DISTRICT ENERGY IN CITIES INITIATIVE

UN environment

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RAPID ASSESSMENTS OF FIVE INDIAN CITIES

COIMBATORE

COPENHAGEN CENTRE ON ENERGY EFFICIENCY
SEforALL EE HUB

ICLEI Local Governments for Sustainability

EESL

Contributing to:

SUSTAINABLE ENERGY FOR ALL

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Consultations between the project team and the Ministry of New and Renewable Energy, Ministry of Power, Ministry of Urban Development, Ministry of Environment, Forest and Climate Change and the Bureau for Energy Efficiency proved invaluable in designing the District Energy in Cities Initiative's activities in India and the approach and methodology for undertaking district energy assessments in Indian cities.

The project team appreciates the vision shown by the Coimbatore City Municipal Corporation for agreeing to be a part of the District Energy in Cities Initiative. We are grateful for all the support extended by the Municipal Corporation and its departments to this exercise.

We extend our sincere thanks to administrators, government departments and stakeholders including the Coimbatore Local Planning Authority, Coimbatore Smart City Limited, IC Centre for Governance, Coimbatore Hi-Tech Infrastructure Private Limited, CODISSIA Trade Fair Complex team, Coimbatore Hi-Tech Infrastructure Private Limited, TIDEL Park Coimbatore Limited, KG Information Services and Technologies Private Limited, Tamil Nadu Pollution Control Board –Coimbatore office, Indian Chamber of Commerce-Coimbatore, Tamil Nadu Electricity Board – Coimbatore office, P.P Associates, Tamil Nadu Agriculture University, whose inputs and contribution to data collection have been invaluable to the successful completion of the district cooling rapid assessment in Coimbatore and the compilation of this document.

The Initiative

The District Energy in Cities Initiative is a multi-stakeholder partnership coordinated by UN Environment, with financial support from the Global Environment Facility and the Governments of Denmark and Italy. As one of six accelerators of the Sustainable Energy of All (SEforAll) Energy Efficiency Accelerator Platform, the Initiative is supporting market transformation efforts to shift the heating and cooling sector to energy efficient and renewable energy solutions. Over 46 organizations, including industry associations, manufacturers, utilities, financiers, non-government groups, as well as 45 champion cities across the world have partnered with the District Energy in Cities Initiative to support local and national governments implement district energy policies, programs and project pipelines that will accelerate investment in modern district energy systems. India is one of the pilot cities in India and Thane, the Initiative's first pilot city in India, was selected as a result of these rapid assessments. The Initiative is working in partnership with Energy Efficiency Services Limited (EESL), the National Coordinating Agency of the Initiative in India.

For more information and contact details please visit districtenergyinitiative.org

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1 Introduction

This report contains the rapid assessment of the Indian city of Coimbatore undertaken alongside four other district cooling rapid assessments of Bhopal, Pune, Rajkot and Thane. This report sets out a high-level analysis of the current impacts of space cooling in Coimbatore, the potential of district cooling and its benefits in the city, policy options to accelerate district cooling and the high-level feasibility of specific district cooling projects. Through the District Energy in Cities Initiative, UN Environment and partners will provide further support to Coimbatore to help realise its district cooling potential.

2 Background on district cooling

Accelerating the uptake of energy efficiency and renewable energy in the global energy mix is the single biggest contribution to keep global temperature rise under 2°C. Cities account for over 70% of global energy use and 40 to 50% of greenhouse gas emissions worldwide. In several cities, heating and cooling can account for up to half of local energy consumption. Any solution for energy transition must explicitly address sustainable urban heating and cooling, as well as electricity consumption. One of the least-cost and most efficient solutions in reducing emissions and primary energy demand is the development of modern (climate-resilient and low-carbon) district energy systems in cities. To facilitate this energy transition, UN Environment and partners formed the District Energy in Cities Initiative as the implementing mechanism for the SEforALL District Energy Accelerator[1].

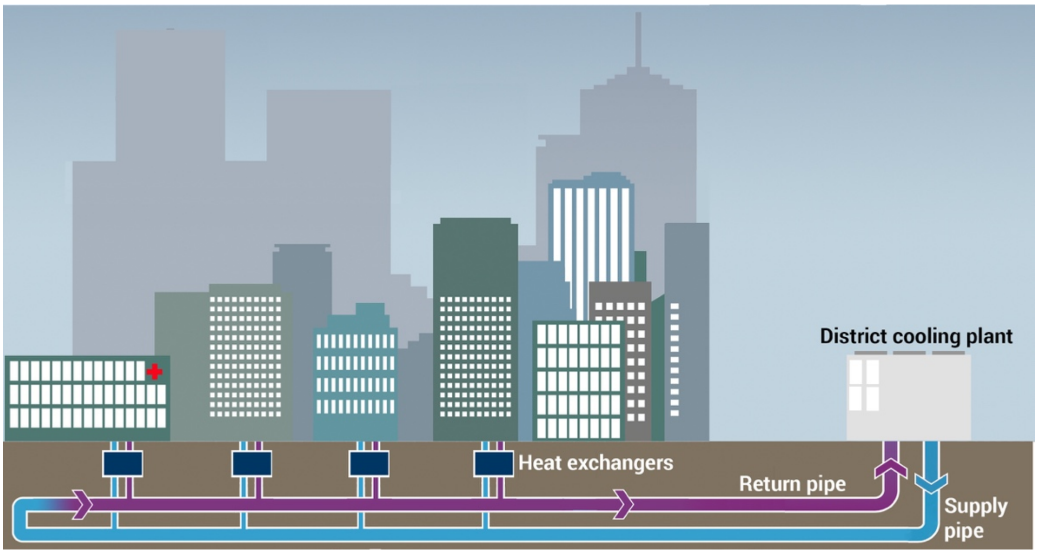
There is no fixed term used worldwide for 'district energy systems', and the authors note the following as being used worldwide: district cooling systems, district heating systems, community cooling/heating, heat networks, cool networks, decentralised energy systems, heat grids, CHP networks, trigeneration networks, community cooling, community heating, neighbourhood energy systems etc. Confusingly 'district' has different meanings worldwide and the authors note that in India it can mean a jurisdiction far larger than a city. 'District' when used in the context of the District Energy in Cities Initiative refers to a city district, i.e. a neighbourhood. UN Environment in its report 'District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy' explains the technology options in detail, as well as the benefits, policies (national and local) and business models[2].

District Energy Systems for Cooling and its Benefits

District cooling systems are a smart city solution that delivers the comfort of air conditioning with significantly reduced impacts, in particular, considerably reduced electricity consumption for space cooling. A district cooling system is a neighbourhood-scale air conditioning system that produces chilled water in a central plant and distributes it to multiple buildings via underground insulated pipes, replacing buildings' stand-alone air conditioning systems. Centralizing production of chilled water and connecting diverse consumers means the central plant can be operated using lots of different efficient sources,

[1] For more information and contact details please visit www.districtenergyinitiative.org
[2] Available from www.districtenergyinitiative.org

and have large-scale thermal storage, leading to more efficient, reliable and environmentally friendly cooling in buildings. By cooling several buildings in a city neighbourhood, district cooling provides the economies of scale required to integrate large scale renewables or waste heat that cannot be connected at the individual building scale, lowering electricity consumption by up to 50%. In particular, district cooling systems dramatically reduce electricity demand for cooling, and shift electricity demand away from peak periods. Consequently, many countries across different climactic zones and at differing stages of economic development are rapidly developing district cooling to reduce energy bills, increase energy security and reduce cooling's impact on the environment. Countries all around the world are turning to district cooling, including but not limited to China, the USA, Malaysia, Japan, South Korea, Thailand, the UAE, Egypt, Colombia and the majority of EU countries.



District cooling systems offer a number of benefits to cities such as

- **Energy Efficiency Improvements and GHG emission reduction:** District cooling systems can help achieve rapid, deep and cost-effective reductions in primary energy consumption and related GHG emissions of at least 30-50% through operational efficiency gains, potential to integrate local energy sources, and thermal storage. District cooling also reduces the consumption of environmentally damaging refrigerants such as hydro chlorofluorocarbons (HCFCs) and hydro fluorocarbons (HFCs).
- **Use of Local and Renewable Resources:** District cooling can harness local energy sources, including free cooling sources such as rivers, lakes or seas; waste heat from metal smelting plants, waste incineration and other industrial processes and locally available renewable energy sources. Treated wastewater or effluent can also be used in the district cooling network instead of fresh water.
- **Air Quality Improvements:** District cooling systems can reduce indoor and outdoor air pollution and their associated health impacts, through reduced fossil fuel consumption (e.g. from coal power plants near cities or diesel generators within city limits)

- **Resilience and Energy Access:** Adopting district cooling can help reduce fuel import dependence and fossil fuel price volatility, while better managing electricity demand and reducing stress on the power grid.
- **Green Economy:** The reduction in energy demand leads to cost savings from avoided or deferred investment in generation infrastructure and peak power capacity, wealth creation through reduced fossil fuel bills, employment from local jobs created in district cooling system design, construction, equipment manufacturing, operation and maintenance.

More information on district cooling, its applications, case studies and benefits can be found on the website of the District Energy in Cities Initiative: www.districtenergyinitiative.org

2.1 Scope and approaches of the rapid assessment

Five Indian cities were selected by the District Energy in Cities Initiative, led by UN Environment, to be rapidly assessed for their district cooling potential. These assessments also examine space cooling's current impacts, ongoing and planned city programmes through which district cooling could be promoted and the policy options available to each city.

Each rapid assessment report includes high-level technical and financial assessments of multiple upcoming or existing real estate projects in the cities and identifies barriers to their implementation. In addition, an assessment of national programmes, barriers and the policy and regulatory framework relevant to district cooling has also been undertaken. Recommendations at the city, state and national level have been made and cities will continue to be supported through the District Energy in Cities Initiative. Apart from Pune, which hosts a small, privately-operated district cooling project, none of the cities have district cooling at the time of publishing.

In-depth stakeholder consultations were undertaken in each city and potential sites identified, high-level techno-economic assessments established, cooling demands estimated, policy and regulatory frameworks analysed and recommendations to city, state and national governments developed. The five cities were selected to have geographical diversity and different demographics climatic conditions, and rates of real estate development. All of the cities are part of the Government of India's Smart City Mission and Solar Cities Program.

The methodology, lessons and model used to assess the five cities will be made available on the Initiative's website.

3 City Overview

3.1 Introduction to the City

Coimbatore has shown leadership in adopting clean technologies and places high emphasis on environmental sustainability. Coimbatore is one of 20 cities selected for the first round of funding under the Government of India's Smart Cities Mission

Coimbatore city, also known as Kovai, is the second largest city in the state of Tamil Nadu. Situated in the western part of the state, Coimbatore forms a focal point and is located in close proximity to the cities of Chennai, Bangalore and Kochi.

The city is a major industrial centre known for its textile industry, engineering firms, automobile part manufactures. It is also a renowned information technology (IT)/ Information Technology enabled Services (ITES) and an educational hub in the state. The city is witnessing significant growth and real estate development in the residential as well as the commercial and service sectors. With Coimbatore's traditionally pleasant climate undergoing change and the city witnessing rising temperatures, considerable demand for space cooling exists in the upcoming commercial properties such as IT/ITES office spaces and shopping malls are having considerable space cooling.

There are two governing bodies within the Coimbatore urban agglomeration area, the Coimbatore City Municipal Corporation (CCMC) and the Coimbatore Local Planning Authority. The CCMC administers the city area spanning 275 sq. km while the Coimbatore Local Planning Authority is responsible for planning and development of the urban agglomeration, spread over 1,276 sq. km.

Table 1: City at a Glance

Particulars	Details
Area	275 sq. km.
Population	1,610,000
Population Density	6,300 persons per sq. km.
Local Economic Base	IT Services, Manufacturing and Engineering, Textile, Education
Average Temperature	28.9ºC
Average Relative Humidity	66.00%
Average Rainfall	694 mm

3.2 Location and Natural Environment

3.2.1 Geographical Location

Coimbatore is located at a distance of 502 km from the state capital of Chennai. Coimbatore is spread on the northern banks of River Noyyal in the west of Tamil Nadu and borders the neighbouring state of Kerala. Coimbatore acts as an entry and exit point for Ooty, a worldfamous tourist destination visited all year round. The city is located at 11° North latitude and 76° East longitude and is situated 411.2 meters above the sea-level.

The city is well connected to major Indian cities by both rail and road. Coimbatore has an international airport at Peelamedu, situated at a distance of 11 km from the city, connecting Coimbatore via air to all major Indian cities and international destinations.

Figure 1: Geographical Location of Coimbatore City

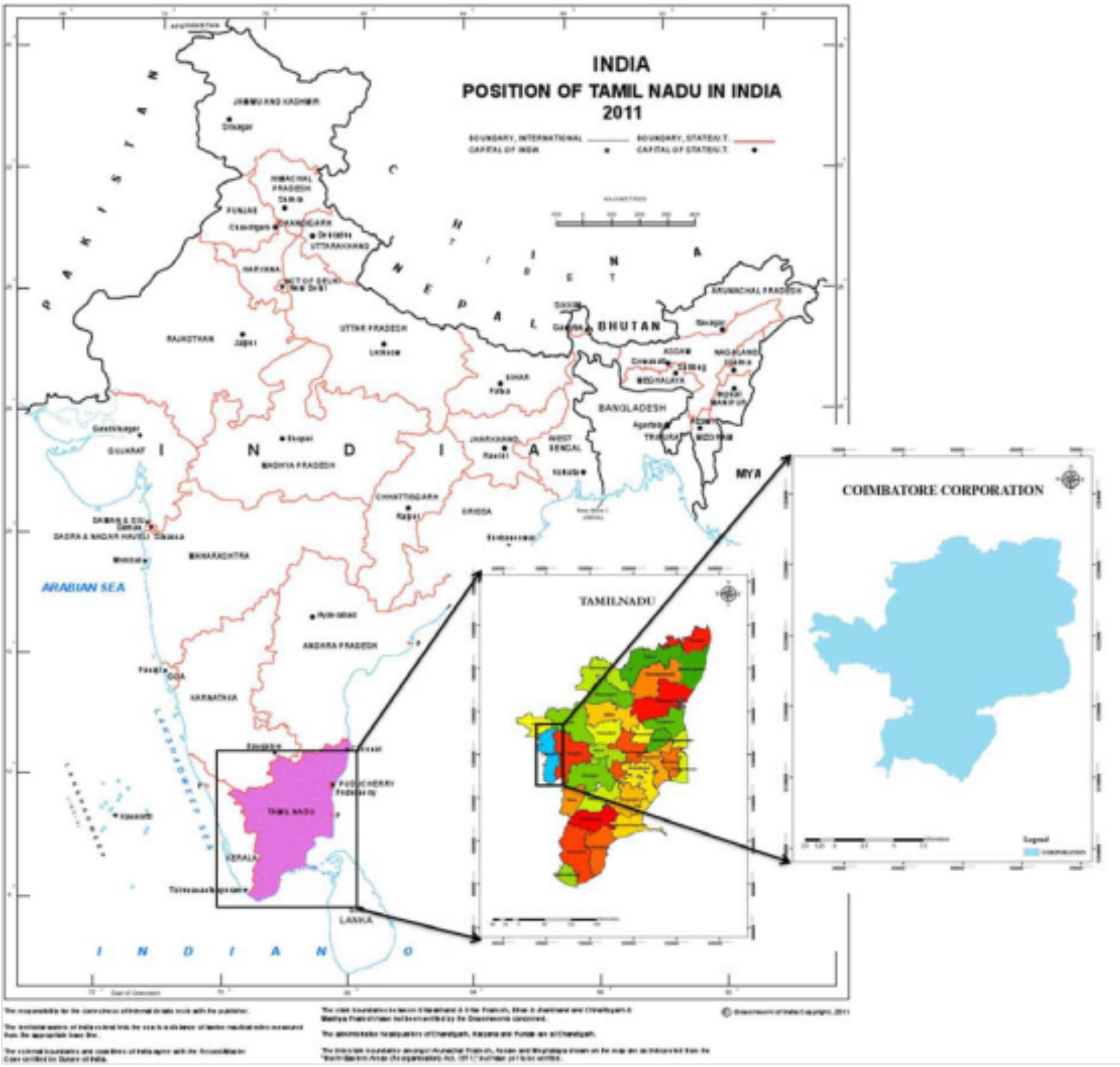
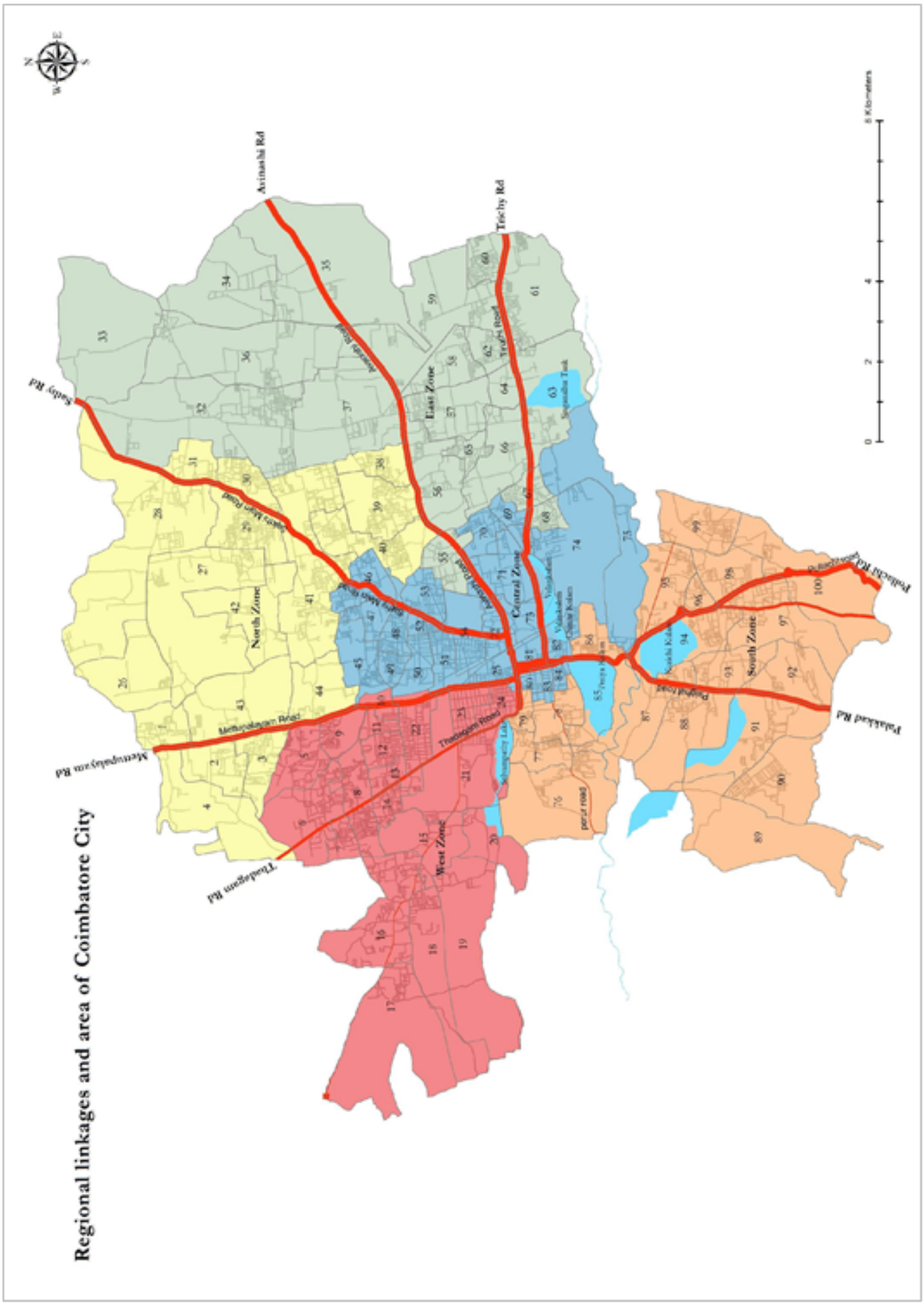


Figure 2: Regional linkages and area of Coimbatore City



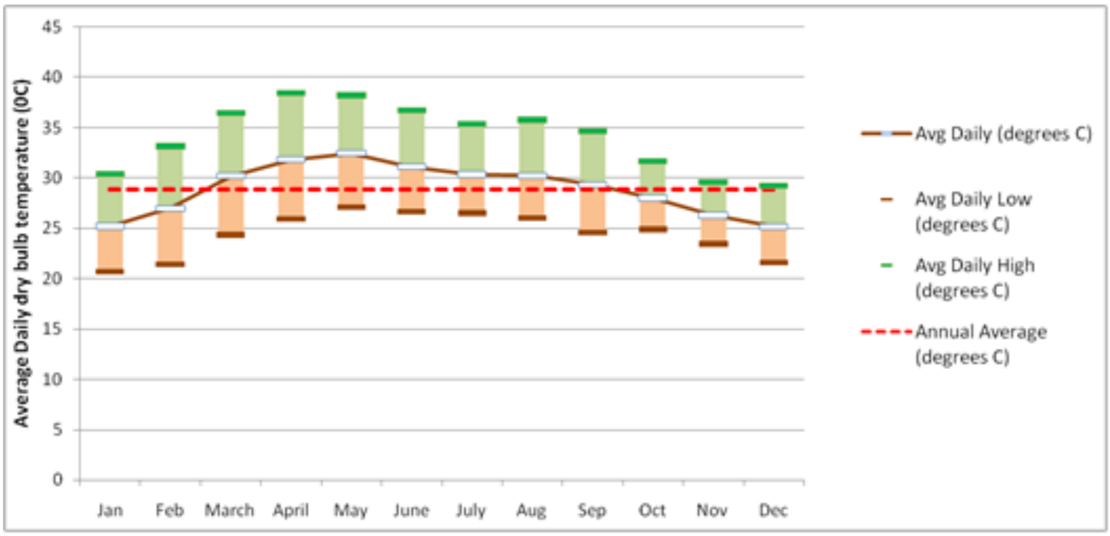
3.2.2 Climate

Coimbatore falls under the warm and humid climatic zone. The city is surrounded by the mountain range of Western Ghats towards its North and North West and by the dense Nilgiri forest reserve towards the North. Since Coimbatore is situated in the midst of the Nilgiri biosphere, the city experiences a characteristically salubrious climate where the typically harsh temperatures are abated by the gentle winds from the Palaghat pass, located towards the West of the city. The average daily temperature of the city typically ranges from 25°C to 32°C (See Figure 3). The monthly mean minimum and maximum temperatures do not show great variation through the year, except in the summer months.

