

Long-Term Electricity Demand in Côte d'Ivoire: End-Use Scenario Modelling, Sensitivity Analysis and Retrospective Evaluation

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Abstract

Reliable long-term electricity-demand projections are essential for power-system expansion in rapidly electrifying economies. This study presents long-term electricity-demand projections for Côte d'Ivoire over the 2013-2045 period. The Model for Analysis of Energy Demand (MAED-2), developed by the International Atomic Energy Agency (IAEA), was used to assess electricity demand under alternative socio-economic and technological development scenarios, with 2013 as the base year. Four scenarios Low (LS), Reference (RS), High (HS), and Optimistic (OS) were considered. By 2045, projected electricity demand reaches 77755.1 GWh under LS, 112978.9 GWh under RS, 176554.3 GWh under HS, and 295542.7 GWh under OS, corresponding to endpoint-implied compound annual growth rates of 8.19%, 9.46%, 11.00%, and 12.80%, respectively. The scenario pathways were retrospectively compared with reported electricity statistics over 2013-2024. Reported electricity supplied to the domestic distribution network remained below the low-growth pathway throughout the post-2013 comparison period. Over 2020-2024, the mean absolute percentage error between the scenario pathways and observed supply ranged from 23.1% (LS) to 61.4% (OS), and the supply observed in 2024 cor-

responded to the level reached by LS around 2021.

Keywords

Electricity Demand Forecasting, MAED-2, Scenario Analysis, Retrospective Evaluation, Côte D'Ivoire, Energy Planning

1. Introduction

Electric energy underpins economic activity worldwide, supporting industry, agriculture, services, and domestic life. It is now widely recognized as a foundational input not only for individual welfare but also for national socio-economic development [1]. For developing countries such as Côte d'Ivoire, electricity consumption is a key indicator of the pace and depth of socio-economic transformation, underpinning investment, industrialization, and improvements in living standards.

Over recent decades, Côte d'Ivoire has experienced sustained population growth [2] [3], alongside a substantial expansion in electricity access, which reached 69.7% of the population in 2020 [4]. Since 2011, Côte d'Ivoire has experienced strong economic growth, with GDP growth reaching 10.76% in 2013 [5], prior to a temporary slowdown associated with the COVID-19 pandemic in 2020. This sustained economic expansion has coincided with rising electricity demand, particularly in the industrial and service sectors. Population growth, economic diversification, and technological change are therefore likely to place sustained pressure on electricity demand, making the evolution of long-term demand a central planning question for Côte d'Ivoire.

This study addresses this need by projecting future electricity demand in Côte d'Ivoire using the Model for Analysis of Energy Demand (MAED-2), an end-use forecasting framework that links electricity demand to demographic, economic, and technological development pathways. This approach has previously been applied to other developing economies, including Bangladesh [6] and Syria [7], demonstrating its suitability for data-constrained national contexts.

Existing electricity-planning studies for Côte d'Ivoire have used statistical forecasting, LEAP and power-system optimisation frameworks, while empirical work has examined the determinants of electricity demand. However, a transparent national MAED-2 end-use scenario analysis that combines alternative long-term electricity-demand scenarios with retrospective comparison against post-2013 electricity statistics remains comparatively underdeveloped. The present study addresses this gap through the construction and execution of four MAED-2 scenarios, the use of direct MAED-2 outputs for all model years, and a retrospective stress test of these trajectories against reported electricity-sector statistics through 2024. Relevant national studies include demand-and-supply forecasting using ARIMA/Holt-Winters/LEAP [8], a TIMES-based 2050 electricity-system analysis [9], and econometric evidence on electricity-demand determinants in West Africa

[10].

This question is directly relevant to ongoing regulatory and investment-planning processes in the country's electricity sector. Tariff levels are set through a formal process led by the Autorité Nationale de Régulation du secteur de l'Électricité (ANARE-CI) under the 2014 electricity code [11], and the sector's most recent long-term investment strategy, the Pacte National de l'Énergie published in 2025, sets an explicit national demand-growth benchmark and mobilises multi-billion-dollar public and private investment commitments [12]. Against this institutional background, transparent and retrospectively tested demand scenarios can provide contextual evidence for reviewing planning assumptions and investment requirements. This policy-planning relevance is examined explicitly in Section 4.5.

2. Materials and Methods

2.1. Study Area

Côte d'Ivoire is located in West Africa, along the Gulf of Guinea, between 2°30' and 8°30'W and 4°30' and 10°30'N (Figure 1). The country covers an approximately square territory with a 515 km Atlantic coastline and land borders with Liberia, Guinea, Mali, Burkina Faso, and Ghana.

According to the 2021 Population and Housing Census (RGPH 2021), Côte d'Ivoire had a resident population of 29,389,150 inhabitants [3]. The country is characterized by substantial demographic growth and a sizeable non-Ivorian population, which accounted for 24.2% of the total population in the 2014 census [2].

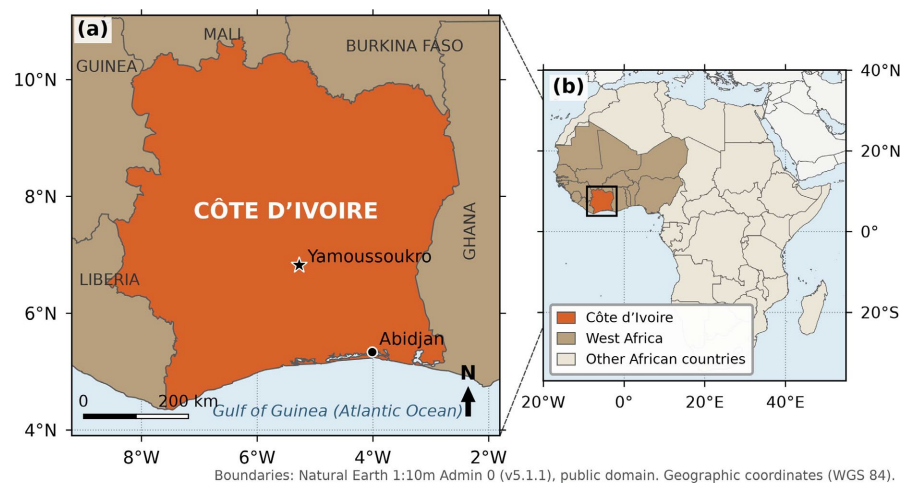


Figure 1. Geographical location of Côte d'Ivoire, West Africa, using QGIS. (a) Côte d'Ivoire, with Abidjan and Yamoussoukro; (b) location of Côte d'Ivoire in Africa. Boundaries: Natural Earth 1:10 m Admin 0 (public domain).

2.2. Economy

Côte d'Ivoire's economy has expanded steadily since 2012. Real GDP growth reached 7.62% in 2012, 10.76% in 2013, 9.37% in 2014, 7.19% in 2015, 7.17% in

2016, and 7.41% in 2017 [5] (**Figure 2**). Growth subsequently moderated to 4.84% in 2018 and 6.72% in 2019, before slowing sharply to 0.70% in 2020 during the COVID-19 pandemic. The economy rebounded in 2021, with real GDP growth reaching 7.06% [5]. Overall, real GDP growth averaged approximately 6.9% per year between 2012 and 2021. Côte d'Ivoire remains the largest economy within the West African Economic and Monetary Union (WAEMU) according to the African Development Bank's 2026 country assessment [13].

