Indo-German Energy Forum

Short-term Demand Shift Potential by India's Cooling Sector

Study by:

Alliance for an Energy Efficient Economy

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Key Findings

01

At present, ~2 GW of peak load equivalent to two large thermal power plants of 1 GW capacity could be avoided by implementing short-term cooling demand shift/reduction in large commercial consumers alone.

02

Among the seven large-commercial consumer segments assessed, Cold Storages and Shopping Centres represent the majority of the cooling demand reduction potential, with each segment accounting for one-third of the total demand reduction potential.

03

Occupant discomfort, health, productivity and ventilation requirements should be carefully looked into while implementing cooling demand shift/reduction.

04

A more profound impact on the late evening peaks could be made by assessing the residential sector cooling demand.

05

Since India experiences twin peaks, a day time peak and a night time peak, the day time peak also warrants a separate cooling demand shift assessment, preferably at the regional, state and DISCOM level.

Preface by GIZ

The Peak demand in India is growing faster than the average electricity demand and is expected to reach 220 GW during 2022. This is mainly due to increased demand for cooling. On a national level this peak is occurring in the evening hours when solar power is not available.

Electricity demand shift is one of the most economic measures to avoid high investments in expensive peak power plants who are required to run for very few hours during the year only.

India has a huge potential for demand shift. With a few large-scale consumers of power for cooling only, already by now up to 2 GW of peak load could be avoided by implementing short-term cooling demand shift or reduction. Investment in two large thermal power plants could be avoided by implementing short-term cooling demand shift for large consumers.

This is equivalent to saving approximately 12000 MT/day of coal or translates to reducing 30000 MT/day of CO_2 emissions.

Among the seven large-commercial consumer segments assessed, cold storages and shopping centres represent most of the cooling demand reduction potential, with each segment accounting for one-third of the total demand reduction potential. India's potential for cooling demand shift at the national level and the reduction potential for improved management of evening peak loads is providing an opportunity for the country in achieving greater grid flexibility.

We are thankful to BEE and the German Ministry for Economic Affairs and Climate Action for having tasked the Indo-German Energy Forum to have a closer look into this promising field of action for the Ministry of Power. This report highlights the cooling demand shift potential in India and highlights the demand for further research.

I wish the reader new insights in the topic of demand shift,

Dr. Winfried Damm
GIZ India

Executive Summary

The growing peak demand in India cannot be addressed by renewable energy alone

As per CEA forecasts, India's peak electricity demand is expected to grow over 10 GW each year from now through FY 2036-37. Driven by the government of India's ambitious solar energy targets, renewable energy generation is growing at a fast pace in India. But due to the variations in the daily and seasonal generation, without storage in the long run, this generation plays a limited role in meeting the peak demand, which also occurs in the evenings. Currently, the grid flexibility comes from coal-based power plants, and the grid operators have to rely on expensive and inefficient thermal power for managing the evening peak loads.

Cooling Demand Response (DR) can be a potential game-changer

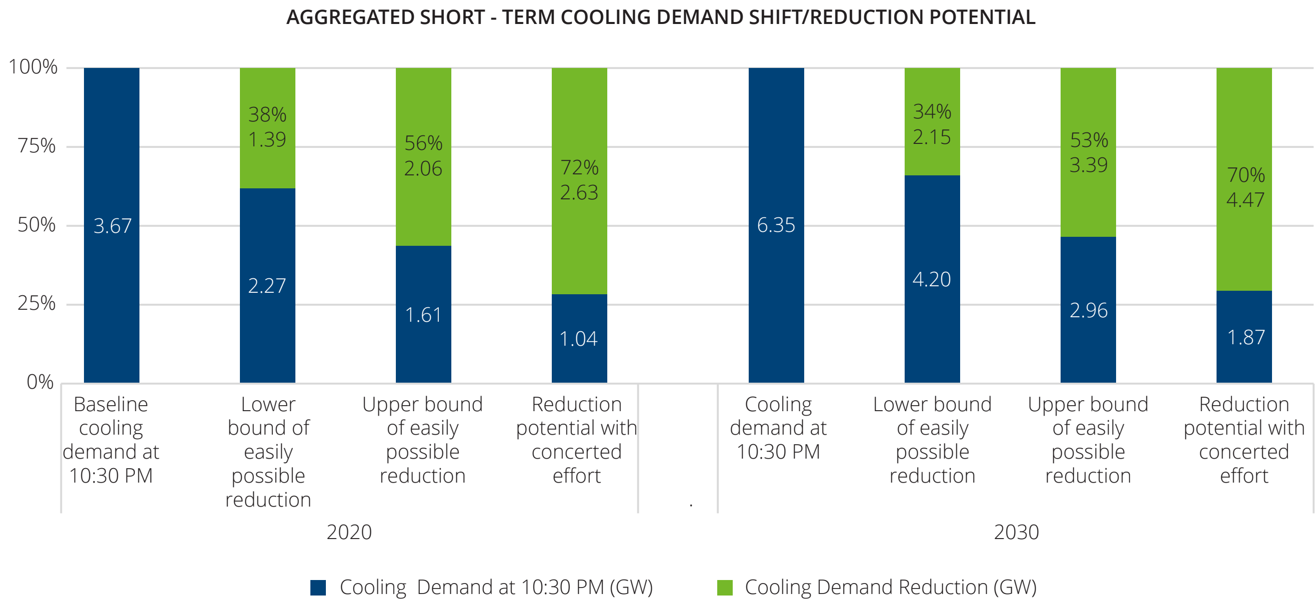
India's electricity demand for air conditioning is snowballing and contributes significantly to the grid peak loads. This report analyses the flexibility that cooling loads can offer to reduce the overall peak load requirement, mainly during the late evening. Reducing cooling demand among specific large consumers for even a short duration (upto 30 minutes assumed in this assessment) can avoid several GW of fossil fuel-based power plants. It may be economically and technically more viable to compensate these large consumers with financial incentives for specific demand reduction than incurring capital and ongoing operational expenses for new generation assets. The study's scope is to identify these large cooling consumers and the technical potential to shift or reduce their demand on short notice during the peak load periods.

Significant potential lies in the large commercial consumers alone

The study evaluates seven large consumers segments for short-term cooling demand shift or reduction potential for 30 minutes at 10:30 PM when India's highest peak demand usually occurs. The analysis reveals that in 2020, up to 2 GW of peak demand, equivalent to two large thermal power plants of 1 GW capacity, could be avoided by implementing a short-term cooling demand shift or reduction in large commercial consumers alone, without any significant effort or investment. The majority of the cooling demand reduction comes from Cold Storages and Shopping Centres, each segment representing one-third of the total demand reduction potential. BPOs and Airports constitute 14% and 9% of the demand reduction potential, respectively. Data Centres, Metro Stations and Hotels are the smallest segments with a total demand reduction potential of 8%.

The ease of user adoption and the implementation of cooling demand shift depends on the nature of functions performed within the target commercial segment. Metro Stations, Shopping Centres (both having transient nature of occupant footfall) and Cold Storages are the best contenders for cooling demand shift implementation due to relatively high allowable tolerance in temperature maintenance, leading to a relatively high willingness of building owners to participate in DR programs. In Airport, BPOs, and Hotels, occupant discomfort, even for a short duration, can be a big issue, thus having a low tolerance for cooling interruption. Health and productivity issues with additional concerns on strict ventilation requirements due to COVID-19 hazard make BPOs and Hotels additionally sensitive. In the case of Data Centres, there are serious concerns that overheating of equipment may corrupt data, and penalty clauses are strictly enforced for deviation in performance.

The aggregated short-term demand shift/reduction potential under three different scenarios: 1) lower bound of easily possible reduction, 2) upper bound of easily possible reduction, and 3) reduction potential with a concerted pre-planning, is summarised below.



Detailed assessment of cooling demand shift potential at the regional, state and DISCOM level is required

The scope of this study is limited to the commercial building sector, primarily due to the prevalence of large (centralized) cooling loads in the sector compared to small (distributed) loads in the residential sector. From the perspective of designing and delivering a DR program, it can be more cost-effective to target a smaller specific segment of large consumers, such as airports, where it is worthwhile for the DISCOMs to enter into agreements with individual consumers. That said, air-conditioning in homes is a significant contributor to the late evening peak loads and should also be explored as an opportunity for load shifting.

A profound impact on the late evening peaks could be made by assessing the residential sector cooling demand, which, although distributed, contributes significantly to the night peak loads. Also, since India experiences twin peaks, a day time peak and a night time peak, the day time peak also warrants a separate peak load shift/ reduction assessment. Anecdotal evidence suggests that the commercial building sector contributes more significantly to the day time peak loads than the night time peaks which was assessed in this study. The time of the peak demand occurrence is of utmost importance, and there is a need to examine the time and duration of both day and night peaks at the regional, state and DISCOM level.

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Abbreviations

ACoS	Average Cost of Service
AEEE	Alliance for an Energy Efficient Economy
AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATC	Adaptive Thermal Comfort
BEE	Bureau of Energy Efficiency
BFSI	Banking, Financial Services & Insurance
BPO	Business Process Outsourcing
BRPL	BSES Rajdhani Power Limited
BYPL	BSES Yamuna Power Limited
CAGR	Compound Annual Growth Rate
CDD	Cooling Demand Days
CEA	Central Electricity Agency
CO_2	Carbon Dioxide
COVID-19	Coronavirus Disease of 2019
DFI	Doubling Farmers Income
DISCOM	Distribution Company
DR	Demand Response
DSM	Demand Side Management
FY	Fiscal Year
GW	Giga Watt
HVAC	Heating, Ventilation and Air Conditioning
ICAP	India Cooling Action Plan
INR	India National Rupee
IT	Information Technology
kW	kilo Watt
M&V	Measurement and Verification
MoUD	Ministry of Urban Development
MT	Metric Tonne
MW	Mega Watt
NO_2	Nitrogen Dioxide
PAT	Perform, Achieve and Trade
PV	Photo Voltaic
SLA	Service Level Agreements
SO_2	Sulphur Dioxide
T/RH	Temperature/Relative Humidity
TR	Tonnes of Refrigeration
UP	Uttar Pradesh
UPPCL	Uttar Pradesh Power Corporation Limited
USD	United States Dollar

Introduction

According to CEA's 19th Electric Power Survey [1] India's peak electricity demand is projected to increase at a CAGR of 5.2% and become 3-fold in 20 years, from 162 GW in FY 2016-17 to 448 GW in FY 2036-37. Steady growth in the cooling demand in India is a significant contributor to the grid peak loads. As envisaged by the India Cooling Action Plan (ICAP), India, with its low levels of access to cooling, will likely witness notable growth in cooling demand in the coming decades for the health and wellbeing of its growing population as well as supporting the engines of economic growth. Even with an increasing share of renewable power in the supply mix, the grid operators have to rely on thermal power generation due to the inability of renewables, primarily solar PV, to meet the evening/night peak loads. Currently, the grid flexibility is coming from coal-based power plants. Since cooling is a significant contributor to the peak loads, a reduction in the cooling demand can potentially decrease the reliance of DISCOMs on expensive and inefficient thermal power for managing the evening peak loads, thus leveraging cooling as a flexible resource.

