Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

tabreed

Bureau of Energy Efficiency
Ministry of Power, Govt. of India

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

IKI INTERNATIONAL CLIMATE INITIATIVE

Kuḷir Nagaraṅkaḷ

District Cooling's Impact on Tamil Nadu's Resource Use Landscape

June 2024

This collaboration is an initiative undertaken as a part of the Memorandum of Understanding signed between Tabreed India and Gesellschaft für Internationale Zusammenarbeit (GIZ)'s 'Energy Efficiency Cooling' programme, jointly implemented with the Bureau of Energy Efficiency (BEE), Ministry of Power, and funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) as part of the International Climate Initiative (IKI), to accelerate adoption of sustainable cooling practices.

Due to rising temperatures and the corresponding surge in air conditioner usage, projections indicate that, by 2050, cooling could be responsible for 60% of peak energy demand in India. Drawing upon GIZ's proficiency in sustainable development strategies, notably its collaboration with BEE on district cooling guidelines, and Tabreed's unrivalled experience in the industry, the partnership aims to promote widespread adoption of energy-efficient district cooling systems to deliver on sustainable and holistic economic and human development in India.

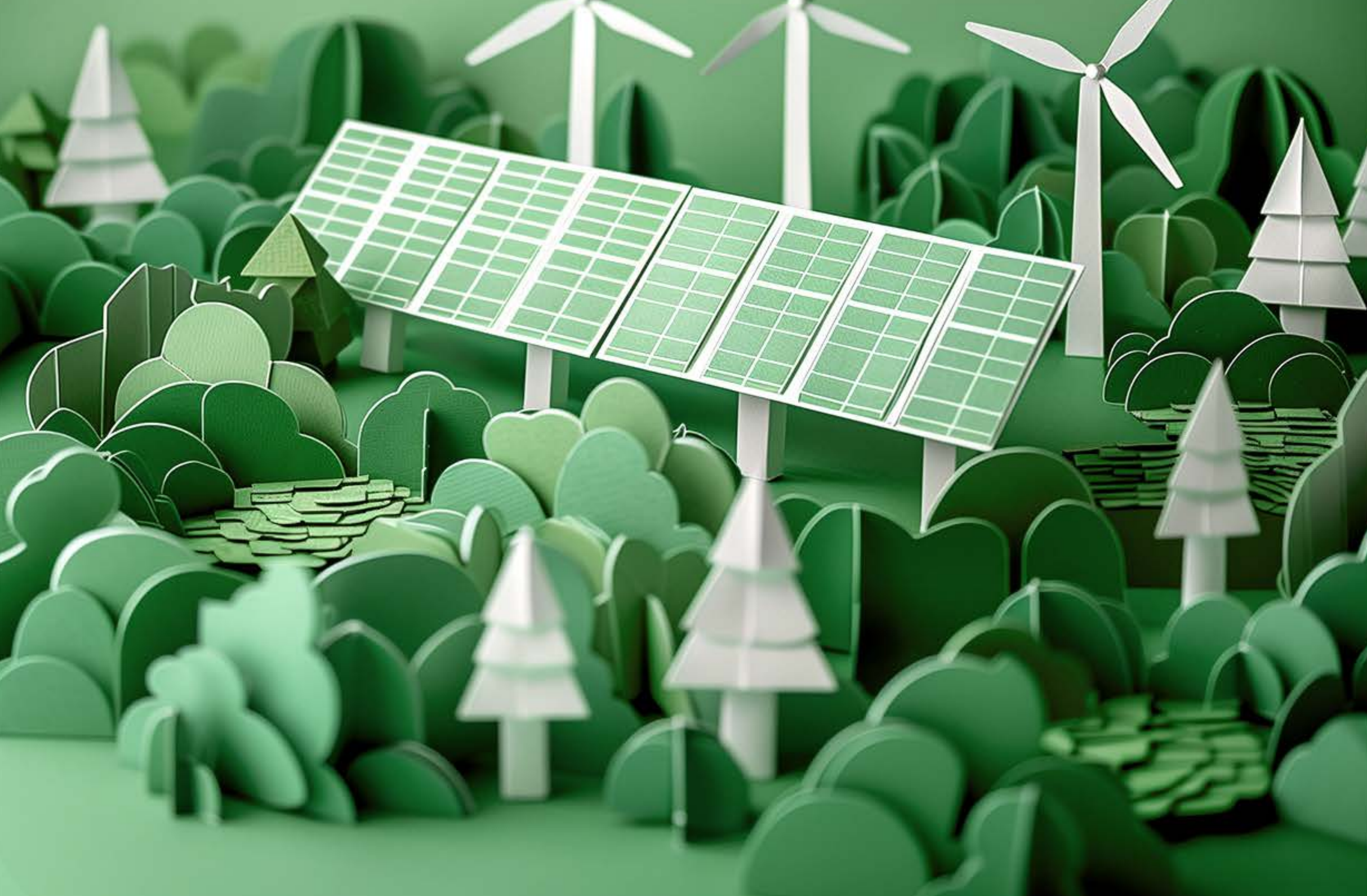
Contact

For any queries or comments about this report, contact:
piyush.sharma@giz.de | amodi@tabreed.in | hita@tabreed.in

We would like to acknowledge our knowledge partners REVOLVE and Kubernein Initiative, and design partner Main Division.

Disclaimer:

Table of Content



Executive Summary

Escalating climate challenges are rapidly changing the world. While India has not been a historical polluter, it is uniquely positioned to lead a global response drawing upon its rich heritage, and indigenous wisdom. Despite the many developmental needs of the country, the Indian ethos is ingrained in centuries-old sustainable practices across diverse communities. This ethos when combined with modern technological innovations could indeed offer new unchartered pathways for more planet-inclusive living.

To bring this ethos in meeting our own developmental needs while balancing the already high climate burden from human activity that amongst others is resulting in significantly increased heat stress especially in our cities is indeed a tight-rope walk. This requires new ways of doing things that embrace the latest in technology but also innovations for a more seamless governance structure between government apparatus across centre, state and cities, business model innovations that cut across sectors and private and public entities.

The impact of increasing heat in India is felt strongly in urban areas where dense concretization, pollution, and reduced tree cover is causing Urban Heat Island (UHI) effects. The direct measurable increase in cooling demand[1] as a result of residential and commercial buildings (with the building sector contributing to the highest growth at 11 times), cold-chain, refrigeration, transport and industries is expected to result in a demand growth of 8 times[2] by 2038 (compared to 2018 levels) and air-conditioning penetration currently at 8%, is expected to reach 40%. A business as usual response with standards and labelling, **minimal incremental technology improvements and uneven market adoption of more energy efficient solutions will increase energy consumption from cooling to account for 45%[3] of the country's peak energy demand by 2050.** As a result, greenhouse gas emissions from increase in air conditioning and refrigeration are projected to rise 90%[4] above 2017 levels by 2050, perpetuating feedback loops for increased heat stress.

Our traditional reliance on unitary or decentralized air conditioning systems, while meeting immediate needs, strain finite resources, intensify greenhouse gas emissions, and exacerbate environmental degradation. **District Cooling is a transformative systems thinking approach to address India's cooling needs sustainably whilst providing pathways for more integrated and circular resource use.** By centralizing production and distribution of cooling energy, District Cooling systems enable substitution of fossil power and potable water with alternate, non-traditional sources of power and waste water for cooling purposes, reducing resource wastage and environmental footprint. Treating cooling as a central utility also democratizes access to cooling services, ensuring affordability and resilience across diverse urban landscapes.

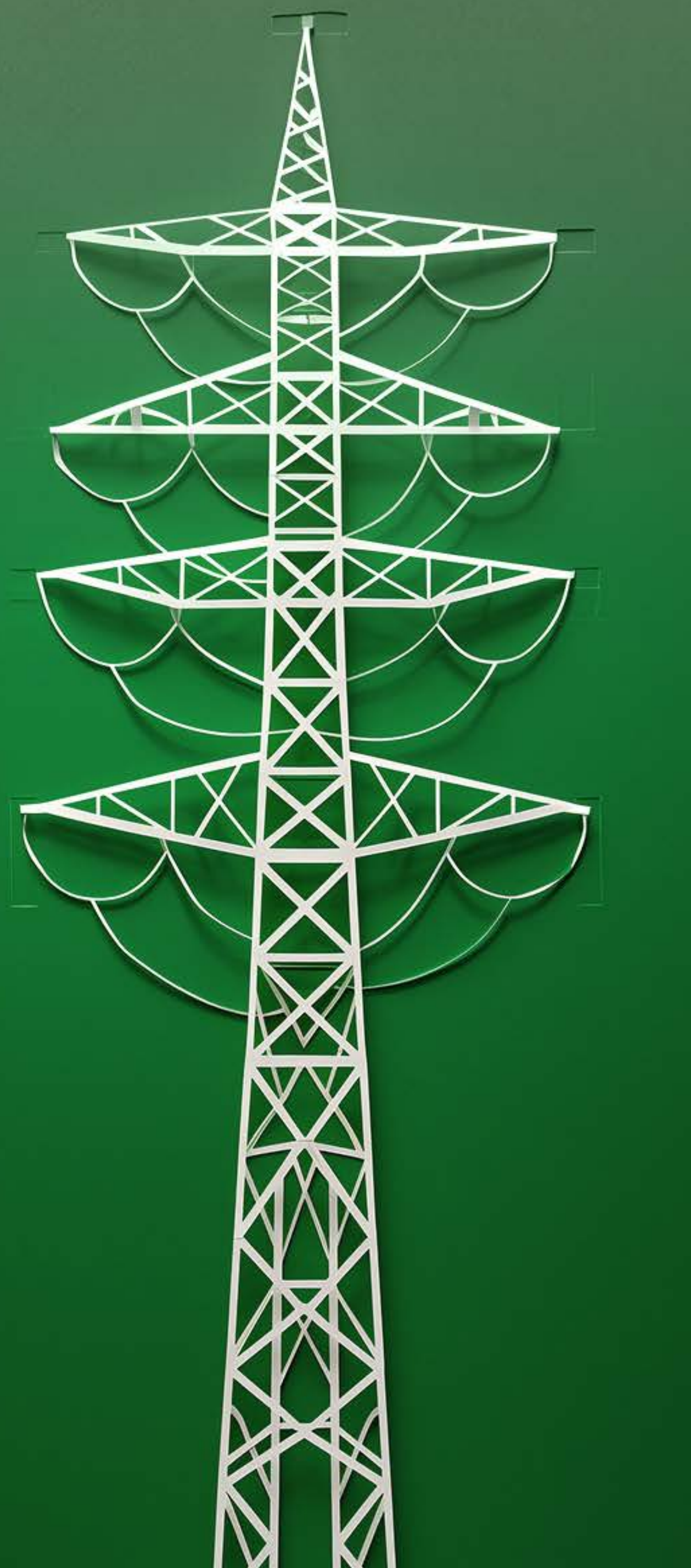
In Tamil Nadu, the imperative for District Cooling is particularly pronounced. With Chennai and other cities like Coimbatore, Madurai, Trichy witnessing a surge in economic activity, the demand for reliable and energy-efficient cooling solutions has reached unprecedented levels, resulting in 50% of electricity demand during peak summer months in some urban areas of Chennai going towards cooling needs. The potential impact of District Cooling extends beyond energy savings. By reducing peak electricity demand and enhancing grid stability, these systems strengthen India's and the state's energy security and resilience. As India transitions towards a sustainable and green future, District Cooling stands poised as a cornerstone of sustainable urban infrastructure. By encouraging collaboration among policymakers, developers, and the private sector, India can build climate-resilient cities and create healthier environments for its citizens.

Introduction - An Increasing Demand for Cooling

Asia, while poised to lead in terms of economic growth over the coming years, is also faced with the increasingly unpredictable consequences of climate change. One of these consequences is heat stress - experienced across the region and particularly in tropical countries like India. In 2024, over an excruciating hot early summer, India has already recorded[5] 56 deaths and over 25,000 cases of heat stroke (through April and May). This number will continue to increase year on year, unless we create better coping mechanisms.

