

ISGF WHITE PAPER
**SUSTAINABLE AIR
CONDITIONING WITH DISTRICT
COOLING SYSTEM**



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ISGF White Paper

SUSTAINABLE AIR CONDITIONING WITH DISTRICT COOLING SYSTEM (DCS)

Abstract

The summer temperature has been on the rise constantly all across India during the past 3 decades. Soon the maximum summer temperature will exceed 50°C in Northern India making it extremely difficult for people without access to cooling. India Cooling Action Plan (ICAP) targets incremental improvements in efficiency of equipment to reduce cooling demand by 25-30% by 2037-38 which is likely to be defeated by sheer increase in the number of air conditioners. Radical approaches are required to address the cooling challenge. District Cooling System (DCS) is an alternative route to address the space cooling challenge effectively. This paper highlights the DCS technology, the technical and commercial benefits it can offer and business models for effective DCS implementation.

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About India Smart Grid Forum

ISGF is a public private partnership initiative of Govt. of India with the mandate of accelerating smart grid deployments across the country. With 170+ members comprising of ministries, utilities, technology providers, academia and research, ISGF has evolved as a Think-Tank of global repute on Smart Energy and Smart Cities. Mandate of ISGF is to accelerate energy transition through clean energy, electric grid modernization and electric mobility; work with national and international agencies in standards development and help utilities, regulators and the Industry in technology selection, training and capacity building.

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1 EXECUTIVE SUMMARY

The summer temperature has been on the rise constantly all across India during the past 3 decades. The maximum temperature in Delhi has increased in the last 3 decades by 6 degree Celsius to exceed 48 degrees in 2019. At this rate by 2030, the summer temperature could be well over 50 degrees making it almost impossible for people to live, work or commute without cooling. Traditionally, space cooling in buildings is provided with room (window) air conditioner (AC) or centralized AC plants. With increasing economic prosperity, urbanization and rising temperatures, sale of room ACs are set to increase rapidly. Installed stock of room ACs in India increased from two million units in 2006 to 30 million units in 2017 and is expected to be between 55 - 124 million by 2030¹. While nationally less than 10% of the urban household's own room ACs, in Delhi almost 30% households own ACs². Already, ACs are accounting for up to 60 percent of the summertime electricity use in Delhi. Per another estimate, about 700 million new ACs by 2030 and 1.6 billion units by 2050 are expected to be added globally. This level of proliferation of ACs will worsen the crisis by increasing the ambient temperature and widen the divide between those who can afford to stay cool and those left out in the unbearable deadly heat!

Room ACs emit heat to the atmosphere creating hot pockets in many parts in a city and increase the overall ambient temperature in the locality. Similarly, millions of air-conditioned cars in large cities like Delhi emitting heat make it very uncomfortable for pedestrians and commuters on 2-wheelers and 3-wheelers. This situation is set to aggravate as the number of rooms ACs and air-conditioned cars are increasing by the day. High temperatures are already affecting people's ability to work, making people sick, and outright killing thousands of elderly and children in low-income communities who cannot afford cooling. While cooling is a luxury at moderate to high temperatures, it is an essential need at temperatures above 40 degree Celsius.

The India Cooling Action Plan (ICAP) issued in March 2019 aims to reduce cooling demand by 25-30% and reduce cooling energy requirements by 25-40% by 2037-38 from 2017-18 levels. ICAP targets efficiency improvement and material substitution and related topics that will yield incremental improvements. The problem being so critical and imminent, it requires a radically different approach – incremental improvement in the efficiency of room AC units and better construction materials will not help to mitigate this challenge. District energy systems are being successfully implemented in many parts of the world have evolved as a matured technology. In the Indian context, the district cooling system (DCS) presents an opportunity to address the space cooling challenge effectively.

