EFFECT, ANALYSIS AND ASSESSMENT OF ELECTRICITY USAGE PATTERN IN AN EDUCATIONAL INSTITUTE DURING COVID-19 PANDEMIC

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Abstract.

The COVID-19 pandemic has caused significant impacts on energy demand in India and many countries worldwide. It is important to understand the impact of emergencies such as pandemic on the electricity usage pattern so as to improve the energy planning and management. The main purpose of this paper is to demonstrate how the recent coronavirus pandemic affected energy consumption in an Indian educational institute. Two different situations of electricity usage patterns are considered: (i) Operation under normal period (non-COVID) (ii) Operation under pandemic period. A data-driven analysis was performed which utilized the measured electricity usage data in real buildings. The forecasting of post pandemic energy demand of the institute has been carried out using predictive models built in Python.

Keywords. COVID-19, Data driven analysis, Educational Institute, Forecasting, Load Modelling.

1. INTRODUCTION

Many countries worldwide have undertaken various measures to tackle the COVID-19 pandemic. Partial or full lockdown have been imposed on public places, commercial and industrial buildings. Building occupancy schedules have been changed into distance work. These radical changes have led to remarkable impacts on energy consumption and electricity usage pattern. This has led to the scope of understanding the sudden increase or decrease of energy consumption.

India imposed an initial lockdown in four successive phases over a span ninety-two days [1] to avoid the spread of COVID-19. Pandemic-driven restrictions changed people's way of life and their working habits. All the government and private educational institutes took many initiatives to avoid the spread of COVID-19[2]. These initiatives significantly changed the energy consumption of educational institutes [3][4][5]. In particular, the virtual class modality generated huge changes in the patterns of energy consumption at the institutional level. With the significant changes in the electricity consumption pattern, the accuracy of the load forecasting tool declined [6] and the demand forecasting has become more challenging ever [7]. Forecast can be improved with machine learning techniques which further helps in better calculation of the flexibility potential of buildings, grid etc. [8][9]. There are several techniques to effectively forecast the time series data out of which the methods which gained significant attentions are classic Auto-Regressive Integrated Moving Average (ARIMA) model and deep learning based Long-Short Term Memory (LSTM) model [10][11].

In this paper, the electricity usage data in an educational institution has been considered. The analysis is made using real time data over a time period from Jan 2018 to Feb 2022. This includes pre-pandemic, pandemic and post-pandemic periods. The study was conducted not only to analyse changes in the energy usage under COVID-19 but also to forecasts the post pandemic energy demand with an objective to assess the future energy utilization in the educational institution. The forecasting has been carried out using predictive models ARIMA and LSTM in Python.

2. DATA COLLECTION OF THE EDUCATIONAL INSTITUTE

The educational building considered in this paper is located in Bengaluru, India. Power supply to the institute campus is supported by power from Bangalore Electricity Supply Company (BESCOM) Ltd. The diesel generator (DG) sets supporting this power supply are also available in the institute campus. Online UPS are installed to support the continuity of supply for few minutes during the change over from BESCOM to DG set. There are three numbers of step-down transformers (11kV/ 440V) of which two transformers TR1 and TR2 with 500kVA and TR3 with 2000kVA. The educational campus has high tension (HT) meter installation in the premises which records the dynamic energy consumption.

The data of six different building types under the institute is studied. The typical consumption under TR1, TR2 and TR3 are 21.2%, 20.6% and 58.2% respectively. The electricity demand of various building types under TR1, TR2 and TR3 is shown in the Figure 1.

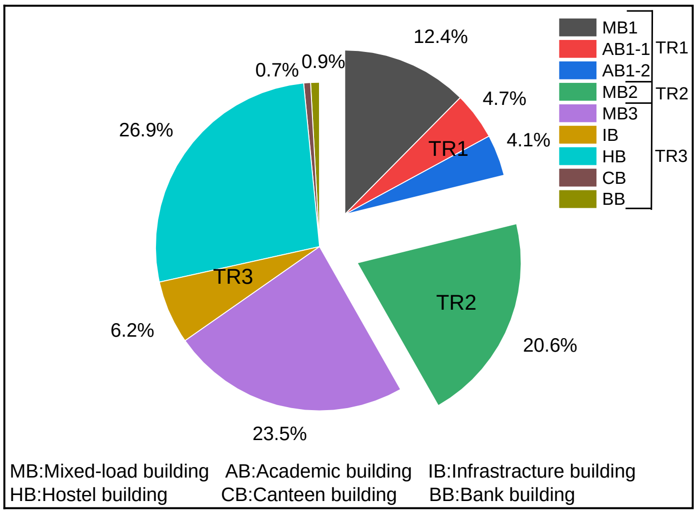

Figure 1. Typical electricity demand of various building types under educational institute

