable renewable energy (solar, wind, hydro)				58579.73184

Table 13: Mali estimation of exploitable renewable energy potential

Mali				
Energy Source	Capacity Factor	Exploitable Potential (GW)	Hours/Year	Estimated Output (GWh/year)
Solar PV	21%	298.812	8,760	536606.5896
Wind	22%	7.962	8,760	15135.12504
Hydropower	54%	1.05	8,760	4966.92
Total exploitable renewable energy (solar, wind, hydro)				556708.6346

Table 14:Senegal estimation of renewable energy potential

Senegal				
Energy Source	Capacity Factor (%)	Exploitable Potential (GW)	Hours/Year	Estimated Output (GWh/year)
Solar PV	20%	37.223	8,760	66,519
Wind	28%	4.531	8,760	10,955
Hydropower	-	-	-	0
Total exploitable renewable energy (solar, wind, hydro)				77,474

Estimates of exploitable renewable energy potential show significant disparities between Côte d'Ivoire, Mali and Senegal. In Côte d'Ivoire, solar energy dominates with approximately 48,639 GWh/year, followed by hydroelectricity (7,106 GWh/year) and marginal wind power (2,854 GWh/year), for a total of approximately 58,580 GWh/year. Mali has immense potential, mainly due to solar energy (536,607 GWh/year), which totals more than 556,709 GWh/year and positions the country as a future regional energy hub. Senegal, for its part, has mainly solar (66,519 GWh/year) and wind (10,955 GWh/year) potential, reaching approximately 77,474 GWh/year. Thus, Côte d'Ivoire offers a more balanced energy mix thanks to hydroelectricity, Senegal focuses on the complementarity of solar and wind energy, and Mali stands out for its enormous solar potential.

3.3.1 Exploitable renewable energy potential vs electricity demand by 2050:

This section represents the figures showing how many times the potential can cover the demand.

- **Côte d'Ivoire**

The results highlight a significant gap between the available renewable potential and future needs, depending on the level of demand growth in Côte d'Ivoire (figure12):

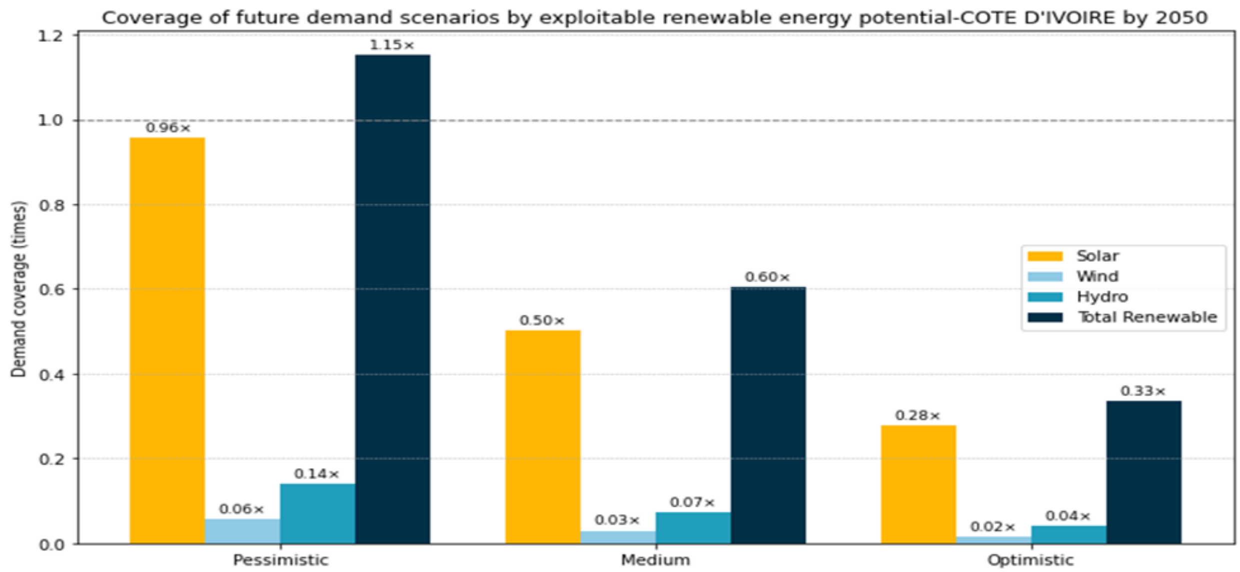

Figure 9:Future energy coverage by exploitable renewable energy potential Côte d'Ivoire

In the pessimistic scenario, where electricity demand remains relatively moderate, renewable potential is more than sufficient. Total coverage reaches 1.15 times demand, driven mainly by solar energy (0.96 times), followed by hydroelectricity (0.14 times) and wind power (0.06 times). This indicates that, in the absence of strong growth in consumption, Côte d'Ivoire could meet all of its electricity needs solely through currently exploitable renewable energies.

In the average scenario, corresponding to moderate but sustained growth in demand, coverage falls to 0.60 times. Solar energy accounts for 0.05 times, hydroelectricity for 0.07 times and wind power for 0.03 times. Thus, renewable energies would cover just over half of projected needs, revealing an energy deficit in renewable resources (solar, wind, hydroelectricity), but this could be offset by using the country's biomass to produce clean energy.

In the optimistic scenario, marked by strong growth in demand, currently exploitable renewable energy would only cover 0.33 times future needs. Solar energy contributes 0.28 times, hydroelectricity 0.04 times and wind power 0.02 times. These results reveal an insufficiency in the exploitable potential of renewable energy.

This analysis highlights that Côte d'Ivoire must also consider producing green energy from biomass and optimize the potential and capacity already in place to meet this growing demand.

- **Mali**

Unlike some neighboring countries, Mali has exceptionally high renewable energy potential, especially solar energy. The results obtained highlight a capacity to cover demand that is well above requirements, regardless of the scenario (figure 13).

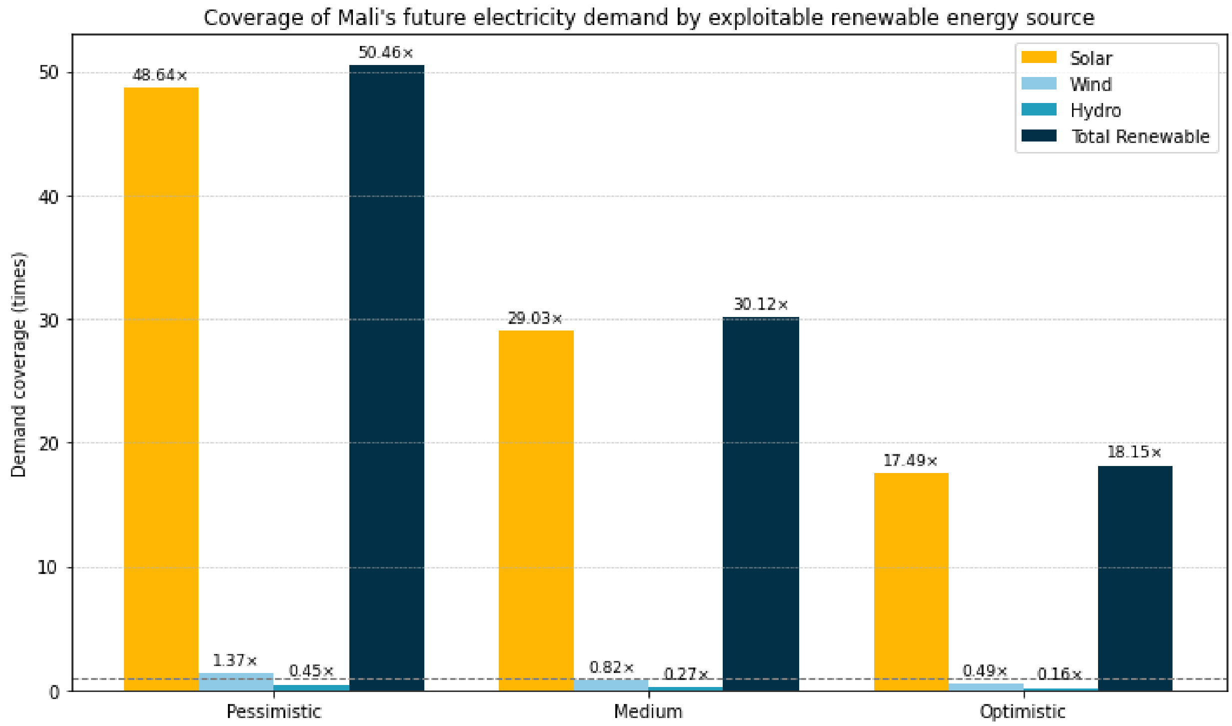

Figure 10: Coverage of future energy electricity demand by exploitable renewable energy potential Mali

In the pessimistic scenario, renewable energies could cover up to 50 times the country's electricity demand. Solar energy alone reaches 48.64 times, hydroelectricity 1.37 times and wind energy 0.45 times. This scenario shows that demand by 2050 will use only a small portion of the exploitable renewable potential, more specifically solar energy.