¹ https://www.ibef.org/download/Consumer_Durables_June_2019.pdf

² Per Motilal Oswal Report of April 2018, out of 65.13 million urban households, only 6.28 million own ACs where as in Delhi out of 2.34 million households, 688,888 of them had ACs. Total market size for room ACs in 2019 was estimated at 6.7 million units. <https://www.motilaloswal.com/site/rreports/636596385051621278.pdf>

2 INTRODUCTION

Globally, buildings consume a third of energy, 50% of electricity and account for 20% of energy-related GHG emissions. Almost 99% of AC and refrigeration loads worldwide are met by electricity. The associated annual electricity demand (and CO₂ emissions to certain extent) has tripled between 1990 and 2016 and touched 10% of global electricity use in 2018. This demand for AC and refrigeration is estimated to triple again to 6200 TWh by 2050 in the baseline scenario (of International Energy Agency) with 70% of this rise attributable to residential users. Another report³ states “the energy required to deliver access to cooling globally could reach 19600 TWh by 2050 without efficiency measures”. This growth will take place essentially due to rises in population in developing economies that are in hot-climate regions (India, China, Pakistan, South East Asia and the Middle East). The cooling energy consumption of typical buildings in hot and hot/humid climates is up to three times higher than in moderate climate zones.

Presently, conventional on-site cooling systems (see figure below) are used mostly which comprise of either window unit in each room in small buildings, or centralized air-conditioning in large buildings with water-cooled or air-cooled chillers which are located on the rooftop or basements. In all the cases the cooling agent to cool the air is produced and distributed at the user end. The efficiency of on-site air-conditioning system is roughly 67% of that of a centralized DCS which produces chilled water in a central chiller plant and deliver to buildings through insulated distribution network and energy transfer stations (ETs) at each building.

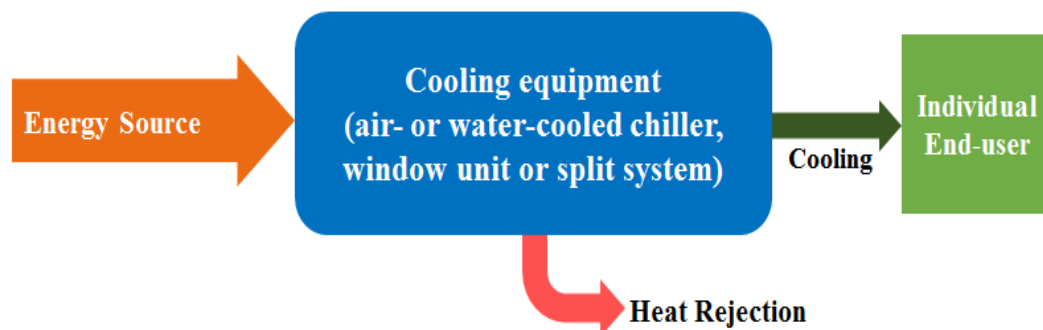


Figure 1: Building Air-Conditioning systems: Conventional on-site Systems

³ 2019 Chilling Prospects: Tackling Sustainable Cooling for All by SE4ALL and Kigali Cooling Efficiency Program

