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

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I. Introduction

This project investigates the impact of rising air conditioner (AC) usage on India's electrical infrastructure. Following is an analysis of the impact of increased AC usage on the total electricity consumption and peak power demands, attributed to different climatic conditions across different geographical locations across India. The locations selected for this purpose are Delhi, Assam and Maharashtra due to the different climatic conditions they experience – Delhi with a continental climate characterised by hot summers and cold winters, Assam with a humid climate all round the year and hot summer months and Maharashtra with humid but relatively mild climate for the greater part of the year.

In addition, the socio-economic factors behind AC adoption and the environmental consequences of the same is also studied.

II. Historic AC Adoption Rates

In 2000-01, around 10-15% of the Delhi households had an AC, mostly the wealthy and upper middle class ones. In Maharashtra the figure was around 5%, almost all of it limited to urban areas. For Assam less than 1% had an AC, owing to the relatively low income and large rural population.

For convenience, we assume 12.5% for Delhi, 5% for Maharashtra and 1% for Assam. Considering the 2001 census data for the number of households, Delhi had around 337000 ACs, Maharashtra had around 530000 ACs and Assam had around 34000 ACs.

In 2010-11, the percent ownership figures rose to 22-25% for Delhi, 12-15% for Maharashtra and 3-5% for Assam. Thus, considering 23.5%, 13.5% and 4% respectively and the 2011 census data, Delhi had around 786000 ACs, Maharashtra had around 1600000 ACs and Assam had around 250000 ACs.

Currently, the percentage ownership figures are 32% for Delhi, 22% for Maharashtra and 5% for Assam. Since, the 2021 census has not be fully conducted, the number of households cannot be said with certainty. But calculations from various websites suggest Delhi has around 4M households, Maharashtra around 14M and Assam around 7.7M. So, Delhi has around 1280000, Maharashtra around 3100000 and Assam around 350000 ACs.

III. Effect of AC on Electricity Consumption Patterns

Let's assume that the standard AC to be considered for the following calculations has a cooling capacity of 1.5 ton and COP = 3.517. Thus, the electrical power rating would be 1.5kW.

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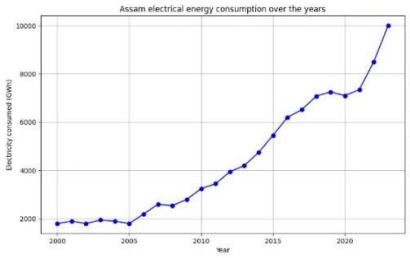

Fig.1 Electricity consumption over the years in Assam

As we will see later (and as we also experience), Assam's climate is most uncomfortable for the 4 months from June to September, owing to both temperature and humidity. Let's assume on average each AC runs for 8 hours everyday for these 4 months i.e. 122 days.

Total energy consumption by an AC = 1.5*8*122 kWh = 1464 kWh. Hence, total energy consumption due to all the ACs in 2001 is 1464*56000 kWh = 82 GWh, in 2011 is 1464*250000 = 366 GWh and in 2023 is 1464*350000 = 512 GWh.

These numbers as a fraction of the state's total electricity consumption accounts for around 4.31% in 2001, 10.6% in 2011 and 5.12% in 2023.

Hence, in 2000 the total electricity consumption due to ACs was a small fraction of the total which more than doubled in

the next decade suggesting the infrastructure failed to keep up with the increased AC use. However, the current value is again close to the 2000 value which suggest significant increase in power grid capacity.

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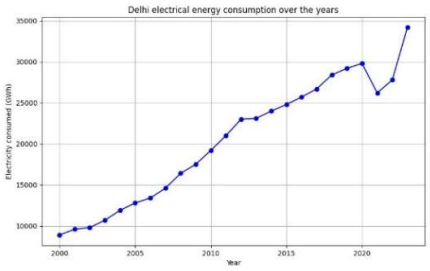

Fig.2 Electricity consumption over the years in Delhi

Delhi experiences a continental climate where the avg temperature stays close to or above 30 deg C for the 5 months from April to August. Let's assume each AC runs for 12 hours a day everyday for these 153 days. (The hours I assumed for Assam is lesser because rains often bring down the temperature there which doesn't happen in Delhi).

Total energy consumption by an AC = 1.5*12*153 kWh = 2754 kWh. Hence, total energy consumption due to all the ACs in 2001 is 2754*337000 kWh = 928 GWh, in 2011 is 2754*786000 = 2164 GWh and in 2023 is 2754*1280000 = 3525 GWh.

These numbers as a fraction of the state's total electricity consumption accounts for around 9.7% in 2001, 10.3% in 2011 and 10.3% in 2023.

Thus, the electricity consumption due to ACs as a fraction of the total has remained almost a constant (around 10%) over the years. This suggests that as the city's population has increased over the years, so has the number of ACs. But the constant figures suggest that the power grid's capacity has also increased progressively to accommodate the growing demands.

