 doi:10.20944/preprints202110.0182.v1

Article

Scenarios simulation and analysis on electric power planning based on multi-scale forecast: a case study of Taoussa, Mali from 2020 to 2035

Moussa Kanté [1, 2], Yang Li [1,*] and Shuai Deng [1]

[1] Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, Tianjin University, MOE, Tianjin 300350, China; sdeng@tju.edu.cn (S.D.); moussankante@gmail.com (M.K.)

[2] Department of Electrical Engineering, Vocational School of Soumangourou KANTÉ, Bamako 63, Mali

* Correspondence: liyangtju@tju.cn; Tel.: +86 022 6037 2516

Abstract: A long-term forecast study on the electricity demand of Taoussa of Mali is conducted in this paper, with various scenarios of socioeconomic and technological conditions. The analysis tool, which is applied in scenarios simulation, is the Model for Analysis of Energy Demand from the International Atomic Energy Agency. The analysis results are annual electricity demand and peak load forecast for the electrification from the period 2020 to 2035. During the planning period, the analysis results show that the electricity demand will increase to 49.40 MW (332.57 GWh) for the low scenario (LS), 66.46 MW (472.61 GWh) for the reference scenario (RS), and 89.47 MW (635 GWh) for the high scenario (HS). In addition, the total electricity demand increased at an average rate of 8.13% in the LS, 10.31% in the RS and 12.56% in the HS in all sectors. The electricity peak demand is expected to grow at 7.92%, 10.53% and 12.91% corresponding to the three scenarios; in this case, the system peak demand in 2035 will increase to 64.88 MW for the LS, 92.2 MW for the RS and 126.22 MW, the days of peak load are between 17th-23rd in May. The Industry sector will be the biggest electricity consumer of Taoussa area.

Keywords: Electricity peak load; Taoussa's energy sources; Long-term electricity demand planning; Scenarios simulation

1. Introduction

Energy is essential to economic and social development and improved quality of life. However, much of the world's energy is currently produced and used in ways that may not be sustainable in the long term. In order to assess progress towards a sustainable energy future (solar energy, wind energy, tidal energy and geothermal energy), energy indicators that can measure and monitor important changes are needed [1].

Energy demand is divided into several end-use categories, each corresponding to a given service or the production of a certain good. The nature and level of demand for goods and services are determined by population growth, number of inhabitants per dwelling, number of electrical appliances used in households, peoples' mobility and preferences for transport modes, national priorities for the development of certain industries or economic sectors, the evolution of the efficiency of certain types of

 doi:10.20944/preprints202110.0182.v1

equipment and market penetration of new technologies or energy forms [2]. The expected future trends for these determining factors, which constitute 'scenarios' are exogenously introduced. The scenario is a potential image whose future could be revealed, a set of scenarios helps to understand the possible future evolutions of complex systems [3].

A model for peak-load demand should take into account the following factors or a part of them, depending on the country in which this model is going to be implemented. There is no unique model that can be applied to utility companies.

These factors are

- The gross domestic product (GDP)
- The population (POP)
- The GDP per capita (GDP/CAP)
- The multiplication of electricity consumption by population (EP)
- The power system losses (LOSS)
- The load factor (LF)
- The cost of one kilowatt-hour (the average rate per unit sale; R/S) (mill/kWh).

The first four factors depend on the behavior of the public; thus, they may vary from country to country, whereas the last three factors depend on the electric power system and the load itself, as well as the consumption of power, generated [4].

Electricity load forecasting is a multifaceted task that encompasses various sides of the economical and safety operations of power supply systems. The forecasting makes assistance for security analysis of supply systems, system control, maintenance etc. It also provides feedback for planning. By considering these important facets of the forecasting, many methods have been applied to predict electricity load forecasting over years to get more accurate results for efficient planning, however, the prediction has still remained a challenging issue that contains many uncertain factors affecting electricity load utilization [5].

There are mostly three categories of energy consumption studies in the literature according to the forecasting horizon. Long-term forecasting (5 to 20 years) is mostly applied for resource management and development investments. Mid-term forecasting (a month to 5 years) is mostly applied for planning the power production resources and tariffs, and short-term forecasting (an hour to a week) is mostly used for scheduling and analyses of the distribution network [6].

Each one of these planning horizons is important; however, long-term forecasting can be considered the most critical horizon due to the consequences of the strategic and costly decisions, such as the expansion of utility plants. An overestimation of electricity demand, especially in long-term forecasting, will result in a significant increase in the construction of unnecessary electricity generation plants. In contrast, an underestimation of electricity demand forecasting will result in a shortage of electricity production and customer dissatisfaction [7].

It is not surprising that factors affecting prediction horizon types may vary. In the short term and mid-term load forecasting, the most important factor for load prediction

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

is temperature and humidity, however, in long term load forecasting, GDP, expected economical situations, changes in the demography etc. are the most common factors which affect load usage [8].

The forecasting methods are classified into traditional (e.g. Fuzzy Logic, Grey model, Metaheuristic algorithms, Regression models, Simulation model, Time series model) and intelligent (e.g. Machine Learning and Neural Network) models. Furthermore, the advantages and disadvantages of both traditional and intelligent forecasting methods as well as research limitations and future researches are determined [9]. The historic time series data is used in many studies to predict the energy consumption, the effect of variables such as GDP, Consumer Price Index (CPI), humidity, temperature, population, energy price, daylight time, number of rainy days, etc. on energy consumption is analyzed in many others. Proposed models can be applied by the producers, suppliers and regulatory authorities who want to securely supply the electricity at a reasonable cost [10].

Researchers use different models and methodologies to forecast electricity demand. For example, Abdelmonaem [11] used **a** hybrid load-forecasting method that combines classical time series formulations with cubic splines to model electricity load, only the hourly temperature is used in the proposed model and predictive power gains are achieved through the modelling of the 24-hour load profiles across weekends and weekdays while also taking into consideration seasonal variations of such profiles. Long-term trends are accounted for by using population and economic variables. Ivana [12] proposed a deep residual neural network model for day-ahead household electrical energy consumption forecasting and integrate multiple sources of information (weather, calendar and historical load). Ali et al. [13] employed a fuzzy logic model for long-term load forecasting of one year based on the weather parameters (temperature and humidity) and historical load data. Abdulla et al. [7] presented long-term forecasting of electrical loads in Kuwait using Prophet and Holt-Winters models of ten years based on the real data of historical electric load peaks (ten years). Hamida et al. [14] also design enhanced machine learning techniques for electricity load and price forecasting, hourly data of one year is used for the forecasting process.

Many future electricity demand projections studies in the literature research have been employed a bottom-up approach using the Model for Analysis of Energy Demand – Energy Demand module (MAED_D), which adopts socio-economic and technological development indicators to make long-term projections, in the case of study Syria, Turkey, Nigeria, Nepal, Tanzania, Bangladesh and Lesotho.

The final energy demand and the final electricity demand of Syria will grow up annually respectively. Both final energy and electricity demand growth rates are lower than the corresponding GDP growth rates, which indicate positive development trends in the elasticity evolution. However, the growth of electricity is continuously higher than that of final energy with increasing tendency over the whole study period. This is a direct result of more automation in industry and more electric equipment in households and services [15]. MAED Model was executed for the above three scenarios and Turkey's annual electric energy demand values were predicted from the study period. The result shows that the future electricity demand will be growing rapidly in Turkey [16]. The forecast of the energy demand of Tanzania for all economic sectors is analyzed by using the Model for Analysis of Energy Demand (MAED) for a study period. In the study, three scenarios were formulated to simulate possible future long-term energy demand based on socio-economic and technological development with the base year. The study results show the highest growth rate of electricity demand is in the industry sector followed closely by service and household sectors [17].

The second module of MAED, MAED_EL (EL = Electricity) used to determine the annual peak load of future Syrian electric power demand. The results indicate that the current residential behaviour of the Syrian power system will shift in the reference scenario more and more to the typical industry behaviour characterized by higher load factors. The future peak load will grow annually [18].

To improve estimates of future electrical energy needs, the International Atomic Energy Agency (IAEA) developed the Model for Analysis of Energy Demand (MAED) on the long-term evolution of energy demand. MAED software has been used to do the simulation of future electric demand for this paper.

2. Information on the Taoussa area

Mali is one of the landlocked countries of the Sahelian, half of the national territory is located in the Saharan zone of West Africa, as shown in Figure 1.

Figure 1. Location of Mali in West Africa [19].

Its surface area is 1 241 248 km², 60% of it is desert land (north). Located between 10° and 25° North in latitude, 3° East and 12° West in longitude. Two of the most important rivers in West Africa cross it; these are the Niger River and Senegal River.

The Taoussa area in Mali is located in the northern regions (Timbuktu and Gao), it has a Sahelian to sub-Saharan climate, and is characterized by low rainfall and limited water resources, which generates a strong dependence on water and energy. In response to the worrying situation in the northern regions, the government of Mali is considering the sustainable development of the Niger Loop between Timbuktu and Gao by building a threshold multifunctional dam on the right of Taoussa; the village of Taoussa which houses the dam site is part of the commune of Bourem in the region of Gao. Situated on

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

the Niger River, it is 280 km downstream from Timbuktu and 120 km upstream from Gao [20].

For a multifunctional dam such as the Taoussa dam, electricity is only one of the components of the project. Its supply alone will not solve the other problems related to irrigation (development of irrigated areas); and access (the road) [20].

2.1. Energy potentials in the Taoussa area

As energy potentials, options include biomass, solar power, hydroelectric power, wind power, uranium, gas and petroleum, as shown in Figure 2 and summarized in Table 1.

Figure 2. Natural resources of Mali [21].

