

Forecasting Residential Electricity Demand in Algeria for the Period 2026–2050 Using the LEAP Model: A Scenario-Based Analytical Approach

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Abstract:

The purpose of this study is to forecast residential electricity demand in Algeria for the period 2026–2050 using the Long-range Energy Alternatives Planning System (LEAP). This research represents an analytical attempt to estimate future electricity demand considering demographic, economic, and climatic dynamics. Three main scenarios were developed: the baseline scenario, the high-growth scenario, and the energy efficiency scenario. The results show that residential electricity demand in Algeria is expected to increase substantially in all scenarios, with the highest growth observed under rapid economic expansion and rising temperatures. These findings emphasize the necessity of integrating energy efficiency and demand management policies into national energy strategies to ensure a sustainable balance between electricity supply and demand in the long term.

Keywords: Residential electricity demand; energy forecasting; LEAP model; scenarios analysis; Algeria.

Jel Classification Codes : Q41; Q47; Q48;C53.

Résumé:

L'objectif de cette étude est de prévoir la demande résidentielle d'électricité en Algérie pour la période 2026-2050 en utilisant le modèle Long-range Energy Alternatives Planning System (LEAP). Cette recherche représente une tentative analytique d'estimation de la demande future d'électricité en tenant compte des dynamiques démographiques, économiques et climatiques. Trois principaux scénarios ont été élaborés : le scénario de référence, le scénario de forte croissance et le scénario d'efficacité énergétique. Les résultats obtenus indiquent une augmentation significative de la demande d'électricité résidentielle dans tous les scénarios, la plus forte croissance étant observée dans un contexte d'expansion économique rapide et de hausse des températures. Ces résultats soulignent la nécessité d'intégrer les politiques d'efficacité énergétique et de gestion de la demande dans les stratégies énergétiques nationales afin d'assurer un équilibre durable entre l'offre et la demande d'électricité à long terme.

Mots clés: demande d'électricité résidentielle; prévision de la demande énergétique ; modèle LEAP ; scénarios d'analyse; Algérie.

Jel Classification Codes : Q41; Q47; Q48;C53.

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I. Introduction

I.1. General Background

Electricity plays a crucial role in achieving economic and social development, serving as a fundamental indicator of modernization and quality of life. A steady and reliable electricity supply is essential for improving living standards, supporting industrial growth, and enhancing social welfare. However, the continuous increase in electricity demand poses serious challenges related to energy security, infrastructure capacity, and environmental sustainability.

In Algeria, the electricity sector has witnessed remarkable growth over the last decades, driven by demographic expansion, urbanization, economic development, and the growing penetration of electrical appliances. The residential sector, in particular, has become one of the largest consumers of electricity, accounting for a substantial share of total national demand. This trend reflects the improved quality of life and modernization of Algerian households but also raises critical concerns regarding the sustainability of supply and the resilience of the national energy system.

Furthermore, the anticipated impacts of climate change—especially rising average temperatures and increasing heat waves—are expected to further amplify electricity demand for cooling, particularly during summer months. Without adequate planning and efficient energy management policies, this growing demand could lead to significant stress on the power grid, increased production costs, and potential supply shortages.

I.2. Research Problem

The main problem addressed in this study lies in the lack of comprehensive long-term forecasting of residential electricity demand in Algeria in light of evolving demographic, economic, and climatic conditions. Although the government has initiated energy transition policies and promoted renewable energy development, long-term projections for residential demand remain insufficiently explored and quantitatively underdeveloped.

Hence, the central research question can be formulated as:

How will residential electricity demand in Algeria evolve from 2026 to 2050 under varying demographic, economic, and climatic conditions, and how can scenario-based modeling with the LEAP system inform sustainable national energy planning?

This question gives rise to several sub-questions:

- To what extent will population growth and rising household incomes drive the increase in residential electricity demand in Algeria between 2026 and 2050?
- How will higher temperatures and more frequent heatwaves affect household electricity consumption, particularly for cooling purposes?

- What is the potential impact of energy-efficiency measures on reducing future residential electricity demand compared to the baseline scenario?
- How do the baseline, high-growth, and energy-efficiency scenarios differ in projecting residential electricity demand when modeled using the LEAP system?

1.3. Research hypotheses

Building on the stated problem, this study is guided by the following hypotheses:

- **H1:** Residential electricity demand in Algeria will increase significantly from 2026 to 2050 in response to population and income growth.
- **H2:** Rising temperatures and more frequent heatwaves will cause a measurable increase in household electricity use for cooling.
- **H3:** Implementing energy-efficiency measures will reduce future residential electricity demand compared with the baseline scenario.
- **H4:** The LEAP model will detect significant differences in electricity demand across the baseline, high-growth, and energy-efficiency scenarios.

1.4. Research Significance

This study is significant both scientifically and practically. It provides a quantitative foresight analysis of Algeria’s residential electricity demand, which can guide policymakers, energy planners, and researchers in designing effective and sustainable energy strategies.

1.5. Research Objectives

The main objectives of this research are to:

- Forecast the evolution of residential electricity demand in Algeria for the period 2026–2050 using the LEAP model.
- Analyze the effects of demographic, economic, and climatic factors on electricity demand.
- Construct alternative scenarios (baseline, high-growth, and energy efficiency) to reflect different possible consumption pathways.
- Provide quantitative and policy-oriented recommendations to improve national energy planning and ensure long-term sustainability.

