Milestone 2: Effect of increased AC use on the Indian power grid

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I. Introduction

In milestone two of the project, we aim to investigate the electricity consumption due to ACs as a fraction of the total daily energy consumption for the state of Maharashtra.

Then we proceed to inspect the effect on peak power demand due to ACs in the hottest months in future through the development of a prediction model with the help of already available monthly data of peak power demands.

Finally, we estimate the carbon emissions due to ACs as a fraction of the total emissions for different states. For this also, we develop a prediction model for future per capita carbon emissions with the help of historically available data and make estimations according to population and per unit carbon emissions.

II. Effect of AC on Daily Electricity Consumption Patterns

MAHARASHTRA

The data of the power demand of the western region for every 15 minutes duration from 17th Oct 2024 to 11th Nov 2024 is available to us. The western region of the national grid comprises Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh, Goa and the UTs Daman and Diu and Dadra and Nagar Haveli. As estimated from the CEA website and the Energy Statistics India 2024 report by the Ministry of Statistics and Program Implementation, to the total energy consumption of the western region, Maharashtra contributes around 35%, Gujarat around 30%, Madhya Pradesh 25% and the rest 10%.

The daily power demand files are stored in a folder and the corresponding energy consumption values of the Western region and then that of Maharashtra are computed (by multiplying 0.35 with the regional values) and plotted using a python script as shown below.

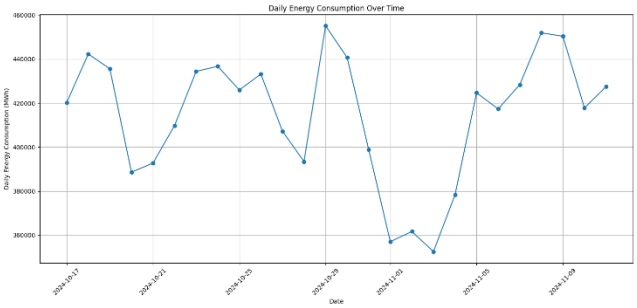

Fig. Daily total energy consumption

From mid Oct to mid Nov, the maximum temperatures in Maharashtra reaches 30°C or above and stays in this range for around 4 hours (typically from 1-5 PM). So, we can assume this is the approximately the time during which the ACs run. Total energy consumption by an AC = 1.5*4 kWh = 6 kWh.

According to consumer reports by the CEA and the Bureau of Energy Efficiency, only around 30% of the population possessing ACs actually use them extensively during this time of the year, which is understandable since temperatures during this time don't go high enough during the sleeping hours and ACs also increase electricity bills thereby discouraging consumers from using them unless when absolutely needed.

Hence, total energy consumption due to all the ACs is 6*3100000*0.3 = 5.58 GWh.

The average daily energy consumption during the aforementioned period is around 415 GWh.

Therefore, the daily electricity consumption due to ACs accounts for around 1.34% during the autumn season.

** We were able to obtain the data (from the group scrubbing the same from the IITK website) only for the Western Region. Hence, have been able to make the estimate only for Maharashtra.

*** *The western region data, the python script and a clear image of the plot are provided in section 2 folder of*

milestone 2 folder of the GDrive link provided in the Resources section at the end of the report. To process the data using the script the .py file and wr_demand_data folder have to be saved together at one location and then the path to the wr_demand_data folder have to be provided in the script accordingly.

III. Forecast of the Effect of AC Usage on Peak Power Demand

For this, first we need to estimate the number of ACs that we might have by 2030. Since a lot of data on this is not available (only 3 data points for each region), let's attempt to simply mathematically estimate the required numbers instead of some prediction model.

Region \ Year	2000-01	2010-11	2023-24
Assam	34000	250000	350000
Delhi	337000	786000	1280000
Maharashtra	530000	1600000	3100000

From 2000-01 to 2010-11, Assam added 21600 ACs/year, Delhi 44900 ACs/year and Maharashtra 107,000 ACs/year. Then, from 2010-11 to 2023-24, the respective numbers are 7692 ACs/year, 38000 ACs/year and 115384 ACs/year.