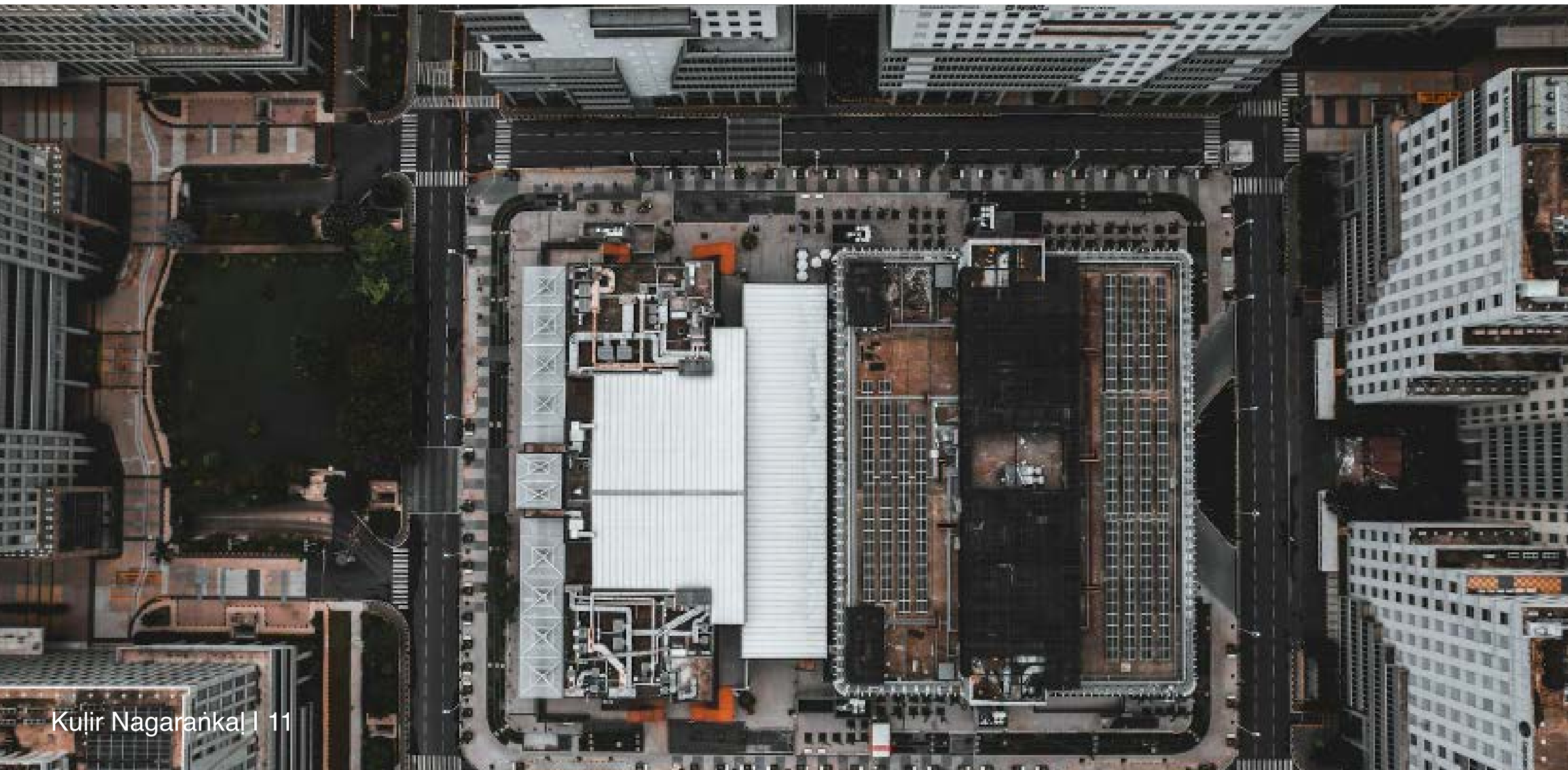
The impact of increasing heat in India is felt strongly in urban areas where dense concretization, pollution, and reduced tree cover is causing Urban Heat Island (UHI) effects. The resulting need for cooling manifests in two ways. First, through a direct measurable increase in cooling demand[6] from residential and commercial buildings, cold-chain, refrigeration, transport and industries where **the space cooling sector alone is expected to grow 8 times in India[7] by 2038 (compared to 2018 levels)** and air-conditioning penetration currently at 8%, is expected to reach 40%. The business as usual response with standards and labelling, minimal incremental technology improvements and uneven market adoption of more energy efficient solutions will increase energy consumption from cooling to account for 45%[8] of the country's peak energy demand by 2050. As a result, greenhouse gas emissions from increase in air conditioning and refrigeration are projected to rise 90%[9] above 2017 levels by 2050 perpetuating feedback loops for increased heat stress.

This is experienced across states, and Tamil Nadu is expected to face the brunt of it with a 45% increase[10] in power consumption by 2030.



Tamil Nadu Generation and Distribution Corporation (TANGEDCO) is already facing challenges to meet this rapidly increasing peak power demand which is now at 21,000 MW and is already resulting in intermittent power purchase from other states. **Chennai, the state capital and largest city by GDP and population has the largest share[11] of power consumption where cooling takes up more than 50%[12] of energy consumed by households.** Tamil Nadu has witnessed an 84%[13] increase in Greenhouse Gas emissions between 2005 and 2019 where **the power sector alone is responsible for 77% or[14] 141 million tonnes CO2 (MT CO2) of greenhouse gas emissions.** Chennai's cumulative emissions are expected to reach 231.9 MTCO2[15] by 2040 at the current pace of urbanization and building construction.

The second manifestation of increasing heat is its effect on health and productivity of citizens, leave alone broader impact on re-generative ecosystems, arable land and overall water cycles and demand in the state. Large sections of India's population live and work in conditions where cooling is not even a consideration, but thermal comfort is now an increasing necessity. **According to World Bank estimates, nearly 75% of India's workforce, or 380 million people, depend on heat-exposed labour for their livelihood.** For instance, about 23 million people[16] are at risk of extreme heat exposure in India's brick industry which is the second largest in the world. Similarly in the animal husbandry[17] sector an increase in animal illness and mortality per rearing cycle is reported, along with a decline in the quality and quantity of eggs and milk produced. Other allied sectors like agriculture, metal-working and construction are also at risk; workers in these sectors are frequently[18] exposed to extreme heat that result in lower productivity due to the need for more frequent breaks, and at times a halt in work altogether for certain periods of time. For example, as the atmospheric temperature increases by 2 degrees, it is predicted[19] that heavy industry workers will be able to dedicate only half of the current time to work, decreasing their economic productivity.



In the state of Tamil Nadu, across its 39 districts, the number of heat-induced discomfort days have increased by 41.5%[20] since 2014 according to a study by the Anna University's Centre for Climate Change and Disaster Management. Discomfort days, where mean temperatures are above 29°C and relative humidity is below 30%, averaged at 107 days per year between 1985 and 2014. This number is set to increase to an average of 150 days per year from 2024 to 2050. Increasing temperatures have already resulted in an increase in medical cases[21] reported. Vulnerable occupations are worse hit. For instance, 90% of salt pan workers[22] are working above the recommended levels of heat exposure. According to the Tamil Nadu Climate Change Mission Document the days where maximum temperatures cross above 40°C (summer days) are projected to increase drastically by the last quartile of the century. Access to cooling, at the household level and for occupations exposed to heat (including even at local markets), would make all the difference.

While mitigation is an important consideration in the long term to address the climate crisis and ecosystem changes being observed, in **the short- and medium-term, access to cooling becomes a key part of adaptation measures.** There are two obstacles to this course: First, conventional means of air-conditioning, while effective, consume large amounts of electricity, and emit greenhouse gasses that exacerbate the climate and ecological crisis. Second, cooling is still seen as a luxury in India, as opposed to in other South Asian countries, such as Singapore for example, where it is considered a necessary part of all public infrastructure. We therefore need environment-friendly alternatives and cooling solutions that can be more widely adopted across various sectors and be accessible to all.

There is growing awareness and acknowledgement of the urgency for action at the policy level as seen through the release of the 2019 India Cooling Action Plan[23] (ICAP), and in acknowledgement of the need for cooling in several climate action plans at state and city levels. Tamil Nadu to 'counter the rising heat' has included this as an objective under its State Action Plan on climate change. Through a Memorandum of Understanding signed[24] in 2023, **the Tamil Nadu government is now working with United Nations Environment Programme (UNEP) to 'implement innovative solutions to bring down the heat index'** through measures that include training and capacity building of stakeholders like builders, architects and urban planners. In Chennai, the government has adopted a 'Climate Action Plan' to identify climate-related challenges in the city, to implement required action.

District Cooling is already being strongly considered amongst a basket of alternative environment friendly cooling solutions, especially as it integrates other supply-side technologies and systems to integrate and optimize resource use, reduce energy consumption and associated emissions.

The delivery of District Cooling through innovative business models such as 'Cooling as a Service' (CaaS) can further make it affordable and accessible to all.

The government has begun laying the framework, but adoption of new solutions and technologies will require transformation of the market; one that can be achieved through a **comprehensive approach bringing together all stakeholders within various government ministries and bodies along with the broader private sector ecosystem.**

This report seeks to introduce the concept of District Cooling, identify challenges, and present the opportunity for the uptake of District Cooling technology within the context of the state of Tamil Nadu.

What is District Cooling (DC) and Cooling as a Service (CaaS) Model?

District Cooling for the Indian context is defined as one single cooling network, distributing chilled water to a cluster of buildings as a self-sustaining service, in District Cooling Guidelines launched in 2023 by Bureau of Energy Efficiency. This centralized system meets the cooling needs of a large, densely occupied space, campus, or network of buildings, occupied by a single user (in airports, malls, hotels) or multiple users (in IT & manufacturing parks, integrated townships and other commercial hubs) through aggregating demand and leveraging diversity factors of varying cooling loads in multiple buildings in a cluster.

Technically, a central plant produces chilled water which is circulated through a network of pre-insulated pipes to multiple buildings in a cluster that are connected to the network. A thermal heat transfer using heat exchangers in each building delivers cooling, and the resulting warmer water is re-circulated back to the plant to be chilled again completing a closed loop.

Depending on the alternatives or baseline being compared against, District Cooling can be upto 50% more energy efficient[25], and can reduce peak power demand by upto 40%. The power source when substituted with renewable energy sources, natural gas through city gas distribution networks, or if combined with a waste to energy plant, the cooling plant can further minimize and in certain unique cases even eliminate dependence on traditional electricity sources. When combined with thermal energy storage solutions further peak load shaving can also typically be achieved.

District Cooling can help **unlock a number of environmental and social benefits** in addition to the reduction of power demand from aggregation benefits and integration of complementary technologies to accelerate circularity in energy, water and waste use (which will be explored further in subsequent sections). For example, District Cooling, in comparison to conventional systems, can

utilize new-generation green refrigerants that support the phasing out of refrigerants with higher global warming potential, thus further reducing greenhouse gas emissions from harmful refrigerant use. Moreover, District Cooling can completely eliminate the leakage of refrigerants through preventive measures, early detection, and containing any leakages leading to minimal impact on the environment.

District Cooling mitigates formation of urban heat islands through heat rejection into treated water or natural water sources such as rivers, seas or lakes. By preventing heat rejection into the surrounding atmosphere, District Cooling dissipates micro-climate feedback loops, which otherwise would further increase the demand for conventional air-conditioning. These systems also eliminate the need for clunky equipment to be placed in basements and rooftop of buildings, thus freeing up space that can instead be used more productively such as the installation of solar panels for on-site power generation or for aesthetic purposes including terrace gardens and recreation. Similarly, the placement of equipment away from buildings reduces vibration and noise leading to a more pleasant outdoor environment, improved air quality, and in turn lower energy consumption for air conditioning.

When it comes to wider adoption of District Cooling in India, initial capital cost is often a concern. Here the **CaaS business model provides a solution where customers can benefit from pay as you go models. CaaS is similar to providing utilities like water, gas or electricity, where the end consumer pays a monthly bill for cooling, depending on use,** in a similar fashion to paying electricity bills or gas bills based on meter readings. Under this model, the entire cooling infrastructure is owned, built, financed by the service provider, who also takes care of operations and maintenance. Since a centralised approach to cooling leads to demand aggregation and a drastic decrease in the quantum of cooling equipment required, the CaaS model is found to save **up to 25% of cooling costs for customers on a lifecycle**

basis. The potential challenges[26] in a CaaS model can be lack of implementation partners given lack of visibility on demand uptake and pre-investment required in laying the network infrastructure, high customer default rates without any security mechanisms in place, and a general unwillingness or inertia to switch to a new technology. These challenges can be dealt with capital mobilisation under a public-private partnership model and through establishment of contractual frameworks for risk mitigation if provision of thermal comfort is indeed considered as a public good.

Over the past decade, the District Cooling model has successfully been adopted in several projects in Asian countries. In Singapore[27] for example, Changi Airport uses District Cooling technology; ST Ang Mo Kio Technopark[28], estimated to be operational by 2025, will have the country's largest District Cooling system; Marina Bay (central business district) has the world's largest underground District Cooling network wherein the private District Cooling service provider, Singapore Power, and the Singapore government have come together to invest in the central plant and the district

cooling network on a modular basis. District Cooling systems have been taken up on a large scale in some Indian projects as well. The Government of Gujarat is implementing District Cooling to meet the air conditioning needs of **Gujarat International Finance Tec-City or GIFT city.**

GIFT District Cooling system is expected to reduce the mechanical load requirement for cooling from 270,000 RT to 180,000 refrigeration tonnes (RT). The District Cooling system is also integrated with Thermal Energy Storage (TES) tanks, which further optimizes power demand for cooling purposes from 240 MW to 135 MW. A District Cooling System of 125,000 RT, Asia's biggest Public-Private Partnership (PPP) based concession, has also been planned for **Hyderabad Pharma City**, the world's largest bulk-drug industrial park being developed by **Government of Telangana**. One of the first Cooling as a Service models was also made operational in 2023 at Gurugram's **Intellion Park** through a strategic alliance between **Tata Realty and Infrastructure Limited** and Tabreed India.