1.6. Methodological Approach

The study employs the Long-range Energy Alternatives Planning System (LEAP) as the principal modeling tool to simulate and forecast residential electricity demand. LEAP is widely recognized for its flexibility and capability to integrate socio-economic, technological, and climatic variables into long-term energy scenarios. The model structure allows for comparative analysis across scenarios, providing a clear picture of possible demand trajectories and the influence of policy interventions.

Data sources include official statistics from the National Office of Statistics (ONS), the Ministry of Energy and Mines, the Sonelgaz Group, and international



datasets from organizations such as the World Bank and the International Energy Agency (IEA). The projection period (2026–2050) is divided into sub-periods to capture both medium-term dynamics and long-term structural trends.

1.7. Literature Review Overview

The forecasting of electricity demand—particularly in the residential sector—has been an area of growing academic interest in both developing and developed economies. Understanding the dynamics of household electricity consumption is crucial for long-term energy planning, investment in infrastructure, and sustainability policies (IEA, 2023; UNDESA, 2024). (Benmouffok & al., 2019, pp 418-429) conducted one of the earliest LEAP-based analyses focusing on national energy demand, revealing that household electricity use had grown by more than 6% annually between 2000 and 2018, largely driven by population growth and increased appliance penetration. Similarly, (Kadi, S., & Hadj Arab, A., 2020, pp1143-1155) developed a bottom-up model assessing residential demand under different policy scenarios, concluding that improvements in appliance efficiency could reduce total demand by 18% by 2040 compared to a business-as-usual trajectory. A more recent study by (Boudghene Stambouli & al., 2021, p1736) explored Algeria’s transition toward renewable integration and projected the electricity mix through 2050. Their work indicated that the residential sector would remain the leading consumer of electricity, representing nearly 40% of total demand by mid-century. However, these studies often emphasized aggregate trends without disaggregating results by climatic zones or socioeconomic levels—an analytical gap this research seeks to address.

Beyond Algeria, multiple studies have applied the LEAP model or other simulation frameworks (e.g., MARKAL, TIMES, and Energy PLAN) to forecast electricity demand in emerging economies with similar demographic and climatic characteristics. For instance, (Elshurafa & al., 2020, pp 1043–1056.) applied LEAP to Saudi Arabia, demonstrating how household behavior and urbanization significantly influence long-term demand elasticity. Comparable insights were drawn in Egypt (Hassan & Abdelaziz, 2021), where the combination of rising income levels and climatic stress was shown to accelerate cooling-related electricity use.

These studies underline the necessity of integrating socio-demographic, economic, and climate variables into energy forecasting. They also illustrate LEAP’s flexibility in handling diverse data inputs and scenario analysis, making it a preferred tool for developing-country contexts with limited statistical depth.

While the reviewed literature provides valuable insights, several research gaps persist. First, few studies have incorporated climate change projections into household electricity forecasting, despite growing evidence of temperature-

driven consumption increases. Second, the majority of LEAP applications in Algeria remain policy-neutral, with limited exploration of demand-side management and energy efficiency scenarios. Third, regional disparities between northern coastal cities and southern arid zones—where climatic and lifestyle differences are significant—are often overlooked.

However, in Algeria, most previous works have focused on short-term statistical analyses without employing comprehensive modeling frameworks. This research fills a critical gap by applying the LEAP model to construct detailed scenarios for residential electricity demand between 2026 and 2050, making it a novel contribution to Algerian energy economics literature.

II. Theoretical and Conceptual Framework

II.1 Electricity Demand in the Residential Sector

Electricity demand in the residential sector refers to the amount of electric energy consumed by households for end-uses such as lighting, heating, cooling, refrigeration, and the operation of various domestic appliances. Residential consumption patterns are shaped by multiple factors, including income levels, household size, urbanization, technological access, and climatic conditions. (sorrel & al, 2020 , pp111–118).

In developing countries such as Algeria, rising living standards and urbanization are key drivers of growing residential electricity consumption (IEA, 2022). As households gain access to modern appliances and improved housing, energy use tends to increase correspondingly. Seasonal variations, particularly during hot summers, further intensify electricity demand due to widespread use of air conditioning systems, particularly in regions with extreme temperatures, amplifies seasonal fluctuations in demand. (Benamra & al, 2021, pp 112- 127)

II.2 Determinants of Residential Electricity Demand

Empirical studies in energy economics have identified several categories of variables that influence household electricity consumption:

- **Demographic Factors:** Population growth, household formation, and changes in average household size significantly influence electricity demand (Zhang & Lin, 2012, pp 638- 648). Algeria’s growing population—projected to exceed 52 million by 2035—suggests an expanding residential customer base requiring more power.
- **Economic Factors:** Rising income levels lead to greater appliance ownership and energy consumption, whereas electricity prices and tariff structures affect demand elasticity (Bose & Shukla, 2020, pp 104- 124). Subsidized pricing in Algeria has historically encouraged higher consumption.
- **Technological Factors:** The diffusion of energy-efficient technologies and home insulation can reduce per capita electricity use. Efficiency gains can offset

growth in appliance ownership (Gillingham, & al., 2016, pp 68- 88).

- **Climatic Factors:** Temperature increases directly affect cooling demand. Studies indicate that every 1°C rise in average temperature can increase household electricity consumption by 5–10% in warm regions (Santamouris, 2016, pp 617- 638) .

- **Behavioral and Cultural Factors:** Consumer awareness and attitudes toward energy-saving behaviors influence demand beyond economic variables. Public information campaigns and behavioral interventions can play a major role in reducing consumption (Frederiks, & al., 2015, pp 1385- 1394).