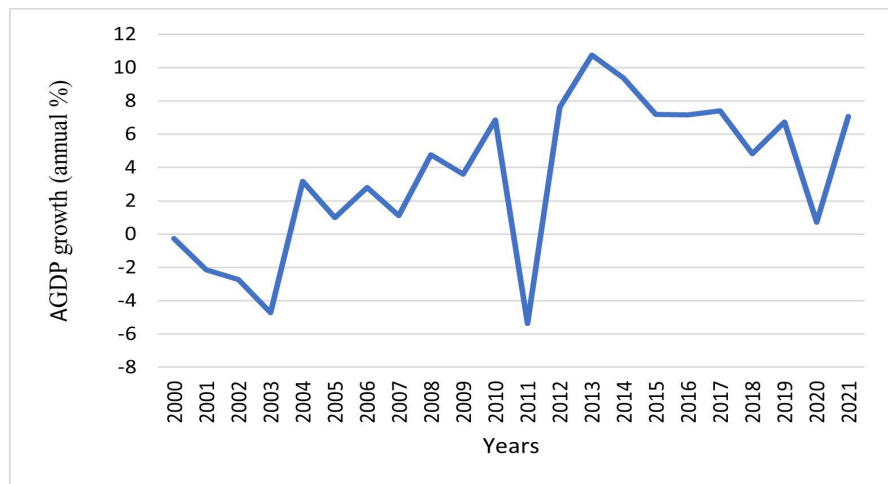


Figure 2. Evolution of real GDP growth in Côte d'Ivoire, 2000-2021. Source: World Bank, World Development Indicators (WDI), GDP growth (annual %) [5].

2.3. Methodology

2.3.1. Energy Demand Model

Future electricity demand was projected using the Model for Analysis of Energy Demand (MAED-2), developed by the International Atomic Energy Agency (IAEA) and based on the end-use methodology originally formulated at the Institut Économique et Juridique de l'Énergie (IEJE), University of Grenoble, under the name MEDEE-2. MAED-2 is a scenario-based planning tool in which each scenario represents a coherent long-term development pathway linking energy demand to demographic, socio-economic, and technological driving factors [14], [15]. Its end-use framework enables the representation of structural changes in energy-consuming activities, technological development, and substitution among energy forms over the projection horizon.

Within MAED-2, energy demand is disaggregated by sector and end-use activity and linked to relevant demographic, socio-economic, and technological drivers. In the present application, final demand was structured across four main consumer sectors: industry (including agriculture, mining, manufacturing, and construction), household, service, and transport (**Figure 3**).

2.3.2. Observational Data

Historical inputs comprised demographic indicators (urban and rural population and population growth), labour-force statistics, macroeconomic indicators (GDP

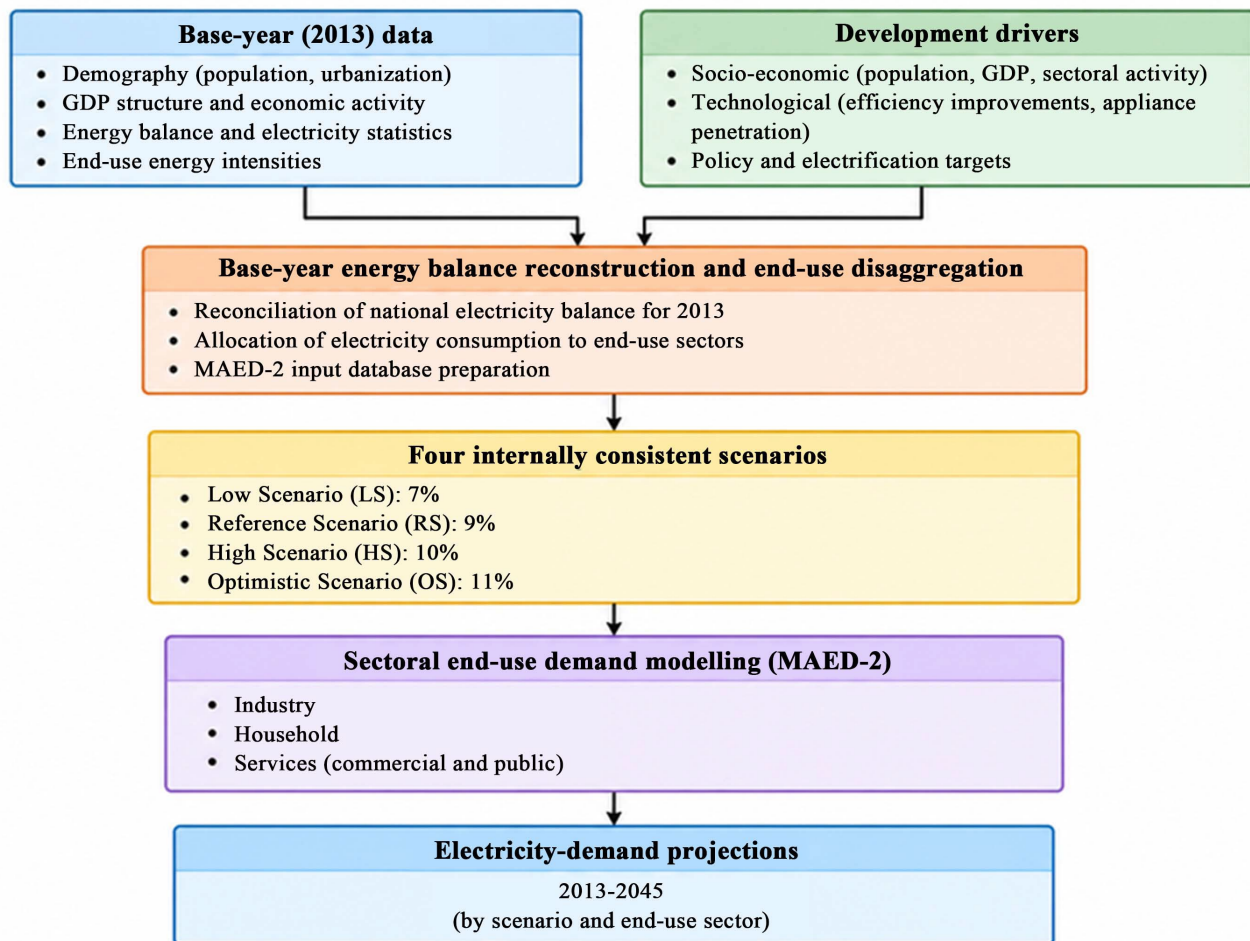


Figure 3. MAED-2 modelling procedure, from base-year data and development driving forces to scenario-specific projected electricity demand, disaggregated by end-use sector.

and sectoral composition), sector-specific energy intensities, household end-use parameters, and base-year electricity data. Data were compiled from the Institut National de la Statistique, World Bank indicators, and national electricity-sector statistics. The primary source for the 2013 electricity base year was the ANARE-CI 2013 energy balance. The MAED-2 base value of 6267.5 GWh is the electricity supplied to the domestic distribution network (7518.5 GWh entering the transmission network, minus 457.6 GWh of transmission losses, 789.0 GWh of net exports, and 4.4 GWh supplied to direct customers); exports are therefore excluded from the base-year quantity. Gross electricity production, exports, electricity supplied to the distribution network, distribution losses, and final billed consumption were treated as distinct electricity-accounting quantities rather than interchangeable measures [16]. Because this boundary lies upstream of distribution losses (1233.9 GWh in 2013, *i.e.* 19.7% of the base value [16]), the MAED-2 base implicitly includes the 2013 distribution losses; this rate subsequently fell to 13.0% in 2020, 8.9% in 2023 and 10.0% in 2024 [17], so that part of the retrospective gap reflects reduced distribution losses rather than lower final demand (Section 4.4).

