Energy Demand Planning in Boma: Towards Sustainable Electrification

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Abstract – *This study focuses on long-term energy demand planning for the residential sector of Boma, Democratic Republic of Congo, due to frequent power outages. The main objective is to analyze energy consumption, carbon dioxide emissions, and associated social costs using LEAP software. Quantitative and qualitative research methods were applied, including surveys of 757 residential consumers. The results show an increasing reliance on alternative energy sources, leading to significant environmental and economic consequences. General findings highlight the need to improve access to sustainable energy sources and promote electrification. Specific findings indicate that the transition to renewable energy could reduce carbon dioxide emissions while improving household quality of life. Lessons learned emphasize the importance of energy planning to ensure a sustainable future.*

Keywords *Boma, CO_2 emissions, energy demand, LEAP, Sustainable energy sources*

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I. Introduction

This study examines frequent power outages in Boma, Democratic Republic of Congo, where load shedding has become an integral part of daily life. On average, these interruptions occur three times a week in the neighborhoods of the Nzadi, Kalamu, and Kabondo communes. In response to these outages, residents adjust their consumption habits, developing an increasing dependence on charcoal, used not only for cooking but also for other needs, involving the burning of wood in their ovens [1], [6].

While this dependence on alternative energy sources helps alleviate electricity shortages, it leads to worrying environmental consequences, such as pollution and adverse impacts on biodiversity, particularly in the Luki Biosphere Reserve, a classified forest threatened by human activities [7]. Furthermore, these challenges generate significant economic costs for households in these three communes, whether they are electrified or not [3]-[4].

The objective of this study is to plan the long-term energy demand for Boma using LEAP software. The analysis will focus on electricity demand, CO_2 emissions, and associated social costs in order to ensure reliable operation of large-scale electricity grids between 2023 and 2053 in the residential sector.

Previous research has examined similar issues, providing a useful contextual framework for our study. For example, study [1] applied the linear regression method to model the electrical energy demand in Banjarnegara, providing insights into future consumption trends. Study [12] projected the sectoral energy demand in a developing country using LEAP, illustrating the effectiveness of this tool for comparable analyses.

Study [18] highlighted the importance of renewable energy for electricity supply and CO_2 emissions reduction in Yogyakarta province, highlighting the need to integrate sustainable solutions into energy plans. The analysis of electrical energy needs in the Pekalongan region, carried out by [14], also provided comparative elements for the Projection of energy demand. Other studies, such as those of [2] and [4], have enriched the debate on long-term energy needs forecasts, using various methodologies to assess the impact of different factors on energy consumption. These works strengthen our understanding of energy dynamics and lay a solid foundation for future analyses. This study utilizes data collected in 2023 from various state infrastructure sources, the National Electricity Company (SNEL), and residential consumers, given the limited availability of energy demand data for the city of Boma.

II. Theoretical Background

Energy planning is crucial to ensure sustainable development and efficient resource management. In this context, the LEAP (Long-range Energy Alternatives Planning) system has emerged as a powerful tool for modeling energy demand. This model facilitates the analysis of the relationships between energy consumption, CO_2 emissions, and costs while integrating various scenarios reflecting socio-economic and technological trends. [1], [6], [12], [14], [18]. The theoretical foundations of this planning are based on the examination of consumption behaviors, influenced by economic, social, and environmental factors. In Boma, frequent power outages lead to increased dependence on alternative energy sources, highlighting the importance of an integrated approach to assess environmental and economic impacts [1]-[2], [6], [12], [14], [18]. Bottom-up modeling helps identify the specific needs of each sector, providing a basis for practical recommendations and a transition to sustainable energy sources, contributing to the energy sustainability of Boma [1]-[2], [4], [6], [12], [14], [18], [20].

III. Materials and Methods

For the study of energy demand in Boma, a rigorous methodology was implemented with the LEAP system (Long-range Energy Alternatives Planning system), a well-known software for energy modeling. This system made it possible to analyze energy demand, CO_2 emissions, and associated social costs. Two models were applied, including the BALU model, which focuses on base scenarios, assuming that the trend in electrical energy consumption patterns remains the same as in the reference year [1]-[2], [6], [12], [14] ,[18], [20]. The analysis of total energy demand is defined by equations [1]-[20]:

$$EC_i = \sum Al_i(t) \times TE_i(t) \quad (1)$$

Where EC is the total energy consumption for a sector, in kWh; Al is the level of social or economic activity, in %; i is the specific sector; t is the period in years; and TE is the total final energy consumption, in kWh.

Fig. 1 illustrates the framework of the final energy demand module in LEAP, focusing on the residential sector in the city of Boma.