Picture Credit : https://media.licdn.com

The Science of District Cooling

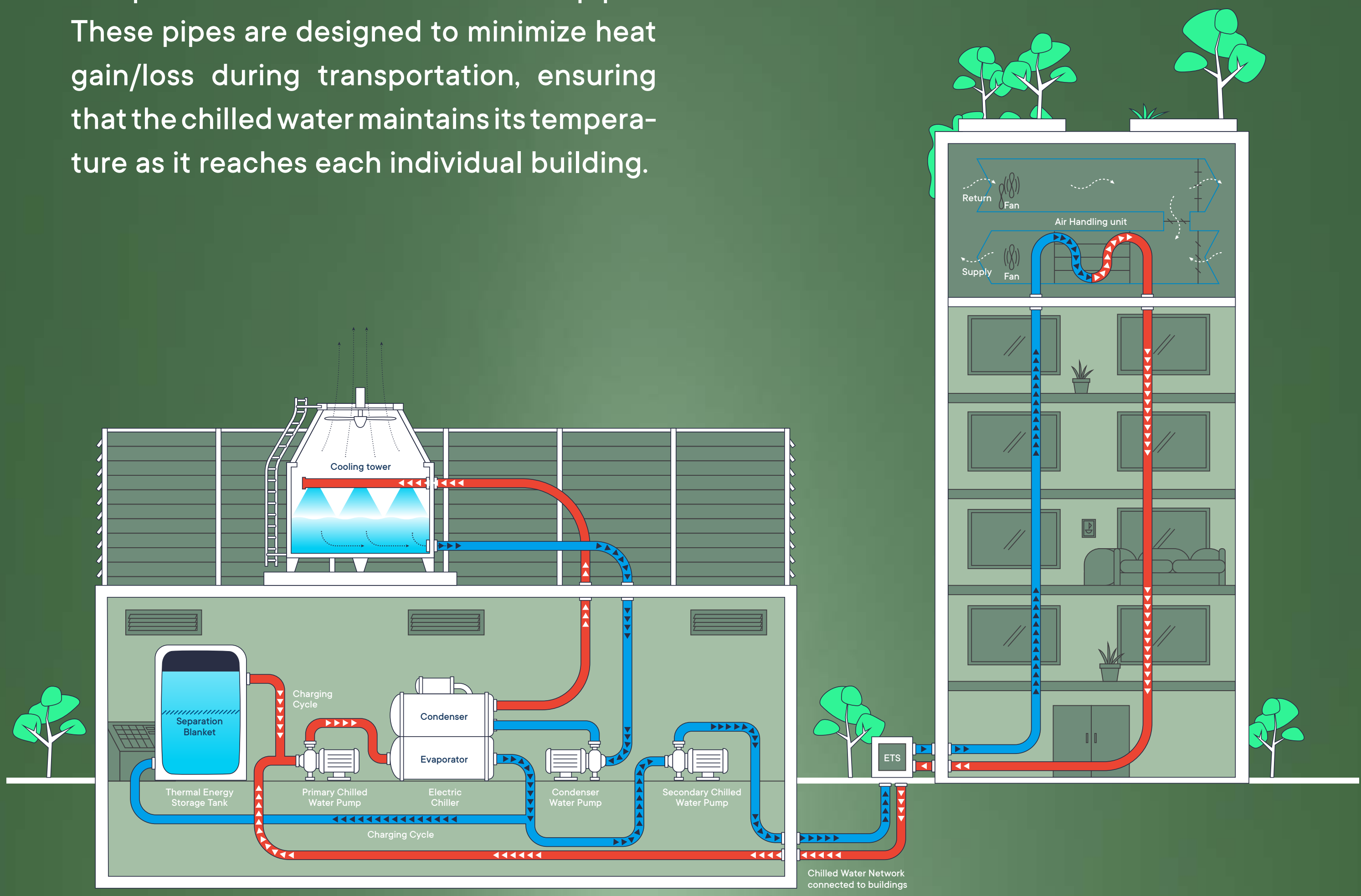
- To begin, the warm water is cooled down by releasing heat into the air using a Cooling Tower. The cooled water gets supplied to the Chiller through the Condenser Water Pump for chilling to the required temperature.

- In the Chiller, the water is chilled using a refrigerant. The refrigerant cools the water through an Evaporator which heats up the refrigerant and in turn needs to be cooled again in the Chiller's Condenser. This completes the refrigeration cycle and the process continues.

- Once chilled to a desired level, the water is pumped using a Secondary Chilled Water Pump into a network of insulated pipes. These pipes are designed to minimize heat gain/loss during transportation, ensuring that the chilled water maintains its temperature as it reaches each individual building.

- At the entry point into each building, an Energy Transfer Station connects the circuit to the building network, enabling delivery of cool air to the end-users of the building through its internal system which can consist of air handlers, fan coil units, or other HVAC (Heating, Ventilation, and Air Conditioning) equipment.

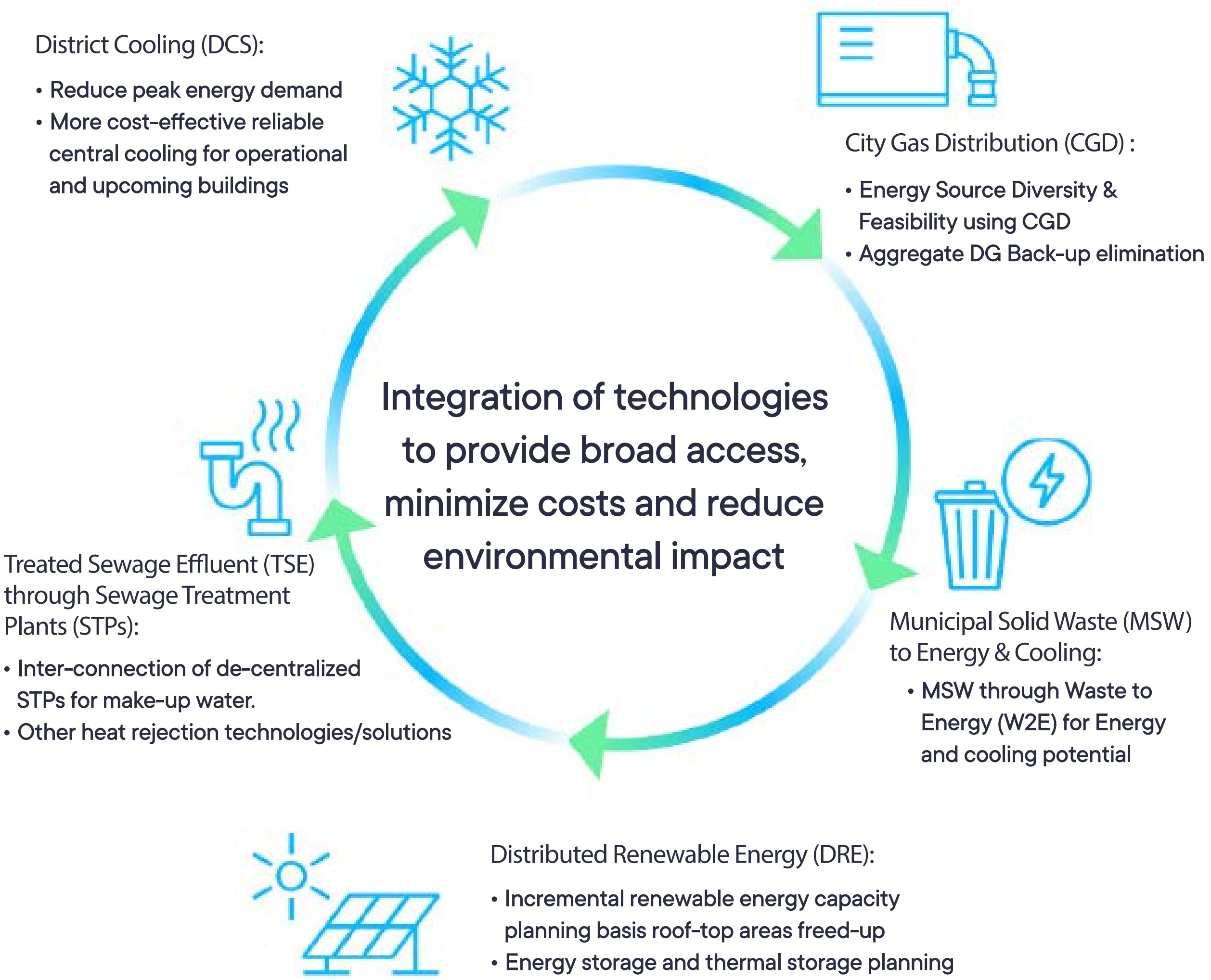
- Heat from the buildings' interior warms the chilled water in the Energy Transfer Station, which is then returned to the Cooling Tower in the central plant for re-chilling through a separate set of returning water pipes. This completes the full District Cooling cycle, allowing the system to continue in a loop.



Benefits from a Systems' Approach to District Cooling

A circular economy[29] or systems approach aims to minimize waste and promote sustainable use of natural resources, through smarter product design, longer use, and recycling, which regenerate the ecosystem. Currently, **only 7.2% materials used in the world are cycled back into the economy,** highlighting the vast scope for the systems approach and benefits it can bring about for beginning to address multiple crises at the intersection of climate change and human welfare. Earth has finite resources, as is widely acknowledged and understood now; immediate measures need to be taken to limit our consumption and resource use to stay within planetary boundaries. **District Cooling's biggest advantage is in the way it lends itself for integration with a range of technologies and systems** such as City Gas Distribution Plants, Waste to Energy Plants (W2E), Traditional Power Plants, and Sewage Treatment Plants (STP) that one, improve the electrical, water and overall resource efficiency through reduced wastage, and two, promote the use of ancillary technologies which may be otherwise unviable.

Tamil Nadu is one of India's most vulnerable states to increasing heat. Given the high level of current industrialization, and projections of rapid urbanization, energy and water are the two resources that will be in high demand vis-à-vis the carrying capacity. A systems approach to **District Cooling could aid in better management of energy and water, thus creating the possibility of development that is equitable and environment-friendly.** To take an example, we know that ~50-60% primary



energy used in power plants in the process of electricity generation is wasted and this number is as high as 70-80% for Waste-to Energy (W2E) plants. This waste heat can be recovered or utilized through the use of absorption chillers to power the District Cooling system to cool the water. This enables recovery of waste heat which makes W2E plants viable. Further, the District Cooling plant could provide cooling for the W2E or power plant, creating a circular loop. Similarly, city gas distribution (CGD) operators often struggle with viability due to lack of anchor demand; District Cooling plants can use gas as an alternate source of fuel to provide that anchor demand and make CGD operations more viable. Furthermore, by leveraging gas as an alternate fuel, the District Cooling plant can eliminate the need for grid power and diesel gensets for back-up at least partially. Other sources of renewable energy like rooftop or utility scale solar can be integrated quite easily with District Cooling systems and thermal storage solutions to address concerns around variability in power generation and demand. Through the use of thermal energy storage solutions, which is a far more technically viable and cost-effective alternative to battery energy storage solutions, the need for large-scale energy storage projects could also be minimized.

Currently, no state in India has a comprehensive strategy for storing green energy and ensuring round-the-clock energy supply. While leads have been made in battery energy storage systems (BESS), it still falls short in terms of commercial viability. In comparison, **Thermal Energy Storage (TES) is a time-tested technology that is an integral part[30] of District Cooling systems to allow buildings to reduce demand from the power grid and also serve as back-up in crunch-times.** TES tanks when integrated with District Cooling can reduce mechanical load requirement and thus the associated power demand for cooling, freeing up the grid's capacity for other uses. Secondly, TES supports demand side management to smoothen the power demand curve by shaving the peaks through use of chilled water stored in TES tanks during these peak hours to prevent peak demand stress exerted on the power distribution grids. An innovative TES material is being tested by **Plaksha University** in Mohali, Punjab, in partnership with Tabreed India, to meet night-time cooling demand of residential or hostel buildings in the campus. To minimize the grid

Picture Credit : https://media.intellion.in

reliance, the tanks are proposed to be charged with solar energy during the day and discharged at night to address the issue of renewable energy's supply variability.

As already highlighted, water is another resource wherein **District Cooling can help reduce the dependency on potable sources through the use of treated sewage effluent (TSE) from STPs.** Integration with District Cooling can increase the commercial viability of STPs that remain underutilized despite the growing demand for water in India. Although India's STP capacity has seen substantial increase in the last few years, there is a significant gap in the use of treated wastewater, which leads to underuse. Currently, only 28% of waste[31] water from urban centers (20,236 MLD) is treated for re-use, whereas the rest is discharged into water bodies. Even as a 'National Framework on Safe Reuse of Treated Water' was launched in 2023, most states, including Tamil Nadu, do not have a treated wastewater reuse policy. **The use of treated water for District Cooling is successful as can be seen in various commercial developments with captive cooling plants including RMZ's One Paramount and Tata Realty's Ramanujan IT Park in Chennai.** The only consideration to be kept in mind is the quality of treatment to ensure it doesn't affect the longevity of cooling equipment. District Cooling systems can also meet its water requirements from natural sources such as lakes, rivers, or oceans without affecting aquatic life, and when the source is cold enough, the use of electricity for chilling the water can be eliminated.