2.3.3. Modelling of Future Electricity Consumption

The modelling procedure began with construction of the 2013 base-year energy-demand structure and reconciliation of the demographic, socio-economic, technological, and electricity-sector inputs required by MAED-2. Four internally consistent scenario assumption sets were then developed, structured around two complementary components: 1) a socio-economic component describing alternative demographic and economic trajectories, and 2) a technological component representing changes in end-use efficiency and the penetration of alternative energy forms. MAED-2 was subsequently executed for the Low (LS), Reference (RS), High (HS), and Optimistic (OS) scenarios. Electricity-demand outputs were obtained directly from MAED-2 for the model years 2013, 2020, 2025, 2030, 2035, 2040, and 2045.

The modelling sequence (**Figure 3**) comprised five steps: 1) disaggregation of total final energy demand by consumption sector, fuel type, and energy form; 2) identification of the socio-economic and technological drivers associated with each end-use category; 3) reconstruction of base-year (2013) final energy consumption from available statistical data; 4) construction of development scenarios reflecting alternative demographic, macroeconomic, and technological trajectories; and 5) evaluation of projected energy demand for each scenario over the 2013-2045 horizon.

For the retrospective year-specific comparison, direct MAED-2 outputs were available for 2020 and 2025, whereas outputs for the intervening years 2021-2024 were not available. Scenario values for these four years were therefore obtained by local exponential interpolation between the corresponding direct 2020 and 2025 MAED-2 outputs:

$$ED_{s,y} = ED_{s,2020} \left(\frac{ED_{s,2025}}{ED_{s,2020}} \right)^{(y-2020)/5}$$

with $ED_{s,y}$ is the interpolated electricity demand for scenario s in year y ; $ED_{s,2020}$ and $ED_{s,2025}$ are the corresponding direct MAED-2 outputs.

This interpolation was used only to obtain year-specific values for the retrospective comparison and was not used to generate the MAED-2 model-year projections or the long-term scenario trajectories. The observational series used for the retrospective stress test is presented in Section 3.3 using a consistent distribution-network accounting boundary wherever explicitly available in ANARE-CI annual energy balances.

2.3.4. Retrospective Assessment and Statistical Metrics

The retrospective assessment compared the MAED-2 scenario trajectories with observed distribution-network supply over 2020-2024. The differences between the scenario values and observed distribution-network supply were quantified using the mean bias error (MBE) and the mean absolute percentage error (MAPE):

$$MBE = \frac{1}{n} \sum_{i=1}^n (P_i - O_i)$$

$$\text{MAPE} = \frac{100}{n} \sum_{i=1}^n \left| \frac{P_i - O_i}{O_i} \right|$$

where P_i represents the MAED-2 scenario value, O_i the observed distribution-network supply, and n the number of years included in the retrospective comparison. MBE indicates the direction and average magnitude of the deviation, with positive values indicating that the scenario values exceed the observations and negative values indicating the opposite. MAPE expresses the average absolute deviation relative to the observed values as a percentage. Because the scenario values exceeded the observations in every year, the mean absolute error equals the MBE and is not reported separately.

The two metrics were calculated separately for LS, RS, HS, and OS over the 2020-2024 comparison period. They were used to quantify the deviation between each scenario trajectory and the observed distribution-network supply rather than as measures of formal model validation.

2.4. Scenario Development

Four development scenarios were constructed for Côte d'Ivoire: The Low Scenario (LS), Reference Scenario (RS), High Scenario (HS), and Optimistic Scenario (OS), characterized by average GDP growth rates over the projection period of 7%, 9%, 10%, and 11%, respectively. These values represent average growth assumptions over the projection horizon rather than constant annual growth rates. The underlying model-year GDP growth assumptions vary over time in all four scenarios and are reported in the Supplementary Material. Beyond GDP growth, the four scenarios also differ in demographic evolution, sectoral development, technological change, energy-efficiency assumptions, and broader development conditions.

The numerical MAED-2 scenario inputs relevant to the electricity-demand analysis for the model years 2013, 2020, 2025, 2030, 2035, 2040, and 2045 are provided in the Supplementary Material. The supplementary tables report population and household parameters, urbanization, electrification-related assumptions, sectoral activity and economic structure, electricity-specific end-use intensities, electricity penetration/substitution assumptions, transport assumptions relevant to electricity demand, and electricity-related end-use efficiency parameters. Consistent with the scope of this study, parameters associated exclusively with non-electric energy carriers are not reported as independent electricity-demand assumptions. Formula-linked or derived MAED-2 quantities are distinguished from user-entered scenario assumptions where applicable. **Table 1** summarises the main qualitative assumptions distinguishing the four development scenarios, with further details provided in Sections 2.4.1-2.4.4. The detailed numerical inputs, including the time-varying model-year GDP growth assumptions of the four scenarios, are reported in the Supplementary Material (**Tables S1-S9**).

2.4.1. Reference Scenario

The Reference Scenario (RS) is characterized by an average GDP growth rate of

9% over the projection period. The underlying model-year GDP growth assumptions vary over time. Demographically, the RS incorporates time-varying population-growth and household-size assumptions. Urban household size decreases from 5.00 persons per household in 2013 to 4.50 in 2045, while rural household size decreases from 5.70 to 5.50; the urban population share increases from 49.5% to 55.0%. Sectorally, the RS assumes relatively balanced development across economic sectors, without a single dominant driving sector. Technologically, energy efficiency improves in line with historical trends, without accelerated adoption of energy-efficient technologies.

Table 1. Summary of demographic, sectoral, and technological assumptions underlying the four development scenarios.

Parameter	LS (7%)	RS (9%)	HS (10%)	OS (11%)
Household size trend	Urban: gradual decrease; rural: near-stable	Urban and rural: gradual decrease	Urban: gradual decrease; rural: near-stable	Urban and rural: decrease (non-monotonic)
Energy efficiency gains	Low	Historical trend	Actively promoted	Rapid adoption
Leading sector(s)	None (broad-based, weak growth)	Balanced across sectors	Industry, mining	Industry, manufacturing
Investment level	Low (regional instability)	Moderate	High (public + private)	Very high
Contextual assumption	Possible climatic/economic shocks	Continuation of 2011-2016 trends	Accelerated industrialization	Emergence of new modern enterprises

2.4.2. Low-Growth Scenario (LS)

The Low Scenario (LS), labelled the 7% scenario, uses time-varying GDP growth assumptions of 8.0%, 7.3%, 7.1%, 6.5%, 6.9%, and 7.0% for 2020, 2025, 2030, 2035, 2040, and 2045, respectively. The scenario reflects reduced domestic and foreign investment under conditions of regional political instability and potential climatic or economic shocks. Demographically, the LS does not assume a constant household size: urban household size decreases from 5.00 persons per household in 2013 to 4.50 in 2045, while rural household size varies from 5.70 to 5.74 over the same endpoints. The urban population share increases from 49.5% to 55.0%. Sectorally, industrial development remains limited, with the mining and manufacturing sectors expanding only marginally over the study period.

2.4.3. High-Growth Scenario (HS)

The High Scenario (HS) is characterized by an average GDP growth rate of 10% over the projection period. The underlying model year GDP growth assumptions vary over time. The scenario reflects increased private and public investment and accelerated industrialization. Demographically, urban household size decreases from 5.00 persons per household in 2013 to 4.50 in 2045, while rural household

size changes from 5.70 to 5.74. The urban population share increases from 49.5% to 55.0%. Sectorally, growth is led by industry, particularly through the expansion of manufacturing and mining activities, alongside continued development in other economic sectors.