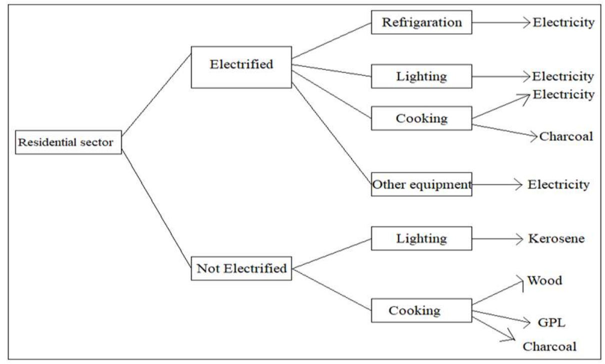

Fig 1. Final energy demand model framework for the Boma residential sector.

Data collection was crucial for the analysis of energy consumers in Boma. Demographic information was obtained at the town hall, providing a solid basis (Table I). In parallel, data on electricity consumption were collected at the SNEL center on October 4, 2024. The social costs of energy are USD 0.16907/kWh for electricity, USD 0.05/kg for firewood, USD 0.03/kg for oil, USD 0.02/kg for LPG, and USD 0.23238/kg for coal. These data were classified into several categories, encompassing industrial, semi-industrial, tertiary, and residential consumers.

TABLE I
BOMA CITY DEMOGRAPHICS

N°	Year	Populat-ion of Nzadi	Populat-ion of Kabondo	Population of Kalamu	Total	Household
1	2014	72 824	79729	105631	258184	43030.7
2	2015	75 184	80162	106263	261609	43601.5
3	2016	75 601	80745	107192	263538	43923.0
4	2017	110204	116312	142211	368727	61454.5
5	2018	112229	116580	142589	371977	61996.2
6	2019	112808	117017	143137	372962	62160.3
7	2020	117425	117195	144061	378681	63113.5
8	2021	119545	117389	145168	382102	63683.7
9	2022	120017	119532	146426	385975	64329.2
10	2023	122887	121062	161592	405541	67590.2

Table II shows the impacts of these groups on the electricity load, providing an overview of the energy challenges and needs of municipalities in 2023 data.

TABLE II
RESIDENTIAL CONSUMERS RECORDED IN THE COMMUNE OF BOMA

Residential consumers	Nzadi	Kabondo	Kalamu	Total
Customers (all)	3 672	6 191	8 064	17 927

Table II lists 17,927 residential consumers in Boma, spread across three municipalities.

The study used a methodological approach combining quantitative and qualitative techniques. A questionnaire was developed to estimate the energy consumption of target groups, including residential consumers. The sample size was determined according to Bernoulli's law, taking into account the total size of consumers, the 5% margin of error, and the estimated proportion of the population [9]:

$$n = \frac{Z_{sc\,ore}^2 * p * (1-p)}{\left[1 + \left(\frac{Z_{sc\,ore}^2 * p * (1-p)}{N * m^2}\right)\right] m^2} \quad (2)$$

Where: n is the sample size, N is the total consumer size, m is the margin of error or threshold (5%), p is the estimated proportion of the population that represents the characteristic being studied (generally estimated at 50%), and the 95% confidence interval is hence Z-score = 1.96.

Table III illustrates the distribution of residential consumers surveyed in the city of Boma, by municipality.

TABLE III
BREAKDOWN OF ELECTRIFIED AND NON-ELECTRIFIED HOUSEHOLDS TO BE SURVEYED IN THE CITY OF BOMA BY MUNICIPALITY

	Nzadi	Kabondo	Kalamu	Total
Number of electrified households	3 672	6 191	8 064	17 927
To be surveyed on the electrified side	77	130	169	376
Number of non-electrified households	16808	13985	18870	49663
To be surveyed, non-electrified	107	145	129	381

We need to obtain the details of the energy needs through the surveys conducted with 757 residential consumers.

Once the data was collected, the demographic projection was carried out. This step was based on a mathematical formula to calculate the projected population based on the initial population and an exponential rate of change. This made it possible to assess the rate of increase in the population over the years, which is a key indicator for anticipating future energy needs [2], [7]-[9], [7]-[9],[14].

This allows us to carry out a demographic projection based on the extrapolation of trends, translated by [4], [7], [3]-[12] :

$$P_t = P_o \times e^{\tau t} \quad (3)$$

Where Pt is the projected population, Po is the starting population, e is the base of natural logarithms, t is the number of years, and τ is the average rate of change.

The estimation of energy needs was carried out using an energy load model based on a bottom-up approach, which focuses on consumption per appliance [1], [6], [12], [14] ,[18], [20]. This method made it possible to collect precise data on the appliances used in households, based on previous surveys from 2020 to 2023 and also during the period from October 6, 2024, to December 20, 2024. For this study, 376 electrified households and 381 non-electrified households were identified, and two residential models were detailed to illustrate consumption.

