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Geospatial estimation and projection of electricity demand in Burkina Faso for efficient and sustainable rural electrification

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E-mail: bagre.b@edu.wascal.org**Keywords:** electricity access, energy demand, planning tool, policy, rural development Burkina Faso, scenarios, water-energy-agriculture-environment nexus**Abstract**

Approximately 75% of Burkina Faso, predominantly in rural areas, still lack electricity access at home. This energy poverty also impacts productive sectors like agriculture and small enterprises, as well as public facilities such as education and healthcare. To gauge the electricity requirements to tackle energy poverty and project them to the year 2060, the Multi-sectoral Latent Electricity Demand (M-LED) model is implemented in Burkina Faso. The analysis aims at supporting effective planning of electricity access infrastructure and allocation of resources with careful assessment of the diverse energy needs across space, time, and sectors. Under a baseline scenario, for example, the total electricity demand including latent is predicted to reach 11.4 TWh by 2030 (compared to the current demand of around 2.7 TWh). The demand is projected to be distributed across 6 TWh for residential load, 1.9 TWh for commercial and micro-enterprise sectors, 335 GWh for irrigation, 3 GWh for crop processing and less than 2 GWh for healthcare and school facilities. However, scenarios of more ambitious agricultural policy could increase the national demand to 12.9 TWh by 2030. Improving electricity planning in agricultural areas will help enhance agricultural productivity, avoid food waste, support food security targets, and improve the quality of healthcare and education sectors. Achieving such ambitious objectives will require improved or ambitious electricity planning programme from the government of Burkina Faso. Our analysis of results from the developed model devotes specific attention to the implications for water-energy-agriculture-development interlinkages.

1. Introduction

Electricity is a cornerstone of human development, powering economic growth, education, agriculture, and health. Yet, over 800 million people still lack access to electricity, two-thirds of them in sub-Saharan Africa [1]. In 2020, only 21% of Burkina Faso's population had access to electricity, ranking it among the least electrified countries in the world. Access was 67.4% in urban areas but just 5.3% in rural ones [2]. To address this gap, the government set ambitious targets: 60% electrification by 2015 and full urban access by 2020, under the National Multifunctional Platforms Programme (PN-PTFM) [3]. Several complementary initiatives followed. The YELEEN project, launched in 2019, planned to deliver electricity to 150,000 households through solar PV

plants, mini-grids, and stand-alone systems, with completion scheduled for 2023 [4]. Similarly, the Electricity Sector Support Project (PASEL) extended the grid to 229 rural communities between 2014 and 2022 [5]. More recently, the Electricity Connection Development Project (PDCEL), running until 2025, aims to make electricity more affordable and stimulate economic growth 2025 [6]. Despite these efforts, electrification rates remain low, and the structural impact of such programmes is still uncertain [7–9].

Meanwhile, electricity demand is rising rapidly. Since 2011, contracted power by subscribers has grown by 11.7% annually, jumping by 26.7% between 2019 and 2020 to reach 2.3 GW [10]. SONABEL, the national utility, increased supply at just 4% per year, providing 365 MW in 2020. To cover demand, Burkina Faso imports electricity from Ghana, Côte d'Ivoire, Benin, and Togo. Total consumption in 2020 was 2,679 GWh, corresponding to an access rate of only 21.66% [11, 12]. Yet even if supply matched demand, significant *latent demand* (the unmet need for electricity where infrastructure or affordability is lacking) would remain. This highlights the urgency of robust energy planning.

Long-term demand assessment is essential to close the energy poverty gap. Forecasting methods include Box-Jenkins techniques [13], linear programming in GAMS [14], and LEAP for integrated energy planning [15–17]. However, these approaches often lack sectoral or spatial granularity. Geospatial Electrification Models (GEMs) address this by guiding governments toward cost-effective electrification strategies [18]. Still, most GEMs focus on supply-side solutions [19] and primarily assess household demand [20].

To capture multisectoral needs, Falchetta *et al* developed the M-LED platform, which integrates electricity demand with water, agriculture, and socio-economic development [1, 18]. Applied in countries such as Kenya, Zambia, Rwanda, Zimbabwe, and Nigeria [21], it provides spatially explicit demand projections. Burkina Faso, however, lacks such detailed datasets. Apart from the CIREG project, which projected 20 TWh demand by 2050 but only highlighted agriculture [22], no comprehensive spatial demand assessment exists. This paper therefore introduces the first application of the M-LED model to Burkina Faso. It estimates geospatial, multisectoral electricity demand up to 2060 across mining, industry, healthcare, education, residential, agriculture, and micro-enterprises. Depending on national policy (baseline, improved, or ambitious) the model can guide sustainable electrification planning and help bridge Burkina Faso's persistent energy gap. Because M-LED framework is designed to estimate electricity demand that is not yet visible in consumption data, particularly in low-access contexts such as Sub-Saharan Africa.

2. Methodology

The M-LED platform initially developed by Falchetta *et al* [1] is the model employed in this paper. M-LED is an electricity demand assessment platform covering all main demand sectors relevant to electricity system planning. These demand sectors are modelled with high spatial resolution and future projections, while also targeting communities that currently lack electricity supply infrastructure. It was originally introduced in Falchetta *et al* [1] and written in the R scientific computing programming language. M-LED explores many geospatial data sources and (sub)-national statistics to produce hourly, monthly and yearly estimates of electricity demand in a set of sectors across a country. The key benefit of the bottom-up methodology is that the output data can both be used at the native local level of analysis such as communities and settlements (also called population clusters) and be aggregated to produce sub-national or national estimates of trends in electricity demand. M-LED is designed to operate at the country-level - calibrating current electricity consumption levels with recent national statistics and downscaling them at the local population cluster level. As a bottom-up assessment platform, M-LED performs calculations at the most granular level allowed for the input data. M-LED demand projections are both driver-driven (i.e., determined by projected growth in population and economic affluence levels) and objective-driven (i.e., aimed at ensuring sufficient electric energy to cover needs such as powering pumps for irrigation, crop processing machinery, or appliances in schools and healthcare facilities) [23].

To adapt M-LED to the Burkina Faso context, publicly available datasets are combined with modelling tools and scenario analysis to support electrification planning including different sectors based on [24]:

Baseline scenario: The baseline scenario projects future electricity use in Burkina Faso's main industries by extending current trends and highlights potential issues if no policy changes are made.

Improved scenario: This scenario seeks to improve living standards in Burkina Faso by expanding access to energy, water, and sanitation, and boosting agricultural yields through irrigation to support the goal of rapid food security.

Ambitious scenarios: This scenario envisions meeting Burkina Faso's nutrition needs and achieving universal access to electricity, water, and sanitation by 2030, powered entirely by renewables, with varying investment levels and impacts on natural resources.

Table 1. Dimensions considered in the stochastic demand assessment from residential sector. Reproduced from [1]. © The Author(s). Published by IOP Publishing Ltd. [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

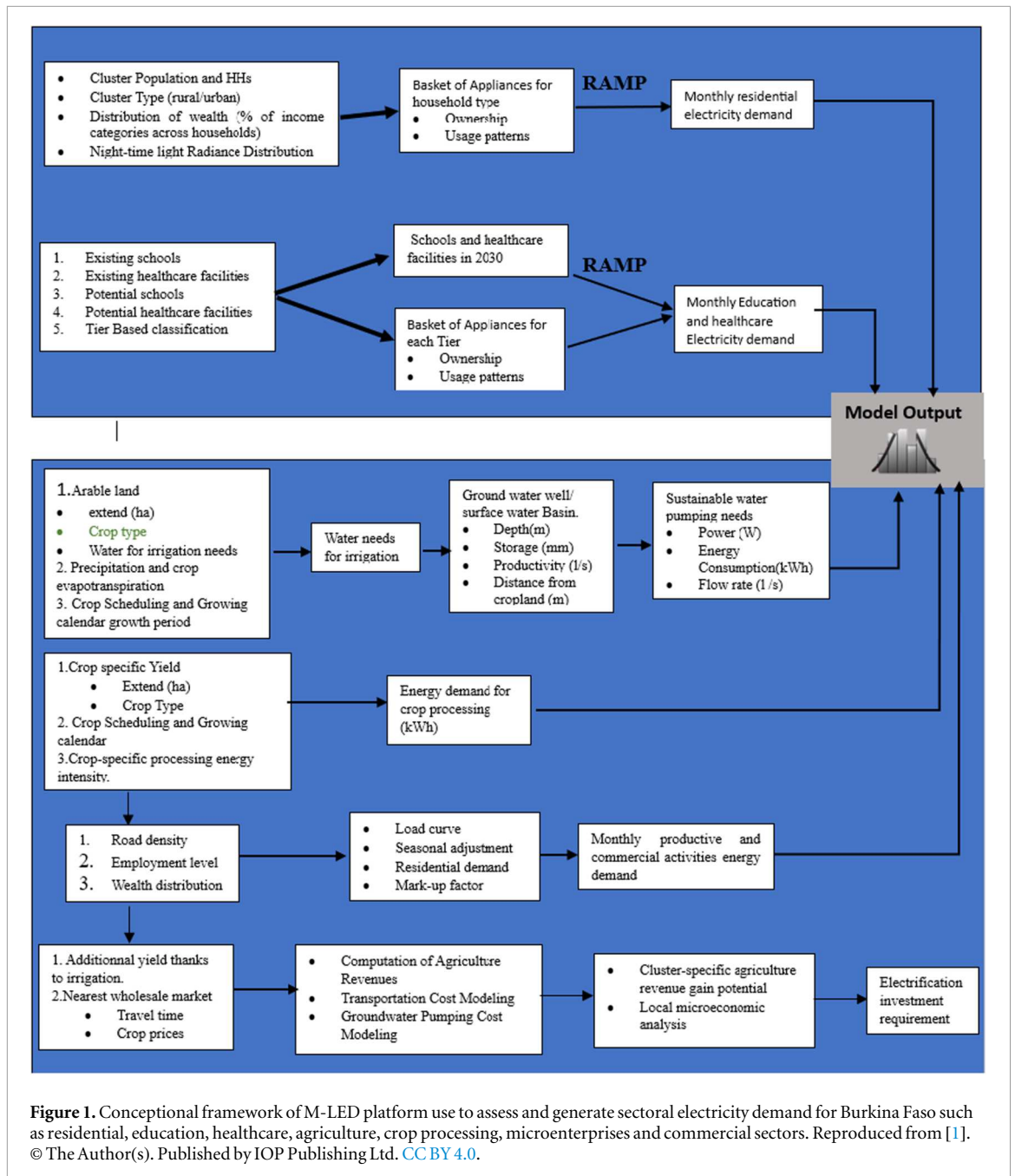
Dimension	Description	Range (unit)
Ownership	Category of User that owns the appliance	User Type
Number of appliances per user	Number of that specific appliance owned by the user	0–22 (–)
Appliance power	Nominal power of the specific appliance, allows for a random variability in a defined range for thermal appliances	0–1000 (W)
Number of daily functioning windows	Number of windows in which the appliance is used during the day	1–3 (–)
Window start and end times	Hours of start and end of time windows in which the appliance can be used	00:00–23:59
% variability of window starts and end times	Percentage of allowed random variation of the length of the usage windows	0–100 (%)
Daily functioning time	Total amount of time that the appliance is used for one day	0–1440 (min)
% of random variability of daily functioning time	Percentage allowed random variation of the total daily time of use	0–100 (%)
Minimum time the appliance is kept on after switch-on event	Minimum amount of time the appliance stays on after has been switched on	0–1440 (min)
Percentage of occasional use	Probability that the appliance is used on a single day	0–100 (%)
Weekends or weekdays use	Allows to constrain the usage of the appliance only on weekdays or in weekends periods	we/wd/none