Table 1. Status of Taoussa's energy potential

Energy potentials	Quantity
Biomass	7 million tonnes
Solar	Electric potential varies from 6 to 8 kWh/m² per day
Hydro	3.1 billion m³ of water, hydroelectric power 25 MW, annual power generation capacity 118 GWh and irrigation 139 000 ha
Wind	Average wind speeds vary from 5 m/s to 7 m/s depending on the locality.
Uranium	200 tonnes
Gas and petroleum	Around 850,000 km² of gas and oil potential

Source [20, 21]

2.2. Economy

After the 2012 crisis, Mali regained its economic dynamism from 2014 when the GDP growth rate was 7.1%. The GDP growth reached 5.3% in 2017, and 4.7% in 2018 and it is estimated to reach 5.6% in 2019. In 2019, Mali has a GDP per capita which gets up to 934 dollars or a Gross Domestic Product of 17.83 billion dollars for 20 million inhabitants. The northern regions represented 5% of national GDP, total GDP of Mali was about 27.1 milliards US$ in 2014 (1.3 milliards US$ in northern regions) [19].

The economy of Mali is dominated to a large extent by agriculture and the mining sector.

2.3. National energy policy

The National Energy Policy attempts the accomplishment of a purpose, among other things, to contribute to the sustainable development of the country, through the provision of energy services accessible to the greatest number of the population at the lowest cost and favoring the promotion of socio-economic activities; satisfy the country's energy needs in terms of quality, quantity and at the lowest cost; elaborate and update coherent and efficient planning tools and systems for the dynamic monitoring of the adequacy of supply and demand for the various energy sub-sectors [22].

3. Energy system models of IAEA

3.1. International Atomic Energy Agency's tools and models

With specific progress, the IAEA has developed a set of energy and environmental impact modelling tools appropriate for this execution of a program, as well as several mechanisms for transferring the tools and the necessary expertise to developing countries.

The IAEA transfers these models to the interested Member States, along with training and technical help, to make them available for national applications. The models provide a convenient framework for conducting energy studies covering: the analysis and assessment of energy demand; energy technology assessment including technical, economic and environmental aspects; the evaluation of alternative supply strategies for energy and electricity; financial analysis; and the assessment of environmental impacts and other external costs.

Presently, over 150 countries and 21 international organizations are using the IAEA's energy models, the IAEA's energy planning tools (models) include:

- **EBS** (Energy Balance Studio) – *to facilitate collection and organization of energy data;*
- **ESST (**Energy Scenarios Simulation Tool) – *to explore energy system development offering scenarios in terms of capacity expansion, investment and GHG emissions;*
- **MESSAGE** (Model for Energy Supply System Alternatives and their General Environmental Impacts) – *to analyse energy supply strategies;*
- **MAED** – *to study future energy demand;*
- **WASP** (Wien Automatic System Planning Package) – *to plan power sector expansion;*
- **FINPLAN** (Financial Analysis of Electric Sector Expansion Plans) – *to assess financial implications of a power project;*
- **SIMPACTS** (Simplified Approach for Estimating Impacts of Electricity Generation) – *to analyse impacts to human health and agriculture of a power project;*
- **ISED** (Indicators for Sustainable Energy Development) – *to analyse and monitor sustainable energy development strategies;*
- **CLEW** (Climate, Land use, Energy, and Water) – *to analyse interactions among key resource systems* [23].

The MAED software is used for simulating the annual electricity demand and peak load forecast for the electrification in Taoussa of Mali under different scenarios from 2020 to 2035.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

3.2. Description of MAED

The MAED model software is the simulation model (not optimization), it evaluates future energy demand for medium and long-term (not short term). MAED is composed of two parts: MAED_D and MAED_EL [24].

3.2.1. Module 1: MAED_D

Module MAED_D is used for energy demand calculations, which is capable of processing the following information: population growth, number of inhabitants per dwelling, number of electrical appliances used in households, peoples' mobility and preferences for transportation modes, national priorities for the development of certain industries or economic sectors, the evolution of the efficiency of certain types of equipment, market penetration of new technologies or energy forms, etc. and calculates the total energy demand for the desired years [24].

3.3.2. Module 2: MAED_EL

Module MAED_EL is used for (hourly electric power demand. The module uses the total annual demand of electricity for each sector (calculated in MAED_D) to determine the total electric power demand for each hour of the year or, in other words, the hourly electric load, which is imposed on the power system under consideration. The model can achieve the following:

- The trend of the average annual growth rate of electricity demand;
- The seasonal changes in electricity consumption (this variation may be reflected on a monthly or weekly basis, depending on available information);
- The changes in electricity consumption owing to the type of day being considered (i.e. working days, weekends, special holidays, etc.);
- The hourly variation in electricity consumption during the given type of day is considered.

The total energy demand for each end-use category is aggregated into three main "energy consumer" sectors: household/service; industry, including agriculture, mining, construction and manufacturing; and the transportation sector [24].

The sequence of MAED methodology is presented in Figure 3.

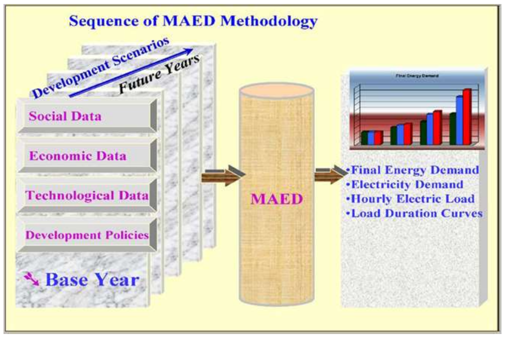


Figure 3. The sequence of MAED methodology (Source: IAEA).

The evaluation of output and the modification of initial assumptions are the basic processes that arrive at reasonable results.

4. Scenarios and background information for MAED

It is necessary to analyze the evolution of energy demand by building scenarios for future development. Scenarios are not predictions or forecasts but are descriptions of images of the future, created from models that reflect different perspectives on the past, present and future.

For the case of Mali, three scenarios were adopted, including one reference scenario and two alternative scenarios (Low and High):

- Reference scenario: it reflects the historical trend (from 2014 to 2019) taking into account the variations in GDP.
- Low scenario: under this scenario, climate change, socio-political and economic crises, threats to territorial integrity will plague Mali and continue.
- High scenario: It reflects a more optimistic view of the future, according to state forecasts.

The three scenarios were developed based on four groups of coherent hypotheses concerning:

- Demographic evolution;
- Economic development;
- Lifestyle change;
- Technological change.

4.1. Input data from the national energy authority of Mali for MAED_D

4.1.1. Assumptions on demographic development

The demographic change assumption is identical for all scenarios as shown in Table 2.

Table 2. Evolution of the demography in the Taoussa area

Item	Unit	2020	2025	2030	2035
Population	Thousand	754.073	895.602	1,089.637	1,351.401
Population growth rate	% per annum	-	3.500	4.000	4.400
Urban population ratio	%	42.000	44.000	46.000	48.000
Number of people per household (urban)	/	6.000	5.900	5.700	5.000
Number of urban households	Thousand	52.785	66.791	82.616	121.886
Rural population ratio	%	58.000	56.000	54.000	52.000
Number of people per household (rural)	/	10.830	10.000	9.000	8.000
Number of rural households	Thousand	40.384	49.258	61.423	82.527
Potential labour force ratio	%	51.000	51.000	54.000	57.000
Participating labour force	%	49.300	49.500	52.500	55.500
Active labour force	Thousand	189.597	226.095	290.223	401.651
Population ratio in cities with public transport	%	25.000	28.000	28.667	28.667

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

Population inside large cities	Thousand	188.518	250.769	293.468	363.968

4.1.2. Assumptions on economic development assumptions

These three scenarios share certain government economic policy objectives, namely: poverty eradication, infrastructure development, food security, economic stabilization (inflation, internal and external debt, etc.), etc.

The GDP growth rates of the three scenarios are:

- Reference scenario: 3.6% till the year 2025, 4.4% during 2026–2030 and 4.6% during 2031–2035 (historical trend);
- Low scenario: 2% till the year 2025, 2.5% during 2026–2030 and 2.5% during 2031–2035 (crisis situation);
- High scenario: 6.1% till the year 2025, 6.5% during 2026–2030 and 6.4% during 2031–2035 (government objectives).

Table 3. Total GDP and GDP structure by main economic sectors for reference scenario

Item	Unit	2020	2025	2030	2035
GDP	US$ Billion	1.30	1.55	1.92	2.41
GDP Growth rate	% p.a.	-	3.6	4.4	4.6
GDP per capita	US$ Billion /Cap	1.72	1.73	1.77	1.78
Sectorial shares of GDP					
Agriculture	%	30.9	30.0	28.0	27.0
Construction	%	5.1	5.6	6.0	7.0
Mining	%	9.5	9.0	7.0	6.0
Manufacturing	%	21.5	21.5	22.0	23.0
Service	%	30.7	30.5	34.0	33.0
Energy	%	2.3	3.4	3.0	4.0
Total	%	100	100	100	100

4.1.3. Assumptions on lifestyle change

A common assumption for all scenarios regarding the number of persons per household:

- Urban areas: 5.9 until 2025, 5.7 from 2026 to 2030, and 5.0 after 2030;
- Rural areas: 10 until 2025, 9 from 2026 to 2030 and 8 after 2030.

Table 4. Dwelling factor for appliances & lighting: electricity penetration

Area	Scenario	2020	2025	2030	2035
	Low	62%	65%	68%	70%
	Reference	62%	82%	90%	95%
Urban	High	62%	85%	95%	100%

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

	Low	20%	25%	35%	50%
	Reference	20%	35%	50%	60%
Rural	High	20%	40%	55%	65%

Table 5. Dwelling factor for appliances & lighting: specific electricity requirements (kWh/dw/yr)

Area	Scenario	2020	2025	2030	2035
	Low	2131.23	2195.17	2261.02	2328.85
	Reference	2131.23	2237.79	2349.68	2467.17
Urban	High	2131.23	2344.35	2578.79	2836.67
	Low	763.24	801.40	841.47	883.55
	Reference	763.24	839.56	923.52	1015.87
Rural	High	763.24	877.73	1009.38	1160.79

4.1.4. Assumptions on technological development

Growth in the energy intensities of fuels and specific uses of electricity in all sectors is based on the following aspects:

- Introduction of agricultural machinery in Agriculture;
- Mechanisation of construction and mining activities;
- Introduction of engines and other supplementary equipment in the manufacturing industry;
- Introduction of IT equipment and other technologies in services.