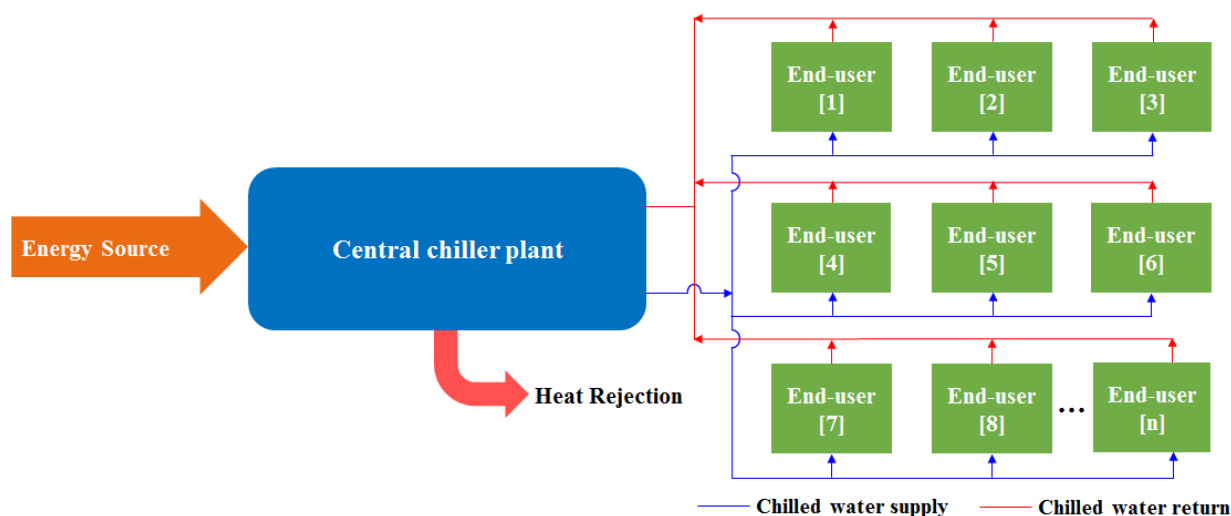


Figure 2: Building Air-Conditioning Systems: District Cooling System (DCS)⁴

The central chiller plant consists of cooling equipment, pumps, heat-rejection equipment, chemical treatment unit, controller and other devices such as cold storage, pumping stations and control systems. Typical ETS is a plate heat exchanger which exchanges the “chillness” of the chilled water from the DCS (normally at 5°C) and cools the water in the building’s air-conditioning system which comprises of air handling units (AHUs), fan coil units (FCUs) and distribution/regulation valves. In the ETS the chilled water at 5°C from the DCS gets heated up to 12-14°C and returns to the centralized chiller. Cold water networks of the DCS and of individual buildings are not mixed – they exchange “chillness” in the ETS. The central chillers typically use R134a as refrigerant gases⁴.

DCS can use either regular water or seawater. DCS can be more than twice as effective as conventional decentralized chillers. The key advantages/benefits of DCS are:

- Low overall power demand and energy consumption: Overall Power demand and energy consumption in a DCS is almost half of the total cooling power requirement compared to distributed standalone cooling systems installed in each building. The largest electricity load in a typical building is the cooling load. With DCS taking that load, the total power demand and energy consumption in a building is significantly reduced. Consequently, the electricity distribution network for the locality can be much cheaper.
- Reduced cooling capacity: DCS can be designed for 60 - 70% of the combined cooling load of the individual buildings because of load diversity and variability in a larger system.
- With thermal energy storage, DCS can reduce peak hour power consumption and run the chillers during off-peak hours at lower power cost

⁴ Montreal Protocol of 1987 mandated progressive elimination of CFC and HCFC refrigerants which was causing ozone layer depletion. The alternate refrigerants used now are HFCs. R134a is the most popular HFC refrigerant today. HFCs have much higher global warming potential than CO₂ - 1430 times higher! Hence the Kigali Amendments to the Montreal Protocol in 2016 laid out a roadmap for progressive reduction of HFCs by 80% by 2050. In India it has to start from 2028 onwards. Cost of R134a has already started going up owing to production curtailments in some countries. Alternatives to HFC are HFO and Ammonia. HFO is fast emerging as a viable option.

Lower Capex and Opex for Individual Buildings:

- Reduced environmental impact: 50% lower carbon emissions; and the reduced emissions at the DCS location is handled better than individual building's air-conditioning systems
- Reliable service (>99.7%) owing to high standard industrial class equipment, backup chillers, professional operation and maintenance support
- DCS eliminates the refrigerant use in individual buildings
- Longer life span: DCS have a typical life span of 30 years or more (the pipe network could last well over 50 years) compared to on-site air-conditioners which have a life of 10–15 years
- Space savings in buildings: The space used for air-conditioners in the building is available for other uses
- Reduction in Heat Island effect
- Lower noise level in the occupied areas
- Better aesthetic of the area
- Additional green rating points for the buildings

3 DCS AND THE ELECTRIC GRID

Space cooling loads in hot climates are subject to large seasonal and daily variations which create strain on electricity grids. While, air-conditioning represents on average 14% of peak electricity demand worldwide, in hot regions such as Middle East (GCC countries), this demand is approximately 50% of peak load and up to 70% of electricity consumption. In South Asian countries, the energy demand from residential and commercial buildings accounts for 60% of total energy consumption and nearly half of it is for space cooling.