Academic building (AB) load constitutes combination of teaching, research, laboratory, library etc. Though mixed-load building (MB) i.e, MB1 and MB2 are dominated by loads similar to AB load type, they have been combined with other loads such as administration, data centre, cafeteria, cell tower etc. MB3 is much more diverse, complex and bulky load compared to rest of all other category of building load types. MB3 consists similar load to that of AB. In addition, MB3 also consists of heavy loads like air handling unit (AHU) of heating ventilation and air conditioning (HVAC) system, administration section, admission section, auditorium, sports complex, sewage treatment plant etc. Infrastructure building (IB) are chiller houses of HVAC system. The campus also has hostel building (HB), bank building (BB), canteen building (CB) where in energy consumption is substantial.

3. EDUCATIONAL BUILDING OPERATIONS UNDER DIFFERENT SITUATIONS

Two different situations of electricity usage patterns have been considered as follows:

3.1. Situation 1 - Electricity demand based on normal mode

Electricity use from 1st Mar 2018 to 29th Feb 2020 which comprises normal conditions without lockdown or other temporary disruption has been considered.

The electricity usage pattern of different building types under two situations is shown Figure 2. The individual building behaviour under two different situations are illustrated in Figure 3. In AB, MB, IB, CB and BB, there is a remarkable difference in electricity demand between daytime on weekdays and off-work hours, which is mainly caused by the different campus activities and attendance between the time slots. The electricity use was at minimum levels during weekend and off-work hours on weekdays, with the almost zero attendance.

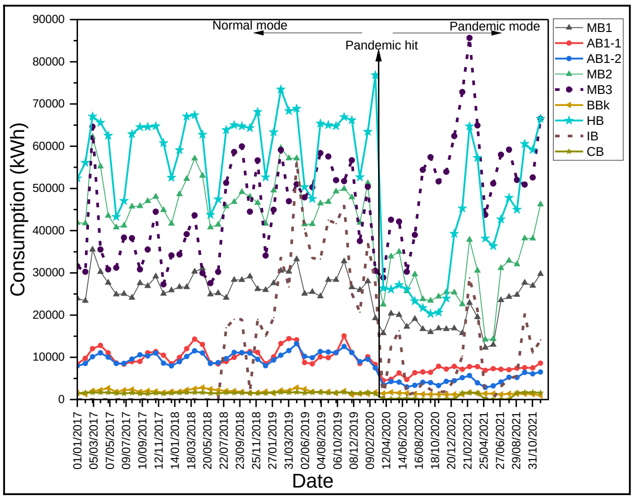

Figure 2. Electricity usage pattern of different building types during normal mode and pandemic mode

The electricity use pattern in HB is unlike the rest of building types. The HB load pattern can be compared to any residential load pattern. It generally has low demand during working hours and high demand when students are at hostel. IB are chiller houses of HVAC system, which use more energy in summer as shown in Figure 3(h). The IB demand has increased drastically during summer time i.e, in the month of May 2019.

3.2. Situation 2: Electricity demand based on pandemic operation mode

The decrease in the electricity usage due to pandemic which comprises the time period from Mar 2020 to Feb 2022 has been considered.

There were significant reductions in energy use during the COVID-19 pandemic in AB because of online teaching mode (Figure 3(a) and Figure 3(b)). similarly, MB1 and MB2 which were dominated by academic loads also showed significant drop (Figure 3(c) and Figure 3(f)). However, in MB3, the energy use change was insignificant due to certain mandatory loads such as HVAC systems. After COVID lockdown, the MB3 load increased drastically as offline activities started (Figure 3(i)).