Thermal process efficiencies will increase in all scenarios, but at different rates:

- Low Scenario: more pessimistic than the historical pace;
- Reference scenario: keep the historical pace;
- High Scenario: more optimistic than the historical pace.

Traditional fuels will be replaced by commercial fossil fuels, but at different rates:

- Low scenario: at a slow pace;
- Reference scenario: at a moderate pace;
- High Scenario: at an accelerated pace.

4.1.5. Technological parameters

The energy demand is calculated separately for four major aggregated sectors: industry, transportation, service and household. The calculation of the energy demand of each sector is performed in a similar procedure, in which the demand for each end-use category of energy is driven by one or several socioeconomic and technological parameters, whose values are given as part of the scenarios.

The technological parameters are:

- *Industry (ACM (agriculture, construction, mining) and manufacturing)*

energy intensities ACM & manufacturing, efficiencies & penetrations in ACM and efficiencies, penetrations & factors in manufacturing;

- *Transport*

generation of freight-kilometers, modal split of freight transportation, energy intensities, modal split of cars intercity transportation, load factors (person per mode type), and energy consumption of international transportation.

- *Household*

shares by dwelling type, dwelling sizes by dwelling type, dwelling factors for water heating, dwelling factors for cooking, dwelling factors for air conditioning, dwelling factors for appliances, dwelling factors for lighting and energy intensities.

- *Service sector*

Labour force, floor area per employee, factor for air conditioning, energy intensities, penetration & efficiencies.

MAED_D requires data on technological parameters [25].

4.2. Input data for MAED_EL

Related input parameters are shown in Tables 6 to 8.

Table 6. Electricity supplied from the grid for each sector

Sectors	Unit	2020	2025	2030	2035
Industry	%	80	80	80	80
Household	%	50	53	53	53
Service	%	60	65	65	65

Table 7. Electricity transmission and distribution system losses

Industry	Household	Service
5%	20%	15%

Table 8. Calendar definitions

Season	Starting date	Type of days
Dry cool 1	January 01	Working days
Dry hot	March 11	Friday
Wet	July 01	Saturday-Sunday-Holiday
Dry cool 2	November 18	

Coefficients definition of the base year (2019):

Figure 4 shows the Hourly load curve of the Taoussa area for the base year 2019. It allows a more detailed analysis (hour by hour) of consumption, it can be seen that the minimum load, the electricity consumption is 0.91 MW. After all, the peak load should only be 5.90 MW.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

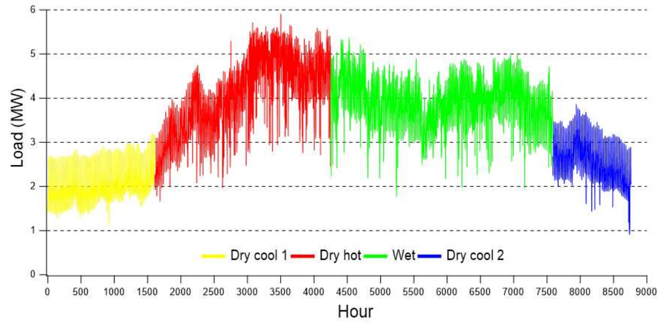


Figure 4. Hourly load curve (2019)

Figures 5, 6 and table 9 show the weekly, daily and hourly load coefficients calculated over the hourly load curve during the base year.

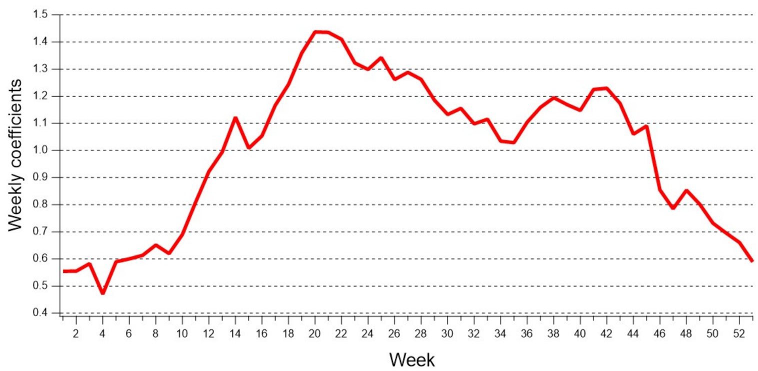


Figure 5. Weekly load coefficients curve of consumption during the base year.

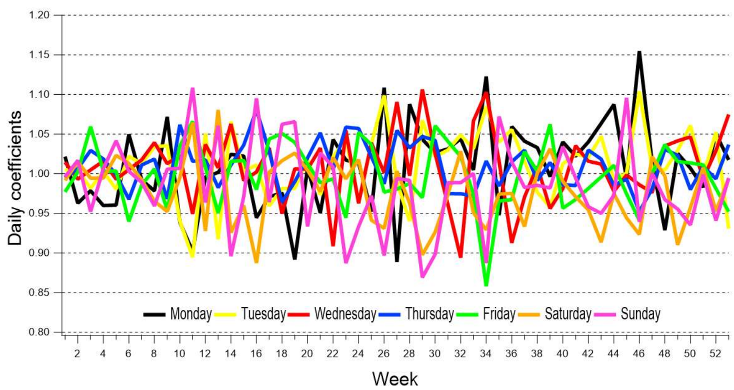


Figure 6. Daily load coefficients for each day of the base year.

Table 9. Hourly load coefficients for typical days by season

	Season											
	Dry cool 1			Dry hot			Wet			Dry cool 2		
Hour	Working day	Friday	Weekend	Working day	Friday	Weekend	Working day	Friday	Weekend	Working day	Friday	Weekend
0	0.968	1.004	0.998	1.012	1.029	1.033	1.017	1.033	1.030	1.001	1.030	1.042
1	0.881	0.909	0.903	0.976	0.990	0.987	0.971	0.987	0.992	0.940	0.907	0.944

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

2	0.828	0.855	0.854	0.941	0.962	0.968	0.938	0.948	0.970	0.899	0.864	0.897
3	0.798	0.821	0.823	0.919	0.913	0.935	0.910	0.919	0.938	0.860	0.825	0.864
4	0.786	0.809	0.806	0.894	0.888	0.911	0.879	0.892	0.914	0.830	0.807	0.834
5	0.790	0.803	0.806	0.867	0.863	0.890	0.849	0.872	0.887	0.814	0.791	0.817
6	0.842	0.834	0.839	0.860	0.846	0.880	0.830	0.834	0.876	0.830	0.806	0.816
7	0.915	0.850	0.879	0.861	0.833	0.883	0.829	0.811	0.876	0.846	0.812	0.807
8	0.894	0.870	0.875	0.876	0.850	0.897	0.843	0.803	0.894	0.824	0.793	0.820
9	0.877	0.858	0.884	0.927	0.957	0.923	0.944	0.984	0.911	0.863	0.866	0.879
10	0.899	0.878	0.911	0.958	1.006	0.954	0.986	0.995	0.950	0.906	0.914	0.911
11	0.918	0.942	0.930	1.019	1.014	0.978	1.021	1.008	0.978	0.937	0.965	0.921
12	0.954	0.978	0.961	1.067	1.077	1.033	1.058	1.061	1.016	0.989	1.007	0.960
13	1.001	0.910	0.992	1.110	1.033	1.058	1.081	1.002	1.050	1.016	1.035	0.973
14	0.995	0.952	0.982	1.069	1.090	1.040	1.084	1.076	1.047	1.011	1.031	0.998
15	1.019	1.009	1.007	1.088	1.081	1.069	1.116	1.099	1.072	1.026	1.081	1.010
16	1.036	1.051	1.016	1.085	1.093	1.047	1.109	1.097	1.059	1.047	1.023	1.046
17	1.064	1.052	1.025	1.032	1.044	1.023	1.045	1.046	1.034	1.048	1.055	1.036
18	1.079	1.073	1.063	0.954	0.949	0.972	0.970	0.981	0.981	1.078	1.096	1.072
19	1.332	1.346	1.314	1.027	0.985	1.015	1.046	1.074	1.002	1.267	1.280	1.288
20	1.372	1.377	1.350	1.098	1.096	1.115	1.123	1.135	1.115	1.306	1.308	1.331
21	1.363	1.372	1.361	1.126	1.137	1.157	1.148	1.158	1.156	1.313	1.318	1.332
22	1.272	1.295	1.287	1.139	1.153	1.150	1.129	1.123	1.157	1.244	1.255	1.270
23	1.116	1.153	1.132	1.095	1.109	1.082	1.072	1.060	1.093	1.103	1.132	1.134

5. Results and discussions

5.1 Final electricity demand by sector

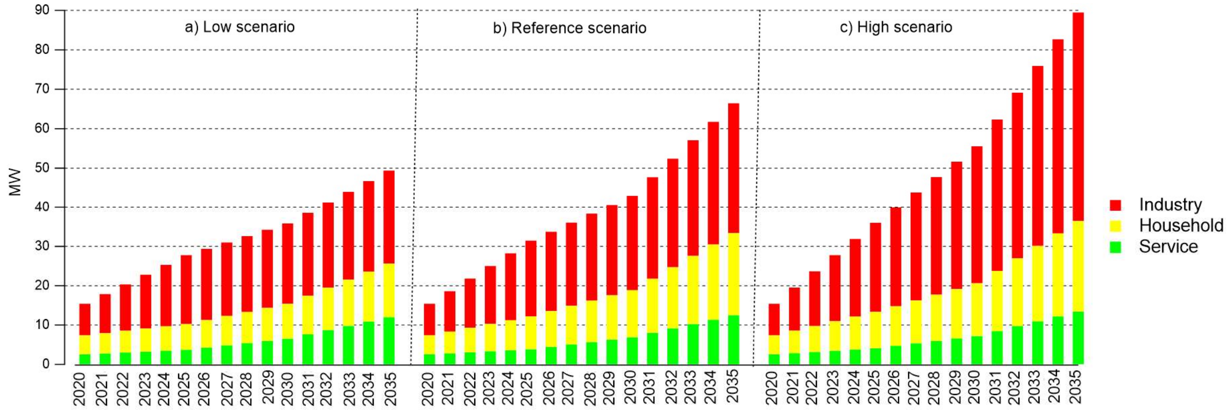


Figure 18. Final electricity demand by sector.