As mentioned above, India is projected to add 55 - 120 million room ACs by 2030 which will take the total stock to 85 - 150 million units. Load of 100 million ACs (1.5 ton) would constitute about 150 GW on the electric grid. Managing these distributed units will be a herculean task for the grid operators particularly in the April to June quarter when the whole country will be experiencing hot weather and most of the ACs will be in operation. Associated power generation, transmission and distribution network investment could be prohibitive.

With DCS, the cooling load will be almost two-third. DCS with thermal storage facility will allow the system to produce ice/chilled water when the electricity is cheap on the grid or when solar plants are generating during the day. The ice/chilled water can be stored in the thermal storage facility for several hours. This can be of great help to balance the load on the grid by shutting-off (or partially running) the electric chillers during peak electricity demand periods on the grid.

There are some studies that indicate that solar energy could completely meet the cooling load by 2050. In most offices, commercial centers, educational institutions etc, cooling load is during the day when solar energy can be locally produced near the DCS locations as well as on the roof of the buildings in the DCS network.

4 COOLING AS A SERVICE

Electricity, water and cooking gas are supplied to buildings as a service by utilities. On the same model, cooling can also be provided to individual buildings as a service. This model has been successfully implemented in several parts of the world including in the GIFT City in Gujarat. Besides all the advantages of the DCS mentioned above, individual flat/building owners need not invest in buying ACs or centralized AC systems. This is a huge savings and a portion of that could be made as a deposit with the DCS utility - similar to the deposit for getting electricity or gas connections. Every residential colony, street, office complex, commercial centre and market should have DCS and the electricity to run the DCS may be generated from solar panels that are installed on the building roofs and other common areas in the locality. New infrastructure being constructed and under planning must be mandated to build with DCS as the integral part. Existing buildings may be mandated to implement DCS in next 10-15 years in all urban areas phase-wise starting with commercial centers, government offices, hospitals and educational campuses to residential areas.

In the low-income communities, it may be explored to create common sleeping rooms and entertainment areas which are cooled.

5 GIFT CITY – FIRST DCS IN INDIA

Gujarat International Finance-Tec (GIFT) City is located between Ahmedabad and Gandhinagar and is India's first smart city. The total planned area is 42 million SqFt of commercial space, 14 million SqFt of residential space and 6 million SqFt of social space. GIFT City has a currently installed DCS capacity of 10,000 TR⁵ with 2 sets of electric chillers of 5,000 TR each (2500 TR x 2 nos; series – counter flow arrangement). The DCS has a thermal storage with capacity of 10,000 TR-Hour. The DCS is in commercial operation since April 2015.

Presently DCS supplies chilled water to twelve commercial/social buildings in GIFT City which are operational at different HVAC loads of the respective buildings. The total design cooling load demand of the twelve buildings is around 15,500 TR. As against the total connected HVAC load the DCS capacity to serve the total load requirement is around 10,000 TR.

If each of these buildings had their own air-conditioning systems, they would have built systems for total of 19,500 TR and would have taken more than 23 MW power connection as against the total power demand for DCS is 9 MW at full load.

There is a plan to build 500 kW of solar PV system in GIFT City that would power the DCS plant independent of the grid at peak hours⁶. This flexibility of DCS load could save money for GIFT City as the chiller plant can be run when electricity prices are low on the power exchange and store the chilled water in the thermal storage unit.

⁵ Cooling capacity is measured in Ton of Refrigerated (TR) or Refrigeration Ton (RT) which is equivalent to 12000 BTUs per hour. TR is the unit measure for the amount of heat removed and is defined as the heat absorbed by one ton of ice causing it to melt completely by the end of one day (24 hours).

⁶ GIFT City has electricity distribution license and is connected to the Gujarat's transmission grid. GIFT City has long-term PPA with a power generation company and they buy daily from the power exchange as well.