The coverage remains very favorable in the average or medium scenario, which anticipates a continuous and very likely increase in demand, with a total factor of 30.12. With a contribution of 29.03, solar energy clearly constitutes a key strategic element of Mali's future energy mix. This potential is complemented, with extremely high safety margins, by wind energy (0.27 times) and hydroelectricity (0.82 times). In the optimistic scenario, corresponding to a sharp increase in demand likely linked to rapid industrialization and improved living conditions, renewable coverage remains more than 18 times higher than projected demand. Solar covers 17.49 times, hydroelectricity 0.49 times, and wind 0.16 times. Even in this scenario, where demand is very high, Mali has an exceptionally comfortable reserve.

These results clearly show a unique opportunity for Mali: not only does the country have the capacity to meet its own future electricity needs through renewable energy, but it could also become a regional player in clean energy by exporting energy to neighboring countries such as Côte d'Ivoire as part of regional energy integration projects.

- **Senegal**

In the case of Senegal, the results reveal a potential for coverage that is generally higher than future demand, with margins varying according to the scenarios (figure 14).

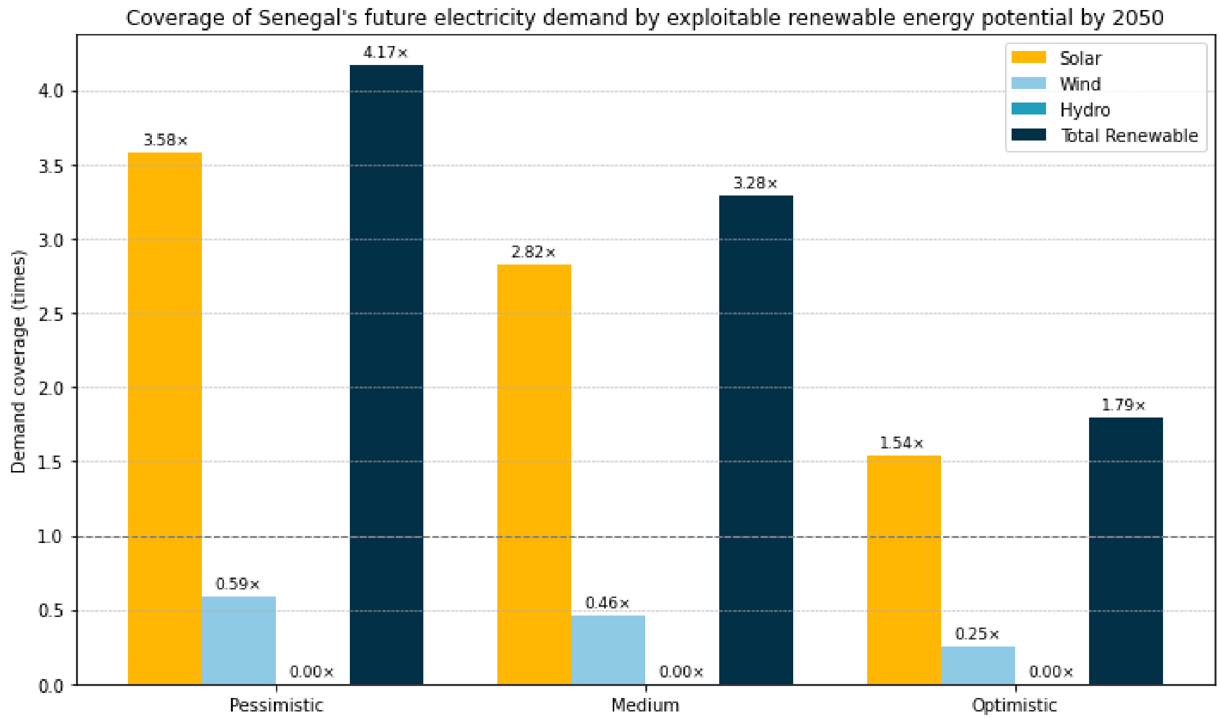

Figure 11: Coverage of future electricity demand by exploitable renewable energy potential Senegal

In the pessimistic scenario, renewable energies would be able to fully cover demand and even exceed it, with 4.17 times the demand in 2050, mainly driven by solar energy (3.58 times) and wind energy (0.59 times). As for hydroelectricity, Senegal has no indicative potential due to its geographical position, but it is crossed by the Senegal River, which is mainly exploited in Mali and provides a share to Senegal via OMVS. This scenario shows that, even with partial deployment of its potential, Senegal could become self-sufficient in green electricity.

The total exploitable potential would provide, on average, 3.28 times more coverage, which remains well above anticipated needs. Their strategic importance in the country's energy transformation is confirmed by the continued predominance of solar energy (2.82 times) and wind power (0.46 times).

The optimistic scenario: even with strong future demand in 2050, renewable energies could still cover 1.79 times the needs (solar 1.54 times and wind 0.25 times).

These results highlight that Senegal has sufficient exploitable renewable potential to achieve complete coverage of its electricity demand by 2050, even in the most ambitious scenario.

3.4 Renewable energy planning by 2050

In the context of the energy transition in Mali, Senegal, and Côte d'Ivoire, three scenarios of electricity production based entirely on renewable sources have been developed for each country. To gradually decarbonize their respective national energy mixes by 2050, these scenarios examine several avenues. The objective is to completely phase out fossil fuels by 2050 and meet all projected electricity demand from renewable energy sources, taking into account each country's exploitable renewable energy potential.

To fully decarbonize the energy sectors, the strategy is in line with ECOWAS's goal of integrating 48% renewable energy by 2030, IRENA's goal of 75% by 2040, and the goal of 100% renewable energy by 2050. Depending on countries' resources and limitations, each scenario relies on a different allocation of hydroelectric, wind, and solar energy.

A useful comparison is the experience of Benin (Akpahou et al., 2024), where official renewable energy penetration targets are set at 24.6% by 2025, 44% by 2030, and 100% by 2050. This reflects a similarly ambitious long-term trajectory. This slower growth can be explained by the fact that Benin started with a significantly lower renewable energy base (less than 3.2% in 2020) than Mali, Senegal, and Côte d’Ivoire. This disparity underscores the critical importance of the starting point in defining national energy trajectories: countries with an established hydropower, wind, or solar base (such as Mali, Côte d’Ivoire, and Senegal) can aspire to a faster ramp-up than those starting with an energy mix dominated by fossil fuels.

The results for Benin suggest that the government’s official targets may be overly ambitious given current trends and the pace of development in the energy sector. In fact, a generation mix consisting of 563 MW of natural gas, 125 MW of solar PV, 200 MW of wind, 600 MW of hydro, and 60 MW of CSP would only allow the country to reach 50% renewables by 2050 under a “50% RE scenario.” This would lead to a 50% reduction in CO_2 emissions compared to current levels (Akpahou et al., 2024).

By contrast, in the cases of Mali, Senegal, and Côte d’Ivoire, the capacity additions required from figure 15 to figure 20 would enable a complete phase-out of fossil fuels and a 100% reduction in CO_2 emissions by 2050. The only exception is Côte d’Ivoire, which may need to complement its renewable portfolio.

Another aspect drawn from the Benin case concerns the development of new sectors, in particular the use of municipal solid waste (MSW) as an energy source, with an estimated potential of more than 1 TWh by 2050. This dimension has not been included in the scenarios developed for Mali, Senegal and Côte d'Ivoire, but it could be a relevant addition to further diversify renewable sources, thereby helping Côte d'Ivoire to achieve 100% renewable energy by 2050, reduce its dependence on imports and contribute to urban waste management.