In Figure 18, the growth rate of electricity demand is slightly higher during the 2020-2025 period, 12.51% for the low scenario (LS), 15.37% for the reference scenario (RS) and 18.6% for the high scenario (HS), there is a slow increase in electricity demand for 5.94%, 7.79% and 9.54% in the LS, RS and HS respectively within 2026-2035 period.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

These represent average annual growth rates over the study period of about 8.13% in the LS, 10.31% in the RS and 12.56% in the HS. The percentage increase by sector is:

- LS: 7.70% in industry, 7.20% in household and 10.93% in service;
- RS: 10.10% in industry, 10.29% in household and 11.24% in service;
- HS: 13.66% in industry, 11.03% in household and 11.79% in service.

The share by sector is:

- LS: 56.77% in industry, 25.60% in household and 17.63% in service;
- RS: 56.13% in industry, 28.55% in household and 15.31% in service;
- HS: 61.16% in industry, 25.67% in household and 13.17% in service.

5.2 Demography and comparative evolution of GDP by scenario

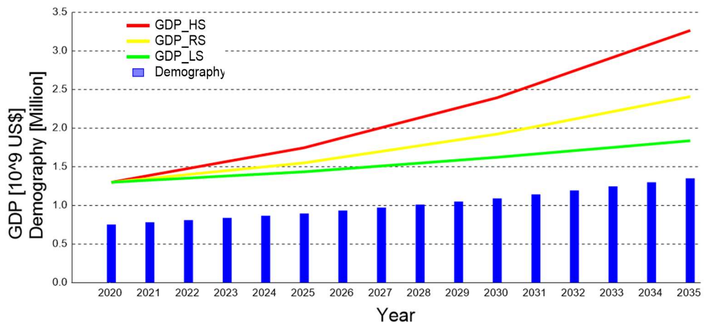


Figure 19. Evolution of the demography and the GDP by scenario.

The projection for the total population and GDP of the Taoussa area are presented in Figure 19, it has been found that the demography will grow up annually at an average rate of 3.97% and the annual average GDP growth rates will be 2.33%, 4.20% and 6.33% for LS, RS and HS, respectively.

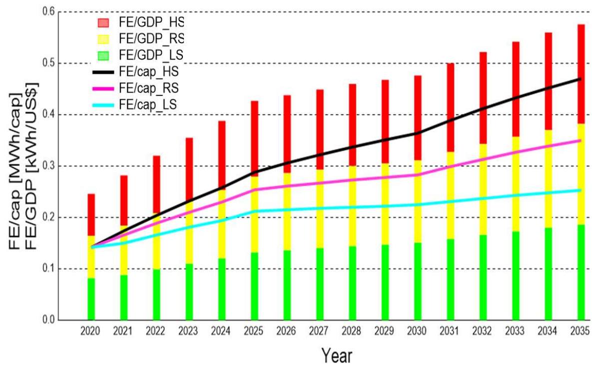


Figure 20. Final electricity demand per capita (FE/cap) and per GDP (FE/ GDP).

The forecast annual average growth rate of GDP/Cap and electricity demand/Cap is shown in Figure 20, during 2020–2035, the GDP/Cap will be 4% for the LS, 6.3% for the RS and 8.5% for the HS whereas the electricity demand/Cap is projected to account for 5.6%, 6.1% and 6% in the LS, RS and HS respectively.

5.3 Total annual electric energy demand and peak load

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

Simulation of total hourly electricity demand forecast for the period from 2020-2035 must meet the peak load time, it is a short period of critical time during which electricity consumption is highest within a year, could have an interesting strong influence on the reliability of electricity supply.

In Table 10, the times ahead system peak load have some illustrative observation that the average annual growth rate of the system peak between 2020 and 2035 represents 7.92% in the Low scenario, in this case, the system peak demand will increase from 20.8 MW in 2020 to 64.88 MW in 2035.

The system peak electricity demand time of day in the Reference Scenario is forecasted to increase at 10.53% per annual from beginning to end of the study period, from 25.35 MW in 2021 to 92.2 MW in 2035. On the other hand, the system peak demand in the High Scenario increases at approximately 12.91% annual, from 26.65 MW in 2021 to 126.22 MW in 2035.

The main objective of the project is to contribute to the sustainable development of the regions of northern Mali, as well as poverty reduction, environmental management and specifically, aims in the long term, to produce 332.57 GWh/yr, 472.61 GWh/yr and 647.02 GWh/yr electricity in the low, reference and high scenarios by 2035.

Table 10. Annual electric energy demand, peak load and increase ratio

	Low Scenario				Reference Scenario				High Scenario			
Year	Energy (GWh)	Increase ratio (%)	Peak (MW)	Increase ratio (%)	Energy (GWh)	Increase ratio (%)	Peak (MW)	Increase ratio (%)	Energy (GWh)	Increase ratio (%)	Peak (MW)	Increase ratio (%)
2020	106.84	-	20.8	-	106.84	-	20.8	-	106.84	-	20.8	-
2021	117.28	10	22.87	10	129.97	22	25.35	22	136.65	28	26.65	28
2022	134.17	14	26.16	14	153.11	18	29.86	18	166.47	22	32.46	22
2023	151.07	13	29.45	13	176.24	15	34.36	15	196.29	18	38.27	18
2024	167.96	11	32.72	11	199.38	13	38.84	13	226.11	15	44.05	15
2025	189	13	36.86	13	227.48	14	44.37	14	261.35	16	50.98	16
2026	199.82	6	38.97	6	243.75	7	47.54	7	289.87	11	56.53	11
2027	210.64	5	41.08	5	260.02	7	50.71	7	318.4	10	62.09	10
2028	221.45	5	43.11	5	276.28	6	53.79	6	346.92	9	67.54	9
2029	232.27	5	45.31	5	292.55	6	57.07	6	375.44	8	73.24	8
2030	243.09	5	47.42	5	308.82	6	60.25	6	403.97	8	78.81	8
2031	260.98	7	50.91	7	341.58	11	66.63	11	452.58	12	88.28	12
2032	278.88	7	54.31	7	374.33	10	72.89	9	501.19	11	97.6	11
2033	296.78	6	57.87	7	407.09	9	79.38	9	549.8	10	107.21	10
2034	314.67	6	61.35	6	439.85	8	85.76	8	598.41	9	116.68	9
2035	332.57	6	64.88	6	472.61	7	92.2	8	647.02	8	126.22	8

5.4 Comparative evolution between annual electricity demand and peak load by scenario

The difference between the annual electricity demand and peak load forecasts is relatively big for all scenarios. This difference will increase at an average annual growth rate of about 7.49%, 10.31% and 13.87% in the Low Scenario from 5.39 MW in 2020 to 15.48 MW by 2035, in the Reference Scenario from 6.73 MW in 2021 to 25.74 MW by 2035, in the High Scenario from 7.12 MW in 2020 to 36.75 MW by 2035 respectively. The following graph (Figure 21) presents a comparison of these forecasts for three scenarios.

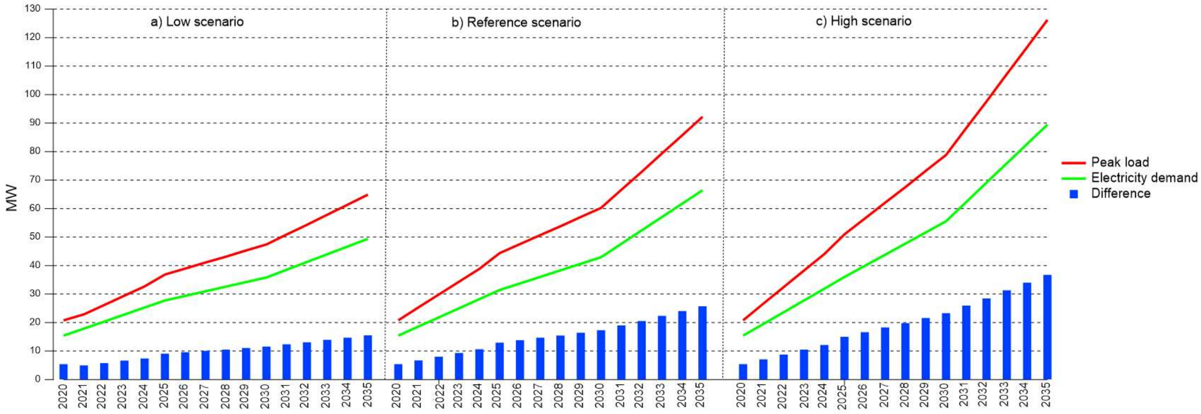


Figure 21. Relation between Peak load and Electricity demand (high scenario).

The ways to reduce the electricity demand during peak load include replacing energy-intensive appliances with more energy-efficient ones, shifting the operation of electricity-consuming equipment during a peak period to periods of inactivity (off-peak hours), organising the implementation of equipment according to a plan, raising awareness of the population towards energy saving, and relieving certain groups of necessary equipment.

5.5 Annual load duration curves for the reference scenario

Figure 22 shows the annual load duration curves (LDC) permit to view the proportion of the time during which the consumption is peak load or minimum load. It is indicated that the peak load during 2020 to 2035 are in the hot dry season between 17th - 23rd in May at 9 p.m., and the minimum load are between 15th - 21st in January at 7 a.m.