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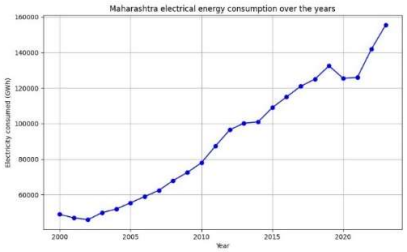

Fig. 3 Electricity consumption over the years in Maharashtra

Maharashtra mostly experiences mild climate all around the year with summer from March to June. So, we can assume maximum AC usage for around 8 hours a day (the sleeping hours) in these 122 days.

Total energy consumption by an AC = 1.5*8*122 kWh = 1464 kWh. Hence, total energy consumption due to all the ACs in 2001 is 1464*530000 kWh = 776 GWh, in 2011 is 1464*1600000 = 2342 GWh and in 2023 is 1464*3100000 = 4538 GWh.

These numbers as a fraction of the state's total electricity consumption accounts for around 1.6% in 2001, 2.7% in 2011 and 3% in 2023.

From these figures it is clear that the electricity consumption due to ACs constitute a very small fraction of the total consumption, understandably due to its mild weather conditions. But though very slowly, this fraction is increasing. So, in future if the number of ACs increase significantly, the power grid might experience some difficulty.

IV. Effect of Weather on Peak Electricity Demand

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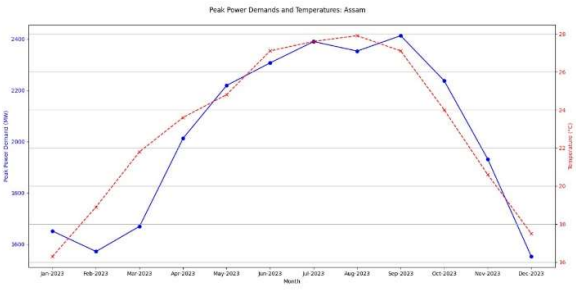

Fig. 4: Change of peak demand with avg. temperature in Assam

In Assam the peak months have an avg. peak demand of 2366 MW. While the rest have a demand of 1856 MW. Thus, the difference is around 510 MW which is 25% of annual average.

The peak demand due to the ACs in 2023 is 1.5* 350000 = 525 MW. Now, this figure is not exact while the previous one is (since that's directly from a govt website). Still, it can be said that for the excess demand in peak power during the summer months, ACs are largely responsible.

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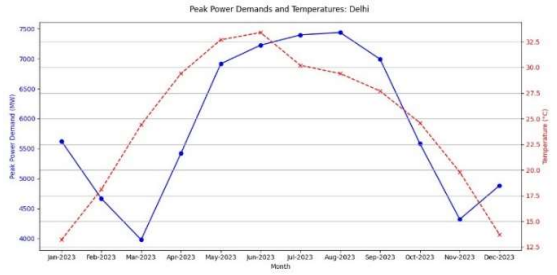

Fig. 5: Change of peak demand with avg. temperature in Delhi

In Delhi the peak months have an avg. peak demand of 6879 MW. While the rest have a demand of 5149 MW. Thus, the difference is around 1730 MW which is 29% of the annual average.

The peak demand due to the ACs in 2023 is 1.5* 1280000 = 1920 MW. Hence, again like Assam, the peak demand in summer months is caused by ACs.

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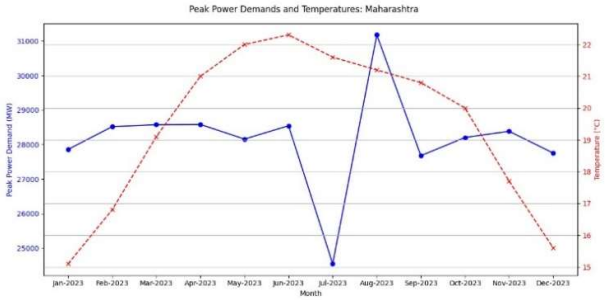

Fig. 6: Change of peak demand with avg. temperature in Maharashtra

In Maharashtra the peak months have an avg. peak demand of 28466 MW. While the rest have a demand of 28015 MW. Thus, the difference is around 451 MW. Unlike Delhi or Assam, this difference in demand as a fraction of the annual average is very low (1.6%). For Assam it is 25% while for Delhi it is 29%. So, in Maharashtra AC usage does not impose much of an issue on the grid capacity.