Finally, the Benin study emphasizes the importance of integrating energy planning into a regional dynamic (West African Power Pool - WAPP) in order to limit the risks associated with production surpluses (curtailment) and secure supply. This perspective is in line with the challenges identified for Mali, Senegal and Côte d'Ivoire, where the variability of intermittent sources (solar and wind) could be better managed through enhanced regional cooperation.

- **Mali**

Scenario 1

The graph shows Mali's electricity production plan according to scenario 1, which aims for an energy mix consisting of 60% solar, 10% wind and 30% hydroelectricity by 2050. The figure 15 shows the evolution of electricity production (in GWh) from 2024 to 2050.

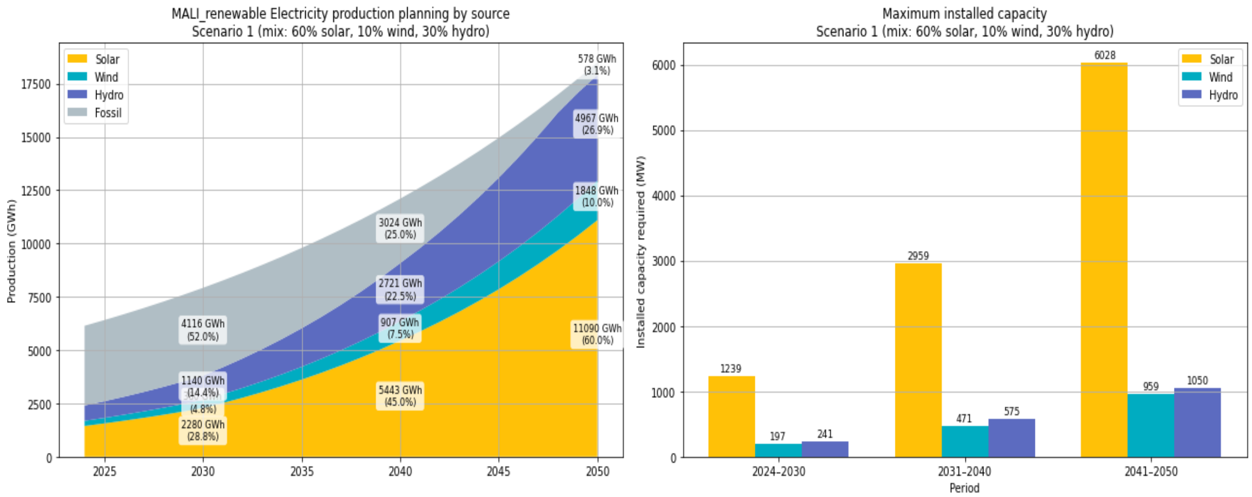

Figure 12:Sustainable energy planning by 2050 scenario 1 (MALI)

Initially, production is mainly provided by fossil fuels, but their share gradually decreases until they disappear completely in 2050. At that point, production becomes 100% renewable, with solar energy dominating (60%), followed by hydroelectricity (30%) and wind power (10%). The graph shows also the maximum installed capacity required (in MW) for each energy source over three periods: 2024-2030, 2031-2040 and 2041-2050. There is a sharp increase in solar capacity requirements, from 1,239 MW to over 6,000 MW, as well as a gradual increase in hydroelectric and wind power capacities. This scenario therefore illustrates an ambitious energy transition plan, in which Mali is moving towards a fully renewable electricity production system by 2050.

Scenario 2

According to scenario 2, Mali's electricity production plan aims to achieve a fully renewable mix by 2050, consisting of 40% solar energy, 30% wind energy and 30% hydroelectricity (figure 16).

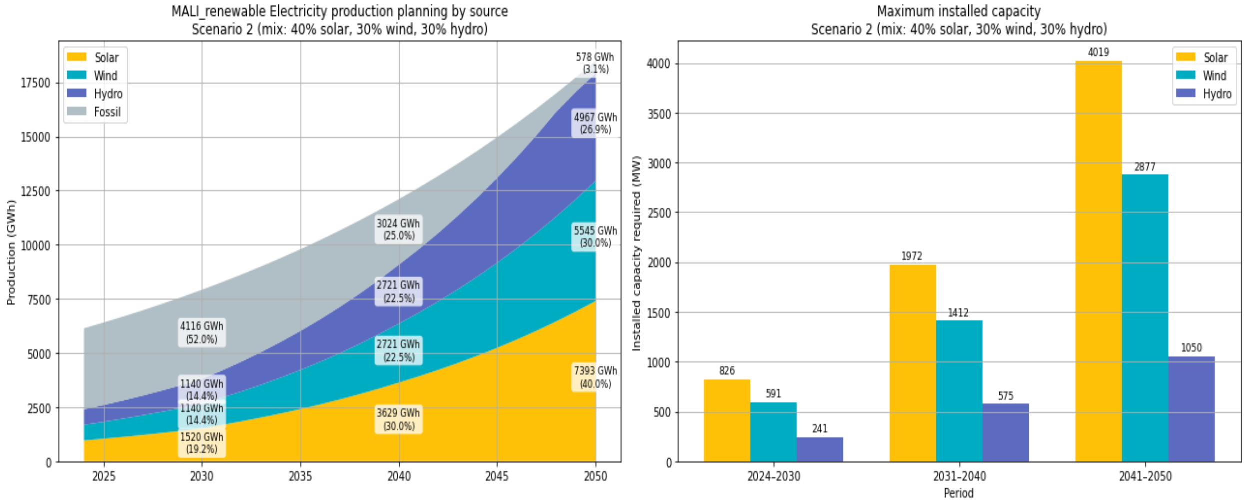

Figure 13:Sustainable energy planning by 2050 scenario 2 (Mali)

This transition is based on a gradual reduction in the use of fossil fuels, until their complete elimination in 2050. To achieve this, significant investment will be required, particularly in solar and wind infrastructure. Solar capacity will need to increase from around 826 MW over the period 2024-2030 to more than 4,000 MW between 2041 and 2050. Wind power will also see strong growth, with installed capacity increasing from 591 MW to nearly 2,877 MW over the same period. Hydroelectricity will increase more moderately, reaching a stable level of 1,050 MW by 2050. This scenario reflects a balanced and diversified energy transition, giving wind energy a more important role, in order to enable Mali to build a fully renewable and sustainable electricity system by 2050.

Scenario 3

Under scenario 3, Mali's electricity production plan envisages a 100% renewable mix by 2050, comprising 30% solar energy, 50% wind energy and 20% hydroelectricity (figure 17).

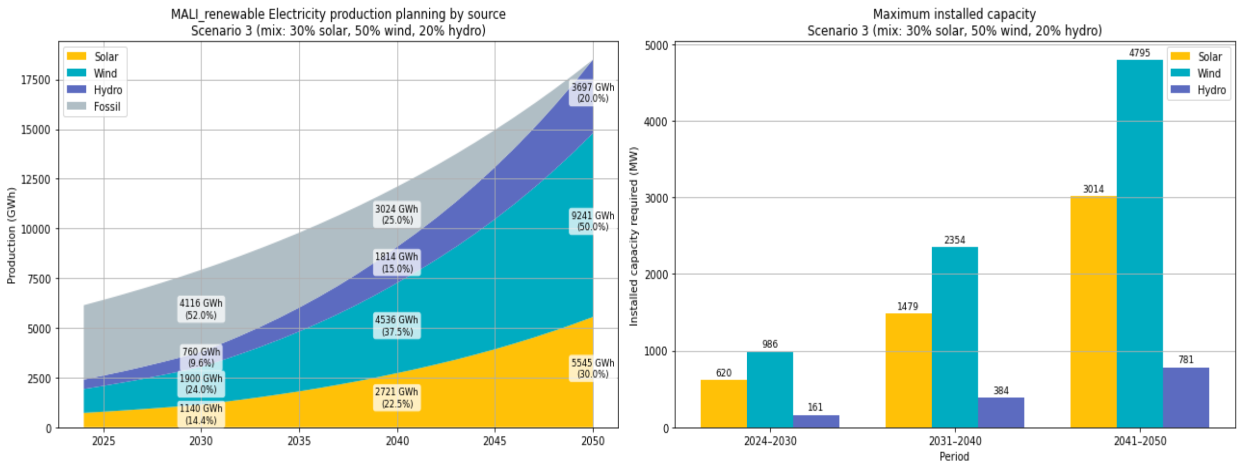

Figure 14:Sustainable energy planning by 2050 scenario 3 (Mali)