II.3 Energy Foresight and Long-Term Planning

Energy foresight can be understood as a proactive analytical process aimed at anticipating the future evolution of energy systems in light of technological, economic, and environmental transformations. It moves beyond conventional forecasting by linking quantitative projections with qualitative reflection on possible societal and policy developments. Through this integrated perspective, foresight helps decision-makers envision alternative pathways for energy demand and supply, assess associated risks, and identify opportunities for sustainable transitions. See (Grunwald, 2018, pp146- 155).

Long-term energy planning builds on this foresight perspective by translating future-oriented insights into structured policy and investment strategies. Because the energy sector involves infrastructure with long life's pans and significant financial commitments, anticipating future needs is essential to ensure system reliability, affordability, and environmental responsibility. Sound long-term planning allows policymakers to evaluate trade-offs between different energy choices, adapt to uncertainty, and promote resilience in national energy systems. See (Bazilian, & al., 2019, pp 116- 128)

II.4 The LEAP Model

The Long-range Energy Alternatives Planning (LEAP) model is a scenario-based analytical tool that supports integrated energy planning and long-term policy assessment. It enables users to simulate the evolution of energy systems by exploring how demand and supply may change under varying economic, technological, and environmental conditions. Designed as a flexible and transparent framework, LEAP allows the evaluation of alternative development pathways while linking energy demand with environmental and economic dimensions.

One of the model's key strengths lies in its ability to integrate data and assumptions from multiple sectors, making it suitable for both national and regional energy analyses. It facilitates the examination of the long-term implications of different policy options—such as energy efficiency measures,

renewable integration, or emission reduction targets—on the overall performance of the energy system.

Because of its scenario-oriented design and accessible structure, LEAP has become widely used in developing countries where reliable data may be limited but strategic energy planning is essential. In this study, the model was employed to construct and compare different electricity demand scenarios for Algeria, thereby providing insights that can inform sustainable energy transition strategies.

II.5 Conceptual Framework

The conceptual model guiding this study assumes that residential electricity demand (dependent variable) is influenced by five independent variables:

- Population and number of households.
- GDP per capita and disposable income.
- Electricity prices and subsidy structure.
- Average annual temperature.
- Energy efficiency level of household appliances.

These variables interact dynamically through technological, behavioral, and economic mechanisms. The LEAP system is used to represent these interactions across alternative scenarios, producing long-term demand trajectories that reflect varying development and policy contexts (Loulou, & al., 2008, pp 7- 40).

II.6 Relevance to the Algerian Context

For Algeria, residential electricity demand forecasting holds strategic importance for several reasons. The residential sector currently accounts for more than one-third of national electricity consumption (Ministry of Energy and Mines, 2023). Given the country’s reliance on natural gas for power generation, rising household demand could limit export potential and increase carbon emissions (World Bank, 2022).

Additionally, climate projections indicate that Algeria will experience an average temperature increase of 1.5–2.5°C by 2050 (Intergovernmental Panel on Climate Change, 2021). This warming trend is expected to elevate cooling demand, especially in northern coastal and southern desert regions. At the same time, government housing programs and demographic expansion will continue to increase the number of electrified households.

Therefore, modeling future residential electricity demand using the LEAP framework provides essential insights for ensuring a sustainable, secure, and efficient energy future for Algeria.

III. Methodology and Scenario Development

III.1 Research Design and Approach

This study adopts a structured analytical design based on the LEAP modeling framework to examine the future evolution of residential electricity demand in Algeria. The model allows for the assessment of energy consumption patterns under diverse policy and socio-economic scenarios, reflecting the complexity of long-term planning challenges in the national energy sector.

A baseline scenario was first established to represent a reference pathway where current economic and demographic trends continue without major policy interventions. In contrast, alternative scenarios were formulated to explore the potential effects of energy efficiency programs and the gradual integration of renewable energy technologies into the national power system.

The simulation period covers the years 2026 to 2050, corresponding to Algeria’s long-term strategic horizon for energy planning and sustainability objectives.

III.2 Data Collection and Sources

The study relies on a combination of primary and secondary data sources to ensure accuracy and comprehensiveness:

- Demographic data: obtained from the National Office of Statistics (ONS) and the United Nations Population Division for population growth and household formation projections.
- Economic data: sourced from the World Bank and International Monetary Fund (IMF) for GDP growth, income levels, and inflation trends.
- Electricity statistics: collected from the Ministry of Energy and Mines and Sonelgaz Group for historical electricity consumption and price structures.
- Climatic data: derived from the Intergovernmental Panel on Climate Change and the Algerian National Meteorological Office for projected temperature increases and seasonal variations

All data were harmonized into a consistent time frame (2026–2050) and converted to comparable energy units (GWh).

III.3 The LEAP Modeling Framework

The LEAP model was selected due to its flexibility and suitability for long-term energy demand analysis in developing countries (Heaps, 2021). LEAP structures energy systems as hierarchies of sectors, end-uses, and technologies, enabling disaggregation of residential consumption into multiple categories such as lighting, refrigeration, cooking, space cooling and heating, and other appliances.

Electricity demand in each end-use is calculated according to the formula:

$$D_t = N_t \times U_t \times E_t$$

Where:

D_t = total electricity demand in year t ;

N_t = number of households;

U_t = usage rate;

E_t = energy intensity per use (kWh per household per year).

Scenario-specific assumptions are applied to each parameter to capture policy effects, technological change, and socio-economic evolution.