Current tenders issued by the Govt. of India show that 7 INR / kWh electricity tariffs are found viable for evening/night peak demand times between 07:00 PM to 12:00 PM. India's highest peak demand is usually occurring during the summer months between 10:00 PM and 11:00 PM hours coming from the residential sector. The main reason found is the cooling of several sleeping rooms before going to bed after having initially cooled down mainly the house's living room area only. Since low-cost solar energy is not available during this time and wind energy may not always be available during this crucial peak demand requirement, India's Central Electricity Authority is currently planning with net capacity additions of coal power plants of around +7 GW per year. Since these plants will be mainly required to cater to the additional peak demand expected during very few hours throughout the year, it is worth considering alternatives to these capital-intensive investments. The additional power procurement cost is ultimately borne by the end-consumers of electricity who end up paying higher electricity tariffs. Any upcoming capacities would have to be compensated for not generating or for generation at reduced load most of the time throughout the year. Since most general and peak demand growth of the next decade is expected to come from cooling, this report aims to analyse the flexibility cooling can offer to reduce the peak load requirement for a short duration mainly during the late evening.

Reducing specific large consumers' cooling demand for only a short duration can avoid several GW of fossil fuel power plant capacities. It may be economically and technically more viable to compensate these large consumers with a bonus for specific demand reduction than compensating new assets at all times all year long with a demand charge primarily for not generating at all. The study's scope is to identify these large cooling consumers and the technical potential to shift/reduce their demand on short notice during the peak load.

1.1 Peak load trends in India at the national and regional level

The total electricity demand is an aggregated demand from multiple end-uses, including space conditioning and varies with time. India is characterized as a region with twin peak demands, a day time peak and a night time peak. The peak demand trend for summer 2019[1], presented in Figure 1 shows that during a typical Indian summer, lasting from March-October 2019, all India peak demand varies between 140 GW and 180 GW. During this period, the night time peak demand is marginally higher than day time peak demand typically. Still, both the peak demands are significant for the power system operator who needs to ensure sufficient ramping capability. Increasing space cooling from residential consumers is the single most contributing factor for evening peak demand, whereas commercial space cooling demand is the leading cause for day-time peak demand. During the winter-summer transition, in March, the day-time demand and night-time demand are almost equal and less than 170 GW. During the peak summer season of May-June, both day time and night time peak demand increases to the season maximum value of around 180 MW as south and central India experience warm and humid weather. In contrast, north and eastern India are experiencing hot and dry weather. Subsequently, both peak demands start to decrease by August when the northern states and states along the Gangetic plain may be experiencing a pretty high peak.

1 2019 is selected as the base year as 2020 is an atypical year for load pattern study because of pandemic and associated lockdown

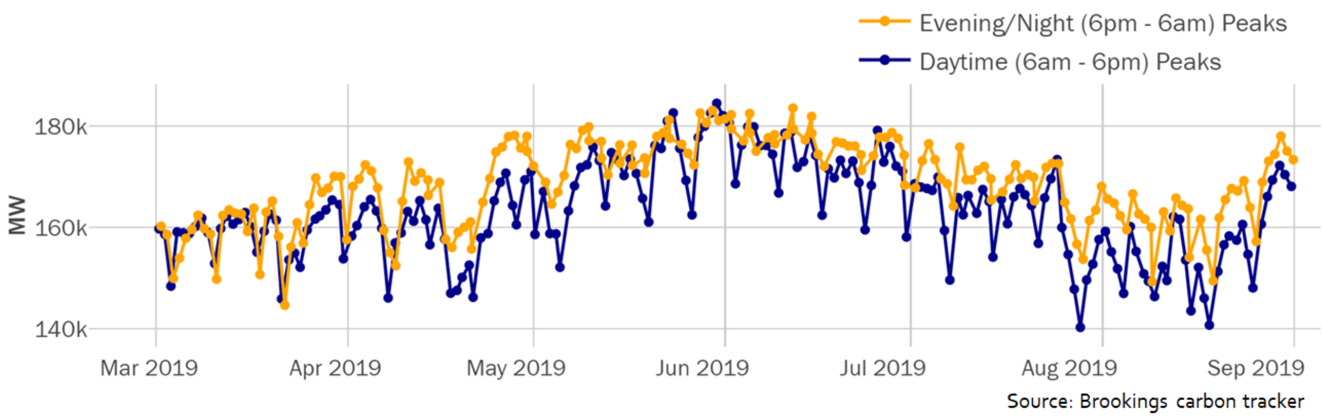

Figure 1: Peak demand trend in summer 2019

Still, the southern and central states begin to experience reduced peak demand. There is an increase in the trend again towards the end of the summer season, and the peak demand gets closer to 180 GW again. [2]

As India is a sub-continent with different climatic zones, it is crucial to examine, the spatial and temporal variation of space cooling demand and its impact on the regional peak demand while studying the national demand trend. The Indian electricity grid comprises 5 regional grids[2], wherein the Northern, Western, Southern and Eastern grid contribute to 98% of the total demand. These regions comprise different States with inherent differences in their consumption pattern, which arises from the variation in multiple socio-economic drivers of demand, including population, gross domestic product, urbanization rate, penetration of air conditioning, and other appliances apart from the major climatic factors[3]. There is a pronounced seasonal and diurnal variation when each region experiences a peak, dependent on the demand characteristics of the different States in the region. The variation of highest recorded demand[4] for each month is examined for the year 2019 for the different regions and states and is presented in Figure 2 to Figure 5. It can be seen that each region has a distinct demand pattern and differs in the quantum of demand which can be attributed to be arising from the variation in the air conditioning penetration and usage in both residential and commercial segment of the States. The northern grid experiences the highest demand of 66 GW in June-July, whereas the Western grid experiences the highest demand of 57 GW in April-June. The major climatic differentiators for this variation in electricity demand are the regional variation quantified in terms of the amount of rainfall[5] and the number of cooling demand days[6] (CDD) [1]. The Northern states, which receive less monsoon rainfall in Apr-May, experience high humidity and temperatures in June-July. The Western region and Southern region with significant coastal regions receive higher rainfall in the June-July period, and consequently, the electricity demand falls in these regions. It is not surprising that the Southern region, where the effect of monsoon is quite prominent in June-July, experiences the highest demand in March-April. In the Eastern grid, the demand increase in summer is less evident, and the highest demand experiences only a marginal variation during monsoon.

2 Northeastern grid is nor considered for evaluation as the highest demand recorded in North Eastern grid is 3 GW, which is 1.7% of the highest recorded all India demand of 183 GW.

3 Climate parameters impact the electricity demand in states where residential, commercial agricultural consumers constitute a significant portion of electricity consumption.

4 The values are the maximum peak demand met reported by the power system operator, POSOCO

5 Though rainfall is expected to reduce the demand of electricity for cooling in most states, the impact of rainfall on electricity demand varies with the level of the rainfall, as well as the temperature and the humidity. For higher levels of rainfall, the relationship seems to be negative and for lower rainfall levels (less than 50 mm annually) the relationship seems relatively weak.

6 Though for majority of states CDD is between 150-200, it varies a lot across states. States in Southern region like Andhra Pradesh, Tamil Nadu, Kerala and Telangana have mean monthly CDD above 200 and Northern region states such as Delhi, Haryana, Punjab, Rajasthan and Uttar Pradesh experience draric variations in CDD.

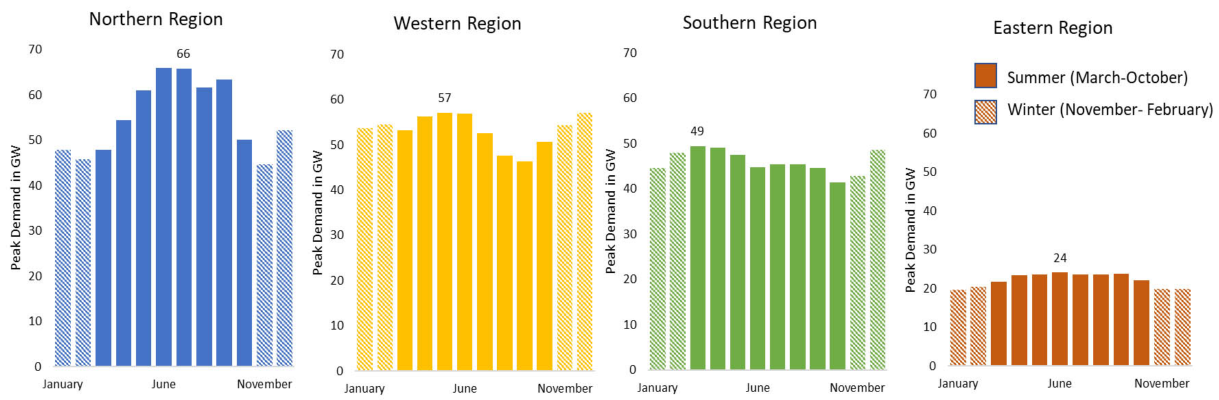

Figure 2: **Regional variation of peak demand in 2019**

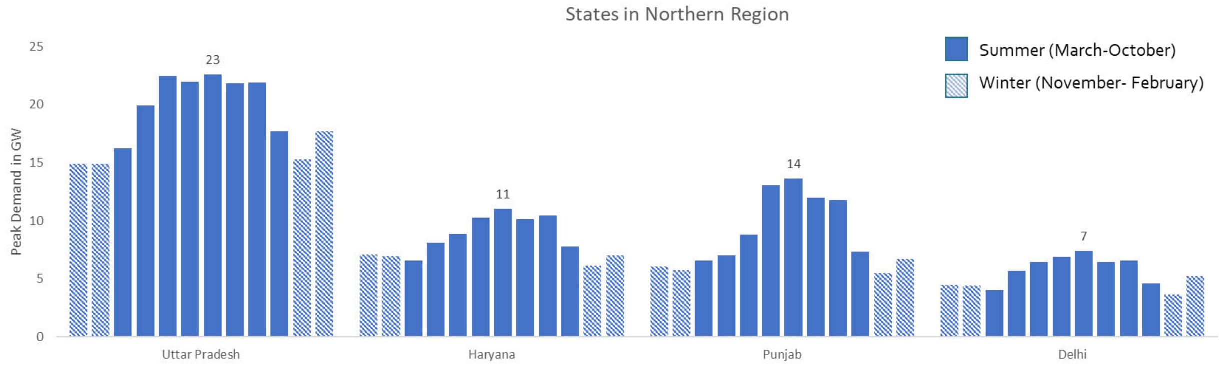

Figure 3: **Demand trend in Northern Region**

The Northern region is constituted by the states of Delhi, Haryana, Himachal Pradesh, Punjab, Rajasthan, Uttar Pradesh, Uttarakhand and the union territories of Chandigarh, Jammu and Kashmir and Ladakh. Among these states, the demand of Uttar Pradesh, Haryana, Punjab and Delhi which experiences a high increase in summer demand in comparison with the winter demand [7] is studied in detail, and the trend is presented in Figure 3. It is evident that there are similarities in the peak demand trend of the states with the demand pattern of the Northern region shown in Figure 2. The state of Uttar Pradesh, which is responsible for 35% of the demand in the region is the highest single contributor to the demand curve. The other three states, Haryana, Punjab and Delhi together contribute to 42% of the demand. These states have a significant share[8] of consumers and cooling demand arising from either residential or commercial segment, any further increase in air conditioning penetration will lead to a significant increase in peak demand.