The transition involves a gradual reduction in fossil fuels, leading to their complete elimination by 2050. To achieve this goal, the country will need to significantly develop wind energy, which will become the main source of production. Installed wind capacity will need to increase from 986 MW over the period 2024-2030 to nearly 4,800 MW between 2041 and 2050. Solar energy will follow a more moderate growth path, with installed capacity reaching around 3,000 MW by 2050. Hydropower, meanwhile, will stabilize at around 781 MW in the long term. This scenario emphasizes the dominant role of wind power in Mali's future energy mix, with complementary support from solar and hydropower, leading to a fully renewable and resilient production system by 2050.[2]

- **Senegal**

Scenario 1:

Senegal's electricity production plan under scenario 1 envisages a gradual transition to a fully renewable mix by 2050, comprising 70% solar energy, 26.7% wind energy and 3.3% hydroelectricity (figure 18).

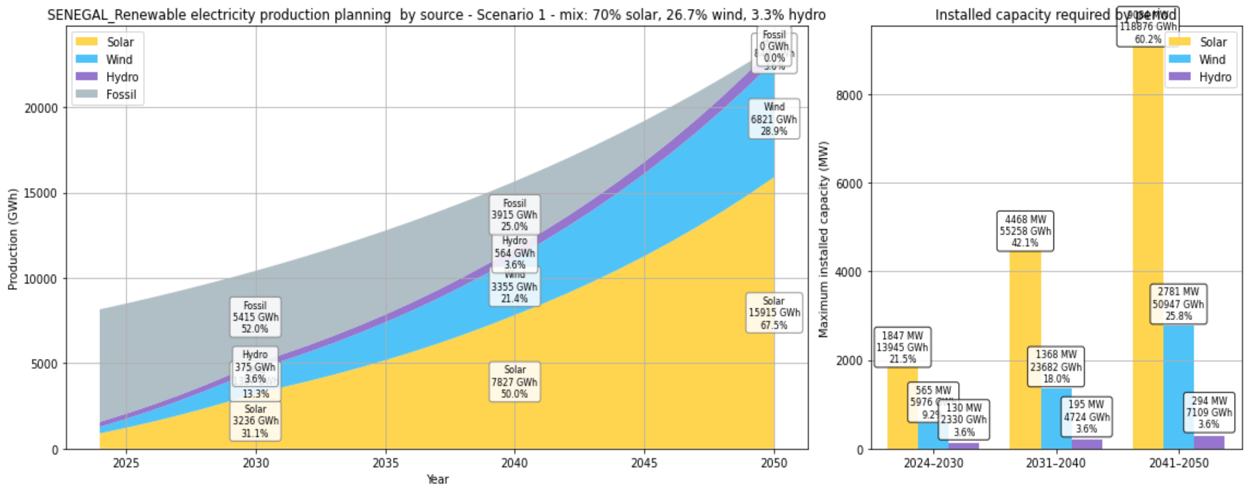

Figure 15: Sustainable energy planning by 2050 scenario 1 (Senegal)

By 2025, production will still rely heavily on fossil fuels, but their share will gradually decline until they disappear completely by 2050. This transition requires strong growth in solar production, which will become the main source of electricity, accounting for nearly 70% of total production. Wind power will also grow significantly to account for around 27% of electricity in 2050, while the share of hydroelectricity will remain relatively low and stable.

The country will need to add more solar capacity in response to this growth, increasing from 1,847 MW between 2024 and 2030 to more than 8,876 MW between 2041 and 2050. With installed capacity expected to reach 2,781 MW by the end of the mandate, wind power will also need to be boosted.

Hydroelectricity, already in place, will stabilize at around 294 MW. This scenario is therefore based on a massive deployment of solar energy, supported by a significant contribution from wind power, in order to enable Senegal to achieve a 100% renewable and low-carbon electricity system by 2050.

Scenario 2:

Under scenario 2, Senegal's electricity production plan envisages a gradual transition to a 100% renewable mix by 2050, comprising 50% solar energy, 46.7% wind energy and 3.3% hydroelectricity (figure 19).

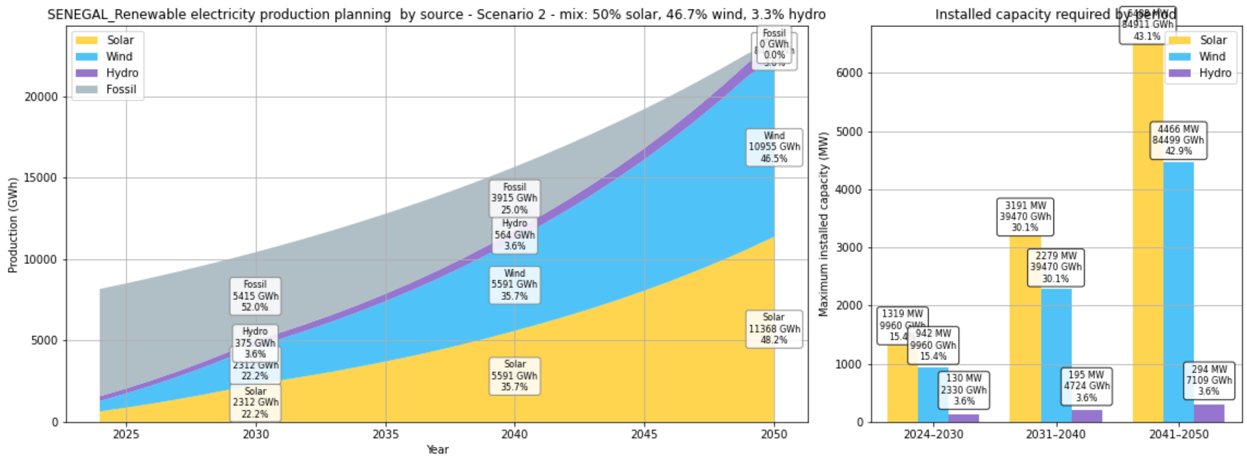

Figure 16: Sustainable energy planning by 2050 scenario 2 (Senegal)

In 2025, production will still be mainly provided by fossil fuels, but their share will decrease over the years until they are completely eliminated in 2050. By that date, solar energy will account for half of electricity production, wind energy will account for around 47%, while hydroelectricity will remain marginal and stable at around 3.3%.

To achieve this goal, the country will have to significantly increase its installed capacity. Solar capacity will increase from 1,310 MW between 2024 and 2030 to around 4,466 MW between 2041 and 2050. Wind energy will see even more significant growth, reaching an installed capacity of 4,381 MW over the same period. Hydropower, meanwhile, will remain constant at 294 MW. This scenario is therefore based on a balance between solar and wind power, with a slight advantage for solar, enabling Senegal to ensure fully renewable, diversified electricity production adapted to its natural resources by 2050.

Scenario 3

Scenario 3 envisages a transition to a 100% renewable energy mix for Senegal by 2050, dominated by 80% solar power, with 16.7% wind power and 3.3% hydroelectricity (figure 20).

