



EMP-A

## Rwanda Energy Demand Analysis in Households: An end-use sector analysis

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## Executive Summary

Rwanda is undergoing rapid demographic and structural transformation, with the number of households expected to double by 2050 and urbanization projected to rise from 27% to 66.5%. These changes present both challenges and opportunities for shaping the country's household energy future. This study analysed household final energy demand under three scenarios to understand how socio-economic, technological and policy pathways could influence future energy use.

The findings revealed that under the Energy Efficiency scenario, household energy demand could decrease substantially despite population growth, driven by a major shift toward clean and efficient energy sources. By 2050, the share of traditional fuels in household energy demand could decline from 96.7% to 17.2%, while electricity and substitutable could increase their combined share from 3% to 70% and urban areas lead in clean energy adoption, however, rural areas continue to lag behind, highlighting the need for inclusive and targeted interventions.

The study underscores the environmental and economic benefits of accelerating the transition to modern energy, to realize these outcomes, the report recommends a set of achievable actions including the full implementation of Rwanda's Integrated clean cooking plan, expansion of rural energy infrastructure, integration of urban development policies and strengthening of public-private partnerships.



# 1. Introduction

## Purpose and Scope

The household sector is a significant component of final energy demand, with energy consumption patterns typically categorized into key end-uses such as space heating, cooking, water heating, appliance usage, and air conditioning (**Aimable Nsabimana, 2022**). In Rwanda, cooking alone accounted for 98.2% of total household energy demand in 2022. Alarming, 99.2% of final energy demand of rural households and 82.2% of urban households still rely on traditional fuels such as wood and charcoal for cooking (**MININFRA, 2023**). This heavy dependence on traditional fuels has far-reaching consequences, including increased respiratory illnesses, deforestation, and GHG emissions.

Understanding the evolution of residential energy demand is critical for informing national strategies that support clean and sustainable energy transitions. This report analyses projected household energy demand under three development scenarios. The objective is to identify or understand similarities, highlight key differences, and draw policy inputs for the successful implementation of national objectives for clean and efficient energy use while contributing to the broader national economic transformation and development.

## Objective and aims

The primary objective is to develop and evaluate scenarios for the transition of residential sector from traditional fuels to modern and clean fuels.

Specifically, the intent is to:

- i. Develop scenarios for transitioning to clean energy forms under various economic transformation trajectories based on national strategic aspirations.
- ii. Estimate projected energy demand across various residential energy end-uses under the different scenarios.
- iii. Assess the implications of the scenario results for promoting targeted and accelerated adoption of energy efficiency measures in the residential sector.



## 2. Methodology

### Modelling Approach/Tool Implemented

The analytical tool used for this analysis is the MAED 2, which was developed by the International Atomic Energy Agency, evaluates future energy demands based on medium to long-term scenarios of socioeconomic, technological, and demographic development (IAEA, 2006).

The base year was reconstructed for the year 2022, with substantial insights from the Rwanda Population and Housing Census, and Rwanda's future scenarios were developed to align with development aspirations of the Vision 2050 of achieving a middle-income country status by 2035 and a high-income country by 2050.

The developed scenarios were sub-divided into three sub-scenarios:

- Visionary (VIS) scenario Reflects a shift to a dynamic system with aggressive economic growth to achieve high income status by 2050. Massive technological change ensues, and population growth follows the high growth trajectory.
- Business As Usual (BAU) Scenario assumes slow socio-economic growth/change with demand growth driven by limited urbanisation and technological change. Population growth follows a low growth trajectory. Universal access to electricity by 2030
- Energy Efficiency (EE) scenario Builds on the economic transformation in the visionary scenario but emphasises on efficient energy forms and technologies/appliances driven by initiatives such as clean cooking transition by 2035.