The western region, with its industrial belts, is the second highest region in terms of peak demand. The distinct pattern in the Western region is the fall of summer peak demand at the end of June, and this trend is visible in the pattern of three out of four states studied as shown in Figure 4. In the Western region, the states of Maharashtra and Gujarat experiences the highest demand and are responsible for 41% and 32% of regional demand. The state of Madhya Pradesh and Chhattisgarh contributes to 19% and 8% of regional demand. In the State of Madhya Pradesh, the monsoon reduction in demand is apparent but the State experiences higher winter demand than summer. Chhattisgarh has a very distinct demand pattern which can be attributed to the distinctive socio-economic characteristic of the State. The peak demand from the state of Goa, as well as the union territories of Daman & Diu and Dadra & Nagar Haveli, is much less significant.

7 The state of Rajasthan has a peak demand of 13 GW in summer, and 11 GW in winter has a distinct demand profile which does not follow the Northern region trend.

8 The agricultural demand is also higher in states like Punjab and Haryana, however typically agricultural feeder supply is limited during peak hours.

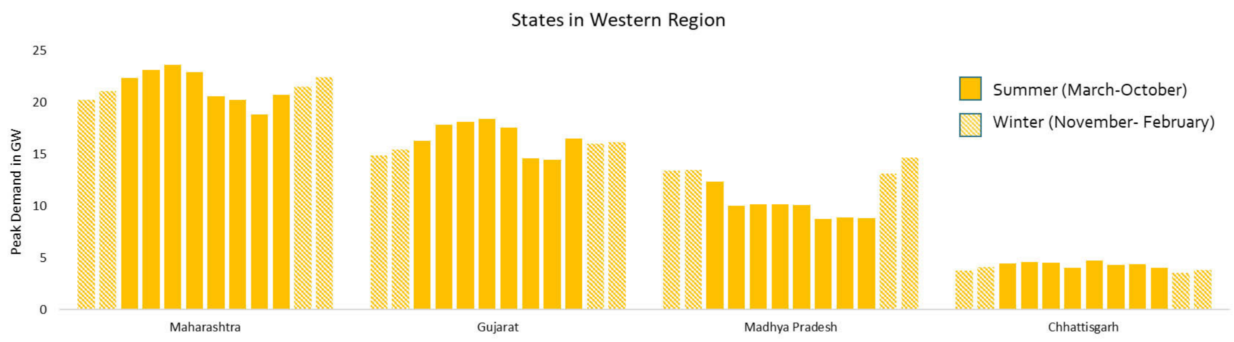

Figure 4: Demand trend in the Western region

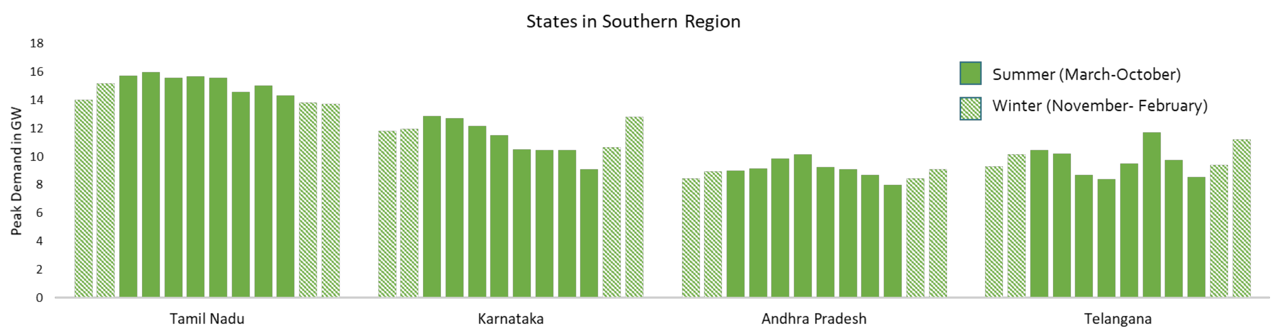

Figure 5: Demand trend in Southern region

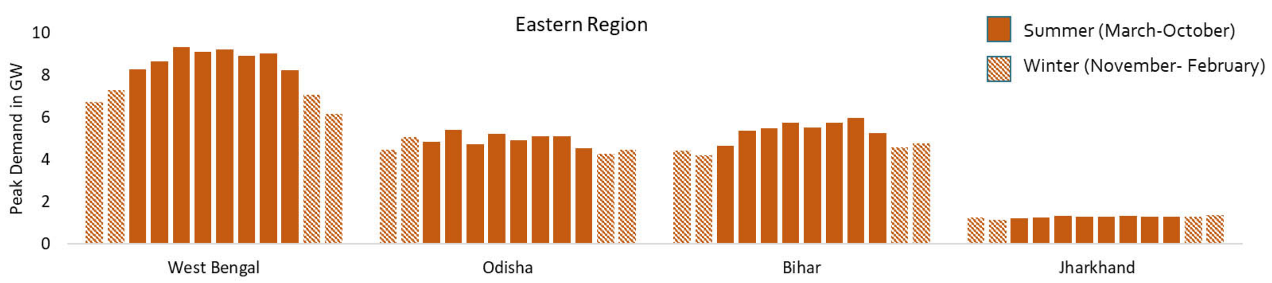

Figure 6. Demand trend in Eastern region

In the Southern region, when examined at the state level, there is no one state which closely follows the pattern of the regional variation in demand. One of the contributing factors to the variation is that the states on the east coast receive lesser rainfall (less than 100 mm) than the states on the west coast. It should be noted that the demand variation cannot be attributed to the climatic factors alone as the States also differ in their socio-economic characteristics, which also impacts the demand. The state of Tamil Nadu, which is the highest contributor to peak demand (33%) receives less rains in June-July, and there is no associated reduction in demand during monsoon. On the other hand, the state of Karnataka, which contributes to 25% of the peak demand, experiences a pronounced fall in demand in the monsoon months. The state of Andhra Pradesh and Telangana, responsible for 20% of the demand each, do not share the same demand pattern. Among these states, only Telangana experiences a fall in demand during rains. The contribution to the demand from the states of Kerala and Puducherry is relatively more minor.

The Eastern region is the lowest contributor to peak demand in the four regions studied. In this region, only the states of West Bengal and Bihar experience a relative increase of more than 20% between winter and summer demand. These two states, incidentally, are also the highest contributors for the peak demand at 38% and 23% of regional demand patterns, respectively. In the state of Odisha and Jharkhand, the marginal variation in demand is relatively less. It can be said that the trend for this region is not much variation in peak demand throughout the year.

All the regions experience twin peak demand, but even within a typical day, the pattern of each region has variations. The study on electric demand pattern has shown that the Northern region experiences the highest demand in the evening, whereas the western region demand day time demand is higher. One of the other significant factors is the rate of increase of demand in the regions is different, especially for the evening peak demand. But it should be noted that with the increase in demand from air conditioning penetration in commercial and residential segments would have an impact on the shape load curve. Typically, with an increase in space cooling demand, states with domestic and commercial consumers show higher variations in between the peak and lean demand. [3]

While assessing the demand shift potential for India's cooling load, an in-depth analysis of spatial and temporal variations in demand is critical. The value proposition from a demand shift depends on the regional load pattern, and eventually on the diurnal and seasonal load curve of the state and the electricity distribution utility (DISCOM). Even if there is a peak demand at the national level at a particular time period, if the state or the DISCOM is not experiencing a coincident peak demand, there is hardly any value from the demand shift. Hence it is essential to study the impact of regional climatic conditions on demand and the diurnal variation demand pattern at the state or even at the city level. The time of the peak demand occurrence is also of utmost importance, and there is a need to examine the time and duration of both day and night peaks at the sub-national level in detail. At the regional and state level only, the highest recorded demand is reported commonly without specifying the time of occurrence of the demand. There is a gap in understanding the time and duration of both the day-time and night-time demand. The detailed demand pattern analysis of India and states was undertaken in 2016, but in the span of the last 5 years the all India peak demand has grown 23%. The states and urban regions have also experienced a corresponding growth during this time period. Analysis of time series data on changing demand patterns is recommended to support the demand shift of cooling load [3].

The comparison between 2019 and 2020

2020 is an atypical year for demand studies due to the significant loss in demand because of COVID-19. A comparison between peak demand trends in 2019 and 2020 for the pre-lockdown period is presented in Figure 7. It is evident that the evening peak demand remained lower than the day time peak demand throughout the first three months of 2020. On 3rd March 2020, a day time peak demand of 170 GW was reported during 8-10 AM. The highest peak was recorded when the regional peak demand from the Northern, Western and Southern region coincided during that time period. The day time peak demand remained 167-168 GW for the next couple of days and then subsequently decreased for the rest of the month during the pre-lockdown period [24].