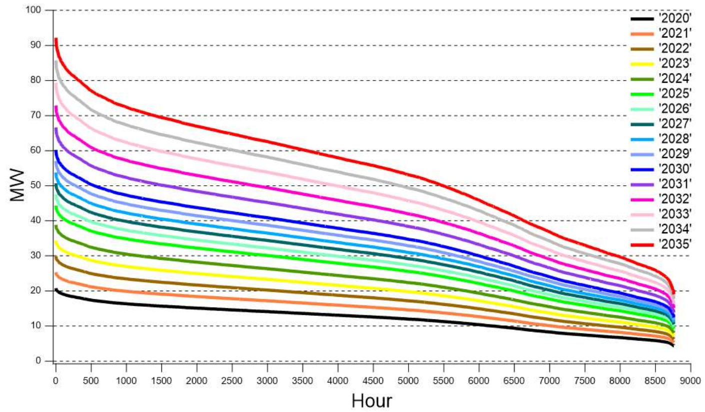


Figure 22. Annual load duration curve of the study period.

The future work will be based on the hybrid renewable energies (solar power, hydroelectric power, wind power) optimization technique using the MESSAGE model to satisfy this electricity demand.

6. Conclusion

During the study period 2020–2035 MAED analysis has shown that the GDP, electric capacity and electricity demand will increase to 1.84 billion US$, 49.40 MW and 332.57 GWh for the Low scenario (LS), 2.41 billion US$, 66.46 MW and 472.61 GWh for the Reference scenario (RS), 3.27 billion US$, 89.47 MW and 635 GWh for the High scenario (HS) respectively. The total electricity demand in the Taoussa area increased at an average rate of 8.13% in the LS, 10.31% in the RS and 12.56% in the HS in all sectors. The demographic is identical for all scenarios and will increase to 1.351 million people.

The industry sector (including manufacturing construction, mining and agriculture) will be the biggest electricity consumer of the Taoussa area. Under the calculated growth, the system peak load, in planning horizon, the electricity peak demand is expected to grow at about 7.92%, 10.53% and 12.91% corresponding respectively to the three scenarios (LS, RS and HS). The days of peak load are in the hot dry season between 17th -23rd in May. The growth rate has gradually increased year by year. Based on the calculation results, the following conclusions can be drawn: there is a need for energy conservation and energy efficiency measures in all electricity sectors, which can reduce the future electricity demand, decrease the greenhouse gas emissions and consequently fight against climate change and bring down the public investment in the electricity production in the Taoussa area.

Funding: This research received no external funding.

Acknowledgements: The first author extends his thanks to Mr. Mario Tot from the IAEA for his help and support in the application of the energy demand assessment tool MAED. The thanks also goes to Mr. Adama Mody DIAKITE, chief, division of studies & planning, national energy authority of Mali and Mr. Isaac Goita from Taoussa planning authority for their cooperation during the data collection.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Summary annual electricity demand

Table A1. Final electricity demand, percentage increase and shares by sector.

		Final electricity demand (MW)			% increase			Shares by sector (%)		
			Scenario			Scenario			Scenario	
Year	Sector	Low	Reference	High	Low	Reference	High	Low	Reference	High
	Industry	8.06	8.06	8.06	-	-	-	52.27	52.27	52.27
	Transport	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
	Household	4.82	4.82	4.82	-	-	-	31.28	31.28	31.28
	Service	2.54	2.54	2.54	-	-	-	16.46	16.46	16.46
2020	**Total**	**15.41**	**15.41**	**15.41**	-	-	**-**	**100.00**	**100.00**	**100.00**

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

	Industry	9.95	10.29	10.98	23.49	27.76	36.28	55.63	55.28	56.21
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	5.16	5.53	5.70	7.12	14.78	18.36	28.87	29.72	29.21
	Service	2.77	2.79	2.85	9.26	10.11	12.28	15.50	15.00	14.58
2021	**Total**	**17.88**	**18.62**	**19.53**	**16.03**	**20.79**	**26.73**	**100.00**	**100.00**	**100.00**
	Industry	11.84	12.53	13.90	19.02	21.73	26.62	58.18	57.41	58.78
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	5.51	6.24	6.59	6.65	12.87	15.51	27.06	28.62	27.87
	Service	3.01	3.05	3.16	8.47	9.18	10.94	14.77	13.97	13.36
2022	**Total**	**20.35**	**21.82**	**23.65**	**13.81**	**17.21**	**21.09**	**100.00**	**100.00**	**100.00**
	Industry	13.73	14.76	16.82	15.98	17.85	21.02	60.17	58.99	60.58
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	5.85	6.96	7.48	6.23	11.41	13.43	25.63	27.80	26.92
	Service	3.24	3.31	3.47	7.81	8.41	9.86	14.20	13.21	12.50
2023	**Total**	**22.82**	**25.02**	**27.77**	**12.14**	**14.69**	**17.42**	**100.00**	**100.00**	**100.00**
	Industry	15.62	17.00	19.74	13.78	15.15	17.37	61.77	60.22	61.92
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	6.19	7.67	8.36	5.87	10.24	11.84	24.49	27.17	26.22
	Service	3.48	3.56	3.78	7.25	7.76	8.97	13.74	12.62	11.86
2024	**Total**	**25.29**	**28.23**	**31.89**	**10.82**	**12.81**	**14.83**	**100.00**	**100.00**	**100.00**
	Industry	17.52	19.23	22.67	12.11	13.15	14.80	63.09	61.19	62.95
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	6.54	8.38	9.25	5.54	9.29	10.59	23.54	26.66	25.68
	Service	3.71	3.82	4.09	6.76	7.20	8.23	13.36	12.15	11.37
2025	**Total**	**27.76**	**31.43**	**36.01**	**9.77**	**11.35**	**12.92**	**100.00**	**100.00**	**100.00**
	Industry	18.11	20.21	25.12	3.37	5.05	10.84	61.63	59.89	62.95
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	7.00	9.10	10.07	7.07	8.56	8.95	23.82	26.97	25.24
	Service	4.27	4.43	4.71	15.19	16.10	15.18	14.55	13.14	11.81
2026	**Total**	**29.38**	**33.74**	**39.91**	**5.82**	**7.33**	**10.85**	**100.00**	**100.00**	**100.00**
	Industry	18.70	21.18	27.58	3.26	4.81	9.78	60.32	58.76	62.95
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	7.46	9.82	10.90	6.60	7.89	8.22	24.07	27.23	24.88
	Service	4.84	5.05	5.33	13.19	13.87	13.18	15.61	14.00	12.17
2027	**Total**	**30.99**	**36.04**	**43.82**	**5.50**	**6.83**	**9.79**	**100.00**	**100.00**	**100.00**
	Industry	19.29	22.15	30.04	3.16	4.59	8.91	59.14	57.76	62.94
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	7.92	10.53	11.73	6.19	7.31	7.59	24.29	27.47	24.58
	Service	5.40	5.66	5.96	11.65	12.18	11.64	16.56	14.77	12.48
2028	**Total**	**32.61**	**38.35**	**47.73**	**5.21**	**6.39**	**8.92**	**100.00**	**100.00**	**100.00**
	Industry	19.88	23.12	32.50	3.06	4.39	8.18	58.08	56.88	62.94
2029	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

	Household	8.38	11.25	12.56	5.83	6.81	7.06	24.50	27.68	24.32
	Service	5.96	6.28	6.58	10.44	10.86	10.43	17.43	15.44	12.74
	Total	**34.22**	**40.65**	**51.63**	**4.95**	**6.01**	**8.19**	**100.00**	**100.00**	**100.00**
	Industry	20.47	24.10	34.96	2.97	4.20	7.56	57.10	56.09	62.94
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	8.85	11.97	13.38	5.51	6.38	6.59	24.68	27.86	24.10
	Service	6.53	6.89	7.20	9.45	9.79	9.44	18.22	16.04	12.96
2030	**Total**	**35.84**	**42.96**	**55.54**	**4.72**	**5.67**	**7.57**	**100.00**	**100.00**	**100.00**
	Industry	21.13	25.90	38.57	3.25	7.49	10.33	54.81	54.35	61.88
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	9.81	13.75	15.31	10.86	14.87	14.38	25.44	28.85	24.56
	Service	7.61	8.01	8.45	16.64	16.21	17.34	19.75	16.81	13.55
2031	**Total**	**38.55**	**47.66**	**62.33**	**7.57**	**10.94**	**12.22**	**100.00**	**100.00**	**100.00**
	Industry	21.80	27.70	42.18	3.15	6.96	9.36	52.82	52.91	61.03
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	10.77	15.53	17.23	9.79	12.95	12.58	26.09	29.66	24.94
	Service	8.70	9.13	9.70	14.27	13.95	14.78	21.09	17.43	14.03
2032	**Total**	**41.26**	**52.36**	**69.11**	**7.03**	**9.86**	**10.89**	**100.00**	**100.00**	**100.00**
	Industry	22.46	29.51	45.79	3.05	6.51	8.56	51.08	51.71	60.34
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	11.73	17.31	19.16	8.92	11.46	11.17	26.67	30.33	25.25
	Service	9.79	10.24	10.94	12.48	12.24	12.88	22.26	17.95	14.42
2033	**Total**	**43.97**	**57.06**	**75.90**	**6.57**	**8.98**	**9.82**	**100.00**	**100.00**	**100.00**
	Industry	23.13	31.31	49.40	2.96	6.11	7.89	49.53	50.70	59.75
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	12.69	19.09	21.09	8.19	10.28	10.05	27.18	30.91	25.50
	Service	10.87	11.36	12.19	11.10	10.91	11.41	23.29	18.39	14.75
2034	**Total**	**46.69**	**61.76**	**82.68**	**6.17**	**8.24**	**8.94**	**100.00**	**100.00**	**100.00**
	Industry	23.79	33.11	53.02	2.88	5.76	7.31	48.16	49.83	59.26
	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Household	13.65	20.87	23.01	7.57	9.32	9.13	27.63	31.40	25.72
	Service	11.96	12.48	13.44	9.99	9.83	10.24	24.21	18.77	15.02
2035	**Total**	**49.40**	**66.46**	**89.47**	**5.81**	**7.61**	**8.21**	**100.00**	**100.00**	**100.00**

Table A2. Peak load, electric energy and load factor.