The summer season in the city usually extends from March to May, with the city experiencing hot and humid weather during this period. The maximum temperature in the summer months is around 38° to 40°C. Coimbatore receives its rainfalls in two spells - first the southwest monsoon from July to September, followed by the northeast monsoon from October to December. The monsoon season lasts from the month of June to August, with the city receiving heavy rainfall of about 600-700 mm in this season. Humidity is relatively high in the afternoons during the summer months.

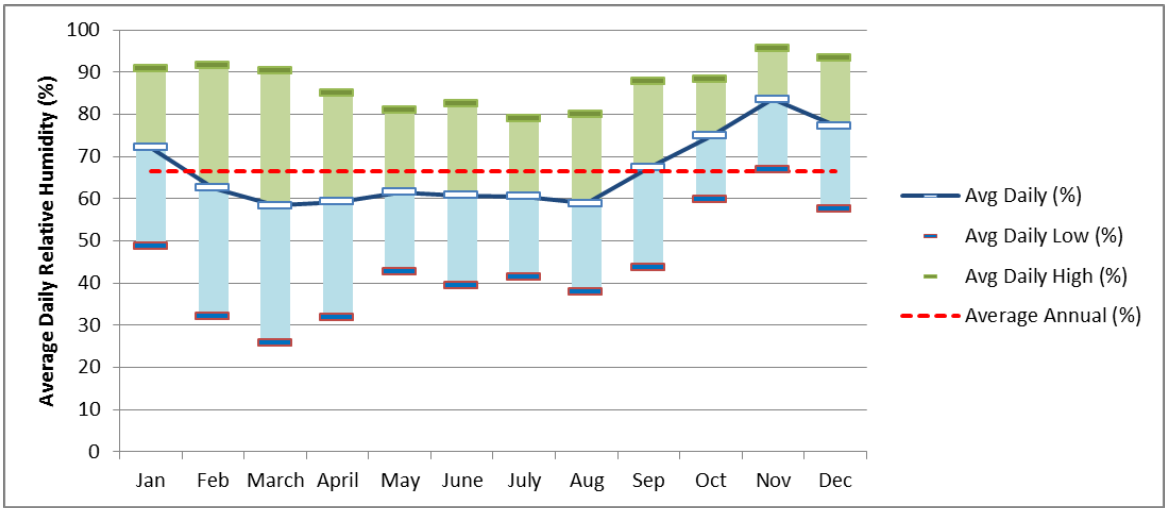
The temperature starts dipping from the month of August onwards up to the end of the winter season. Coimbatore has moderate winters from December to February, with average daily low temperatures of about 20°C. Humidity rises during the spell of the northeast monsoon from October to December.

Figure 3: Month wise average daily temperature variation with respect to annual average temperature for Coimbatore city (1982-2006)



Source: Analysis based on data from (ASHRAE, 2009)

Figure 4: Month wise average daily relative humidity variation with respect to annual average relative humidity for Coimbatore city (1982-2006)



Source: Analysis based on data from (ASHRAE, 2009)

Coimbatore and the Tamil Nadu state as a whole has been witnessing high volatility in its weather patterns in the recent past. There is a distinct trend of increasing temperatures and erratic rainfall, coupled with more intense cyclones and floods[3]. The Tamil Nadu State Action Plan on Climate Change indicates that Tamil Nadu's monsoon trend has been changing in the past decade, the southwest monsoon has been decreasing from its share of 48% to 24%, and the northeast monsoon has increased from 34% to 63%.

Projections carried out for temperature as part of the Tamil Nadu State Action Plan indicate that the maximum temperature over Tamil Nadu state is expected to rise by 1^{0}C by 2020, 2^{0}C by 2050 and 3.1^{0}C by the end of the century as compared to the baseline of 1970-2000. The projections of minimum temperature for the same periods also show an increase of 1.1^{0}C, 2.3^{0}C and 3.4^{0}C respectively. **The average maximum and minimum temperature for Coimbatore district is projected to increase by 3.3°C and 3.4°C respectively by the end of the century[4].**

The total number of annual cooling degree days (CDD)[5] for Coimbatore is 1,623 (for a base temperature of 23^{0}C). The cooling degree days are high in the summer months and observed to be largely consistent between the months of August to December. It is evident from the information presented earlier that the Coimbatore's climate will not remain as pleasant in the coming years and there will be an increased demand for thermal comfort in the city. Other cities have developed successful district cooling projects with far lower CDDs.

[3] While intense rainfall brought about damaging flash floods in districts across Tamil Nadu towards the end of the year 2015, areas of the state (including Coimbatore) are witnessing drought in 2017, all in a matter of 15 months. Available at http://indiaclimatedialogue.net/2017/01/23/changing-climate-inflicts-drought-tamil-nadu/

[4] The projections of temperature and precipitation conducted as part of the Tamil Nadu State Climate Action Plan are based on UK Met Office Hadley Centre's regional climate model PRECIS. The model was run at the Centre for Climate Change and Adaptation Research, Anna University at a spatial resolution of 25 km x 25 km and the GHG emission drivers are generated by the IPCC A1B SRES scenario

[5] Cooling Degree Days (CDD) is a measure of how much (in degrees) and for how long (in days), the outside air temperature is above a given level of comfort (base temperature) for which cooling is required. The higher the CDD, more is the cooling required. The base temperature selected is 18ºC and has been chosen to enable international comparison. For many buildings, air conditioners will maintain temperatures higher than this.

3.2.3 Soil Conditions

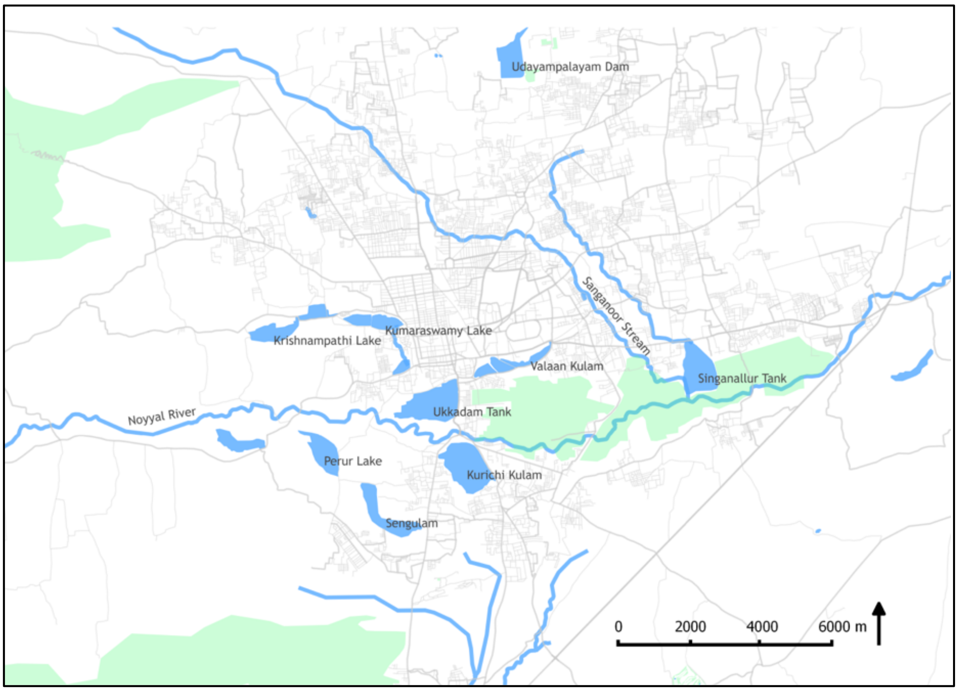
The soil in Coimbatore city is generally hard and has sand, clay and gravel as the main constituents. Four major types of soil can be identified in the city - alluvium, colluvium, black cotton soil and reddish brown or red or brown loamy soil. The soil profile observed in the Nanjundapuram and Ukkadam areas in the city shows non-uniform topsoil of 0.5 m having underlying layers of clayey sand and sand with disintegrated rock. (CPHEEO, 2016)

In general, unstable and poor soil conditions can lead to higher district cooling network installation costs. The soil conditions in Coimbatore are not expected to affect the commercial viability for district cooling in Coimbatore but should be further analysed at more detailed stages of project development.

3.2.4 Surface and Groundwater Availability

Coimbatore has two major water channels, the Noyyal River which traverses from west to east and Sanganurpallam stream which flows from the north towards the east. The city has eight prominent lakes including Perur Lake, Periya Kulam, Kurichi Lake, Valan Kulam, Krishnampathy Lake, Kumarasamy Lake, Singallur Lake and Ukaddam Lake. The Noyyal River is a seasonal river which has good flow for short periods during the north-east and south-west monsoons. However, the Noyyal River as well as the lakes are highly polluted due to discharge of untreated domestic effluent from upstream villages as well as discharge of untreated domestic and industrial effluents from in and around Coimbatore city (a consequence of the city's inadequate wastewater collection network). The surface water shows higher concentration of total dissolved solids and chloride.

Figure 5: Major water bodies (in blue) in Coimbatore city



The rivers and the lakes that exist in Coimbatore city and the surrounding area, are unlikely to be able to provide significant 'free cooling' to district cooling systems as their temperatures are too high, at over 30°C. However, temperatures may be lower at deeper points of these water bodies and further analysis should be undertaken during pre-feasibility stage of projects and city-wide assessments, particularly for projects in the vicinity of these water bodies. This analysis should also account for the possible environmental benefits and impacts that can come from rejecting waste heat into the water bodies.

Water supply for Coimbatore is sourced mainly from two main water sources namely, Siruvani reservoir and Pillur reservoir sources, located at a distance of 36 km and 95 km from the city, respectively. Groundwater sourced through bore wells (operated by the CCMC and private) supplements a part of the city's total water requirement. The duration for which water is supplied to households in the city is inadequate, typically spanning 4 hours and going as low as 10 to 15 minutes in some areas. The volatile climate and rainfall that the city has been experiencing of late is adversely impacting availability of both surface and groundwater (see section 3.2.2 for more details). Coimbatore generates about 106 million litres of wastewater per day (MLD) and is served by three sewage treatment plants (STPs) which are located at Ukkadam, Ondiputhur and Nanjundapuram. The wastewater collection network however caters to only 31% of the city.

Coimbatore has placed high priority towards addressing the pollution of its surface and ground water sources and improving the water and wastewater management in the city. The city is implementing various projects in these areas. Coimbatore is also keen to promote and implement wastewater reuse projects and has initiated a study to evaluate the feasibility for reuse and recycling of domestic sewage.

District cooling systems without 'free cooling' consume significant amounts of water, more than stand-alone air-cooled systems but less than stand-alone water-cooled systems[6]. Existing buildings in Coimbatore that have centralized cooling use a mix of air-cooled chillers and water-cooled chillers (see Section 9.1).

These costs could be reduced through the use of Treated Sewage Effluent (TSE) or water from the creek or lakes in the cooling towers, which could lower operational costs and reduce the consumption of potable water for cooling. This would require TSE or water from the lakes/creek to be connected to the district cooling plant which imposes an additional cost unless the plant is located near such sources. Furthermore, such water may need further treating at the district cooling plant. The costs of using TSE or water from local water bodies in Coimbatore are beyond the scope of this analysis but should be considered in future pre-feasibility studies of district cooling.

3.2.5 Air Quality

Industrial foundry units and vehicular emissions are the major pollution sources impacting air quality in Coimbatore. The city does not have other significant pollution sources such as electricity generation from coal-fired power stations and petrol and metal refining. Based on

[6] For example, GIFT City in Gujarat, India, which already operates district cooling, have identified 20% reduction water use compared to water-cooled chillers (Source: GIFT City presentation at workshop on district cooling in Rajkot, India in May 2016)

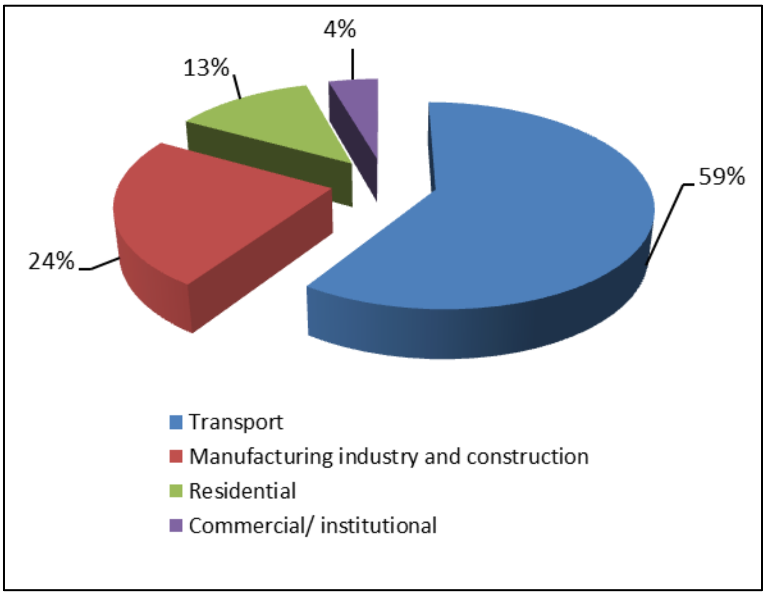
data recorded by three air quality monitoring stations in the city, the concentration of pollutants such as nitrous oxide (NOx), sulphur dioxide (SOx) and particulate matter in residential and commercial areas is found to be within acceptable limits (Air Pollution Database for Tamilnadu, 2014). The pollution levels in the industrial areas are relatively higher, with concentration of particulate matter emissions exceeding the permissible limits prescribed by the National Ambient Air Quality Standards. Information on pollution from point sources is not available in the city. To address this issue and for rigorous monitoring of air quality, the CCMC has prioritized setting up a network of advanced air quality monitoring stations across the city under the Smart City plan.

It is not expected that district cooling will have a significant impact or benefit on local air quality in Coimbatore. However, improving the efficiency of electricity through district cooling could have upstream benefits on air quality outside of Coimbatore by reducing the need for new power plants or the use of existing plants.

3.2.6 Energy Consumption

The total energy consumption for Coimbatore city is approximately 49.1 million GJ. Transport sector consumes the maximum energy with its share amounting to 59%, followed by manufacturing industries and construction sector with a consumption of 24% of the city's total energy. This is followed by the residential sector consuming 13% and commercial/ institutional sector consuming 4% of the total city energy consumption respectively.

Figure 6: Sectoral Share of Energy Consumption in Coimbatore, 2015-16

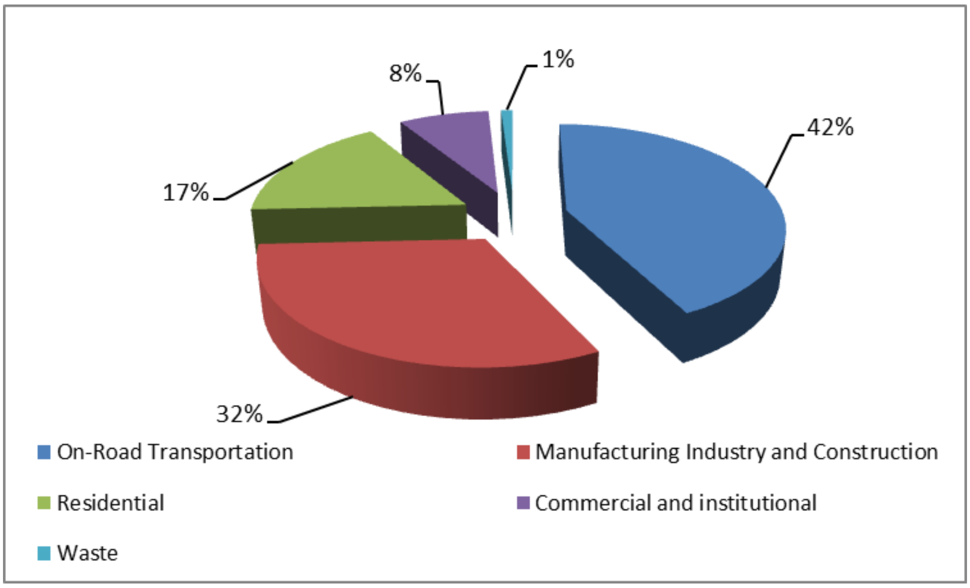


Source: (ICLEI South Asia, 2017)

3.2.7 Greenhouse gas emissions

Coimbatore has voluntarily prepared its baseline GHG emission inventory for the year 2015-16. The transportation sector has the largest contribution to GHG emissions (43%), followed by the industrial sector (31%). Residential, commercial and institutional buildings (along with public infrastructure facilities) account for a fourth of Coimbatore's emissions. The emission inventory does not include refrigerant emissions.

Figure 7: Sectoral Share of GHG emission for Coimbatore City, 2015-16



Source: (ICLEI South Asia, 2017)

3.3 Socio Economic Status

3.3.1 Population

Coimbatore city is spread across an area of 275 sq. km and houses a population of 1.61 million persons (National Census, 2011). In the year 2011, city's area was extended from 105.6 sq. km to 275 sq. km. Consequently, the city density decreased from 8,800 persons per sq. km to 6,300 persons per sq. km. The larger Coimbatore urban agglomeration houses 21 million people (National Census, 2011). The resident population of Coimbatore city is projected to increase to 2.02 million persons by 2025 and go up to 2.5 million persons by 2040.

Coimbatore city has a total of 319 slum pockets with 46,650 households. The slum population makes up nearly 16% of the total population in the city. As of 2010-11, the annual per capita income for Coimbatore district was INR 77,975 (USD 1,162) (Coimbatore District Profile, 2016).

3.3.2 Local Economy and Real Estate Growth

Coimbatore is a major commercial, business and educational hub in the state of Tamil Nadu. Key sectors contributing to the economy of Coimbatore city are textiles, automotive components, IT/ITES manufacturing, education and healthcare. As of 2010-11, Coimbatore had the fourth largest Gross District Domestic Product (GDDP) in the state. Coimbatore district's economy is pre-dominantly service based, with service sector contributing to at 52.8 % of the GDDP. Sectors such as commercial distribution and retail of industrial and food products, jewellery and gems have a share of 41.8 % in the GDDP, followed by the industrial sector (manufacturing, engineering and textile) which contributes 5.3 %.

Coimbatore city is a major IT/ITES centre and is the second largest software service provider in the state. The IT and ITES sector has grown rapidly, especially with special economic zones (SEZ) and IT parks coming up in the city. Coimbatore currently has two prominent SEZs, the Coimbatore Hi-Tech Infrastructure (CHIL) SEZ and the Coimbatore TIDEL Park, and five more SEZs are proposed to be developed at present.

Coimbatore is a major textile hub, housing a large number of small, medium and large textile mills along with textile research institutes like the Central Institute for Cotton Research – Southern Regional Station Association. A number of industrial units engaging in both light and heavy engineering such as wet grinders, foundries and manufacturing of motors and pumps are present in the city.

Coimbatore is a renowned centre of education and is home to 7 universities, 54 engineering colleges, 3 medical colleges, 35 technical polytechnic colleges, more than 70 arts and science colleges, a number of schools and research institutes. With nearly 750 hospitals located in and around Coimbatore, the city remains the preferred healthcare destination for people from nearby districts and also from the neighbouring state of Kerala.

Coimbatore is a radial city with a densely populated core area at the centre and rapidly growing areas along its major radial roads, especially towards the north and east. The growth in the past has been largely towards the east owing to this area having a number of technical and educational institutions, textile mills and information technology parks on the major highway towards Avinashi Road, which connects the central zone of the city to the north-eastern boundary of the city. Significant growth is also taking place along the Sathy road in the north east and the development includes information technology companies, shopping malls and a large number of residential apartments.

Other areas that have seen significant development in the recent years includes PN Palayam and Thudiyalur in the north, Ganapathy in the north-east, Kalapatti and Chinniampalayam and Singanallur, Sulur and Irugur along Trichy road in the east, and Kuniamuthur and Madukkarai on the south. The areas that are undergoing rapid development are largely observed to be well planned with regular street pattern, well-shaped plots and spaces for public use. This in contrast to the centrally located old areas of the city such as Kaundampalayam, Kuruchi and Kundapur which are characterized by high density residential development and are devoid of public spaces and a regular street pattern.

Coimbatore's Master Plan also proposes that development along the radial corridors be grouped into 8 well organized urban nodes within the Local Planning area. These proposed urban nodes would be largely self-sufficient and have their own centres of employment, housing and commerce, spanning an area of 167 sq. km. The 8 urban nodes proposed include Tudialur, Saravanam Patti, Sulur, Irugur, Kuniamuthur, Periyanaiken Palayam, Madukkarai and Vadavalli. The IT corridor of Sarvanapatti and Keeranatham in particular has witnessed high mixed-use development and is expected to undergo rapid growth in the coming years.