To estimate load profiles for the residential, health and education sectors from Burkina Faso; the required input data by MLED such as household size, parameters related to healthcare and education (number of students or pupils per school) were used Falchetta *et al* [1, 25]. These load profiles are calibrated by a representative tier of access estimated through the RAMP ((Remote-Areas Multi-energy systems load) appliance-based stochastic model Lombardi *et al* [26], and tiers being parsed to each population settlement based on a set of determinants. The dimensions considered in stochastic demand assessment are mainly ownership, number of appliances per user, appliance power, number of daily functioning, start and end time, daily functioning time, percentage of occasional use weekend and weekend days use. The description of these dimensions is illustrated in table 1.

In Burkina Faso, many healthcare and educational establishments are also faced with major constraints on their activities, as they are unable to operate equipment that is essential for guaranteeing the well-being and development prospects of the local population. Only 47% of health centres are electrified in Burkina Faso, with two out of three and 3% for schools in urban and rural areas respectively. In M-LED, electricity demand for services in these establishments is modelled with a similar approach to the residential sector, i.e. in a bottom-up approach based on appliances.

As part of the community entrepreneurship programme, taking account of energy demand in the agricultural sector (irrigation and crop processing) now and in the future would be an asset in supporting the government's policy of food self-sufficiency. In Burkina Faso, 40% of land is arable, but only 0.5% is irrigated [27], even though it rains throughout the country. Overall, access to electricity in rural areas is poor, even though these are areas with great agricultural potential. Combined with the lack of fertilisation, unmet demand for irrigation water leads to low agricultural yields [28]. Following this paradigm, the energy requirements to enable sufficient artificial irrigation and the transformation of raw crops into more refined products is estimated with the aim of assessing the potential local economic gains. To this end, information on agricultural land, hydro-climatic factors and cropping patterns is fed into a set of agro-climatic equations to estimate the daily irrigation water requirements for each crop type through modelling (WaterCrop model). Figure 1 illustrates the method for developing the energy demand model for integration into MLED. For irrigation, only maize, rice and vegetables are considered. However, the energy demand for crop processing could concern all varieties.

The conceptual framework or approach illustrated (figure 1) and used in this study to assess residential, healthcare, educational, and agricultural (irrigation and crop processing) demands refers to the M-LED platform [1]. The population cluster, health and educational facilities data were collected from GRID3 website, world Pop Hub website (100 m resolution) and OpenStreetMap Export respectively. The crop land and water requirement for crop yield growth potential are assessed using WaterCROP model. The year 2020 serves as the reference year to calibrate the model for electricity demand projections in Burkina Faso. To check the model consistency and robust additional data for 2021 and 2022 were used. Thus, the sectoral electricity demand and electricity access data were collected from the General Direction of Energy, and total population data from the latest 2019–2020 population census report [29]. The methodology and data source used to assess electricity demand is described as follows:



- The residential electricity load of Burkina Faso is evaluated based on share of wealth classes in Burkina FAO in non-electrified clusters determination. These clusters were obtained using high resolution settlement (from GRID3) layer to clustering population and classification, night-time based consumption estimated by Falchetta 2019 [12] and Demographic and Health Surveys (DHS) [30] for distribution of wealth across clusters; to identify non electrified clusters and distribution of wealth in each cluster. Then, the residential load for Burkina Faso considering appliances ownership, appliance use patterns and identification of urban user and rural user classes.
- The prediction of future consumption is based on lights based consumption during night-time estimate by Falchetta 2019 [12] combined with wealth across cluster distribution from DHS [30] using a statistical regression model.
- The energy demand load in schools is estimated based on distribution of schools over Burkina Faso (data from OpenStreetMap Export), average number of pupils per school [31] and typical school appliances adoption.

- iv. Electricity demand specific to healthcare beds is evaluated by identifying appliance ownership after examining the distribution of health facilities across Burkina Faso (data from OpenStreetMap Export), categorizing them into five types, and considering the average number of beds per health category and the adoption of typical healthcare facility appliances [32, 33].
- v. Electricity demand, power and water flow rate from agriculture sector is made from irrigation water requirement necessary to improve crop yield over Burkina Faso. Water for irrigation is assessed based on cropland (arable area (ha), crop type and irrigation field) [33], precipitation and evapotranspiration [34] and crop scheduling, growing periods and crop factors [35]. Then, from the water requirement, ground water well (considering depth (m), availability (mm) and productivity(l/)) (MacDonald *et al*, 2012) [35] and surface water basin distribution (distance from cropland (m)) [35].
- vi. Crop processing energy demand is obtained considering crop specific yield (area (ha) and crop type) [34], crop scheduling and growing periods [35] and energy intensity for crop-specific processing (M-LED platform, File F3) [1].
- vii. In the agriculture sector, to look at the suitable or cost-effective water pumping system for irrigation (connection to the grid or should of-grid), agriculture revenue gain potential for cluster-specific is modelled. Thus, agriculture revenues calculation, transportation cost modeling and groundwater pumping cost modeling are done based on additional yield thanks to irrigation (data from WaterCROP model), crop prices [36] and traveling time over Burkina Faso [37].
- viii. Monthly productivities and commercial activities electricity demand is assessed considering road density of Burkina Faso (Global Roads Open Access Data Set), employment levels and wealth distribution [30, 38] and productive load curve from ENERGYDATA.INFO.
- ix. For micro-enterprises and commerce, the model for assessing electricity demand incorporates small-scale infrastructure in the range of 1500 kWh to 3100 kWh per year and small-scale commercial activities in the range of 1200 kWh to 1800 kWh per year. The model assumes that demand varies according to local economic and geographic factors [39]. The proxy approach makes it possible to estimate the contribution of productive sub-location in relation to household demand (linked to the poverty index) and the percentage of unemployment at the sub-location level.

Then, each sector feeds into M-LED with its own logic:

- i. Residential demand: derived from population, household size, electrification tier (e.g., Tier 1–5 from SE4ALL Multi-Tier Framework), and appliance ownership.
- ii. Health demand: based on number and type of facilities (clinic, hospital), services offered (lighting, refrigeration, ICT, lab), and corresponding load profiles.
- iii. Education demand: linked to school type (primary, secondary), number of students, teaching hours, ICT penetration.
- iv. Agriculture: estimated through mechanization needs (irrigation, milling, cold storage), scaled by production volumes or land under cultivation.
- v. Commercial and productive uses: micro-enterprises, shops, services scaled by urbanization and GDP.
- vi. Mining/industry: large but localized; estimated through mining production data and typical electricity intensity per ton.

Table 2 gives succinct details of the exact assumptions and how electricity demand was estimated in M-LED for the different sectors.

2.1. Study area

Burkina Faso (case study) is considered as study area in this study (figure 2). Burkina Faso is a West African country with 12° 14' 22.20" N as latitude and 1° 33' 30.27" W with a total land area of 272,967 km². It is a country that had a total population of 20505155 peoples inhabitants according to the results of the latest census (2019–2020) [29]. The average density of the population is 75.1 inhabitants km⁻² with a minimum density of 31 inhabitants km⁻² in the Sahel region and a maximum of 1014 inhabitants km⁻² [29]. According to the world bank Burkina Faso had a Gross domestic product (GDP) per capita of 831 \$USD in 2020 [38] with a total access

Table 2. Details on energy demand estimation with the exact assumptions.