Year	Season	Maximum load (MW)			Relation to annual peak			Energy (GWh)			Load factor (%)		
		Scenario			Scenario			Scenario			Scenario		
		Low	Reference	High	Low	Reference	High	Low	Reference	High	Low	Reference	High
	Dry cool 1	12.17	12.17	12.17	0.58	0.58	0.58	11.73	11.73	11.73	59.06	59.06	59.06
	Dry hot	20.8	20.8	20.8	1	1	1	38.35	38.35	38.35	69.83	69.83	69.83
2020	Wet	19.52	19.52	19.52	0.94	0.94	0.94	46.15	46.15	46.15	70.87	70.87	70.87

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

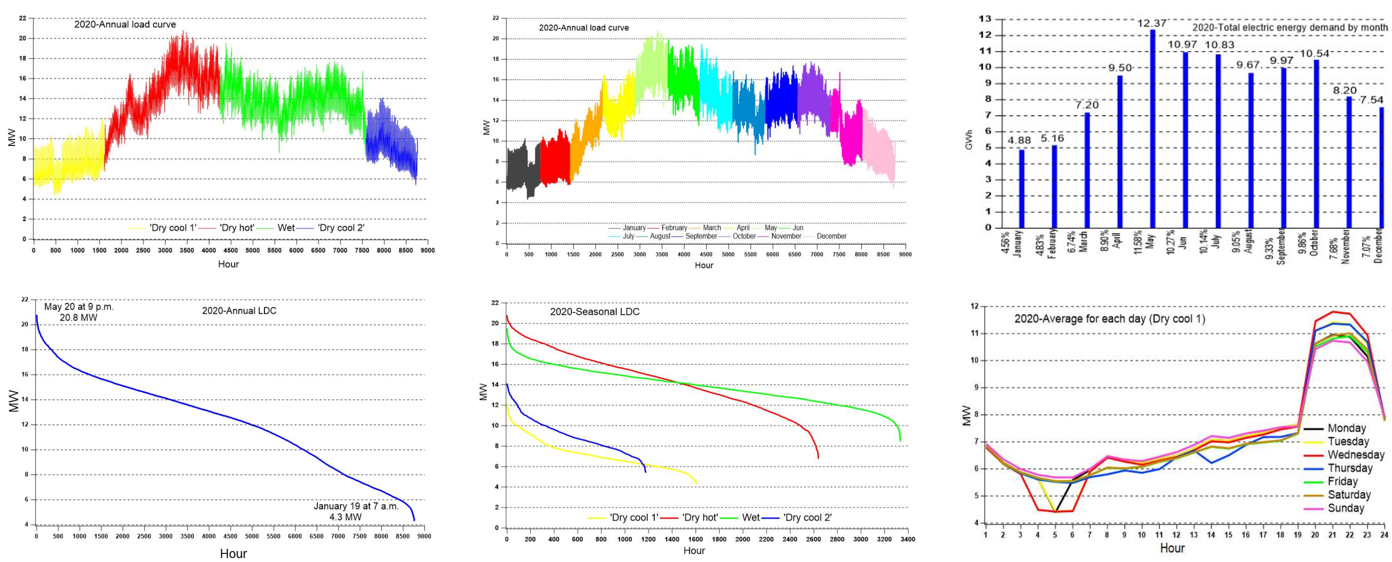
	Dry cool 2	14.12	14.12	14.12	0.68	0.68	0.68	10.6	10.6	10.6	63.84	63.84	63.84
	Dry cool 1	13.38	14.82	15.59	0.58	0.58	0.58	12.77	14.15	14.88	59.37	59.37	59.37
	Dry hot	22.87	25.35	26.65	1	1	1	42.31	46.89	49.3	70.07	70.07	70.07
	Wet	21.46	23.78	25.01	0.94	0.94	0.94	50.63	56.1	58.99	70.71	70.71	70.71
2021	Dry cool 2	15.53	17.21	18.09	0.68	0.68	0.68	11.58	12.83	13.49	63.41	63.41	63.41
	Dry cool 1	15.3	17.46	18.98	0.58	0.58	0.58	14.67	16.74	18.21	59.64	59.64	59.64
	Dry hot	26.16	29.86	32.46	1	1	1	48.54	55.39	60.23	70.28	70.28	70.28
	Wet	24.55	28.02	30.46	0.94	0.94	0.94	57.79	65.94	71.7	70.55	70.55	70.55
2022	Dry cool 2	17.76	20.27	22.04	0.68	0.68	0.68	13.17	15.03	16.34	63.05	63.05	63.05
	Dry cool 1	18.07	21.09	23.49	0.61	0.61	0.61	16.61	19.38	21.58	57.15	57.15	57.15
	Dry hot	29.45	34.36	38.27	1	1	1	54.81	63.94	71.21	70.48	70.48	70.48
	Wet	27.64	32.25	35.91	0.94	0.94	0.94	64.91	75.73	84.35	70.4	70.4	70.4
2023	Dry cool 2	19.99	23.33	25.98	0.68	0.68	0.68	14.74	17.19	19.15	62.67	62.67	62.67
	Dry cool 1	19.13	22.71	25.76	0.58	0.58	0.58	18.32	21.75	24.67	58.68	58.68	58.68
	Dry hot	32.72	38.84	44.05	1	1	1	59.81	71	80.52	69.25	69.25	69.25
	Wet	30.7	36.44	41.33	0.94	0.94	0.94	72.96	86.61	98.22	71.24	71.24	71.24
2024	Dry cool 2	22.21	26.36	29.9	0.68	0.68	0.68	16.86	20.01	22.7	64.56	64.56	64.56
	Dry cool 1	21.56	25.95	29.81	0.58	0.58	0.58	20.42	24.58	28.24	58.91	58.91	58.91
	Dry hot	36.86	44.37	50.98	1	1	1	67.68	81.47	93.59	69.55	69.55	69.55
	Wet	34.59	41.64	47.83	0.94	0.94	0.94	82	98.7	113.39	71.06	71.06	71.06
2025	Dry cool 2	25.02	30.12	34.6	0.68	0.68	0.68	18.89	22.74	26.12	64.19	64.19	64.19
	Dry cool 1	22.79	27.8	33.06	0.58	0.58	0.58	21.66	26.42	31.42	59.11	59.11	59.11
	Dry hot	38.97	47.54	56.53	1	1	1	71.84	87.64	104.22	69.83	69.83	69.83
	Wet	36.57	44.61	53.05	0.94	0.94	0.94	86.46	105.47	125.42	70.87	70.87	70.87
2026	Dry cool 2	26.45	32.27	38.38	0.68	0.68	0.68	19.86	24.22	28.81	63.84	63.84	63.84
	Dry cool 1	24.02	29.66	36.31	0.58	0.58	0.58	22.93	28.31	34.67	59.37	59.37	59.37
	Dry hot	41.08	50.71	62.09	1	1	1	75.98	93.8	114.86	70.07	70.07	70.07
	Wet	38.55	47.58	58.27	0.94	0.94	0.94	90.92	112.24	137.44	70.71	70.71	70.71
2027	Dry cool 2	27.88	34.42	42.15	0.68	0.68	0.68	20.79	25.67	31.43	63.41	63.41	63.41
	Dry cool 1	26.46	33.01	41.44	0.61	0.61	0.61	24.64	30.75	38.61	57.08	57.08	57.08
	Dry hot	43.11	53.79	67.54	1	1	1	80.22	100.08	125.67	70.48	70.48	70.48
	Wet	40.46	50.47	63.38	0.94	0.94	0.94	95.02	118.54	148.85	70.4	70.4	70.4
2028	Dry cool 2	29.27	36.51	45.85	0.68	0.68	0.68	21.57	26.91	33.79	62.67	62.67	62.67
	Dry cool 1	26.5	33.38	42.83	0.58	0.58	0.58	24.93	31.4	40.29	58.5	58.5	58.5
	Dry hot	45.31	57.07	73.24	1	1	1	82.49	103.9	133.34	68.96	68.96	68.96
	Wet	42.52	53.55	68.73	0.94	0.94	0.94	101.25	127.53	163.66	71.38	71.38	71.38
2029	Dry cool 2	32.65	41.13	52.78	0.72	0.72	0.72	23.6	29.73	38.15	61.46	61.46	61.46
	Dry cool 1	27.73	35.23	46.09	0.58	0.58	0.58	26.19	33.27	43.52	58.72	58.72	58.72
	Dry hot	47.42	60.25	78.81	1	1	1	86.7	110.15	144.08	69.25	69.25	69.25
	Wet	44.5	56.53	73.95	0.94	0.94	0.94	105.76	134.36	175.75	71.24	71.24	71.24
2030	Dry cool 2	32.19	40.9	53.5	0.68	0.68	0.68	24.44	31.05	40.62	64.56	64.56	64.56
2031	Dry cool 1	29.77	38.96	51.63	0.58	0.58	0.58	28.2	36.91	48.9	58.91	58.91	58.91