### Data sources

**Table 1: Data sources**

<b>Data</b>	<b>Source</b>	<b>References</b>
Energy balance	Ministry of Infrastructure	(UN, 2024)
Population	National Institute of Statistics of Rwanda	(NISR, 2022)
Average Household size	National Institute of Statistics of Rwanda	(NISR, 2022)
Population projections and growth rate	National Institute of Statistics of Rwanda	(NISR, 2022)
Urbanisation	National Institute of Statistics of Rwanda	(NISR, 2022)
Cooking technologies	National Integrated Clean Cooking Plan	(SE4All, 2024)

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Data	Source	References
House/dwelling sizes	Land Use Master Plan	(NLA, 2026)
Electricity access	Energy Sector Strategic Plan 2024-2029	(MINIFNRA, 2024)

## Scenarios, Assumptions and sensitivity analysis

Table 2: Assumptions

Scenario label	Assumptions
Business As Usual (BAU)	<ul style="list-style-type: none"><li>• Average GDP growth rate 8.4%.</li><li>• Urbanisation rate follows historical patterns to only double by 2050, i.e. 55% urban dwellers.</li><li>• Traditional fuels cookstoves (Tier 3) still dominate 60%, 30% in rural and urban HHs by 2050.</li><li>• Electricity access: 100% by 2030</li><li>• Limited adoption of new technologies.</li><li>• Average population growth rate 1.95%.</li></ul>
Visionary (VIS)	<ul style="list-style-type: none"><li>• Average GDP growth 12%.</li><li>• Traditional fuels cookstoves (Tier 3) still dominate 49%, 20% in rural and urban HHs by 2050.</li><li>• Urbanisation rate changes from current 27% 2022 to 66.5% of urban dwellers by 2050.</li><li>• Average population growth rate 2.06%.</li></ul>
Energy Efficiency (EE)	<ul style="list-style-type: none"><li>• GDP growth, urbanisation and population growth prospects identical as in the Visionary scenario (above).</li><li>• Clean Cooking adoptions by 2035:<ul style="list-style-type: none"><li>○ Tier 4&amp;5: (Urban; Rural: 96.01%; 58.7%)</li><li>○ Tier 3: (Urban; Rural: 3.99%; 41.27%).</li></ul></li></ul>

The energy efficiency scenario presented above provides a sensitivity analysis of the economic development prospects relative to targeted and accelerated efficient energy use.

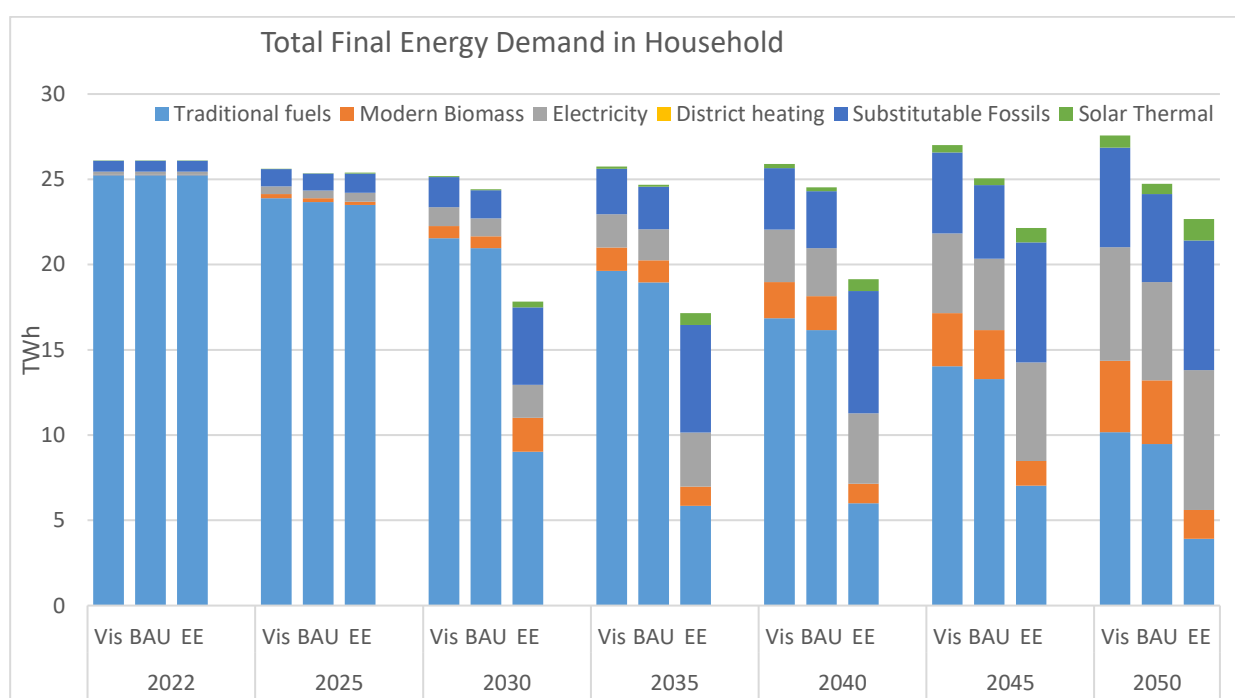
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### 3. RESULTS