2.4.4. Optimistic Scenario (OS)

The Optimistic Scenario (OS) is characterized by an average GDP growth rate of 11% over the projection period. The underlying annual/model-year GDP growth assumptions vary over time. The scenario reflects strong simultaneous development across economic sectors. Demographically, the OS uses time-varying household-size assumptions: urban household size changes from 5.00 persons per household in 2013 to 4.50 in 2045 and rural household size from 5.70 to 5.10. The urban population share increases from 49.5% to 55.0%. Sectorally, growth is led by industry and manufacturing, alongside strong development in other economic sectors. Technologically, the OS assumes rapid adoption of energy efficient technologies and improvements in industrial processes, supported by sustained investment in modernisation.

2.5. Base Year Reconstruction

The year 2013 was selected as the MAED-2 base year to establish the demographic, economic, and electricity-demand conditions used for model initialization. Subsequent model years were defined as 2020, 2025, 2030, 2035, 2040, and 2045.

Base-year economic activity was characterized using sectoral value-added indicators from the World Bank's World Development Indicators (WDI). In 2013, agriculture, forestry and fishing accounted for 15.34% of GDP, manufacturing for 11.85%, and services for 38.81%, while industry including construction represented 18.98% of GDP. Because manufacturing is included within the WDI industry aggregate, these indicators were not treated as additive components. The industry aggregate was used to characterize the overall industrial structure, while the detailed sectoral assumptions were specified separately for the subsequent scenario construction [18].

Demographic, labour-market, and household conditions for the base year were compiled from official national statistics. According to the 2013 employment survey conducted by INS Côte d'Ivoire, the projected national population was 23.203 million, of which 14.501 million were of working age, corresponding to 62.5% of the total population. Household characteristics were estimated at 5.756 million households nationwide, with an average household size of 4.0 persons per household [19]. The demographic and household parameters used for the base-year reconstruction are summarized in **Table 2**. These INS values are statistical references; in the MAED-2 workbooks, the 2013 population is initialised at 22.106 million and household size is specified separately for urban (5.00) and rural (5.70) households, with an urban population share of 49.5% (Supplementary Material, **Table S4**).

Table 2. Demographic and household parameters for the 2013 base-year reconstruction [19].

Table 2. Demographic and lifestyle parameters for the 2013 base year.

Parameter	Unit	2013 value
Total population	Million persons	23.203
Working-age population	Million persons	14.501
Working-age population share	%	62.5
Estimated number of households	Million households	5.756
Average household size	Persons/household	4.0
Estimated households in Abidjan	Million households	1.008
Average household size in Abidjan	Persons/household	4.3
Estimated rural households	Million households	3.382
Average rural household size	Persons/household	4.0
Estimated households in other urban areas	Million households	1.366
Average household size in other urban areas	Persons/household	4.0

3. Results

3.1. Projected Electricity Demand

MAED-2 projects a sustained increase in electricity demand across all four scenarios over the 2013-2045 period (**Figure 4; Table 3**). The trajectories are based on direct MAED-2 outputs for the model years 2013, 2020, 2025, 2030, 2035, 2040, and 2045. Starting from the common 2013 base-year value of 6267.5 GWh (exact model value: 6267.459 GWh), electricity demand increases progressively over the projection horizon under each scenario.

In 2020, projected demand reaches 11589.4 GWh under LS, 11462.8 GWh under RS, 12202.7 GWh under HS, and 13633.2 GWh under OS. The LS value for 2020 exceeds the RS value despite lower GDP growth, because its services-sector electricity demand (5158 vs 4450 GWh) more than offsets its lower industrial demand (4547 vs 5138 GWh). By 2030, the corresponding values increase to 24466.9, 27010.5, 35207.4, and 41355.2 GWh, respectively. The upward trajectories continue through 2040, when projected demand reaches 51346.3 GWh under LS, 68715.2 GWh under RS, 110121.3 GWh under HS, and 148439.9 GWh under OS. By 2045, demand reaches 77755.1 GWh under LS, 112978.9 GWh under RS, 176554.3 GWh under HS, and 295542.7 GWh under OS.

Over the full 2013-2045 projection period, the corresponding endpoint-implied compound annual growth rates are 8.19%, 9.46%, 11.00%, and 12.80% for LS, RS, HS, and OS, respectively.

3.2. Comparative Analysis across Scenarios

The magnitude of the projected increase differs substantially across the four sce-

narios. Relative to the common 2013 base value, electricity demand in 2045 is approximately 12.4 times the base-year level under LS, 18.0 times under RS, 28.2 times under HS, and 47.2 times under OS. The resulting spread is particularly pronounced between the two outer scenarios, with the OS projection approximately 3.80 times the LS projection in 2045.

Table 3. Summary of projected electricity demand by scenario (2013 and 2045) and corresponding compound annual growth rates (CAGR).

Scenario	Average GDP growth rate over the projection period (%)	2013 demand (GWh)	2045 demand (GWh)	CAGR 2013-2045 (%)
Low-growth (LS)	7%	6267.5	77755.1	8.19
Reference (RS)	9%	6267.5	112978.9	9.46
High-growth (HS)	10%	6267.5	176554.3	11.00
Optimistic (OS)	11%	6267.5	295542.7	12.80

Substantial differences are also observed between the intermediate scenarios. In 2045, projected electricity demand under HS is approximately 56.3% higher than under RS. Thus, considerable differences in long-term electricity-demand outcomes emerge not only between the lowest and highest scenarios but also between the intermediate development pathways.

These differences reflect the combined influence of the demographic, economic, sectoral, and technological assumptions embedded in each MAED-2 scenario. Although LS, RS, HS, and OS are characterized by average GDP growth rates over the projection period of 7%, 9%, 10%, and 11%, respectively, the differences in projected electricity demand cannot be attributed to GDP growth alone because several scenario assumptions vary simultaneously.

3.3. Retrospective Comparison with Observed Distribution-Network Supply

A retrospective comparison was conducted to assess how the MAED-2 electricity-demand pathways relate to the observed evolution of electricity supplied to the domestic distribution network after the 2013 base year. **Figure 4** compares the four scenario trajectories with available distribution-network supply observations through 2024, while **Table 4** reports the values used for the retrospective assessment. The observed series increased from the common base value of 6267.5 GWh in 2013 to 9245.2 GWh in 2020 and then rose every year, to 9918.5 GWh in 2021, 10541.3 GWh in 2022, 11580.6 GWh in 2023, and 12633.4 GWh in 2024 [17].

In 2020, the direct MAED-2 outputs were 11589.4 GWh for LS, 11462.8 GWh for RS, 12202.7 GWh for HS, and 13633.2 GWh for OS, compared with an observed distribution-network supply of 9245.2 GWh. The observed value was

therefore below all four scenario outputs. This separation persisted through 2024, with the observed series remaining below the corresponding scenario trajectories (**Figure 4**).

Table 4. MAED-2 scenario trajectories and observed distribution-network electricity supply in Côte d'Ivoire, 2020-2024.

Year (GWh)	LS (GWh)	RS (GWh)	HS (GWh)	OS (GWh)	Distribution-network supply (GWh)
2020	11589.40	11462.80	12202.70	13633.20	9245.20
2021*	12362.00	12409.30	13501.30	15345.30	9918.50
2022*	13186.00	13433.90	14938.10	17272.40	10541.30
2023*	14065.00	14543.10	16527.80	19441.40	11580.60
2024*	15002.50	15743.90	18286.70	21882.90	12633.40

Note: Values marked with an asterisk for 2021-2024 were obtained by local exponential interpolation between the direct 2020 and 2025 MAED-2 outputs and are used solely for the retrospective comparison. Observed values: ANARE-CI annual reports [17] (energy balances; 2020: pp. 34-35; 2021: pp. 34-35; 2022: pp. 38-39; 2023: pp. 42-43; 2024: p. 51).