Figure 8: Proposed Land-use Map of Coimbatore City - 2021

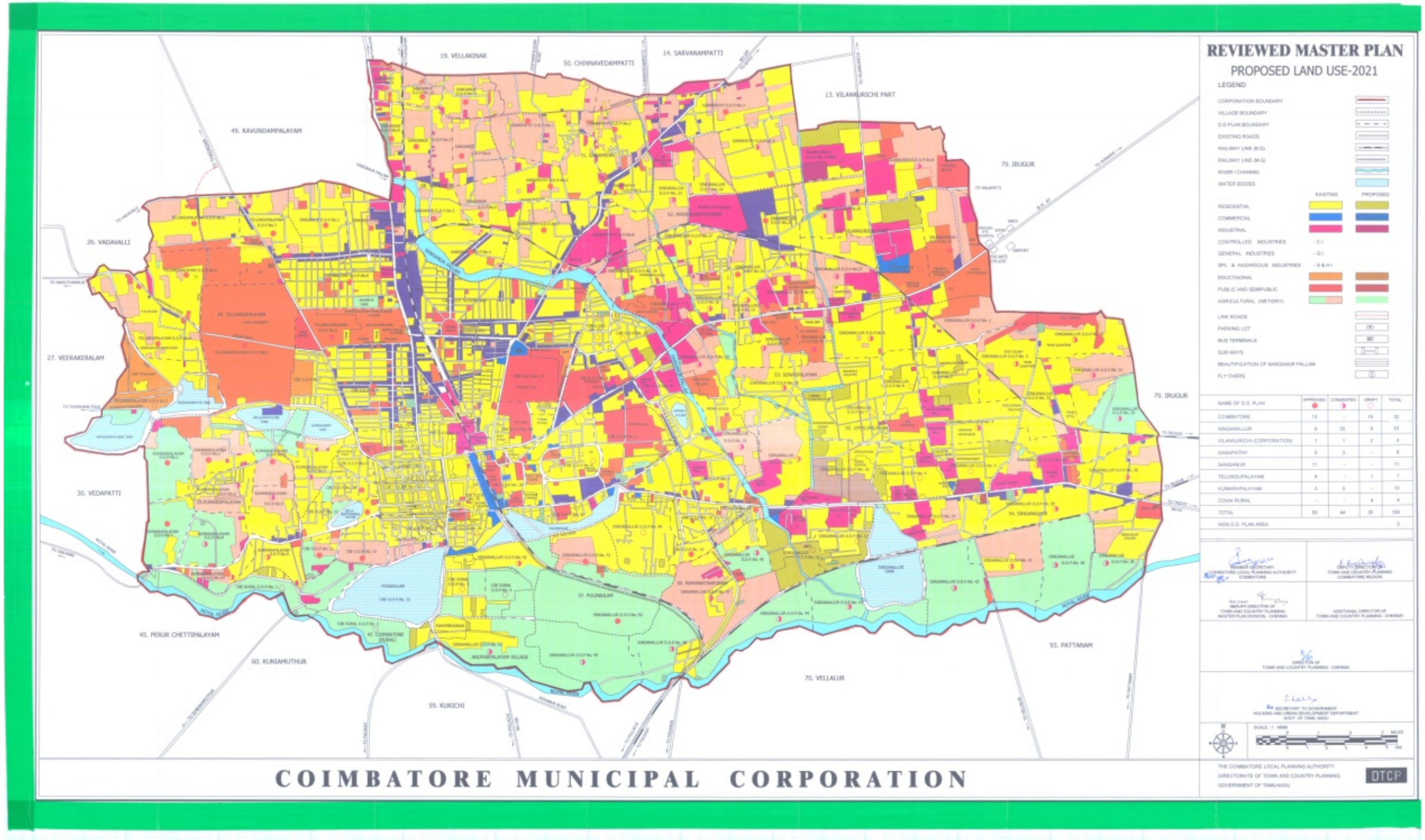
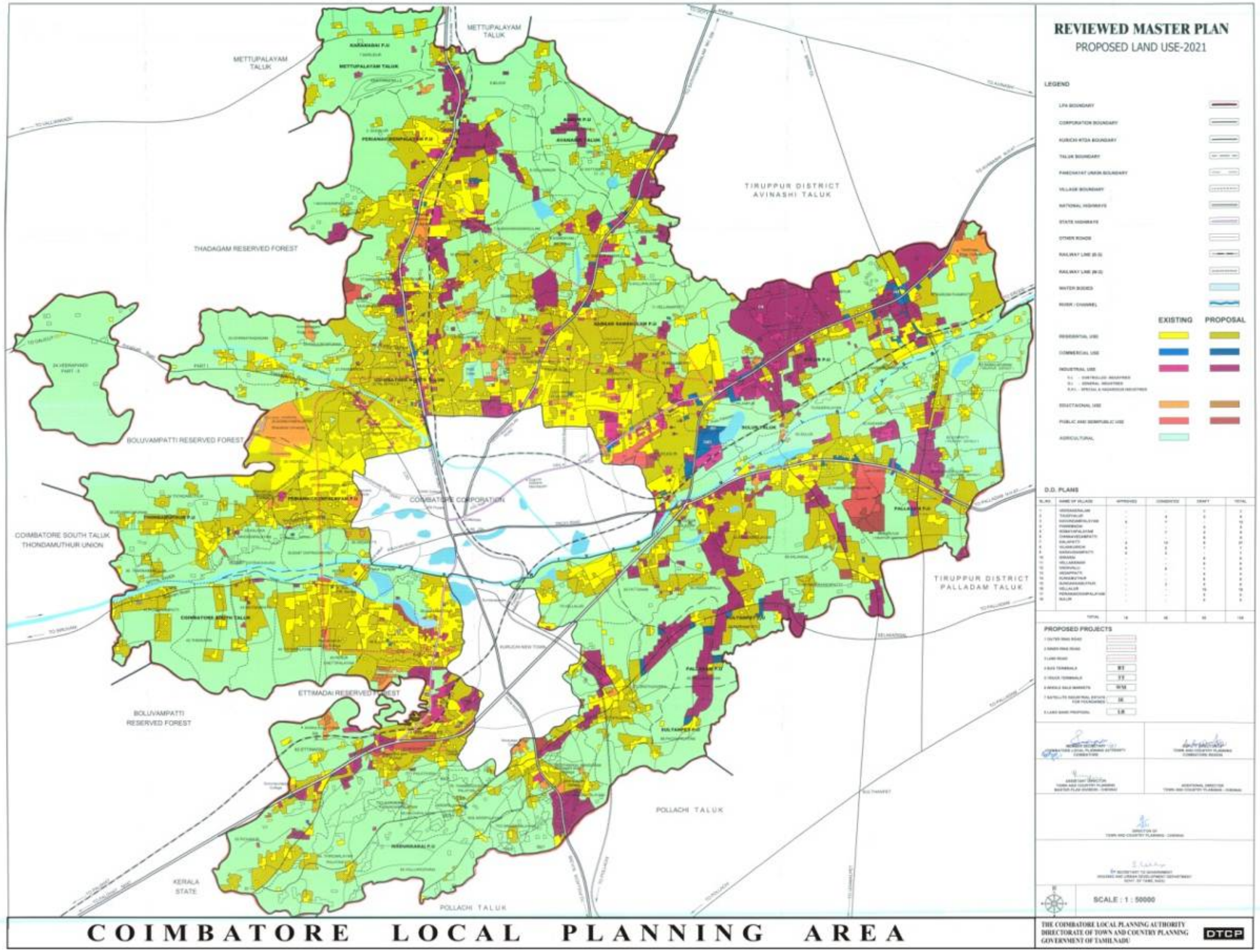


Figure 9: Proposed Land-use Map of Local Planning Area Coimbatore – 2021



4 Stakeholder Mapping

Relevant stakeholders for district cooling development for Coimbatore are listed as below.

Institution type	Agency	Mandates and Role
City Planning and Policy level Interventions	• Coimbatore City Municipal Corporation (CCMC) • Coimbatore Local Planning Authority (CLPA) • Coimbatore Smart City Limited (CSCL)	**Mandates and Functions** A. **CCMC:** The CCMC is main planning authority for the city of Coimbatore. CCMC is responsible for development planning, regulation, control and coordination of urban growth within the territorial jurisdiction of the city. Zoning and mandating the type of land use over its entire jurisdiction is one of its key functions. CCMC is also responsible for the provision of basic civic amenities to the citizens along with the preparation and execution of infrastructural development projects. This includes water supply services for domestic, industrial and commercial purposes. CCMC plays the role of planner, controller and implementer within its jurisdiction. B. **CLPA: CLPA** typically deals with granting the planning permissions. The CLPA grants planning permission for developments up to the specific limits. For buildings exceeding those limits, the CLPA forwards the application to the Commissioner of T & CP for obtaining technical clearance. Once the technical clearance is received from the Commissioner, the LPA issues the planning permission, on collection of all charges. C. **CSCL:** The key responsibility of CSCL is to oversee the planning and execution of Smart City plan for Coimbatore city. This includes the implementation of proposed smart and sustainable solutions throughout the city as well as in the area-based development. CSCL's main focus remains on improvement of urban infrastructure and governance while

Institution type	Agency	Mandates and Role
		addressing priority areas outlined in the Smart city plan. **Role with respect to district cooling:** A. Integrate district cooling development as a focus area in the city's long-term vision and strategy through policy and planning frameworks such as the Master Plan, Smart City Plan, and Low Emission Development Plan etc. B. Leverage its role in city master planning to help identify strategic high density mixed-use zones and building clusters (existing and planned), key economic sectors with opportunities for district cooling network development C. Share information such as city plan(s) detailing zones, existing and future development density, building locations, building use etc. to help determine demand density and new network designs and assess feasibility D. Facilitate planning and implementation of district cooling infrastructure by identifying strategic location and securing land for district cooling production facilities, assisting in excavation permits and rights of way for laying district cooling pipelines, co-ordinating schedules with other planned infrastructure and building construction E. Use the existing local regulatory framework for urban development and buildings such as building permits, bye-laws and development control regulations, building efficiency standards to develop complementary policies to encourage district cooling development and adoption F. Share data on local government buildings and utilities, offering connections to local government buildings such as large hospitals, office buildings to act as anchor loads with

Institution type	Agency	Mandates and Role
		high cooling demand to assist viability of district cooling G. Facilitate stakeholder coordination, raise awareness and acceptance H. Lead implementation of district cooling through public private partnership funding mechanisms
Real Estate, Property Developers and related Institutions	• Coimbatore Builders and Contractors Association • KG Information Services and Technologies Pvt. Ltd. (KGiSTL) • Casa Grande Private Limited • Sree Daksha Property Developers • Srivari Infrastructure Private Limited • Pricol Properties Limited • PARSN GROUP • True Value Homes • Pearl Construction • Confederation of Real Estate Developers Associations of India (CREDAI) - Coimbatore	**Mandates and Functions:** CREDAI - Coimbatore is a registered body that represents the organized property development sector of Coimbatore city. It comprises of member organizations whose primary business is property development and is headquartered or has projects in Coimbatore. It promotes best practices among the Coimbatore property developer community **Role with respect to District Cooling:** A. Identify existing and upcoming large scale high rise buildings and mixed-use developments in the city with potential for district cooling integration, share information on property and building plan, floor space, utilities and cooling technology for the same B. Provide inputs on practical issues, risks and possible enabling policies and programmes with regards to district cooling integration and market acceptance C. Provide information relating to prevalent cooling technology and infrastructure in the real estate market D. Facilitate measurement and monitoring of baseline cooling demand in buildings to assess feasibility for district cooling
Architects, Building Design and Civil Engineering	• Indian Green Building Council (IGBC) – Coimbatore Chapter • Coimbatore Civil Engineers	**Mandate and Functions:** Promote interests of architects- learning as well as practicing – and promote best practices in urban planning and architecture. Enable exchange of knowledge and present a platform to share new techniques,

Institution type	Agency	Mandates and Role
related Institutions	Association (COCENA) • Association of Consulting Civil Engineers (India)-Coimbatore Centre • Indian Institute of Architects (IIA) - Coimbatore Centre • Design n Architecture Studio India Pvt Ltd • Davidar & Associates • Prabhu Associates • Sundar Sundaram Architects • Sankar & Associates	technologies and developments in the field of civil engineering. **Role with respect to district cooling** A. Identify existing and upcoming large scale high rise buildings and developments in the city with potential for district cooling integration B. Share information on typical cooling demand for different building types in the city in consideration of the local climate, building use, envelope and size, and prevalent cooling technology in use and its cost C. Provide technical inputs on integrating district cooling in the prevalent building design and other practical aspects in terms of expertise, market acceptance etc. D. Provide inputs for promoting district cooling through existing or new building design and efficiency standards/regulations
Electricity Distribution company	Tamil Nadu Electricity Board (TNEB)	**Mandate and Functions:** TNEB is a power generation and distribution company owned by Government of Tamil Nadu. The main objectives of Tamil Nadu Electricity Board are to generate, transmit and distribute electricity efficiently and to ensure supply of quality power to its consumers. **Role with respect to district cooling:** A. Share information on baseline and future energy and cooling demand, daily, seasonal and annual load profile, power availability for specific locations/consumers and for the city B. Assist in identification of buildings/consumers with high load and energy demand C. Share information on infrastructure status or augmentation required in the

Institution type	Agency	Mandates and Role
		local electricity network to support the required power demand of the district cooling production plant D. Share information on existing and future tariff structure (fixed, variable, time of use) for different consumer categories, any incentives for electricity conservation to assist in design of district cooling system, assess commercial viability and establish pricing levels for the district cooling service for different consumers
State Designated Energy Agency	Tamil Nadu Energy Development Agency (TEDA)	**Mandate and Functions:** TEDA is an independent agency setup by Government of Tamil Nadu, to create awareness and drive policy and interventions in the State to promote use of renewable energy and energy efficiency. It is a nodal agency for disbursement of central financial assistance/subsidies for renewable energy projects. **Role with respect to district cooling:** A. In its role as the nodal energy agency for the State, TEDA can assist in promoting district cooling by formulating and implementing enabling policy, regulations and schemes for the same B. Coordinate with other State and Central government departments for implementation and promotion of energy efficiency programmes and technology (including district cooling). Create buy-in amongst such departments on district cooling development. C. Share information on existing and planned renewable energy generation in the city for integration with district cooling D. Generate awareness on district cooling among local stakeholders through targeted programmes.

Institution type	Agency	Mandates and Role
Regional Pollution control board	Tamil Nadu Pollution Control Board (TNPCB)	**Mandate and Functions:** TNPCB plans a comprehensive programme for the prevention, control and abatement of water and air pollution in the state. It advises the State Government on any matter concerning the prevention, control or abatement of water and air pollution. It collects and disseminates information relating to water and air pollution and the prevention, control or abatement thereof. The TNPCB is responsible for issuing consents to establish and operate a business/industry which is likely to discharge pollutants/effluents/hazardous waste into atmosphere during the process. The TNPCB regulates and monitors discharge and treatment of sewage or trade effluent and performance of air pollution control systems. **Role with respect to district cooling:** A. Identify potential waste heat sources in the city for use in the district cooling system B. Share information on potential sources of water (e.g. location, temperature, depth, quality) for use in the district cooling network C. Provide inputs on potential environmental constraints, environmental permits and assisting in obtaining requisite clearances for construction and operation of the district cooling project
Industry related Institutions	• Tamilnadu Industrial Development Corporation Ltd. (TIDCO) • Electronics Corporation of Tamil Nadu Ltd. (ELCOT)	**Mandate and Functions**: Promotes co-operation among the industries to evolve a policy on all subjects involving their common interest. Collects and circulates information relating to commercial interests in general to promote beneficial measures relating to the Industries.

Institution type	Agency	Mandates and Role
	• TIDEL Park Coimbatore Ltd. • Indian Chamber of Commerce, Coimbatore • Coimbatore District Small Industries Association (COIDISSIA) • Confederation of Indian Industries	**Role with respect to district cooling:** • Identify existing and upcoming large scale industrial developments such as IT, business and manufacturing hubs/parks, special economic zones in and around the city with high cooling demand and potential for district cooling integration • Share information on typical cooling demand for different industry building types in the city in consideration of the local climate, building use, envelope and size, and prevalent cooling technology in use and its cost • Provide inputs on existing enabling provisions and how existing industrial policy and regulatory frameworks can be used to promoting district cooling in large industry related developments • Share information on potential waste heat sources (from industries such as foundries that exist in the city), availability of gas/biogas • Facilitate coordination and awareness generation for industries • Provide input on how existing building designs can adopt district cooling facilities • Provide inputs on adopting district cooling in future real estate project developments

5 City Strategies and Initiatives

Coimbatore city has engaged in a number of national and international climate and energy initiatives over a period of time and undertaken strategic initiatives on energy efficiency and renewable energy to positively influence low emission development in the city. The CCMC has indicated its interest to develop and facilitate district cooling projects. Currently the city does not monitor cooling consumption and its impacts in the city, and as such has not developed a strategy that specifically addresses the cooling sector. Key strategies and initiatives undertaken by the CCMC are described below.

5.1 Coimbatore Smart City

Coimbatore is one of 12 cities from Tamil Nadu to be shortlisted in the 100 cities to be developed as Smart Cities under the Government of India's Smart Cities Mission. Based on a competitive evaluation of its Smart City proposal, Coimbatore has been further selected in the initial list of 20 cities to be taken up for funding in the first round of the Mission.

Coimbatore's Smart City proposal envisions Coimbatore as an "**Inclusive, Resilient, Competitive and Secure Global Metropolis** that embraces **Citizen-centric, Technology-enabled Governance** to foster a **Dynamic and Vibrant Economy,** offer **Universal Access to Affordable Best-in-Class Civic Services and efficient Transit Orientation**, nurture a **Clean, Green, and Sustainable Environment,** to provide the **Highest Quality of Living standards** for a **Progressive, Diverse and Talented Populace"**.

Under the aegis of this Vision, Coimbatore has identified five Core Themes – **Universal Access to Best-in- class Civic Services, Seamless Mobility, Sustainable Environment, Vibrant Economy, and Effective Governance** – and priority goals as well under each of the Core Themes (see Figure 10). Strategies have further been outlined under each of the 5 Core Themes to meet the priority goals.

Figure 10: Core Themes and Priority Goals for Coimbatore Smart City

Source: (Smart Cities Challenge - City wide Concept Plan for Coimbatore, 2015)

Coimbatore places high emphasising on achieving and maintaining a **Sustainable Environment,** one of the Core Themes identified. The priority strategies outlined under the Sustainable Environment theme further demonstrate that Coimbatore recognizes the need to take action towards addressing energy use and climate change. Coimbatore is committed to promote renewable solar and wind energy, reduce energy consumption through implementing through renewable energy and energy efficiency related actions identified under its Solar City Plan, and build its resilience towards Climate Change. The city remains keen to improve the quality of its air and water resources and promote water reuse as well.

Figure 11: Priority Goals and Strategies under the Sustainable Environment Theme

Increase Green Cover

- Rejuvenate improve eight lakes and green areas
- Rejuvenate Singanallur Tank
- Implement proposed program to develop Parks
- Road improvements and Avenue Trees

Arrest Water Pollution and improve Ground water table

- Continued focus on RWH and thrust on Re-use
- Stringent enforcement of Industrial Pollution prevention measures
- Complete Underground drainage projects and implement septage management policy of Government of Tamil Nadu

Increase share of Clean Energy

- Continued thrust on Solar and Wind generation

Improve Air Quality

- Ambient Air Quality monitoring
- Initiate traffic improvement measures
- Awareness programs to reduce idling in traffic

Implement Recommendations and Actions identified under Solar City Plan

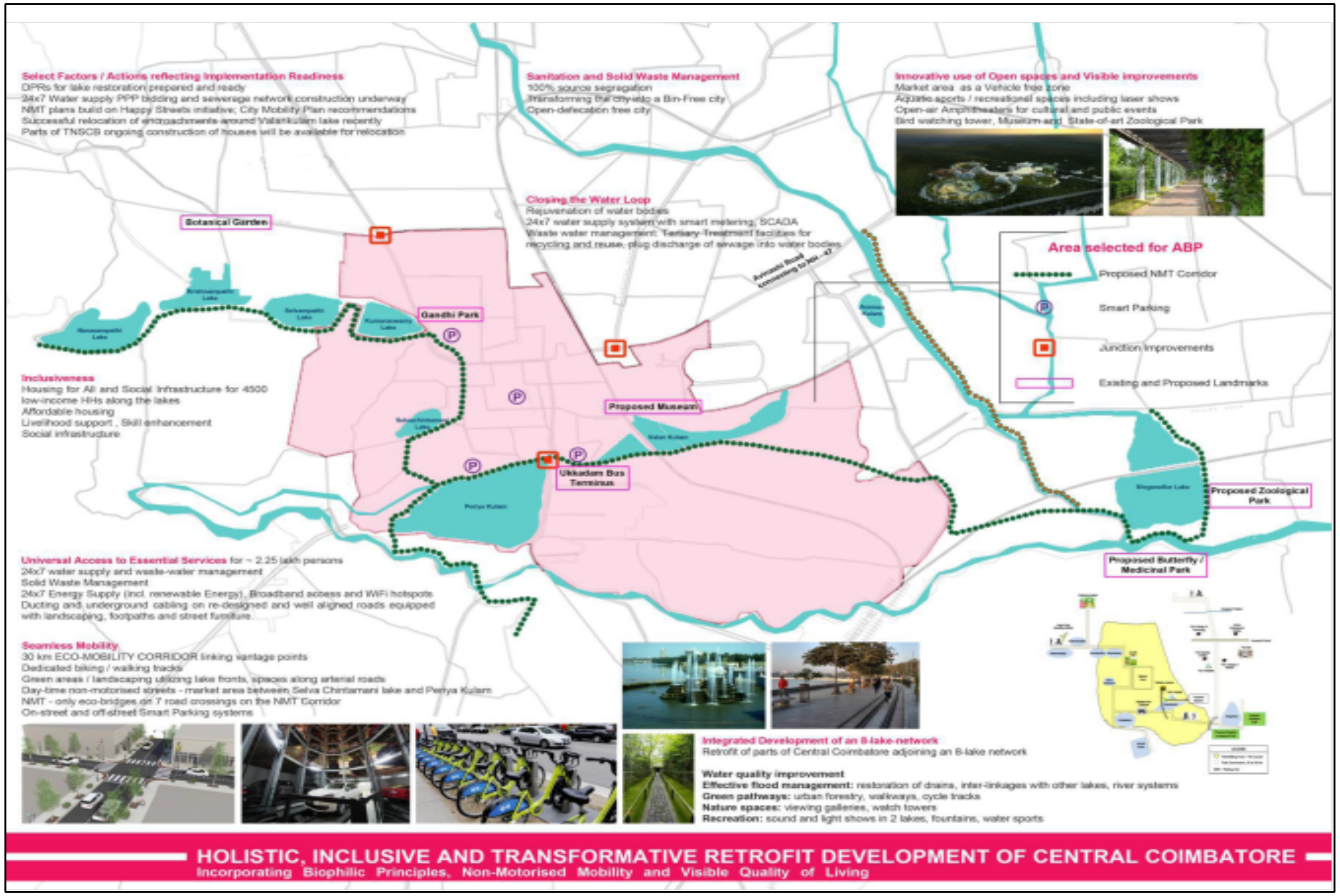
Identify and implement Actions to deal with Climate Change and build resilience

Source: (Smart Cities Challenge - City wide Concept Plan for Coimbatore, 2015)

Under its **Pan-city proposal**, outlining implementation of smart solutions across the city, the Coimbatore plans to refurbish its street lighting with energy efficient light emitting diode (LED) street lights and equip these with surveillance cameras and Wi-fi facilities connectivity to help in smart traffic management, provide seamless connectivity, prevent crime/accidents, enable expeditious emergency and disaster response. Installation of air quality monitoring systems is planned across the city.

As part of the **Area Based Development proposal**, Coimbatore will be going for a hybrid retrofit and redevelopment model targeting an area spanning about 4,200 acres in central Coimbatore. This includes development of an eight-lake network to restore it to health, reinforce its flood management capacity and create life-spaces, with lake-front low-income housing and social infrastructure. There are also plans to create a 30-km non-motorised corridor with dedicated biking/walking tracks. 24x7 power supply, integrating renewable energy, will be provided to a resident population of about 0.2 million in this area.

Figure 12: Proposed Area Based Development in Coimbatore



The Coimbatore Smart City Limited, a special purpose vehicle (SPV) created for the implementation of the Smart Cities Mission, has been setup in mid-2016 (Smart Cities Mission, 2016). The Coimbatore Smart City Limited is headed by the serving Municipal Commissioner of the CCMC and will plan, apprise, approve, release funds, implement, operate and evaluate the smart city development projects.

The total cost of Coimbatore's Smart City proposal is INR 15,700 million (USD 235 million), of which INR 14,270 million (USD 213 million) pertains to Area Based Development and INR 1,430 million (USD 21 million) is for the Pan-city proposal (Smart Cities Mission, 2016). Coimbatore has allocated a budget of INR 456 million (USD 6.8 million) for setting up rooftop solar power plants in the Area Based Development. Implementation of the energy efficient LED street lighting project across the city is pegged at INR 590 million (USD 8.8 million). Implementation of the proposed projects has commenced and the projects at different stages of implementation. The Coimbatore Smart City Limited has proposed to set up a 2 MW solar power plant at its old dump yard in Kavundampalayam and has recently requested for proposals for preparation of a detailed project report for the same.