To illustrate energy consumption, a table was developed, presenting the specifications of the appliances used in a household. This table detailed the power in watts (P), the number of units, the duration of use, the ownership rate (Tp), as well as the average energy consumption in kilowatt-hours (kWh/year) for each appliance. This made it possible to visualize consumption habits and identify the most energy-intensive appliances.

A table IV was presented to illustrate the consumption of an electrified residential model with the specifications of the devices.

TABLE IV
ESTIMATION OF THE CONSUMPTION OF AN ELECTRIFIED HOUSEHOLD

City of Boma

Appliance	P(W)	No	Ku	Tu	P(kWh)	Tp (%)	$P_{moytotal}$ (kWh/Year)
Lamp	40	4	1	6	0.96	100	9.6
Outdoor Lamp	40	4	1	2	0.32	100	28.8
Iron	1300	1	1	0.25	0.325	100	9.8
Water heater	2200	1	1	0.25	0.55	55	16.5
Kettle	1500	1	1	0.5	0.25	20	11.3
Freezer	1620	1	1	8	12.96	70	388.8
Fan	60	2	1	5	0.6	90	18
Ceiling light	60	4	1	5	1.2	30	36
Laptop	45	2	1	1	0.09	5	2.7
Led TV	110	1	1	8	0.88	100	26.4
Charger	5	5	1	0.5	0.0125	20	0.4
Fridge	250	1	1	9.6	2.4	100	72
Radio	600	1	1	1	0.6	100	18
Baffle	500	1	1	1	0.5	40	15
Stove	2500	1	0.7	4	7	100	210
Coal firebox						100	40.5kg

A Table V was presented to illustrate the consumption of a non-electrified residential model with the specifications of the appliances.

TABLE V
ESTIMATION OF THE CONSUMPTION OF A NON-ELECTRIFIED HOUSEHOLD

City of Boma		
Appliance	Tp (%)	P (kg)
Oil lamp	100	33
Firewood	100	40
LPG stove	55	15
Coal fireplace	20	40.5

This methodology, combining advanced modeling and precise data collection, made it possible to analyze Boma's energy needs and formulate recommendations for its energy management [1]-[20].

IV. Results and Discussion

Energy demand is crucial for the economic and social development of a city. In Boma, the BALU scenarios provide projections on energy consumption for electrified and non-electrified households. This allows decision-makers to better plan and manage energy resources in Figs 2 to 10.

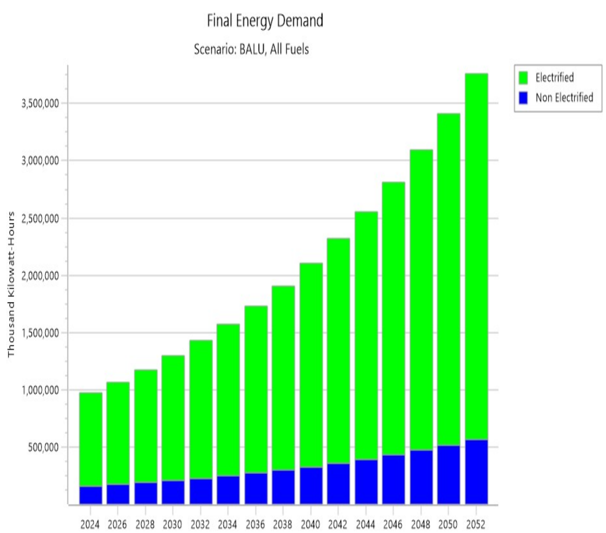

Fig. 2. BALU scenario energy demand residential consumers

The energy demand analysis for the city of Boma, based on the BALU model, reveals an interesting trend in energy consumption between 2023 and 2053. In the first decade, from 2023 to 2033, electrified demand is estimated at approximately 13.3 million kWh, while non-electrified demand reaches approximately 20 million kWh. This translates into a total demand of approximately 33.3 million kWh, with electrified energy representing only about 40% of the total. This situation highlights a still significant dependence on non-electrified energy sources. Moving forward in time, the period from 2034 to 2043 shows a notable trend. Electrified demand increases to approximately 22.8 million kWh, while non-electrified demand remains stable at around 36 million kWh. Total demand for this period is therefore approximately 57.1 million kWh, with an electrified energy share reaching approximately 40%. This trend clearly indicates a shift towards renewable energy sources, signaling a significant energy transition in the city. Finally, for the period from 2044 to 2053, electrified demand continues to grow, approaching 40 million kWh, while non-electrified demand remains around 60 million kWh. Total demand reaches almost 144.9 million kWh, with an electrified share of approximately 28%. This latter finding underscores the growing importance of electrification in Boma's energy landscape, although dependence on non-electrified sources remains significant. Analysis of the figs reveals a growth dynamic in electrified demand, but also a persistence of non-electrified demand, which poses challenges for the city's energy future. Efforts towards electrification and energy transition will be crucial to ensuring a sustainable future for Boma.