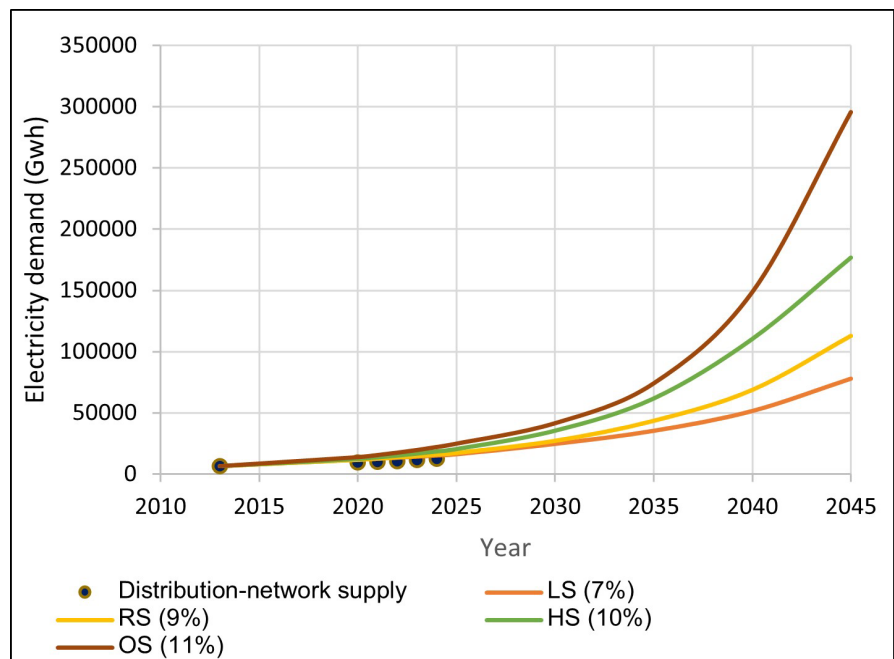


Figure 4. Comparison of MAED-2 electricity-demand trajectories with observed distribution-network supply in Côte d'Ivoire over 2013-2045. Observed distribution-network supply is shown for available years through 2024.

The differences between the MAED-2 scenario trajectories and observed distribution-network supply over 2020-2024 were quantified using the MBE and MAPE metrics defined in Section 2.3.4 (**Table 5**).

Table 5. Statistical metrics for the retrospective comparison between MAED-2 scenario trajectories and observed distribution-network supply over 2020-2024.

Scenario	MBE (GWh)	MAPE (%)
LS	2457.2	23.1
RS	2734.8	25.3
HS	4307.5	39.5
OS	6731.2	61.4

All four scenarios overestimated observed supply in every year (positive MBE), and the deviation increased from LS to OS. The supply observed in 2024 (12633.4 GWh) lies between the LS values for 2021 and 2022 (**Table 4**), *i.e.* roughly three years behind the lowest scenario pathway.

In sum, the retrospective comparison indicates that MAED-2 represents the long-term direction of increasing electricity demand, while the magnitude of projected demand varies substantially with the scenario assumptions.

4. Discussion

4.1. Comparison with Other Sub-Saharan African Case Studies

The compound annual growth rates projected for Côte d'Ivoire (8.19% - 12.80%) are broadly comparable to those obtained in comparable end-use modelling studies elsewhere in West Africa. Using the same MAED framework, Kanté *et al.* [20] projected electricity demand growth rates of 8.13% (low scenario), 10.31% (reference scenario), and 12.56% (high scenario) for the Taoussa region of northern Mali over 2020-2035 a range similar to that obtained in the present study, despite differences in country, study period, and spatial scale (national vs. sub-national). This similarity across two independent West African applications of the MAED methodology provides a useful regional plausibility context for the magnitude of the projected growth rates.

A more recent MAED-D application to Sierra Leone [21], one of the least electrified countries in sub-Saharan Africa, similarly projected substantial relative demand growth across baseline, high-, and low-demand scenarios to 2050, from an extremely low per-capita consumption base. Although expressed in different units (petajoules rather than gigawatt-hours) and therefore not directly comparable in absolute terms, this study reinforces the broader regional pattern of rapid projected electrification-driven demand growth across data-constrained sub-Saharan African economies.

4.2. Comparison with End-Use Studies in Asia

MAED-2 has also been applied to long-term energy- and electricity-demand analysis in Asian developing economies, including Bangladesh [6] and Syria [7], which supports its methodological relevance beyond the West African context.

4.3. Comparison with Mature Economies: Europe and the United States

The magnitude of electricity demand growth projected for Côte d'Ivoire contrasts sharply with long-term projections for mature, highly electrified economies. In the European Union, electricity demand is projected to grow at an average annual rate of approximately 1.1% between 2020 and 2050 [22]. More recent short-term projections indicate that electricity demand increased by 0.9% in 2025 and is expected to grow by approximately 2.3% per year over 2026-2030, driven by increasing electricity use in buildings, transport, industry, and data centres [23]. In the United States, electricity demand increased by 2.1% in 2025 and is projected to grow by close to 2% per year on average through 2030, with data-centre expansion expected to account for approximately half of the increase [23]. The long-term EIA reference case projects growth of approximately 0.9% - 1.6% per year through 2050 [24].

These growth rates remain substantially below the 8.19% - 12.80% endpoint-implied CAGR obtained for Côte d'Ivoire, reflecting different stages of economic and energy-system development. In mature economies, recent electricity-demand growth follows a prolonged period of relatively stagnant demand associated partly with efficiency improvements and industrial restructuring, whereas Côte d'Ivoire is characterized by a lower electricity-consumption base and continuing demographic and economic development. This contrast is consistent with the broader global pattern reported by the International Energy Agency: emerging markets and developing economies accounted for approximately 80% of global electricity-demand growth in 2025 and are expected to maintain a similar share through 2030, compared with an average of approximately 95% over the previous decade. The declining share reflects the renewed contribution of advanced economies, where electricity demand is increasing again after approximately 15 years of stagnation, supported by data centres, electrification, advanced manufacturing, and other emerging loads [23].

4.4. Implications of the Comparative Analysis

This comparative analysis situates the present projections for Côte d'Ivoire within two complementary bodies of evidence. First, the similarity with the Malian case study [20], using the same modelling framework in a neighbouring West African country, provides a useful regional benchmark for the magnitude of projected demand growth. Second, the marked contrast with mature-economy trajectories in Europe and the United States [22]-[24] places the Côte d'Ivoire projections within a different demographic, economic, and electricity-sector development context, in which continued growth in electricity use has important implications for future generation capacity and grid infrastructure. This comparative perspective reinforces the practical relevance of the scenario-based approach adopted in this study for examining alternative long-term electricity-demand pathways and informing electricity-system planning in Côte d'Ivoire.

4.5. Retrospective Stress Test against Reported Data (2013-2024)

A useful test of scenario relevance is whether subsequently observed outcomes remain within, or systematically depart from, the scenario envelope. The retrospective comparison presented in Section 3.3 shows that observed distribution-network supply remained below all four MAED-2 scenario trajectories over 2020-2024. Among the four scenarios, the Low Scenario (LS) showed the smallest deviation from the observed series, although observed distribution-network supply remained below this trajectory throughout the comparison period.