Opportunity for District Cooling in Tamil Nadu

State of Play

At the start of this report, we understood aspects of Tamil Nadu state's vulnerability to increasing heat and growing energy demand. **At the policy level, the Government of Tamil Nadu is taking some important steps to counter the situation.** Climate missions have been established in all 38 districts[32] with an aim to reduce greenhouse gases and promote innovative technologies. An INR 1,000 Crore Green Climate Fund[33] has been set up for investment in energy transition and circular economy projects.

Energy transitions to renewables and achieving net zero emissions by 2070 is a priority[34] for Tamil Nadu. To fast track the state's energy transitions, a separate entity, the Tamil Nadu Green Energy Corporation Limited (TNGECL), has been recently launched[35] by the renewable energy wing of Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO). Estimates suggest that Tamil Nadu will need solar and wind power generation capacities of 475 GW and 90 GW[36] respectively to achieve net zero emissions by 2070 whilst the state's current installed capacity falls far short of this with an installed base of 7.4 GW[37] of solar power and 8.9 GW of[38] wind power.

In 2023, Chennai city adopted the 'Climate Action Plan'[39] (CAP) that targets 40% emission reduction (from 2018 levels) by 2040, and achieving net zero emissions by 2050. CAP strategies to reduce emissions include - 100% decarbonization of the electric grid by 2050, use of Waste to Energy model for waste management, and electricity for cooking, and increasing the share of solar rooftops and other renewable energy sources in the city.

Opportunity for Circular and Integrated Resource Use with DC in the Context of Tamil Nadu

The integration of District Cooling into existing energy systems will complement Tamil Nadu's, and more specifically Chennai's climate ambitions. **For example, Greater Chennai Corporation (GCC) and Chennai Smart City Limited aim to install solar rooftops in all 1,378 GCC buildings,** which are projected to fulfil approximately 80%[40] of the energy needs for these buildings. **Serving the cooling needs of these buildings through District Cooling will free up building rooftop space** traditionally occupied by cooling towers in captive cooling plants or outdoor units in conventional air conditioning systems. Similarly, to decarbonize the grid through integration with renewable energy, robust storage technologies will need to be adopted. The Government of Tamil Nadu is considering **options for storage of green energy** during peak generation seasons to utilize during lean periods, when renewable energy isn't available. This can be enabled through **TES tanks integrated with District Cooling systems to store energy during off peak hours and to utilize in peak hours, thus unburdening the grid.** This is even more pertinent since peak loads are observed primarily due to a burgeoning demand for cooling, which constitute 60-70% of all energy demand in commercial buildings.

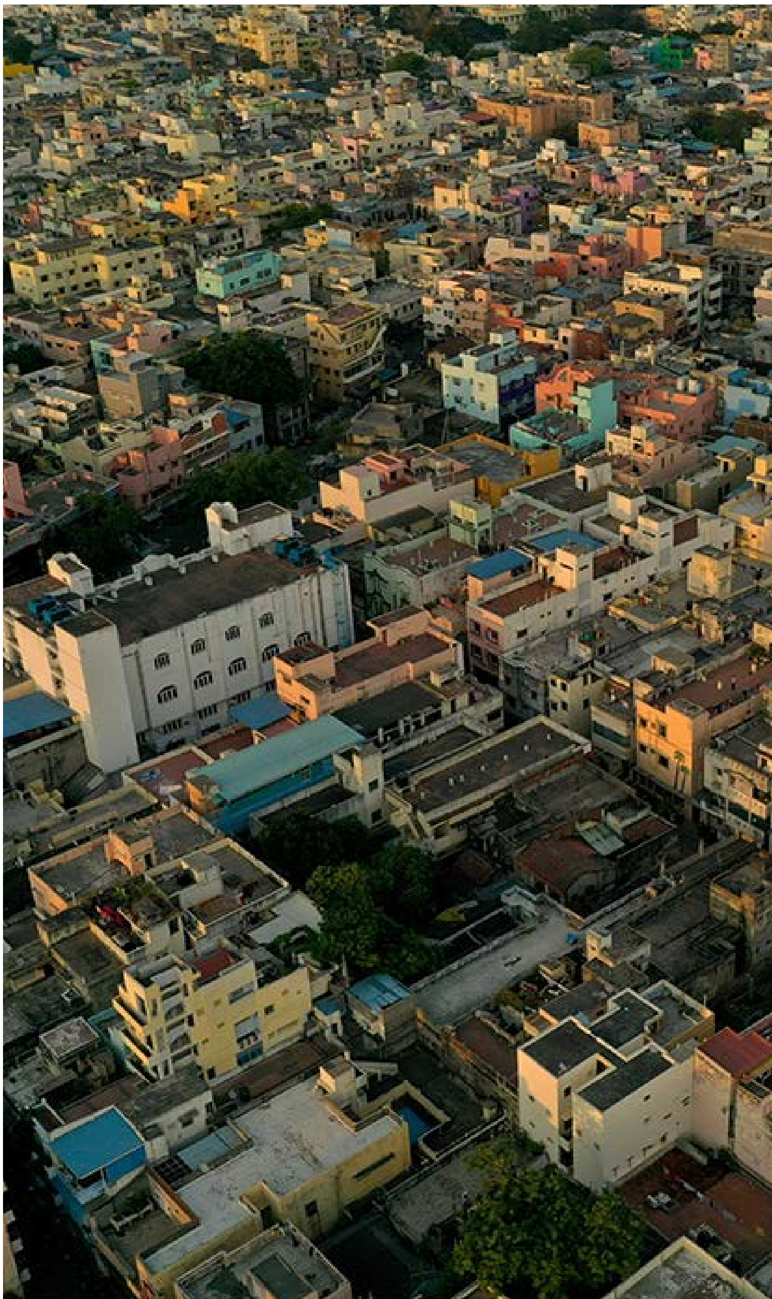
The other key resource, water, can also benefit from integration with District Cooling systems. During the summer of 2019, in Chennai city, four major reservoirs experienced complete depletion, leading to a 'Day Zero' water crisis. **Re-use and recycled water are an important strategy for Tamil Nadu to deal with some of its water availability issues.** Tamil Nadu is targeting 100% sanitation[41] coverage through STPs that will be set up in all village panchayats and municipalities. To prevent irregularities in smaller STP projects and ensure effective monitoring of operation, since 2022, the Tamil Nadu Pollution Control Board (TNPCB) has mandated construction projects with a built-up area of less than 20,000 sq. mt. to also obtain consent for building and operating an STP. **Integration of STPs with District Cooling systems to utilize treated sewage effluent water can minimize dependence on potable water, while increasing their adoption and improving their commercial viability.**

Sectoral Analysis in Tamil Nadu

The Government of Tamil Nadu is already looking at adoption of District Cooling[42]. **Tamil Nadu Industrial Development Corporation (TIDCO) is considering District Cooling for FinTech City,** a state-of-the-art business district spanning over 56 acres of land at Nandambakkam village, Alandur Taluk, Chennai District. Over 50% of energy demand at FinTech City is likely to be for air-conditioning, and adoption of District Cooling to manage this demand can make this project a pioneer for sustainable, environmental, and cost-efficient benchmarks. Estimates suggest that with District Cooling in combination with TES, the installed mechanical load to meet the cooling demand for **FinTech City can be reduced from 18,000 RT to 10,000 RT, saving 10-15 MW of power demand, avoiding ~15 GWh of electricity consumption annually to eliminate ~15,000 tons of carbon emissions and resulting in 25-35% savings for end users on a lifecycle basis.** Further, FinTech City will set the tone for similar adoption by other greenfield projects in various parts of the city, state and the country, especially as alternative cooling solutions are under serious policy consideration by the Government of India.

Based on the existing stock of buildings, **the potential for adoption of District Cooling in Chennai is immense with an estimated cooling demand of 455,000 RT coming from offices and campuses (375,000 RT), retail establishments (30,000 RT) and data centres (50,000 RT) with combined investment opportunities exceeding US$ 860 million.**

Tamil Nadu has the highest power demand among the southern States at 20,000 MW, out of India's total energy demand of[43] 243,271 MW in the year 2023-24. Wider adoption of innovative cooling technologies calls for cooperation among a number of stakeholders like builders and developers, local municipal authorities, policymakers, state planning commission, urban planners and architects, civil society, and public-at-large. We highlight below a few key sectors where there is a large market opportunity for adoption.



• Space Cooling and Building Infrastructure

The building sector, comprising of commercial, retail, hospitality, educational institutions, hospitals, retail in India is responsible for 33%[44] of total electricity consumption, of which 57%[45] goes towards cooling requirements alone.

In 2023, Chennai accounted for 10% of India's commercial office space, marking a decade-high supply of 6.4 million sq. ft. and a record absorption of 10 million sq. ft. Nearly 38% of the city's office space is now green-certified, reflecting its commitment to sustainable commercial development. The city boasts a diverse mix of takers from IT parks, Global Capability Centres (GCCs), banking to logistics, manufacturing, and engineering companies. **Commercial buildings were responsible for 26%[46] of the total energy consumed in Tamil Nadu in 2020, which is expected to rise to 50% by 2070,** thereby increasing power demand, power consumption and associated emissions.

India's Bureau of Energy Efficiency brought out the Energy Conservation Building Code[47] (ECBC) in 2007 to improve energy efficiency of new commercial buildings. About 23 states in the country have adopted the code that aims to reduce energy consumption and carbon emissions through adoption of innovative urban design and installation of green technologies. Tamil Nadu adopted the ECBC[48] in 2022 and mandated energy efficiency norms for new commercial buildings with connected load of greater than 100 KW or area exceeding 2,000 sq m. The ECBC code also specifies certain aspects of building design, especially walls and roofs, to minimize heat, dependence on artificial lighting, as well as the use of renewable energy. Since adoption, **Tamil Nadu government's outreach campaigns have highlighted the economic and comfort benefits of cooling initiatives like cool roofs within ECBC.** Installing rooftop solar systems alongside cool roofs[49] can drastically reduce electricity bills and negative environmental impacts. This has helped address concerns over the initial cost barrier and led to easier and quicker adoption of cool roofs in urban infrastructure of Tamil Nadu state.

Many cities across the world are adopting passive cooling[50] methods to minimize dependence on air-conditioning for residents and end users. This includes painting the building roofs white, planting more trees, creating natural cooling corridors through waterways, etc. Additionally, measures[51] aimed at urban design and architecture, like natural ventilation, use of heat resistant or reflective materials, and shading can also greatly help reduce the need for mechanical cooling. In 2023-24, ECBC is being revamped to take a more holistic view to include sustainability aspects beyond carbon and extend to residential sector as well. **When District Cooling is introduced as an additional second layer after consideration of natural and passive design measures, it will result in the most optimized scenario** wherein, first, the need for mechanical cooling is reduced to the extent possible with passive measures, and two, the remaining cooling demand is aggregated to take advantage of diversity factor to meet the residual cooling demand with district cooling. This will not only result in lesser but more efficient equipment but also reduced power demand, freeing up the grids capacity, saving in energy bills for customers and users, and quicker adaptation to changing weather patterns.

There are ample opportunities for development in Tamil Nadu, which indicate a growth uptick in space cooling requirements in the coming time. The Market of India, SPR City, spanning over 124 acres, has an estimated peak cooling demand of 10,000 RT. With an investment of around USD 20 million, District Cooling systems can lead to 20% cost savings, and reduce annual energy consumption by more than GWh. In the following sections, we deep-dive into a few select brownfield and greenfield projects that offer opportunities for District Cooling adoption.

• Industries & Manufacturing Facilities

Tamil Nadu has a diversified manufacturing sector[52] and is amongst the states that are leading in several industries including automobiles and auto components, engineering, pharmaceuticals, garments, textiles, leather, chemicals, and plastics among others. It has amongst the highest number of factories and industrial workers. **Between 2016 and 2021, State's Gross Domestic Product expanded at a rate of 10.56% to reach USD 265.49 billion[53], where the tertiary sector contributed 54.26%, followed by secondary sector at 32.39%.** According to Department for Promotion of Industry and Internal Trade, cumulative Foreign Direct Investment inflow in Tamil Nadu and Puducherry stood at US$ 3.33 billion between October 2019 and March 2021. In January 2021, Tamil Nadu approved 34 key investment proposals worth US$ 7.14 billion. These investments are likely to create more than 93,000 jobs in electronics, automobile and auto components sectors, including electric vehicles and solar cell manufacturing.

As Tamil Nadu's industrial and manufacturing sector continues to expand, the demand for cooling solutions in both space and process applications is expected to surge. Industries such as electronics manufacturing, pharmaceuticals, textiles, and food processing are particularly reliant on precise temperature control to maintain product quality and operational efficiency. For instance, the electronics industry, which is expected to see substantial growth with the rise of electric vehicles and solar cell manufacturing, requires extensive cooling. Similarly, the pharmaceutical sector needs rigorous climate control to ensure the stability of medical products. The textile and garment industries, which form a substantial part of Tamil Nadu's manufacturing sector, also have high cooling requirements to control humidity and prevent damage to fabrics and machinery. **According to industry reports, approximately 30-50% of the total energy consumption in these sectors can be attributed to cooling needs.**

This underscores the significant impact on the state's energy resources and the need for integrating energy-efficient cooling systems.