**Figure 1** illustrates projected changes in household final energy demand in Rwanda under three scenarios: Visionary, business as usual and energy efficiency. While urbanization presents opportunities to drive modern energy adoption, its success depends on the effective implementation of national urbanization strategies. These strategies must be aligned with energy planning to enable positive spillover effects, particularly in facilitating a clean energy transition within the residential sector.

The figure also highlights a clear shift in energy demand patterns across all scenarios, with notable differences in efficiency adoptions towards 2035 onwards.



*Figure 1: Total final energy demand across all 3 scenarios*

Figure 2 and 3 shows that the adoption of clean and more efficient energy forms is mostly prevalent in urban areas compared to rural areas. Among the various end-uses, clean cooling emerges as the primary driver of this transition.

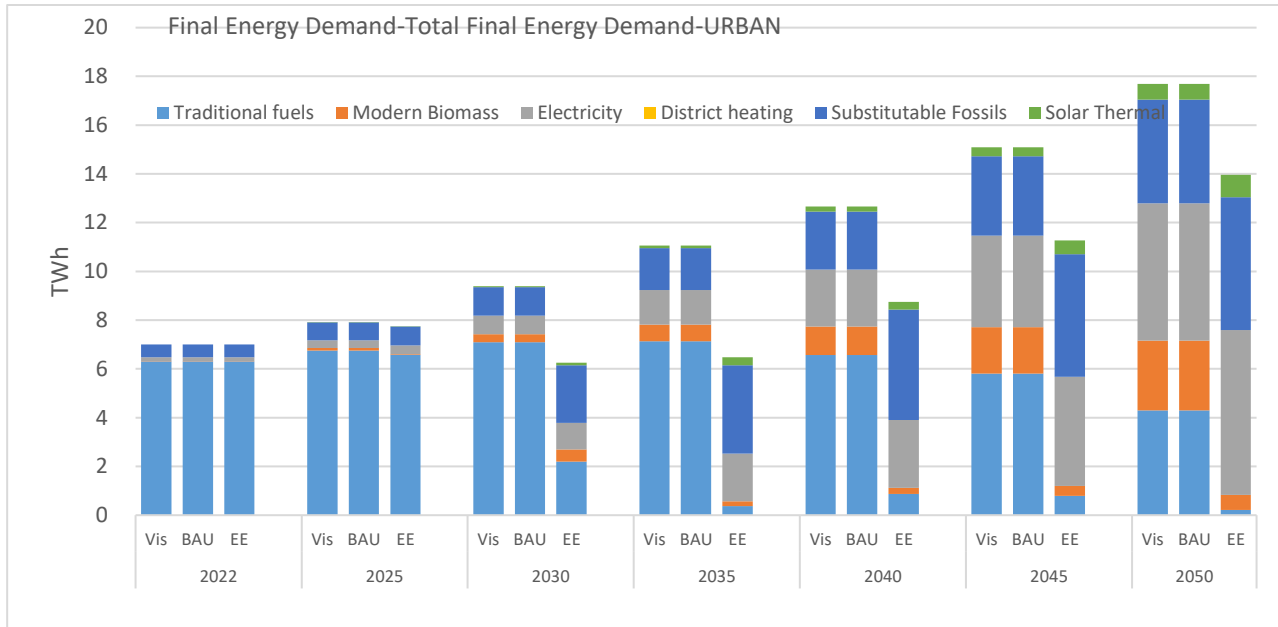


Figure 2: Final Energy Demand-Total energy demand-URBAN

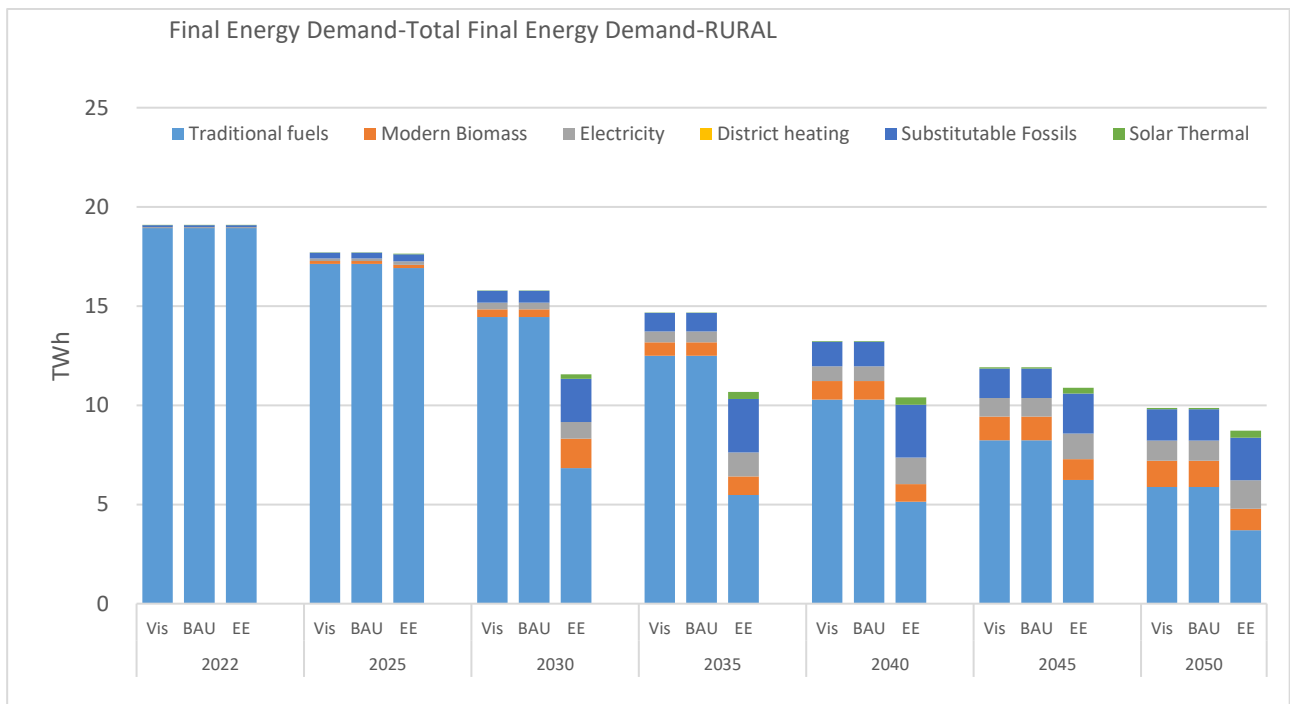
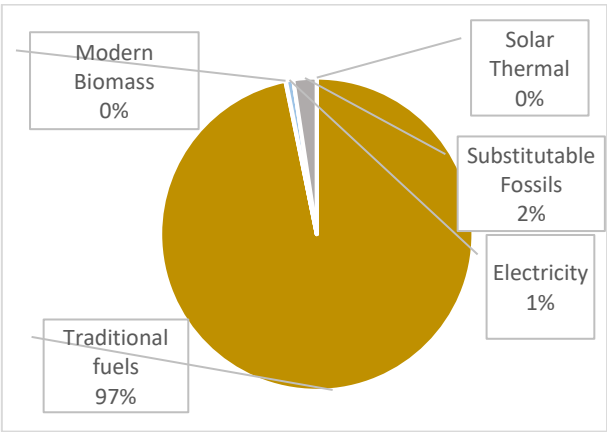