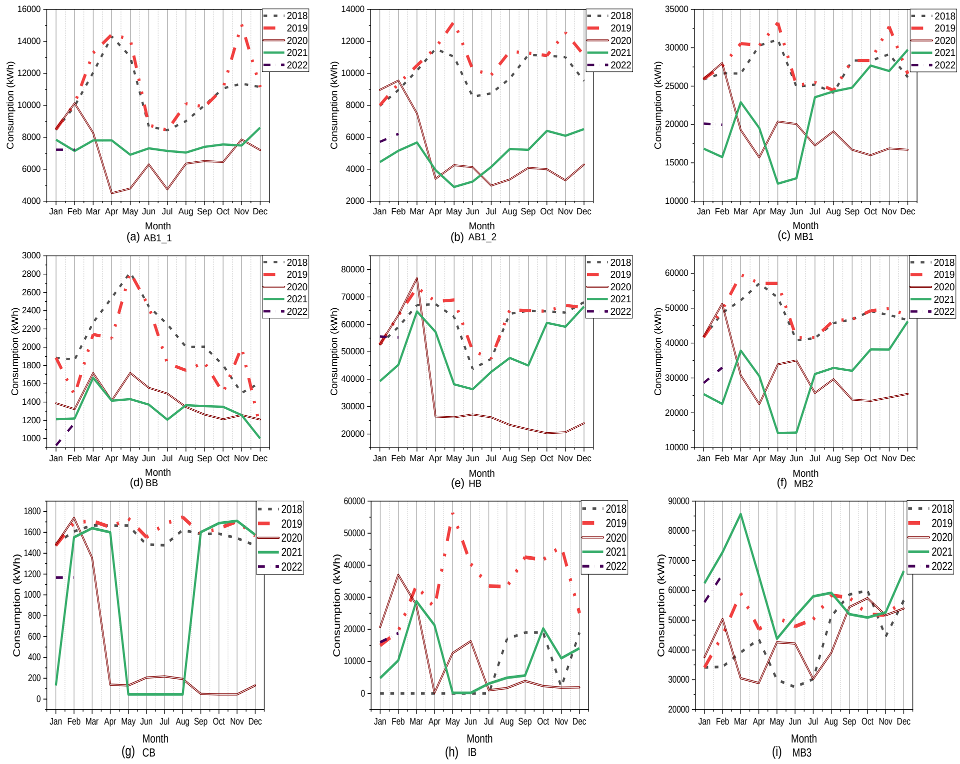

Figure 3. Behaviour of different building types during normal mode and pandemic mode

BB being the commercial establishment and open to public, the usage pattern has shown less deviation during pandemic and post pandemic period (Figure 3(d)). Due to the lesser number of students, there is a rapid decrease in the HB demand (Figure 3(e)). CB too is severely affected during pandemic. Canteens were completely shut down to prevent people from gathering. Though canteens were kept open for very few months during loosing of lockdown restriction in the year 2020, later it was completely closed (Figure 3(g)).

AHU were kept under ON condition, however the chillers/IB were under off during most of the building working hours due to low occupancy. Therefore, the energy used by IB in situation 2 was considerably lower to that of situation 1, resulting in the energy use differences being more statistically significant (Figure 3(h)).

4. RESULTS AND DISCUSSION

Figure 4, Figure 5 and Figure 6 show the electricity usage pattern on monthly, daily and hourly basis. The trendlines show several features, summarized below:

The first phase of COVID-19 was reported during Mar 2020 due to which there was sudden drastic reduction in the energy consumption by the end of Mar 2020 and full month of Apr 2020, as the government of India undertook the decision of nationwide full lockdown which can be seen in Figure 4 as well as in Figures 6(c) and 6(d). The second wave started in the year 2021 with announcement of another complete lockdown in the month of May 2021 whose impact can be can be seen in Figure 6(e). It is interesting to observe that in the initial months of the year 2021 the electricity demand was increasing steadily day by day, whereas it started declining by the end of Apr 2021. The demand was low throughout months May and Jun 2021. Again, there was improvement from the month of Jul 2021 onwards.