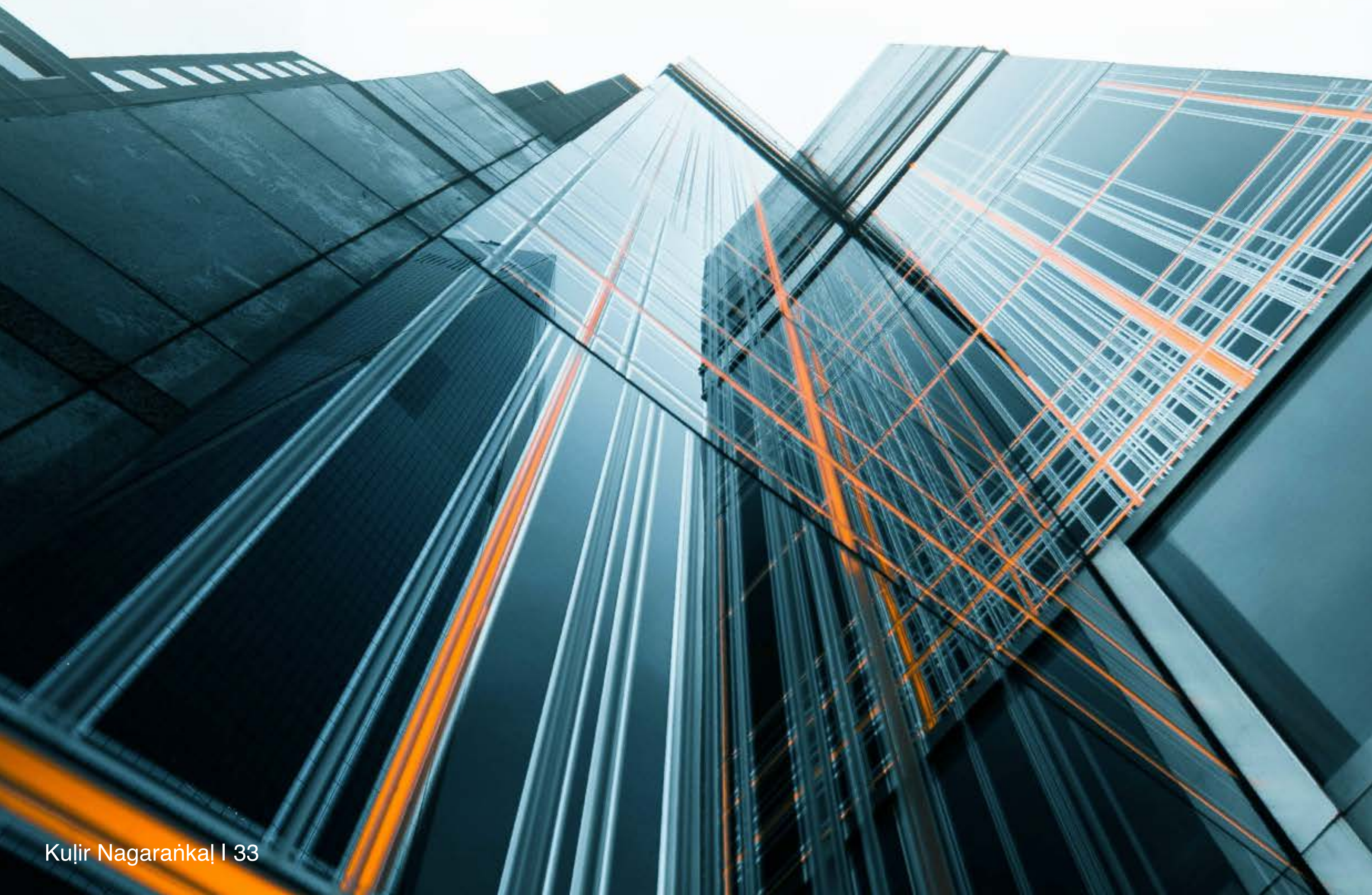
Heavy Engineering Hub in Ponneri, which will cover 700 acres, with an investment of USD 130 million is **one such opportunity wherein district cooling can help manage peak cooling demand of 60,000 RT, and lead to energy savings of up to 56 GWh per year.** This infrastructure park will be used for shipbuilding industries, electrical and engineering industries, and auto component manufacturers. Another large infrastructure project, the HLL Medi Park that will house medical devices and equipment zone, research & development centres, bio information zone, and knowledge management infrastructure in Chengalpattu, spread over an area of 330 acres, will have peak cooling demand of 30,000 RT. **An investment of USD 60 million in District Cooling systems can save up to 28GWh of energy annually.**

• IT and Data Centres

District Cooling is not limited to large projects and can be applicable to emerging areas like data centres that tend to generate a lot of heat and need stable, dependable round the clock cooling.

Tamil Nadu's focus on Data Centers stems from the State's complementary prowess in manufacturing of electronics and electrical equipment such as server systems, mobile device handsets, tablets and storage devices used in technology, media and telecom sector. Through this, the State provides a ready built and well-established supply chain[54] for Data Centers. This has made the state a favourable destination for such investments by data center players. Meta Platforms, which owns Facebook, Instagram and WhatsApp, will set up[55] is first data centre in India at the Reliance Industries Ltd (RIL) campus in Chennai.

The current size of the **Tamil Nadu Data Center market stands at 135.6 MW, which is expected to grow annually at 22.18%[56] over the next five years to reach 500 MW, with Chennai now emerging as one of the fastest growing[57] Data Centre markets in India,** next to Mumbai and Bengaluru. Established data centre locations in the city include Ambattur and Siruseri, and the total installed capacity of data centres is approximately 115 MW. Tamil Nadu's IT sector stretches beyond Chennai into potential data centre locations in Tier II cities. Seven dedicated IT special economic zones were created across Tier II locations such as Coimbatore, Madurai (two sites), Tiruchirappalli, Salem, Tirunelveli and Hosur, spread over approximately 1,300 acres of land. Further, mini-IT parks called TIDEL NEO have been established in six Tier II and III locations.



- ## Cold Chain

Agricultural cold chain is critically under-developed in India. According to the India Cooling Action Plan, this is especially the case for agricultural packhouses, refrigerated transport and logistics. This has numerous socio-economic and environmental impacts, including lower farmer incomes and high levels of food loss in a country with the highest number of people living in hunger, and one-third of all malnourished children.

The lack of availability of cold-chain is estimated to lead to an average of 15-20% loss of food in India. This amounts to about 50% of all post-harvest food loss in the country. Moreover, farmers today receive less than half the wholesale price for their produce and for perishable goods. Increasing access to cold chain infrastructure can help reduce food loss, expand market connectivity, protect the quality and safety of food, increase farmers revenues and improve the resilience of farmers and the rural communities in which they are located.

In Tamil Nadu, the gap in cold storage is found to be exceeding 10 lakh MT[58] according to estimates by Ministry of Food Processing Industries. It is also among the top seven states that have a growing demand of cold storage facilities.

Yet only 21 out of 38 districts in the state have cold storage facilities, which in absolute numbers comes up to 180 cold storage and 64 packhouses.

In consultation with the Ministry of Environment, Forests and Climate Change (MoEFCC) of India, United Nations Environment Programme, Auroville and Tabreed India are developing and implementing the **Praṇa project**, a demonstration project for integrated, market linked and localised cold chain services for the agricultural and vaccine supply chain in Villupuram District, Tamil Nadu, India. It includes innovative technology which will consist of a net-zero carbon, net-zero water use, zero waste and a net energy surplus cold chain packhouse based on circular economy principles that can contribute to a more resilient local power grid. Food to vaccines project will explore possibilities to extend the cold infrastructure for other end uses like vaccine storage, access to refrigeration for local workers and a cooled village community centre. The business model project will be developed to demonstrate commercial viability and showcase a sustainable and circular model to deliver high-quality cold chain services that boost farmer incomes and strengthen livelihoods of the rural community.

Brownfield - Potential Case Analysis

As mentioned in the sectoral analysis, the largest share of cooling demand comes from space cooling in buildings and is projected to grow from 66.5 Mn RT in 2017 to 268 Mn RT by 2030 across India. While room air-conditioners (window/split ACs) and non-refrigerant-based cooling systems such as fans and air-coolers form the largest pools of cooling technologies used in residential buildings, space cooling in data centers, commercial and retail buildings are more reliant on chiller systems, packaged direct expansion (DX) systems, and variable refrigerant flow (VRF) systems. The adoption of the more energy efficient alternative, which are the chiller systems or captive district cooling systems for meeting the cooling needs of large campuses with multiple buildings can likely be explained by the global and local focus on net zero targets through recognition that built environment is a sector with one of the largest carbon footprints. Therefore, with an eye on the space cooling sector, **the estimated growth in installed chiller base is projected to rise from 5 MN RT in 2017 to 14 MN RT in 2030 in India.** Accordingly, the **commercial sector has the highest potential of adopting District Cooling to maximize energy savings.**

In Chennai, basis our preliminary assessment, the chiller market size for existing brownfield developments (commercial buildings and campuses, malls, hotels, hospitals & data centers) totals approximately 400,000 RT, spread over 90 million square feet.

The developments that are currently in operation (brownfield) and those are in the process of being built (greenfield) offer different but significant opportunities for energy efficiency. Brownfield developments most of which are due for HVAC equipment replacement, through appropriate retrofit including super-efficient chillers, cooling towers, pumps, etc. can impact the energy efficiency of the building by way of providing savings on power and water bill. Whereas for greenfield developments, early interventions through design and planning can significantly reduce the upfront mechanical installed capacity and with it, the energy demand from the grid.

To understand and exemplify the benefits of District Cooling, **a study of some of the largest and most prominent commercial establishments in Chennai was undertaken.** The data set for the purpose of the assessment includes Grade A commercial buildings, with over 1 million square feet, malls, hotels, hospitals and data centers, across the central and peripheral regions of the city.

Many of the buildings and campuses under consideration have received green building certifications and other accolades. Even so a closer look at some of them, as seen in the table below demonstrates that by leveraging principles of District Cooling, the total installed capacity can be optimized from 224,000 RT to 164,000 RT. As a consequence of the lower installed capacity and use of professionally operated and managed energy efficient equipment, we can see **reduction in power demand, freeing up more than 70 MW of grid capacity for other uses.** Similarly, we can see up to **1,000 KLD savings in water usage,** be it potable or treated, due to maintenance of water quality, reuse of the same water in several cycles, greatly relieving Chennai's water scarcity disposition.

	Project Details - Chennai				Installed Capacity (RT)		Power Demand (kW)		Water Consumption (KLD)	
SN	Project Name	Building Type	GLA (msf)	Location	BAU	DCS	BAU	DCS	BAU	DCS
1	Hyatt Regency	Hotel	325.00	Teynampet	1,268	1,077	1,521	1,077	274	163
2	Phoenix Market City	Mall	1.00	Velachery	5,000	4,250	6,000	4,250	1,080	643
3	VR Mall	Mall	0.99	Anna Nagar	5,000	4,250	6,000	4,250	1,080	643
4	STT - Chennai DC 2	Data Center	0.40	Ambattur	4,000	3,800	4,400	3,800	960	638
5	Chennai One	Business Park	4.14	Thoraipakkam	13,800	9,384	11,730	6,569	945	450
6	Atos (Syntel)	Standalone campus	0.65	Siruseri	6,000	5,100	6,000	4,335	411	245
7	Capgemini	Standalone campus	0.29	Siruseri	1,500	1,275	1,500	1,084	103	61
8	Cognizant	Campus	1.77	Siruseri	8,830	6,004	7,506	4,503	605	288
9	Hexaware	Standalone campus	1.20	Siruseri	6,000	5,100	6,000	4,335	411	245
10	TCS Techno Park	Campus	1.42	Siruseri	6,000	5,100	6,000	4,335	411	245
11	Cognizant	Campus	2.70	Sholinganallur	13,500	9,180	11,475	6,885	925	440
12	Ford	Campus	2.63	Sholinganallur	13,000	8,840	11,050	6,630	890	424
13	HCL	Campus	3.20	Sholinganallur	16,000	10,880	13,600	8,160	1,096	522
14	Infosys	Standalone campus	0.45	Sholinganallur	2,250	1,913	2,250	1,626	411	245
15	Tech Mahindra	Standalone campus	0.60	Sholinganallur	3,000	2,550	3,000	2,168	205	122
16	Wipro	Campus	1.43	Sholinganallur	7,150	4,862	6,078	3,647	490	233
17	Adani	Data Center	0.40	Siruseri	8,000	7,600	8,800	7,600	1,920	1,277
18	Gleneagles Global Health City	Hospital	1,000.00	Perumbakkam	5,600	5,040	6,720	5,040	1,344	847
19	Embassy Tech Zone	Business Park	3.06	Pallavaram	12,500	8,500	10,625	5,950	856	408
20	Embassy Tech Zone	Business Park	7.58	Manapakkam	21,950	14,926	18,658	10,448	1,503	716
21	ITC Grand Chola	Hotel	600.00	Guindy	2,340	1,989	2,808	1,989	505	301
22	Sri Ramachandra Medical Center	Hospital	1,500.00	Porur	8,400	7,560	10,080	7,560	2,016	1,270
23	Ramanujan IT City	Business Park	4.61	Taramani	12,100	8,228	10,285	5,760	829	394
24	Ascendas ITPC	Business Park	2.11	Taramani	2,250	1,530	1,913	1,071	154	73
25	Brigade WTC	Business Park	1.80	Perungudi	2,000	1,360	1,700	952	137	65
26	DLF Downtown Taramani	Business Park	1.89	Taramani	6,000	4,080	5,100	2,856	411	196
27	Global Infocity Park - Block I	Business Park	2.59	Perungudi	3,300	2,244	2,805	1,571	226	108
28	RMZ Millenia	Business Park	2.48	Perungudi	15,800	10,744	13,430	7,521	1,082	515
29	TIDEL Park	Business Park	1.28	Taramani	10,000	6,800	8,500	4,760	685	326
	Total		**3,476**		**223,638**	**163,894**	**205,567**	**130,016**	**21,784**	**11,934**
	Cumulative Savings				**27%**		**37%**		**45%**	