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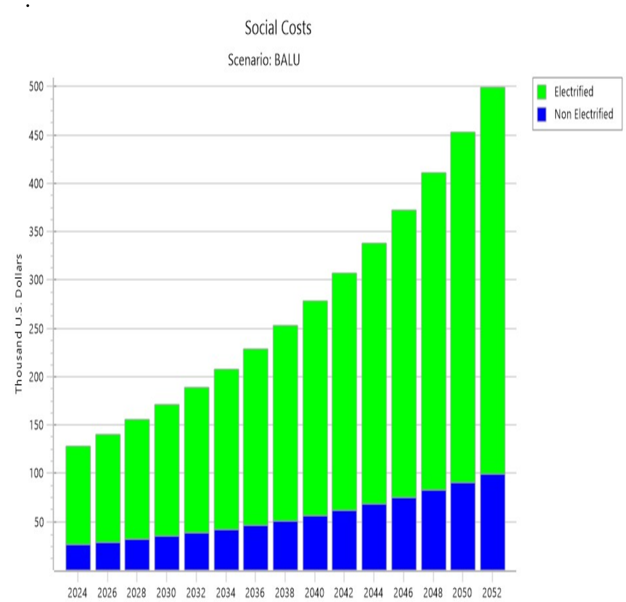

Fig. 3. BALU scenario of the social cost of residential consumers

In 2023, the BALU model shows social costs of 200000 USD, dominated by non-electrified households. This situation leads to negative impacts on health and education. By 2053, these costs reach 900000 USD, with the majority of households electrified. Costs for electrified households increase from 87.1 thousand USD to 378.5 thousand USD, while those for non-electrified households increase from 25.1 thousand USD to 108.8 thousand USD. By integrating renewable energy sources, such as solar or wind power, Boma could reduce long-term costs associated with fossil fuels and decrease environmental impacts. It could also stimulate the local economy by creating jobs in the renewable energy sector and improving the city's energy resilience. The shift from a majority of electrified households to an electrified majority, coupled with the adoption of renewable energy, promises not only a reduction in long-term social costs but also a significant improvement in the quality of life and sustainable development in Boma.

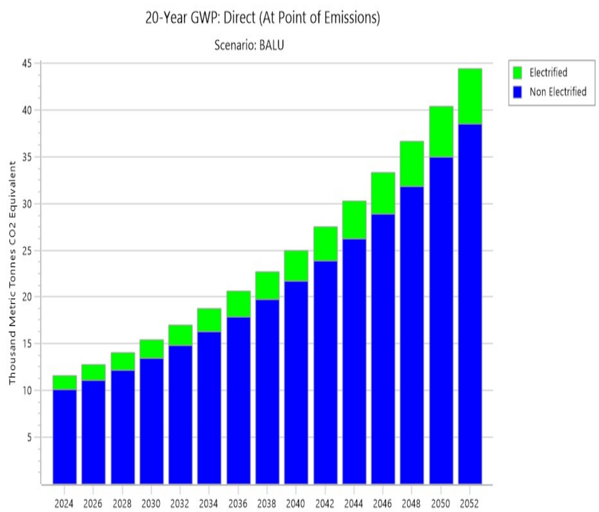

Fig. 4: BALU scenario of CO_2 emissions from residential consumers

In 2023, CO_2 emissions in Boma amount to approximately 2679 tons, of which 2508.6 tons come from non-electrified households. This reliance on fossil fuels harms air quality and degrades local ecosystems. In 2026, emissions increase to 3106.2 tons, with non-electrified households having the dominant impact on biodiversity. In 2043, emissions reach 6406.1 tons, despite the growth of electrified households, which contribute 431.9 tons. In 2053, emissions peak at 11763.2 tons, highlighting the urgency of adopting renewable energy to protect ecosystems. Rising CO_2 emissions contribute to climate change, which disrupts natural habitats and threatens diverse species. Boma's aquatic and terrestrial ecosystems may experience increasing stress, affecting food chains and biodiversity. Additionally, increased air pollutants can negatively affect air quality, impacting the health of both residents and animal species. Finally, the Luki Biosphere Reserve, home to unique biodiversity, is particularly threatened by human activities linked to energy demand. Deforestation for firewood and other resources leads to the loss of critical habitats for many species while also promoting soil erosion and water pollution. These cumulative impacts risk compromising the resilience of the ecosystem and leading to the extinction of some endemic species.