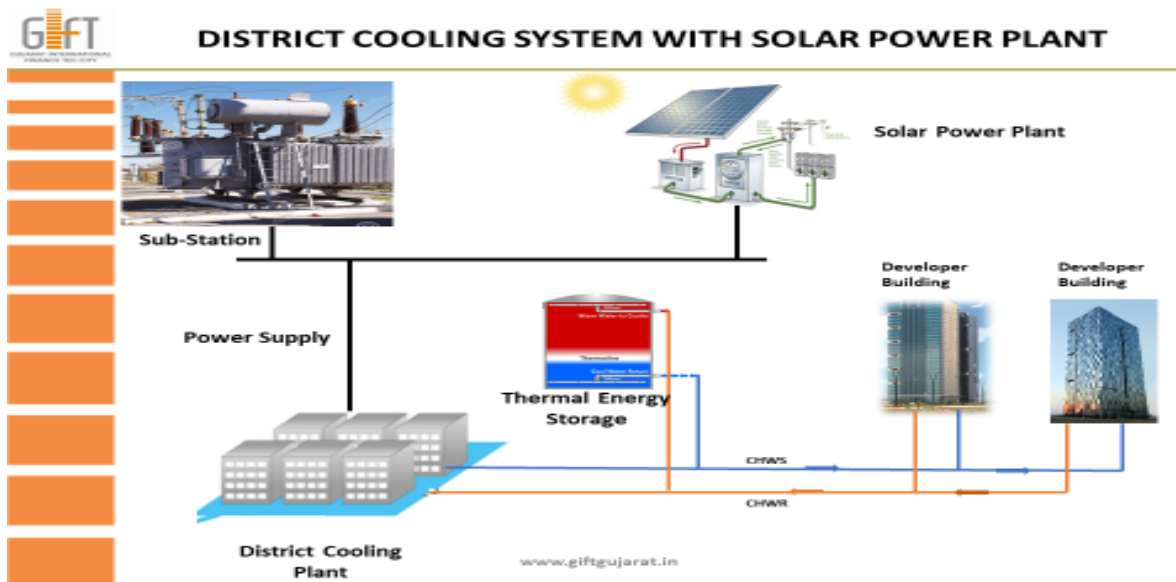


Figure 3: District Cooling System with Solar Power Plant

6 OTHER DCS INITIATIVES IN INDIA

6.1 Amaravati District Cooling Scheme

The new state of Andhra Pradesh has a greenfield capital city planned in Amaravati with world-class and sustainable infrastructure features, inter alia, an elaborate and interconnected District Cooling Scheme to serve cooling loads of up to 100,000 TR. The Amaravati Government Complex (AGC) featuring the State Assembly, the High Court, 5 secretariat towers and two future mixed-use towers is planned among the initial developments in the capital city with a cooling requirement of 19,989 TR. The Andhra Pradesh Capital Region Development Authority (APCRDA), entrusted with developing the capital city, launched a Design, Finance, Build, Own, Operate and Transfer (DBFOT) tender for a District Cooling System (DCS) to be developed in a phased manner after being convinced of the significant benefits that a DCS could provide in meeting the cooling demand of AGC in a sustainable manner vis-a-vis the standalone cooling system it had planned earlier. This would make the AGC DCS as India's first cooling scheme developed through a Public Private Partnership (PPP) concession model.