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

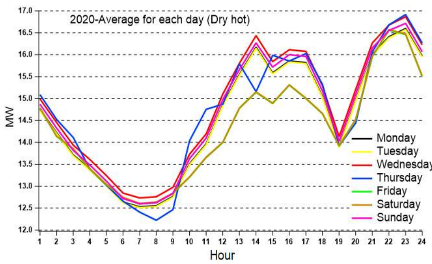
	Dry hot	50.91	66.63	88.28	1	1	1	93.46	122.32	162.08	69.55	69.55	69.55
	Wet	47.77	62.52	82.83	0.94	0.94	0.94	113.23	148.2	196.36	71.06	71.06	71.06
	Dry cool 2	34.56	45.23	59.92	0.68	0.68	0.68	26.09	34.14	45.23	64.19	64.19	64.19
	Dry cool 1	31.76	42.63	57.08	0.58	0.58	0.58	30.74	41.26	55.24	59.31	59.31	59.31
	Dry hot	54.31	72.89	97.6	1	1	1	100.45	134.83	180.53	70.07	70.07	70.07
	Wet	50.96	68.4	91.58	0.94	0.94	0.94	120.2	161.34	216.02	70.71	70.71	70.71
2032	Dry cool 2	36.86	49.48	66.25	0.68	0.68	0.68	27.49	36.9	49.4	63.41	63.41	63.41
	Dry cool 1	33.84	46.42	62.7	0.58	0.58	0.58	32.46	44.52	60.13	59.64	59.64	59.64
	Dry hot	57.87	79.38	107.21	1	1	1	107.37	147.29	198.92	70.28	70.28	70.28
	Wet	54.3	74.49	100.6	0.94	0.94	0.94	127.81	175.32	236.78	70.55	70.55	70.55
2033	Dry cool 2	39.28	53.89	72.78	0.68	0.68	0.68	29.13	39.96	53.96	63.05	63.05	63.05
	Dry cool 1	37.65	52.63	71.6	0.61	0.61	0.61	34.6	48.36	65.8	57.15	57.15	57.15
	Dry hot	61.35	85.76	116.68	1	1	1	114.16	159.57	217.1	70.48	70.48	70.48
	Wet	57.57	80.48	109.48	0.94	0.94	0.94	135.22	189	257.14	70.4	70.4	70.4
2034	Dry cool 2	41.65	58.22	79.2	0.68	0.68	0.68	30.7	42.91	58.38	62.67	62.67	62.67
	Dry cool 1	37.94	53.92	73.82	0.58	0.58	0.58	35.69	50.72	69.44	58.5	58.5	58.5
	Dry hot	64.88	92.2	126.22	1	1	1	118.11	167.85	229.79	68.96	68.96	68.96
	Wet	60.88	86.51	118.44	0.94	0.94	0.94	144.97	206.02	282.04	71.38	71.38	71.38
2035	Dry cool 2	46.76	66.44	90.96	0.72	0.72	0.72	33.79	48.02	65.74	61.46	61.46	61.46

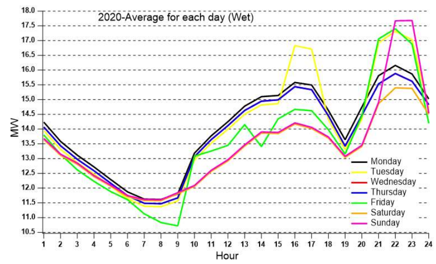
Figure A1. Load curves, load duration curves, total electric demand by month and daily load curve (Reference scenario).

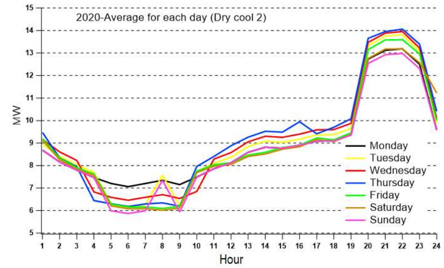
2020



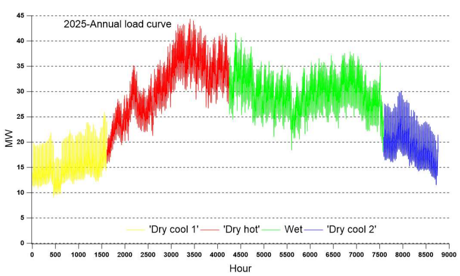
Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 October 2021 doi:10.20944/preprints202110.0182.v1