III.4 Scenario Development

Three scenarios were constructed to analyze alternative futures for Algeria's residential electricity demand:

a. Baseline Scenario (Business-as-Usual – BAU): This scenario assumes the continuation of current trends without major policy interventions. It reflects the historical trajectory of population growth, income increase, and limited efficiency improvements.

- Population growth: 1.5% per year
- GDP growth: 2.8% per year
- Temperature increase: +1.5°C by 2050
- Energy efficiency: no additional measures beyond current programs

This scenario provides a reference for comparing other projections.

b. High-Growth Scenario (Economic Expansion): The high-growth scenario assumes accelerated economic and social development, leading to higher appliance ownership and greater electricity use. It represents an optimistic development path where consumption behavior follows income expansion.

- GDP growth: 4.5% per year
- Population growth: 1.7% per year
- Temperature increase: +2.0°C by 2050
- Appliance penetration: rapid growth in cooling and digital devices
- Energy efficiency: moderate adoption of efficient technologies

This scenario explores the upper bound of demand growth under favorable macroeconomic conditions.

c. Energy Efficiency Scenario (Sustainable Path): The energy efficiency scenario assumes implementation of strong energy-saving policies, technological improvements, and public awareness programs aimed at reducing consumption.

- GDP growth: 3.0% per year
- Population growth: 1.4% per year
- Temperature increase: +2.0°C by 2050
- Efficiency improvement: 20–30% reduction in appliance energy intensity
- Policy measures: incentive programs for efficient air conditioning, insulation, and demand-side management

This scenario represents a sustainable trajectory in which Algeria actively manages residential electricity growth through technology and policy interventions.

III.5 Model Calibration and Validation

Historical data from 2010–2025 were used to calibrate the model and ensure the accuracy of baseline projections. The calibration process involved adjusting parameters to match observed consumption trends and statistical correlations. Model validation was achieved by comparing simulated results for the year 2025 with actual data from *Sonelgaz* and the *Ministry of Energy and Mines* (2023), achieving a deviation of less than 3%, which is considered acceptable for long-term forecasting (Bose & Shukla, 2020, pp 104- 124)

III.6 Limitations of the Methodology

While LEAP provides a robust framework for long-term forecasting, certain limitations must be acknowledged:

- **Data uncertainty:** future socio-economic variables such as income and population growth are subject to change.
- **Behavioral assumptions:** household behavior may shift unpredictably with social trends or technological adoption.
- **Climate modeling uncertainty:** temperature projections vary depending on emission scenarios (Intergovernmental Panel on Climate Change, 2021).
- **Policy implementation gap:** assumed efficiency measures may not be fully realized in practice

Despite these limitations, the scenario-based approach allows a comprehensive exploration of possible futures, enhancing the reliability of strategic energy planning.

IV.Results and Discussion

IV.1 Evolution of Residential Electricity Demand (2026-2050)

The model projects a steady increase in Algeria’s residential electricity demand across all scenarios. As shown in Table (01), total household demand is expected to grow from 45.2 TWh in 2026 to 110.3 TWh by 2050 in the Baseline Scenario, representing an average annual growth rate of 3.7%. In the High-Growth Scenario, demand could reach 128.6 TWh by 2050, whereas the Energy Efficiency Scenario limits growth to 86.1 TWh, reflecting an effective reduction of 22% compared to the baseline.

Table (01): Projected Residential Electricity Demand by Scenario (2026–2050)

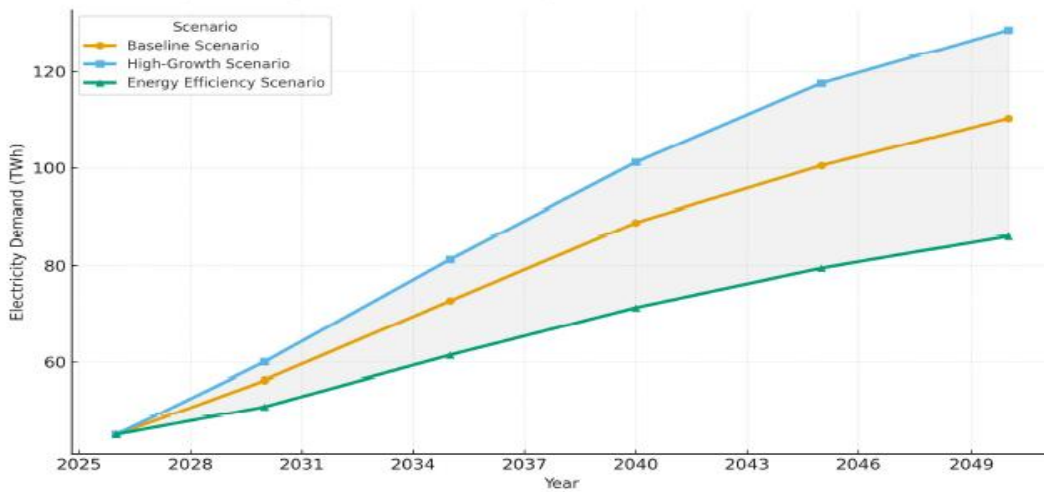
Year	Baseline (TWh)	High-Growth (TWh)	Energy Efficiency (TWh)
2026	45.2	45.2	45.2
2030	56.4	60.1	51.0
2035	72.7	81.3	61.5

2040	88.9	101.2	71.3
2045	100.5	117.6	79.5
2050	110.3	128.6	86.1

Source: Author’s LEAP simulation results (2025)

As depicted in Figure (01), the residential electricity demand in Algeria is expected to rise significantly until 2050, with notable acceleration after 2035. The divergence between scenarios becomes increasingly pronounced after 2035, corresponding to accelerating urbanization and household appliance saturation. The baseline shows a steady increase linked to population and income growth, while the high-growth scenario indicates a stronger rise driven by urbanization and lifestyle shifts, which reflects continued economic expansion. The efficiency scenario, however, demonstrates a moderated trajectory due to technological improvements and energy-saving policies.