Source: Analysis by Tabreed

While the savings demonstrated above are noteworthy and can be achieved through a central and efficient cooling plant at a campus level, the aggregation of such systems to supply cooling at a wider scale through a true District Cooling System or **a merchant District Cooling System has a greater multiplier effect through the diversity benefits offered.**

One such example is the **cluster of commercial establishments/IT Parks in the Taramani and Perungudi neighborhoods of Chennai,** the largest of which is Tata Realty's Ramanujan IT Park, surrounded by other noteworthy properties developed by the likes of RMZ, DLF, Ascendas, Brigade, etc.

Ramanujan IT Park is recognised as India's first net-zero campus by IFC Edge and, amongst many other noteworthy accolades, is also a zero-discharge and LEED Platinum certified campus. Located in suburban Chennai and forming a central part of the IT corridor, it has a high degree of self-reliant captive infrastructure including water treatment, sewage treatment, RO facilities and back-up DG sets. Spread across 25.75 acres, the 6 towers that form part of the campus, give rise to 12,100 RT of cooling demand through central cooling plant.

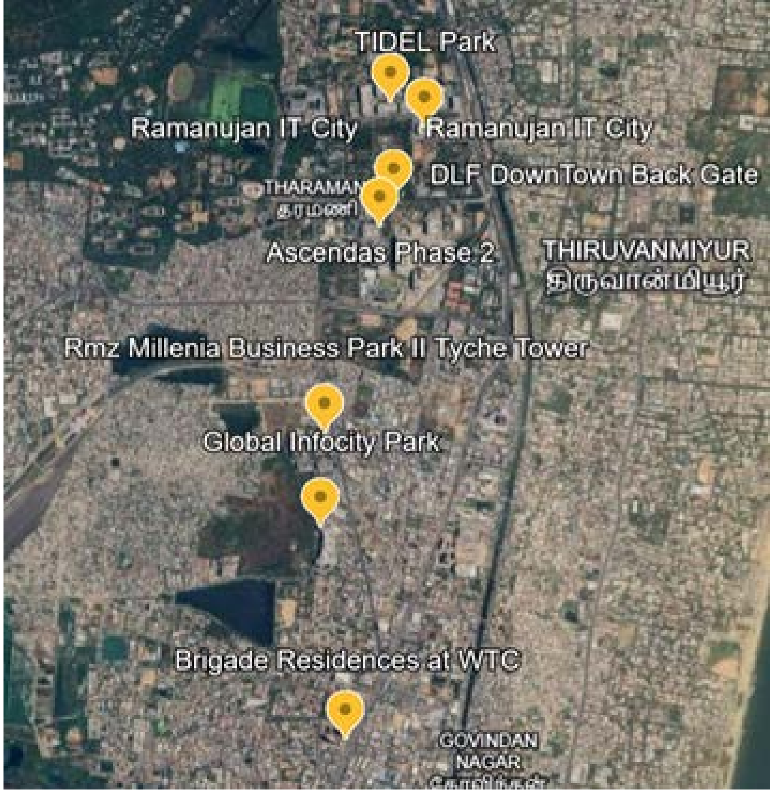
Ramanujan, along with other noteworthy properties, as listed in the table below, create a robust stock of premium office space of close to 16.76 msft and a cumulative installed cooling capacity of 51,450 RT. Given the age of the buildings, there is an opportunity to aggregate and optimize the cooling demand through a merchant District Cooling system. Where the equipment is relatively new and in good shape, it can be reused within the District Cooling plant through smart technical design interventions.

Developments	Age of Buildings (yrs)	Area (msft)	Cooling Load (RT)
Ramanujan IT City	8 - 13	4.61	12,100
Ascendas ITPC	14 - 17	2.11	2,250
Brigade WTC	4	1.80	2,000
DLF Downtown Taramani	2	1.89	6,000
Global Infocity Park	9 - 15	2.59	3,300
RMZ Millenia	16 - 19	2.48	15,800
TIDEL Park	24	1.28	10,000
Total		**16.76**	**51,450**

The results of such aggregation and consolidation are promising as summarized in the table below.

Despite the buildings having similar end-use, the installed mechanical load can be reduced by 26% through leveraging diversity benefits at campus level; through the use of larger, industrial grade energy efficient equipment power demand can be reduced by up to 45%. Correspondingly, there will be savings in power bills and associated emissions of 35,115 tCO2e which is equivalent to the carbon dioxide absorbed by 580,630 saplings over a period of 10 years. This is without including the savings on O&M due to a centralized, professional team ensuring asset is operated in line with the design intent. with a view on asset longevity and lifecycle costs.

The business model can be such that a District Cooling provider acquires the existing captive cooling plants within the campuses for an upfront purchase consideration. A dedicated utility plot can be allocated by the municipality within the identified circumference to the provider for setting up a District Cooling system. Over time, ensuring minimal disruption and downtime, the captive cooling systems are decommissioned and the cooling needs of the buildings are met through the merchant District Cooling system.



Even when there is limited space availability, cooling systems of some of the larger identified campuses can be interconnected to serve cooling needs of other smaller campuses in the vicinity, thus maximizing benefits.

Parameters	Unit	Business as Usual (BAU)	District Cooling System (DCS)	Savings	
Installed Mechanical Load	RT	51,450	38,000	13,450	26%
Thermal Storage	RT	-	4,000	-	-
Power Load	MW	59	32	27	45%
Annual Power Consumed	Million kWh	148	109	39	26%
Annual Carbon Emission Savings	tonnes	1,34,606	99,491	35,115	26%

A second example to **showcase potential savings in Chennai is through the upcoming campus of SIPCOT IT Park.** District Cooling would have been ideal for adoption within this campus given the diversity of cooling requirements through different user types, that is, business processing offices and global capability centers which often work on US and UK shifts. A District Cooling system would have been immensely effective in this case as the same optimized mechanical installed load could have met different cooling needs during the day and night, reducing equipment idling and ensuring it operates near peak loads for maximum efficiency. Additionally, a merchant District Cooling system would have prevented the need for building-wise captive cooling plants placed in basements and rooftops that more often than not use air-cooled chillers or a mix of air-cooled and water-cooled chillers, which are less efficient and moreover create a lot of noise and vibrations.

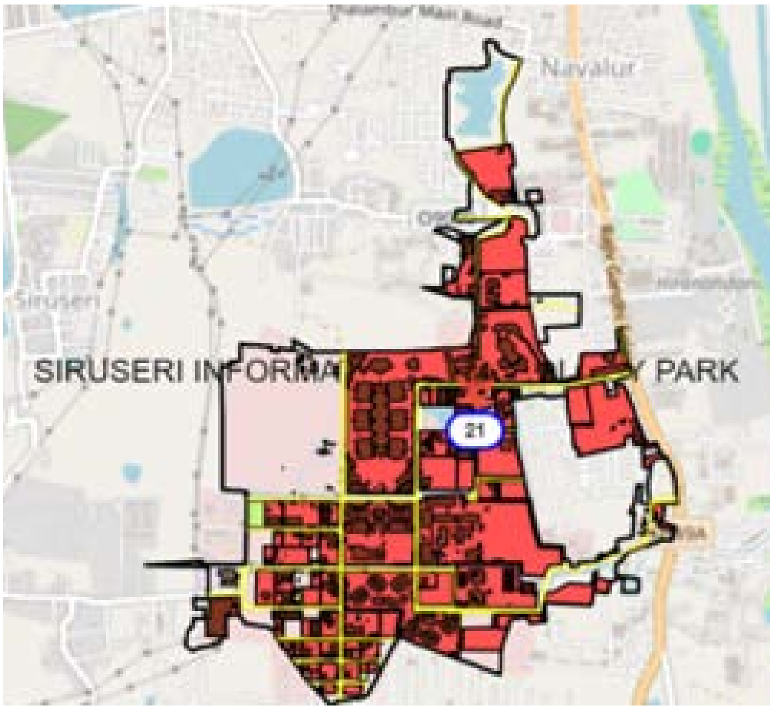
Since allocation of land for the IT Park in 1998, the built infrastructure is being developed gradually, with large parts of the total plot area of 400 acres still unutilized or unoccupied. One common misconception related to implementation of District Cooling is the large, upfront capital requirement or pre-investment needed when there is limited visibility on how and when future buildings will come up. **District Cooling enables modular build out of the cooling infrastructure based on the cooling requirements of upcoming buildings, thus, minimizing and limiting pre-investment** to the entrenched piping network. Furthermore this approach of phased development of cooling infrastructure allows **newer and more efficient technologies to be integrated within the District Cooling system,** rather than being locked in old, inefficient and often irrelevant technologies.

Picture Credit : pbs.twimg.com/

In terms of alternate fuel, a District Cooling system and associated back-up could have been powered fully or in-part by piped natural gas (PNG), providing anchor demand for viability of PNG distribution, while reducing or eliminating reliance on grid electricity. This would have fast-tracked PNG adoption for residential household requirements in the vicinity. Additional resources such as neighboring waterbodies could have served as heat rejection sinks.

The multitude of opportunities that open up for SIPCOT IT Park through District Cooling have been quantified as estimated savings in the table below and serve as an illustration of the benefits. With a ~40% reduction in installed capacity when integrated with thermal storage, the District Cooling system would consume up to 55% less power and can avoid 37,500 MWh for electricity annually, roughly equivalent to 6.9 wind turbines running for a year.

Accompanying the savings projected above, if regulations were relaxed to allow the SIPCOT IT Park to serve neighboring residential and other mix-use buildings whose primary demand peaks at night, the broader mechanical load and power demand of the region could be further brought down.



In conclusion, given that most of the brownfield developments seen above are fairly recent, the overall outlook of potential savings that Chennai could have achieved through planning and early intervention reveal a missed opportunity. However, this study encourages the view that through diligent, aggressive and collaborative measures, existing projects can still benefit from the aggregation benefits of District Cooling that align with the current broader decarbonization and circularity goals of Chennai including by extension of Tamil Nadu.

Parameters	Unit	Business as Usual (BAU)	District Cooling System (DCS)	Savings	
Installed mechanical	RT	60,000	35,000	25,000	42%
Thermal Energy Storage	RT	-	5,000	-	-
Power Load	MW	66	30	36	55%
Annual Power Consumed	Million kWh	165	127	38	23%
Annual Carbon emission savings	tonnes	1,50,150	1,16,025	34,125	23%

Greenfield - Potential Case Analysis

Casting a net beyond Chennai to all of Tamil Nadu, this section delves into the plethora of greenfield opportunities that await the State when appropriate planning is considered by each masterplan. A selection of prominent, yet diverse projects at the design stage are explored, which when integrated with District Cooling can enjoy its varied benefits. These examples bring out the stark contrast to the business-as-usual approach, highlighting the environmental and financial costs that may otherwise come to the state. In comparison with other states, Tamil Nadu still has tremendous commercial space cooling developmental potential and the steps that the state takes in the next few years will be crucial and can be a game-changer.

- ## IT Park, Vilankurichi, Coimbatore

Coimbatore is the second-largest city in the state of Tamil Nadu, and has gone through various stages of economic evolution: from being an agro-processing industrial zone to an electrical and automobile hub, and further to the educational and information technology hub that it is today. Giving an additional thrust to the surging information technology sector in Coimbatore, the Tamil Nadu Government has decided to build an INR 1,100 crore IT Park in Vilankurichi, Coimbatore, over an area of 2 MN sqft, to be built in two phases.

Geographically, **Coimbatore is one of the "hottest" biodiversity hotspot regions of the world,** surrounded by the Nilgiri Biosphere Reserve in the north and the Anaimalai and Munnar mountain ranges in the east. As the city undergoes urbanization and population growth, more and more land is being converted into built-up environment, impacting the city's power and water demand, environment and ecology. There is a need to incorporate improved urban design, focusing on building typologies and various mechanical elements for the IT Park under consideration.