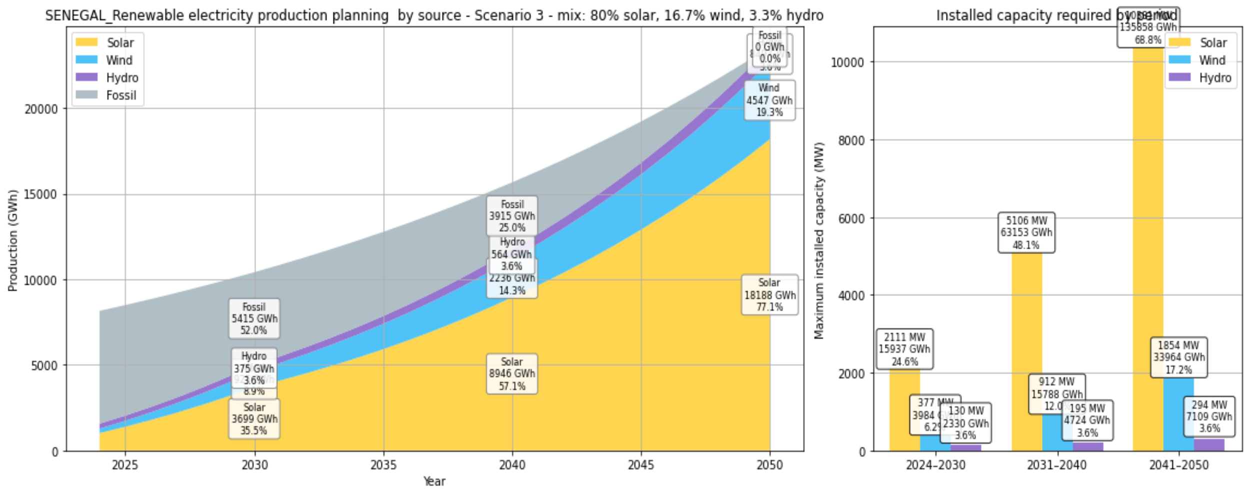

Figure 17: Sustainable energy planning by 2050 scenario 3 (Senegal)

The share of fossil fuels gradually decreases until it disappears completely. Electricity production then relies mainly on solar power, reflecting the country's strong potential in this area.

To achieve this, solar capacity will have to grow significantly, from 2,111 MW between 2024-2030 to nearly 8,993 MW in 2041-2050. Wind power will reach 1,854 MW over the same period, while hydroelectricity will remain stable at 294 MW. This scenario relies on an intensive solar strategy, supported by limited contributions from wind and hydro, to build a reliable, renewable and low-carbon electricity system by 2050.

- **Côte d'Ivoire**

As demonstrated above, the exploitable potential of solar, wind and hydroelectricity in Côte d'Ivoire is not sufficient to fully meet projected electricity demand by 2050. The transition plan is therefore based on maximizing the use of these three sources, with a breakdown of 80% solar, 5% wind and 15% hydroelectricity (figure 21).

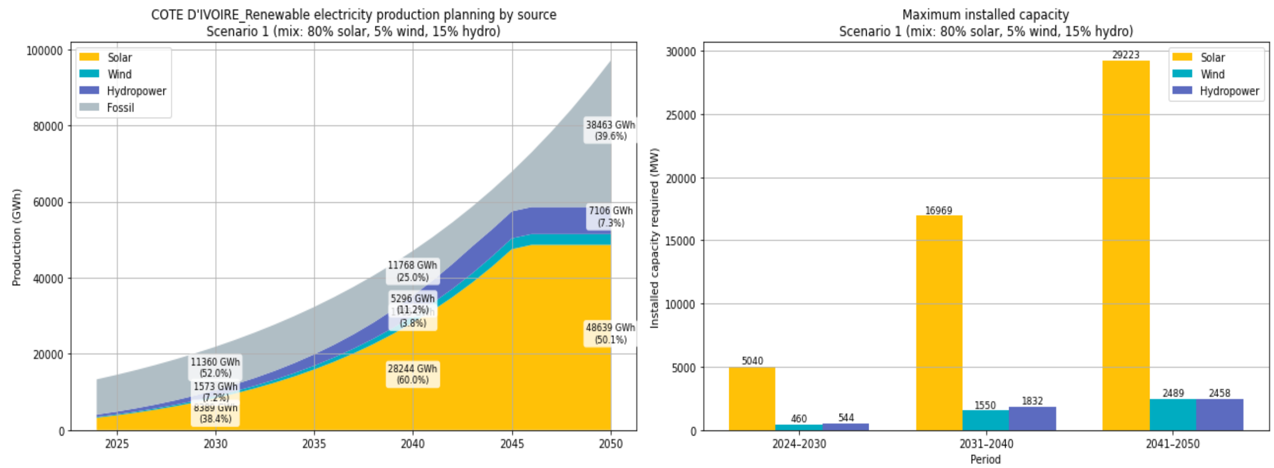

Figure 18: Sustainable energy planning by 2050 (Côte d'Ivoire)

This combination enables the intermediate targets to be met: 48% renewable energy production in 2030 and 75% in 2040, with increasing installed capacity. for example, 5,040 MW of solar, 460 MW of wind and 544 MW of hydro between 2024 and 2030, then 16,969 MW of solar, 1,550 MW of wind and 1,832 MW of hydroelectricity between 2031 and 2040.

However, in 2050, despite the deployment of maximum capacity; 29,223 MW of solar, 2,489 MW of wind and 2,458 MW of hydro. renewable production will peak at 60.4%, leaving 39.6% still covered by fossil fuels. This is because the technical production potential of all three sources is already saturated. Thus, even by adjusting the proportions between solar, wind and hydroelectricity, no combination is capable of achieving 100% renewable coverage. To go beyond this structural limit, it is essential to explore other options such as biomass recovery, the integration of storage technologies, and the strengthening of energy efficiency and regional interconnections.

3.5 CO_2 avoidance

The data presented in Table 14 illustrates the amounts of CO_2 that could be avoided if the energy transition plans of Mali, Senegal, and Côte d'Ivoire are fully implemented between 2024 and 2050. Mali has the highest reduction potential, with approximately 3.85 million tonnes of CO_2 avoided between 2024 and 2030, 13.87 million between 2031 and 2040, and 23.25 million between 2041 and 2050. This result is explained not only by the scale of its transition plan to a 100% renewable energy mix, but also by a particularly high initial emission factor for its electricity grid, which makes each substitution of fossil fuels with renewables all the more efficient.

Senegal follows a similar trajectory, with 2.87 million tonnes avoided between 2024 and 2030, 11.27 million between 2031 and 2040, and 20.51 million between 2041 and 2050, reflecting a gradual increase in clean energy, particularly solar and wind power. Côte d'Ivoire, on the other hand, posted more modest results: 1.34 million tonnes of CO_2 avoided between 2024 and 2030, 6.21 million between 2031 and 2040, and 12.09 million between 2041 and 2050. This limited performance is explained by a relatively low CO_2 emission factor, due in part to the already significant share of hydropower in its initial mix, but also by the rapid saturation of its technical potential in solar, wind, and hydroelectric power, which limits the long-term expansion of renewable energies.

Table 15: CO_2 emissions avoided

Country	Period	CO_2 avoided (tons)
Mali	2024-2030	3,849,989
	2031-2040	13,869,348
	2041-2050	23,248,644
Senegal	2024-2030	2,868,158
	2031-2040	11,267,560
	2041-2050	20,512,199
Côte d'Ivoire	2024-2030	1,340,998
	2031-2040	6,212,083
	2041-2050	12,088,727

Partial conclusion

The prospective analysis (2024–2050) highlights three major conclusions. First, the expected growth of GDP and population leads to a rapid increase in electricity demand in the three countries, although the magnitudes are significantly different. Secondly, the exploitable potential of renewable energies (solar, wind, hydro) is sufficient, in Mali and Senegal, to fully meet the projected demand by 2050 under all scenarios; in contrast, Côte d'Ivoire shows a structural deficit of exploitable potential, covering only about 60% of the demand in the medium scenario and 33% in the high scenario, which requires supplements (sustainable biomass, storage, regional interconnections). Thirdly, the modeled transition trajectories confirm a spillover effect on energy security and decarbonization: the volumes of avoided emissions reach substantial orders of magnitude by 2050 (61 Mt in Mali, 54 Mt in Senegal,17 Mt in Côte d'Ivoire), while supporting long-term economic activity.

COCLUSION AND PERSPECTIVES

GENERAL CONCLUSION AND PERSPECTIVES:

This study has demonstrated that the transition to renewable energy is not only a response to environmental and climate challenges, but also a powerful driver of economic development in West Africa, particularly in Mali, Senegal, and Côte d'Ivoire. The prospective analysis carried out through 2050, which combined projections of energy demand, exploitable technical potential, and various electricity mix scenarios, shows that:

Mali possesses a remarkable potential for renewable energy, particularly solar power, which is ready to satisfy the nation's future electricity requirements and even facilitate the export of clean energy to neighboring regions.

Senegal has sufficient solar and wind energy potential to achieve 100% renewable energy coverage by 2050, provided consistent investments and careful planning are maintained.