Figure 3: Final Energy Demand-Total energy demand-RURAL

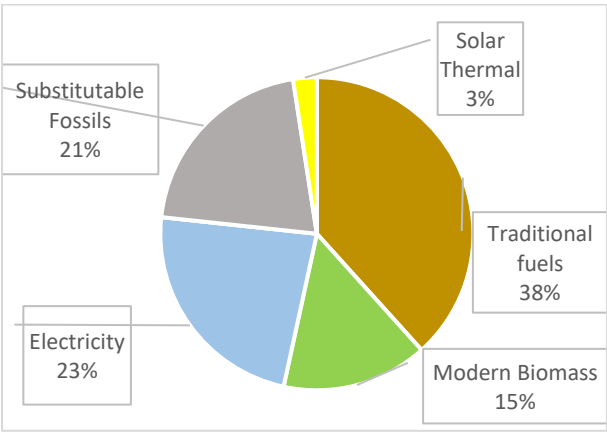
**Figure 4** illustrates the progressive shift toward clean energy and efficient technologies across all scenarios, marked by a substantial decline in reliance on traditional fuels from 97% in 2022 to 38% under the **Business-as-Usual** scenario, 37% under the **Visionary** scenario, and just 17% under the **Energy Efficiency** scenario by 2050. This transition reflects improved access, behavioral change, and supportive policy environments.

Electricity demand shows strong growth potential, rising from **198 GWh in 2022** to **5,760 GWh** (Business as Usual), **6,661 GWh** (Visionary), and **8,205 GWh** (Energy Efficiency) by 2050. The sharp increase under the Energy Efficiency scenario highlights the role of electrification, particularly in cooking and appliances as a key driver of clean energy adoption in households.

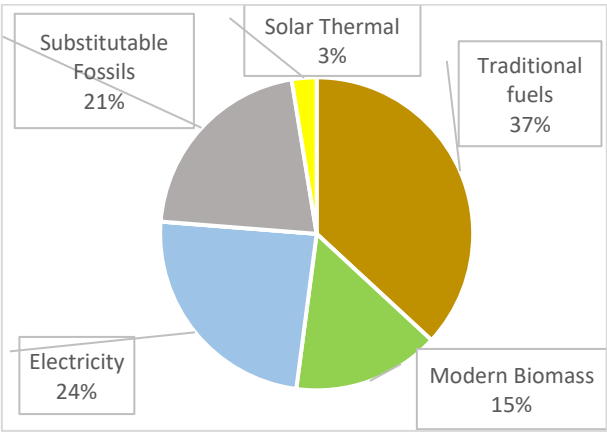
Total Final Energy Demand-Residential in 2022



Total Final Energy Demand-Residential in 2050-BAU



Total Final Energy Demand-Residential in 2050-Vis



Total Final Energy Demand-Residential in 2050-EE

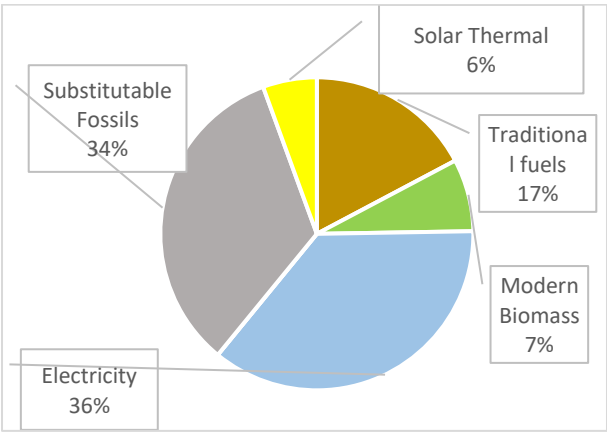


Figure 4: Residential total final energy demand comparison across scenarios (BAU, Visionary, EE) from baseline, 2022



## 5. Discussion

The number of households in Rwanda is projected to double by 2050, increasing from approximately 3.3 million in 2022 to around 7 million. During the same period, the urbanization rate is expected to rise sharply from 27% to 66.5%, signaling a major demographic and spatial transformation. These trends will have significant implications for residential energy demand and the structure of energy consumption.

Under the Business as usual (BAU) scenario, the energy transition progresses at a much slower pace. Without significant policy shifts or scaled-up investment, household energy consumption remains heavily reliant on traditional biomass. By 2050, traditional fuels are projected to continue dominating rural household energy use, while overall biomass consumption decreases only marginally. Adoption of electricity and clean fuels remains largely confined to urban areas. The use of traditional fuels such as firewood and charcoal is expected to drop from 25.2 TWh in 2022 (accounting for 96.7% of total household energy demand) to just 9.5 TWh by 2050 (38%).