Sectors	Agriculture	Residential	Healthcare and school facilities	Socioeconomics and other	Population growth
Assumption	The water pumping energy demand is quantified by $P_i = \frac{\rho g q h}{\eta}$ The total electricity load for crops processing $E_{im} = \sum_i^N Y Yield_c^{im} \times kWh/kg_c$ Before computing the energy requirement, the yearly crop yield in each cluster i for each of the 42 crop classes c is computed as follows: $Y Yield_c^{im} = \overline{Y Yield_c^{im}} \times cropland_c^i$	Total demand = Σ (Households \times Energy per household per tier).	Healthcare Tier 1 -> dispensary; Tier 2 -> Health clinics; Tier 3 -> Sub-district hospital; Tier 4 -> District Hospital / Provincial General Hospital; Tier 5 -> National Referral Hospital. Facilities with missing beds number: Tier 1 -> 0; Tier 2 -> 45; Tier 3 -> 150; Tier 4 -> 450; Tier 5 -> 2000. Number of beds in healthcare facility i of tier k * per-bed load at tier k. Education Number of pupils in school i * per-pupil load	The commercial activities (SMEs) and non-farm micro enterprises electricity demand is expressed by: $CommProd_{imh} = (1 + PCA_i^{range}) \times Residential_{imh} CommProdCurve_{mh}$	The change in the population of each grid cell was estimate by applying the yearly country-level population growth rate and the share of urban population as expressed in the equation: $Pop_t^i = U (Pop_{t-1}^{i\ urb} (1 + PGR_t^{BF} (1 + \Delta URB_t^{BF})), Pop_{t-1}^{i\ rur} (1 + PGR_t^{BF} (1 + \Delta RUR_t^{BF})))$ Where: Pop_t^i : the population in each cell I in year t PGR_t^{BF} : population growth rate in Burkina Faso (BF) at year t (e.g. it was around 2.43523% in Burkina Faso in 2020 [40]) ΔURB_t^{BF} : increase of share of Urban population at year t respect to previous year in BF ΔRUR_t^{BF} : increase of share of Urban population at year t respect to previous year in country and in BF

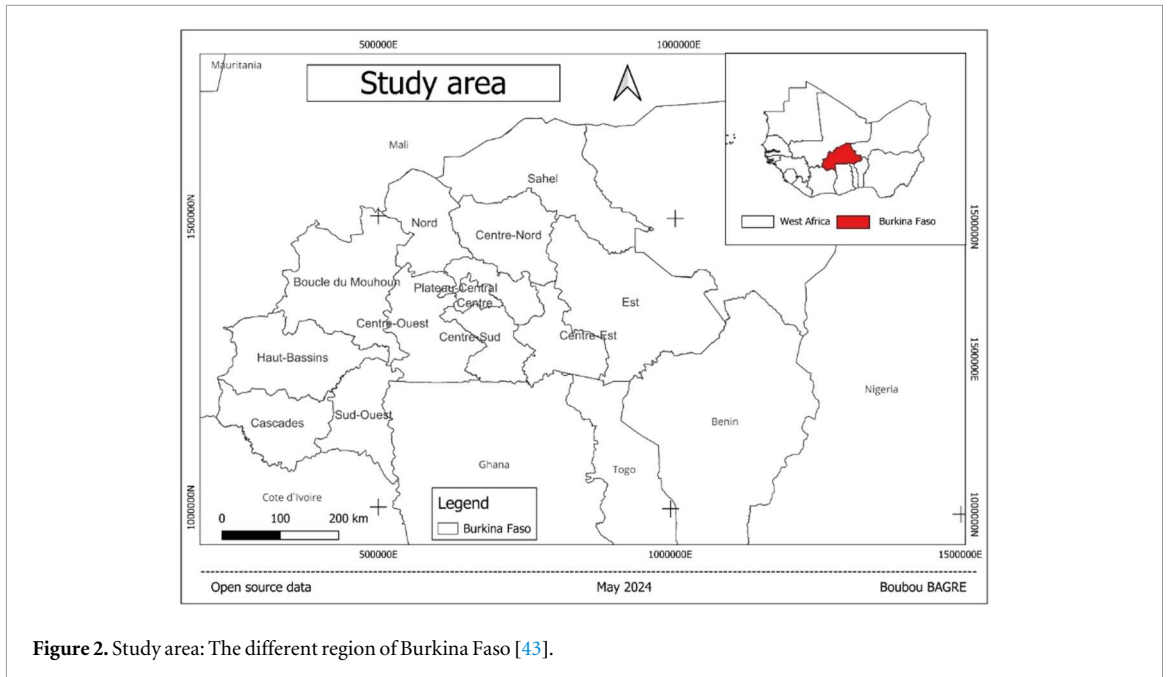


Figure 2. Study area: The different region of Burkina Faso [43].

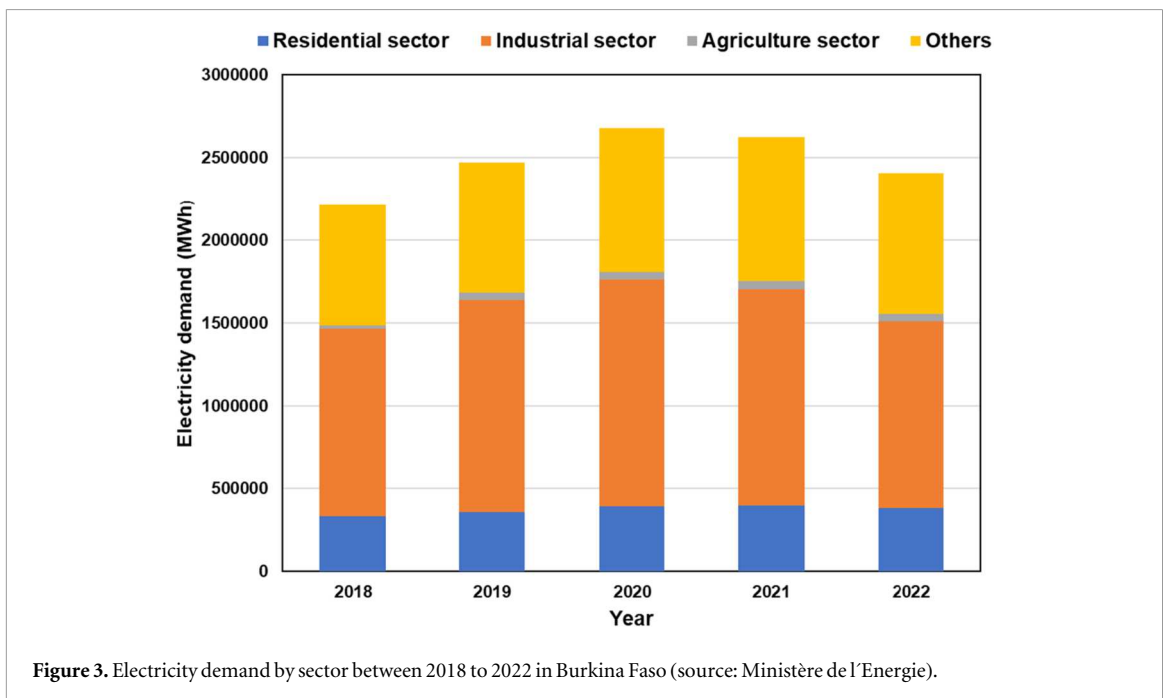
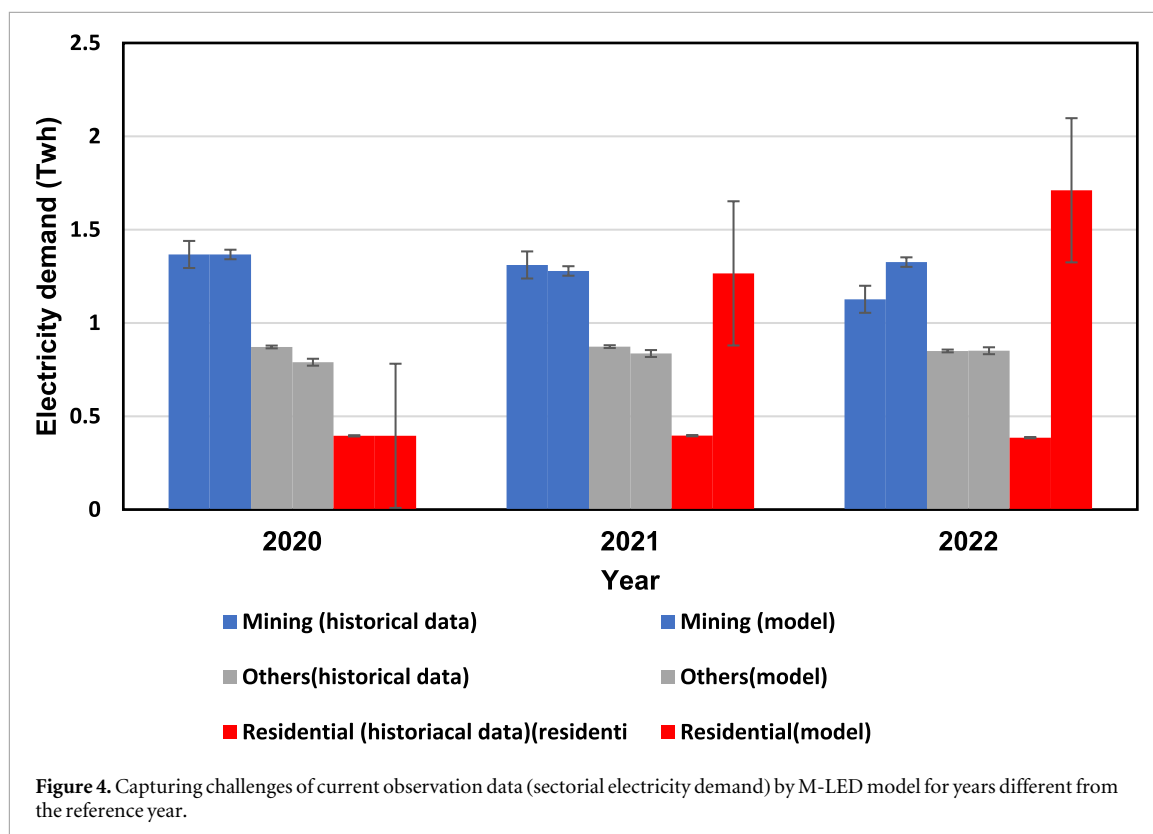