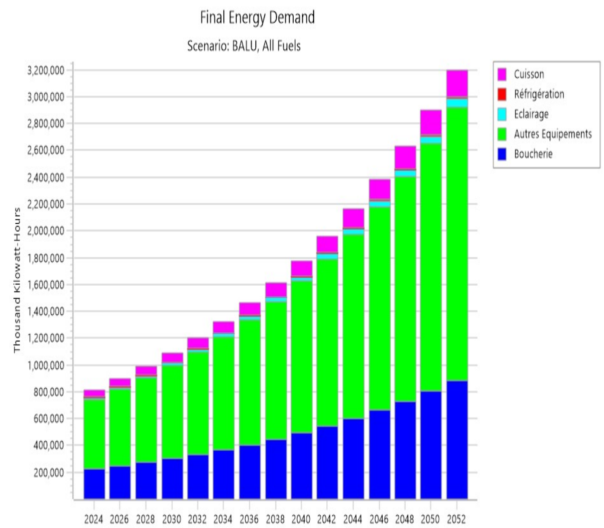

Fig. 5. BAU Scenario Energy Demand of Electrified Households

The analysis of the energy demand of electrified households in the BALU model reveals an upward trend over the years. In 2023, demand amounts to approximately 13287.6 thousand kilowatt-hours, with cooking and refrigeration sectors dominating consumption. This demand increases considerably, reaching nearly 57718.1 thousand kilowatt-hours in 2053. The continued growth in demand indicates a growing need for energy, particularly for essential needs such as cooking and refrigeration, essential to improving the quality of life of electrified households.

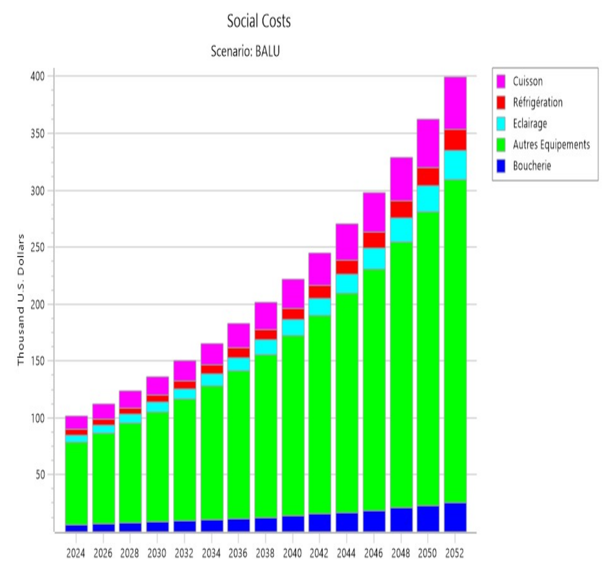

Fig. 6. BALU scenario of the social cost of electrified households

The BALU model's analysis of the social costs associated with electrified household energy demand shows an upward trend, with costs rising from approximately 87.1

thousand USD in 2023 to nearly 378.5 thousand USD in 2053. Cooking and refrigeration represent the largest share of these costs, while other equipment also contributes significantly. Rising electricity costs amplify this trend, highlighting the growing importance of electrification for household well-being while posing long-term economic challenges for the population.