With 50-70% of energy demand at this IT Park likely to be for air-conditioning, DCS vis-à-vis business-as-usual approach of setting up standalone basement cooling plants with a mix of air- and water-cooled chillers, can help achieve multiple objectives of energy and water efficiency, alongside reduced emissions to support Tamil Nadu's vision of achieving net zero ahead of India's target of 2070 as seen below:

- Lower mechanical load and improvement in electrical efficiency enabled from aggregation of campus demand centrally and use of larger, industrial grade water cooled, centrifugal chillers in DCS as opposed to small, air-cooled or air- and water-cooled chillers for each building.
- Reduction in power load of 5 MW through reduced installed mechanical cooling load and better efficiency which frees up grid capacity. This can be further optimized if a TES tank were to be installed.
- Annual savings in power bills with reduced power consumption, and accordingly ~5,500 tonnes of savings in carbon emissions. Zero refrigerant leakage – use of 0 Ozone Depleting Potential (ODP), low Global Warming Potential (GWP) refrigerant.
- Zero dependence on potable water – STP/grey water plus improved water efficiency, reducing water consumption.
- **Overall lifecycle cost savings of 20-30%**

Particulars	Units	Business as Usual (BUA)	District Cooling System (DCS)
Peak Cooling Demand	RT	8,000	
Installed Cooling Load	RT	8,000	5,500
Power Load	MW	9	4
System Efficiency	ikW/RT	1.10	0.80
Annual Power Consumed	Million kWh	22	16
Water Consumption	Kilo-litre per day	548	384
Annual Utility Cost Savings	INR Cr	INR 6 - 10 Crores	

• Unity Mall

In a first of its kind initiative, the state government has decided to construct a mega mall in Egmore for an estimated cost of Rs 227 crore to promote traditional handloom and handicraft products made by Tamil Nadu Handloom Weavers' Cooperative Society, popularly known as Co-optex.

Unity Mall will be built on a total area of 0.46 million square feet under the Union Government's "One District One Product' (ODOP) Scheme and is planned to be completed in two years. The sprawling mall will be a nine-story, air-conditioned building with two basement car parking lots.

Air-conditioning in shopping malls is generally through captive cooling systems with multiple air handling units to cool large indoor spaces. In comparison to conventional cooling systems often designed on an ad-hoc basis, an outsourced model for cooling such as cooling-as-a-service or CaaS can provide cooling in a far-more cost-effective and efficient manner. However, there are challenges - operators often prefer additional capital investments for efficiency improvement made by owners from time to time instead of long-term O&M focus as a result of owner-operator agency issues. Similarly, due to shared Integrated Facility Management (IFM) teams for all MEP aspects, the separation of HVAC scope gets complicated.

By virtue of outsourced, professionally managed operations and maintenance of the cooling system, asset longevity can be ensured, while keeping in mind the energy efficiency aspects and lifecycle costs.

Further, such standalone buildings are ideal for integration with merchant District Cooling models. If we can include District Cooling at the master planning stage itself, with very little pre-investment and modular build-out plans, the cooling demands of the area can be met far more optimally.

Below we summarize the advantages of a CaaS model vis-à-vis a business-as-usual approach: Overall, we see that despite minimal reduction in load, the power demand and consumption has come down significantly, positively reducing associated GHG emissions and proving to be more cost effective on a lifecycle basis.

Particulars	Units	Business as Usual (BUA)	District Cooling System (DCS)
Peak Cooling Demand	RT	2,040	
Installed Cooling Load	RT	2,040	1,700
Power Load	MW	2.20	1.40
System Efficiency	ikW/RT	1.20	0.80
Annual Power Consumed	Million kWh	6	4

Picture Credit : pbs.twimg.com

- ## Central Plaza

Chennai's iconic Central Square is about to undergo a remarkable transformation with the construction of a 27-storey building on its premises. Central Square stands as a vital multi-modal hub for commuters, facilitating seamless transitions between Metro Rail, suburban and long-distance trains, and buses. The square, inaugurated in March 2022, boasts a range of amenities including landscaping, pedestrian plazas, escalator-equipped subways, and renovated bus bays.

Central Plaza, spanning across 1 million square feet, is estimated to be completed at a cost of INR 688 crores. This new building will cater to the office space needs of public sector, commercial enterprises and IT companies. It will be built through a Special Purpose Vehicle to be created by a joint venture Chennai Metro Rail Limited and Tamil Nadu Development Corporation (TIDCO).

Given the density of this micro-market, it is important to integrate measures to address extreme heat and take forward diverse demonstration projects to showcase viability and benefits of sustainable cooling technologies. Beyond the environmental benefits, District Cooling systems can offer several commercial advantages as well. As seen below, through savings in utilities and more efficiently managed operations, the payback on the initial capex could be much faster:

Particulars	Units	Business as Usual (BUA)	District Cooling System (DCS)
Peak Cooling Demand	RT	4,000	
Installed Cooling Load	RT	4,000	3,500
Power Load	MW	4.00	2.80
System Efficiency	ikW/RT	1.00	0.80
Annual Power Consumed	Million kWh	10	8
Water Consumption	Kilo-litre per day	270	190
Savings in O&M Costs and Utilities over a period of 30 years	INR Cr	75	

- ## SIPCOT Industrial Park, Sengipatti, Thanjavur

Since inception and with the objective to promote industrial growth in Tamil Nadu, State Industries Promotion Corporation of Tamil Nadu Limited (SIPCOT) has nurtured the development of 28 industrial parks including 6 SEZs, spread over 16 districts over a total area of about 38,538 acres. It is now in the process of setting up 11 new industrial parks in the state across sectors that would generate more than two lakh jobs in the region. As per the Tamil Nadu budget 2024-25, in order to create employment opportunities in the Thanjavur region, SIPCOT will establish a new industrial park, spanning 300 acres, near Sengipatti, at a cost of INR 120 crore.

Industries are generally categorized as a "hard to abate" sector, and hence any scope to minimize carbon footprint associated with the sector should be fully exploited. In the table below, a brief overview is given of how a District cooling system can prove to be more advantageous when compared to a conventional cooling system.

As we can see, while the capex may be higher for a District Cooling system due to significant civil and infrastructural works including laying of piping and network, even without considering environmental benefits, the savings on utility and O&M in District Cooling will pay back many times over.

Particulars	Units	Business as Usual (BUA)	District Cooling System (DCS)
Peak Cooling Demand	RT	50,000	
Installed Mechanical Load	RT	50,000	35,000
Thermal Energy Storage	RT	-	5,000
Power Load	MW	50	30
System Efficiency	ikW/RT	1.00	0.80
Annual Power Consumed	Million kWh	125	100
Water Consumption	Kilo-litre per day	3,400	2,400
Annual Utility Cost Savings	INR Cr	35	
Annual CO2 Emissions	Tonnes	~25,000	
Capex	INR Cr	500	500-600

• Parandur Airport

New Chennai Greenfield International Airport is a proposed greenfield airport project to serve the city of Chennai. It will be built near Parandur in Kanchipuram district in the state of Tamil Nadu. It will serve the city alongside the existing Chennai International Airport. The proposed airport will be spread around 5,000 acres. The Government of Tamil Nadu has declared that Tamil Nadu Industrial Development Corporation (TIDCO) will lead the project.

The airport will be built in four phases with a capacity to handle 100 million passengers. The total cost of the entire project is estimated at INR 32,704.92 crore. The construction of the first phase will begin in January 2026 and end by December 2028 and following this, the other phases will be subsequently taken up, with the final phase winding up by December 2046.

Most airports in India provide space cooling through large, centralised air conditioning plants, which are captive by nature, that is, will not serve the air-side development. Some examples of airports in India that have DCS for air-side development include Delhi Airport (~20,000 TR), Mumbai Airport (~20,000 TR), Chennai Airport (~12,000 TR), Kolkata Airport (~12,000 TR). The absence of outsourced cooling models in airports is primarily due to the aero-tariff regulation models linking revenue to asset base, disincentivizing the divestment of HVAC assets for air-side developments (terminal buildings, etc.). Secondly, on the land-side, there is a preference to lease/sell plots for developers to plan cooling as appropriate than integrated approach to utilities including District Cooling, sewage treatment or waste to energy systems.

Below is a brief overview of how a District Cooling system can prove to be very advantageous:

Particulars	Units	Business as Usual (BUA)	District Cooling System (DCS)
Peak Cooling Demand	RT	30,000	
Installed Cooling Load	RT	30,000	20,000
Thermal Energy Storage	RT	-	5,000
Power Load	MW	30	16
System Efficiency	ikW/RT	1.00	0.80
Annual Power Consumed	Million kWh	75	60
Water Consumption	Kilo-litre per day	2,000	1,500
Annual Utility Cost Savings	INR Cr	20	
Annual CO2 Emission Savings	Tonnes	14,000	

• Hi-tech Film City

The state of Tamil Nadu plans to establish a state-of-the-art Hi-tech film city at Poonamallee. The 'city of dreams' will be developed over an anticipated 150 acres of land parcel on a Public-Private Partnership (PPP) basis at an estimated cost of INR 500 crores.

Film cities generally have pre- and post-production facilities, studios, outdoor shooting locations, make-up rooms and permanent shooting locations. Usually, rather than a central air conditioning system for the entire film city, there are separate air conditioners in each of the indoor locations including studios, dressing/make-up rooms, food court, conference halls etc. District Cooling systems can prove to be a good alternative here, given the utilization in a year. Instead of individual air conditioning units, a central system can have a much lower installed base given varying and generally staggered utilization, providing upfront savings on capex despite the higher network costs. Furthermore, given if the District Cooling system will replace packaged, split or window air conditioning systems, the benefits in terms of energy usage, power costs, and sustainability aspects can be immense as seen below:

Particulars	Units	Business as Usual (BUA)	District Cooling System (DCS)
Peak Cooling Demand	RT	8,000 RT	
Installed Cooling Load	RT	8,000 RT	5,500 RT
Power Load	MW	11.20 MW	4.70 MW
System Efficiency	ikW/RT	1.40	0.85
Annual Power Consumed	Million kWh	28	17
Water Consumption	Kilo-litre per day	-	550
Annual Utility Cost Savings	INR Cr	11	
Annual CO2 Emission Savings	Tonnes	10,000	
Capex	INR Cr	85	75

While the expression 'the grass is greener on the other side' may apply to those who are not accustomed to introspect, the 6 case studies illustrate that with early planning and thoughtful execution, meaningful impact is possible and on the very 'Greenfields' that Tamil Nadu still proposes to build. The pathways that the state is building are promising and with support and interventions from multi-stakeholders, the road towards sustainable cooling is not difficult nor far away.

Way Forward

Large-scale adoption of District Cooling will require several changes in the ecosystem. While some of these will be long term, others may be more easily achievable in the short term. We present a few immediate steps that can be taken in the direction for greater adoption:

- **Pre-feasibility Studies for District Cooling for Integrated Urban Planning:**

At the building infrastructure level, ECBC guidelines provide a framework to catalyze adoption of energy efficient systems like District Cooling. Integrating District Cooling into urban planning and development strategies is crucial. Planners and developers should consider cooling needs early in the design process to ensure that District Cooling systems can be efficiently integrated into new developments and retrofitted into existing ones. A further push for mandatory undertakings of pre-feasibility studies for large developmental projects, including through public-private partnership model, will be useful. It can help provide a more accurate picture of District Cooling opportunities for the market, investors, developers, and also the state authorities. This will also increase awareness on benefits of adoption of District Cooling, and enable greater level of cooperation among concerned stakeholders, including the government.

- **Cooling as a Utility:**

More generally for merchant District Cooling projects to come to light, cooling provision needs to be treated same as that of utilities like water, gas and electricity. Recognizing cooling as an essential utility will facilitate the development of centralized District Cooling systems, which can provide energy-efficient and cost-effective cooling solutions across built environment. Such a shift would enable integrated planning and investment in cooling infrastructure, ensuring reliable and sustainable cooling services that meet the growing demands of commercial and industrial sectors more holistically. This sort of an application of District Cooling to mass-level urban infrastructure and planning can help energy transition, especially in more vulnerable heat exposed regions like Tamil Nadu.

- **Innovative Business and Partnership Models:**

Enabling pre-investment and financing options for initial expenditure that goes into setting up of the District Cooling systems, with spreading awareness among key stakeholders about its long-term benefits for the ecosystem. Exploring feasible business and partnership models for recovery of initial cost such as public private partnership or CaaS. When cooling is treated as a necessary utility, automatically through

the PPP model, investment in the entrenched network that needs to be built upfront could be taken care of by relevant government agencies, while the plant itself would be the responsibility of the District Cooling provider.

- **Policy and Regulatory Support:**

To foster growth of District Cooling, the government should establish clear policies and regulatory frameworks that promote and incentivize the adoption of District Cooling systems. This can include fiscal and non-fiscal incentives, streamlined permitting processes for projects that incorporate District Cooling, etc. Additionally, setting mandatory energy efficiency standards and linking the same to annual reporting for maintaining green building certifications can drive the transition towards more sustainable cooling solutions.