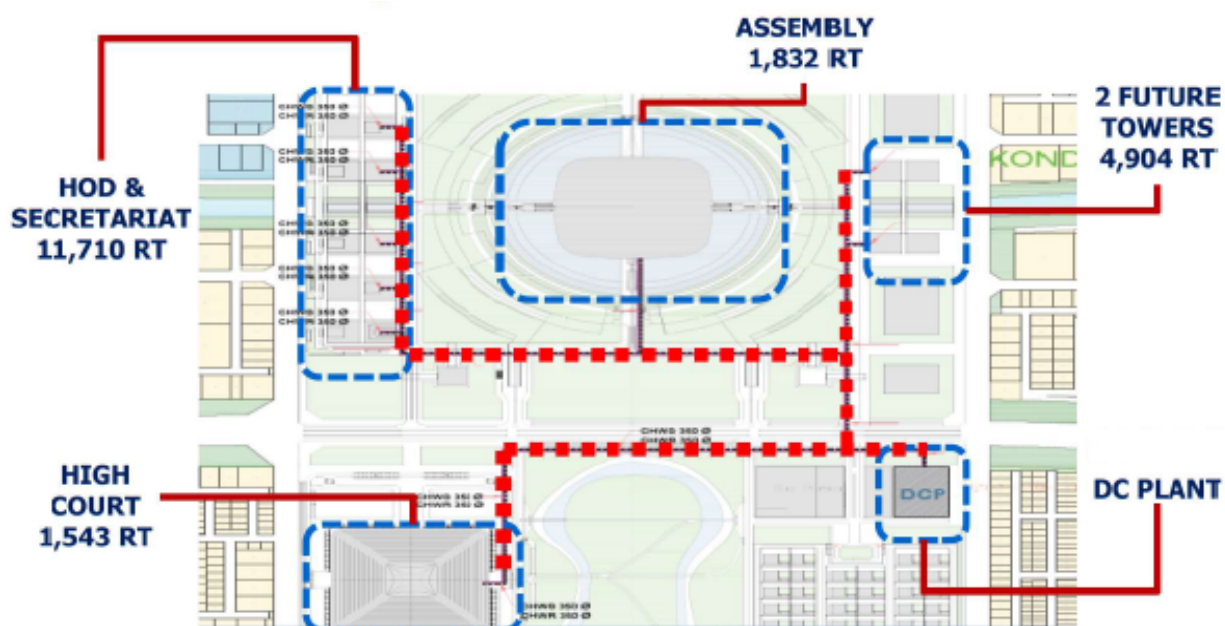


Figure 4: Cooling Requirements at AGC

The various benefits that accrue from a DCS for meeting AGC's cooling needs compared to standalone water cooled or air-cooled systems are:

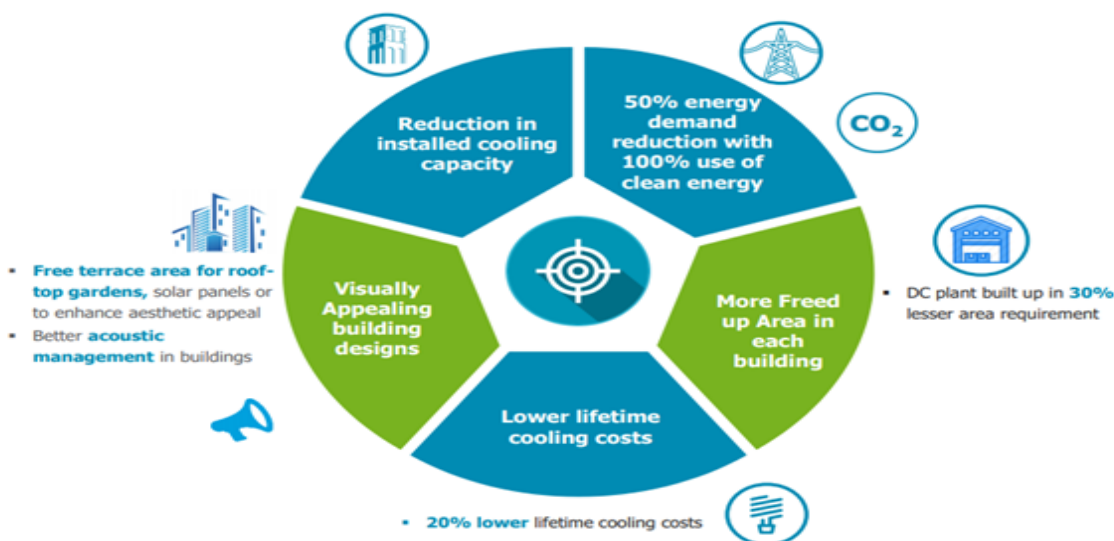


Figure 5: Benefits of DCS

The DFBOT global tender for DCS by APCRDA attracted several bids from which Tabreed (amongst the world's largest District Cooling utility based out of UAE) was selected as the winner with an investment commitment of INR 3750 million. The tender process successfully culminated into a 32-year cooling concession agreement between APCRDA and Tabreed, following which Tabreed started its operations

in India through its country office set-up in the NCR in 2019. After the change in State Government in 2019 and the lack of visibility in the development timelines of the AGC, the DCS project is currently on hold.