Box 1: Smart city recommendations

The Area Based Development site in Coimbatore offers potential opportunities to test the integration and promotion of district cooling. However, as of now limited information is available with regards to the detailed plans for redevelopment of this area, which presents challenges towards undertaking detailed analysis of this site, including costs and impacts of district cooling against the business-as-usual case. It would be pertinent to undertake further investigations on the suitability of district cooling for this particular area when the requisite information becomes available in the future.

If possible, district cooling concepts could be incorporated into the design stage of the Area. The Smart City SPV could be supported to undertake such an analysis. If district cooling is feasible, the SPV could coordinate development of district cooling within the smart city area and promote its replication across each city. Furthermore, the SPV and/or the city could be a direct investor into the district cooling project, or provide finance and support for related projects such as key municipal buildings converting to centralised HVAC or demonstration projects with a particular social or environmental value that are deemed 'smart' (e.g. use of wastewater recycling, solar cooling, waste-to-energy connection etc.)

The significant transport links planned in greenfield sites need to be coordinated with district cooling rollout and the creation of new underground piping for sewage and for metro lines creates opportunities to lay district cooling systems at the same time if the requisite cooling demand is available or coming up. District cooling should be analysed before other utilities are laid. Furthermore, the

transport areas will lead to densification and are likely to be high potential areas for district cooling development as well (high priority zones).

5.2 Coimbatore's Solar City Master Plan

Coimbatore city has been selected under the Solar Cities Programme and has prepared its Solar Master Plan which targets a total energy reduction of 10% in its energy consumption over a 5 year period from 2011-2016, translating to cumulative energy savings of 589.5 million kWh. The Solar Master Plan proposes achieve the target through a combination of renewable energy and energy efficiency measures. Targets are set depending upon the potential, resources, funds and applicability of renewable energy and energy efficiency measures across the residential, commercial and institutional, industrial and municipal sectors. Different alternate energy options like solar water heaters, solar photovoltaic, and bio gas have been proposed for residential, commercial and institutional, industrial and municipal buildings. Similarly, energy efficiency measures like the use of energy efficient lighting, energy efficient appliances (including air conditioners) and energy savers have also been recommended for implementation in these sectors.

For targets relating to the renewable energy measures, the industrial sector has the highest share at 56 %, followed by the residential sector and the Commercial and institutional sector (see Table 2).The residential sector accounts for 60% of the energy efficiency related target. Contribution of the industrial sector and the commercial and institutional sectors is significant, accounting for the 22% and 11% of the energy efficiency target. While the targets for the municipal sector which includes operations of the CCMC are comparatively lower as compared to the other sectors, the local government can play a key role in identifying opportunities and implementing projects in its public buildings and operations to demonstrate leadership and create awareness.

Table 2: Sector-wise Targets for Renewable Energy and Energy Efficiency for Coimbatore

Sector	Energy Saving Target (Million kWh)	% contribution to the Target
Renewable Energy	**336**	**57%**
Residential	92.7	27.6%
Commercial and Institutional	44.1	13.1%
Industrial	189.4	56.4%
Municipal	9.53	2.8%
Energy Efficiency	**254**	**43%**
Residential	153.4	60.4%
Commercial and Institutional	28.2	11.1%
Industrial	56.4	22.2%

Sector	Energy Saving Target (Million kWh)	% contribution to the Target
Municipal	15.7	6.2%
Total	**589.5**	**100%**

Source: (Coimbatore Solar City - Final Master Plan, 2012)

The target to achieve 10% reduction in conventional energy consumption under the cities is not an obligatory target. It is seen that the implementation of the Solar Master plans in nearly all the Solar Cities in India has been slower than anticipated in terms of physical progress and meeting the large scale sector-wise targets owing to a number of barriers[7]. The Solar City Programme, however, has provided a platform to motivate and enable cities to assess current and future energy demand and undertake strategic planning for promoting and implementing interventions to reduce energy demand. The programme has definitely helped to create an eco-system for adoption of renewable energy and energy efficient technology by consumers

While Coimbatore has not been able to bring about transformational change in the energy supply and demand across sectors, the CCMC has assumed a leading role and implemented a number of renewable energy and energy efficiency projects in its buildings and facilities, particularly in the recent past. About 279 kWp of solar PV has been installed by the CCMC across its offices, schools, bus stations, maternity centres and canteens. In due recognition of its commitment to promote renewable energy and energy efficiency, in the year 2015 Coimbatore was selected as one of 13 cities to be developed as 'Pilot Solar Cites'. Each of the 'Pilot Solar Cities' will receive financial support of up to INR 25 million (USD 0.37 million) for installation of renewable energy projects. As part of this programme, CCMC is currently undertaking installation of 350 kWp of solar PV plants at its sewage treatment plants and water pumping stations (see section 6.5 for more details).

Box 2: Solar City Program Analysis

The Solar City Master Plan's combined approach of improving energy efficiency and increasing renewables is a fundamental tenet of district cooling systems (and modern district energy systems more generally) and the main reason cities around the world are turning to this technology. Given this shared approach, the Master Plan could provide a strong policy framework to take action on district cooling and could include district cooling justifying its inclusion as a technology that aligns well with the Solar City Program's objectives.

Modern district cooling systems maximize the use of renewables or waste heat, including renewables connected to the electricity grid such as solar PV, as well as through direct connection to a district cooling system such as industrial waste heat

[7] Multiple barriers applicable across multiple levels of governance in India have contributed to the slower than anticipated implementation and progress of the Solar City Master Plans in most of the Solar Cities. These include the higher capital cost of renewable and energy efficient systems, delayed disbursement of funds, ineffective project planning and monitoring, ineffective procurement planning, inadequate institutional capacity and coordination, and low awareness with regards to energy efficiency and renewable energy.

or a waste-to-energy plant (connected to absorption chillers), while also reducing primary energy consumption for cooling by up to 30-50%. Many cities set district energy-specific goals in their strategies that are linked to broader energy targets, such as on energy efficiency, greenhouse gas emissions, fossil fuel consumption, or energy intensity. An update of the Solar City Master Plan could indicate district cooling goals such as: the share of total GHG reduction target to be met by district cooling, percentage increase in energy performance of buildings due to district energy, the share of renewables or waste heat to be used in a district energy system, or the share of cooling capacity provided by district energy.

Modern district cooling systems maximize the use of renewables or waste heat, including renewables connected to the electricity grid such as solar PV, as well as through direct connection to a district cooling system such as industrial waste heat or a waste-to-energy plant (connected to absorption chillers), while also reducing primary energy consumption for cooling by up to 30-50%. Many cities set district energy-specific goals in their strategies that are linked to broader energy targets, such as on energy efficiency, greenhouse gas emissions, fossil fuel consumption, or energy intensity. An update of the Solar City Master Plan could indicate district cooling goals such as: the share of total GHG reduction target to be met by district cooling, percentage increase in energy performance of buildings due to district energy, the share of renewables or waste heat to be used in a district energy system, or the share of cooling capacity provided by district energy.

The first step to set such goals and/or justify the inclusion of district cooling in the Solar City Master Plan, is to calculate the beneficial impact of district cooling on energy consumption and identify the benefits and linkages to Coimbatore’s policy goals (e.g. Pan-City goals from the Smart City Mission such as availability of plug and use infrastructure – including for IT/ITeS which is a key economic sector, increased adoption of renewable energy, promoting environmental sustainability, implementing actions to tackle climate change and build resilience,; meeting 10% energy consumption reduction target).

Analysis of the current energy consumption of space cooling and its potential growth will be extremely important, including its impacts environmentally and economically. The analysis should also examine the impacts and benefits of district cooling in Coimbatore relative to this baseline and link this to achieving city objectives. This will help justify incorporating district cooling under the implementation of the Master Plan and under other city initiatives going forward.

Building upon the rapid analysis of cooling loads based on available information presented in Section Error! Reference source not found. will be important, including linking the analysis to politically important topics such as PV installations, clean water in Coimbatore’s lakes and smart infrastructure. For example, whether the benefits of new clean energy installations in Coimbatore are being offset by installation of low efficiency space cooling elsewhere in the city.

5.3 Coimbatore's Voluntary Initiatives

Coimbatore has been actively involved in strategic initiatives on low emission development, climate resilience building and sustainable energy in the past decade. These include international initiatives such as the Urban Climate project[8], the Local Renewables Model Communities Network project[9] and the recently concluded Urban-LEDS programme[10].

The Urban Climate project provided technical and financial support to the CCMC for implementing four pilot interventions viz, energy efficiency implementation in CCMC's JnNURM Cell, energy audits and energy efficiency implementation for bore wells, wind-solar hybrid and energy efficient lighting at Coimbatore's new Bus Terminal. These projects resulted in annual energy savings of about 166,000 kWh and GHG emission reduction of 5,900 tCO_2e.eve

Coimbatore is one of four Indian cities currently participating in the CapaCITIES project (under SDC's Global Programme on Climate Change), which is to be implemented from 2016-2019. The project will assist Coimbatore to plan and implement measures to address both climate mitigation and adaptation in an integrated manner. Under the project, Coimbatore will be identifying and implementing two quick-win pilot projects in its key sectors. Under the CapaCITIES programme, Coimbatore has voluntarily prepared its baseline GHG emission inventory for the year 2015-16. The transportation sector has the largest contribution to GHG emissions (43%), followed by the industrial sector (31%). Residential, commercial and institutional buildings (along with public infrastructure facilities) account for a fourth of Coimbatore's emissions. The emission inventory does not include refrigerant emissions.

Coimbatore has leveraged opportunities that such international initiatives offer in terms of knowledge exchange, networking, and peer learning to draw on from experiences of its peers and imbibe knowledge to further its own local energy agenda. As indicated previously, CCMC has installed solar plants on its buildings and facilities. The city has undertaken pilot scale retrofitting of its conventional streetlights with

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[8] The Urban Climate Project, funded by the United States Department of State (USDoS) under their Asia Pacific Partnership (APP) Programme, was implemented during 2008-11.

[9] The Local Renewables Model Communities Network project has been implemented in Coimbatore city with funding through the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. This international project, implemented from 2005-2010, provided support to strengthen participating local government in promoting sustainable energy and to become model city in their national and regional contexts.

[10] The objective of the Urban-LEDS project, an international programme funded by the European Commission and implemented in select cities from emerging economy countries of Brazil, India, Indonesia and South Africa, was to enhance the transition to low emission urban development by integrating low-carbon strategies into the local development planning process. In India, two Model Cities – Thane and Rajkot engaged in this programme along with six Satellite Cities, which included Coimbatore. The programme was implemented from 2012-2016.

energy efficient LED street lights in phased manner. The city is utilizing funding available under the Solar Cities Programme for the establishment of a 'Solar City Cell' - an administrative body which can assist the city in planning and implementation of energy projects and actively pursue community awareness programmes.

Box 3: City leadership

Coimbatore is showing leadership on a range of sustainability issues, particularly promoting clean energy technologies and climate change action. Coimbatore could similarly provide leadership to the district cooling sector, helping to pilot and promote this technology. Coimbatore's promotion and involvement in an early demonstration project will be particularly important. Coimbatore could finance and/or attract concessional finance to a demonstration project which could be financed using a commercial structure. This demonstration project could: showcase the business model and demonstrate commercial viability; build capacity; increase stakeholders' trust and confidence in the technology (e.g. Vancouver) and provide concrete data and experience and ultimately legitimize a city-wide energy plan focused on scaling up district energy.

If the demonstration project were to be partially owned by Coimbatore then it could later be privatized once commercial viability is proven, creating a profit for Coimbatore. In this way, the city can assume a strong public-sector role in preparing the district energy market for eventual private sector takeover so that city capital can be used in other projects. In addition, Coimbatore could use its own buildings to promote district cooling and lower risks or use tracts of public land under a concession contract, to create a public-private partnership (PPP).

Coimbatore could also take leadership by setting a target that requires all public buildings to be connected to district cooling in high priority zones (see zoning in Box 4). Alongside this, new or redeveloping public buildings could be mandated to have centralized cooling to ensure long-term district cooling connection.

In the medium-term, Coimbatore could establish a 'sustainable energy delivery unit' that would be responsible for advocating and promoting district cooling to companies and building developers keen to establish premises in Coimbatore. This could be allied with setting up of the 'Solar City Cell' in the city and could also be undertaken by the SPV established to deliver the Smart City Plan to build upon existing efforts and resources being utilized in this regard. The unit would present the potential cost savings, environmental benefits and any local incentives available; and provide locally-relevant information to potential district cooling customers or developers to encourage connection and development of networks. This could include making available best practice assessment methodologies, tools to rapidly analyse cooling costs, sample contracts, previous feasibility studies and demonstration project results – including CCMC's experiences and

savings from connecting to district cooling[11]. Also important are formal and informal networks and contacts between, for example, municipal employees or officials and state utilities, building developers and housing associations.

Coimbatore could promote and accelerate the district cooling sector by establishing and leading a multi-stakeholder coordination group of city departments, developers, utilities and building associations - building upon its already existing efforts towards stakeholder coordination on climate change - to ensure coordinated development of district cooling across the city. Such coordination could include smooth planning processes for district cooling projects and coordinated timing of the laying of utilities and roadworks in order to save costs and minimize disruption. This group could also be consulted on new policies, plans and financing instruments designed to support district cooling. This is a key best practice from cities worldwide. This group could also be led by the SPV established to deliver the Smart City Plan and incorporated with the 'sustainable energy delivery unit'.

Coimbatore can promote district cooling development and ensure strong analysis of district cooling opportunities by undertaking and maintaining a GIS energy mapping[12] of the city incorporating spatial analysis of cooling demand, upcoming building developments (for example those indicated in Sections Error! Reference source not found. **and 1.8.1) and assessments of renewable and waste heat options (see Section 10.2). This could also be used as a public awareness tool to help the city explain planned actions on district cooling and can help identify potential district cooling projects, renewable interconnection, opportunity zones for district cooling and as such can be used to develop long-term city plans on district cooling. Finally, such a tool could also be used to help Coimbatore undertake other spatial analysis related to the energy sector, such as delivering smart grid, resource mapping and targeted building efficiency programmes. Box 10 describes further how such a mapping could be developed.**

[11] The District Energy in Cities Initiative will support a pilot city and with the pilot city ground-test methodologies, tools, procurement processes etc. adapted to the Indian context and later promote these to other cities.
[12] The District Energy in Cities Initiative will support one pilot city to establish a GIS based energy map which will be maintained, owned and updated periodically by the pilot city. The software will be open source and the methodologies and training associated made available to all cities.

6 Local Policies and Legal Framework

6.1 Planning Authority and Framework

The key institutions involved in development planning and building approvals in Coimbatore are:

- Department of Town and Country Planning (DTCP): responsible for overseeing and handling preparation of Master Plans, issuance of planning permissions and consent to build in non-plan areas
- Coimbatore Local Planning Authority: primarily responsible for assisting in preparation of Master Plan for local planning area, enforcement of provisions related to planning and issuance of planning permissions within the Coimbatore urban agglomeration (i.e. Coimbatore Local Planning area)
- CCMC: primarily responsible for implementation of the Master Plan, issuance of licenses for buildings, and issuance of planning permissions for buildings up to a certain size within the city limits. The Town Planning department in the CCMC largely handles these responsibilities.

The city is undertaking two types of planning, macro level planning and micro level planning. At macro level, the urban planning is conducted in the form of city development plan or a Master plan for the entire city area or the development area. The second level is micro level urban planning, in the form of detailed development plans, which are prepared for smaller areas of the city, keeping in view the needs of such smaller areas. Broader level planning proposals are included in Master Plan prepared for the Urban Area. Master plan shows the broad areas under different land use zones, land reservations for roads and other different purposes. The Master Plan is to be revised every 20 years or maybe revised whenever a need arises to respond to the changing context. Land use zoning, development density, building heights, and other development and building related guidelines in Coimbatore city and its Local Planning area are regulated by the General Development Control Regulation (GDCR) issued by the DTCP in 2010.

In the year 2010-11, Coimbatore city's administrative boundaries were expanded to include the surrounding areas[13] and the area of the city more than doubled, from 105 sq. km to 257 sq. km. Documented information on Coimbatore's land use status is not available after 2002. Preparation of the revised Master plan for the city, providing an updated status of the existing and proposed land use pattern for the long term, is currently underway.

Residential land occupies the major share of Coimbatore city's land area; both for the year 2002 and in the proposed land use for the year 2021 (see Table 3). The proportion of land under agricultural use is significant as well. With Coimbatore being a major educational hub, the land under educational use has the second largest share in the developable land area in the city. Commercial and industrial land use constitute relatively lower share of the land use.

[13] The surrounding areas added to the jursidction of the CCMC include Kavundampalayam, Kurichi, Kuniamuthur, Kalapatti, Saravanampatty, Thudiyalur, Vadavalli, Veerakeralam, Chinnavedampatti, Vellakinar, Chinniyampalayam and Vilankurichi.

In the larger urban agglomeration or metropolitan region (i.e. the Coimbatore Local Planning area), comprising of areas other than Coimbatore city, majority of the land is predominantly agricultural (see Table 4). Residential land use makes up the major share of the developable land area, followed by industrial and educational development.

For Coimbatore city, a significant share of the agricultural land (available under the erstwhile city area in 2002) is proposed to be utilized towards residential, commercial and institutional development. The recently added areas around the periphery of Coimbatore have been growing rapidly, with the population in these areas rising by 74% in the decade between 2001-2011 as compared to a population rise of 15% in the erstwhile city areas. Development is expected to be concentrated in and around the periphery of the city, with the proposed growth in residential, commercial, industrial and other developments notably higher in the larger Coimbatore urban agglomeration as compared to the Coimbatore city area (see Table 3 and Table 4). The area under residential use will more than double for the Coimbatore Local Planning area by 2021 as compared to 2002 along with multi-fold growth in the area under commercial and industrial use, with most of the agricultural land being diverted to these land uses.

Table 3: Existing and Proposed Land Use for Coimbatore City

Land Use Category	2002			2021		
	Area (sq. km)	Share of developed area (%)	Share of Total area (%)	Area (sq. km)	Share of developed area (%)	Share of Total area (%)
Residential	63.18	78.8	59.8	66.17	73.3	62.3
Commercial	2.79	3.5	2.6	4.33	4.8	4.1
Industrial	4.91	6.1	4.6	7.21	8.0	6.8
Education	6.61	8.2	6.3	8.05	9.0	7.6
Public and Semi- public[14]	2.71	3.4	2.6	4.52	5.0	4.3
Agriculture	25.37	--	24.0	15.29	--	14.5

Source: (Coimbatore Master Plan, 2011)

Note: *The land use information has been documented and proposed before the expansion of Coimbatore city took place and hence covers the erstwhile city area. Land use information has not been documented for the expanded city area as yet.*

Table 4: Existing and Proposed Land Use for Coimbatore Local Planning Area

	2002	2021

[14] Includes government and quasi government offices, hospitals, sanitary and other medical/public health institutions, airports, parks, exhibition grounds, and other public and semi-public open spaces.

Land Use Category	Area (sq. km)	Share of developed area (%)	Share of Total area (%)	Area (sq. km)	Share of developed area (%)	Share of Total area (%)
Residential	155.21	75.0	13.2	362.89	71.6	31.0
Commercial	1.99	1.0	0.2	8.66	1.7	0.7
Industrial	23.28	11.2	2.0	92.15	18.2	7.9
Education	15.33	7.4	1.3	18.86	3.7	1.6
Public & Semi-public	12.21	5.4	1.0	24.32	4.8	2.1
Agriculture	963.37	--	82.3	663.51	--	56.7

Source: (Coimbatore Master Plan, 2011)

Box 4: Integrating energy into planning and land-use policies

CCMC uses zoning to influence development in the city by defining different land uses in different zones. Through zoning, CCMC can promote district cooling by ensuring new large developments are mixed-use. This delivers a diversity of building types in a new area which improves significantly the commercial viability of district cooling and lowers the environmental impact of the new development.

CCMC could also ensure that public buildings are established in new areas, such as hospitals, large administrative buildings, and complexes to host business conference or trade fairs, that can 'anchor' new district cooling development by connecting a significant cooling demand and lowering risk through the participation of the public sector. Furthermore, CCMC could make space available where energy centres could be placed in public buildings or otherwise.

CCMC can use its zoning authority to create 'high priority' and 'medium priority' zones for district cooling, based on data from GIS energy mapping (recommended in Box 3 and described further in Box 10) recommendations from urban planners and using benchmarks for district cooling viability (e.g. cooling demand density). The city could then attach specific conditions to building permits within these zones. CCMC could require large new developments entering the planning process, in a designated 'priority zone for district cooling' to have to submit an 'energy efficiency plan' in order to obtain a building permit. This plan would outline the building development's targets for building efficiency, assessments of waste and renewable energy, and assessments on the technical and economic feasibility of connecting to existing district cooling or developing new systems. If district cooling is feasible, developers could be asked to justify if they do not proceed with this technology choice. If the barrier is financial, CCMC could help attract finance by providing incentives or reducing risk for the project. Ultimately, planning permission could be withheld if justifications for not developing district cooling are unsatisfactory.

To begin with, simple metrics could be developed to determine whether a specific development should consider district cooling, such as a minimum cooling demand of 2000 RT planned, or a minimum floor space area. Developments in medium priority zones could then have requirements such as ensuring buildings are 'district cooling ready' for future connection (see Box 6), in exchange for density bonuses etc. (see Box 5). Given the lack of experience on district cooling, buildings that are required to assess district cooling could be provided with support from CCMC and international experts. In particular, ensuring high-quality of assessments given the lack of district cooling experience in India will be important[15].

Similarly, requests for re-zoning by building developers above a certain size could provide an opportunity for Coimbatore to accelerate district cooling. CCMC could permit re-zoning under the condition that the developer meets stricter operational/primary efficiency building standards[16] and/or evaluates the potential for district cooling and if techno-economically feasible, then establishes district cooling systems.

CCMC can use the planning process to put in place specific connection policies (of different buildings types) in the high priority areas. Furthermore, CCMC can designate these areas as exclusive franchise zones, wherein potential developers of district cooling will have exclusive access to consumers if they are granted the franchise/license to operate in that particular zone. This will have to be developed together with a licensing scheme that protects consumers from monopoly pricing. This can be done by ensuring that the license is only granted for exclusive access, if they can show that they will deliver the service at equal to or less than the next available cooling alternative. Furthermore, CCMC could use its regulatory authority to enforce that after the investor /operator has gained its return on investment at a certain percentage, it has to then share the profits with consumers ensuring that they too benefit from the efficiency gains of DC. Such a licensing scheme is more likely to be established in the longer-term once district cooling has been demonstrated.