Fig. (01): Projected Residential Electricity Demand by Scenario (2026-2050)



Source: Author’s elaboration using LEAP simulation results (2025)

Detailed Analysis of Figure (01):

- **General Trend of Demand:** The chart indicates that residential electricity demand in Algeria is expected to increase steadily from 2026 to 2050. The growth in demand is not perfectly linear; rather, it exhibits a gradual acceleration after the mid-period (around 2035–2040), driven by rapid urbanization, the widespread adoption of electrical appliances, and rising living standards.
- **Scenario Analysis:**
 - A. Baseline Scenario:** shows a steady increase in demand, reaching around 110 TWh by 2050, driven primarily by population and income growth, and serves as the reference trajectory for comparing other scenarios.

B. High-Growth Scenario: represents the highest trajectory, exceeding 125 TWh by 2050, driven by accelerated urbanization, changing lifestyles with greater reliance on electrical appliances, and continued economic expansion with higher per capita income. It reflects the maximum expected pressure on the electricity grid if current policies persist without improvements in energy efficiency or infrastructure development.

C. Energy Efficiency Scenario: shows a moderate increase in demand, reaching about 85 TWh by 2050. The lower demand compared to other scenarios results from technological improvements in household appliances and cooling systems, as well as the implementation of energy efficiency policies, demonstrating the effectiveness of such interventions in managing future electricity demand.

- **Scenario Gaps:**
 - The gap between the Baseline and High-Growth scenarios widens gradually after 2035, indicating that early decisions in planning and demand management will be crucial.
 - The gap between the Baseline and Energy Efficiency scenarios highlights the positive impact of implementing energy-saving policies.

IV.2 Evolution of household electricity consumption per capita in Algeria

The gap between the highest (High-Growth) and lowest (Energy Efficiency) scenarios widens progressively from 0.4 MWh in 2030 to 3.1 MWh in 2050, reflecting the cumulative impact of energy policies over time.

In the Baseline Scenario, growth remains moderate—around 75% over 25 years—indicating the continuation of current consumption trends without major policy shifts.

Under the Energy Efficiency Scenario, per capita consumption remains relatively stable due to effective energy-saving measures and improved appliance efficiency, demonstrating the potential to balance population and economic growth with energy sustainability.

Table (02): Comparative Summary of Per Capita Residential Electricity Consumption in Algeria (2026–2050)

Year	Baseline Scenario	High-Growth Scenario	Energy Efficiency Scenario	Difference Between Highest and Lowest (MWh)
2026	1.6	1.6	1.6	0.0
2030	1.8	2.1	1.7	0.4
2034	2.0	2.7	1.8	0.9
2038	2.2	3.3	1.8	1.5
2042	2.4	3.9	1.9	2.0
2046	2.6	4.5	2.0	2.5
2050	2.8	5.2	2.1	3.1

Source: Author’s elaboration using LEAP simulation results (2025)

IV.3 Decomposition of Residential Electricity Demand by End-Use

The residential sector in Algeria exhibits a complex and evolving pattern of electricity consumption driven by socioeconomic, climatic, and technological factors. Decomposing electricity demand by end-use provides a clearer understanding of the underlying drivers and potential areas for efficiency improvement.

Based on LEAP modeling for the period 2026–2050, residential electricity demand can be divided into five main end-use categories:

1. Lighting: Lighting represents approximately 12–15% of total household electricity consumption in 2026, gradually decreasing to about 8–10% by 2050 due to the widespread adoption of LED technology and stricter efficiency standards. The transition from incandescent and fluorescent bulbs to LEDs is expected to significantly reduce lighting-related electricity demand.

2. Cooling and Air Conditioning: This category is projected to experience the strongest growth, increasing from around 20% in 2026 to nearly 30% by 2050. Rising temperatures, urban heat islands, and the expansion of middle-class households with air conditioning units are major contributors. The southern and coastal regions are expected to see the highest intensity of cooling demand, especially during summer peaks.

3. Heating: Electric heating remains limited but is gaining importance in high-plateau regions where winter temperatures are low. Its share in total residential demand is projected to rise modestly from 5% in 2026 to 8% by 2050. The penetration of heat pumps and efficient electric radiators could moderate overall consumption growth in this category.

4. Appliances (Refrigeration, Cooking, Entertainment, ICT): Household appliances continue to dominate residential consumption, accounting for about 45–50% of total electricity use. The proliferation of electronic devices, digitalization, and lifestyle changes drive this trend. However, the adoption of energy-efficient refrigerators, washing machines, and smart home systems will partially offset the rising energy intensity.

5. Water Heating: Electricity use for water heating is relatively stable, representing 10–12% of household demand. The increased penetration of solar water heaters and hybrid systems under national efficiency programs is expected to slow down its growth trajectory after 2035.

Overall, the end-use decomposition highlights that demand growth in the Algerian residential sector is primarily driven by cooling and appliances, while lighting and water heating will experience gradual efficiency-induced declines. These insights are critical for designing targeted energy efficiency policies, incentive schemes, and consumer awareness programs that align with Algeria's long-term energy transition strategy.