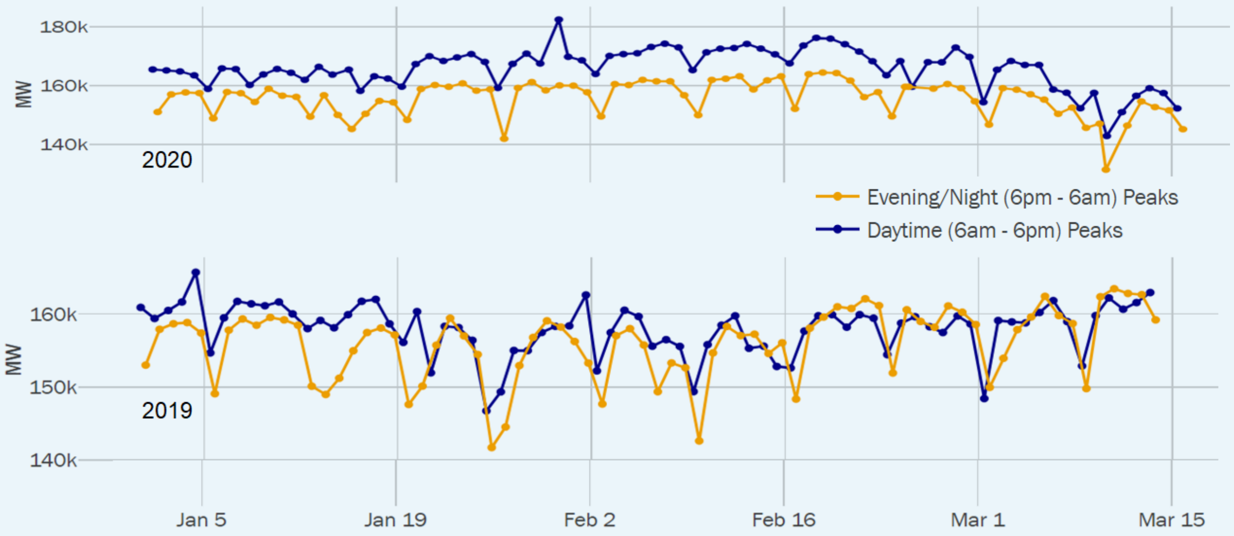

Figure 7. **Peak demand trend comparison 2019 and 2020**

1.2 Approach

The approach adopted for this assessment relied primarily on desktop research supplemented with expert interviews given the short term of the assignment and resource availability. AEEE's past research publications on commercial building stock modelling [4], cooling demand by sector in India [5], and in-house building stock research for ICAP [6] development was referred for estimating various data point on the built-up area, air-conditioned area, installed cooling capacity, efficiency (& type) of the air-conditioning system and their respective growth rates. Additionally, the Heating, Ventilation & Air Conditioning (HVAC) design practices for different commercial building categories and penetration of active air conditioning were also looked at by the team. One-on-one interviews with 13 leading cooling sector experts were conducted to validate the key assumptions and fill information gaps on short-term cooling demand reduction potential.

The cooling sector experts were selected from:

01 Leading commercial buildings' facility management firm
02 In-house HVAC facility management experts in IT Parks and BPOs
03 In-house design and operation of Data Centre HVAC systems
04 Airport HVAC services facility management
05 Design and operation of Airport HVAC systems
06 Leading air conditioning and refrigeration industry association in India
07 Leading HVAC equipment and control manufacturing firms
08 Leading HVAC design consultancy firms
09 Independent HVAC design, operations, retrofitting and M&V experts
10 Independent Cold Storage design, operations and retrofitting expert

1.3 Current Demand Response (DR) experience in India

Demand Response (DR) is a tool that can effectively help India in handling the future electricity demand and operate reliably in a greener grid. The application of DR in the Indian case is limited to a few pilots, which have not been scaled up to commercial programs. There is hardly any consolidated literature to assist and analyse all the DR pilots' key learnings. The AEEE research team was able to study eight pilot programs, as summarised in Table 1, through available documentation and stakeholder consultation. It is interesting to note that in all the pilot programs, space cooling demand is considered as an ideal candidate for DR.

Tata Power, a privately owned DISCOM in Mumbai that pioneered DR in India, in 2012 targeted cooling loads of commercial and industrial consumers [7]. The pilot included raising the temperature setpoint of air-conditioners in an airport and switching off chillers by engaging pre-cooling in commercial office spaces. In 2014, a Smart Meter based DR pilot was done in Delhi targeting commercial and industrial consumers. Cold storages, hospitals and other industrial consumers contributed to significant shed during this pilot [8]. In 2014, another DR pilot was conducted in Rajasthan, targeting industrial zones in the outskirts of Jaipur. Under this pilot, the value proposition from DR for grid balancing and reduce the unbalance between the scheduled and actual drawl was explored. One of the significant takeaways from this pilot was that DR should be designed to the local area's needs, especially the DISCOM level peaks, which may not coincide with the state level peak demand. [9]

Table 1: Summary of major DR pilots in India

State	Electric Utility	Year	Rationale	DR Strategy	Consumer Segments
Maharashtra	Tata Power Ltd – Mumbai	2012	Peak Demand	Aggregator Based and Automatic DR	Commercial and industrial
Delhi	Tata Power Delhi Distribution Limited (TPDDL)	2014	Peak Demand Grid Stress	Automatic DR	Commercial and industrial
Rajasthan	Jaipur Vidyut Vitaran Nigam Ltd (JVVNL)	2013-14	Deviation from schedule	Manual DR with Energy market integration	Industrial
Delhi	BSES Yamuna Power Limited (BYPL)	2017	Deviation from schedule	Manual DR	Commercial and industrial
Uttar Pradesh	Uttar Pradesh Power Corporation Limited (UPPCL)	2019	Peak demand	Manual DR	Commercial and industrial
Delhi	BSES Rajdhani Power Limited (BRPL)	2019	Peak Demand	Behavioural DR	Residential
Delhi	BRPL	2019	Peak Demand	Blockchain based Automatic DR	Residential and Commercial
Delhi	BYPL	2020	Peak Demand	Auto DR	Residential and Commercial

In 2017, BSES Yamuna Power Limited (BYPL) set up the DR program to balance the load and to reduce the deviation between scheduled and actual demand. This was a well-planned DR pilot where cost economics for incentive structure was studied. A consumer survey to study the willingness to participate in the DR program showed that at an incentive of INR 1.25 to 3.00 per kWh, 94% of the survey consumers were willing to participate. Out of 24 consumers, 13 consumers expressed their willingness to participate at an incentive of less than INR 1.25 per kWh, which can result in meeting 60% of DR potential. An incentive of INR 1/kWh was provided and post-implementation analysis of this pilot revealed that the gross savings varied from INR 2.11 to 3.30 per kWh over the months of the project. [10] [11]

Uttar Pradesh (UP), a state which experiences peak deficit, ran a DR program for peak management. The design rationale for the pilot was that the peak power prices in the short-term market can be as high as INR 7 per kWh. This is much higher than the Average Cost of Service (ACoS) of the UP DISCOMs at INR 6.35 per kWh. This pilot project targeted commercial consumers, with a minimum contract demand of 500 kVA, including shopping malls, hospitals, hotels, IT parks and manufacturing industries. These consumers reduced the air conditioning demand by reducing the load of chiller, air compressor, Air Handling Units (AHUs), Window ACs and other non-essential pumping and lighting loads. [12] [13]

In 2019 and 2020, the Delhi DISCOMs tried three DR pilot projects. The Behavioural DR pilot in BRPL was designed for residential consumers through home energy reports [14]. The pilot program in BYPL in 2020, provided a test environment at their office in New Delhi to demonstrate the feasibility of using ACs for demand response. To reduce the energy consumption during a specific time window, ACs are triggered to reduce the cooling demand by changing the operation behaviour by changing to fan mode. This DR solution can be applied to both residential and commercial units where AC units are not switched off, but only setpoints and operating modes are changed. As only the heat exchange is interrupted and the fan remains on, airflow is maintained during the DSM/DR events. [15]

The presence of residential consumers as a potential DR target, as evident in the recent pilots is a significant shift. In the urban areas, with a relatively high share of residential energy consumption, and increasing residential space cooling demand has resulted in a significant increase in summer peak demand. As all the participating customers were domestic customers, the main controllable load used in the DR pilot in BRPL was air conditioning load. In this pilot, using smart plugs, control was possible at the granular level of appliances such as air-conditioners during the afternoon and late evening peak periods. [16]

2. Cooling demand reduction potential at large consumers of cooling power (grid-connected)

Air-conditioning in homes is a significant contributor to the late evening peak loads, while most of the commercial sector cooling systems run on part loads (part occupancy) during that time. However, only the commercial building sector was targeted for this study, primarily due to the prevalence of large (centralized) cooling loads in the sector as compared to small (distributed) loads in the residential sector. It was identified that commercial buildings over 300 TR of cooling load typically go for centralized air conditioning. From the perspective of designing and delivering a Demand Response (DR) program, it is much more cost-effective to target a smaller specific segment of consumers, who individually have a significant peak demand compared to a larger pool of segregated cooling consumers, i.e. individual households. Hence, this study focussed on the commercial building sector and started with a comprehensive set of 10 commercial building segments having significant cooling demand at present and likely to witness encouraging growth in the coming decade.

Table 2. Commercial Building Segments

S. No.	Commercial Building Segments
1	Airports
2	Metro Stations
3	IT Parks (BPOs)
4	Data Centres
5	Shopping Centres (Malls)
6	Hotels
7	Cold Storages
8	Hospitals
9	Industrial Process Cooling
10	District Cooling

2.1 Selection of large commercial consumers

The ten commercial building segments may or may not show substantial short-term cooling demand shift/reduction potential. To identify appropriate commercial building segments having promising cooling demand reduction potential, preselection criteria were developed to perform a rapid eligibility assessment. Allowable tolerance on maintaining specified temperature/relative humidity (T/RH) conditions, likely willingness of the customer to participate in DR programs, and data availability, as described in Table 3, were considered to identify the large commercial consumers with significant cooling demand, to be further evaluated for short-term demand shift/reduction potential.

Table 3. Preselection criteria for identifying large commercial cooling consumers

S. No.	Selection Criteria	Description
1	**Operational flexibility** in maintaining prescribed temperature conditions	This criterion indicates the **allowable tolerance on maintaining specified T/RH conditions** for providing either thermal comfort for the building occupants or the right environmental conditions for other cooling applications such as cold storages or industrial process cooling. High operational flexibility means higher tolerance on T/RH requirements, i.e. less operational challenges regarding unmet T/RH conditions.
2	Likely **willingness** of the customer to participate	This criterion indicates the electricity customers’ willingness, i.e. facility owners, to participate in a Demand Response program driven by DISCOMs. This will depend primarily on the nature of building functions and their sensitivity towards T/RH maintenance, apart from the financial incentives available.
3	**Data availability**	This criterion indicates the quantity and quality of data on the no. of customers in different segments and their built-up area, air-conditioner penetration, energy performance, and operational characteristics.

An evaluation of ten commercial building segments based upon the selection criteria discussed above is presented in Table 4 below. The operational flexibility has been assessed primarily based on the building operators' current practices and understanding of temperature setpoints. It is worth noting here that appropriate operating temperature setting is often less understood and rarely practised amongst the commercial building operators in India. Typically, the commercial buildings are operated at or around the design temperature setpoints (24±1°C), which could be as low as 22°C in the case of hotels, with complete disregard to Adaptive Thermal Comfort (ATC) based operation, which relies on user adaptation and behavioural changes. According to ASHRAE 55 (2004) standard[9], people who get acclimatized with "higher" or "lower" temperatures outside of the typically accepted comfort range are tolerant of wider temperature ranges without experiencing thermal discomfort. While there have been research efforts to experimentally quantify the energy savings through the adoption of ATC based setpoints [17], no such studies are available on quantifying the instantaneous power draw impact of changes in temperature setpoint for centralized air-conditioning systems.

Seven commercial building segments have been shortlisted from the ten segments evaluated. The selection rationale for these commercial building segments is discussed in Table 5.