Figure 3. Electricity demand by sector between 2018 to 2022 in Burkina Faso (source: Ministère de l’Energie).

to electricity of 21.66 according to the ministry of energy. The main activity is rainfed agriculture with low income. Therefore, around 63% of the population work in agriculture sector [29] which is more based on rainfed. The agriculture sector is followed by commercial activities (9.9%), then micro-enterprise (6.3%) and educational activities (3.1%). Agriculture, that employs more than 63% of the population has the lowest electricity demand while mining and industry, that employs 1.5% of the population has more than 51% of total electricity demand as illustrated in figure 3. Figure 3 shows also an increasing of electricity demand between 2018 and 2020 and a decreasing after 2020. The decreasing of electricity demand after 2020 may be explained by the insecurity issue that causes the shutdown of five (5) industrial mining sites such as Aresso, Nord Gold, Bouroum, Riverstone Karma and Bounou [41]. So, thanks to the census done between 2019 and 2020, the year 2020 is considered as reference year in this study. In addition to that since 2012 the electricity demand increases by an average of 10% a year [42].



3. Results and discussion

3.1. Model calibration

The comparison of the model results of electricity demand (2820.8 GWh) from the grid for the year 2020 to the historical data collected (2679 GWh) from the Ministry of Energy for the year 2020 shows a maximum deviation of 5.3% from actual electricity consumption. And these uncertainties could reach 21.12% and 33.56% for 2021 and 2022 respectively. This deviation from the actual demand includes both latent electricity demand and the actual demand from education, health, and socio-economic sectors not connected to the grid. Because the model considered the living condition of communities to target all the electricity need from the reference. In addition, the latent demand could make up a large portion of the estimated demand, meaning that actual consumption could be significantly underestimated. Unless latent demand can be disaggregated from the load served, it seems challenging to draw a meaningful comparison. This is illustrated by figure 4. The most challenging sector to capture is residential load and agriculture sector. This is because, in addition to off-grid electrification loads (standalone power generation systems), a significant latent demand emerged in the residential sector.

In the agriculture sector, irrigation currently covers only 0.5% of arable land [27], while the M-LED model includes the entire area that could potentially be irrigated through either off-grid or grid-connected solutions. For example, the load for irrigation (only off-grid) assessed with M-LED is 139 GWh in 2020 against 45.6 GWh for observation data. Therefore, considering both actual and latent demand, the model is successfully calibrated before assessing Burkina Faso's future electricity demand under various scenarios.

3.2. Sensitivity analysis using Monte Carlo simulations

Monte Carlo simulation is, in essence, the generation of random objects or processes by means of a computer. Monte Carlo techniques are an essential tool in many quantitative investigations [44] and is useful for electronic computing. This method was used to estimate the interval for the total electricity demand considering independent uncertainties, conservative correlated uncertainties. Tables 3–6 and figure 5 illustrate the uncertainties (table 3) across sectors and scenarios with confident interval across scenarios (tables 4–6 and figure 5) from Monte Carlo base on lower correlation between drivers.

Both $N = 5,000$ and $N = 10,000$ Monte Carlo runs yield consistent probabilistic ranges Using $N = 10,000$ $N = 10,000$ $N = 10,000$ slightly tightens the confidence intervals but does not change the conclusions. The ordering of scenarios remains stable under uncertainty:

Table 3. Sensitivity analysis across sectors (standard deviation, σ).

Parameter	Previous value			New value			Effect
Number of simulations (N)	5,000			10,000			Higher statistical confidence correlation between drivers
Correlation between drivers (ρ)	0.5			0.3			
Year	2030	2050	2060	2030	2050	2060	[2030; 2060]
Population σ	5%	15%	20%	3%	10%	15%	Less uncertainty
Residential σ	8%	12%	15%	5%	10%	12%	Less uncertainty
SME σ	20%	20%	20%	15%	15%	15%	Moderate uncertainty
Irrigation σ	15%	25%	30%	10%	20%	25%	Less uncertainty
Mining σ	10%	12%	15%	8%	10%	12%	Less uncertainty
Social σ	10%	12%	15%	8%	10%	12%	Less uncertainty
Irrigation σ	15%	25%	30%	10%	20%	25%	Less uncertainty

Table 4. Interval confident under baseline scenario.

Year	Median (TWh)	P5 (N = 5 k)	P95 (N = 5 k)	P5 (N = 10 k)	P95 (N = 10 k)	Confident interval (N = 5000)	Confident interval (N = 10000)
2030	11.40	9.45	13.86	10.22	12.80	[9.45; 13.86]	[10.22; 12.80]
2050	29.16	19.36	43.84	22.48	38.16	[19.36; 43.84]	[22.48; 38.16]
2060	35.60	21.90	58.70	25.17	50.88	[21.90; 58.7]	[25.17; 50.88]

Table 5. Interval confident under improved scenario.

Year	Median (TWh)	P5 (N = 5 k)	P95 (N = 5 k)	P5 (N = 10 k)	P95 (N = 10 k)	Confident interval (N = 5000)	Confident interval (N = 10000)
2030	11.56	9.60	14.05	10.36	12.99	[9.60; 14.05]	[10.36; 12.99]
2050	25.50	17.42	37.31	20.14	33.92	[17.42; 37.31]	[20.14; 33.92]
2060	33.44	20.91	53.55	24.19	48.34	[20.91; 53.55]	[24.19; 48.34]

Ambitious Scenario

Table 6. Interval confident under ambitious scenario.

Year	Median (TWh)	P5 (N = 5 k)	P95 (N = 5 k)	P5 (N = 10 k)	P95 (N = 10 k)	Confident interval (N = 5000)	Confident interval (N = 10000)
2030	11.87	9.84	14.42	10.64	13.30	[9.84; 14.42]	[10.64; 13.30]
2050	29.83	19.94	44.46	23.13	38.83	[19.94; 44.46]	[23.13; 38.83]
2060	37.56	23.21	61.64	26.70	53.19	[23.21; 61.64]	[26.7; 53.19]

The simulation and sensitivity analysis shows that for 2030, uncertainty is relatively small: ± 15 to 20% around the median, across all scenarios. For 2050 and 2060, uncertainty widens due to compounding uncertainties in population growth, electrification rates, and irrigation intensity. Increasing the number of simulations slightly tightens the confidence intervals but does not change enough. Despite uncertainties, the ordering of scenarios (Baseline < Improved < Ambitious) remains robust across the entire time horizon as highlighted in tables 4–6. The results show more confidence working under improved scenario.

3.3. Sectoral electricity demand in Burkina Faso under different scenarios by 2060

Figures 6–9 illustrate the sectoral electricity demand including latent demand from 2020 to 2060 under baseline, improve and ambitious scenarios respectively for Burkina Faso generated with M-LED platform. Across the different scenarios, the residential sector is projected to require the most significant amount of electricity in Burkina Faso in the future. Under baseline scenario (figure 6), Burkina Faso government may want to attain faster food security and rural socio-economic development. So, effort must be made in the agricultural sector because the electricity demand in the water pumping sector for irrigation is important. However, that scenario needs to be improved because the education and health sectors require electricity for quality education and medical care, respectively. Thus, under the improved scenario (figure 7), the electricity

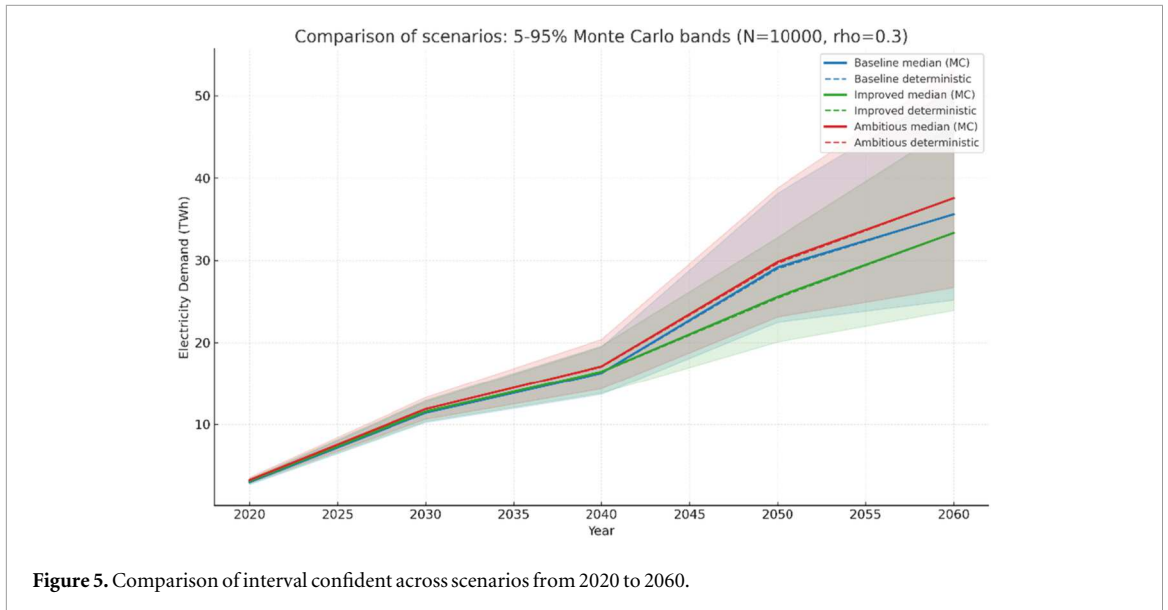


Figure 5. Comparison of interval confident across scenarios from 2020 to 2060.