For Maharashtra, the successive growth rates are almost similar. So, let's assume the trend will continue till 2030. So let the growth rate for upcoming 6 years be (115384+107000)/2 = 111,192. So, number of ACs in Maharashtra by 2030 will be 3100000 + 7*111192 = 3767152 i.e. nearly 3770000.

For Delhi and Assam, the numbers have decreased successively. This can be because of reasons like Covid and the following recession that have significantly impacted the purchase of consumer goods in the last few years. However, since the per capita income is expected to increase in the upcoming years and as we observed in the milestone 1 report, AC purchase have a direct correlation with income. Articles from The Indian Express and the Hindustan Times also predict sharp rise in AC purchase in upcoming years. So, let's assume the growth rates will return nearly to the old levels.

Thus by 2030, Delhi will have 1600000 + 6*44000 = 1864000 and Assam will have 350000 + 6*21500 = 479000 ACs.

ASSAM

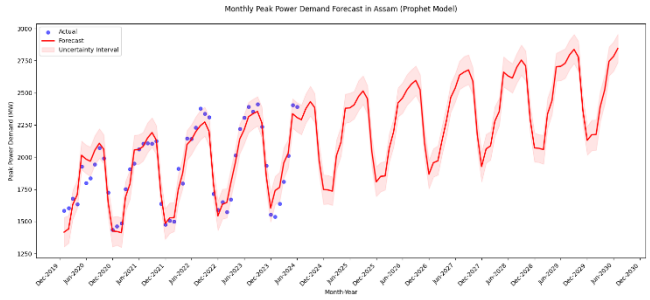

Fig. Forecast of seasonal peak power demand in Assam

By 2029-2030, the peak demand for electricity in Assam due to ACs will be around 1.5*479000 = 718.5 MW. As seen in the model, the peak demand by 2029 will rise to 2732 MW, 2820MW, 2840 MW and 2828 MW in the 4 hottest months (Jun-Sept). Therefore, the peak demand due to ACs range from 26.29% to 25.29% in these months which is a big share.

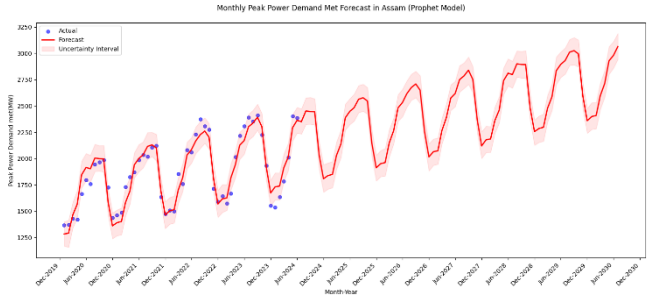

Fig. Forecast of the peak power demand met in Assam

As seen from the CEA data on the total power demand met in Assam, the state has not been able to meet the total peak power demand till 2022, with supply being around 90-95% of the actual demand. However, they achieved 100% in 2023. The above prediction model of the power demand met by 2029-2030 shows that Assam will be able to meet demands of more than 3000MW in the 4 months of concerns, which is greater than the actual predicted demand. Hence, even though demand due to ACs are likely to comprise a fourth of the total electricity demand, the same is likely to be met without difficulty.

DELHI

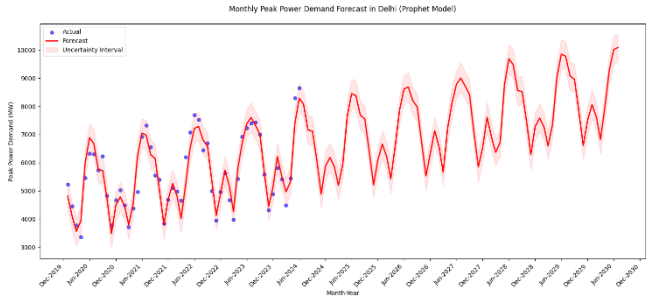

Fig. Forecast of seasonal peak power demand in Delhi

By 2029-2030, the peak demand for electricity in Delhi due to ACs will be around 1.5*1864000 = 2796 MW. As seen in the model, the peak demand by 2029 will rise to 9010 MW,

9850MW, 9848 MW, 9780 MW and 9080 MW in the 5 hottest months (Apr - Aug). Therefore, the peak demand due to ACs range from 31.03% to 28.38% in these months which is quite a significant share.