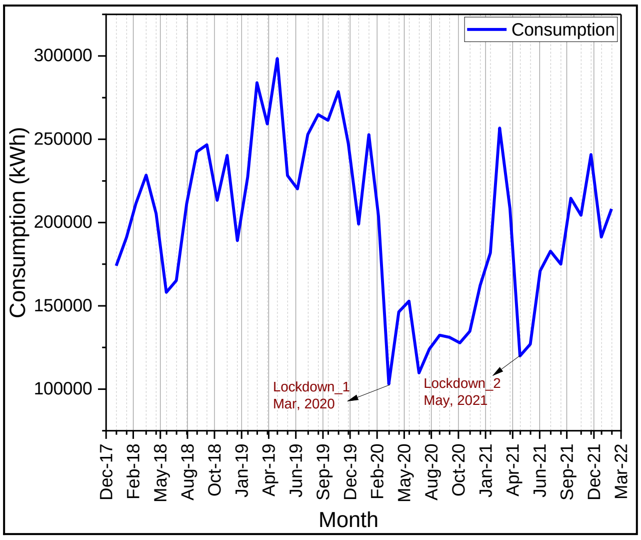

Figure 4. Monthly electricity demand of the educational institute from Jan 2018 to Feb 2022

Electricity demand for all the months in the year 2018 and 2019 were high and were declined only in the months Jan, Feb, Jun and Jul due to semester holidays. The energy demand reduced significantly on daily basis during 2020 which can be seen in Figure 5. The demand dips were sharper and more instant both in 2020 as well as 2021 when there was complete lockdown, whereas they were curvy during other pandemic. This is because during complete lockdown some of the essential loads such as administration staff, research work, HVAC systems, canteen facility etc too were at halt. The electricity demand for lockdown months in the year 2020 were identical to 2019 weekend demand profiles. For the rest of the months in the year 2020 the demand profiles were extreme low and steady. Summary of the daily electrical demand variation is given in Table. 1.

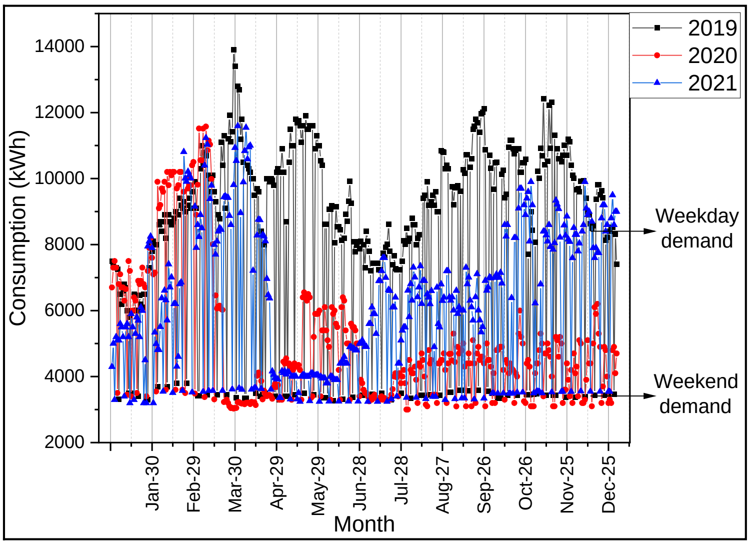

Figure 5. Daily electricity demand of the educational institute, which illustrates the impact of COVID-19

Table 1. SUMMARY OF THE DAILY ELECTRICAL DEMAND VARIATION

		Daily demand reduction in 2020 compared to 2019	Daily demand reduction in 2021 compared to 2019	Daily demand increase in 2021 compared to 2020
Weekday	Max demand	-16.71%	-16.58%	0.14%
	Min demand	-47.28%	-34.48%	24.75%
	Average demand	-43.42%	-27.64%	27.89%
Weekend	Max demand	-5.26%	-3.84%	1.5%
	Min demand	-8.08%	-1.96%	6.66%
	Average demand	-5.15%	-0.38%	5.02%