V. Effect of Income on AC Adoption

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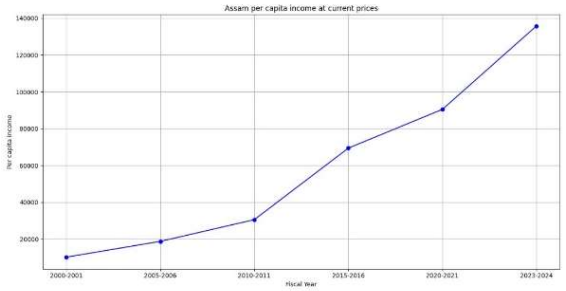

Fig. 7: Per capita income of Assam over the years

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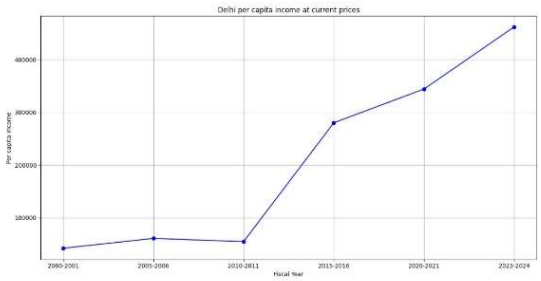

Fig. 8: Per capita income of Delhi over the years

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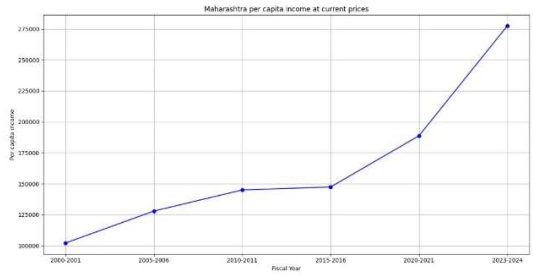

Fig. 9: Per capita income of Maharashtra over the years

As can be seen from the above plots and the numbers mentioned in section II, the rate of AC adoption increases with increase in income. This is understandable since summers are uncomfortable almost everywhere in India and hence, people choose to buy ACs if their finances permit.

VI. Effect of AC Adoption on Emissions

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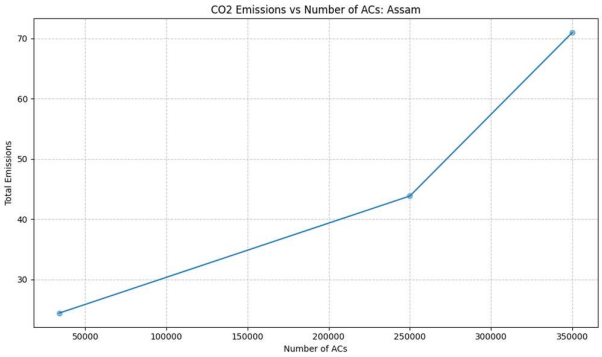

Fig. 10: Assam emissions vs no of ACs

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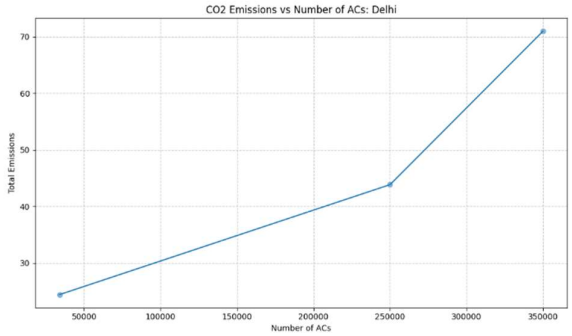

Fig. 11: Delhi emissions vs no of ACs

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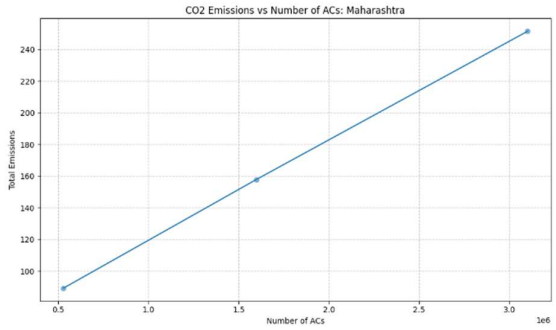

Fig: Maharashtra emissions vs no of ACs

Clearly emissions have increased significantly with the increase in number of ACs. The growth rate of emissions, however, is steeper for Delhi and Assam than Maharashtra. This, perhaps, can be attributed to the prolonged use in the former regions due to warmer climate.

VII. CONCLUSION

At the end of milestone 1, we have put forward an analysis of the effect of AC use on the total consumption of electricity and its effects, attributed to climatic patterns, on the peak power demand.

We also have performed a brief review of the impact of economic growth on AC adoption and the environmental consequences of the same in terms of emissions.

REFERENCES

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2. Peak power demand- CEA Dashboard; Temperatures- Online sources
3. Per Capita Income- StatisticsTimes.com and other websites
4. Emissions data – ourworldindata.com (emissions per person data. Total emissions were calculated by multiplying population)
5. No. of ACs – estimated from newspaper reports (HT), some online reports of market research firms like Nielsen and Blue Star AC annual reports.