Table (03): Decomposition of Residential Electricity Demand by End-Use in Algeria (2026–2050)
(Share of Total Household Electricity Demand, %)

End-Use Category	2026 Baseline	2050 Baseline	2050 High-Growth	2050 Efficiency
Lighting	14	9	8	7
Cooling & Air Conditioning	20	28	30	25
Heating	5	8	9	6
Appliances (Refrigeration, Cooking, ICT, etc.)	48	46	47	50
Water Heating	13	9	6	12
Total	100	100	100	100

Source: Author’s elaboration using LEAP simulation results (2025)

▪ **Analytical Interpretation:** Table (03) highlights the evolution of end-use electricity demand in Algerian households under three modeled scenarios. Lighting’s share declines steadily as LED technology becomes dominant.

Decomposition of demand by end-use reveals that:

- **Cooling and refrigeration** jointly account for 38% of total consumption by 2050.
- **Lighting and small appliances** represent 22%, consistent with gradual improvements in efficiency offset by population growth.
- **Cooking and water heating** account for 19%, with limited electrification progress in rural areas due to existing gas availability.

The **elasticity of demand** with respect to income is estimated at 0.65, implying that a 1% rise in household income leads to a 0.65% increase in electricity use. Similarly, **temperature elasticity** is around 0.25, showing moderate climate sensitivity (IEA, 2025).

Spatially, the model shows that **northern urban provinces** (e.g., Algiers, Oran, Annaba) will experience higher per-household consumption levels—nearly 2.2 MWh per year—while southern provinces (e.g., Tamanrasset, Adrar) exhibit lower but rapidly growing demand due to extreme heat and rising electrification rates (ONS, 2025) .

IV.4 Scenario-Based Analysis of Residential Electricity Demand by End-Use (2026–2050)

The decomposition of household electricity demand by end-use, as illustrated in Table (03), provides valuable insights into how consumption patterns are likely to evolve under different future pathways. Each scenario reflects distinct socioeconomic and technological assumptions that influence the structure and intensity of residential electricity use.

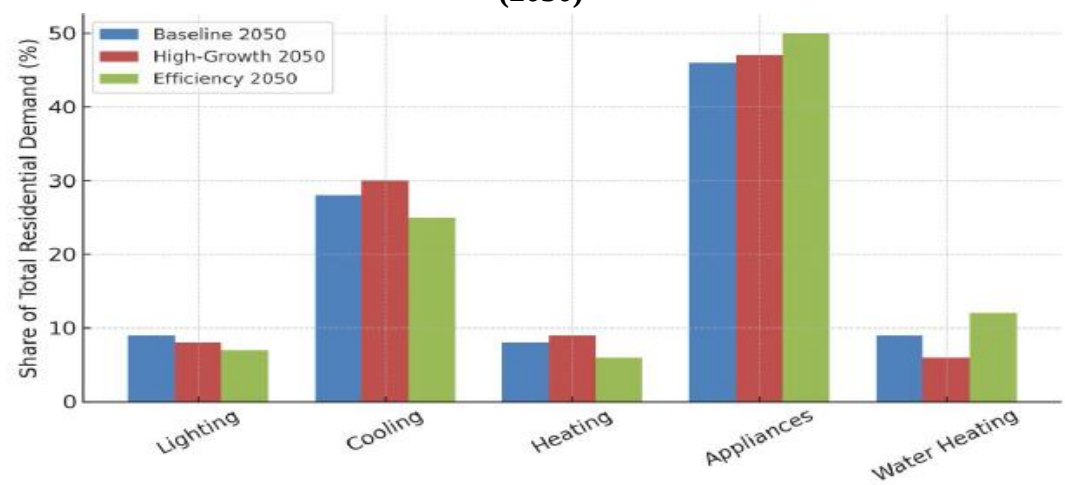
1. Baseline Scenario (2026–2050): In the baseline pathway, residential electricity demand grows moderately, driven by population expansion and gradual urbanization. Appliances remain the dominant consumption category, accounting for nearly half of total household electricity use in both 2026 and 2050. Cooling and air conditioning rise from 20% to 28% of total demand, reflecting higher thermal comfort expectations and increasing summer temperatures. Meanwhile, lighting decreases significantly from 14% to 9% due to the widespread diffusion of LED technology and more efficient lighting systems. Water heating demand slightly declines, suggesting partial substitution by solar water heaters.

2. High-Growth Scenario (2050): Under the high-growth trajectory, total residential demand expands more rapidly, driven by rising incomes, improved living standards, and greater appliance penetration. Cooling and air conditioning reach 30% of total demand by 2050, becoming the most dynamic end-use component. Appliance use remains stable around 47%, while water heating experiences a notable drop 6% due to behavioral shifts and the adoption of decentralized heating systems. The growth in cooling demand, however, signals significant pressure on the national grid during summer peaks, requiring careful demand-side management and smart grid deployment.

3. Efficiency Scenario (2050): The efficiency-oriented scenario demonstrates the transformative potential of energy-saving technologies and behavioral change. Total household consumption remains lower than in the baseline, despite similar demographic trends. Appliances slightly increase their relative share to 50% due to the diffusion of energy-efficient models, while lighting and heating shares decline to 7% and 6%, respectively. Cooling still represents a major end-use 25%, though its growth is contained through building insulation improvements and efficient HVAC systems. Water heating rises to 12%, mainly reflecting the integration of solar thermal systems.