Despite notable progress and a partially decarbonized energy mix thanks to hydropower, Côte d'Ivoire faces technical limitations in exploiting its solar, wind, and hydropower resources. However, given the current potential, it is not possible to fully meet future demand from these three sources alone. It is therefore necessary to integrate additional solutions, such as biomass, storage technologies, regional interconnections, and improved energy efficiency.

The results also confirm that increasing the share of renewable energy in the electricity mix significantly reduces CO_2 emissions, with particularly significant gains for Mali and Senegal due to the high carbon intensity of their initial mixes. From an economic perspective, the identified bidirectional relationship between gross domestic product (GDP) growth and electricity consumption supports the hypothesis that the development of energy infrastructure, particularly renewable energy, promotes economic growth, while itself being stimulated by it.

In light of everything mentioned above, find below the necessary recommendations that must be implemented for decarbonized energy security, a sustainable and green economy:

Strengthen national energy planning: Define clear and legally binding roadmaps to achieve renewable energy targets for 2030, 2040 and 2050 and establish regular evaluation mechanisms to adjust strategies over time.

Accelerate renewable energy investments: Model international climate funds such as the Green Climate Fund and public-private partnerships to overcome budget constraints. Provide stable and attractive regulatory frameworks to encourage private sector participation.

Upgrade power grids and storage capacity: modernize and expand transmission and distribution networks to integrate intermittent renewable energy (solar, wind). Also, to Develop large-scale storage systems (batteries, pumped hydro) to balance supply and demand.

Enhance regional cooperation: Use ECOWAS and WAPP interconnections to share surplus electricity and cover seasonal deficit and promote cross-border trade in renewable energy

Diversify energy Sources and improve efficiency: Integrate sustainable biomass and biogas into national energy strategies (especially in Côte d'Ivoire).

Launch national energy efficiency programs to reduce energy intensity

Develop and Mobilize local expertise: Strengthen technical and academic training in renewable energy sectors; establish local industrial hubs for manufacturing, assembly, and maintenance of renewable energy equipment.

Beyond the results obtained, this work opens up several research prospects that deserve further investigation. It would be relevant to extend the analysis to other energy sources such as sustainable biomass, biogas, geothermal energy, and green hydrogen, in order to complete the scenarios studied. Future studies should also incorporate a more detailed economic and financial dimension, assessing investment, operating, and storage costs and financing mechanisms, while considering energy efficiency and conservation policies that could moderate demand growth. In addition, the use of more sophisticated dynamic models (such as MARKAL, TIMES, or LEAP) would make it possible to simulate complex transitions, taking into account variables such as carbon prices, technological developments, and regional integration. The analysis of electricity interconnections in West Africa also represents a promising avenue for quantifying the benefits of energy cooperation, particularly in terms of surplus exchanges and security of supply. Finally, future research would benefit from exploring in greater depth the socio-economic impacts (employment, urban-rural inequalities), the effects of climate change on renewable potential, and the institutional and political feasibility of the proposed trajectories.

BIBLIOGAPHY REFERENCES

BIBLIOGRAPHY REFERENCES:

AFRICA DEVELOPEMENT BANK. (2025). https://www.afdb.org/en/mission-300-africa-energy-

Akpahou, R., Odoi-Yorke, F., Mensah, L. D., Quansah, D. A., & Kemausuor, F. (2024). Strategizing towards sustainable energy planning: Modeling the mix of future generation technologies for 2050 in Benin. *Renewable and Sustainable Energy Transition*, *5*(December 2023), 100079. https://doi.org/10.1016/j.rset.2024.100079

Allington, L., Cannone, C., Pappis, I., Cervantes Barron, K., Usher, W., Pye, S., Brown, E., Howells, M., Zachau Walker, M., Ahsan, A., Charbonnier, F., Halloran, C., Hirmer, S., Cronin, J., Taliotis, C., Sundin, C., Sridharan, V., Ramos, E., Brinkerink, M., … To, L. S. (2022). Selected 'Starter kit' energy system modelling data for selected countries in Africa, East Asia, and South America (#CCG, 2021). *Data in Brief*, *42*, 108021. https://doi.org/10.1016/j.dib.2022.108021

Annuel, R., & Fmi, D. U. (2025). *Cap sur la croissance*.

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, *38*(1), 656–660. https://doi.org/10.1016/j.enpol.2009.09.002

Bank, T. W., Stage, A., Prepared, D., & No, R. (2022). *Program Information Documents (PID)*. 1–9.

Bolson, N., Prieto, P., & Patzek, T. (2022). Capacity factors for electrical power generation from renewable and nonrenewable sources. *Proceedings of the National Academy of Sciences of the United States of America*, *119*(52), 1–6. https://doi.org/10.1073/pnas.2205429119

Breeze. (2022a). *Electricity - Côte d'Ivoire - Côte d'Ivoire - Operating Margin Grid Emission Factor*. https://mybreeze.app/ef/electricity---côte-divoire---côte-divoire---operating-margin-grid-emission-factor---ifi---2022-01-25?utm

Breeze. (2022b). *Electricity - Mali - Mali - Operating Margin Grid Emission Factor*. https://mybreeze.app/ef/electricity---mali---mali---operating-margin-grid-emission-factor---ifi---2022-01-25?utm

Climatiq. (n.d.). *Emission factor*. Retrieved July 30, 2025, from https://www.climatiq.io/data/emission-factor/a0c46399-a97d-4b10-aebf-f7156b764b85?utm_

Dogan, E., Altinoz, B., Madaleno, M., & Taskin, D. (2020). The impact of renewable energy consumption to economic growth: A replication and extension of Inglesi-Lotz (2016). *Energy Economics*, *90*, 104866. https://doi.org/10.1016/j.eneco.2020.104866

ECREEE. (2024). *Ecowas centre for Renewable energy and energy efficiency*. https://www.ecreee.org/renewable-energy/

European central bank. (2025). *Exploring an uncertain future with the help of scenarios*. https://www.ecb.europa.eu/press/blog/date/2025/html/ecb.blog.20250115~f016f263dd.en.html?utm

European Commission. (2019). Going climate-neutral by 2050 – A strategic long-term vision for a prosperous, modern, competitive and climate-neutral EU economy. *European Commission*, 1–20. https://data.europa.eu/doi/10.2834/02074

Gyimah, J., Yao, X., Tachega, M. A., Sam Hayford, I., & Opoku-Mensah, E. (2022). Renewable energy consumption and economic growth: New evidence from Ghana. *Energy*, *248*(7), 123559. https://doi.org/10.1016/j.energy.2022.123559

Hafner, M., & Raimondi, P. P. (2022). Energy and the economy in Europe. In *The Palgrave Handbook of International Energy Economics*. https://doi.org/10.1007/978-3-030-86884-0_36

Hirsh, R. F., & Koomey, J. G. (2015). Electricity Consumption and Economic Growth: A New Relationship with Significant Consequences? *Electricity Journal*, *28*(9), 72–84. https://doi.org/10.1016/j.tej.2015.10.002

Ibitoye, F. I., & Adenikinju, A. (2007). Future demand for electricity in Nigeria. *Applied Energy*, *84*(5), 492–504. https://doi.org/10.1016/j.apenergy.2006.09.011

IEA. (2023). *Sénégal 2023 - Revue de la politique énergétique*. www.iea.org

International monetary fund. (2025a). *Côte d'Ivoire*. https://www.imf.org/en/Countries/CIV?utm_source

International monetary fund. (2025b). *Mali*. https://www.imf.org/en/Countries/MLI?utm_source

IRENA. (2018). *planning and prospects for renewable power: WEST AFRICA*.

IRENA. (2022). World energy transitions outlook 2022. In *World Energy Transitions*. https://irena.org/Digital-Report/World-Energy-Transitions-Outlook-2022%0Ahttps://irena.org/publications/2021/March/World-Energy-Transitions-Outlook

IRENA. (2023a). Scaling up renewable energy investments in West Africa. *Business and Investors Group*, *2023*, 1–13.

IRENA. (2023b). World energy transitions outlook 2023: 1.5°C Pathway. In *International Renewable Energy Agency,Abu Dhabi*. https://www.irena.org/Publications/2023/Jun/World-Energy-Transitions-Outlook-2023

IRENA. (2024). Renewable Generation Costs in 2023 EXECUTVE SUMMARY. *International Renewable Energy Agency*, 1–12.