In Coimbatore, urban redevelopment is planned in existing urban areas, such as the highly dense central area spanning 4,200 acres (see Section 1.3.1), with huge levels of redevelopment and retrofitting and application of sustainable practices in buildings. Such urban redevelopment projects often have significant influence from local authorities and can have district cooling concepts incorporated from the start of development, for example setting aside land specifically for use by a district cooling plant, developing buildings with centralized cooling and in a phased approach that could match district cooling construction. In addition, CCMC could use existing public services within such areas, such as hospitals and schools, to 'anchor' the new district cooling system which would then connect new buildings as they materialize. Renovation of single public or large

[15] The District Energy in Cities Initiative will be undertaking pre-feasibility studies in India which will help to set the benchmark for a high-quality assessment. Although benchmarks for district cooling feasibility, such as minimum project size, density of buildings etc. are useful in selecting projects, bespoke studies are needed to really understand feasibility that take into account building layout, construction timeline, building cooling demand and expected occupation, local renewables etc.

[16] Primary energy efficiency building standards look at the system level use of energy rather than at, for example, the efficiency of electricity use. The primary energy efficiency of electricity may only be 20-40% due to efficiency limits on power plants and transmission and distributions losses, this should be accounted for when considering efficiency measures.

commercial buildings also provide an opportunity for CCMC to step-in and work with developers to ensure district cooling is appropriately assessed – this could be the case for the multitude of large stand-alone buildings along Avinashi Road or the Saravanampatti area.

Parcels of undeveloped land adjacent to existing developments in these areas could be set aside for district cooling plants or have adapted planning requirements placed upon them to ensure district cooling connection. This is assessed further in Section Error! Reference source not found..

Finally, as a provider of utility services such as water and sanitation, CCMC has the authority over the installation of new utility lines such as district cooling pipes. During consultations, CCMC has indicated that it can fast-track permissions needed for installation of piping and roadworks and can coordinate to ensure other utilities are installed in parallel.

CCMC uses zoning to influence development in the city by defining different land uses in different zones. Through zoning, CCMC can promote district cooling by ensuring new large developments are mixed-use. This delivers a diversity of building types in a new area which improves significantly the commercial viability of district cooling and lowers the environmental impact of the new development. CCMC could also ensure that land is set-aside for public buildings in new areas, such as hospitals and schools, that can 'anchor' new district cooling development by connecting a significant cooling demand and lowering risk through the participation of the public sector.

Requests for re-zoning by building developers could provide an opportunity for Coimbatore to accelerate district cooling by allowing re-zoning under the condition that the developer establishes district cooling systems or that stricter efficiency standards for buildings are met.

For large new developments entering the planning process, perhaps in a designated 'priority zone for district cooling', CCMC could require developers to ensure that they assess the technical and economic feasibility of district cooling in their planned sites. If district cooling is feasible, developers could be asked to justify if they do not proceed with this technology choice. If the barrier is financial, CCMC could help attract finance by providing incentives or reducing risk for the project. Ultimately planning permission could be withheld if justifications for not developing district cooling are unsatisfactory. To begin with, simple metrics could be developed to determine whether a specific development should consider district cooling, such as a minimum cooling demand of 2000 TR planned, or a minimum floor space area.

Urban redevelopment projects often have significant influence from local authorities and can have district cooling concepts incorporated from the start of development, for example setting aside land specifically for use by a district cooling plant, developing buildings with centralized cooling and in a phased approach that could match district cooling construction. In addition, CCMC could use existing public services within such areas, such as hospitals and schools, to 'anchor' the new district cooling system which

would then connect new buildings as they materialize. Renovation of single public or large commercial buildings also provide an opportunity for CCMC to step-in and work with developers to ensure district cooling is appropriately.

Finally, as a provider of utility services such as water and sanitation, CCMC has the authority over the installation of new utility lines such as district cooling pipes. During consultations, CCMC has indicated that it can fast-track permissions needed for installation of piping and roadworks and can coordinate to ensure other utilities are installed in parallel. In addition, CCMC may enter into a PPP to deliver a waste-to-energy (WTE) plant in Coimbatore. CCMC could use its planning authority to ensure the WTE is constructed so that waste heat capture is achievable. CCMC could also promote building development relatively near the vicinity of the WTE that could use the waste heat for a district cooling system.

6.2 Building Regulations and Certifications

The GDCR, 2010 regulates and lays out guidelines for land use zoning, density, floor space index (FSI), building heights and other development and building related guidelines in Coimbatore city and its Local Planning area as indicated previously in section 6.1. Three institutions handle issuance of planning permissions for buildings in Coimbatore – the CCMC, the Coimbatore Local Planning Authority and the DTCP - based on the size of the building (see Table 5).

Table 5: Building types and size granted planning permission by the Municipal Corporation

Use	Floor Area	Authority issuing planning permission
Residential	4,000 sq. ft.	CCMC
	>4,000-15,000 sq. ft.	Coimbatore Local Planning Authority
	>15,000 sq. ft.	DTCP
Commercial	2,000 sq. ft.	CCMC
	>2,000-12,000 sq. ft.	Coimbatore Local Planning Authority
	>12,000 sq. ft.	DTCP
Institution	25,000 sq. ft.	DTCP
Schools	Any Area	DTCP

Source: (Town Planning Department, CCMC, 2016)

The permissible floor space index (FSI) for different building types in Coimbatore is given in Table 16 in Annexure 2.3. FSI of 1.5 is permissible for residential, commercial and institutional development in Coimbatore. The FSI for multi-storeyed buildings (exceeding 4 storeys and with a height of 15 m or more) can go up to 2.5, depending upon the size of the plot and location of the site. An additional FSI of 0.25 is available for Hospital buildings. To further promote the IT sector in Coimbatore, additional FSI is offered for IT related development.

Box 5: Incentivizing district cooling through density bonuses

Coimbatore could establish premium FSI payments or TDR to promote connection or development of district cooling. Buildings under development that commit to connect to district cooling or develop a district cooling network could be granted additional FSI or have FSI payments reduced as an incentive. Coupled with this the city could highlight the floor space saved from connecting to district cooling. For many building developers, the prospect of additional rentable floor space would be a significant incentive and could help to establish initial networks and secure customers to a district cooling network. To ensure the long-term sustainability of such an incentive scheme, requirements to be given an FSI bonus could become increasingly difficult, could be linked more generally to building efficiency (for example through building certification schemes such as GRIHA or LEED). Several cities around the world are actively promoting district energy using this urban planning tool. Other cities in India, such as Pune, already provide FSI bonuses linked to sustainability criteria. Furthermore, the Bank of Maharashtra, a leading nationalized bank in India, has announced a rebate of 0.25 percent in the interest rate on housing loans for projects that are Eco-housing certified in Pune – CCMC can hold dialogues with banks to develop a similar incentive in Coimbatore.

Solar Water Heating

In order to promote adoption of solar water heating systems (SWHS), the state and local building and development regulations have been amended to include mandates for installation of SWHS in all new buildings[17]. This mandate has been linked to approvals sought for new buildings, with provisions for SWHS required to be shown as part of any plans submitted for building planning permission. The city intends to harness solar energy and to promote rooftop solar power generation in government, institutional and residential buildings. Formulating mandates for the same by amending the building bye-laws is a key strategy outlined in the Smart City Plan for Coimbatore.

Box 6: District cooling ready buildings[18]

Coimbatore could adapt the GDCR to ensure buildings are developed that in the long-term are district cooling ready, specifically requiring centralized cooling for specific building types, or for those over a certain size, or in a specific zone (e.g. high/medium priority

[17] The building categories with mandatory SWHS installation include a) nursing homes and hospitals exceeding 500 sq. m. in floor area; b) Hotels and lodges exceeding 500 sq. m. in floor area; c) Hostels exceeding 50 rooms; d) Community centres, banquet halls, marriage halls exceeding 500 sq. m. in floor area and; e) Individual residential building having more than 150 sq. m. plinth area.

[18] District cooling ready buildings: i.e. use centralised cooling systems with chilled water produced on the ground floor and space in any multi-utility tunnels leading into the building for district cooling pipes

zone). Such a mandate could be developed in a similar way to the Solar Water Heating mandate. A mandate requiring centralized cooling in hospitals above a specific FSI has already been developed in Rajkot, and experiences from Rajkot could be gained by Coimbatore and applied to multiple building types. In this way, even if buildings operate their own chillers, eventually they could be connected into a district cooling system. In some cities, buildings that already have their own chillers can still be connected into the district cooling network – the network operator can use their chiller to feed the building and the wider district cooling network – a more efficient and cost-effective use of the chiller. Building developers could also be given flexibility under the GDCR if they develop district cooling.

Coimbatore already uses zoning to apply specific planning conditions, primarily conditions surrounding land-use (see Section Error! Reference source not found.**). Mandates for connection to, or development of, district cooling systems in high priority zones, as discussed in Section** Error! Reference source not found.**, could be exercised through adaptation of the GDCR. Such a policy would need to be accompanied by a support programme to the city and developers to ensure district cooling assessments and tendering do not slow down the development of real estate.**

Green Building Policy

Coimbatore does not currently have other green building polices in the city that promotes energy efficiency, renewable energy or sustainability more generally as other cities do such as Pune. Adoption of the Energy Conservation Building Code (ECBC) and its mandates on buildings will be a major step towards having such a policy.

6.3 Legislation relating to Space Cooling

Coimbatore's existing local development and building regulations merely address the structural aspects and placement of air conditioning installations. Provisions for improved building energy efficiency and mandates or standards for efficient space cooling are lacking. Reuse of wastewater in central air conditioning plants is promoted in the GDCR, 2010 as per the clause mentioned below:

'All centrally air-conditioned buildings shall have their own waste water reclamation plant and use reclaimed wastewater for cooling purposes.'

The state of Tamil Nadu has amended the Energy Conservation Building Code (ECBC) to suit its local and regional climatic conditions in 2012. The process of issuing a notification mandating compliance with the ECBC for large commercial buildings is underway in the state. Thus, while Coimbatore city has undertaken efforts towards assessing its capacity needs to adopt and enforce the ECBC[19], this building efficiency standard is presently not being enforced by the city.

Box 7: Ensuring the ECBC promotes district cooling growth

Adopting the ECBC will be a major step for delivering sustainable buildings in Coimbatore. Its adoption will involve incorporating the ECBC into the DCR for Coimbatore, establishing guidelines for how ECBC will be enforced in the city and building capacity in the city to enforce the new requirements. This will involve trainings to building assessors and developers as well as pilot buildings demonstrating the new guidelines. These trainings could also serve to build capacity and awareness on district cooling, which can also be presented as an energy efficiency measure to the building industry.

The adoption of new guidelines provides an opportunity for Coimbatore to ensure that efficiency improvements to buildings that connect to district cooling are acknowledged in its local building regulations. Coimbatore can adapt ECBC requirements to ensure DC connected buildings meet ECBC requirements when the DCR is updated for ECBC standards. This would also serve as a demonstration to other cities in India on how to adapt ECBC to appropriately reflect the benefits of district cooling.

In the event that adapting the ECBC code for district cooling is too ambitious at such an early stage in the market, Coimbatore could ensure that any benefits and incentives linked to the ECBC are also made available to a district cooling demonstration project. Such incentives and benefits have not yet been defined, but some other states in India that have notified ECBC have developed rating systems and incentive schemes based on compliance with the standards within ECBC (e.g. the State of Andhra Pradesh (Pacific Northwest National Laboratory, 2016).

6.4 Incentives and Subsidies

At present, Coimbatore does not have any kind of incentives to promote either green buildings, renewables or efficient space cooling. The CCMC recognizes the need to address this and is keen to amend its local policy regulation and bye-laws to incentivize adoption of green buildings, solar energy and other sustainable technologies (Times of India, 2017). This is also a key strategy outlined by the city in its Smart City Plan. In this vein, the CCMC has allocated funds of INR 20 million (USD 0.29 million) in its existing budget to convert schools in the city into 'Green schools' on a pilot scale. Under this project, the CCMC will be planning to select five schools from its five administrative zones and convert these into Indian Green Building Council certified Green buildings (Times of India, 2017).

[19] Coimbatore was one of three cities in Tamil Nadu (Chennai and Madurai), involved in a ECBC capacity building and training needs assessment for Tamil Nadu study undertaken in 2012 by ICLEI South Asia in partnership with the Centre for Human Settlements (CHS) and Anna University

Such incentives, when established could be adapted to ensure they treat district cooling connected buildings fairly, particularly if incentives are linked to certification schemes (e.g. GRIHA) or building code compliance levels (e.g. 'ECBC plus' or 'Super ECBC' levels) that do not account for the full benefits of district energy.

From analysis of other cities in India, local and/or state government incentives such as rebates on property tax, provision of low cost solar power to district cooling projects, reductions to VAT/GST for district cooling sales and lower off-peak electricity tariffs to encourage thermal storage could be used to promote district cooling.

6.5 Demonstration Projects

The CCMC has been proactively implemented a number of renewable energy and energy efficiency projects in its buildings and facilities in the past 2 years, with about 600 kW of solar PV installed across its offices, schools, bus stations, maternity centres, canteens and sewage treatment plants and water pumping stations (see Table 6).

Table 6: Details of Solar Photovoltaic Installations in Coimbatore's public buildings and facilities

Location	Installed capacity (kWp)	Energy savings (kWh)	Reduction in power bill (INR)
Amma Canteens	8	25,920	208,656
Administrative Buildings	87.5	382,576	3,079,731
Water Treatment and Sewage Treatment Plants	350	150,675	1,135,445
Urban Health Centers	45	165,690	1,333,805
CCMC Higher Secondary Schools	112.5	513,920	4,137,043
Total	**603**	**1,238,781**	**9,894,680**

Source: (Engineering Section, CCMC, 2016)

The CCMC has installed street lighting controller and power savers equipped with automatic timers and dimmers. Dimming of the streetlights is being done after 11 pm for 140 street lighting service connections which are located on the main streets or the busy streets. The remaining 2,460 street lighting service connections on the other roads in the city are being dimmed at 10 pm. This has resulted in an average energy demand reduction of 2 MW and annual energy savings of about 6 million kWh. About INR 38 million (USD 0.56 million) of monetary savings in the power bills are being realized annually as a result of the dimming of street lights and the power saver. The project has been implemented in the Build Operate Transfer (BOT) model in a shared savings ESCO mode and thus the financial investment and risk was borne by the private contractor. The project period has been fixed as 5 years and the CCMC shares 95 % of the monetary savings with the private ESCO.

Other notable renewable energy and energy efficiency projects implemented by the CCMC include

- Installation of 712 solar street lights at a cost of INR 18.7 million (USD 0.28 million)
- Installation of energy saver in the CCMC's JNNURM building to reduce power consumption by 15%
- Replacement of sewage pumps with energy efficient pumps to achieve energy saving of 165,000 kWh and monetary savings of INR 1.87 million (USD 28,029) annually
- Incorporating energy efficient lighting at the new bus terminal at the Mettupalayam Road to reduce energy demand by 24 kW annually

The CCMC has been monitoring the reduction in energy consumption and monetary savings as a result of these projects. The CCMC is also taking efforts to share the benefits and impacts of these measures with other public institutions as well as with relevant stakeholders in the community to the extent possible. These initiatives have resulted in successful demonstration of technologies and in improved awareness amongst different stakeholders. It is however, difficult to assess the extent of impacts these have had in terms of adoption across the community.

Box 8: Coimbatore as a demonstrator

CCMC's willingness to invest in, and promote, innovative energy efficient and renewable technologies demonstrates a high-degree of interest by the city in supporting new markets and promoting sustainability. Such intervention is not undertaken by all cities. Given how crucial city support and coordination is to deliver successful district cooling projects, investors and project developers will be reassured by the hands-on approach of CCMC and its experience in coordinating relatively large sustainability programmes.

6.6 Project Financing

The CCMC has been accessing funds available from the Central and State government under various progammes and schemes such the Smart Cities Mission, the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Integrated Urban Development Mission, and the Solar Cities Programme and utilizing its own funds as well to implement infrastructure and energy projects. The administrative bodies in Coimbatore understand the complementarity that exists between these programmes and place high emphasis on strategic integrated planning to maximize funding opportunities available to implement projects in key sectors such as energy, water, wastewater, solid waste and transportation.

CCMC has also been effectively partnering with the private sector on a number of projects. Implementing a shared savings ESCO model has helped realize significant energy savings in the city's street lighting without any upfront investment (see section 6.5 for more details). The CCMC intends to install energy efficient LED street lamps and energy saving equipment in 40 wards which have come under its jurisdiction when the city's area was extended from 105.6 sq. km to 275 sq. km in 2011. The project will be undertaken in a Public–Private Partnership mode, with the private agency that will be engaged responsible for undertaking the retrofits and long-term maintenance of the street lights. The project is estimated to cost INR 26 million (USD 0.38 million) and will be financed through a combination of the state government grant, funds available under the Government of India's Integrated Urban Development Mission and the CCMC's own funds. The CCMC will also explore how private investment can be leveraged as successfully done for street lighting energy efficiency previously. Coimbatore has also been utilizing corporate social responsibility (CSR) of local businesses to fund to undertake segregated collection of solid waste in its wards 28, 90 and 91 in the city.

Coimbatore also plans to set up a 2 MW solar power plant at its old solid waste dumpsite at Kavundampalayam under the Smart Cities Mission (see section 5.1 for more details). The CCMC has been willing to invest its own funds, to either complement other funding sources or to unilaterally fund renewable energy and energy efficiency projects. A number of solar PV plants have been installed in the CCMC's buildings and facilities through a combination of its own funds and financial support available under the MNRE's Pilot Solar City programme (see sections 6.5 for more details). The CCMC further plans to install solar panels for energy generation at 17 of its Urban Health Centres, with a budgetary allocation of INR 10 million (USD 0.15 million) made for the same in its budget. Plans are also in place to convert five existing schools into Indian Green Building Council certified green buildings. The city has also successfully partnered with international organizations and donor agencies under voluntary initiatives and continues to do so while accessing technical and financial support (see section 5.3 for more details).

Coimbatore remains committed towards taking action to integrate clean technologies in its infrastructure up gradation and to address energy and climate change locally. The city is willing to work with a variety of partners and explore different engagement models to help maximize impacts of any technical support and investments that are made.

Box 9: Financing district cooling

CCMC has experience of a range of business models and projects that it can build upon when participating in or promoting district cooling business models. However, district cooling involves large, upfront investments, complex financing arrangements with long returns, difficult tendering processes and contractual negotiations. Indian cities will require significant capacity building in order to bring district cooling projects to tender themselves. This is alongside unique risks posed by district cooling systems such as ensuring buildings connect and consume cooling and the management of multiple stakeholders with varying development timelines.

A demonstration project will highlight capacity building and training required for CCMC and other stakeholders including local financiers to be able to deliver and finance a district cooling project. Analysis of how CCMC and other Indian cities have handled similarly large infrastructure projects should be done and lessons learnt for district cooling. National support programmes and entities could be made available and international expert law firms, consultancies, multi-lateral development banks and international district cooling operators should be used to help smooth the financing and handling of district cooling, which will be crucial during the 'demonstration phase' of this technology[20].

7 Applicable Business Models for District Cooling

Worldwide, district cooling projects are developed under a wide variety of business models. These business models are categorized by the organizations owning the district cooling system and operating it. While project proponents may have an early idea of the likely business model that may be used and the financing structure, in reality this is defined at a later stage in project development, typically after a full feasibility study has been completed and the amount of investment and resulting returns on investment better understood.

There are numerous parties that could invest:

- Municipal ownership and control
- National and state level support
- Utilities
- Building developers
- International expertise (operators and providers)
- International finance
- Smart City SPVs

[20] Within the pilot city, the District Energy in Cities Initiative will create a training programme around business models, tendering and procurement of district energy with support from international partners to the Initiative. This training will be made available to all Indian cities signed up to the Initiative.

- EESL / ESCO model

These are elaborated as follows

- CCMC could either make a direct investment or have a partial stake based on the value of incentives they are willing to provide – such as land, access to energy sources, access to city-owned wastewater utilities and connections (e.g. London) - and this could create a revenue stream for the city (e.g. Paris/Toronto). As CCMC has a tight city budget and no precedent of previously guaranteeing or providing loans the latter is more likely. CCMC could also be involved in a joint cooperation model with the private sector and invest into helping the project succeed through their strong planning authority, and coordination and by encouraging connection which would lower risks and thus financing costs. In return, the city can direct the private sector to achieve specific environmental or social objectives, or have special tariffs for poor segments of society, and/or sit on board for the utility.
- The Ministry of New and Renewable Energy (MNRE) could provide a portion of the funds needed for district cooling demonstration projects as a loan or grant from existing central government schemes. The State Government, including State Renewable Energy Development Agencies (such as TNEDA), could also provide additional funding or subsidy from state funds. Such support could be crucial in the roll-out of district cooling, helping to lower risks and the cost of financing for district cooling demonstrations. Such support would only be required in the initial period and could be slowly phased out.
- It could be extremely beneficial to district cooling in India if state electricity utilities were incorporated into the business model as they have power to scale-up the district cooling model across multiple cities and can internalize the power system benefits – including the investment in upstream infrastructure. However, tight utility budgets and a disincentive to invest in measures that reduce demand make their investment unlikely. But if the business model is designed correctly, district cooling could provide an alternate revenue stream for them. Further, where capital budgets allow, utilities can host an ESCO model for district cooling where they can expand the number of consumers while reducing demand.
- Bringing building developers into the business model has been successful in other countries as they control the development timetable. However, many want a quick ‘out’ so they can invest capital elsewhere, but some may like the steady returns post-sale. Some developers could become multi-utility providers, particularly in integrated townships, providing services for their properties such as water, waste, power, cooling (e.g. Dubai).
- EESL could build upon its ESCO model used for small-scale appliances and expertise in efficiency projects to develop a business model for investing and operating district cooling projects – this has huge potential as EESL has a large amount of capital, well-developed existing programmes related to cooling, a desire to export abroad and strong links to utilities and cities. EESL’s expertise in district cooling could be boosted through partnership with international private sector to

operate the system through a joint venture and/or with a local utility so as to internalize the benefits to the power system.

- There is little expertise in India regarding district cooling. Bringing in international private sector to invest in and/or operate projects would help to transfer knowledge and capacity to the local stakeholders and ensure initial projects are of a high quality – extremely important in such a nascent market which needs to establish a strong reputation. International private sector also has significant levels of capital and can invest significantly. However, the risk assessment of Indian cities and projects may not be favourable and the returns demanded may be too high. International private sector can also be brought in to operate systems, directing investments without risking significant amounts of their own capital.
- Smart City SPVs. The SPVs being established to deliver the Smart City Plans could provide a useful conduit for district cooling investment. The SPVs will be attracting investment from external parties and would manage building development and utility development in an area, helping to lower risk for the DC project. However, this would require cities incorporating district cooling into their Smart City plans as a priority. In Coimbatore the Smart City Area should be assessed at an early stage for district cooling potential and if possible, district cooling concepts incorporated into the design stage.
- District cooling should attract international concessional finance from multi-lateral development banks given the strong potential in India for this technology and DC's environmental credentials. However, projects would have to be designed so that there is significant social value in the investment, the inclusion of public buildings (government, hospitals, schools, etc.) would justify this. Bringing the banks into the feasibility stage of the project development can help shape the project and also can benefit from these banks' international experience in financing large infrastructure projects including district energy systems.