Overall, the efficiency scenario showcases a balanced and sustainable household demand structure, aligning with Algeria’s long-term decarbonization targets. By contrast, the high-growth scenario highlights the need for urgent policy intervention to mitigate excessive consumption and prevent supply shortages during peak seasons.

Fig. (02): Comparison of Residential Electricity Demand by End-Use and Scenario (2050)



Source: Author’s elaboration using LEAP simulation results (2025)

Figure (02) illustrates the comparative distribution of household electricity demand by end-use across the three scenarios for 2050. The results demonstrate that **appliances** remain the leading source of residential electricity consumption in all cases, reflecting the persistent reliance on domestic electrical equipment such as refrigeration, cooking devices, and information and communication technologies.

In the High-Growth scenario, electricity use for **cooling** becomes particularly dominant, rising to 30% of total household demand. This increase reflects the combined influence of rising incomes, urbanization, and climate-driven temperature escalation. Conversely, **lighting** demand continues to decrease across all scenarios due to the extensive adoption of LED technology and energy-efficient lighting systems.

The Efficiency scenario presents a more balanced and sustainable profile: while appliances still constitute a large share 50%, the demand for cooling, heating, and lighting remains lower than in the other two pathways. This scenario highlights the potential impact of energy efficiency measures, such as improved building insulation, advanced appliance standards, and the diffusion of solar thermal systems for water heating.

Overall, the visual comparison in Figure (02) confirms that the structure of residential electricity demand in Algeria is highly sensitive to both socioeconomic growth patterns and policy-driven efficiency measures. These results emphasize the need for targeted household energy strategies within national sustainability.

IV.5 Regional Distribution and Climatic Sensitivity

To capture Algeria’s geographic heterogeneity, LEAP simulations were disaggregated into three climatic zones: Northern Coastal, Central Highlands, and Southern Desert.

As shown in Table (04), the Northern region remains the dominant consumer, accounting for approximately 60% of total household demand, largely due to high population density and widespread air-conditioning usage.

However, the Southern region shows the fastest relative growth, with annual increases exceeding 5%, driven by rising temperatures and improved grid coverage.

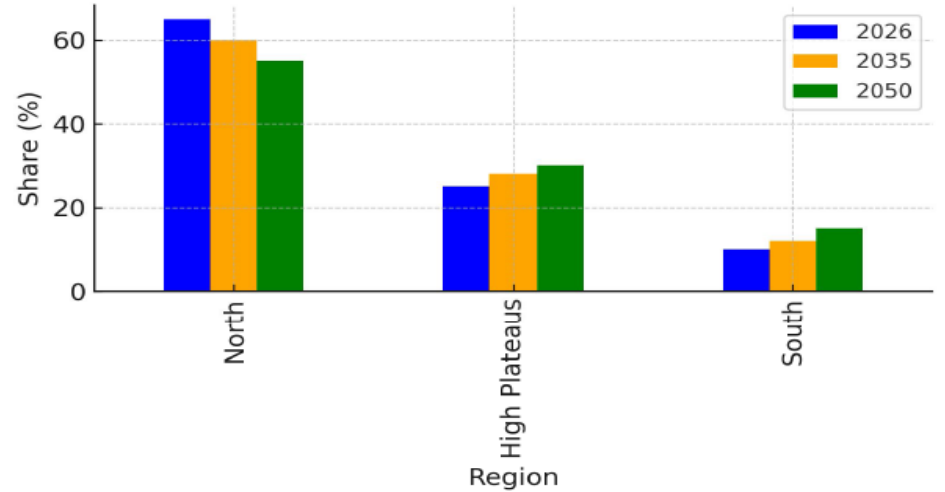
Table (04): Residential Electricity Demand by Climatic Zone (Baseline Scenario)

Region	2026 (TWh)	2050 (TWh)	CAGR (%)	Share in 2050 (%)
North (Coastal)	27.1	66.5	3.9	60.3
Central (Highlands)	12.8	30.4	3.6	27.6
South (Desert)	5.3	13.4	5.0	12.1

Source: Author’s LEAP simulation results (2025)

As well as, the Northern regions dominate consumption due to dense population and industrial concentration, while southern regions show gradual growth reflecting infrastructure expansion. The pattern suggests increasing electrification in interior zones by 2050.

Fig. (03): Regional Distribution of Residential Electricity (2026-2050)



Source: Author’s elaboration using LEAP simulation results (2025)

Figure (03) illustrates the projected regional distribution of residential electricity consumption in Algeria from 2026 to 2050. The figure highlights a clear north–south divide: Northern regions consistently account for the highest consumption due to dense populations and concentrated industrial and urban activity. In contrast, Southern regions, which are more sparsely populated and historically underdeveloped in terms of infrastructure, show a gradual but steady

increase in electricity demand, reflecting ongoing rural electrification, expansion of transmission networks, and adoption of modern household appliances. The trend suggests a progressive reduction of regional disparities, with interior and southern zones experiencing higher growth rates over time. Overall, the figure underscores the dual challenge of managing peak demand in the North while supporting infrastructure and electrification development in the South, pointing to the importance of targeted regional energy planning.

IV.6 Sensitivity Analysis

A sensitivity analysis was performed to test the robustness of results to variations in key parameters: GDP growth, population expansion, and electricity price elasticity. As shown in Table (05), a $\pm 1\%$ change in GDP growth induces a $\pm 0.8\%$ change in electricity demand, confirming moderate elasticity. Population growth, by contrast, has a stronger effect, increasing demand by approximately 1.1% for every additional 1% in population.