The quantitative assessment further illustrates this divergence. Over 2020-2024, LS produced the lowest MBE and MAPE among the four scenarios, followed by RS, HS, and OS (**Table 5**). The increasing magnitude of the deviations toward the higher-demand scenarios indicates that the observed evolution during the early part of the projection horizon has been closer to the lower end of the scenario range than to the higher-demand pathways. This finding does not invalidate the longer-term scenarios, which represent alternative development pathways through 2045 rather than short-term forecasts.

Two factors explain much of this divergence. First, distribution losses fell sharply after 2013: at the 2013 loss rate (19.7%), the electricity delivered to consumers in 2024 would have required about 14,160 GWh of distribution-network supply instead of 12,633.4 GWh, which corresponds to roughly two-thirds of the 2024 deviation from LS. Second, economic growth during the retrospective period did not consistently follow the scenario assumptions; because the scenarios combine several demographic, economic, sectoral, and technological assumptions, the remaining gap cannot be attributed to GDP growth alone.

4.6. Policy Implications for Electricity-Sector Planning and Regulation in Côte d'Ivoire

Under the 2014 Electricity Code [11], ANARE-CI proposes electricity tariffs to the State, a mechanism applied to the 10% tariff adjustment effective from 1 January 2024 [25]. The present analysis does not model sector revenues, costs, or tariff formation; its implication is that demand assumptions constitute an important input to electricity-sector planning and that comparing them with subsequently observed data strengthens the evidence available to planners and regulators.

The results are also relevant to investment planning. Côte d'Ivoire's Pacte National de l'Énergie, published in January 2025 in connection with the World Bank Group and African Development Bank Mission 300 initiative [12], estimates total financing needs of USD 15.02 billion, of which USD 6.56 billion remained to be financed, and aims to mobilise about USD 2 billion of private investment in electricity generation, transmission, and distribution. The national electricity-sector investment plan to 2040 estimates average annual growth in domestic electricity consumption at 6.5% over 2025-2030 [26]. Over the same 2025-2030 period, the direct MAED-2 outputs imply average growth of 8.9% (LS), 9.7% (RS), 11.7% (HS), and 10.9% (OS) per year, all above this benchmark; the lower OS than HS

rate over this sub-period mainly reflects slower growth of industrial (12.1% vs 13.6% per year) and household (1.1% vs 2.9% per year) electricity demand in OS. This comparison indicates that the MAED-2 scenarios embed stronger demand-growth assumptions than the recent national planning reference and provides a contemporary benchmark for interpreting the magnitude of the scenario trajectories.

More broadly, the substantial differences among the LS, RS, HS, and OS trajectories indicate that future generation and network requirements may vary considerably depending on the evolution of electricity demand. Transparent scenario envelopes combined with retrospective comparison can therefore help planners and investors assess the implications of alternative demand pathways for generation-capacity expansion and transmission and distribution infrastructure. The results support the use of alternative demand scenarios rather than reliance on a single long-term demand trajectory when examining future electricity-system requirements.

4.7. Strengths and Limitations

This study has several methodological strengths. First, the four electricity-demand scenarios were constructed and executed using the MAED-2 end-use framework, allowing long-term demand to be represented under alternative demographic, economic, sectoral, and technological development pathways. Second, the analysis uses direct MAED-2 outputs for the model years 2013, 2020, 2025, 2030, 2035, 2040, and 2045 rather than reconstructing the long-term scenario trajectories from the 2013 and 2045 endpoints. Third, the retrospective comparison with observed distribution-network supply through 2024 provides an additional assessment of how the early evolution of the electricity system relates to the original scenario pathways. The use of MBE and MAPE further provides a quantitative characterization of these deviations.

Several considerations are important when interpreting these results. The four scenarios represent alternative combinations of demographic, economic, sectoral, and technological assumptions rather than probabilistic forecasts. Because these drivers vary jointly across scenarios, the relationship between GDP growth and electricity-demand growth should not be interpreted as an isolated GDP effect. In addition, observed distribution-network supply does not necessarily represent unconstrained electricity demand. The 2020–2024 retrospective comparison is therefore used to assess the early alignment of observed electricity-system evolution with the original scenario trajectories.

The combination of end-use scenario modelling, transparent scenario assumptions, direct model outputs, and retrospective comparison provides a coherent framework for examining alternative long-term electricity-demand pathways in Côte d'Ivoire. These demand pathways can also provide inputs for subsequent assessments of generation, network, and flexibility requirements.

5. Conclusions

This study applied the MAED-2 end-use framework to examine long-term elec-

tricity-demand pathways in Côte d'Ivoire over 2013-2045 under four alternative development scenarios: Low (LS), Reference (RS), High (HS), and Optimistic (OS). Starting from a common base-year electricity demand of 6267.5 GWh in 2013, the direct MAED-2 outputs reach 77755.1 GWh under LS, 112978.9 GWh under RS, 176554.3 GWh under HS, and 295542.7 GWh under OS by 2045. The corresponding endpoint-implied CAGRs range from 8.19% to 12.80%, demonstrating substantial long-term demand growth across all four development pathways.

The retrospective comparison provides an additional perspective on the long-term projections. Observed distribution-network supply remained below all four scenario trajectories over 2020-2024, with the smallest deviations occurring under LS; the supply observed in 2024 corresponded to the LS level of about 2021. This early divergence indicates that observed electricity-system evolution has proceeded more slowly than the original demand pathways, partly because distribution losses were substantially reduced.

For electricity-system planning, the substantial spread among the 2045 demand outcomes indicates that future generation and network requirements could differ markedly depending on the development pathway realised. The scenario envelope can therefore support consideration of alternative long-term electricity-demand conditions rather than reliance on a single demand trajectory. Combining such scenario analysis with subsequent comparison against observed electricity-sector data provides a transparent basis for assessing the continued relevance of long-term planning assumptions.

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Author Contributions

Aka Jacques Adon: Conceptualization, Methodology, Data curation, Software (construction and execution of the MAED-2 scenarios), Formal analysis, Investigation, Visualization, Writing-original draft. N'da Amino Edith Julie Kouadio: Conceptualization, Methodology, Validation, Supervision, Writing-review & editing. Arona Diedhiou: Investigation, Validation, Supervision. Yacouba Moumouni: Investigation, Visualization, Xavier Bouo-Bella: Validation, Supervision, Saleye Yahaya: Validation, Supervision Yao Tchetché: Validation, Supervision Aka Boko: Validation, Supervision; All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Supplementary Material: Numerical Inputs Used in the MAED-2 Scenario Construction

Scope. This supplementary document reports the numerical inputs and scenario assumptions used in the MAED-2 analysis and is aligned with the values reported in the manuscript. Base-year demographic, household, economic, and electricity-accounting values follow the sources and definitions used in Section 2.5, while scenario-specific future assumptions reproduce the MAED-2 scenario inputs for the model years 2020–2045. No missing values have been estimated or invented. Where a 2013 value reported as a statistical reference (INS, WDI) differs from the 2013 entry of the MAED-2 workbooks, the difference is stated in the note below the table concerned. Scenario inputs and outputs are read from the MAED-2 workbooks *scenario_7_MASTER_FIN.xlsx* (LS), *scenario_9_MASTER_FIN.xlsx* (RS), *scenario_10_MASTER_FIN.xlsx* (HS), and *scenario_11_MASTER_FIN.xlsx* (OS): demography in sheet Demogr-D, GDP in sheet GDP-D, and electricity demand in sheet “Final results (User unit)” (converted at 11,630 GWh per Mtoe).