8 Barrier Analysis for Implementation of District Cooling in Coimbatore

- **Unavailability or limited access to relevant information for district cooling project planning:** Limited data exists on: cooling demand, existing energy baselines, prevalence of technology and appliance usage for space cooling (particularly centralized cooling systems), and detail on chilled water systems installed across the city (including age, size, building, load profile etc.). In order to structure a district cooling project, critical data on potential cooling demand and on patterns and usage of cooling systems is needed but not readily available. There is no appliance level sub-metering to assess cooling loads. In addition, there is no quantitative and spatial data on potential waste heat sources in the industrial sector, biogas sources along with documented information on existing installation and generation from renewable energy systems. Documented information on underground networks, updated city development and built up area is not available in Coimbatore. City-wide GIS mapping with a property and utility map is not available in Coimbatore. This poses a challenge with regards to assessment and planning for integration of district cooling in the city.

- **Limited awareness on District Cooling:** Lack of awareness with regard to district cooling concept, technology, benefits and subsequent perceived risk of cost escalation among property developers and buyers/leaser's is a key barrier to district cooling development in the city. This also inhibits sharing of confidential information by property developers. The limited awareness amongst all stakeholders in general restricts market demand for district cooling.
- **Lack of local technical expertise:** While Coimbatore has a strong pool of technically skilled human resources owing to its large number of technical institutes, local technical expertise on district cooling is inadequate, thereby requiring hiring of international consultants at a high cost and also impacting the pace of design and construction for any district cooling projects.
- **Possibility of low continuous cooling demand impacting district cooling feasibility:** Given the city's historically pleasant climate conditions, it emerged from interactions conducted during the rapid assessment visits that there is no demand for continuous space cooling in the city. While continuous cooling demand may not exist in residential buildings in the city, impacting the feasibility of district cooling in areas primarily having residential type of development, it may be more pertinent to target large industrial and commercial developments (having diverse set of buildings), considering Coimbatore's recent growth in consumer services and IT sector growth. Large commercial buildings require substantial space cooling, which is usually served by conventional centralised air conditioning systems, as observed in the case of the IT office spaces at TIDEL park and in the newly developed Coimbatore Hi-Tech Infrastructure Private Limited (CHIL) Special Economic Zone (SEZ).
- **Difficulty in retrofitting existing building developments:** Most of the core central areas in Coimbatore city have already been developed and are densely populated, with utilities and infrastructure provided and transportation networks already constructed. Limited information is available on buildings having centralized chilled water system in the city. Thus, retrofitting existing development with district cooling systems is a challenging prospect. Limited information is available on buildings having centralized chilled water system in the city, making identifying retrofit projects harder. Another possible concern could be that building developers or owners who have already invested in centralized chillers in existing commercial real estate projects in the city will be reluctant to connect to the district cooling network. This concern can possibly be addressed through solutions including: waiting for such chillers to be retired when their efficiency falls; using such chillers as standby systems; or to use them to provide a portion of the cooling demand (e.g. base load) for a certain period before these can be incorporated into the main district cooling network. Given these barriers, retrofitting existing brownfield development with district cooling systems is a challenging prospect.

- **Lack of enabling local regulations/policies and financial incentives to promote district cooling**: There are no regulations framed by the Central or State Government directly intended to promote district cooling systems. Furthermore, requisite provisions in the local building and development regulations and incentives to promote efficient space cooling in buildings are lacking.
- **Lack of local demonstration-scale district cooling projects:** A lack of pilot scale demonstration projects in the city leads to challenges in estimations of costs and future benefits. Given the lack of demonstration of the technology and its impacts at the local level, gaining confidence of stakeholders and real estate developers is difficult.
- **Lack of financing and project development experience:** The city and local stakeholders do not currently have the 'district cooling specific' experience to support a project from concept to construction, including feasibility studies, tendering, financing, business model design, procurement, negotiations, contracting and construction. Local financing institutions are unlikely to have the required experience to provide the complex finance required to district cooling projects which can have long returns and high initial investments.

The key barriers towards implementation of district cooling in Coimbatore city are summarized in the following matrix.

Barrier	Type of barrier	Degree
Limited data/information for district cooling project planning	Technical	High
Limited awareness and lack of local technical expertise on district cooling	Technical & Institutional	Medium
Lack of enabling local regulations/policies and financial incentives to promote district cooling	Regulatory	Medium
Possibility of low continuous cooling demand impacting district cooling feasibility	Technical	Medium
Difficulty in retrofitting existing building developments	Technical & Financial	High
Lack of local demonstration-scale district cooling projects	Technical	Medium
Lack of project development and financing experience	Technical & Financial	High

9 Space Cooling in Coimbatore

Given the relatively pleasant climate and the prevalent lifestyles and income levels, air conditioning has not been prevalent in buildings in Coimbatore traditionally. However, this is changing with economic growth and building envelopes and building occupancy, particularly in sectors such as IT/ITeS are major drivers of air-conditioning demand.

9.1 The extent of air-conditioning in Coimbatore

Buildings in Coimbatore have not felt the need to own air conditioners to provide thermal comfort and cooling in the past. However, with IT/ITeS sector driving economic growth and changes in the city's weather in recent years (see section 3.2.1), the penetration of air conditioners in the city has increased of late.

Non-Residential

Sample surveys undertaken in 2010-11 as part of the Solar Master plan for Coimbatore indicate that 14% of the residential households, 33% of commercial units and 14% of industrial establishment use air conditioning systems. A number of the large IT offices, business parks, and commercial spaces coming up in Coimbatore are opting for efficient central air conditioning systems. For instance, the TIDEL park which is a large technology park located along the Avinashi road uses a relatively efficient water cooled centralized air conditioning system with chillers of 4,000 TR capacity and thermal energy storage of 6,000 TR. Business and commercial spaces in and around the CHIL-SEZ, which has come up in the vicinity of Coimbatore, outside the city limits, are seen to be using chillers to provide centralized air conditioning. The city has also witnessed growth in consumer-oriented services leading to large retail and leisure spaces coming up such as the Prozone mall which uses a centralized cooling system.

However, public offices, schools, universities etc. may not have centralized cooling, or may only have centralized cooling for a portion of the building. Smaller commercial buildings are also less likely to have centralized cooling. Data regarding the extent to which buildings have air conditioning and whether it is a centralized HVAC system or not is unavailable[21]. Data or benchmarks relating to the size and costs of systems installed is also unavailable although consultations with stakeholders and building owners in Coimbatore has provided some information on the size of systems they have used. In upcoming developments, it can be difficult to establish the size of HVAC systems planned until late in the development cycle.

Residential

Air conditioning systems are not common in residential building in Coimbatore. About 14% of the residential households in the city used air conditioning systems as of 2010-11[22]. The authors are not aware of any current or planned residential buildings in the city that are using centralized cooling.

Box 10: Identifying opportunities for district cooling

[21] It is important to distinguish whether a building has centralised cooling or not as district cooling systems can only connect to buildings with centralised cooling systems (air-cooled or water-cooled). Some buildings may be partially centrally cooled (e.g. a building's auditorium).
[22] Sample surveys undertaken in 2010-11 as part of the Solar Master plan for Coimbatore

In order to assess the scale of cooling in Coimbatore, effectively promote and plan for district cooling and identify potential district cooling projects, a GIS energy mapping of Coimbatore is recommended (also described in Box 3). This would help to resolve some of the barriers linked to a lack of data described in Section Error! Reference source not found.. **Initially, major buildings could be incorporated under such a mapping, particularly in zones deemed to have high potential and building owners trained and questionnaires sent requesting information. In particular, understanding the type of system installed, the floor-area cooled, the typical use of the cooling and the age of the system will be important – in this way retrofit projects can be more easily identified. It is likely that metering at the appliance level will be required of specific buildings to understand their actual annual cooling load for connection to district cooling. This would also crucially feed into the development of benchmarks on cooling load for different buildings (see below). CCMC will need to play a crucial role in encouraging and supporting building owners to install meters and ensure these can be monitored. CCMC can lead by example and support the installation of meters in some public buildings[23].**

Understanding the cooling demand of existing developments is important, but equally important is having benchmarks on cooling for future developments that can be used by planners and assessors of district cooling potential. These benchmarks should include the size of cooling systems installed in different building types (especially for different building efficiency levels), their typical cooling demand profiles and also the costs of installing such systems. Such benchmarks can be established for Coimbatore (and would also be relevant for the wider metropolitan area) and could take inputs from a coordinated group of local HVAC engineers, building developers and architects. As part of the rapid assessment exercise, a high-level analysis of building efficiency, occupancy and climate has led to the development of some benchmarks which should be built-upon in the future in Coimbatore[24].

The combination of improved mapping, data and benchmarks will enable a full analysis on the current and longer-term impacts of space cooling in Coimbatore, justifying new policies, technologies and investments. These impacts are likely to intensify with increasing population, increasing wealth and new business developments. Section 9.4 explores what can be deduced from the currently available data and it is recommended further, deeper analysis is undertaken.

No examples of residential buildings with centralized HVAC were identified in Coimbatore, although luxury apartments could install such systems in the future. Residential buildings do have a cooling profile that is very different to commercial buildings (particularly offices), consuming significant amounts of cooling at night when residential buildings are occupied. A district cooling system connecting both residential

[23] The District Energy in Cities Initiative will develop a metering strategy in a selected pilot city to identify how best to install and rollout metering – this strategy and its development will be made available to other cities.

[24] The District Energy in Cities Initiative will support a city to develop benchmarks on cooling load, profile and costs of installed systems in a selected pilot city and this will be made available to other cities to support their analysis.

and commercial buildings would have a lower diversity factor[25], essentially meaning the same installed district cooling chillers that serve offices during the day could also serve residential buildings at night.

However, it is recommended that residential buildings do not feature in initial district cooling systems for various reasons including: they have lower cooling consumption compared to commercial buildings; are unlikely to be developed with centralised cooling systems; often access a subsidised, lower electricity tariff than commercial rates; different apartment tenants have very different thermal comfort levels; tenants could install an AC unit, lowering chilled water revenue for district cooling; and are more difficult to bill for cooling demand.

9.2 The operation of air-conditioning in Coimbatore

Interactions with stakeholders in Coimbatore, including developers, owners and managers of commercial properties, business parks and residential apartments and city officials confirmed that though operation of cooling systems all through the year is not common in buildings in the city, the demand for cooling rises in the summer period. Offices located in large IT parks in the city, some of which operate 24 hours such as the TIDEL park, do need to use cooling systems to cater to space cooling demand through the year. Data regarding operation of cooling systems across the seasons and at different periods of the day is not available except for some building operators being able to give average power consumption for cooling in different seasons. Data for specific buildings' power demand and daily load profiles was also not available from TNEB. This makes it difficult to make an in-depth assessment of the impacts that growing development of commercial and office buildings has on energy demand and seasonal variations thereof.

9.3 Impacts of cooling on electricity consumption

TNEB is the utility that distributes power in Coimbatore city. The electricity consumption for Coimbatore has been growing rapidly at an annual growth rate of 15.7%, with a total consumption of 2,314 million kWh in the year 2015-16 (see Table 7).

Industrial consumers with high tension service connections are the largest end-use power consumer and account for 38% of Coimbatore's total electricity consumption, followed by the residential sector which has a share of 31% (see Figure 13). Industrial consumers with low tension service connections and the Commercial sector both account for 14% each of the total electricity consumption. While the share of government and private educational institutions in the city's electricity consumption stands at a low 2%; considering the large number of educational institutes in the city these represent an important end-user.

[25] Diversity factor in district cooling system means the percentage of cooling capacity saved because the peak cooling load of different buildings do not appear at the same time. It depends on the building types and area the district cooling system supplies, ranging from 10%-45%.

Analysing the impacts of cooling separately to electricity demand, including within GHG emission baselines and forecasts, is important to ensure space cooling is properly addressed and can help to justify future policies and inclusion of district cooling in city goals (see Box 2). Space cooling should be considered separately to other appliance electricity demand where possible. This could include estimating buildings' cooling demand based on real data from metering similar buildings (i.e. benchmarking) or energy modelling and electricity bills.

Table 7: Year-wise Total Electricity Consumption for Coimbatore City

Consumer Category	Electricity Consumption (Million kWh)					
	2011-12	2012-13	2013-14	2014-15	2015-16	Annual Growth Rate
Residential	430	582	627	672	711	13.4%
Commercial	183	247.5	273	303	324	15.3%
Industrial (Tiny & LT)	185	210	245	307	332	15.7%
Industrial (High Tension (HT))	457	676	775	848	881	17.8%
Government and Private Institutions[26]	27	41	44	46	49	16.0%
Bulk Supply, Public Worship & Temporary Supply[27]	6.6	9	11.8	15	15	22.3%
Municipal Services[28]	1.3	1.7	1.9	2	2.2	14.1%
Total	**1,290**	**1,767**	**1,977**	**2,194**	**2,314**	**15.7%**

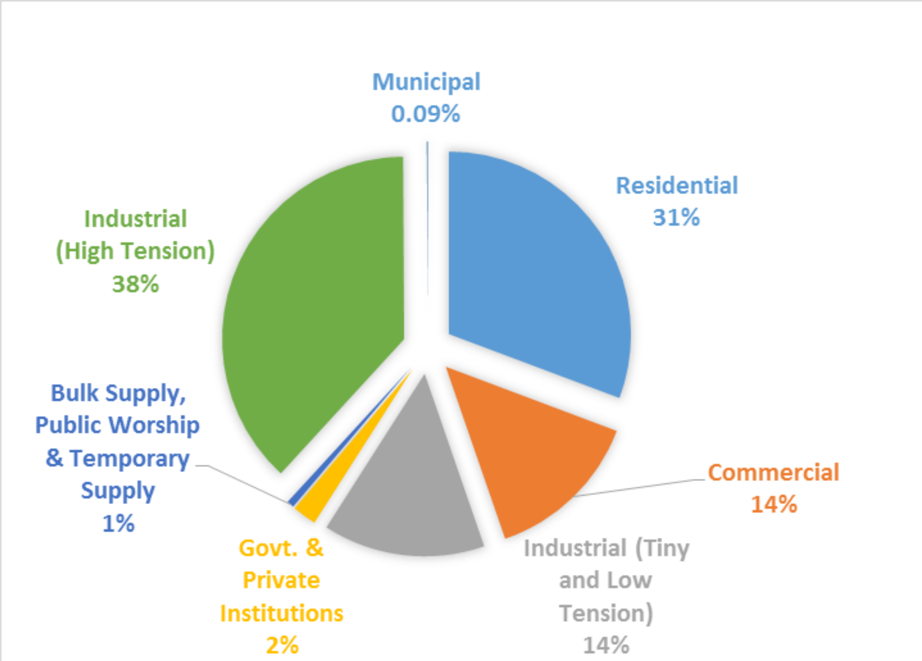
Source: (TNEB, Coimbatore Office, 2016)

Figure 13: Share of Electricity Consumption by End-Use Consumers for Coimbatore City (2015-16)

[26] Includes Educational/Welfare Institutions and Hostels, Hospitals, Health Centres, Research Laboratories/Institutes, Public libraries, art galleries and musuems

[27] Bulk supply includes residential colonies of government employees such as railway colonies, plantation worker colonies, defence colonies, police quarters etc. Public workshop is applicable to the premises of public worship places including roads and path ways leading to the temple. Temporary supply is applicable to temporary activities, construction of buildings and lavish illumination.

[28] Includes public lighting by Government/Local Bodies and public water supply and public sewerage system by Government/Local Bodies



Source: Analysis based on data received from (TNEB, Coimbatore Office, 2016)

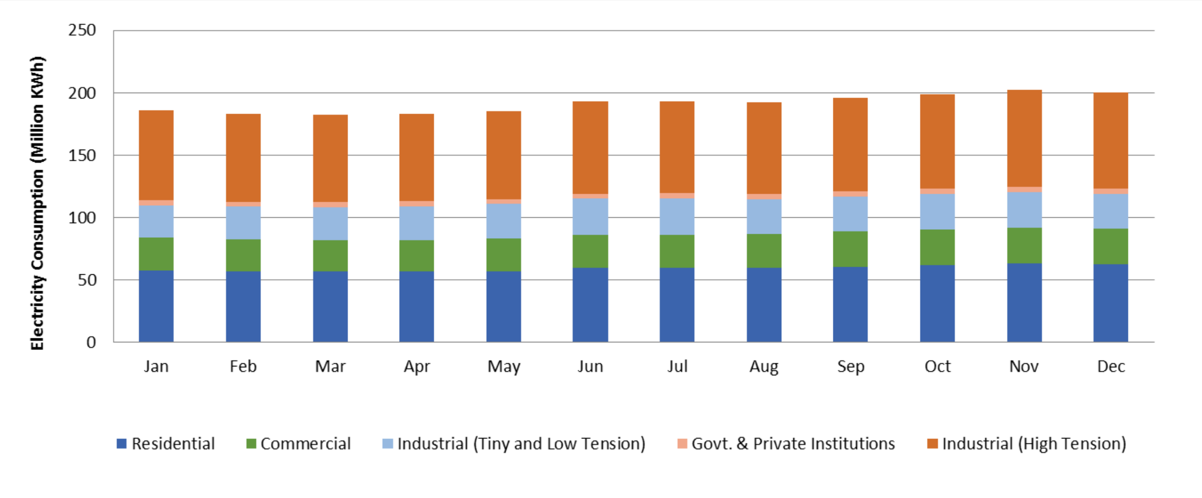
Monthly electricity consumption can be very useful in understanding minimum and peak consumption in cities and the seasonal variations therein. The monthly electricity consumption indicates that consumption is increasing from March till November in particular, with highest electricity consumption of 204 GWh observed in the month of June, a rise of 10% compared to the electricity consumption in March.

Electricity consumption is seen to rise during the monsoon months when humidity or the level of thermal discomfort is high, starting with the months of June, July and August and peaking during the second spell of monsoons in the months of October, November and December.

However, it is difficult to extract the full impact of cooling from monthly power consumption. Other loads in a city can be seasonal such as lighting and refrigeration and monthly data cannot demonstrate the full impact of cooling on peak demand and thus on power infrastructure, as peaks due to cooling are averaged with period when cooling is used less. Given the urban setting of Coimbatore city, there is little irrigation pumping. The seasonal variation in electricity consumption is likely to be predominantly caused by space cooling (including fans, desert water coolers, air conditioners and chillers). Demand for lighting may slightly increase during the monsoon season, when hours of daylight is diminished, however it is not expected to create a significant seasonal variation[29]. The Cooling Degree Days (CDD) for Coimbatore are significantly higher during the summer months of March, April and May and remain relatively high during the monsoon months as well.

Figure 14: Sector-wise Monthly Electricity Consumption (2015-16)

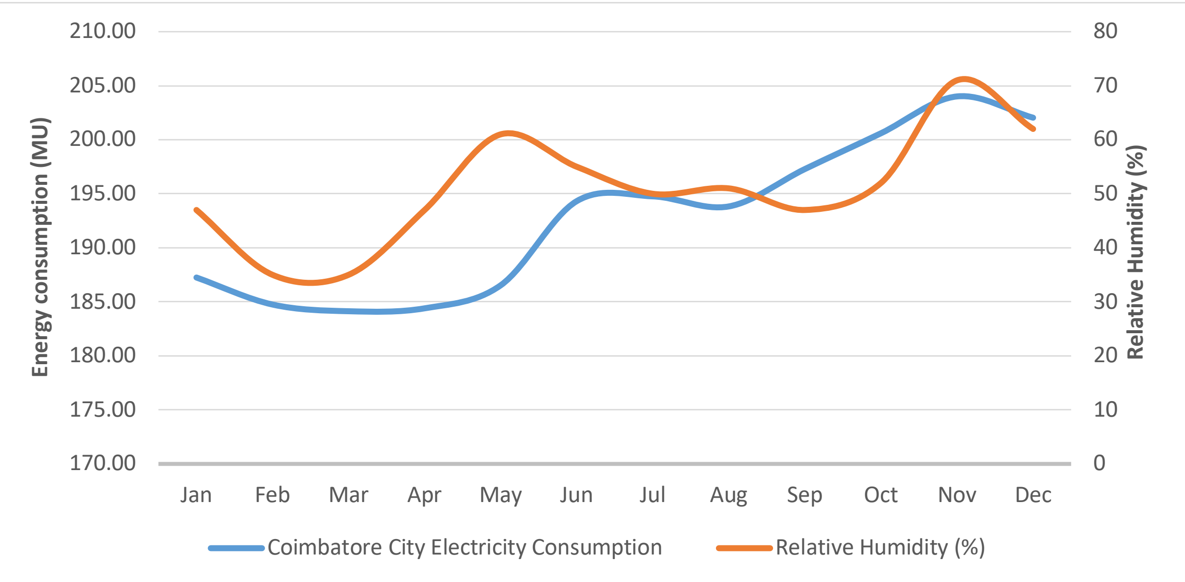
[29] Electricity demand for lighting demand varies negligibly between winter and summer in Gujarat cities and this is also expected in Coimbatore.

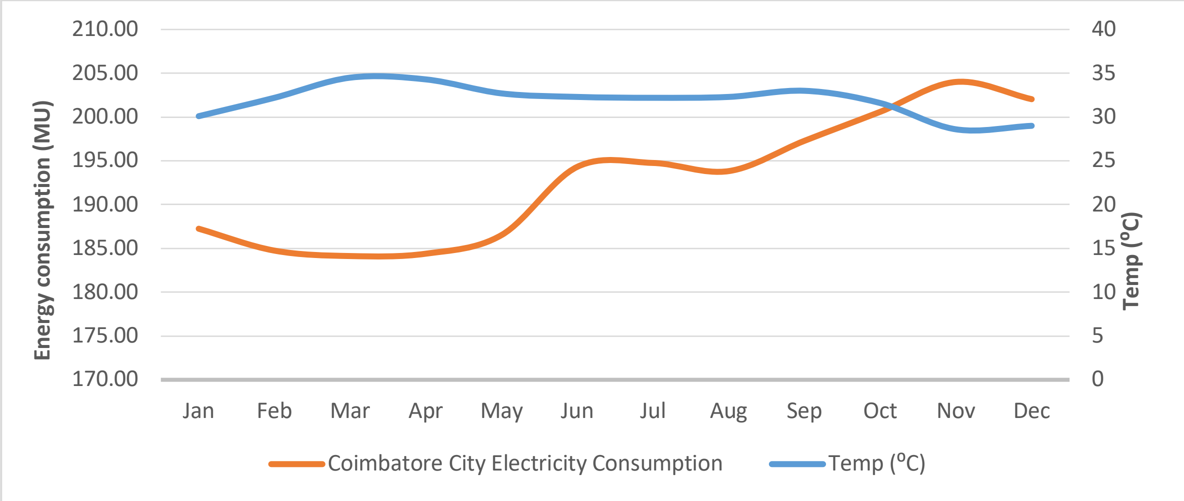


Source: Analysis based on data from (TNEB, Coimbatore Office, 2016)

A positive correlation is observed between electricity consumption and monthly relative humidity, with electricity consumption increasing when the humidity is increasing.