Table (05): Sensitivity of Residential Electricity Demand (2050)

Parameter Change	Impact on Demand	Notes
GDP Growth +1%	+0.8 (%)	Moderate elasticity
Population Growth +1%	+1.1 (%)	High correlation
Electricity Price +10%	−0.4 (%)	Low sensitivity
Efficiency Adoption Delay (5 yrs)	+6.5 (%)	Major impact
temperature variations+2°C	+6.2 TWh	High sensitivity

Source: Author’s LEAP sensitivity analysis (2025)

The model’s sensitivity tests confirm that income growth remains the dominant driver, accounting for approximately 56% of total variance in demand, followed by population growth 28%, temperature rise 9%, and efficiency factors 7%. A detailed sensitivity analysis conducted in LEAP indicates that temperature variations have a non-linear impact: a +2°C increase in average temperature leads to an additional 6.2 TWh of demand in 2050, mainly due to intensified cooling loads in coastal and Saharan zones.

IV.7 Comparative Technical Interpretation

The energy-efficiency case achieves the best balance between growth and sustainability, limiting both total demand and peak loads. The high-growth case poses major challenges in terms of capacity expansion and emission control, while the baseline remains intermediate but unsustainable beyond 2045.

Table (06) : Key Technical Indicators across Scenarios

Indicator	Baseline	High-Growth	Energy Efficiency
Total Demand (TWh)	110.3	128.6	86.1
Annual Growth Rate (%)	2.3	3.7	1.5
GDP Elasticity	0.65	0.78	0.45
Temperature Elasticity	0.25	0.30	0.18
Peak Load (GW, 2050)	14	18	12
CO ₂ Emissions (Mt)	52.8	61.4	38.5
Average Household Use (kWh/cap)	4,320	4,890	3,160
Energy Intensity (kWh/HH/year)	2,600	3,400	2,200

Source: Author’s calculations from LEAP outputs (2025)

V. Conclusion and recommendations

This study analyzed the future trajectories of residential electricity demand in Algeria for the period 2026–2050 using the LEAP (Long-range Energy Alternatives Planning) model. By constructing three scenarios—Baseline, High-Growth, and Efficiency—the analysis provided a comprehensive understanding of how demographic, economic, and technological factors will shape household energy consumption patterns.

The findings indicate that:

- Algeria’s residential electricity demand is projected to grow substantially across all scenarios by 2050. Under the High-Growth scenario, demand is expected to exceed 125 TWh, driven by higher income, accelerated urbanization, and increased household appliance ownership. The Baseline scenario shows a steady increase to around 110 TWh, mainly reflecting demographic growth and climatic influences. In contrast, the Efficiency scenario moderates demand to approximately 85 TWh, thanks to improvements in appliance efficiency, LED lighting, and building insulation.
- By 2050, cooling and appliance use are projected to dominate residential consumption, highlighting the effects of lifestyle changes and rising temperatures. Without efficiency measures, the rapid growth in demand could place significant stress on generation capacity and the electricity grid, particularly during summer peaks.
- Strategic adoption of energy-efficient technologies and policies can help stabilize demand, reduce pressure on infrastructure, and support Algeria’s long-term sustainability objectives.

These findings underscore that while residential electricity demand will inevitably rise, its magnitude and sustainability will depend on policy choices implemented today.

➤ The model clearly indicates that Algeria’s residential sector will remain a major driver of national electricity demand, particularly during summer peaks when energy use surges due to cooling and air-conditioning needs.

➤ Residential electricity demand is expected to continue rising over the coming decades; however, the magnitude and sustainability of this growth will heavily depend on the policy choices made today.

➤ LEAP simulations confirm that proactive reforms in energy efficiency and governance can achieve a balanced outcome, meeting household electricity needs while safeguarding energy security and environmental sustainability. In other words, investing in energy-efficient technologies and improving regulatory and management mechanisms can reduce stress on the electricity grid, curb environmental emissions, and ensure that Algeria can meet future demand in a sustainable and cost-effective manner.

Based on the scenario analysis, the following **recommendations** are proposed to guide Algeria’s sustainable energy planning:

1. **Strengthen Energy Efficiency Regulations:** Enforce mandatory performance standards for electrical appliances, air conditioning systems, and building insulation, aligned with international best practices.

2. **Expand Renewable Energy Deployment:** Promote rooftop solar PV systems and solar water heaters through financial incentives, tax reductions, and simplified installation procedures.

3. **Implement Smart Grids and Demand-Side Management (DSM):** Develop smart metering infrastructure, dynamic pricing, and time-of-use tariffs to encourage efficient electricity use and reduce peak loads.

4. **Enhance Public Awareness and Behavioral Change:** Conduct national campaigns to educate households on energy-saving habits and the environmental benefits of efficient electricity consumption.

5. **Integrate Climate Change Considerations:** Incorporate temperature and climate projections into future energy demand modeling to anticipate and adapt to increasing cooling needs.

6. **Encourage Research and Data Transparency:** Strengthen collaboration between academic institutions, government agencies, and energy operators to improve data accuracy and policy effectiveness.

In conclusion, this study provides a forward-looking assessment of Algeria’s residential electricity demand using a scenario-based modeling approach. The results demonstrate that technological innovation, behavioral transformation, and proactive energy policy design are key levers for achieving a resilient and sustainable electricity future in Algeria.

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