Table 4. Evaluation of commercial building segments on preselection criteria

S. No.	Segment	Operational flexibility	Willingness to participate	Data availability
1	Airports	Low (±1°C)	High	Moderate
2	Metro Stations	High (±3°C)	High	Moderate
3	IT Parks (BPOs)	Low (±1°C)	High	Moderate
4	Data Centres	Low (±1°C)	Low	Low
5	Shopping Centres (Malls)	High (±3°C)	Moderate	Moderate
6	Hotels	Low (±1°C)	High	High
7	Cold Storages	High (±3°C)	High	High
8	Hospitals	Low (±1°C)	Low	Moderate
9	Industrial Process Cooling	Low (±1°C)	Low	Low
10	District Cooling	High (±3°C)	High	Low

Table 5. Large consumers selection rationale

S. No.	Large Consumers	Selection Rationale
1	Airports	Airports are amongst the biggest users of centralized air conditioning, thus promising huge cooling demand reductions from a single facility.
2	Metro Stations	Ideal candidates for implementing cooling demand shift due to high operational flexibility because of the transient nature of passenger movement and the facility owners' high willingness to participate in a likely cooling demand reduction call.
3	BPOs	The IT sector is already huge in India, and the BPO segment with a high concentration of centralized cooling demand contributes significantly to the grid peaks. Only BPO buildings are selected for this assessment as they are operational 24X7 while the rest of the IT offices are mostly day time operational and wouldn't impact the night time peak loads.
4	Data Centres	Data Centres score low on most selection criteria. However, they are still considered for an in-depth analysis as the segment shows promising growth potential in the coming decade and is likely to contribute significantly to the peak demand.
5	Shopping Centres	The segment shows relatively high operational flexibility, moderate willingness to participate, and has moderate data availability. It is considered primarily due to the segment's sheer size and the high growth rates estimated for the coming decade.
6	Hotels (4 & 5 Star)	Hotels have been selected irrespective of the low operational flexibility as the segment is considered a designated consumer under the PAT regime. Hence, the facility owners' willingness to participate in programs to reduce their energy intensity will likely be high. The active cooling demand from 3 Star and below hotels is likely to be low, and they are unlikely to be running central plant type HVAC systems. Hence, only 4 Star and above hotel types have been selected for this assessment.
7	Cold Storages	Cold Storages are amongst the best candidates for cooling demand shift/reduction at night. It's a general practice to intermittently switch off the refrigeration system during the holding seasons for potato cold storages, which constitute the bulk of the country's cold storages.

9 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 55: Thermal Environmental Conditions for Human Occupancy

Hospitals, Industrial Process Cooling, and District Cooling are excluded for further in-depth analysis of the cooling load due to the following reasons as highlighted in Table 6.

Table 6. **Large consumers exclusion rationale**

S. No.	Large Consumers	Exclusion Rationale
1	Hospitals	Hospitals are not considered due to the critical nature of cooling requirements in the healthcare sector. The willingness of hospital owners, administrators, and operators to participate in any cooling demand shift/reduction programs are likely to be pretty low.
2	Industrial Process Cooling	In Industrial Process cooling, such as in textiles or food processing, a shift/reduction in cooling demand can likely impact the entire production cycle, negatively impacting the output. Due to this low operational flexibility, the industry owners and operators' willingness will be significantly low. Additionally, the availability of cooling demand data is also quite limited for the industrial process cooling segment.
3	District Cooling	Regarding District Cooling, the segment is relatively small – still at an evolving stage – and does not have a significant impact on the peak loads experienced by the electricity grids. While the district cooling system operators' willingness to participate in DR programs may be high, the segment's current size and the data available on growth projections are pretty low. Hence it is excluded despite the segment's relatively high operational flexibility.

2.2 Estimation of short-term cooling demand (GW) reduction potential in 2020 and 2030

The short-term cooling demand shift/reduction for the seven selected commercial building segments has been analysed segment-wise and presented below.

1. Airports

India's passenger traffic grew at a CAGR of 11% during FY16-FY20, and it is expected that the country will become the third-largest aviation market in terms of passengers by 2024 [18]. The expansion of existing airports and the development of new greenfield airports can likely lead to a CAGR of over 6% in India's airport built-up area. Airport buildings are typically fully air-conditioned (up to 95%) and are designed for reasonably high occupancy loads. The cooling load intensity varies from 10 to 20 m^2/TR and experiences high infiltration loads due to the frequent opening of doors from passenger movement, both in and out of the facility. The segment's total installed cooling capacity stands at ~0.3 million TR in 2020, which can grow up to 0.5 million TR in 2030. The cumulative impact of cooling requirements in airports across the country on the electricity grids is to the tune of 0.32 GW in 2020 and 0.53 GW in 2030. While this is the cumulative load and not the peak coincident load, the actual cooling load, even on the year's peak loading day, will vary across the day due to changes in solar incident heat and passenger occupancy variations. The cumulative cooling load at 10:30 PM in the night is assumed to be 80% of the airports' peak load, primarily due to the absence of solar heat load in the night.

It is estimated that 50 to 70% of the cooling demand for airports, constituting roughly 0.13 to 0.18 GW of grid-connected load, can be quickly shifted/reduced at 10:30 PM for half an hour without significant impact on the conditioned environment and any additional investment. A combination of the following strategies can achieve this: raising the temperature setpoint in cooled spaces, raising the chilled water setpoint and/or staging or switching off the major energy-guzzling equipment in the air-conditioning plant, that is, the chiller. It is advised that the air-side equipment are kept operational throughout the half-hour demand shift/reduction period to maintain the prescribed airflow quantities for breathing and indoor air quality contaminant dilution.

However, while implementing cooling demand shift/reduction (for longer durations) in airport premises, one must consider its likely impact on passenger discomfort, potentially a big issue. There have been examples of airport authorities at international airports in India being sued by the passengers for not providing necessary thermal comfort while waiting or boarding flights. The entry and exit points (opening and closing doors) will likely be the most impacted areas where the heat built-up will happen quickly compared to other core spaces in case of the cooling system partial shut-down. More significant cooling demand shifts/reductions are possible for longer durations through segregating the air distribution systems for different conditioned areas. For instance, the cooling system for targeted boarding gates could be switched off as per the flight schedule, which dictates the passenger footfall in the departure area's specific pockets. However, such load segregation is best done at the design stage itself.

Table 7. Airport segment's summary sheet for estimating short-term cooling demand shift/reduction

	unit	2020	2030	CAGR / (remarks)
No. of buildings/facilities	Nos.	120 to 150	~300	
Built-up area	*million m²*	2.4 to 5.8	4.2 to 10.3	6%
Air-conditioned area	*%*	90 to 95	95 to 100	
Cooling load intensity	*m²/TR*	10 to 20		
Installed cooling capacity	*million TR*	~0.3	~0.5	5%
Overall HVAC system operating efficiency	*kW/TR*	~1.1	~0.9	-2.0%
Peak electrical cooling demand	*GW*	0.32	0.53	5%
Cooling demand at 10:30 PM	*GW*	0.26	0.43	(20% reduction over peak)
Short-term cooling demand shift/reduction potential				
Lower bound of easily possible reduction	*GW*	0.13	0.21	(50% reduction over 10:30 PM)
Upper bound of easily possible reduction	*GW*	0.18	0.30	(70% reduction over 10:30 PM)

The table below summarises the key numbers (derived or calculated) utilized for estimating the cumulative short-term cooling demand shift/reduction potential at Airports for 30 minutes at 10:30 PM.

2. Metro Stations

As per the Ministry of Urban Development (MoUD), about 316 km of metro rail is operational, and more than 500 km of metro rail is under construction in India. There is a demand for metros in different cities across India, and the state governments are planning the development of new metro facilities in the respective states. The total built-up area of the metro facilities is around 1.5 to 2.8 million m² at present that is likely double in the next 10 years. The underground metro stations are fully conditioned, whereas the over-ground ones are only partially air-conditioned. Hence the overall air-conditioned area of metro stations has been considered on the lower side (50-60%). The cooling load intensity varies from 10 to 20 m²/TR, and the total installed cooling capacity is estimated to be ~0.1 million TR in 2020 that may double by 2030. The peak electrical cooling demand is estimated to be around 0.1 GW in 2020 and 0.2 GW in 2030. The cumulative cooling load at 10:30 PM in the night is assumed to be 80% of the peak load for metro stations due to the absence of solar heat load and low occupancy loads in the night.

It is estimated that 60 to 70% of the cooling demand for metro stations, constituting roughly 0.05 to 0.06 GW of grid-connected load, can be quickly shifted/reduced at 10:30 PM for half an hour without any significant impact on the conditioned environment and any additional investment. A combination of the following strategies can achieve this: raising the temperature setpoint in cooled spaces, raising the chilled water setpoint and/or staging or switching-off the major energy-guzzling equipment in the air-conditioning plant, i.e. the chiller. It is advised that the air-side equipment are kept operational throughout the half-hour demand shift/reduction period to maintain the prescribed airflow quantities for breathing and indoor air quality contaminant dilution.

In implementing cooling demand shift/reduction (for longer durations) in metro station premises, one must consider that while the passenger discomfort may not be a major issue since the footfall is highly floating, however, some critical metro equipment requires air-conditioning, which should not be compromised during the demand shift/reduction implementation.

The table below summarises the key numbers (derived or calculated) utilized for estimating the cumulative short-term cooling demand shift/reduction potential at Metro Stations for 30 minutes at 10:30 PM.

Table 8. **Metro station segment's summary sheet for estimating short-term cooling demand shift/reduction**

	unit	2020	2030	CAGR / (remarks)
No. of buildings/facilities	Nos.	<100	~200	
Built-up area	*million m²*	1.5 to 2.8	2.8 to 5.5	7%
Air-conditioned area	*%*	50 to 60	60 to 70	
Cooling load intensity	*m²/TR*	10 to 20		
Installed cooling capacity	*million TR*	~0.1	~0.2	7%
Overall HVAC system operating efficiency	*kW/TR*	~1.1	~0.9	-2.0%
Peak electrical cooling demand	*GW*	0.10	0.20	7%
Cooling demand at 10:30 PM	*GW*	0.08	0.16	(20% reduction over peak)
Short-term cooling demand shift/reduction potential				
Lower bound of easily possible reduction	*GW*	0.05	0.10	(60% reduction over 10:30 PM)
Upper bound of easily possible reduction	*GW*	0.06	0.11	(70% reduction over 10:30 PM)

3. BPOs

The IT and BPO services market in India is poised to grow at a CAGR of 8% during the period 2018-2022. The rising cost pressure to maintain in-house IT systems, access to new technology, domain expertise, and round the clock service are key growth drivers in the IT and BPO services market [19]. The BPOs constitute roughly 20% of total IT parks in India [20]. The new facilities are likely to lead to significant growth (~6% CAGR) in the total built-up area of BPOs by 2030. The built-up area of BPOs is typically 80-85% air-conditioned using a centralized air conditioning system. The cooling load intensity varies from 20 to 30 m²/TR, and the total installed cooling capacity is estimated to be ~0.8 million TR in 2020, which can increase up to 1.5 million TR in 2030. This can lead to a peak electrical cooling demand of 0.91 GW in 2020 and 1.61 GW in 2030. The cumulative cooling load at 10:30 PM in the night is assumed to be 80% of the peak load for BPOs, primarily due to the absence of solar heat loads in the night.