Keeble, B. R. (1988). The Brundtland Report: “Our Common Future.” *Medicine and War*, *4*(1), 17–25. https://doi.org/10.1080/07488008808408783

Koçak, E., & Şarkgüneşi, A. (2017). The renewable energy and economic growth nexus in black sea and Balkan Countries. *Energy Policy*, *100*(October 2016), 51–57. https://doi.org/10.1016/j.enpol.2016.10.007

Koua, B. K., Koffi, P. M. E., Gbaha, P., & Touré, S. (2015). Present status and overview of potential of renewable energy in Cote d’Ivoire. *Renewable and Sustainable Energy Reviews*, *41*, 907–914. https://doi.org/10.1016/j.rser.2014.09.010

Lowcarbonpower. (2023a). *Electricity in Côte d’Ivoire*. https://lowcarbonpower.org/region/Côte_d’Ivoire

Lowcarbonpower. (2023b). *Electricity in Mali*. https://lowcarbonpower.org/

Lowcarbonpower. (2023c). *Electricity in Mali in 2023*. https://lowcarbonpower.org/region/mali

Lowcarbonpower. (2023d). *Electricity in Senegal*. https://lowcarbonpower.org/region/Senegal

Lowcarconpower. (2023). *Electricity in Côte d’Ivoire in 2023*. https://lowcarbonpower.org/region/Côte_d’Ivoire

Master, I., Energy, I. N., & Hydrogen, G. (2025). *The role of suistainable energy on west africa economic growth | Mendeley*. 2024–2025. https://www.mendeley.com/search/?page=1&query=The role of suistainable energy on west africa economic growth&sortBy=relevance

Name, P., Instrument, L., Agency, I., Completion, A., Approval, B., & Review, C. (2014). *Project Information Document (Pid)*. *i*, 1–9.

Nayan, S., Kadir, N., Ahmad, M., & Abdullah, M. S. (2013). Revisiting Energy Consumption and GDP: Evidence from Dynamic Panel Data Analysis. *Procedia Economics and Finance*, *7*(48714), 42–47. https://doi.org/10.1016/s2212-5671(13)00216-5

Nopenyo, E. D., Safiatou, A. N., Souleymane, B., Smail, K., & Bagui, D. (2019). Mali Renewables Readiness Assessment. In *Irena* (Issue September).

https://www.irena.org/publications/2019/Sep/Renewables-Readiness-Assessment-Mali

Okesanya, O. J., Adigun, O. A., Shomuyiwa, D. O., Olabode, O. N., Hassan, H. K., Micheal, A. S., Adebimpe, O. T., Atewologun, F., Ogaya, J. B., Manirambona, E., & Lucero-Prisno, D. E. (2024). Introducing African-led Innovation to tackle the challenges of climate change in Africa. *Pan African Medical Journal One Health*, *13*. https://doi.org/10.11604/pamj-oh.2024.13.2.41492

Pib, L., Pib, L., Sas, E., & Unies, N. (2018). *0-6 Le PIB par habitant et le revenu disponible brut des ménages*. 0–2.

Principles, E. D. F. G., & Emissions, C. A. (2024). Calculation Principles of CO2 Avoided Emissions Within EDF Group. *Edf*, *January*, 1–5. https://www.edf.fr/sites/groupe/files/2024-03/edfgroup_emissions-co2_evite_20240301_va.pdf

pwc. (2023). Masdar and PwC Middle East Launch Report on Accelerating Renewable Energy Investment in West Africa at the Abu Dhabi Finance Week. https://www.pwc.com/m1/en/media-centre/2023/masdar-and-pwc-middle-east-launch-report-on-accelerating-renewable-energy-investment-in-west-africa.html

PWC. (2023). *Accelerating renewable energy investment in West Africa*. https://www.pwc.com/m1/en/publications/accelerating-renewable-energy-investment-in-west-africa.html

Raihan, A., Ibrahim, S., Ridwan, M., Rahman, M. S., Bari, A. B. M. M., & Guneysu Atasoy, F. (2025). Role of renewable energy and foreign direct investment toward economic growth in Egypt. *Innovation and Green Development*, *4*(1), 100185. https://doi.org/10.1016/j.igd.2024.100185

Res4Africa. (2023). *Untapping West Africa's Renewable Energy Potential through Regional Integration*. https://res4africa.org/news/2023/untapping-west-africas-renewable-energy-potential-through-regional-integration/

Riti, J. S., Riti, M. K. J., & Oji-Okoro, I. (2022). Renewable energy consumption in sub-Saharan Africa (SSA): Implications on economic and environmental sustainability. *Current Research in Environmental Sustainability*, *4*(March), 100129. https://doi.org/10.1016/j.crsust.2022.100129

Rosen, M. A. (2021). Energy Sustainability with a Focus on Environmental Perspectives. *Earth*

Systems and Environment, *5*(2), 217–230. https://doi.org/10.1007/s41748-021-00217-6

Routledge Taylor and francis Group. (2025). https://blog.routledge.com/

Springer nature. (2024). *Energy Transition in West Africa as a Pathway to Sustainable DevelopmentNo Title*. https://link.springer.com/rwe/10.1007/978-3-031-17465-0_114

Tradinge conomics. (n.d.). Ivory Coast - Access To Electricity, Rural (% Of Rural Population). Retrieved May 26, 2025, from https://tradingeconomics.com/ivory-coast/access-to-electricity-rural-percent-of-rural-population-wb-data.html

WAPP. (2019). *ECOWAS Generation and Transmission Master Plan*. *0*. www.ecowapp.org/sites/default/files/volume_0.pdf

World bank. (2023). *Scaling Up Energy Access for Green, Resilient, and Inclusive Development in Western and Central Africa*. https://www.worldbank.org/en/results/2023/11/17/scaling-up-energy-access-for-green-resilient-and-inclusive-development-in-western-and-central-africa

World bank. (2025a). *Electric power comsumtion*. https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC

World bank. (2025b). *Electricity power comsumption*. https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC?lang=en-gb&locations=CI-ML-SN

WORLD BANK. (2023). https://data.worldbank.org/?locations=CI

World bank group. (2025a). *Électrifier l'Afrique : l'impact transformateur des projets énergétiques régionaux en Afrique de l'Ouest*. https://www.banquemondiale.org/fr/results/2025/02/06/powering-africa-the-transformational-impact-of-regional-energy-projects-in-west-africa

World bank group. (2025b). *The World Bank in Côte d'Ivoire*. https://www.worldbank.org/en/country/cotedivoire/overview?utm_source

WORLD BANK GROUP. (2023). Accelerating Access to Renewable Energy in West Africa. https://www.worldbank.org/en/news/press-release/2023/01/31/accelerating-access-to-renewable-energy-in-west-africa?utm_source

WORLD BANK GROUP. (2025). *Powering Africa: The Transformational Impact of Regional Energy Projects in West Africa*. https://www.worldbank.org/en/results/2025/02/06/powering-africa-the-transformational-

impact-of-regional-energy-projects-in-west-africa

Appendices: GDP and GDP per capita projections datas (Côte d'Ivoire, Mali, Senegal)

Côte d'Ivoire GDP Projection			
Year	Pessimistic scenario **(Thousands USD)**	Medium scenario **(Thousands USD)**	Optimistic scenario **(Thousands USD)**
2024	86538413	86538413	86538413
2025	90427968.51	92373698.19	94319427.87
2026	94492343.98	98602456.66	102800064.9
2027	98739396.88	105251220.3	112043229.9
2028	103177337.8	112348310.1	122117484.9
2029	107814746.4	119923956.6	133097556.5
2030	112660588	128010429	145064890.1
2031	117724230.8	136642172.3	158108254.7
2032	123015464.1	145855953.9	172324400.3
2033	128544517.1	155691020.9	187818776.4
2034	134322079	166189266.5	204706313.9
2035	140359319.2	177395408.7	223112277.4
2036	146667909.1	189357181.1	243173194.7
2037	153260045	202125535.8	265037869.3
2038	160148471	215754860.7	288868484.3
2039	167346504.1	230303211	314841805.2
2040	174868060.1	245832556.5	343150491.3
2041	182727679.9	262409045.8	374004524.5
2042	190940558.2	280103287.7	407632767.4
2043	199522572.6	298990652.4	444284660
2044	208490314.1	319151592.1	484232070.9
2045	217861119.8	340671984	527771313.4
2046	227653105.7	363643495.8	575225343.2
2047	237885202.2	388163976.8	626946154.7
2048	248577190.5	414337873.7	683317391.3
2049	259749740.9	442276676.6	744757191.2
2050	271424452.7	472099392.9	811721289.3