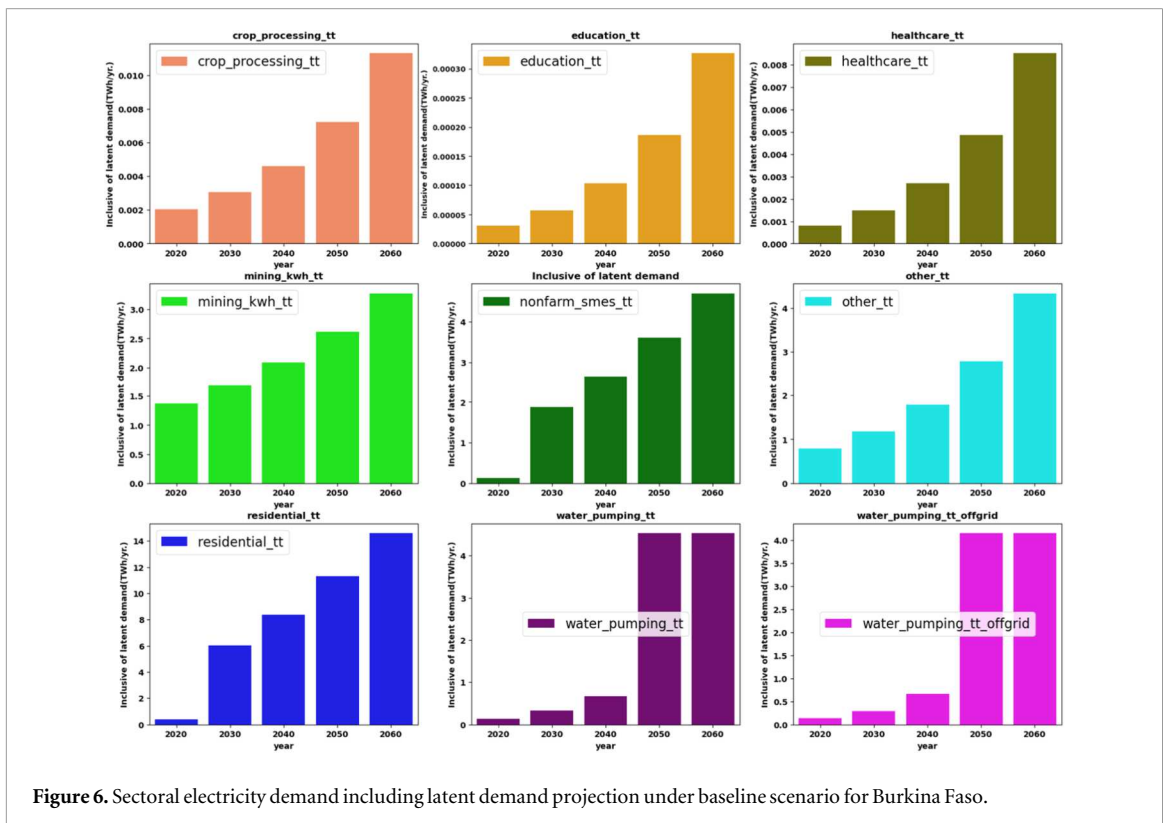


Figure 6. Sectoral electricity demand including latent demand projection under baseline scenario for Burkina Faso.

demand in the education and health sectors increases up to one hundred times compared to the baseline. In addition, crops yield grown thanks to irrigation, requires more electricity for crops processing. But water requirements are going to be reduced. Therefore, for an ambitious government (figure 8), water requirement must keep growing, driving to more electricity demand in that sector compared to improved scenario.

More details of sectoral electricity demand trend from 2020 to 2060 are illustrated in figure 9 (grouped bar chart). For instance, M-LED platform application estimates the total average urban and rural residential electricity demand of 6013 GWh year⁻¹ (including latent demand) by 2030 in Burkina Faso under the different scenarios. That value represents 52.74%, 52.02%, 50.69% of national electricity demand under baseline, improve and ambitious scenarios respectively. Urbanization would be a key factor of the future electricity demand rising because urban zone currently account for 74% of the electricity use with 33% for residential sector [45]. Currently, the residential electricity demand represents only 12.79% (395 GWh year⁻¹) lower than industry sector requirement which require 46.16% in the current situation. However, by 2030, the electricity requirement for industry and mining is projected to increase to 1690

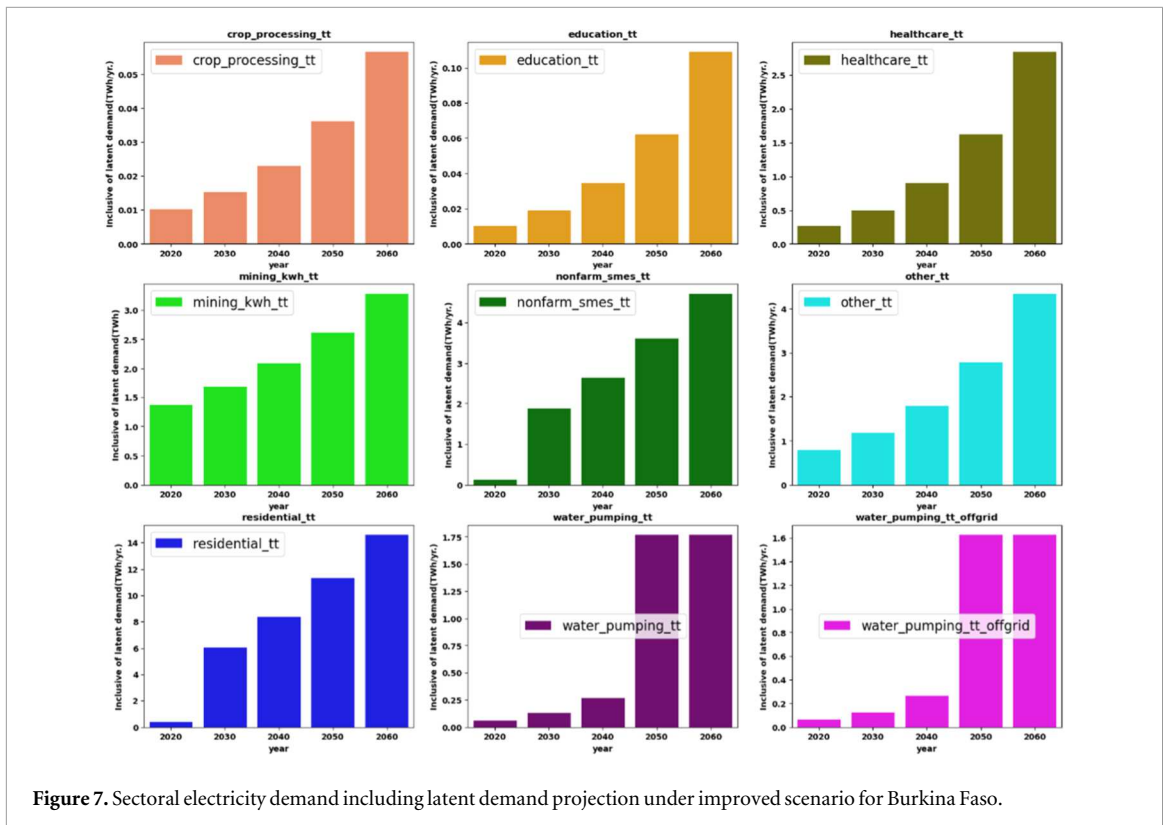


Figure 7. Sectoral electricity demand including latent demand projection under improved scenario for Burkina Faso.