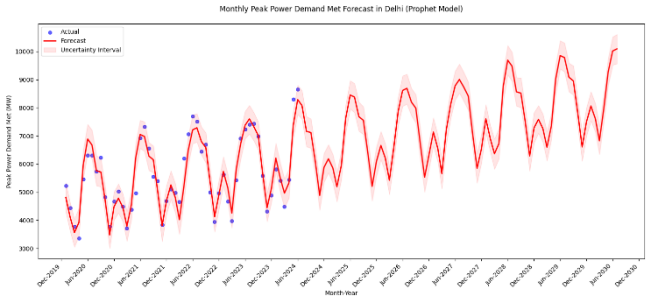

Fig. Forecast of the peak power demand met in Delhi

As seen from the CEA data on the total power demand met in Delhi, the city has always been able to keep up with the actual peak power demand. The above prediction model of the power demand met by 2029-2030 also shows the same trend and the supply numbers are almost the same as the demand.
Hence, just as now Delhi should be able to handle its demand for electricity due ACs in future too.

MAHARASHTRA

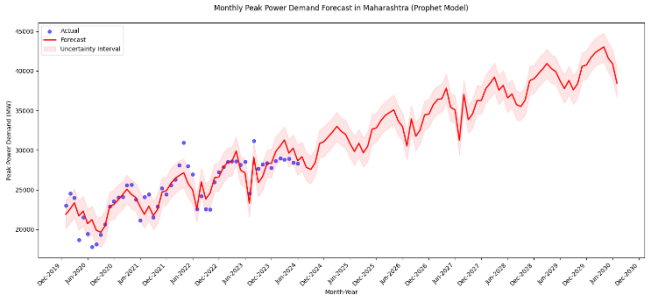

Fig. 6: Change of peak demand with avg. temperature in Maharashtra

By 2029-2030, the peak demand for electricity in Maharashtra due to ACs will be around 1.5*3770000 = 5655 MW. As seen in the model, the peak demand by 2029 will rise to 40930 MW, 40278 MW, 39880 MW and 38749 MW in the 4 hottest months (Mar - Jun). Therefore, the peak demand due to ACs range from 13.82% to 14.59% which, compared to Delhi or Assam are quite low.

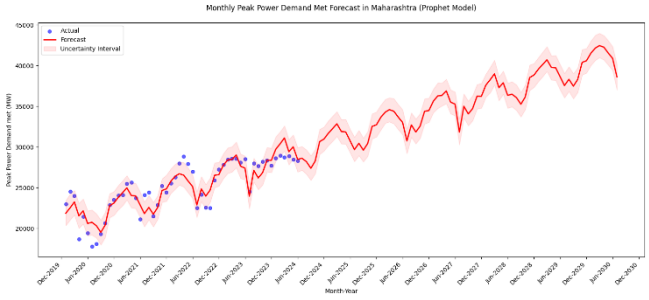

Fig. Forecast of the peak power demand met in Maharashtra

As seen from the CEA data on the total power demand met in Maharashtra, the state, like Delhi, has almost always been able to keep up with the actual peak power demand. Even in the worst cases it has been able to reach up to 99.5% of the actual demand. The above prediction model of the power demand met by 2029-2030 also supports this.
Hence, like Delhi, Maharashtra should also be able to meet the electricity demand due to ACs effectively. It, further, has an edge in this because its demand due to ACs is much lesser than Delhi.

** *The data for the power demand and power demand met are provided in the Processed data folder of milestone 2 folder of the GDrive link provided in the Resources section at the end of the report. The nature and corresponding state of the data can be understood from the names of the .xlsx files. The script used to develop the above models is also uploaded alongside the Processed data folder. To see a plot simply the name of the filepath has to be changed. Clear images of the plots are also uploaded there*

IV. FORECAST OF THE EFFECT OF AC ADOPTION ON EMISSIONS

We obtain the per capita emissions data for India from 1858 to 2023 from "Our world in data" website and use this data to predict the future emission values till 2030 using a python model.