Whereas for the Rwanda Visionary (Vis) scenario, household final energy demand is projected to progressively decrease by 2030 and picks up again by 2040. This decline reflects a major shift toward the adoption of cleaner and more efficient energy sources. Specifically, the use of traditional fuels such as firewood and charcoal is expected to drop from 25.2 TWh in 2022 (accounting for 96.7% of total household energy demand) to just 10.2 TWh by 2050 (37%). This moderate reduction highlights the impact of socio-economic change in households' disposable income adopting energy efficiency and the increasing availability of alternative energy sources.

Under the Energy Efficiency (EE) scenario, household final energy demand is projected to decrease substantially. This decline reflects a major shift toward the adoption of cleaner and more efficient energy sources. Specifically, the use of traditional fuels such as firewood and charcoal is expected to drop from 25.2 TWh in 2022 (accounting for 96.7% of total household energy demand) to just 3.9 TWh by 2050 (17.2%). This sharp reduction highlights the impact of targeted efficiency measures and the increasing availability of alternative energy sources.

Urban areas demonstrate the most significant progress in adopting clean energy technologies. This trend is largely attributed to better access to modern energy infrastructure, higher income levels, evolving lifestyles, and technological advancements. As a result, urban households are increasingly switching to electricity and substitutable fossils, while rural areas still face barriers related to affordability, access, and awareness.

The share of electricity and substitutable fossil fuels in total household energy demand is projected to increase dramatically, from just 3% in 2022 to 70% by 2050. Electricity alone is expected to account for 36% of household energy consumption by 2050. This transition not only represents a major structural shift in the energy mix but also brings considerable benefits, including reduced risks to respiratory diseases, reduced energy losses, and enhanced environmental sustainability.

These findings emphasize the critical need to strengthen and scale up policy interventions that promote the adoption of clean energy technologies, particularly in cooking. The Integrated Clean Cooking Plan, which was incorporated into the modeling for this study, demonstrated significant positive impacts. Therefore, its full and effective implementation by the Government of Rwanda can play a key role in accelerating the clean energy transition, especially for rural and vulnerable populations.

## 7. Conclusion

### Recap and lessons learnt

In Rwanda, the projected doubling of households and rapid urbanization by 2050 will significantly reshape the country's residential energy consumption/landscape. This study was done to understand the evolution of residential energy demand to critically inform national strategies aimed at clean and efficient energy transitions. By using analytical tool known as MAED 2, under an energy efficiency scenario, household energy demand can be substantially reduced through the widespread adoption of clean and modern energy sources, particularly in urban areas. The dramatic decline in reliance on traditional fuels from 96.7% to 17.2% highlights the transformative potential of targeted policies and technological advancement.

Electricity and substitutable fossil fuels are expected to play a dominant role in the future energy mix, with electricity alone reaching 36% of households demand. These shifts will contribute not only to environmental sustainability but also improved public health and reduced energy inefficiencies.

The results reinforce the urgent need for robust policy frameworks and sustained investment to accelerate clean energy adoption, particularly in rural areas.

### Recommendations

Based on the study's findings the following are the key recommendations.

- **Accelerate Implementation of the Integrated Clean Cooking Plan;** Prioritize the roll-out of the Integrated Clean Cooking Plan by ensuring funding, coordination among stakeholders, and clear monitoring mechanisms. This plan is essential to reduce dependence on traditional biomass, particularly in rural areas.
- **Integrate energy planning into urban development policies:** Ensure that urban planning frameworks explicitly incorporate energy access and efficiency goals.
- **Expand Access to Modern Energy Infrastructure in Rural Areas;** Invest in decentralized energy solutions such as mini-grids and off-grid solar systems to improve rural access to electricity and clean cooking technologies, reducing urban-rural disparities.
- **Enhance Public Awareness and Behaviour Change Campaigns;** Conduct nationwide campaigns to raise awareness about the benefits of clean energy, health risks of traditional fuels, and the availability of cleaner alternatives. Community engagement is especially important in rural areas.
- **Establish Robust Data Collection and Monitoring Systems;** To improve future work, conducting comprehensive national energy consumption surveys would add value to MAED analysis by allowing to best capture end-use energy products across sectors. This would reduce imputation and deductions and for an efficient and accurate end-use sector demand analysis.

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