- **Legal Framework:**

Given the nascency of District Cooling technology and the complexity of multi-party contracts involved, establishing a comprehensive legal framework is essential to facilitate its large-scale adoption. This framework should include the development of model contracts that clearly define the roles, responsibilities, and expectations of all parties involved, Service Level Agreements (SLAs) that specify performance standards, response times for maintenance and repairs, and penalties for non-compliance, pricing structure including ongoing service fees and any variable charges based on usage, terms for the termination of the contract, etc.

- **Awareness:**

At the larger citizen level, greater information and knowledge sharing about cooling alternatives, such as District Cooling, with involvement of government, private sector, and civil society representatives in the form of workshops will be helpful. Engagement with local government bodies to understand regional differences, hurdles and suitability, can assist to devise programs for large-scale implementation at city or village levels.

- **Training and Capacity Building:**

Building the necessary technical expertise to design, implement, and manage District Cooling systems is essential. Offering training programs and certification courses for engineers, architects, urban planners, and other stakeholders can ensure that the workforce is equipped with the skills needed to support the widespread adoption of District Cooling.

- **Showcase Projects and Case Studies:**

Implementing pilot projects in different regions can demonstrate the feasibility and benefits of District Cooling. These projects can serve as case studies to showcase best practices, identify challenges, and provide valuable data to inform future developments. Successful pilot projects can also build confidence among stakeholders and attract further investment.

About Tabreed India

Tabreed India Private Limited is a wholly owned subsidiary of Tabreed Asia Central Cooling Company, a 75/25 joint venture between National Central Cooling Company PJSC (Tabreed UAE) and World Bank's International Finance Corporation (IFC). In 2023, Tabreed has been awarded a 32-year concession to develop Asia's largest district cooling scheme of 125,000 RT for Hyderabad Pharma City in Telangana and signed a concession with Tata Realty to provide cooling as a service (CAAS) for their Grade A commercial campus in Gurugram for 6,600 RT. With strong design, engineering and development capabilities, Tabreed India continues to develop local supply chain and O&M capabilities to ensure global best practices could seamlessly be implemented in the country.

About Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is a German federal enterprise with worldwide operations. GIZ supports the German Government in the field of international cooperation for sustainable development. The current thematic areas of GIZ in India are – Energy, Environment, Climate Change and Biodiversity, Sustainable Urban Development and Sustainable Economic Development. The Federal Ministry for Economic Cooperation and Development (BMZ), the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), as well as the Federal Ministry for Economic Affairs and Climate Action (BMWK), are the main commissioning parties of GIZ in India. Other clients include Indian public sector clients, the European Union and foundations. The Government of India has launched numerous important initiatives to address the country's economic, environmental and social challenges, and GIZ is contributing to some of the most significant ones under the umbrella of the Indo-German Partnership for Green and Sustainable Development.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

tabreed

Bureau of Energy Efficiency
Ministry of Power, Govt. of India

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

IKI INTERNATIONAL CLIMATE INITIATIVE

About Bureau of Energy Efficiency (BEE)

The Government of India has set up Bureau of Energy Efficiency (BEE), under the Ministry of Power (MoP) ,on 1st March 2002 under the provision of the Energy Conservation Act, 2001. The mission of Bureau of Energy Efficiency is to assist in developing policies and strategies with a thrust on self-regulation and market principles with the primary objective of reducing energy intensity of the Indian economy within the overall framework of the Energy Conservation Act, 2001. This will be achieved with active participation of all stakeholders, resulting into accelerated and sustained adoption of energy efficiency in all sectors. The BEE coordinates with designated consumers (DCs), designated agencies, and other organizations and recognizes, identifies, and utilizes the existing resources and infrastructure, in performing the functions assigned to it under the EC Act. BEE recently launched DCS guidelines to give impetus to sustainable cooling in India.

Notes

1. “India Cooling Action Plan”. Ozone Cell Ministry of Environment, Forest & Climate Change. Government of India. 2019. Source
2. “India Cooling Action Plan”. Ozone Cell Ministry of Environment, Forest & Climate Change. Government of India. 2019. Source
3. “India Cooling Action Plan”. Ozone Cell Ministry of Environment, Forest & Climate Change. Government of India. 2019. Source
4. UNEP and IEA. 2020. “Cooling Emissions and Policy Synthesis Report: Benefits of cooling efficiency and the Kigali Amendment”. United Nations Environment Programme (UNEP) and International Energy Agency (IEA). Source
5. Fernandes, Jocelyn. 2024. “Heatwave: 56 Heat-related Deaths, 25,000 Heatstroke Cases Reported in India From March to May.” Mint. Source
6. “India Cooling Action Plan”. Ozone Cell Ministry of Environment, Forest & Climate Change. Government of India. 2019. Source
7. “India Cooling Action Plan”. Ozone Cell Ministry of Environment, Forest & Climate Change. Government of India. 2019. Source
8. “India Cooling Action Plan”. Ozone Cell Ministry of Environment, Forest & Climate Change. Government of India. 2019. Source
9. UNEP and IEA. 2020. “Cooling Emissions and Policy Synthesis Report: Benefits of cooling efficiency and the Kigali Amendment”. United Nations Environment Programme (UNEP) and International Energy Agency (IEA). Source
10. S. Venkadesan. 2024. “Why TN Needs to Clean up Its Power Act, and Fast.” The Times of India. Source
11. Shivakumar, C. 2023. “Tamil Nadu Exploring Alternatives for ACs to Cut Down Power Consumption.” The New Indian Express. Source
12. Viswanath, Madhumitha. 2019. “Chennaites Use 60% Power on Cooling: Survey.” The New Indian Express. Source
13. TNGCC and CEEW. 2024. “Tamil Nadu’s Greenhouse Gas Inventory and Pathways for Net-Zero Transition.” Chennai: Tamil Nadu Green Climate Company, Department of Environment, Climate Change and Forest, Government of Tamil Nadu; and Council on Energy, Environment and Water (CEEW). Source

14. Chaitanya, SV Krishna. 2024. “TN Greenhouse Gas Report: 77% Emissions From Energy Sector, Long Road to Achieve Net Zero.” The New Indian Express.
Source 🔗

15. IIT Madras. 2023. “IIT Madras Researchers Highlight Extensive CO2 Emissions Due to Buildings Alone Over the Next Two Decades | Indian Institute of Technology Madras.”
Source 🔗

16. Anti-Slavery International Volunteers for Social Justice. 2017. “Slavery in India’s Brick Kilns & the Payment System: Way forward in the fight for fair wages, decent work and eradication of slavery”.
Source 🔗

17. Chandrashekar, Nirmita. 2024. “Heat Stress in the Informal Sector | IDR.” India Development Review.
Source 🔗

18. Shagun. 2024. “ILO Flags Risk of Excessive Heat to 2.4 Billion Workers Globally; Indian Workers Among Those at High Risk.” Down to Earth.
Source 🔗

19. Sangomla, Akshit. 2024. “Duration of Heavy Work to Halve for 800 Million People if World Warms 2°C:Report Provides Solutions to Tackle Heat Stress.” Down to Earth.
Source 🔗

20. J, Padmaja. 2024. “Hot? Uncomfortable? It’s Going to Get Worse Tamil Nadu.” The Times of India.
Source 🔗

21. Jane, Sinduja. 2024. “Heatwave Hits Many in Tamil Nadu, No Deaths Reported.” The New Indian Express.
Source 🔗

22. Sivapriyan, ETB. 2023. “Rising Heat Stress Poses Grave Occupational Health Risk for Workers in Tamil Nadu: Study.” Deccan Herald.
Source 🔗

23. “India Cooling Action Plan”. Ozone Cell Ministry of Environment, Forest & Climate Change. Government of India. 2019.
Source 🔗

24. “Government of Tamil Nadu Launches Tide Turner, Green School and Urban Cooling Initiatives with United Nations Environment Programme on the sidelines of G-20 Environment and Sustainability Summit at Chennai.”. DIPR Secretariat. 2023.
Source 🔗

25. “District Cooling for Decarbonizing Real Estate Sector”. Realty Plus Magazine 2023.
Source 🔗

26. Abramskiehn, Dario and Richmond, Morgan. 2019. “Cooling as a Service (CaaS) Lab Instrument Analysis”. The Lab.
Source 🔗

27. SP Group. “District Cooling and Heating”.
Source 🔗

28. “Breakthrough: Singapore’s Largest Industrial District Cooling System at ST'S AMK TechnoPark, 1st Industrial Project for SP Group.” ST Life.Augmented Blog. 2022.
Source 🔗

29. "What is circular economy and why does it matter?". UNDP Climate Promise. 2023.
Source 🔗

30. "Thermal Storage, District Energy." District Energy.
Source 🔗

31. Bassi Nitin, Gupta Saiba, Chaturvedi Kartikey. 2023. "Reuse of Treated Wastewater in India Market Potential and Recommendations for Strengthening Governance". Council on Energy, Environment and Water (CEEW).
Source 🔗

32. B, Aravind Kumar. 2022. "Tamil Nadu Sets up Climate Change Missions in All 38 Districts." The Hindu.
Source 🔗

33. "Tamil Nadu Green Climate Fund". Tamil Nadu Infrastructure Fund Managaement Corporation Ltd. 2022.
Source 🔗

34. "Tamil Nadu leads the way on climate action, promises net-zero well ahead of 2070". DIPR Secretariat. 2024.
Source 🔗

35. The Hindu Bureau. 2024. "T.N. Forms New Green Company by Merging TEDA And Tangedco's Renewable Energy Wing." The Hindu.
Source 🔗

36. "Tamil Nadu leads the way on climate action, promises net-zero well ahead of 2070". DIPR Secretariat. 2024.
Source 🔗

37. S, Venkadesan. 2024a. "Tamil Nadu Absorbs 40.5mu Solar Power Into Grid, Maximum in a Day so Far." The Times of India.
Source 🔗

38. Preetha, M. Soundariya. 2024. "Wind Energy Generation Picks up in Tamil Nadu." The Hindu.
Source 🔗

39. Shivakumar, C. 2023. "Climate Action Plan to Be Integrated With Chennai's Masterplan." The New Indian Express.
Source 🔗

40. "Installation of Solar Rooftops in Greater Chennai's Corporate Buildings - C40 Cities." 2022. C40 Cities. March 18, 2022.
Source 🔗

41. The Hindu Bureau. 2023. "'Faecal Sludge and Sewage Treatment Plants to Be Set up in All Panchayats and Municipalities in Tamil Nadu.'" The Hindu.
Source 🔗

42. Shivakumar, C. 2024. "Fintech City in Chennai's Nandambakkam Likely to Be First Infra in State to House a District Cooling System." The New Indian Express.
Source 🔗

43. "Year End Review of Ministry of Power (up to November 2023)" Ministry of Power 2024.
Source 🔗

44. "Energy Benchmarking guidelines for Climate Proofing Buildings in U.T. of Puducherry". Department of Science, Technology and Environment. Puducherry Climate Change Cell. 2022.
Source 🔗

45. Kumar, S., Sachar, S., Kachhawa, S., Goenka, A., Kasamsetty, S., George, G. 2018. "Demand Analysis of Cooling by Sector in India in 2027". New Delhi: Alliance for an Energy Efficient Economy.
Source

46. TNGCC and CEEW. 2024. "Tamil Nadu's Greenhouse Gas Inventory and Pathways for Net-Zero Transition." Chennai: Tamil Nadu Green Climate Company, Department of Environment, Climate Change and Forest, Government of Tamil Nadu; and Council on Energy, Environment and Water (CEEW).
Source

47. "Energy Conservation Building Code (ECBC)". Bureau of Energy Efficiency, Government of India, Ministry of Power."
Source

48. Vijayakumar, Sanjay. 2022. "Tamil Nadu Finally Notifies Energy Conservation Building Code for Commercial Buildings." The Hindu.
Source

49. Dammala, Rachel. 2024. "Adoption of ambitiously carved 'cool roof policy' remains dismal". Deccan Chronicle.
Source

50. "These 5 Cities Are Embracing Passive Cooling for a Sustainable Future." World Economic Forum. 2023.
Source

51. "Urban Energy Technical Note". Promoting Energy Efficiency in Buildings in East Africa. UN Habitat. 2023.
Source

52. "India: A Snapshot." India Brand Equity Foundation. 2024.
Source

53. "Industrial Development & Economic Growth in Tamil Nadu State Presentation Report | IBEF." India Brand Equity Foundation. 2023.
Source

54. "Tamil Nadu Data Centre Policy 2021". Information Technology Department, Government of Tamil Nadu. 2021.
Source

55. Kumar, Abhijeet. 2024. "Meta's First Data Centre to Come up in Reliance's Tamil Nadu Campus: Report." Business Standard.
Source

56. "Incentivising Growth: Enabling Data Centre Policies in Gujarat and Tamil Nadu" Tele.Net. 2024.
Source

57. The Hindu Bureau. 2022. "Chennai's Data Centre Capacity to Double by 2024." The Hindu.
Source

58. "India-Cool Coalition." Cool Coalition. 2023.
Source