6.2 District Energy in Cities Initiative of the United Nations Environment Program

The **District Energy in Cities Initiative** is a global, multi-stakeholder partnership that assists developing countries and cities to accelerate their transition to lower-carbon and climate resilient societies through promoting modern district energy systems. In India, the initiative is coordinated by the United Nations Environment Programme (UNEP), in collaboration with Energy Efficiency Services Limited (EESL), ICLEI-Local Government for Sustainability (South Asia) as well as contributions from its 60 global partners. It provides technical assistance and capacity building activities to local governments and stakeholders for developing modern district energy approach, particularly for district cooling that can be scaled up in the country.



Figure 6: United Nations Environment Program

The Initiative has completed five years of work in District Cooling Systems. It has been working to unlock investments and build momentum and policy support for district energy (particularly district cooling and tri-generation) at city and state-level, within industry and with relevant national ministries. Specific milestones achieved by this initiative till date are listed below:

- a) Report on “National District Cooling Potential and Policy recommendations” which is under review with National Steering Committee and expected to be launched in January 2021 by Energy Efficiency Services Limited (EESL) who are the National coordinators for District Cooling System (DCS) related work.
- b) Pilot City Rajkot has incorporated DCS in Smart City Plan and awarded the tender for EPC work on district cooling network.
- c) Pilot City Amaravati has successfully tendered and awarded a DCS project in the government complex (currently on hold).
- d) Tools and methodologies have been developed and will be used as a standard for how to support cities on District Energy Systems (DES). They have been developed following a deep research of how 45 champion cities globally have prepared DES projects. The methodology goes beyond just supporting demo projects but also to stakeholder coordination, energy mapping, local policies, energy master planning, MRV etc.
- e) As a part of pilot city methodology, UNEP is supporting Thane and Rajkot cities in GIS energy mapping, master planning and local policies for district cooling.

- f) Developing virtual platform which will capture the case studies, training material, and learning, tools, methodologies etc. on district cooling projects across the world and India.
- g) Prepared rapid assessments of district cooling in five cities (Thane, Coimbatore, Rajkot, Pune and Bhopal).
- h) Organized numerous training workshops and webinars with different stakeholders on district cooling over last five years.

6.3 Chiller Plant Optimization Case Study at Taj Palace, New Delhi

Until 2014, 52-58% of total electrical consumption was from HVAC and in HVAC also 40-45% was contributed by Chillers/Heat machines and its connected accessories like pumps and cooling tower. A comprehensive energy evaluation of the entire HVAC system including the building load and energy pattern was conducted by AdvanTEC team of experts at Carrier. Key drivers for conducting this evaluation / audit were:

- i. To minimize operating cost
- ii. Upgrade existing system with latest technologies and futuristic designs
- iii. Best/optimum performance at plant system level, benchmarking the global standards
- iv. Environment safety and Government regulation – Reduction in Carbon Footprint

Basis the evaluation, The Carrier High Efficiency 23XRV Tr-rotor Screw Chiller and the Heat Machine, coupled up with plant system manager with advanced controls and other plant room equipment were integrated into the system. In addition various interventions were also undertaken at three different levels – Equipment, System and Integration.

Equipment	System	Integration
<ul style="list-style-type: none"> •High Efficient Chiller •New Variable Pumps •CTI certified cooling tower •Anti-Fouling devices on heat exchanger 	<ul style="list-style-type: none"> •Dedicated pumping for zero bypass/leakage, •All variable system design to sustain plant performance, •System designed for <0.8 lKw/Tr performance 	<ul style="list-style-type: none"> •Chiller plant optimizer, •Real time data logging •Advance remote monitoring •Adaptive algorithms for continuous performance improvement

The entire project execution was performed by the Carrier team which resulted in 26 percent increase in the productivity of the plant room, leading to saving of over 1 million kWh of electricity over a period of 9 months. By the end of the 2015-16 financial year, the hotel had achieved monetary savings of INR 9 million by reducing electricity consumption. The system uses various techniques such as cooling tower staging, cooling tower fan speed control, condenser water pump speed control, secondary water pump speed control, chiller staging, chilled water reset, etc. to work in fully automatic mode using Carrier Advanced Plant Room System Optimization solution. The control system also conducts plant room energy diagnostics to determine possible areas of plant waste and to provide accurate information on waste prevention and correction.

NOTES

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