Table S1. Electricity accounting and final electricity consumption for the 2013 MAED-2 base year.

Electricity-accounting component	2013 value (GWh)	Accounting interpretation	Source	Link
Electricity entering the transmission network	7518.5	Electricity entering the transmission network	ANARE-CI, Rapport d'activité 2013	ANARE-CI 2013 Report
Transmission losses	457.6	Losses in the transmission network	ANARE-CI, Rapport d'activité 2013	ANARE-CI 2013 Report
Net electricity exports	789.0	Net cross-border electricity exports	ANARE-CI, Rapport d'activité 2013	ANARE-CI 2013 Report
Direct supply to eligible customers	4.4	Electricity supplied directly to eligible customers	ANARE-CI, Rapport d'activité 2013	ANARE-CI 2013 Report
Electricity transferred to the national distribution network	6267.5	7518.5 – 457.6 – 789.0 – 4.4	Derived from ANARE-CI (2013)	ANARE-CI 2013 Report
Industry final electricity consumption	1900.0	Final electricity consumption by industry	JICA, Table 2.7; original source: IEA, World Energy Balances 2018	JICA report—Table 2.7
Agriculture final electricity consumption	0.0	Final electricity consumption by agriculture	JICA, Table 2.7; original source: IEA, World Energy Balances 2018	JICA report—Table 2.7
Commerce/public services	1258.0	Final electricity consumption by commerce and public services	JICA, Table 2.7; original source: IEA, World Energy Balances 2018	JICA report—Table 2.7
Residential/households	1712.0	Final household electricity consumption	JICA, Table 2.7; original source: IEA, World Energy Balances 2018	JICA report—Table 2.7

Continued

Not allocated to the sectors above	176.0	Derived: 5046.0 – (1900.0 + 0.0 + 1258.0 + 1712.0)	Derived from JICA, Table 2.7	JICA report—Table 2.7
Total final national electricity consumption	5046.0	Reported final national electricity consumption	JICA, Table 2.7; IEA World Energy Balances 2018 (ANARE-CI billed sales: 5045.3 GWh, see below)	JICA report · ANARE-CI electricity sales
Isolated power plants (added downstream)	11.7	Electricity from isolated plants added at distribution level	ANARE-CI, Rapport d'activité 2013	ANARE-CI 2013 Report
Distribution losses	1233.9	Losses in the distribution network (19.7% of 6267.5)	ANARE-CI, Rapport d'activité 2013	ANARE-CI 2013 Report
Billed final consumption	5045.3	6267.5 + 11.7 – 1233.9	ANARE-CI, Rapport d'activité 2013	ANARE-CI 2013 Report

Table S2. Demographic and urbanization inputs for the 2013 MAED-2 base year.

MAED-2 input	2013 value	Source/basis	Link
Total population	23.203 million	INS Côte d'Ivoire, Enquête Emploi 2013, Section 1.2	INS Côte d'Ivoire—Enquête Emploi 2013
Population growth rate	2.5% yr ⁻¹	World Bank, WDI	World Bank—Population growth, Côte d'Ivoire
Urban population share	48.6%	World Bank, WDI; underlying source: UN Population Division	World Bank—Urban population (% of total), Côte d'Ivoire
Rural population share	51.4%	Calculated as 100 – 48.6	World Bank—Urban population (% of total), Côte d'Ivoire
Potential labour force/working-age population share	62.5%	INS Côte d'Ivoire, Enquête Emploi 2013, Table 1.1	INS Côte d'Ivoire—Enquête Emploi 2013
Working-age population	14.501 million	INS Côte d'Ivoire, Enquête Emploi 2013, Section 1.2	INS Côte d'Ivoire—Enquête Emploi 2013
Estimated number of households	5.756 million	INS Côte d'Ivoire, ENSETE 2013, p. 23, Table 3	INS Côte d'Ivoire—ENSETE 2013
Average household size	4.0 persons/household	INS Côte d'Ivoire, ENSETE 2013, p. 23, Table 3	INS Côte d'Ivoire—ENSETE 2013
Estimated households in Abidjan	1.008 million	INS Côte d'Ivoire, ENSETE 2013, p. 23, Table 3	INS Côte d'Ivoire—ENSETE 2013
Average household size in Abidjan	4.3 persons/household	INS Côte d'Ivoire, ENSETE 2013, p. 23, Table 3	INS Côte d'Ivoire—ENSETE 2013
Estimated rural households	3.382 million	INS Côte d'Ivoire, ENSETE 2013, p. 23, Table 3	INS Côte d'Ivoire—ENSETE 2013
Average rural household size	4.0 persons/household	INS Côte d'Ivoire, ENSETE 2013, p. 23, Table 3	INS Côte d'Ivoire—ENSETE 2013
Estimated households in other urban areas	1.366 million	INS Côte d'Ivoire, ENSETE 2013, p. 23, Table 3	INS Côte d'Ivoire—ENSETE 2013
Average household size in other urban areas	4.0 persons/household	INS Côte d'Ivoire, ENSETE 2013, p. 23, Table 3	INS Côte d'Ivoire—ENSETE 2013

Table S3. Electrification-Related assumptions used in the MAED-2 scenarios.

Parameter	Unit	Scenario	2013	2020	2025	2030	2035	2040	2045
Urban household electricity penetration	%	LS/RS/OS	62.4	63	64	65	66	67	68
Urban household electricity penetration	%	HS	62.4	63	64	65	66	67	67
Rural household electricity penetration	%	All	75.0	74	74	72	71	70	70

Table S4. Demographic and urbanization assumptions used in the MAED-2 scenarios.

Parameter	Unit	Scenario	2013	2020	2025	2030	2035	2040	2045
Population	million	Base/LS	22.106	26.457	30.080	34.199	38.882	44.207	50.260
Population growth	% yr ⁻¹	LS	2.5	2.60	2.60	2.60	2.60	2.60	2.60
Population growth	% yr ⁻¹	RS	2.5	2.52	2.60	2.60	2.60	2.50	2.50
Population growth	% yr ⁻¹	HS	2.5	2.52	2.60	2.60	2.60	2.60	2.60
Population growth	% yr ⁻¹	OS	2.5	2.52	2.60	2.60	2.60	2.60	2.60
Urban population	%	All	49.5	51.0	51.5	52.0	52.5	53.64	55.0
Rural population	%	All	50.5	49.0	48.5	48.0	47.5	46.36	45.0
Urban household size	persons/hh	LS	5.00	5.00	4.94	4.85	4.75	4.65	4.50
Urban household size	persons/hh	RS	5.00	5.00	4.70	4.75	4.75	4.65	4.50
Urban household size	persons/hh	HS	5.00	5.00	4.94	4.85	4.75	4.65	4.50
Urban household size	persons/hh	OS	5.00	4.50	4.20	4.30	4.75	4.65	4.50
Rural household size	persons/hh	LS/HS	5.70	5.80	5.77	5.73	5.68	5.60	5.74
Rural household size	persons/hh	RS	5.70	5.80	5.77	5.50	5.50	5.50	5.50
Rural household size	persons/hh	OS	5.70	5.70	5.00	5.73	5.68	5.60	5.10
Potential labour force	%	All	62.5	63.0	63.5	64.0	64.5	65.0	65.5

Note: The 2013 population shown is the MAED-2 workbook value (22.106 million), from which the 2020-2045 values follow at the LS growth rate; the INS 2013 estimate (23.203 million; **Table S2**) is a statistical reference. Household sizes are workbook inputs by urban and rural area; the INS average of 4.0 persons per household (**Table S2**) is a survey statistic. Non-monotonic series (e.g., OS household size) are reported as entered in the scenario workbooks. The 2013 urban share in the workbooks is 49.5% (WDI: 48.6%; **Table S2**).