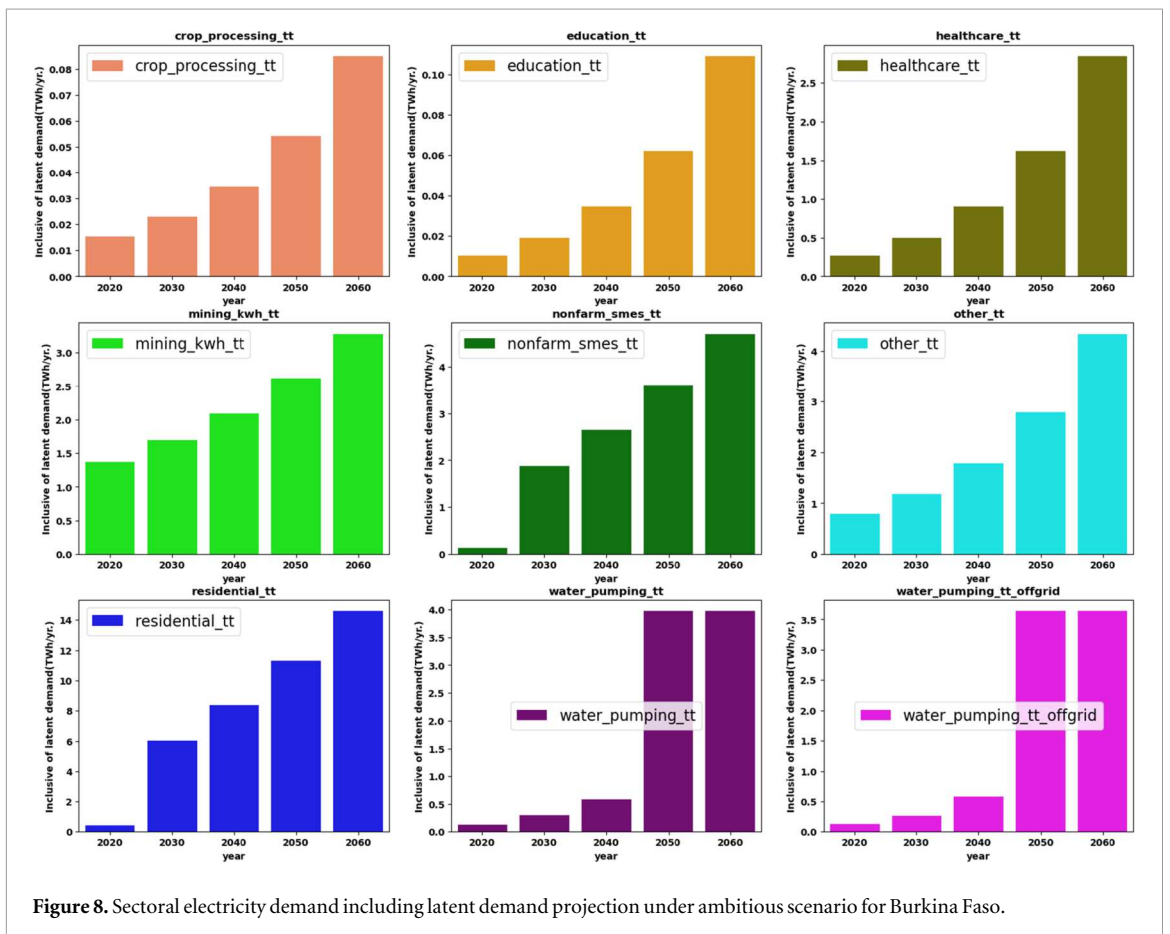
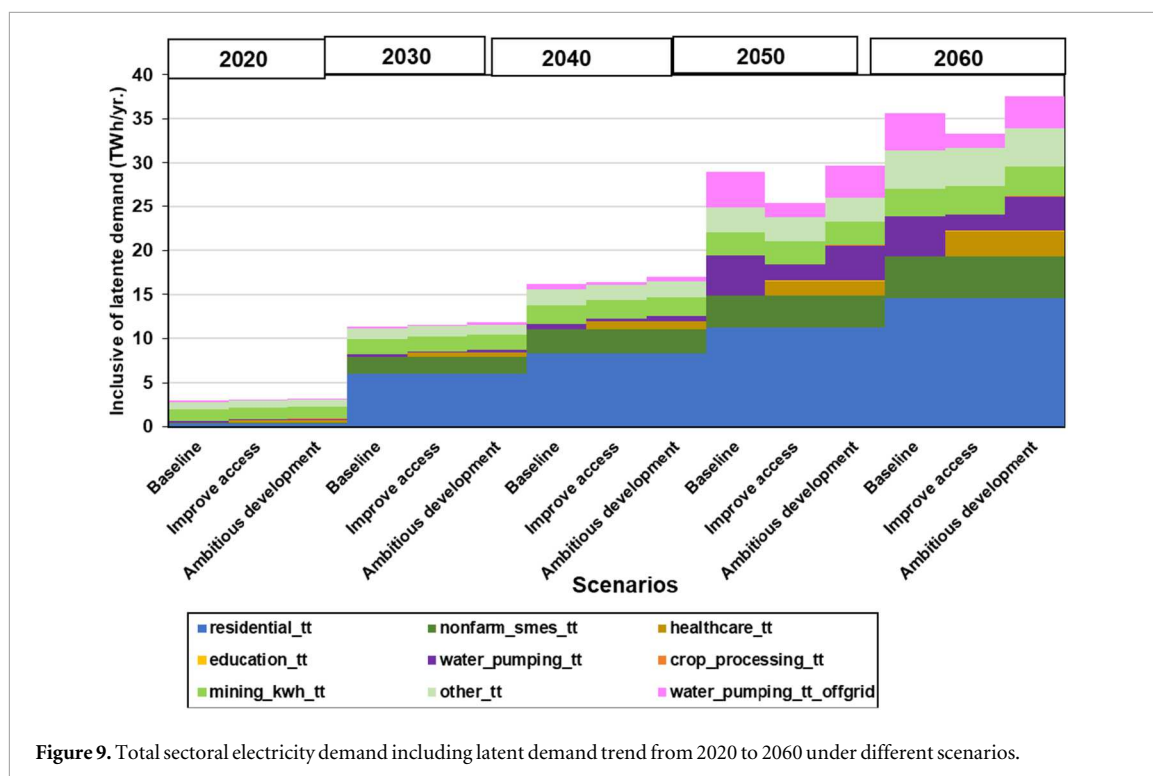


Figure 8. Sectoral electricity demand including latent demand projection under ambitious scenario for Burkina Faso.



GWh, but this will still be significantly lower than the residential electricity requirement ($6013 \text{ GWh year}^{-1}$). The change of electricity demand in commercial activities and small scale-handcraft was not enough and was estimated of around 1.88 TWh under the different scenarios. Therefore, that sector is going to require more electricity by 2030 than industry following by other user's demand. The main change in electricity demand in Burkina Faso from one government to another can be observed in social activities and agriculture sector. For example, by 2030, the electricity demand in education sector is estimated at $0.1 \text{ GWh year}^{-1}$ under baseline and $19.2 \text{ GWh year}^{-1}$ under improve and ambitious scenario. In the same way, healthcare load is $1.5 \text{ GWh year}^{-1}$ under baseline scenario and $500 \text{ GWh year}^{-1}$ under improved and ambitious scenarios. For the well-being of Burkina Faso, more social infrastructures are needed to enhance social activities; this would be achievable under the improved and ambitious scenarios. In the agriculture sector, the total yearly load for irrigation is $627 \text{ GWh year}^{-1}$ and $3.1 \text{ GWh year}^{-1}$ for crop processing under baseline scenario, $255.6 \text{ GWh year}^{-1}$ and $15.3 \text{ GWh year}^{-1}$ under improved scenario and $552 \text{ GWh year}^{-1}$ and 23 GWh year^{-1} under ambitious scenarios. These results indicate that, under the baseline scenario, more electricity load is currently required in the agriculture sector for irrigation to achieve food security. However, it is also crucial to consider electricity demand for crop processing and cold storage of vegetables to prevent food waste. To face that issue, the government of Burkina Faso must work under improved or ambitious scenarios.

3.4. Comparison of the estimated demand with previous studies

A direct comparison with previous demand estimates in the literature is not straightforward. Most earlier studies were designed to calibrate supply-side geospatial electrification models. In Burkina Faso, geospatial electricity demand studies are very limited. Moner-Girona *et al* [46] estimated electricity demand per settlement for a universal access scenario. They projected less than 2000 GWh by 2030. However, by 2020, demand under the baseline scenario had already reached 2600 GWh with only 21.66% access. This figure did not include off-grid, stand-alone, or latent demand. Relying only on population growth to estimate future needs [46] risks underestimating the load required to reach universal access. The lack of detailed rural data and the statistical approach used in [46] may also have led to lower projections. This underlines the importance of including all development sectors in demand assessments. Residential, socio-economic, healthcare, education, and agriculture must all be considered to estimate electricity needs for sustainable development. Differences can also arise from how demand is expressed. Some studies use yearly sectoral consumption in kWh, others rely on daily load curves in W. Demand is further parsed by settlement type, such as urban or rural, poor or non-poor. Hoff *et al* [22] applied a transdisciplinary approach with LEAP under several scenarios. They projected a total demand of 20 TWh by 2050 in the universal access scenario. This ambitious case included additional electricity for households, schools, and health facilities. By contrast, the M-LED model produces an estimate of 25.4 TWh . Unlike LEAP, M-LED includes latent demand and off-grid electricity needs. It accounts for demand across all sectors and all settlements. For instance, off-grid demand for water pumping alone could reach 3637 GWh by 2050 [47].