Mali GDP projection (Thousands USD)			
Year	Pessimistic scenario **(Thousands USD)**	Medium scenario **(Thousands USD)**	Optimistic scenario **(Thousands USD)**
2024	26588067	26588067	26588067
2025	27194381.28	27741164.88	28287948.48
2026	27814521.95	28944271.46	30096510.17
2027	28448804.31	30199555.57	32020700.45
2028	29097550.84	31509280.09	34067911.92
2029	29761091.39	32875806.06	36246009.8
2030	30439763.32	34301596.89	38563362.19
2031	31133911.68	35789222.85	41028872.19
2032	31843889.4	37341365.65	43652012.1
2033	32570057.46	38960823.34	46442859.84
2034	33312785.05	40650515.29	49412137.64
2035	34072449.8	42413487.49	52571253.25
2036	34849437.94	44252918.03	55932343.76
2037	35644144.53	46172122.83	59508322.22
2038	36456973.6	48174561.62	63312927.3
2039	37288338.43	50263844.18	67360775.99
2040	38138661.69	52443736.84	71667419.84
2041	39008375.74	54718169.27	76249404.66
2042	39897922.74	57091241.55	81124334.1
2043	40807754.97	59567231.6	86310937.28
2044	41738335.01	62150602.87	91829140.74
2045	42690136	64846012.37	97700145.02
2046	43663641.86	67658319.08	103946506.1
2047	44659347.55	70592592.72	110592222
2048	45677759.31	73654122.87	117662825.1
2049	46719394.94	76848428.53	125185480.2
2050	47784784.02	80181268.02	133189088.7

Senegal GDP projection (Thousands USD)			
Year	Pessimistic scenario **(Thousands USD)**	Medium scenario **(Thousands USD)**	Optimistic scenario **(Thousands USD)**
2024	32267254	32267254	32267254
2025	33341818.09	33666652.54	34492823.31
2026	34452167.32	35126741.59	36871896.81
2027	35599493.39	36650153.25	39415062.15
2028	36785027.72	38239633.75	42133637.23
2029	38010042.72	39898048.42	45039720.59
2030	39275853.16	41628386.88	48146245.24
2031	40583817.62	43433768.39	51467036.22
2032	41935339.92	45317447.5	55016872.1
2033	43331870.61	47282819.88	58811550.82
2034	44774908.56	49333428.49	62867959.92
2035	46266002.57	51472969.95	67204151.72
2036	47806752.98	53705301.18	71839423.67
2037	49398813.47	56034446.39	76794404.24
2038	51043892.76	58464604.3	82091144.69
2039	52743756.47	61000155.72	87753217.21
2040	54500229.05	63645671.47	93805819.86
2041	56315195.68	66405920.6	100275888.7
2042	58190604.33	69285878.97	107192217.5
2043	60128467.83	72290738.26	114585586.4
2044	62130866.07	75425915.28	122488898
2045	64199948.17	78697061.8	130937324.8
2046	66337934.84	82110074.68	139968464.9
2047	68547120.75	85671106.51	149622509.8
2048	70829876.96	89386576.72	159942423.2
2049	73188653.53	93263183.17	170974131.9
2050	75625982.07	97307914.16	182766730.7

Côte d’Ivoire GDP per capita projection (USD)			
Year	Pessimistic scenario	Medium scenario	Optimistic scenario
2024	2709.899585	2709.899585	2709.9
2025	2764.409699	2823.89123	2883.373
2026	2821.147759	2943.858601	3069.182
2027	2880.288311	3070.242164	3268.369
2028	2941.449974	3202.902312	3481.409
2029	3004.584247	3342.044042	3709.166
2030	3069.85837	3488.122101	3952.835
2031	3136.860466	3640.944818	4212.927
2032	3205.484058	3800.651719	4490.355
2033	3275.493135	3967.22382	4785.884
2034	3346.943887	4140.988239	5100.729
2035	3420.578638	4323.153952	5437.281
2036	3496.387137	4514.048208	5796.957
2037	3574.165414	4713.75367	6180.927
2038	3654.328881	4923.176687	6591.511
2039	3737.189455	5143.141388	7031.061
2040	3822.765056	5374.10952	7501.563
2041	3911.341625	5616.945522	8005.681
2042	4002.7694	5871.926213	8545.382
2043	4096.920164	6139.359657	9122.771
2044	4194.217045	6420.399208	9741.337
2045	4295.705487	6717.24497	10406.4
2046	4401.814789	7031.273802	11122.34
2047	4512.116748	7362.547837	11891.68
2048	4626.366445	7711.402773	12717.48
2049	4745.210285	8079.684036	13605.52
2050	4868.866854	8468.614609	14560.82

Mali GDP per capita projection (USD)			
Year	Pessimistic scenario	Medium scenario	Optimistic scenario
2024	1086.17814	1086.17814	1086.17814
2025	1079.194661	1100.893479	1122.592297
2026	1072.585288	1116.150757	1160.583457
2027	1066.332184	1131.954711	1200.215766
2028	1060.384422	1148.27361	1241.51628
2029	1054.779218	1165.169535	1284.61478
2030	1049.544879	1182.698597	1329.641722
2031	1044.604815	1200.799787	1376.60047
2032	1040.009661	1219.555204	1425.658585
2033	1035.852172	1239.102926	1477.060251
2034	1032.102299	1259.441089	1530.895143
2035	1028.810567	1280.666473	1587.378107
2036	1025.95384	1302.788621	1646.626352
2037	1023.568589	1325.893361	1708.859904
2038	1021.618084	1349.975011	1774.190919
2039	1020.216409	1375.228846	1843.004325
2040	1019.380092	1401.72987	1915.545481
2041	1019.006017	1429.389014	1991.844077
2042	1019.072012	1458.223447	2072.076257
2043	1019.524353	1488.203487	2156.357352
2044	1020.435962	1519.483473	2245.07656
2045	1021.810009	1552.122122	2338.502414
2046	1023.632159	1586.153336	2436.878416
2047	1025.925171	1621.669857	2540.550871
2048	1028.647095	1658.664975	2649.725491
2049	1031.795069	1697.192991	2764.713914
2050	1035.332818	1737.253812	2885.751968

Senegal GDP per capita projection (USD)			
Year	Pessimistic scenario	Medium scenario	Optimistic scenario
2024	1743.992443	1743.992443	1743.992443
2025	1761.141961	1778.299981	1821.938993
2026	1778.956915	1813.788935	1903.901
2027	1797.300376	1850.344708	1989.93579
2028	1816.138392	1887.954726	2080.208196
2029	1835.650087	1926.829091	2175.140071
2030	1855.860454	1967.022248	2275.003733
2031	1876.823586	2008.621311	2380.124718
2032	1898.738793	2051.873091	2491.041435
2033	1921.693915	2096.911718	2608.191102
2034	1945.721688	2143.815026	2731.966563
2035	1970.732942	2192.527382	2862.608142
2036	1996.758232	2243.12457	3000.537615
2037	2023.916693	2295.784928	3146.340281
2038	2052.224848	2350.575303	3300.482738
2039	2081.775362	2407.652199	3463.585033
2040	2112.619392	2467.12871	3636.241491
2041	2144.733563	2529.033327	3818.952618
2042	2178.086919	2593.385451	4012.227911
2043	2212.651568	2660.207738	4216.604655
2044	2248.434064	2729.564353	4432.7116
2045	2285.537084	2801.638603	4661.407368
2046	2323.876368	2876.388337	4903.218777
2047	2363.533914	2953.976235	5159.047854
2048	2404.501996	3034.456805	5429.656132
2049	2446.816158	3117.940453	5715.944322
2050	2490.572735	3204.61872	6019.013888