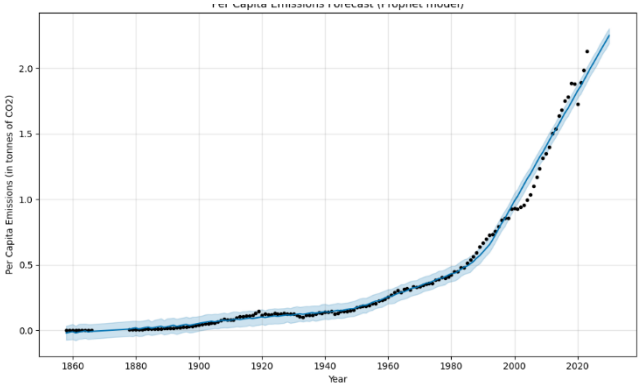

Fig. Forecast of the per capita emissions for India

From this model we find that in 2030 per-capita emission for India will be 2.25 tons of CO2 per person. In 2030, the population of Assam is predicted to be around 38M, Delhi around 24.3M and Maharashtra around 133M (obtained from StatisticsTimes.com website).

Therefore in 2030, total emissions will amount to $2.25*38000000 = 85.5*10^6$ tons for Assam, $2.25*24300000 = 54.6*10^6$ tons for Delhi and $2.25*133000000 = 299.25*10^6$ tons for Maharashtra.

As per the CO2 Baseline Database for the Indian Power Sector of the CEA, 0.82 kg of CO2 is produced per kWh. The total energy produced per AC per year is 0.82*1464 kWh = 1200.5 kg in Assam, 0.82*2754 kWh = 2258.3 kg in Delhi and 0.82*1464 = 1200.5 kg in Maharashtra (The energy values are from the milestone1 report).

Therefore, in 2030, the total carbon emissions due to ACs will be 479000*1200.5 = $5.75*10^5$ tons for Assam, 1864000*2258.3 = $4.21*10^6$ tons for Delhi and 3770000*1200.5 = $4.53*10^6$ tons for Maharashtra.

Therefore, in 2030, carbon emissions due to ACs will account for 0.6%, 7% and 1.5% of the total carbon emissions of Assam, Delhi and Maharashtra respectively.

Thus, if effective measures are adopted towards the development of eco-friendly ACs there is a scope of reducing emissions of Delhi by 7% which is considerable. The scope however is low for Assam and Maharashtra as the percentage margins themselves are low. But talking in terms of absolute figures, the change can be quite significant.

** *The raw and processed data for the above model, the python script and a clear image of the plot are uploaded in section 4 milestone 2 folder of the GDrive link provided in the Resources section at the end of the report.*

V. Conclusion

At the end of this project, we can say that the energy consumption due to ACs both daily (as seen in section II) and annually (as seen in section III of milestone 1) constitute a very small fraction of the total energy consumption in different states and regions of India. Hence, ACs usage, in terms of energy consumption, do not really pose a serious challenge to the national grid.

The peak power demand increases significantly due to AC usage, especially during the summer months. But we have seen from the demand supply patterns that this increase in demand has been handled quite efficiently by the existing infrastructure. The predictions also suggest the same for the upcoming years as well. Hence, the current rate of infrastructure development of the grid is good enough for this purpose at least.

Finally, the increase in number of ACs will surely increase the emissions. Hence, much can be done in this regard, like development of environment friendly AC technologies, to cool without carbon.

VI. References

1. Population data - StatisticsTimes.com website
2. Peak power demand and power demand met- CEA Dashboard
3. Per capita emissions data - ourworldindata.com website
4. Emission per kWh data - CO2 Baseline Database for the Indian Power Sector – Report by the CEA
5. Daily power data – eal.iitk.ac.in – Scrubbed by Swapn

VII. Resources

Google Drive link:

https://drive.google.com/drive/folders/1a9C4WkqpRglnamShs-1FtOadhxSdKWmQ?usp=sharing