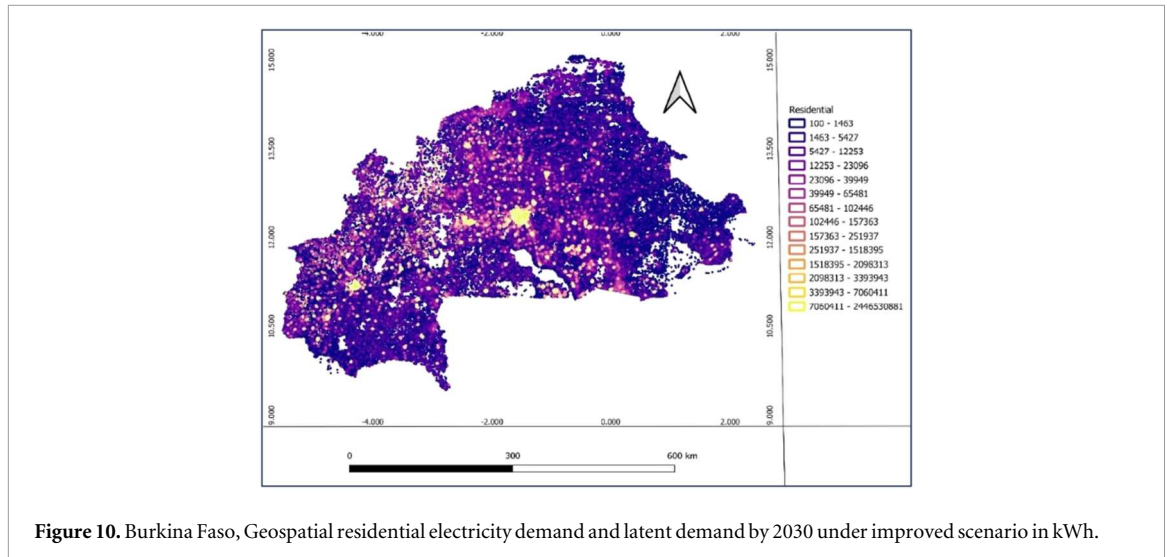


Figure 10. Burkina Faso, Geospatial residential electricity demand and latent demand by 2030 under improved scenario in kWh.

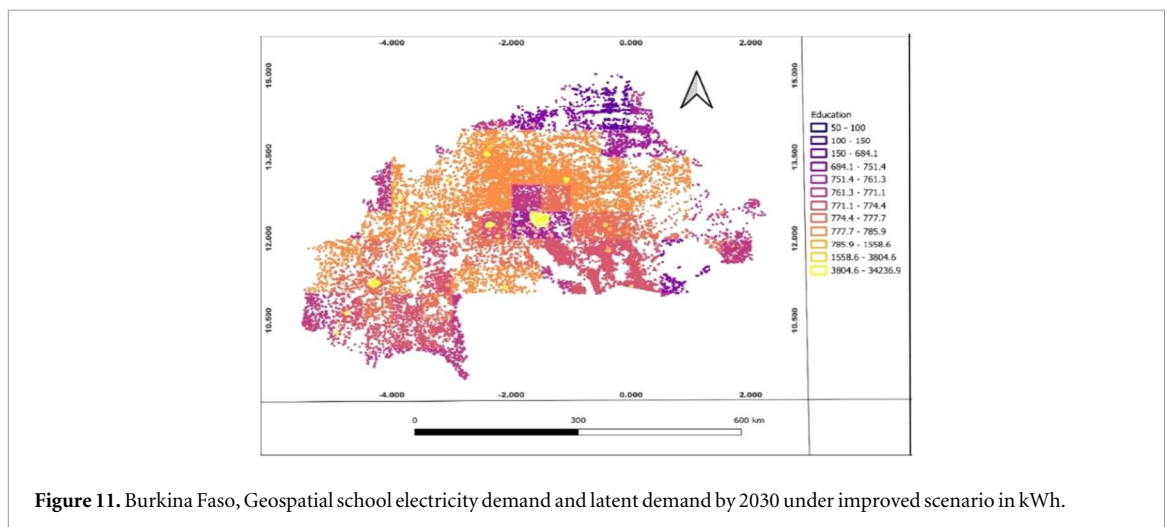


Figure 11. Burkina Faso, Geospatial school electricity demand and latent demand by 2030 under improved scenario in kWh.

3.5. Distribution over Burkina Faso of yearly sectoral electricity demand

Figures 10–16 illustrate geospatial electricity demand of different development sectors in Burkina Faso. White pixels indicate areas without population or without sectoral electricity demand, such as natural parks, protected areas, desert areas or cropland (for sectors different from agriculture). Electricity demand varies widely across the residential, commercial, and micro-enterprise sectors (figures 10 and 16). The demand closely follows urbanization and population density. Regional capitals carry the highest loads, with Ouagadougou in the Central region being the largest. However, demand from commercial and microenterprise respectively is lower than residential in some areas. For example, the largest electricity demand can reach $2450 \text{ GWh year}^{-1}$ for residential sector against $7.34 \text{ GWh year}^{-1}$ for commercial in the central region. This can be justified by lower employment and market accessibility [1]. Schools is going to be relatively more distributed with less electricity demand intensive (figure 11) while healthcare facilities are being highly sparse but at the same time requiring a high demand density (figure 11). Irrigation (figures 13 and 14) and crop processing (figure 15) electricity demand is more intensive, in the ‘Boucle de Mouhoun, Centre Ouest, Haut-Bassin, Cascade, Centre Sud, Sud-Ouest, Centre Est, Est’ regions which are the most suitable agriculture districts in Burkina Faso [36]. This shows that Burkina Faso has high irrigation potential.

The clarify sensitivities analysis across sectors and scenarios can guide policy to address the following points:

- (i) The high sensitivity of sectoral electricity demands policy assumptions.
- (ii) The dependance of mining and industrial demand is heavily on local GDP growth rates and site-specific activity, hence their volatility.

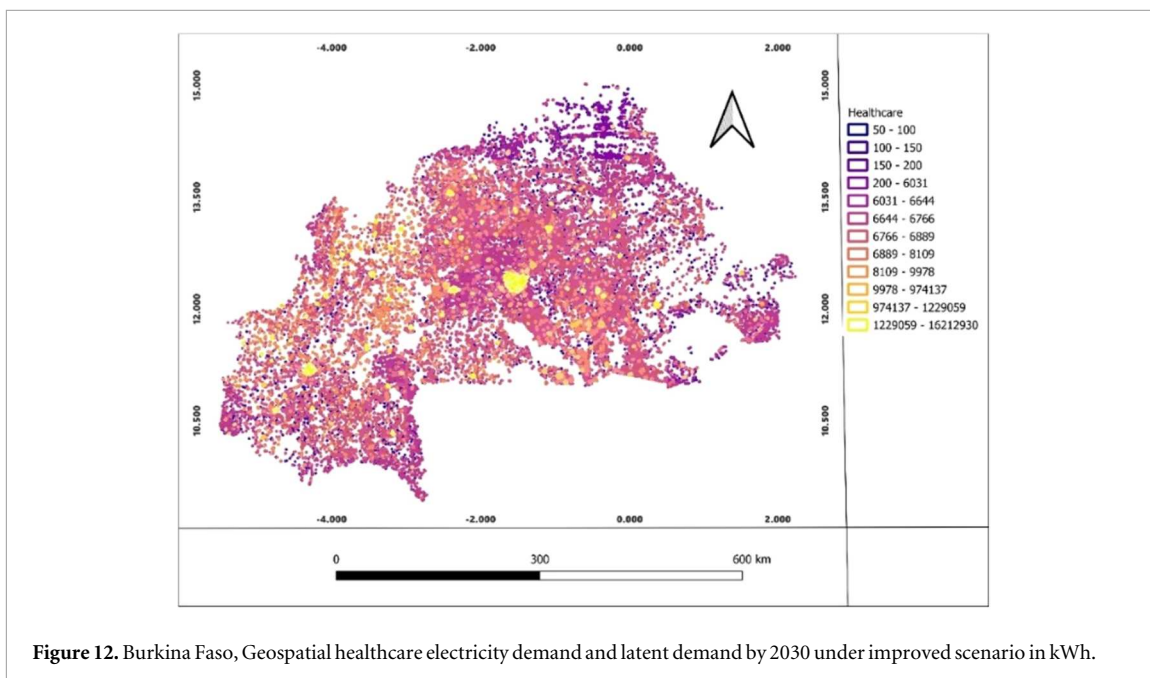


Figure 12. Burkina Faso, Geospatial healthcare electricity demand and latent demand by 2030 under improved scenario in kWh.

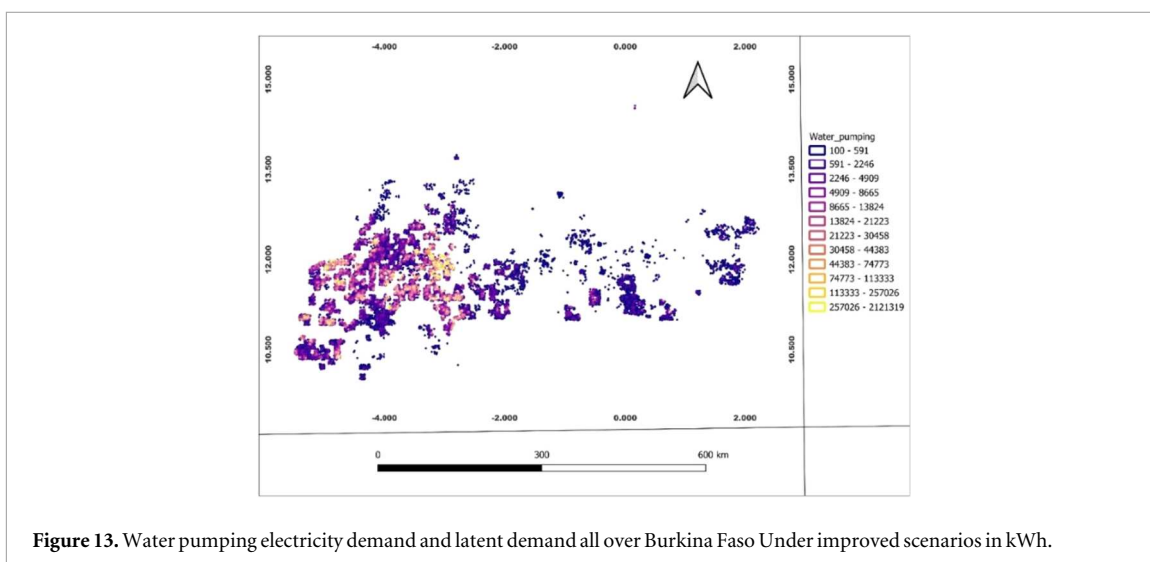


Figure 13. Water pumping electricity demand and latent demand all over Burkina Faso Under improved scenarios in kWh.