Figure 15: Relationship between Monthly Temperature/Relative Humidity and Electricity Consumption for Coimbatore City (2015)





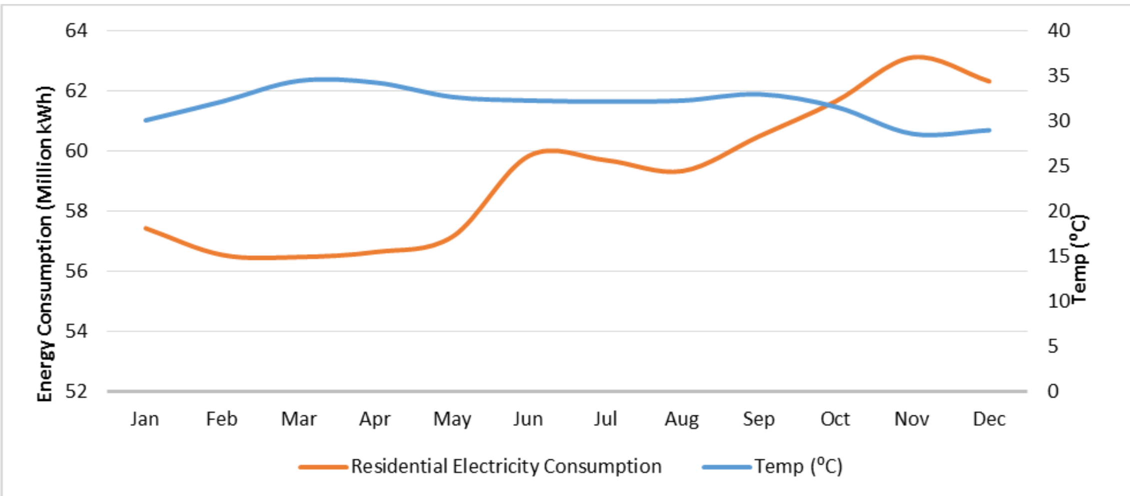
Source: Analysis based on data from (TNEB, Coimbatore Office, 2016) and (TNAU Coimbatore Station, 2015)

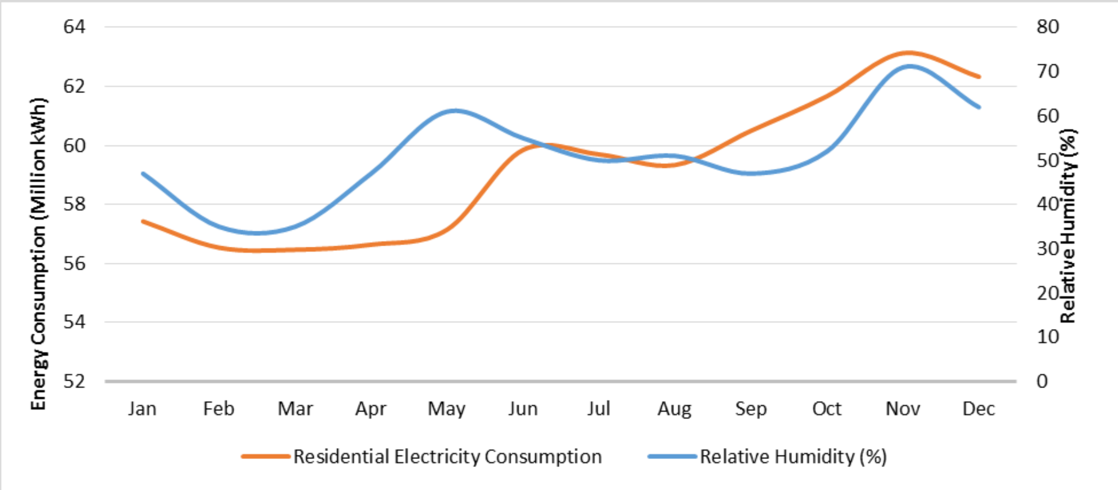
9.4 Sector-wise Analysis of Cooling Demand

9.4.1 Residential Sector

The electricity consumption in households is seen to follow the trend of the city's overall power consumption, rising in the months during the two monsoon spells, starting from May onwards and peaking in December. Residential electricity consumption and humidity have a positive correlation, with the increased demand for thermal comfort due to higher humidity linked to the rising power consumption. The seasonal load ratio for the Residential sector is 11%.

Figure 16: Relationship between Monthly Temperature/Humidity and Electricity Consumption for Residential Sector (2015)



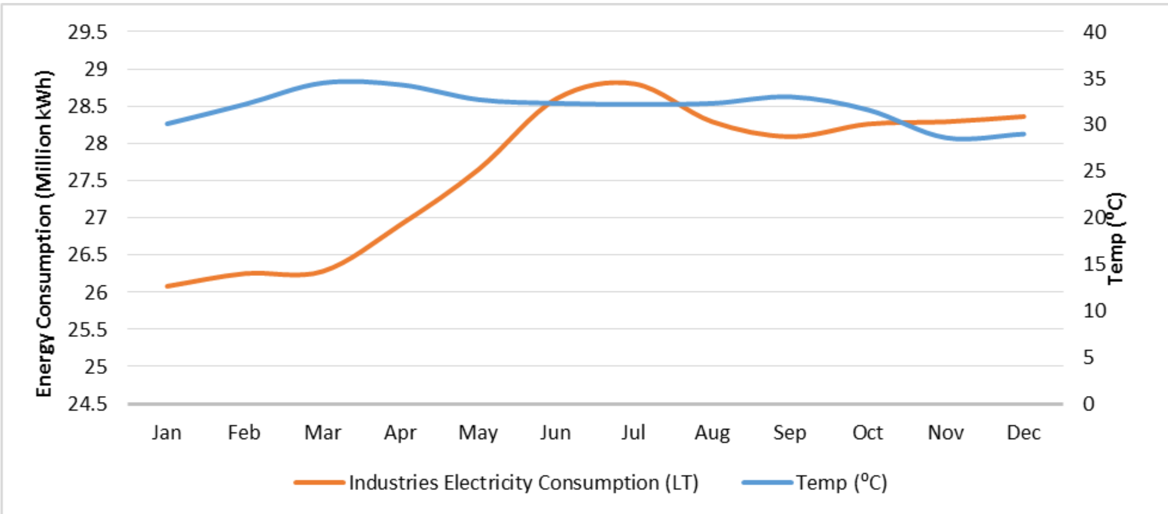


(Source: Analysis based on data from (TNEB, Coimbatore Office, 2016) and (TNAU Coimbatore Station, 2015)

9.4.2 Micro Scale and Low-Tension Consumers in the Industrial Sector

Electricity consumption in the micro scale industries and industries with low tension service connections[30] is increasing slightly during month of March till July and remains largely consistent during the months of August to December.

Figure 17: Relationship between Monthly Temperature and Electricity Consumption for Industrial Sector (LT) (2015)



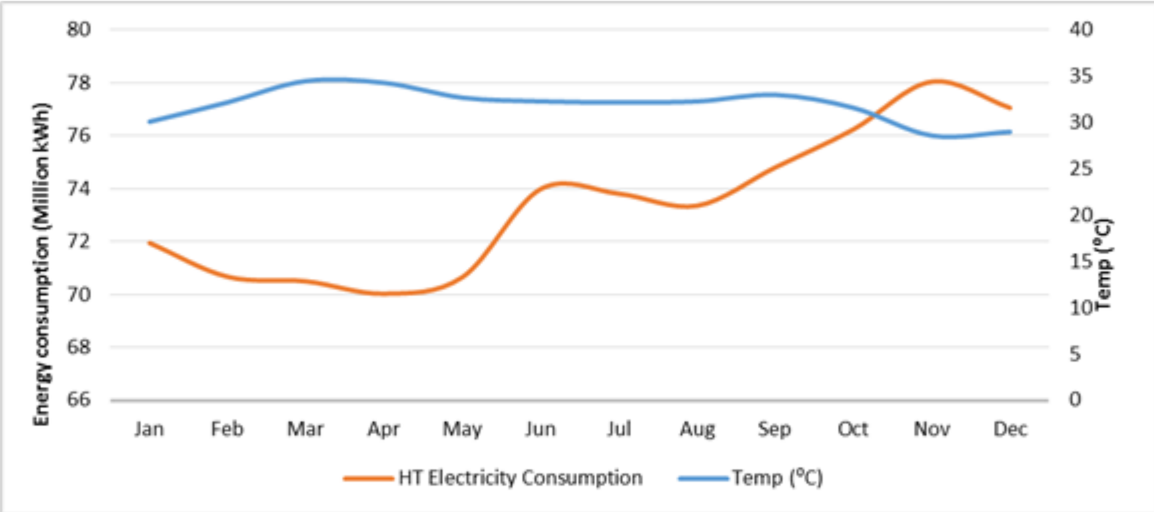
Source: Analysis based on data from (TNEB, Coimbatore Office, 2016) and (TNEB, Coimbatore Office, 2016)

[30] Includes Cottage and Tiny Industries, Agricultural and allied activities, Sericulture, Floriculture, Power Looms etc.

9.4.3 High Tension Consumers in the Industrial Sector

Electricity consumption by high tension Industrial consumers[31] peaks in the month of November and slightly increases during the months between August to December.

Figure 18: Relationship between Monthly Temperature and Electricity Consumption for High Tension Consumers (2015)

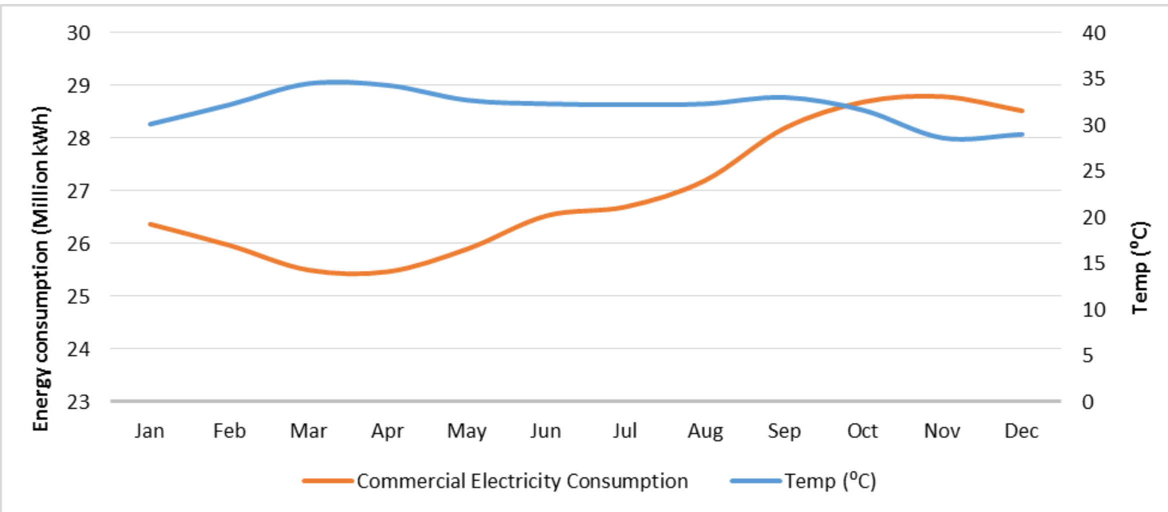


Source: Analysis based on data from (TNEB, Coimbatore Office, 2016) and (TNAU Coimbatore Station, 2015)

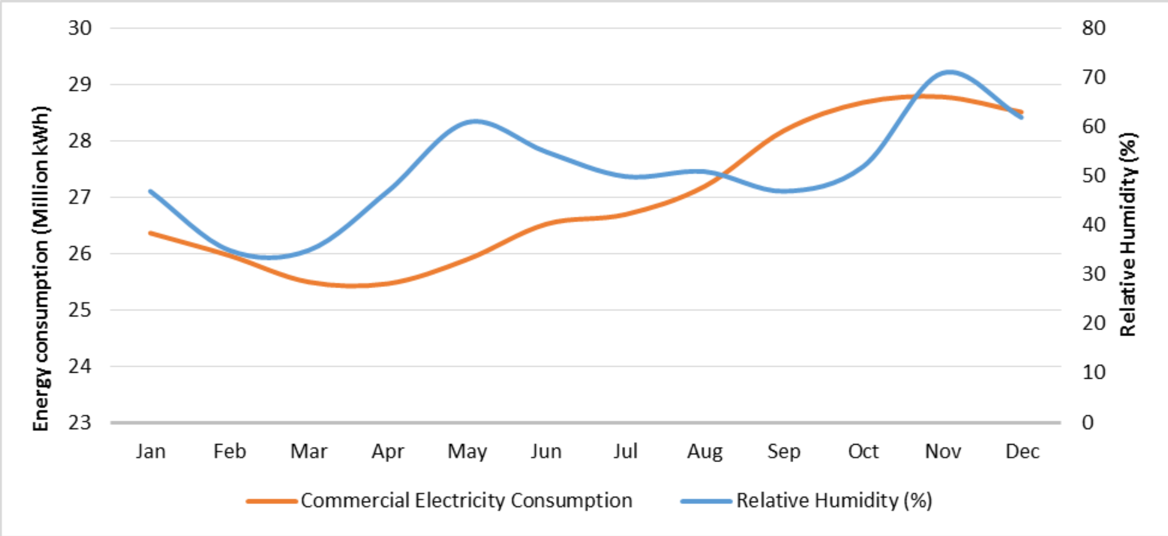
9.4.4 Commercial Sector

Power consumption in the Commercial sector increases by about 14% from May onwards and has a consistently high pattern from May to December. The seasonal load for the Commercial sector is 12%.

Figure 19: Relationship between Monthly Temperature/Humidity and Electricity Consumption for Commercial Sector (2015)



[31] Includes high energy consuming industries such as steel plants, refineries, tea and coffee plantations, textiles, foundries, rubber factories



Source: Analysis based on data from (TNEB, Coimbatore Office, 2016) and (TNAU Coimbatore Station, 2015)

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10 The Potential for District Cooling

10.1 Real estate development

New developments, high cooling load density, diversity of consumers and a focus on commercial, institutional and industrial developments are vital components of typical project types that can lead to profitable district cooling schemes

Coimbatore is a recognised IT/ITES hub with large IT companies such as Cognizant, Wipro and Bosch amongst others having a presence in the city. The IT/ITES SEZ such as the Coimbatore Hi-Tech Infrastructure and the Coimbatore TIDEL Park are located in the north and north eastern directions and house a number of IT businesses. The growth corridors such Avinashi Road, Trichy Road and Metupalayam road located towards the east, north and north-east of Coimbatore have witnessed significant development in recent years. Analysis of data received from the Town Planning Department, CCMC on buildings which have received permissions in the year 2015-16 also indicates that large upcoming residential, commercial and educational developments continue to be located in the areas towards the eastern, northern and north-eastern directions (see **Table 35** in Annexure 14.3 for more details).

A number of large residential apartments have come up in these areas and thereby the north and the east zone of Coimbatore account for 75% of the city's residential supply (ICICI Property Services, 2010). A number of commercial offices, luxurious hotels, retail outlets and leisure spaces have come up and continue to do so along these growth corridors. The Fun Republic mall, which started operations in 2012 and is spread over 400,000 sq. ft., is located along the Avinashi road.

The impacts of this development, changing lifestyles and Coimbatore's changing weather patterns is leading to an annual growth of 15% in Coimbatore's power demand%. With additional FSI being offered for the IT sector leading to high densities in such developments, similar existing and upcoming large IT developments in Coimbatore will have significant demand for space cooling during the summer season and the monsoon period with high humidity. Building developers are increasingly incorporating energy efficient technologies into similar building designs, aiming to reduce energy expenses and improve environmental credentials.

Sarvanampatti and its adjacent Keeranatham area, both prominent IT hubs located in the city outgrowth to the north, are poised to witness significant mixed-use development in the coming years. There could be potential for integrating district cooling networks to meet cooling demand in areas such as the CHIL-SEZ in Saravanampatti or the Avinashi road housing the CODISSIA trade fair complex, the TIDEL Park. Both these areas are expected to generate significant employment and witness large developments and have a good mix of residential, commercial, educational and social infrastructure present in close proximity. A key factor to be explored with regards to applicability of district cooling in Coimbatore is whether the demand for thermal comfort is consistently significant enough across the year to justify district cooling projects.

Many of the upcoming development projects in the city have multiple facilities integrated within mixed-use townships. Such mixed-use development that includes large commercial and retail spaces, IT offices, business parks, hotels, hospitals, and educational institutes in close vicinity could be promising for district cooling since it delivers sizeable anchor loads for space cooling and a diverse set of consumers. However, townships that have low proportions of commercial buildings could make the profitability of district cooling more difficult. Section 1.9 examines the high-level feasibility of some areas with large IT based anchor loads and mixed-use development, located in and around Coimbatore, for district cooling.

Building developers in Coimbatore do not currently consider district cooling systems when developing projects. A lack of demonstration projects in India makes cost estimations and calculating future benefits difficult. Once the technology has been demonstrated, and the supporting policies, it is likely that building developers will assess district cooling as an option. Similarly, not all commercial, institutional and public buildings are developed with centralized cooling, even though savings could be realized when compared to window or split air conditioners. Developing buildings with centralized cooling can ensure their future connection to district cooling networks. District cooling delivers a wide-range of benefits for different stakeholders, such as improving the environmental credentials of new development and reducing the stress on local power grids. Developing new district cooling projects in Coimbatore will allow the city to take advantage of these benefits.

10.2 Prospects of renewable and innovative technologies

The economic analysis presented in Section 11 has focused on electricity-based district cooling systems, i.e. systems that use highly efficient electric chillers to produce chilled water centrally. However, Coimbatore has opportunities to develop district cooling using innovative renewable technologies in addition to electricity-based chillers. From stakeholder consultations and review of available resources, the most likely renewable or low-carbon options could be direct use of municipally-owned solar electricity by the district cooling project. The temperature of the Coimbatore's lakes is expected to be too high for use as 'free-cooling' (see Section **Error! Reference source not found.**). No information on geothermal potential was available and so has not been considered.

There are also opportunities for innovative technologies to be used with district cooling systems. Use of Treated Sewage Effluent (TSE) instead of potable water in district cooling systems would be possible in Coimbatore (see Section **Error! Reference source not found.**), lowering requirement of fresh water for cooling while also helping the city to achieve its goals on clean water in its water bodies through promoting of wastewater reuse or recycling.

High-level analysis of the power prices in Coimbatore (presented in Section 11.4) has indicated that thermal storage (TES) is unlikely to be cost-effective for electricity-based district cooling, unless the difference between peak and off-peak tariffs is increased

More detailed city-wide assessments and pre-feasibility studies of projects should focus more on local renewable opportunities and innovative technologies, which could improve the commercial viability of projects for example through the lower running costs of such renewables.

11 Techno-economic analyses of district cooling in Coimbatore

This section presents the project analysis of district cooling undertaken in Coimbatore including description of the modelling, a generic development archetype tested across all the cities and the sites that have been selected in Coimbatore for assessing the high-level feasibility of deploying district cooling systems.

11.1 Development of evaluation tool

A general district cooling evaluation model has been developed for use in all five cities being rapidly assessed. The model compares stand-alone centralised cooling systems with electricity-based district cooling systems. The adaptive model contains several sub-models and can be used to calculate the technical requirements as well as economical viabilities and sensitivities of different technical solutions on a basis of rapid assessment.

- **Sub-model 1: Input**

The required input data includes:

1) built-up area of building types in the area planned for district cooling implementation
2) occupancy of building types
3) development timeline for different buildings
4) electricity and water tariffs charged to stand-alone buildings and a district cooling project
5) cooling demand per m^2
6) operational parameters including annual average COP and EFLHs[32]
7) capital and operating cost assumptions on stand-alone cooling systems, district cooling plants, land and network
8) CO_2 emission baseline.

Some data inputs are set to default values across cities to allow rapid analysis, these should be revisited during the pre-feasibility assessments of projects.

- **Sub-model 2: Calculation and output of district cooling technical solutions**

[32] EFLH or Equivalent Full Load Hours is the number of hours a cooling source has to operate at full capacity installed to produce the same amount of cooling delivered by the system at different part loads at a constant thermostat setting over a cooling season.

Based on the input data from sub-model 1, the technical parameters of the district cooling system in the area are calculated. This outputs the following results which are inputted into sub-model 3:

1) End-users description. Built-up areas are broken down into percentage of different building types, so that the end-user types can be better understood.
2) Cooling demand. The hourly cooling demand of typical design day in the region is presented.
3) District cooling plant requirements, including installed cooling capacity, district cooling plant built-up area, outdoor space for cooling towers and the total estimated cost for district cooling plant.
4) Operation and Maintenance costs (O&M) for both of district cooling system and standalone system, including annual cooling supply, annual electricity consumption and fee, annual water consumption and fee, and finally total operation fee. This will show the annual cost savings of the district cooling system relative to standalone systems.
5) Environmental benefits from the district cooling system, including reduction of annual CO_2 emissions, life-cycle refrigerant reduction, reduced water consumption relative to water-cooled stand-alone systems

- **Sub-model 3: Economic and sensitive analysis of district cooling application**

Based on the input data from sub-model 1 and results from sub-model 2, sub-model 3 calculates the financial viability of the district cooling system including project IRR and payback period. Financial viability is always established by setting the district cooling project to be cheaper for end-users than stand-alone systems. This model is based on some specific inputs including:

1) Tariff structure for district cooling including connection charge, capacity charge and chilled water price
2) End-user discount for using district cooling – the annual payments of an end-user for district cooling are kept below the annual payments for an end-user using a stand-alone system. This discount is fixed across all the five cities at 20% and acts as a buffer in case VAT is applied to district cooling sales

As well as financial results for a district cooling system, the model also outputs total annual payments that end-users have to pay by using standalone system or district cooling systems over a 22-year period.

Finally, in order to show the most important parameters that affect the cost-effectiveness of district cooling system, sensitivity analysis is undertaken cooling demand, investment and chilled water tariff.