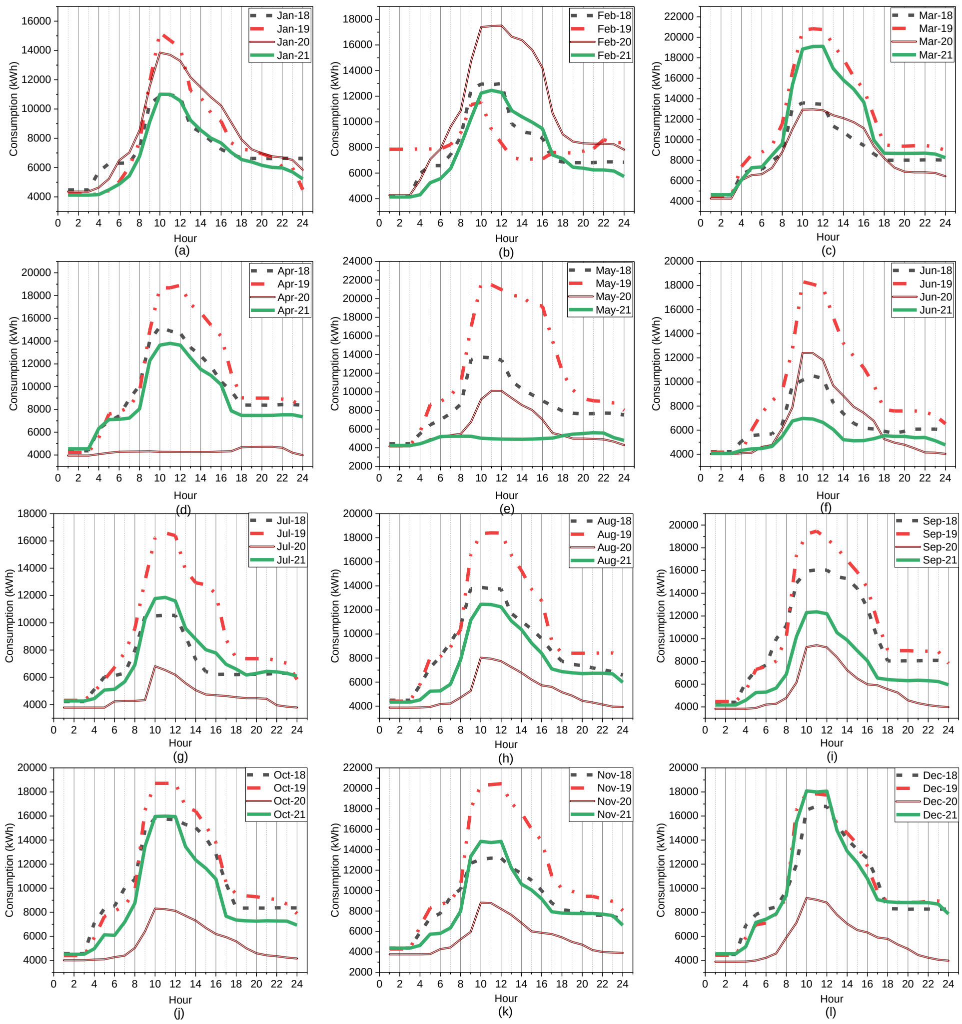

Figure 6. Hourly electricity demand of the educational instiute, which illustrates impact of impact of COVID-19

To further clarify the phenomena, the daily demand variation for the month of Mar and the first week of Apr for the years 2019, 2020 and 2020 are shown in Figure 7. The consumption profiles show how increasing lockdown measures caused a decrease in energy demand. In particular, from the second week of Mar 2020, a decrease in load was observed. Each box plot in Figure 7 shows the distribution of daily electrical demand. The median daily electrical demand of the institute was around 10300 kWh, 6000 kWh and 8500 kWh for the years 2019, 2020 and 2021 respectively and it was lowest for the year 2020 compared to other years. Furthermore, for the year 2020, the electrical demand values are approximately distributed between 3000 and 11500 kWh, which gives a wide range of possible electrical demand scenarios and illustrates the uncertainty in the demand during pandemic hit.