- (iii) Shape the irrigation demand by a trade-off between expanded cultivation and irrigation efficiency gains.
- (iv) Electrification of social sectors drives non-linear growth in demand when ambitious policies are adopted.

4. Conclusion, policy application and perspective

Electricity demand assessment is an important factor in energy planning, as it reflects the outcome of supply-side electrification models. In this study, the M-LED model has been successfully developed for Burkina Faso to assess electricity demand across different sectors, based on the M-LED platform developed by Falchetta *et al* [1]. The results demonstrate how big data and bottom-up energy modeling can be jointly leveraged to represent the sectoral potential demand for electricity with high spatio-temporal resolution. A large-scale electrification planning tool for improving energy planning and policy until 2060, providing detailed demand-side insights, is now available on the RE4AFAGRI platform (Dashboards-Burkina Faso) for Burkina Faso. These are potentially beneficial for policy makers (Burkina Faso government), researchers, consultants and other stake-holders involved in the electrification planning in Burkina Faso. For instance, the results could contribute to the prioritization decisions for the allocation of limited governmental funding by leveraging consumers. Specifically, these insights can help prioritize consumers who are likely to have the greatest impact on increasing economic growth through electricity provision to existing productive activities or by attracting private

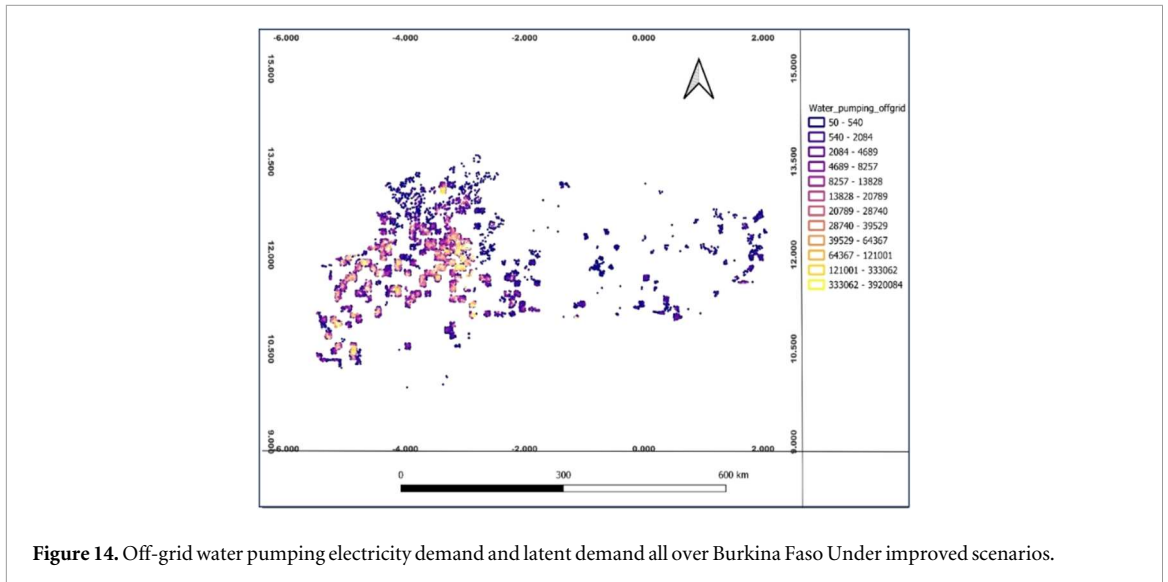


Figure 14. Off-grid water pumping electricity demand and latent demand all over Burkina Faso Under improved scenarios.

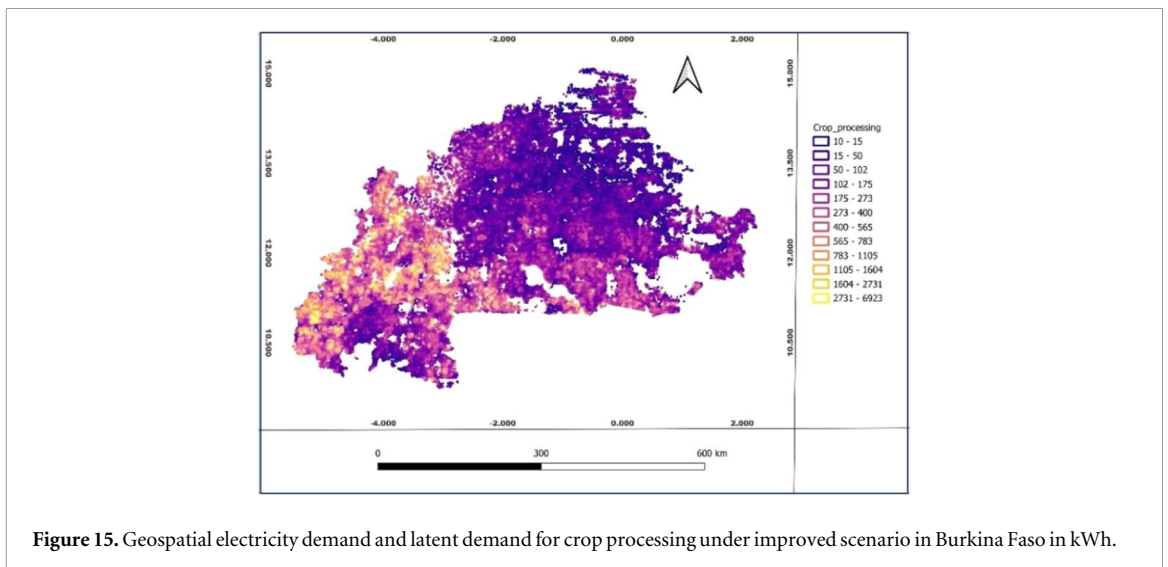


Figure 15. Geospatial electricity demand and latent demand for crop processing under improved scenario in Burkina Faso in kWh.

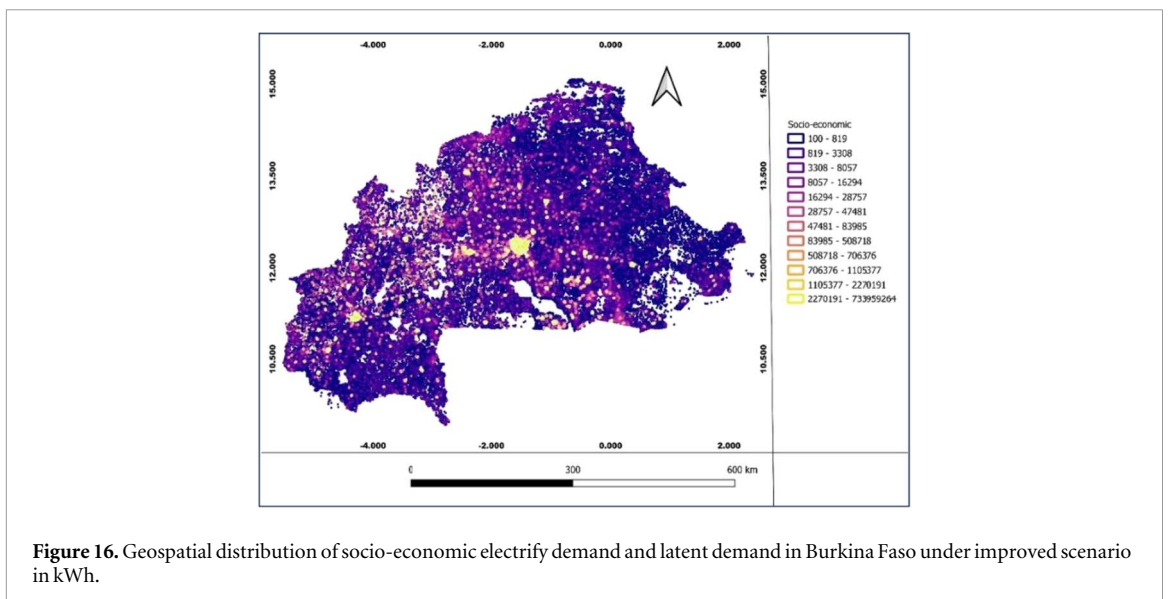


Figure 16. Geospatial distribution of socio-economic electrify demand and latent demand in Burkina Faso under improved scenario in kWh.

investments in the most productive areas. For example, to meet faster food security and reduce unemployment, second season (in agriculture sector) can be developed between December and March via irrigation in several regions of Burkina Faso. For future work, a model will be developed, utilizing the geospatial demand estimates produced in this paper, to identify the least-cost electrification strategies to meet electricity demand and increase electricity access in Burkina Faso. In addition to that, a critical analysis of cost behavior on the electrification strategies will be an asset when using micro- concentrating solar power plants of 10 kW_{el} to 1000 kW_{el} (integrating thermocline energy storage system based on local material), PV, Diesel [48, 49] or wind for remote area in Burkina Faso and Sub-Saharan-Africa.

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Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: <https://www.re4afagri.africa/dashboards-burkina-faso/>; <https://github.com/bagre2019/Burkinafaso-/releases>.

Author contributions

Jacques Nébié
Writing – original draft (equal)

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