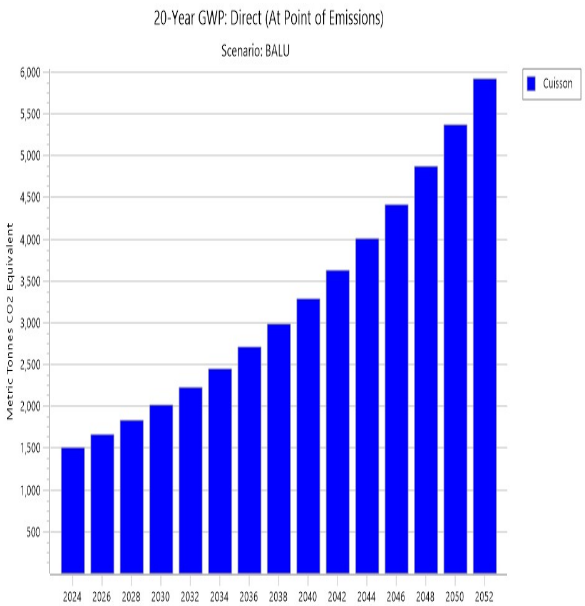

Fig. 7. BALU scenario of CO_2 emissions from Electrified household

Analysis of CO_2 emissions from cooking energy demand in electrified households, based on the BALU model, reveals a clear increase in emissions over the years. In 2023, emissions amount to approximately 170.4 tons, gradually increasing to approximately 740.0 tons in 2053. This trend underscores the environmental challenges associated with growing cooking energy demand. Each year, the increase in emissions reflects growing consumption, highlighting the need for efficient energy resource management to mitigate the environmental impacts associated with this increase. The increase in CO_2 emissions from electrified households has several implications for local biodiversity and ecosystems. First, although electrification is generally considered an improvement over unsustainable energy sources, the increase in emissions indicates that the energy sources used can still have a significant environmental impact. For example, if electricity generation relies on fossil fuels, this contributes to air pollution and soil acidification. Second, increased greenhouse gas emissions contribute to climate change, which affects natural habitats. Changing weather patterns can cause species displacement, biodiversity loss, and ecosystem disruption. Species that cannot adapt quickly to temperature changes or variations in precipitation are at risk of extinction. Third, the growing demand for energy for cooking can also put increased pressure on natural resources. If energy demand increases without effective management, it can lead to overexploitation of water and forest resources, thus affecting local ecosystems that depend on these resources. Finally, it is crucial to implement energy resource management strategies that promote the use of renewable energy and improve energy efficiency. This would not only reduce CO_2 emissions but also protect biodiversity and preserve local ecosystems while ensuring a sustainable energy supply for electrified households.

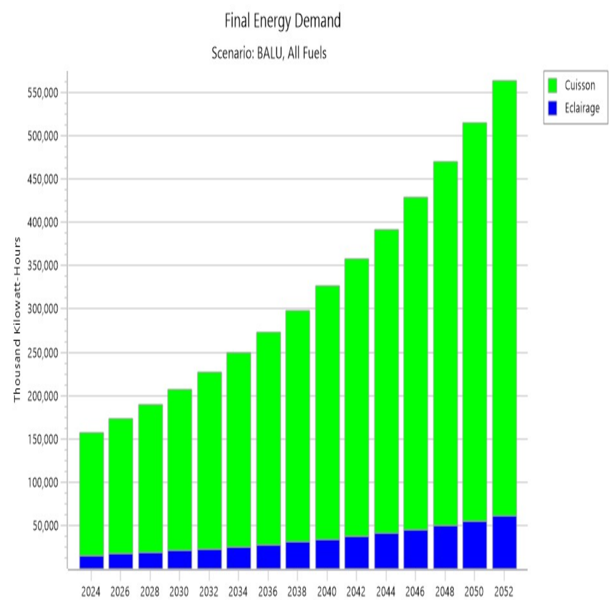

Fig. 8. BALU scenario energy demand non-electrified household

The analysis of the energy demand of non-electrified households according to the BALU model reveals a continuous increase over the years. In 2023, demand is estimated at approximately 20061.0 thousand kilowatt-hours, reaching nearly 87140.9 thousand kilowatt-hours in 2053. This trend highlights the significant increase in energy needs, particularly for cooking and lighting. Non-electrified households face significant challenges in meeting their basic needs. This increase in demand highlights the urgent need for access to sustainable and reliable energy sources to improve quality of life and reduce dependence on less efficient methods.

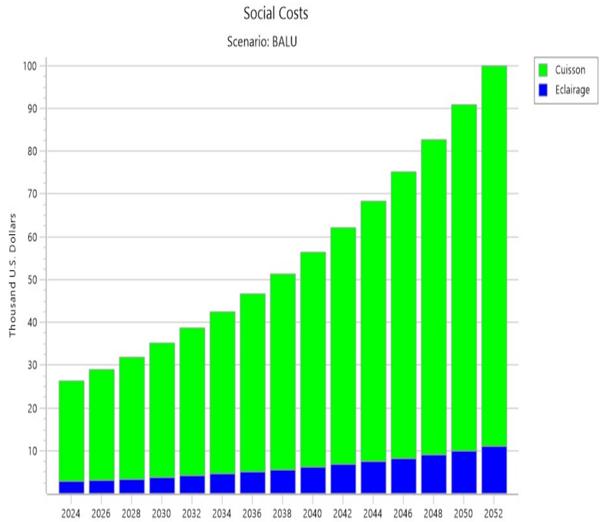

Fig. 9. BALU scenario of the social cost non-electrified household

The analysis of the social costs associated with energy demand for cooking in non-electrified households, according to the BALU model, reveals a continuously increasing trend. In 2023, these costs amount to approximately USD 25.1 thousand, reaching nearly USD 108.8 thousand in 2053. This increase underlines the growing expenses associated with cooking, highlighting the economic and environmental challenges these households face. The rising costs reflect the difficulties in accessing more sustainable and efficient energy sources, highlighting the need for strategic interventions to improve the living conditions of non-electrified households.