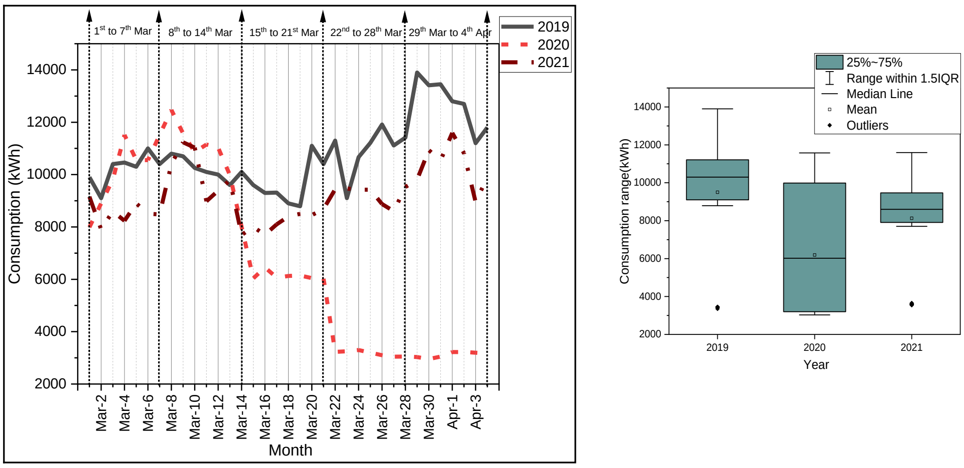

Figure 7. Five-week daily energy demand comparison and its descriptive statistics

Machine learning models were developed to assess the impact of COVID-19 and to forecast the post pandemic demand of the institute. In the modelling study, two different machine learning approaches were selected which includes ARIMA and LSTM. For determining the accuracy of the model, the current data is divided into two sets. They are training dataset (80% of the total data) and testing dataset (20% of the total data). Actual and predicted daily demand values are shown in Figure 8.

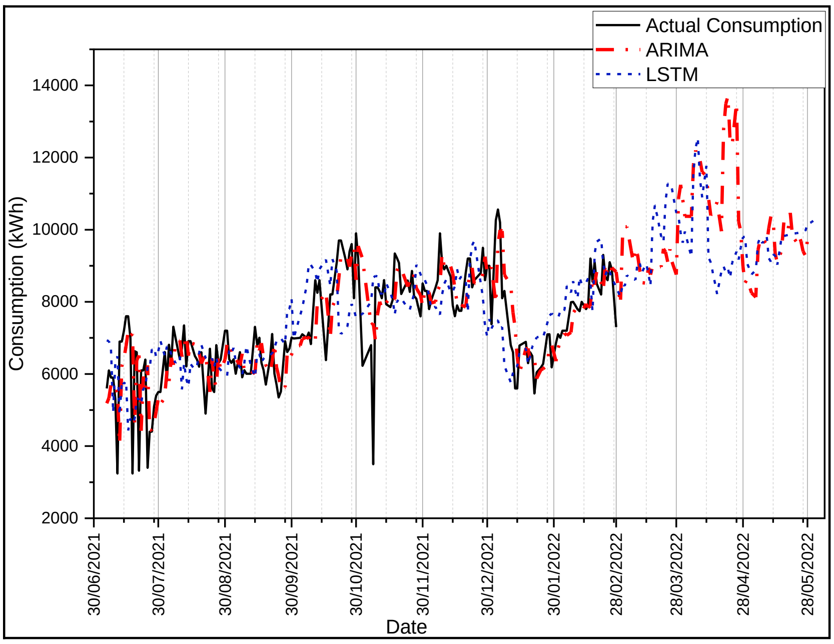

Figure 8 Daily electricity demand forecast

The last 3 months of the daily demand data were predicted and evaluated. When all the prediction values are evaluated, it can be said that the LSTM approach gave effective results compare to ARIMA. Prediction accuracy for ARIMA was 101.20 while the prediction accuracy for LSTM was 87.66.

5. CONCLUSION

COVID-19 has influenced the overall energy consumption of the educational institute. The overall energy consumption dropped by 43.42% in the year 2020 compared to its previous year 2019. However, the magnitude of impact varied from one category of building to another. In post covid condition the energy demand started increasing slowly which resulted in increase in the energy consumption by 23.48% in the year 2021 compared to its previous year 2020. LSTM technique is proved to be the most accurate approach for the data analysed in this study. However, the impact of the COVID-19 pandemic continues, and will have a long-term effect on stabilization of energy consumption of the educational institutes. Hence it is critical to study the future energy utilization and to forecast the energy usage pattens under various situations using various tools and techniques.

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