The cooling demand reduction potential in BPOs is pretty low as compared to Airports and Metro Stations. In 2020, only 10 to 40% of the cooling demand for BPOs, constituting roughly 0.07 to 0.29 GW of grid-connected load, can be quickly shifted/reduced at 10:30 PM for half an hour without any significant impact on the conditioned environment and any additional investment. Occupant discomfort, health and productivity loss are significant issues for facility managers, and there are additional concerns on strict ventilation requirements due to the COVID-19 situation.

However, with concerted efforts and pre-planning from facility managers in terms of pre-cooling the facility before the demand reduction call and keeping the ventilation system running at all times, a short-term cooling demand reduction potential of up to 70% could be realized in BPO buildings. A combination of the following strategies can achieve this: raising the temperature setpoint in cooled spaces, raising the chilled water setpoint and/or staging or switching off the major energy-guzzling equipment in the air-conditioning plant, i.e. the chiller.

The table below summarises the key numbers (derived or calculated) utilized for estimating the cumulative short-term cooling demand shift/reduction potential at BPOs for 30 minutes at 10:30 PM.

Table 9. **BPO segment's summary sheet for estimating short-term cooling demand shift/reduction**

	unit	2020	2030	CAGR / (remarks)
No. of buildings/facilities	*Nos.*	>2000	~3500	
Built-up area	*million m²*	17.3 to 26.2	29.6 to 46.9	6%
Air-conditioned area	*%*	80 to 85	95 to 100	
Cooling load intensity	*m²/TR*	20 to 30		
Installed cooling capacity	*million TR*	~0.8	~1.5	6%
Overall HVAC system operating efficiency	*kW/TR*	~1.1	~0.9	-2.0%
Peak electrical cooling demand	*GW*	0.91	1.67	6%
Cooling demand at 10:30 PM	*GW*	0.73	1.33	(20% reduction over peak)
Short-term cooling demand shift/reduction potential				
Lower bound of easily possible reduction	*GW*	0.07	0.13	(10% reduction over 10:30 PM)
Upper bound of easily possible reduction	*GW*	0.29	0.53	(40% reduction over 10:30 PM)
Reduction potential with a concerted pre-planning	*GW*	0.51	0.93	(70% reduction over 10:30 PM)

4. Data Centres

Data Centres serve the following industry verticals in India: Banking, Financial Services & Insurance (BFSI), IT & Telecom, Media, Retail and Manufacturing. According to various market intelligence reports, the Indian Data Centre segment is expected to value over USD 2 billion by 2027 end and register a CAGR of over 11% from 2020 to 2027 [21]. Currently, there are 152 colocation Data Centers in India spread across 26 different locations [22]. Key data centre market players in India include CTRLS, ST Telemedia, ESDS, Netmagic, Sterling & Wilson, Innovative Infocom & IT Parks, PX Global Systems, and Pi Datacenters. The cooling load intensity varies from 20 to 30 m^2/TR leading to the current installed cooling capacity of around 0.1 million TR[10], which will grow triple in size by 2030. This can lead to a peak electrical cooling demand of 0.11 GW in 2020 and 0.26 GW in 2030. Unlike other commercial building segments analysed in this report, the Data Centres will not experience any measurable drop in the cooling demand at nights (10:30 PM) as the equipment (server) load, which is 24X7 and weather independent, constitute the bulk of the cooling demand.

The cooling demand reduction potential in Data Centres, in percentage and absolute terms, is the lowest amongst the commercial building segments analysed in this report. In 2020, only 10 to 30% of the cooling demand for Data Centres, constituting roughly 0.01 to 0.03 GW of grid-connected load, can be quickly shifted/reduced at 10:30 PM for half an hour without any significant impact on the conditioned environment and any additional investment. A penalty clause is strictly enforced for deviation in the specified indoor condition. Concerns on overheating of equipment leading to server malfunctioning, overheating, damage or data corruption are extremely prevalent in the industry. The servers have inbuilt temperature sensors and may raise the alarm to the IT department if temperatures overshoot the specified thresholds.

However, with concerted efforts from facility managers in terms of pre-cooling the facility before the demand reduction call and keeping the chilled water circulation pumps running, a short-term cooling demand reduction potential of up to 50% could be realized in BPO buildings through a combination of the following strategies: marginally raising the temperature setpoint in cooled spaces, raising the chilled water setpoint and/or staging or switching-off the major energy-guzzling equipment in the air-conditioning plant, i.e. the chiller. Additionally, more research coupled with in-situ monitoring can make a case for greater operational flexibility in maintaining the prescribed temperature conditions for the server racks.

The table below summarises the key numbers (derived or calculated) utilized for estimating the cumulative short-term cooling demand shift/ reduction potential at Data Centres for 30 minutes at 10:30 PM.

Table 10. Data Centre segment's summary sheet for estimating short-term cooling demand shift/reduction

	unit	2020	2030	CAGR / (remarks)
No. of buildings/facilities	*Nos.*	150 to 200	400 to 600	11%
Built-up area	*million m^2*	~3	~7	
Air-conditioned area	*%*	95 to 100		
Cooling load intensity	*m^2/TR*	20 to 30		
Installed cooling capacity	*million TR*	~0.1	~0.3	12%
Overall HVAC system operating efficiency	*kW/TR*	~1.1	~0.9	-2.0%
Peak electrical cooling demand	*GW*	0.11	0.26	9%
Cooling demand at 10:30 PM	*GW*	0.11	0.26	(same as peak)
Short-term cooling demand shift/reduction potential				
Lower bound of easily possible reduction	*GW*	0.01	0.03	(10% reduction over 10:30 PM)
Upper bound of easily possible reduction	*GW*	0.03	0.08	(30% reduction over 10:30 PM)
Reduction potential with a concerted pre-planning	*GW*	0.06	0.13	(50% reduction over 10:30 PM)

10 This is based upon the limited available data in the public domain. The actual number of Data Centres and the corresponding cooling capacity is likely higher than the considered conservative estimates.

5. Shopping Centres

India presently has around 700 to 750 shopping centres and malls with a total built-up area of ~44 million m^2. The built-up area is estimated to grow at a CAGR of ~7% through the next decade. Most of the shopping malls have 80 to 85% of the air-conditioned area with the cooling load intensity varying from 15 to 25 m^2/TR. The total installed cooling capacity for shopping malls is ~1.9 million TR in 2020, estimated to grow up to ~4.4 million TR in 2030. The cumulative impact of cooling requirements on the electricity grids is to the tune of 2.27 GW in 2020 and 4.70 GW in 2030. Since the stores and shops start to close around 10 PM, the cooling demand at 10:30 PM in the night is assumed to be 40% lower than the peak cooling demand.

It is estimated that 30 to 50% of the cooling demand for shopping centres, constituting roughly 0.41 to 0.68 GW of grid-connected load, can be quickly shifted/reduced at 10:30 PM for half an hour without any significant impact on the conditioned environment and any additional investment. This can be achieved by a combination of the following strategies- raising the temperature setpoint in cooled spaces, raising the chilled water setpoint and/or staging or switching off the major energy-guzzling equipment in the air-conditioning plant i.e. the chiller. It is advised that the air-side equipment are kept operational throughout the half-hour demand shift/reduction period to maintain the prescribed airflow quantities for breathing and indoor air quality contaminant dilution. With concerted efforts and pre-planning from the facility managers in pre-cooling the facility before the demand reduction call and keeping the chilled water circulation pumps running, a short-term cooling demand reduction potential of upto 70% could be potentially realized in Shopping Centres.

At 10:30 PM in the night, shops are mostly shut, while the multiplexes (theatres) and restaurants remain to run at full occupancy. In the likely event of an extended cooling demand reduction, customer discomfort and user experience can be a big issue for the restaurant patrons and movie-goers.

The table below summarises the key numbers (derived or calculated) utilized for estimating the cumulative short-term cooling demand shift/ reduction potential at Shopping Centres for 30 minutes at 10:30 PM.

Table 11. Shopping Centre segment's summary sheet for estimating short-term cooling demand shift/reduction

	Unit	2020	2030	CAGR / (remarks)
No. of buildings/facilities	*Nos.*	700 to 750	~1500	
Built-up area	*million m^2*	41.8 to 45.4	82.1 to 93.5	7%
Air-conditioned area	*%*	80 to 85	95 to 100	
Cooling load intensity	*m^2/TR*	15 to 25		
Installed cooling capacity	*million TR*	~1.6	~3.5	8%
Overall HVAC system operating efficiency	*kW/TR*	~1.1	~0.9	-2.0%
Peak electrical cooling demand	*GW*	2.27	4.70	8%
Cooling demand at 10:30 PM	*GW*	1.36	2.82	(40% reduction over peak)
Short-term cooling demand shift/reduction potential				
Lower bound of easily possible reduction	GW	0.41	0.85	(30% reduction over 10:30 PM)
Upper bound of easily possible reduction	GW	0.68	1.41	(50% reduction over 10:30 PM)
Reduction potential with concerted pre-planning	GW	0.95	1.98	(70% reduction over 10:30 PM)

6. Hotels (4 & 5 Star)

The hospitality industry in India is expected to grow at a CAGR of ~13% during the 2018-2023 period due to an increase in the number of foreign tourists and international business delegates [23]. The government of India has also allowed 100% foreign direct investment (FDI) in tourism construction projects and the development of hotels which will act as a driving force for the development of new hotels across the country. This may likely lead to the construction of 200 more premium category hotels in the coming decade. The 4-star and 5-star hotels are typically fully air-conditioned (up to 95%) using a centralized air conditioning system. The cooling load intensity varies from 15 to 25 m^2/TR, and the total installed cooling capacity is estimated to be ~0.3 million TR in 2020 that can grow up to 0.4 million TR in 2030. This can lead to a peak electrical cooling demand of 0.31 GW in 2020 and 0.43 GW in 2030. The cumulative cooling load at 10:30 PM in the night is assumed to be 80% of the hotels' peak load due to the absence of solar heat load during the night.

The cooling demand reduction potential in Hotels is pretty low compared to Airports, Metro Stations and Shopping Centres. In 2020, only 10 to 30% of the cooling demand for Hotels, constituting roughly 0.03 to 0.08 GW of grid-connected load, can be quickly shifted/reduced at 10:30 PM for half an hour without any significant impact on the conditioned environment and any additional investment. Guest experience is an essential consideration for facility managers, and there are additional concerns on strict ventilation requirements due to COVID-19 related precautions. Poor guest experience may lead to complete loss of recurring business and even penalties in case of unmet thermal conditions.