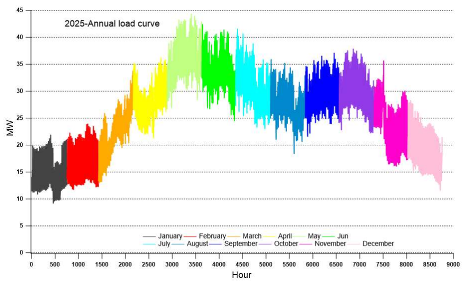


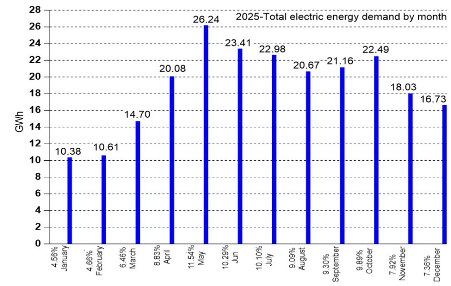


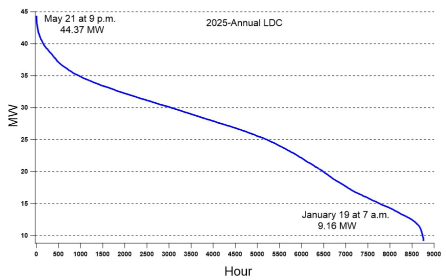


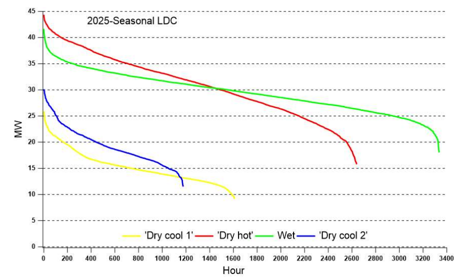
2025

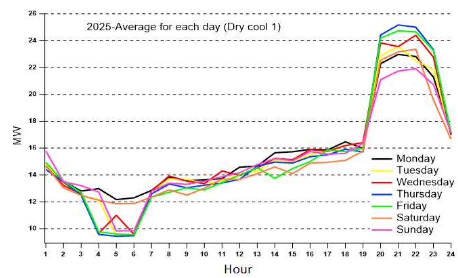


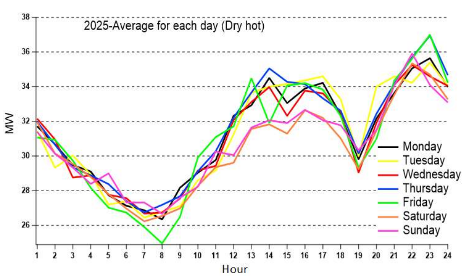


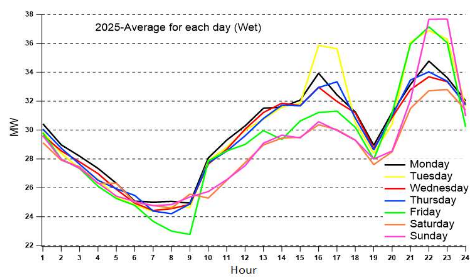


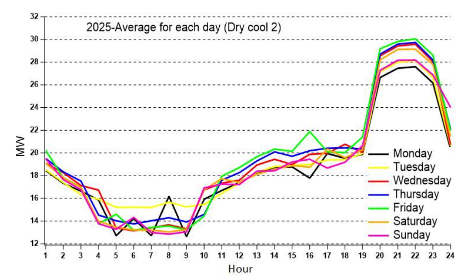




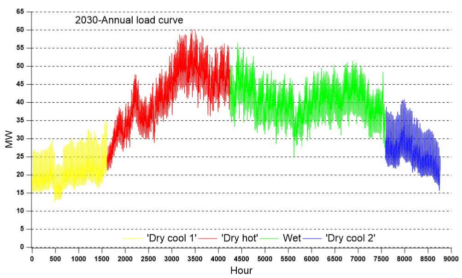


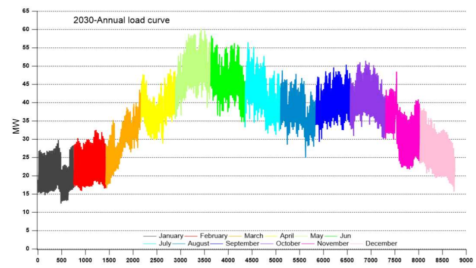


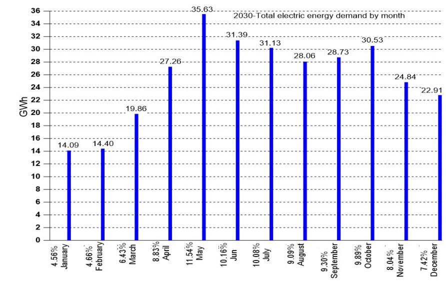


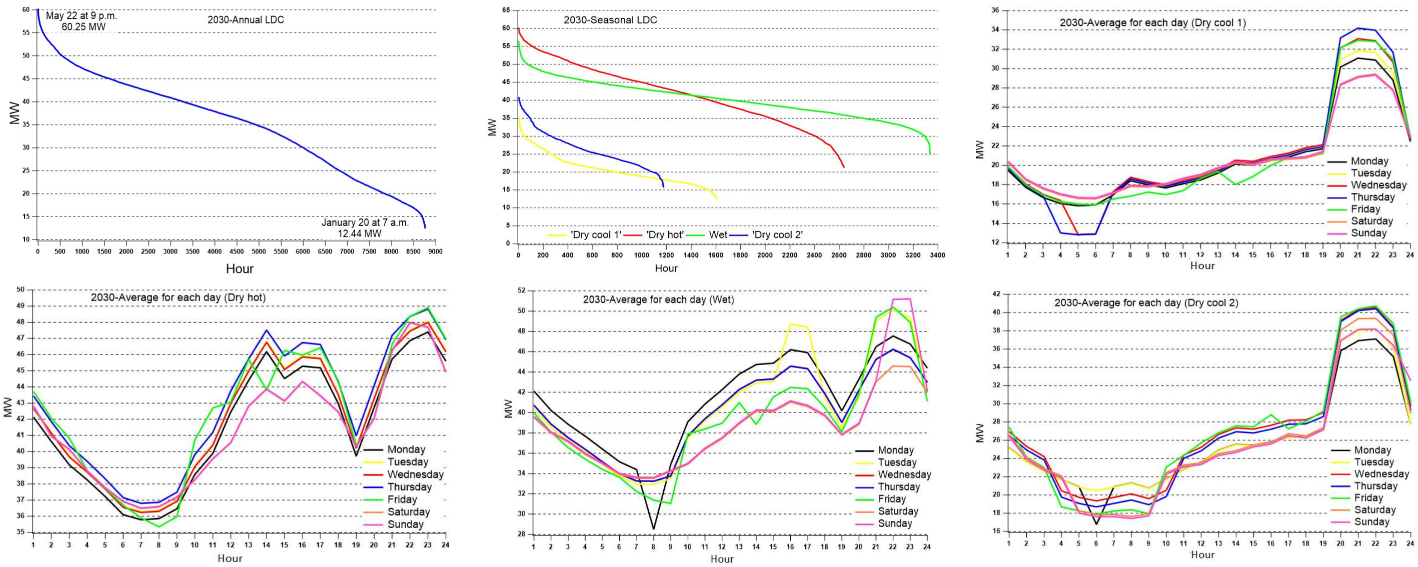


2030

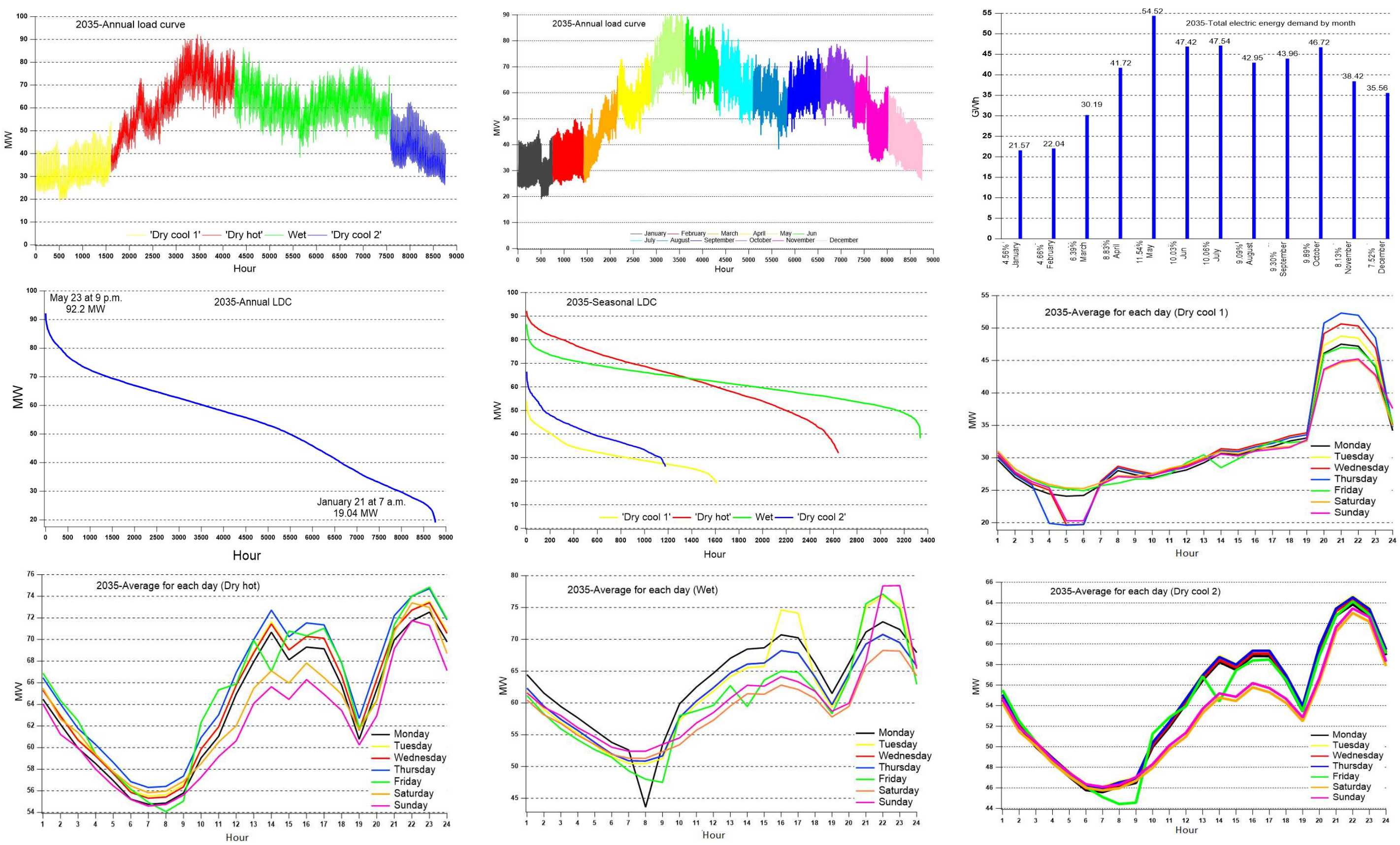








2035



References

1. IAEA. Indicators for Sustainable Energy Development. **2002**. [CrossRef]
2. IAEA. IAEA Tools and Methodologies for Energy System Planning and Nuclear Energy System Assessments. **2009**. [CrossRef]
3. IAEA. Facilitate and supervise fellowships on IAEA's Model for Energy Demand Analysis (MAED) for Mali and Senegal. **2012**.

 doi:10.20944/preprints202110.0182.v1

4. Soliman, S.A.-h.; and Al-Kandari, A.M. Electrical load forecasting: modeling and model construction. **2010**. Elsevier. [CrossRef]
5. Song, Q.; Zhao, X.; Feng, Z.; An, Y.; Song, B. Hourly electric load forecasting algorithm based on echo state neural network. in 2011 Chinese Control and Decision Conference (CCDC). *IEEE*. **2011**. [CrossRef]
6. Abdel-Aal, R. Univariate modeling and forecasting of monthly energy demand time series using abductive and neural networks. *Comput. & Ind. Eng.* **2008**, 54(4), p. 903-917. [CrossRef]
7. Almazrouee, A.I.; Almeshal, A.M.; Almutairi A.S.; Alenezi, M.R.; Alhajeri, S.N. Long-term forecasting of electrical loads in kuwait using prophet and holt–winters models. *Appl. Sci*. **2020**, **10**(16), p. 5627. [CrossRef]
8. Yazici, I., L. Temizer, and O.F. Beyca, *Short term electricity load forecasting with a nonlinear autoregressive neural network with exogenous variables (NarxNet)*, in *Industrial Engineering in the Big Data Era*. **2019**, Springer. p. 259-270.
9. Nia, A.R.; Awasthi, A.; Bhuiyan, N. Industry 4.0 and demand forecasting of the energy supply chain: A. *Comput. & Ind. Eng*. **2021**. 154, p. 107128. [CrossRef]
10. Ghalehkhondabi, I.; Ardjmand, E.; Weckman, G. R. W.; Young, A. An overview of energy demand forecasting methods published in 2005–2015. *Energy Systems*, **2017**, **8**(2): p. 411-447. [CrossRef]
11. Jornaz, A.; Samaranayake, V.A. A Multi-Step Approach to Modeling the 24-hour Daily Profiles of Electricity Load using Daily Splines. *Energies*, **2019**, 12(21), p. 4169. [CrossRef]
12. Kiprijanovska, I.; Stankoski, S.; Ilievski, I.; Jovanovski, S.; Gams, M.; Gjoreski, H. HousEEC: Day-Ahead Household Electrical Energy Consumption Forecasting Using Deep Learning. *Energies*, **2020**, 13(10), p. 2672. [CrossRef]
13. Ali, D.; Yohanna, M.; Puwu, M.; Garkida, B. Pacific Science Review A: Natural Science and Engineering Long-term load forecast modelling using a fuzzy logic approach. Natu. Sci. and Eng. **2016**, 18(2), p. 123-127. [CrossRef]
14. Bano, H.; Tahir, A.; Ali, I.; ul Hussen Khan, R. J.; Haseeb, A.; Javaid, N. Electricity Load and Price Forecasting Using Enhanced Machine Learning Techniques. in International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing. **2019**. Springer. [CrossRef]
15. Hainoun, A.; Seif-Eldin, M.; Almoustafa, S. Analysis of the Syrian long-term energy and electricity demand projection using the end-use methodology. *Energy Policy*, **2006**, 34(14), p. 1958-1970. [CrossRef]
16. Yuksek, O.; Komurcu, M. I.; Yuksel, I.; Kaygusuz, K. Hydroelectric power: a key potential in meeting the long term electric energy demand of Turkey. *Energy Policy*, **2006**, 34(17): p. 3093-30103. [CrossRef]
17. Kichonge, B.; John, G.; Mkilaha, I.; Hameer, S. Modelling of future energy demand for Tanzania. *J. Energy Technol. and Policy*, **2014**, 4(7), p. 16-31. [CrossRef]
18. Hainoun, A. Construction of the hourly load curves and detecting the annual peak load of future Syrian electric power demand using bottom-up approach. *I. J. Electrical Power & Energy Syst.* **2009**, 31(1), p. 1-12. [CrossRef]
19. CSAO/OCDE. Malian regions of Gao, Kidal and Timbuktu. National and Regional perspectives. **2015**. [CrossRef]
20. Taoussa planning authority. Social and environmental impact assessments of Taoussa dam, Mali; **2018**. *volume I.*
21. Ministry of Mines. Natural resources of Mali officially announced by the government, Mali; **2011**. [CrossRef]
22. Ministry of Mines, Energy and Water of Mali. National energy policy, Mali; **2006**. [CrossRef]
23. IAEA. IAEA's energy planning tools. **2020**. [CrossRef]
24. IAEA. User manual, Model for Analysis of Energy Demand (MAED). **2006**. [CrossRef]
25. National Energy authority of Mali. MAED requires data on economy, demography and technological parameters. **2014**.
26. Electricity of Mali. Annual activity report. **2019.**