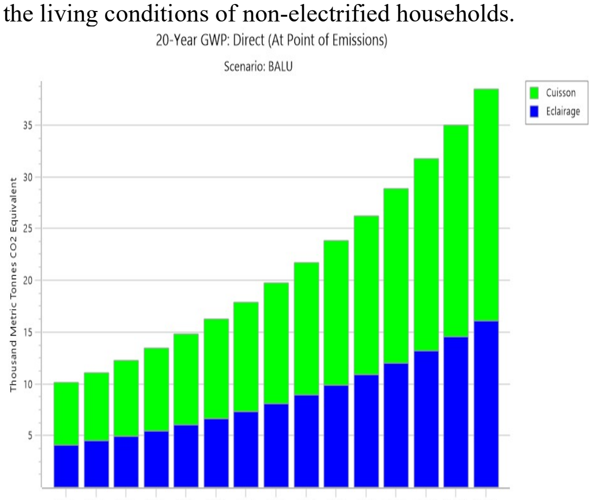

Fig. 10. BALU scenario of CO_2 emissions from non-electrified household

Analysis of CO_2 emissions from cooking and lighting in non-electrified households, according to the BALU model, shows a continuous increase over the years. In 2023, these emissions amount to approximately 2508.6 tons, reaching nearly 10492.5 tons in 2053. This increase illustrates the growing environmental challenges these households face due to their reliance on less sustainable energy sources. The significant increase in emissions underscores the urgent need to improve access to more efficient energy solutions to reduce the environmental impact and improve the quality of life of non-electrified households. Rising CO_2 emissions have direct and indirect impacts on biodiversity and surrounding ecosystems. First, the combustion of fossil fuels and biomass releases pollutants that can harm air quality. This phenomenon affects not only human health but also that of wildlife. Particles and gases from this combustion can cause respiratory problems in animals and disrupt the life cycles of sensitive species. Second, the growing demand for energy resources, particularly wood for cooking, contributes to deforestation. This deforestation leads to the destruction of natural habitats, threatening the survival of many species. Biodiversity loss reduces the resilience of ecosystems to environmental changes, such as climate change. Third, increasing CO_2 emissions contribute to climate change, which alters weather patterns and ecosystems. Aquatic habitats, for example, can be affected by ocean acidification and temperature fluctuations, disrupting food chains and threatening species such as fish and corals. Finally, this situation underscores the importance of access to sustainable and efficient energy solutions. Improving access to renewable energy could reduce greenhouse gas emissions, protect local ecosystems, and promote biodiversity while improving the quality of life of households without electricity.

This increase in emissions highlights the environmental challenges faced by non-electrified households, illustrating the impact of their energy practices on climate change. The increase in CO_2 emissions highlights the urgency of developing sustainable and accessible energy solutions in order to reduce the carbon footprint of these households and improve their quality of life while preserving the environment.

The examination of electricity demand, CO_2 emissions, and associated social costs in the residential sector is consistent with the main conclusions of several studies. The energy demand analysis for the city of Boma, based on the BALU model, reveals interesting trends in energy consumption between 2023 and 2053. In the first decade, from 2023 to 2033, electrified demand is estimated at approximately 13.3 million kWh, while non-electrified demand reaches approximately 20 million kWh. This translates into a total demand of approximately 33.3 million kWh, with electrified energy accounting for only about 40% of the total. This situation highlights a still significant dependence on non-electrified energy sources. During the following period, from 2034 to 2043, a notable trend emerges. Electrified demand increases to approximately 22.8 million kWh, while non-electrified demand remains stable at around 36 million kWh. The total demand for this period is therefore approximately 57.1 million kWh, with the share of electrified energy also reaching approximately 40%. This change clearly indicates a shift towards renewable energy sources, signaling a significant energy transition in the city. Finally, for the period from 2044 to 2053, electrified demand continues to grow, approaching 40 million kWh, while non-electrified demand stagnates around 60 million kWh. The total demand reaches almost 144.9 million kWh, with an electrified share of approximately 28%. This finding highlights the growing importance of electrification in Boma's energy landscape, although the reliance on non-electrified sources remains significant. Subsequent works, such as [1]-[3] and[19]-[20], provide confirmation of these results. They show that in similar contexts, the transition to renewable energy sources is often accompanied by an increase in electrified demand, reinforcing the idea that policies promoting electrification are essential for a sustainable energy future.

The social cost analysis for the city of Boma, based on the BALU model, reveals significant results that highlight the challenges associated with electrification. In 2023, social costs amount to USD 200000, mainly dominated by non-electrified households. This situation has negative impacts on health and education, exacerbating social inequalities. At the same time, by 2053, these costs reach USD 900000, even though the majority of households are electrified. Costs for electrified households increase from USD 87.1 thousand to USD 378.5 thousand, while those for non-electrified households increase from USD 25.1 thousand to USD 108.8 thousand. This dynamic underscores a transition towards electrification, with increasingly significant costs for electrified households, which can be interpreted as an investment in a better quality of life. By integrating renewable energy sources, such as solar or wind power, Boma could reduce long-term costs associated with fossil fuels and decrease environmental impacts. In addition, this transition could stimulate the local economy by creating jobs in the renewable energy sector and improving the city's energy resilience. Subsequent studies, such as those in [1], [12], [10], [15] and [16], confirm these findings. They show that the integration of renewable energy is generally associated with reduced social costs and improved living conditions, thus supporting the idea that electrification and renewable energy are essential levers for sustainable development.