Raising the guest rooms' temperature setpoint is difficult for facility managers as the thermostat is typically placed in the guest rooms. However, with concerted efforts from facility managers in terms of pre-cooling the facility before the demand reduction call and keeping the ventilation system running at all times, a short-term cooling demand reduction potential of upto 50% could be realized in Hotel buildings through staging or switching-off the major energy-guzzling equipment in the air-conditioning plant, i.e. the chiller.

The table below summarises the key numbers (derived or calculated) utilized for estimating the cumulative short-term cooling demand shift/reduction potential at Hotels for 30 minutes at 10:30 PM.

Table 12. **Hotel segment's summary sheet for estimating short-term cooling demand shift/reduction**

	unit	2020	2030	CAGR / (remarks)
No. of buildings/facilities	*Nos.*	~300	~500	
Built-up area	*million m^2*	4.9 to 5.7	6.9 to 8.5	5%
Air-conditioned area	*%*	90 to 95	95 to 100	
Cooling load intensity	*m^2/TR*	15 to 25		
Installed cooling capacity	*million TR*	~0.2	~0.3	4%
Overall HVAC system operating efficiency	*kW/TR*	~1.1	~0.9	-2.0%
Peak electrical cooling demand	*GW*	0.31	0.43	3%
Cooling demand at 10:30 PM	*GW*	0.25	0.35	(20% reduction over peak)
Short-term cooling demand shift/reduction potential				
Lower bound of easily possible reduction	*GW*	0.03	0.03	(10% reduction over 10:30 PM)
Upper bound of easily possible reduction	*GW*	0.08	0.10	(30% reduction over 10:30 PM)
Reduction potential with a concerted pre-planning	*GW*	0.13	0.17	(50% reduction over 10:30 PM)

7. Cold Storages

India has a large inventory of more than 8000 Cold Storages, primarily utilized for storing potatoes. As per the India Cooling Action Plan, the storage capacity is likely to grow at a marginal rate of 1 to 2% from ~38 million Metric Tonne (MT) in 2020 to ~44 million MT in 2030. The growth drivers are directly linked with the Government of India's initiative like Doubling Farmers Income (DFI) that will help plug the infrastructure gaps and provide important market linkages for reducing food loss across the food supply chain. The average cooling load intensity is assumed to be ~64 MT/TR considering the refrigeration system used for a 5000 MT capacity cold storage. The total installed cooling capacity for cold storages is ~0.6 million TR in 2020, estimated to grow up to 0.7 million TR in 2030. The cumulative impact of cooling requirements in cold storages on the electricity grids is to the tune of 0.87 GW in 2020 and 1.00 GW in 2030.

There is a significant cooling load at the (potato) cold storages during the loading time, around the harvest season, due to the pull-down load (field heat removal). Post the loading season, when the produce temperature is brought down to the storage conditions, the cooling load during the holding periods is considerably low. During the holding seasons for potato, i.e. March onwards in India's northern plains, the cold storages' refrigeration plant is typically operated intermittently for just 4-6 hours daily. During this time, up to 80 to 85% of the cooling demand for Cold Storages, constituting roughly 0.70 to 0.74 GW of grid-connected load in 2020 can be quickly shifted/reduced at 10:30 PM for half an hour without any significant impact on the conditioned environment and any additional investment. While implementing such cooling demand reduction, the ventilation requirements (for diluting the concentration of CO_2 or other undesirable gases), which constitute roughly 10 to 15% of the total cooling load should not be compromised. The cooling load reduction potential in other cold storage facilities handling food products such as ice-creams, frozen processed food, meat, fish, etc., may be quite low as any substantial variations in the temperature conditions may affect the product quality and shorten its storage life. But the share of such food product cold storages in India's overall cold storage stock is also very low.

The table below summarises the key numbers (derived or calculated) utilized for estimating the cumulative short-term cooling demand shift/reduction potential at Cold Storages for 30 minutes at 10:30 PM.

Table 13. **Cold Storage segment's summary sheet for estimating short-term cooling demand shift/reduction**

	unit	2020	2030	CAGR / (remarks)
No. of Cold Storages	*Nos.*	~8000	~10000	
Storage capacity	*million MT*	~38	~44	1%
Cooling load intensity	*MT/TR*	~64		
Installed cooling capacity	*million TR*	~0.6	~0.7	2%
Overall HVAC system operating efficiency	*kW/TR*	~1.4	~1.2	-2%
Peak electrical cooling demand	*GW*	0.87	1.01	2%
Cooling demand at 10:30 PM	*GW*	0.87	1.01	(same as peak)
Short-term cooling demand shift/reduction potential				
Lower bound of easily possible reduction	*GW*	0.09	0.10	(10% reduction over 10:30 PM)
Upper bound of easily possible reduction	*GW*	0.35	0.40	(40% reduction over 10:30 PM)
Reduction potential with a concerted pre-planning	*GW*	0.61	0.71	(70% reduction over 10:30 PM)

3. Aggregated results

The key results have been aggregated to give an overview of the total number of eligible facilities for Demand Response program, the segment-wise short-term demand shift/reduction potential under three different scenarios- i) lower bound of easily possible reduction, ii) upper bound of easily possible reduction, and iii) reduction potential with a concerted pre-planning, and the possible constraints for cooling demand shift implementation in the identified large commercial building segments.

3.1 Total number of eligible facilities

The total number of large commercial facilities that could be targeted for Demand Response programmes is ~11450 in the year 2020. The total no. of eligible facilities may increase by 44% to 16500 in 2030. A segment wise break-up of the total number of eligible facilities is presented in Figure 8 below:

3.2 Aggregated flexible cooling demand in 2020 and 2030

The segment wise short-term cooling demand shift/reduction potential under three different scenarios is summarised in Figure 9 below.

The aggregated short-term demand shift/reduction potential under three different scenarios is summarised in Figure 10 below.

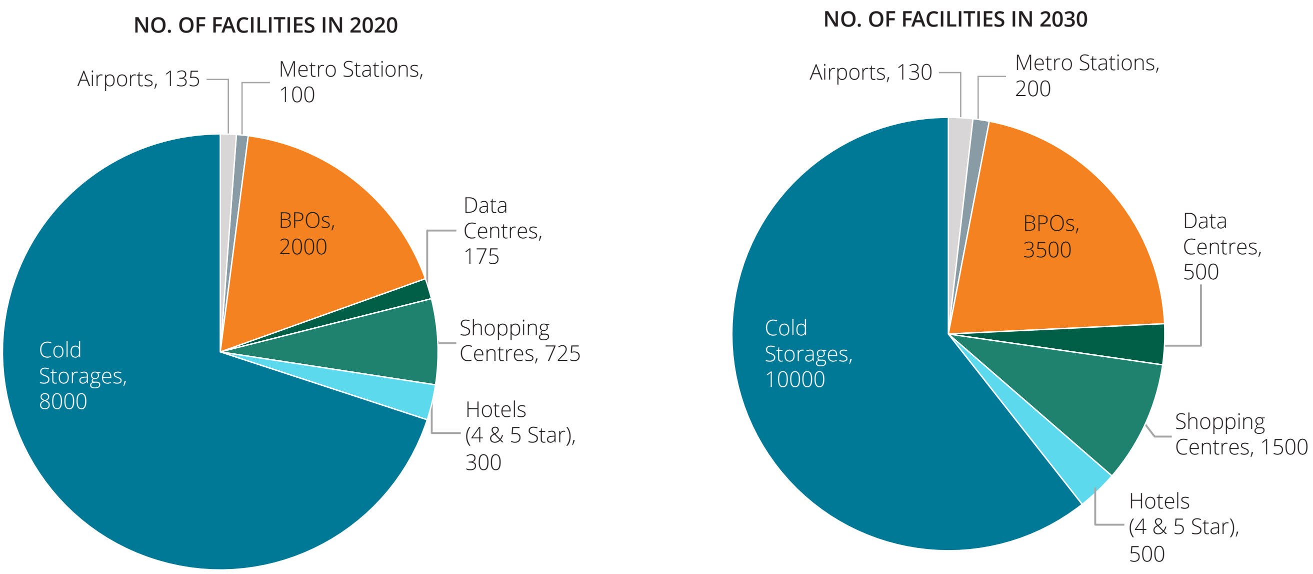

Figure 8: Estimated total number of facilities eligible for a Demand Response program

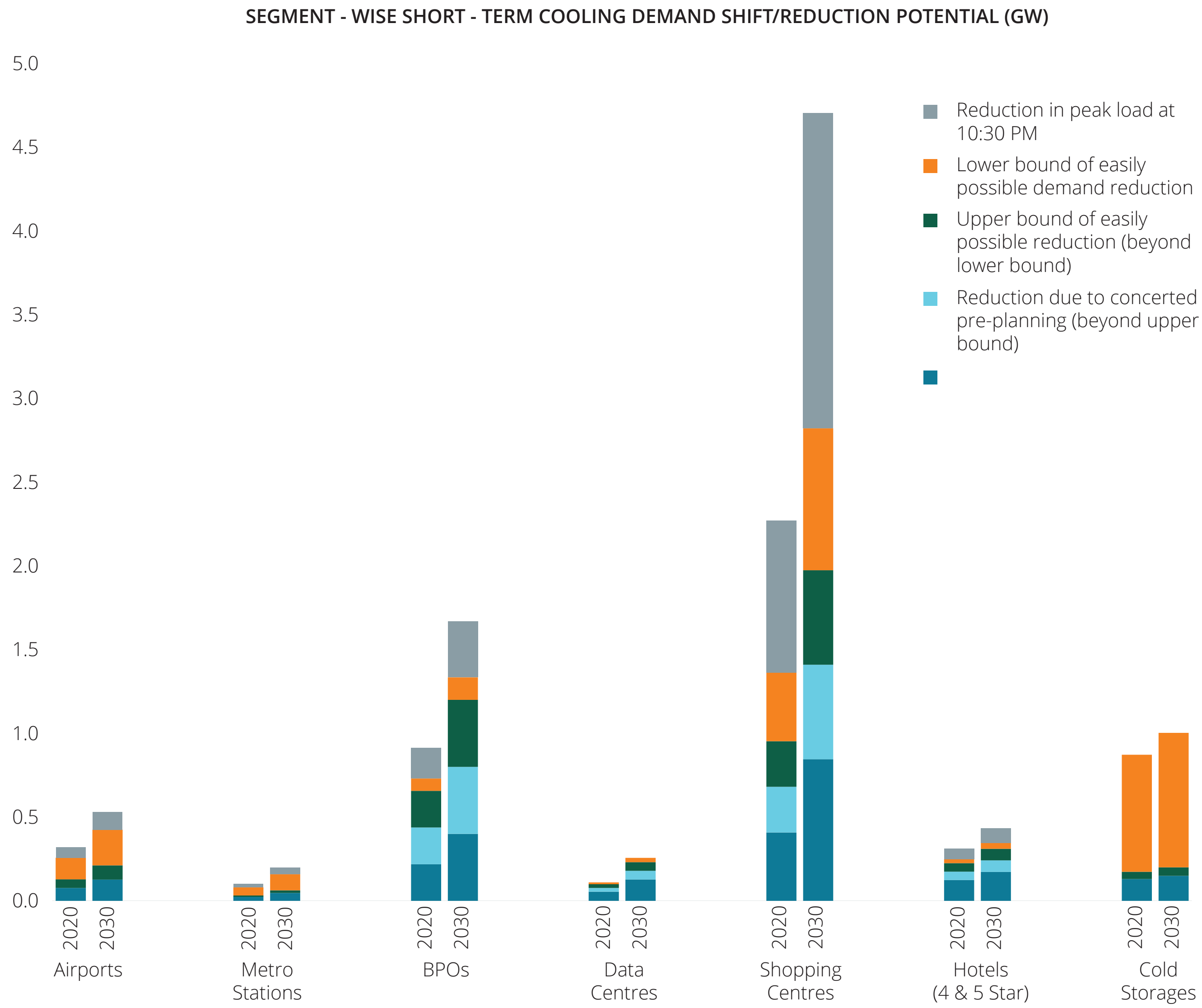

Figure 9. **Segment-wise short-term demand shift/reduction potential (GW) under three different scenarios**