Table S5. GDP formation in the base year 2013 and sectoral activity basis.

Sector/indicator	Unit	2013	Source/basis
GDP	billion constant 2010 US\$	39.078	World Bank WDI/WITS
GDP growth	% yr ⁻¹	10.76	World Bank WDI/WITS
Agriculture	% GDP	15.34	World Bank WDI—Agriculture, forestry and fishing, value added (% of GDP)
Construction	% GDP	—	Not used as a separate 2013 base-year share in the manuscript
Mining and quarrying	% GDP	—	Not used as a separate 2013 base-year share in the manuscript
Manufacturing	% GDP	11.85	World Bank WDI—Manufacturing, value added (% of GDP)
Services	% GDP	38.81	World Bank WDI—Services, value added (% of GDP)
Energy (electricity, gas and water)	% GDP	—	Not used as a separate 2013 base-year share in the manuscript
Industry including construction	% GDP	18.98	World Bank WDI—Industry (including construction), value added (% of GDP)
Construction + Mining + Energy	% GDP	—	Not used as a separate 2013 base-year share in the manuscript

Source: World Bank, World Development Indicators (WDI), Côte d'Ivoire. The 2013 base-year shares used in the manuscript are Agriculture, forestry and fishing = 15.34% of GDP; Manufacturing = 11.85%; Services = 38.81%; and Industry (including construction) = 18.98%. Manufacturing is included within the WDI industry aggregate and the two indicators are therefore not additive. Construction, mining and quarrying, and electricity/gas/water are not reported as separate 2013 WDI shares in the manuscript and are not reconstructed here.

Table S6. Sectoral activity assumptions used in the MAED-2 scenarios.

Parameter	Unit	Scenario	2013	2020	2025	2030	2035	2040	2045
GDP growth	% yr ⁻¹	LS	10.76	8.0	7.3	7.1	6.5	6.9	7.0
GDP growth	% yr ⁻¹	RS	10.76	9.0	8.7	9.2	9.2	9.0	9.3
GDP growth	% yr ⁻¹	HS	10.76	8.3	9.8	11.0	10.8	10.5	9.9
GDP growth	% yr ⁻¹	OS	10.76	9.5	10.5	10.95	11.0	12.4	11.6
Agriculture	% GDP	LS/RS	15.34	29.0	28.0	29.0	29.0	28.0	27.0
Agriculture	% GDP	HS	15.34	28.0	23.0	22.0	23.03	20.0	21.0
Agriculture	% GDP	OS	15.34	28.0	29.0	30.0	27.0	26.0	26.0
Industry incl. construction	% GDP	All	18.98	—	—	—	—	—	—
Manufacturing	% GDP	LS/RS	11.85	14.0	13.4	14.5	13.5	13.0	14.0
Manufacturing	% GDP	HS/OS	11.85	13.0	12.0	12.8	11.9	11.0	12.5
Services	% GDP	LS/RS	38.81	33.0	34.0	35.0	33.5	35.0	37.0
Services	% GDP	HS	38.81	41.4	44.0	45.0	42.0	45.0	38.0
Services	% GDP	OS	38.81	41.4	44.0	45.0	42.0	45.0	45.0

Note: The 2013 shares are WDI statistics (**Table S5**), whereas the 2020-2045 shares are workbook inputs defined by the MAED-2 sectoral classification; the two series are therefore not directly continuous (e.g., agriculture 15.34% in 2013 vs 28% - 29% in 2020).

Table S7. Electricity-specific end-use intensity assumptions (Low Scenario, four industrial sub-sectors).

Parameter	Unit	Scenario	2013	2020	2025	2030	2035	2040	2045
Agriculture	kWh/USD	LS	0.013800	0.017	0.020	0.030	0.040	0.050	0.060
Construction	kWh/USD	LS	0.479000	0.500	0.700	0.800	0.900	1.000	1.300
Mining	kWh/USD	LS	0.385374	0.400	0.500	0.600	0.660	0.680	0.600
Machinery & equipment	kWh/USD	LS	0.102060	0.200	0.250	0.300	0.350	0.400	0.450

Note: **Table S7** reports the LS electricity intensities of four industrial sub-sectors only; intensities of the other sectors and of the RS, HS, and OS scenarios are not reproduced in this document.

Table S8. Renewable-energy assumptions used in the MAED-2 scenarios.

Sector/parameter	Unit	Scenario	2013	2020	2025	2030	2035	2040	2045
Manufacturing— Solar, steam generation	%	All	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manufacturing— Solar, space/water heating	%	All	0.0	1.0	2.0	4.0	4.9	5.0	6.0
Manufacturing— Solar share	%	All	0.0	0.0	1.0	1.5	2.0	3.0	3.5
Manufacturing— Biomass share in cogeneration	%	All	0.0	1.5	2.0	2.2	2.5	2.7	3.0
Services—Modern biomass, space heating	%	All	1.0	1.0	1.0	1.0	20.0	30.0	40.0
Services—Soft solar, space heating	%	All	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Services—Modern biomass, other thermal uses	%	All	0.0	0.0	2.0	10.0	15.0	25.0	30.0
Services—Soft solar, other thermal uses	%	All	0.0	0.0	1.0	3.0	5.0	9.0	15.0

Scope of efficiency parameters. Consistent with the electricity-demand scope of the study, **Table S9** reports only end-use efficiency parameters directly relevant to electricity demand in the MAED-2 workbooks. Parameters associated exclusively with non-electric energy carriers (e.g., traditional fuels, modern biomass, fossil fuels, and non-electric air conditioning) are not reported as independent electricity-demand assumptions. Values below were extracted directly from the four scenario workbooks; no values were estimated, harmonized, or corrected.

Table S9. Electricity-related end-use efficiency parameters used in the MAED-2 scenarios.

Sector/end use	Efficiency parameter	Unit	Scenario	2013	2020	2025	2030	2035	2040	2045
Manufacturing	Heat pumps COP	ratio	All	2	3	4	5	5	6	7
Manufacturing	Cogeneration efficiency	%	LS	65	66	67	67.5	68	68.5	68.9
Manufacturing	Cogeneration efficiency	%	RS	65	66	67	67.5	66.6	67.2	68.9
Manufacturing	Cogeneration efficiency	%	HS/OS	65	66	67	67.5	68	68.5	68.9
Manufacturing	Heat/electricity ratio	ratio	LS	5	5	5.5	5.3	6	6.2	6.6
Manufacturing	Heat/electricity ratio	ratio	RS/HS/OS	5	5	5.5	5.8	6	6.2	6.6
Urban households— space heating	Heat-pump COP	ratio	All	2	2	2	2	2	2	2
Urban households— water heating	Heat-pump COP	ratio	All	2	2	2	2	2	2	2
Urban households— air conditioning	Electric AC COP	ratio	All	2	2	2	2	2	2	2
Rural households— space heating	Heat-pump COP	ratio	All	2	2	2	2	2	2	2
Rural households— water heating	Heat-pump COP	ratio	All	2	2	2	2	2	2	2
Rural households— air conditioning	Electric AC COP	ratio	All	2	2	2	2	2	2	2
Services— thermal uses	Heat-pump COP	ratio	All	2	2	2	2	2	2	2
Services—air conditioning	Electric AC COP	ratio	All	2	2	2	2	2	2	2