Analysis of CO_2 emissions for the city of Boma reveals worrying results that highlight the environmental impact of current energy dependencies. In 2023, emissions amount to approximately 2679 tons, of which 2508.6 tonnes come from non-electrified households. This reliance on fossil fuels harms air quality and degrades local ecosystems. In 2026, emissions increase to 3,106.2 tonnes, with non-electrified households continuing to have a dominant impact on biodiversity. In 2043, emissions reach 6406.1 tons, despite the growth of electrified households, which contribute only 431.9 tonnes. Finally, in 2053, emissions peak at 11763.2 tonnes, highlighting the urgency of adopting renewable energy to protect ecosystems. This rise in CO_2 emissions contributes to climate change, disrupting natural habitats and threatening species diversity. The findings clearly show that reliance on non-electrified energy exacerbates environmental problems. Boma's aquatic and terrestrial ecosystems are under increasing stress, affecting food chains and biodiversity. Furthermore, increased air pollutants can adversely affect air quality, impacting the health of residents and animal species. The Luki Biosphere Reserve, a unique biodiversity refuge, is particularly threatened by human activities related to energy demand, including deforestation for fuelwood, which leads to the loss of critical habitats. Studies such as [1], [12], [10] and [18] reinforce these findings. They show that the adoption of renewable energy sources is associated with a significant reduction in CO_2 emissions, strengthening the argument for an energy transition in Boma. The results of Boma's analysis are corroborated by previous studies highlighting the importance of electrification and renewable energy in reducing social costs and CO_2 emissions. These studies provide a solid basis for arguing for an energy transition, showing that the benefits of such a transition are not only environmental but also economic and social.

The energy demand analysis reveals several critical assumptions. First, it is likely that persistent dependence on non-electrified energy sources will continue to hamper the transition to sustainable energy systems, despite the significant increase in electrified demand. As Boma's population grows and urbanization intensifies, electricity demand is expected to continue to grow, but this may be insufficient if the necessary infrastructure to support this transition is not put in place. Second, technological advances in renewable energy, such as improved efficiency of solar panels and wind turbines, could transform the dynamics of energy supply. Integrating these technologies could reduce costs and increase the accessibility of electricity, which, in turn, could stimulate faster adoption by non-electrified households.

To address these challenges, several policy recommendations can be made. First, it is essential that local authorities implement incentive policies to promote electrification, particularly by subsidizing renewable energy installations for low-income households. This could reduce initial investment costs, making electrification more accessible. Furthermore, an awareness-raising plan should be developed to inform the population about the economic and social benefits of renewable energy. This program could include community workshops and media campaigns, particularly targeting non-electrified households. Finally, it is recommended to strengthen collaboration between local stakeholders, including private companies and NGOs, to create small-scale renewable energy projects that meet the specific needs of the community. Establishing public-private partnerships could also facilitate access to financing for sustainable energy projects.

V. Conclusion

The analysis of energy demand in the residential sector in Boma, according to the BALU model, highlights the importance of an urgent energy transition in the face of a significant increase in CO_2 emissions, which increase from 2679 tons in 2023 to 11763.2 tons in 2053. This situation, exacerbated by the dependence on non-electrified sources, highlights the need to develop sustainable energy practices. Electrification offers significant benefits, including improving the quality of life of households while reducing the long-term costs associated with unsustainable energy sources. The analysis also illustrates a growing energy demand, increasing from 33348600 kWh in 2023 to almost 144859000 kWh in 2053, thus highlighting the associated economic challenges. In conclusion, a strategic and collective approach, focused on access to renewable energy and improving energy efficiency, is essential to ensure a sustainable future for Boma.

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Conflict of Interest

The authors declare no conflict of interest in the publication process of the research article.

Author Contributions

Author 1 was responsible for writing and preparing the original version, as well as analyzing the data. Author 2 focused on collecting the data needed for the study. In parallel, Author 3 took charge of revising the survey to ensure its relevance and clarity. Author 4 was involved in editing the original version to improve the quality of the text. Author 5 contributed additional revisions to refine the content. Authors 6 provided oversight throughout the process, ensuring that all steps were followed correctly. Finally, Author 7 performed the final revision, ensuring that the paper was ready for publication.

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