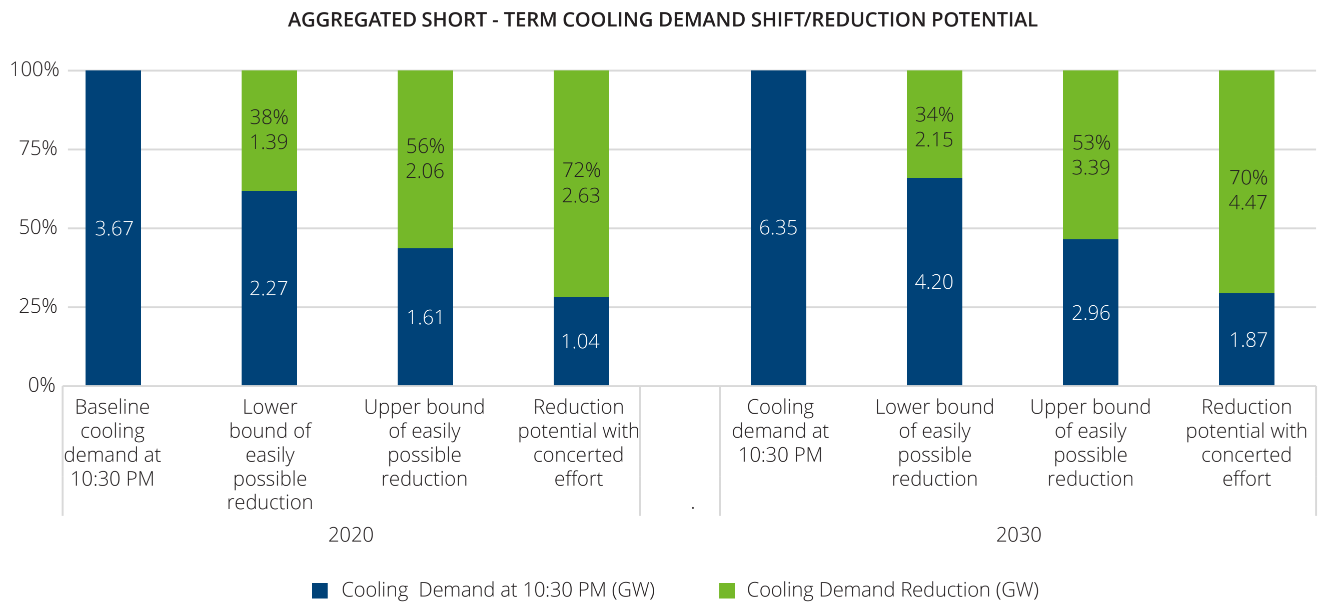

Figure 10. **Aggregated short-term demand shift/reduction potential under different scenarios**

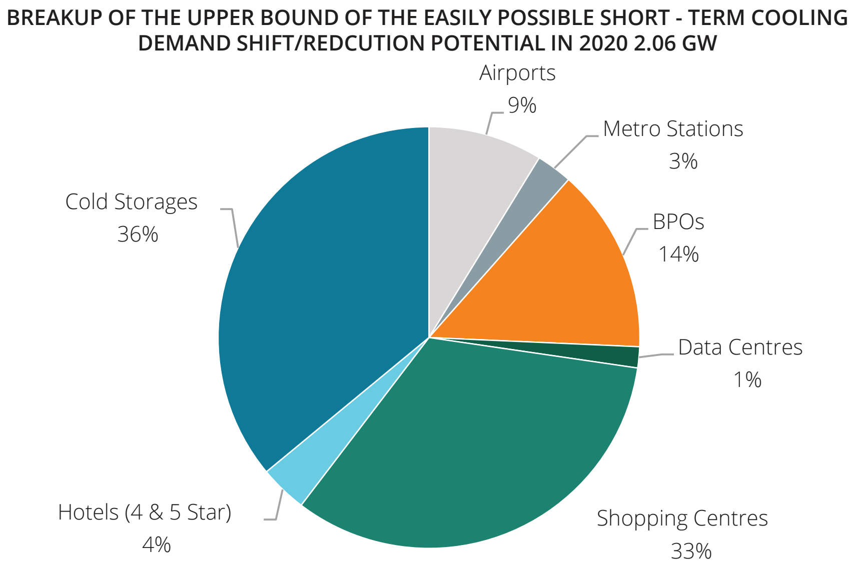

Figure 11. Break-up of the aggregated short-term cooling demand shift/reduction potential in 2020 across different commercial building segments

Up to 56% (~2.06 GW) of the aggregate cooling demand in 2020 at 10:30 PM could be easily reduced shifted/ reduced for half an hour without any significant effort or investment. With some concerted effort and pre-planning, a cooling demand reduction of 72% corresponding to 2.63 GW could be achieved in 2020.

A break-up of the upper bound of the easily possible cooling demand shift/reduction potential across different commercial building segments is presented in the pie chart below. The majority of the cooling demand reduction comes from Cold Storages and Shopping Centres, each segment representing one-third of the total demand reduction potential. This is followed by BPOs and Airports, which constitute 14% and 9% of the demand reduction potential, respectively. Data Centres, Metro Stations and Hotels are the smallest segments in terms of the cooling demand reduction potential having 1%, 3% and 4% demand reduction respectively.

In the year 2030, an estimated aggregated cooling demand shift/reduction potential of 3.39 GW could be easily reaped at the upper end of the demand reduction potential. While concerted efforts, a cooling demand reduction of 4.47 GW could be achieved in 2030 from the assessed large consumers.

3.3 Constraints for cooling demand shift implementation

A summary of possible constraints for cooling demand shift implementation has been presented in Table 14 below which maps the enforcement of temperature conditions in Service Level Agreements (SLA), the allowable tolerance in maintenance of temperature conditions, willingness of building owners to participate in DR programs and finally the operational constraints and adverse consequences of not being able to maintain prescribed temperature conditions.

Table 14: Identification of possible constraints for cooling demand shift implementation

Commercial Building Segments	Enforcement of temperature conditions in SLAs	Allowable tolerance in temperature maintenance	Willingness of building owners to participate in DR programs	Operational constraints and adverse consequences of not being able to maintain prescribed temperature conditions
Airports	Yes	Low (±1°C)	High	Passenger discomfort can be a big issue; airport authorities have been sued in the past for not providing necessary thermal comfort
Metro Stations	No	High (±3°C)	High	Passenger discomfort is not a major issue as the footfall is floating, however, some critical equipment require air-conditioning
IT Parks (BPOs)	Yes	Low (±1°C)	High	Occupant discomfort, health and productivity loss are big issues; concerns on strict ventilation requirements due to COVID-19 condition

Commercial Building Segments	Enforcement of temperature conditions in SLAs	Allowable tolerance in temperature maintenance	Willingness of building owners to participate in DR programs	Operational constraints and adverse consequences of not being able to maintain prescribed temperature conditions
Data Centres	Yes	Low (±1°C)	Low	Penalty clause is strictly enforced for deviation in performance; concerns on overheating of equipment may corrupt data
Shopping Centres (Malls)	No	High (±3°C)	Moderate	Loss of sale/business may be attributed/ blamed on the temperature by the shop owners
Hotels	Yes	Low (±1°C)	High	Poor guest experience may lead to loss of recurring business; penalties may be enforced in case of unmet thermal conditions; ventilation concerns are more critical
Cold Storages	Yes	High (±3°C)	High	Affects product quality and storage life; loss of revenue & business

The ease of user adoption and the implementation of cooling demand shift depends on the nature of functions performed within the target commercial segment. Metro Stations, Shopping Centres, both having transient nature of occupant footfall and Cold Storages are the best contenders for cooling demand shift implementation due to relatively high allowable tolerance in temperature maintenance, leading to a relatively high willingness of building owners to participate in DR programs. However, in Cold Storages and Shopping Centres, the product quality or customers' shopping experience respectively, being adversely affected by a cooling interruption may be perceived as a reason for business loss. In Airport, BPOs, and Hotels, occupant discomfort, even for a short duration, can be a big issue, thus having a low tolerance for cooling interruption. Health and productivity issues with additional concerns on strict ventilation requirements due to COVID-19 hazard make BPOs and Hotels additionally sensitive. In the case of Data Centres, there are serious concerns that overheating of equipment may corrupt data, and penalty clauses are strictly enforced for deviation in performance.

4. Conclusion and future recommendations

In 2020, up to 2 GW of peak load equivalent to two large thermal power plants of 1 GW capacity could be easily avoided by implementing short-term cooling demand shift/reduction in large commercial consumers alone. With each 1 GW coal-fired power plant avoided, approximately 12000 MT/day of coal, 101 m^3/day of furnace oil, and 98000 m^3/day of fresh water could be saved. This translates to reducing 30000 MT/day of CO_2 emissions, 680 MT/day of SO_2+NO_2 emissions and 4200 MT/day of ash. In 2030 more than three large thermal power plants of 1 GW capacity could be easily avoided by implementing short-term cooling demand shift implementation.

A more profound impact on the late evening peaks could be made by assessing the residential sector cooling demand, which, although distributed, contributes significantly to the night peak loads. Also, since India experiences twin peaks, a day time peak and a night time peak, the day time peak also warrants a separate peak load shift/reduction assessment. Anecdotal evidence suggests that the commercial building sector contributes more significantly to the day time peak loads than the night time peaks which was assessed in this study.

The regional load patterns and the diurnal and seasonal load variations at the state and the DISCOM level are more important from a DR program perspective. The utility of the national-level cooling demand shift/reduction potential estimated in this study is limited by the coincident occurrence of peak load at the state or DISCOM, which may or may not happen. The time of the peak demand occurrence is of utmost importance, and there is a need to examine the time and duration of both day and night peaks at the sub-national level in detail.

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