11.2 Assumptions used in Coimbatore

Cooling demand

As explained in Box 10, no benchmarks for building cooling demand or consumption are available in the city of Coimbatore. Furthermore, due to the early stage of greenfield projects, the detailed building design including building plan, façade, HVAC design and operation etc., are not yet available. Building upon research, stakeholder consultations and site visits (including the projects presented in Section 11) high-level benchmarks for cooling demand and cooling system capacity have been simulated or calculated with several assumptions made according to local standards or conditions. More detailed benchmarking should be part of a more detailed pre-feasibility study.

In the annex are detailed the specific assumptions on building occupancy and building efficiencies used in establishing cooling demand for different building types. Cooling demand is also calculated based on expected appliance use leading to heat gain as well as climate. These are conservative estimates, for example, building efficiency assumptions are based on the ECBC standards which are not currently mandatory in any of the five cities.

Based on this analysis the cooling demands of different building types are listed below. This data should be further verified based on monitoring or metering on the operation of cooling sources in existing buildings (as explained in Box 10).

Table 8: Assumptions of cooling demand

	Hotel	Office	Shopping mall	Hospital	Residential Apartment	Campus building
W/sqm	169	275	328	222	143	219

Equipment costs

In order to calculate the economic viability of a district cooling system and compare with standalone cooling systems inside buildings, several cost assumptions have been made. This cost data has been provided by local and international partners of the District Energy in Cities Initiative for rapid analysis and can be further verified in the future. The costs are conservative estimates. Table 9 summarises these assumptions.

Table 9: Investment costs of district cooling system and standalone system per unit of installed capacity

District cooling plant	133000	Rs./TR
	2000	USD/TR
Standalone system	120000	Rs./TR
	1800	USD/TR

It should be noted that district cooling systems require less chiller capacity to be installed than the aggregated capacities of multiple stand-alone systems because of the diversity of buildings served. District cooling systems are able to supply cooling to various buildings including offices, shopping malls, hospitals and hotels etc. All these buildings have different occupancies and cooling system parameters so that the peak loads of these buildings do not appear at the same time. As a result, the diversity of building types can result in an overall lower cooling capacity for the district cooling system. The more diverse building types that connect to a district cooling system, the lower the diversity factor that it has and the lower investment in cooling equipment. The diversity factor is quite specific on how many square meters of each building types connect to district cooling system. According to experience, it could be as low as 0.55 for campus buildings, to as high as 0.85 for Centre Business District (CBD) with commercial buildings.

Other costs of the district cooling system that need to be included are:

- Land cost for district cooling plant: 512 USD/ m^2 (34,133 INR/ m^2)
- Distribution network cost (including pipes, metering, insulation and installation): 180 USD/TR[33] (12,000 INR/TR)
- FAR of cooling plant: 2

Cooling system characteristics

The cooling systems operates with different portions of loads (full or part load) throughout the year. According to site visits of buildings and district cooling experience in other countries, the annual average Coefficient of Performance (COP) of each cooling system[34] is estimated as following (the chilled water temperature is 5/13 ℃):

Table 10: Annual efficiency (COP) of district cooling system and standalone system

District cooling COP	1.0	kW/RT
Standalone COP	1.5	kW/RT

The operation of the district cooling and stand-alone systems for a given cooling load can, for high-level analyses, be characterised by the Equivalent Full Load Hours (EFLH). EFLH is the number of hours a cooling source has to operate at full capacity installed to produce the same amount of cooling delivered by the system at a constant thermostat setting with different loads throughout the whole cooling season. According to input from local partners and fast calculation of hourly cooling demand in buildings, EFLH in Coimbatore is conservatively estimated as 2145 hours.

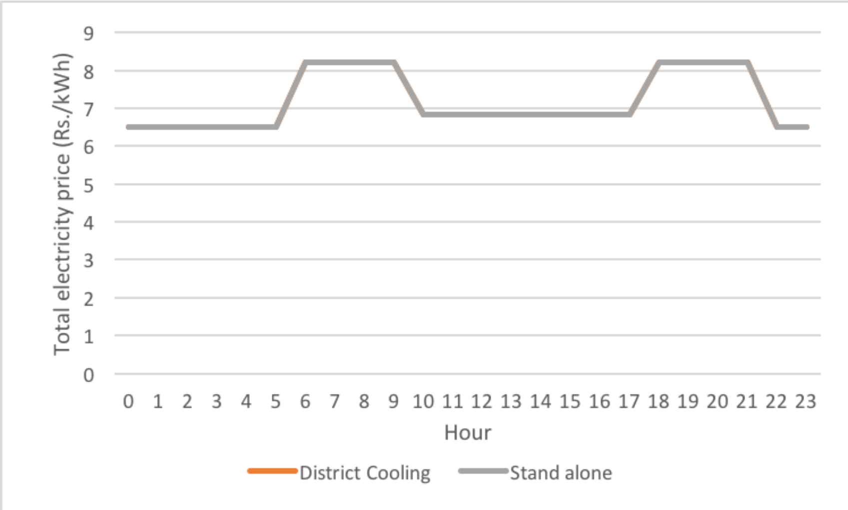
Operation and Maintenance costs

[33] At the rapid assessment stage it is sufficient to assume a fixed network cost per ton of refrigeration installed. In reality, network costs can vary significantly based on the density and spatial layout of cooling demand, the size of pipes required, number of consumers, ground conditions etc.

[34] The annual COP presented here is equivalent to the annual average electricity used to produce one refrigeration ton of cooling (including electricity consumption of chillers, pumps and cooling towers). Chillers, pumps and cooling towers have different efficiencies under different loads. Normally, chillers have the highest efficiency in 75%-100% cooling load. This takes into account the expected operation of the system for different loads, the expected COPs of individual chillers and best practice high efficiency operation of using parallel chillers in district cooling systems. Such a COP should not be compared with the COPs in the specifications of individual chillers as this would not be a like-for-like comparison.

Electricity tariffs are calculated from Tamil Nadu Electricity Board (TNEB) tariffs and presented in Figure 20. In Coimbatore, unlike the other cities assessed, the tariffs charged to stand-alone buildings would be the same as the tariff charged to a district cooling site.

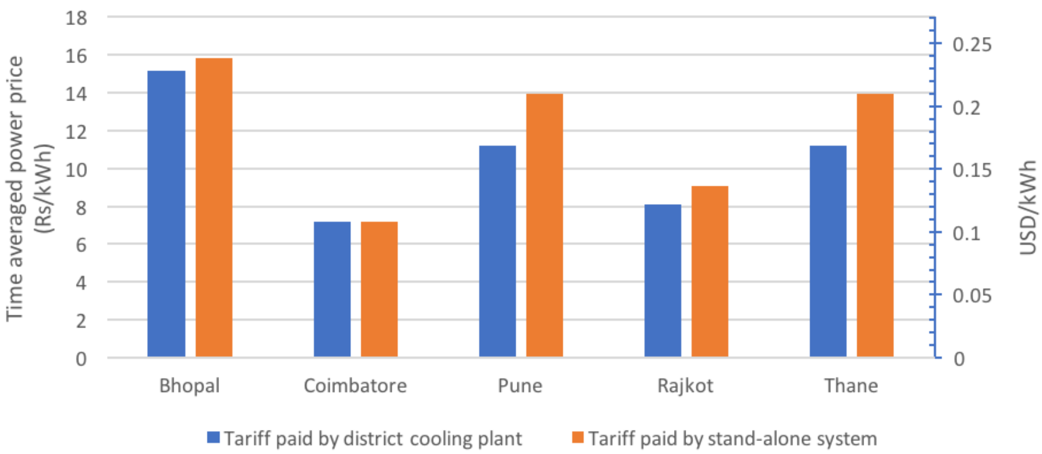
Figure 20: Electricity prices in Coimbatore (Energy charge fee)



Source: Based on tariff charged by (TNEB, Coimbatore Office, 2016)

Compared to the other cities assessed in India, Coimbatore has relatively low electricity prices, as can be seen in Figure 21. This can hinder the business model for district cooling as it makes being energy efficient in cooling slightly less profitable than in other cities.

Figure 21: Comparison of time-averaged electricity prices across all cities as paid by district cooling plants and stand-alone commercial cooling systems



(Source: Analysis based on tariff charged by state utilities for each city)

Other O&M costs include water, chemicals, spare parts, operating staff costs, general & administrative and insurance.

Tariff structure of chilled water from district cooling system

Due to limited district cooling projects in India, the pricing structure of chilled water in district cooling systems is considered to use the same structure as in Malaysia, Singapore and China etc. The pricing structure contains three charges:

- Connection charge. This charge is collected from end-users by the operator of district cooling system as soon as they connect to the system. It is a one-time charge. For simplicity, it has been assumed that this charge is the equivalent of 20% of the district cooling system's capital expenditure.
- Capacity charge. This charge is collected monthly, based on the capacity of end-users. Per year it is assumed that the total capacity charges collected will be the equivalent of 7% of the district cooling system's capital expenditure
- Metering charge. This charge is collected monthly, based on the real cooling consumption of end-users and is charged per ton of refrigeration-hour (TR.h). As district cooling is not a regulated utility in India, the metering charge is adjusted by project so that the annual total of the metering charge and capacity charge is 20% below the annual total operating costs of a stand-alone system. This 20% buffer is added because VAT on chilled water has not been accounted for in the analysis, as the level of VAT that will be charged is not known.

The three charges are illustrated in Figure 25, the 20% buffer is shown by a red arrow and is 20% of the total district cooling payments.

Tax

A tax on profits of 25% has been assumed for the district cooling system.

As described above, VAT has not been applied and instead a buffer added to ensure that if VAT is applied, district cooling will still work out cheaper than stand-alone. VAT has not been fully assessed as this is only a high-level calculation and the level of VAT on chilled water is not known and VAT for electricity varies from state to state in India. Furthermore, the district cooling system may be able to recuperate VAT paid on electricity, effectively lowering the amount of VAT paid on chilled water. Such analysis should be undertaken in a pre-feasibility study.

Development timescales

The timescale of a development including when construction starts and when first cooling is required can affect the project financial significantly. In order to simplify analysis at this stage, the following has been assumed:

- In year 1, all connection charges are paid
- In year 3, the district cooling system begins operating, initially serving 50% of demand
- In year 4, 75% of demand is now being served
- In year 5, 100% of demand is served and afterwards demand remains constant

This timescale will vary project to project and also on the contracting arrangements of when connection charges should be made. This timescale can be seen in the payments made in Figure 22.

Financial structuring

Financial structuring of district cooling projects depends significantly on the investors and project proponents. As this is a rapid assessment, only project IRR, which is independent of the equity-to-debt ratio, is presented and not equity IRR. Commercial debt rates in India have been estimated at 11%. Project pre-feasibility studies should analyse possible financing structures and debt rates, look at the returns expected by different investor types and assess different tariff structures including charging lower connection charges to consumers to attract connection.

The development timeline above has a significant effect on the payback period presented which is calculated from year 1, even though full operation is in year 5.

11.2.1 Analysis of generic project archetype

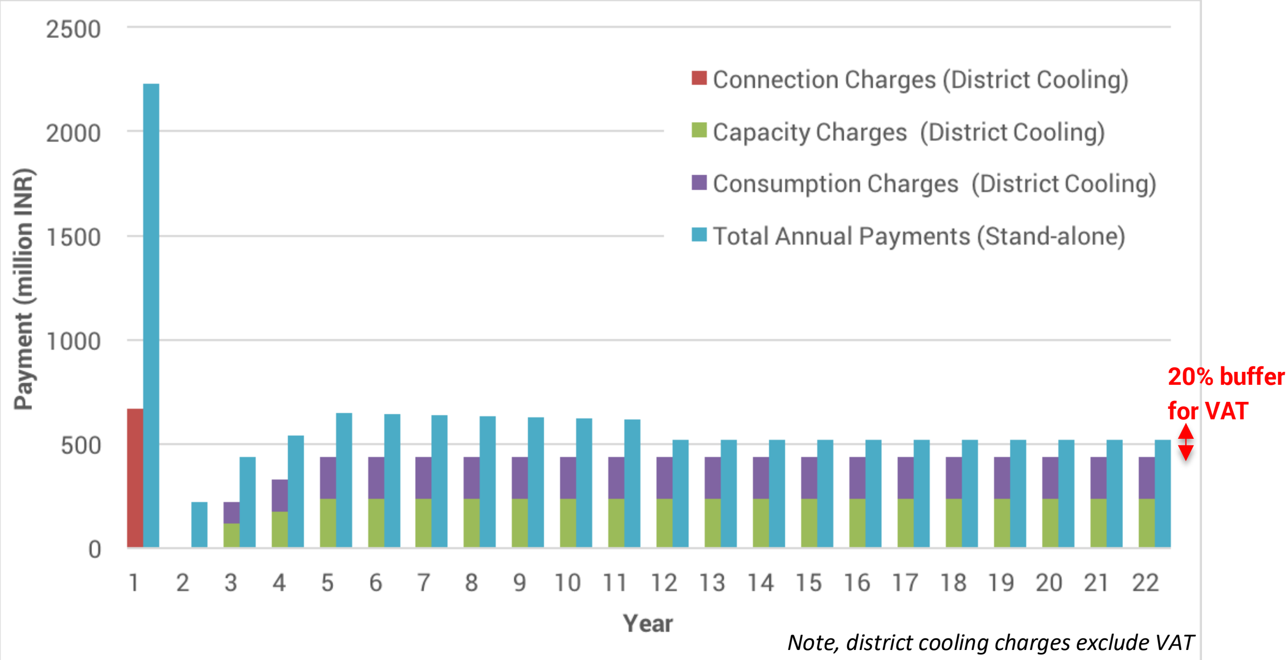
Through analysis of projects across all five cities, a development archetype was chosen that could be used as a typical development to enable comparison across all cities. The make-up of this archetype is shown in Table 11 below, it is mixed-use with multiple buildings with centralised cooling.

Table 11: Input data for a generic, mixed-use development archetype in Coimbatore

Development archetype details:	Ground Floor Area (sqm)	Floor area ratio (FAR)	Built-up area (sqm)
- *Hotel*	20,000	2.5	50,000
- *Office*	70,000	3	21,000
- *Shopping Mall*	30,000	3	90,000
- *Hospital*	5,000	2.5	12,500

The IRR of this project is 6% in Coimbatore and the payback period is 20 years.

Figure 22: Cost comparison for consumers for district cooling vs. stand-alone systems in the generic project archetype



The benefits accrued from this generic project are shown below. Note this is for an electricity-based district cooling system without thermal storage or renewable energy. If renewables were used in conjunction with electric chillers, the benefits would be even more, similarly if thermal storage were used (and the project able to be cost-effective), peak power demand reduction relative to stand-alone could be up to 50%, compared to 30-35% without TES.

CO_2 savings	30-35%
Life cycle refrigerant saving (20 years)	10-15%
Water savings (compared to water-cooled chillers)	15-20%
Electricity demand reduction.	30-35%
Peak power demand reduction	30-35%

With such a low return on investment, district cooling would have to attract very concessional finance in order to be investable in Coimbatore. As mentioned previously, Coimbatore has the lowest electricity price of all the cities analysed, this makes it harder for district cooling projects to be profitable while still lowering costs to consumers. Further, Coimbatore was the only city analysed where the electricity tariff paid by a district cooling operator would be the same as a stand-alone commercial building – in the other cities assessed, district cooling is expected to pay a lower tariff. Sensitivity analysis on the CHIL-SEZ project indicate that reducing the electricity price by 15% would raise the IRR from 11% to 12% and setting VAT for chilled water at 0% would raise the IRR to 15%.

This is only high-level analysis and cannot conclude that district cooling would not be profitable in Coimbatore but it does indicate that project development would be significantly more difficult than other cities. A project pre-feasibility study of a high-potential project should be undertaken to understand district cooling's viability further. Strong project design can also have a huge impact on profitability – for example, the analysis of CHIL-SEZ below yields a higher IRR. In the analysis of CHIL-SEZ are other recommendations for how to increase the IRR in Coimbatore.

11.3 Selection of Probable Project Sites

Two potential sites for district cooling projects have been identified in Coimbatore for assessing the high-level feasibility of deploying a district cooling system. The sites have been identified based on discussions with stakeholders in the city including city authorities, the town planning department, building owners/users and real estate developers. The potential project sites selected are mixed-use developments (existing and partially completed) with significant cooling demand and the presence of anchor loads.

11.3.1 Site 1: CHIL –SEZ, Saravanapatti

Coimbatore Hi-Tech Infrastructure Private Limited (CHIL) is the first private SEZ in Tamil Nadu. CHIL-SEZ is located in the IT corridor of Saravanapatti/Keeranatham. The site lies to the north-east of the city at a distance of 12 km and is situated outside the city limits.

For this project, 250 acres of land has been acquired and will house about 4 million sq. ft. of built up area. The IT/ITES SEZ is spread over 150 acres and will house support infrastructure in the form of residences and amenities in 100 acres. The SEZ will be developed as an integrated township including apartments, hotel, hospital, entertainment complex, shopping complexes, landscaped parks and other amenities.

About 1 million sq. ft. of built up space is operational in the SEZ and includes

- Robert Bosch – 28 acre Campus
- Cognizant Technology Solutions – 23 acre Campus
- Perot Systems - 7.2 Acre Campus
- India land – KGISL IT Park-1.8 Million sq. ft. Multi-tenant facility
- Ugam Solutions
- SPI Healthcare Documentation
- KGTESCO Engineering Services

Figure 23: Location of CHIL-SEZ site in Coimbatore

Building developments within the SEZ for which information is available have been listed along with buildings in the close vicinity of the SEZ.

India Land KGiSL Tech Park

The India Land KGiSL Tech Park is spread over 11.74 acres and houses prominent IT companies such as Robert Bosch, Dell, Ebix and others. The total built up area is 1.8 million sq. ft. (leasable area of 1.5 million sq. ft.) with 4 towers. The Tech Park uses 8 x 400 TR air cooled screw type chillers for air conditioning.

Table 12: Detailed information on India Land KGiSL Tech Park

Description	Details
Development	11.74 Acres of land with 1.5 million sqft of Leasable area
Number of Towers	4 Towers – A,B,C and D (Contiguous)
No. of Floors	9 (1 Basement + Stilt + 7 upper floors)
Floor Plate Size	51,000 to 55,000 sq. ft., approximately in each Tower
External Finish	Glazing, Block work with paint over a coat of plaster
Design Load and Construction Type	500 Kg/m², Framed structure with Pre Stressed slabs
Total Power	12,500 KVA with 100% back-up through DGs
AC Capacity	8 Nos of 400 TR (Air cooled Screw type)
Current Tenants	Robert Bosch, MModel, Ugam, Aditi, Maxval, Point Perfect, Ebix and Dell

Figure 24: Location of India Land KGiSL Tech Park

Figure 25: Plan and Photographs of India Land KGiSL Tech Park

Master-plan

Residential Projects in the CHIL-SEZ Site

The following residential projects are located in the Non-SEZ areas within the CHIL premises.

Project – I: KGiSL Platina is a residential project with houses 388 apartments in 6 towers and has been constructed. The total built up area of this project is more than 367,480 sq. ft.

Table 13: Details of KGiSL Platina

KGiSL Platina		Each Building Area (sq. ft.)	Total No. of Apartments	Total Area (sq. ft.)
Tower 1 & 2	**Total Model (R+S)**			**130,880**
	R - Unit I	1500	24	36,000
	Unit II	1500	24	36,000
	S - Unit I	920	32	29,440
	Unit II	920	32	29,440
Tower 3 & 4	**Total Model (J+K)**			**140,160**
	J - Unit I	1240	32	39,680
	Unit II	1240	32	39,680
	K - Unit I	950	32	30,400
	Unit II	950	32	30,400
Tower 5	**Total Model (P+Q)**			**55,440**
	P	1250	28	35,000
	Q	730	28	20,440
Tower 6	**Total Model (A+B+C)**			**41,000**
	A	690	20	13,800
	B	680	20	13,600
	C	680	20	13,600

Figure 26: Location of KGiSL Platina

Project – II: KGiSL Metropolis is a residential project that consists of 7 towers in two clusters spread over 4.8 acres- CORAL apartments and PEARL apartments

Figure 27: Location of KGiSL Metropolis

i) The CORAL apartments are spread over -200,160 sq. ft. and each floor consists of 8 x 1BHK apartments of 695 sq. ft. each

Table 14: Specifications of KGiSL CORAL apartments

KGiSL Metropolis		Each Building Area (sq. ft)	Total No. of Apartments	Total Area (sq. ft)
CORAL	Total Model			200,160
	Tower 1	695	72	50,040

	Tower 2	695	72	50,040
	Tower 3	695	72	50,040
	Tower 4	695	72	50,040

Figure 28: Floor plan of CORAL apartments

ii) The PEARL apartments are spread over 127,980 in sq. ft. and each floor consists of 4 x 1 BHK apartment of 1185 sq. ft. each

Table 15: Specifications of KGiSL PEARL apartments

KGiSL Metropolis	Each Building Area (sq. ft)	Total No. of Apartments	Total Area (sq. ft)	Each Building Area (sq. ft)
PEARL	Total Model			140,160
	Tower 1	1185	36	42,660
	Tower 2	1185	36	42,660
	Tower 3	1185	36	42,660

Figure 29: Floor plan of PEARL apartments

KCT Tech Park

KCT Tech Park is operational since 2008 and spread over 4.18 acres of land with 250,000 sq. ft. of built up area. KCT Tech Park is located in the vicinity of the CHIL-SEZ, within the premises of the Kumaraguru College of Technology (KCT). KCT Tech Park is built to house software development companies, BPOs and corporate offices. Several reputed organizations are already operating from KCT Tech Park. C-Bay Systems and Cognizant Technology Solutions operate from STPI-IT Park housed at Dr. Mahalingam Vigyan Bhavan in the main campus of the Kumaraguru College. KCT Tech Park uses air cooled chillers having a total capacity of 1062 TR to meet its cooling demand.

Figure 30: Location of KCT Tech Park

Figure 31: Actual Site of KCT Tech Park

Table 16: Salient features of KCT Tech Park

Plot Size	**4.18 Acres**
Size of the Building	2.50 lakh sq. ft. (including common facilities and cafeteria)
Levels	Basement + 5 levels
Structure	PT Slab on Office Space, Conventional Slab on Toilet Area
Cladding & Glazing Structure	Glazed aluminium structure with 6 mm super silver blue Reflective annealed glass.
Height of the Building	22 meters
Car Parking	Adequate parking space in the campus with 117 cars space in basement.
Air Conditioning	Air cooled chillers totalling to 1062 TR capacity
Power	Grid Power- connected load 11KV Captive Power- Cummins make diesel gensets with 100% power backup Electrical Distribution-Two separate risers for 100% redundancy Dedicated Electrical Shaft Two electrical rooms on every floor
Waste Water Management	Through sewage treatment plant with capacity of 200,000 litres per day
Green building	KCT Tech Park built with a green building concept
Tenants	Ford Business Services Centre Firstsource Solutions Limited Cordy's Software India Pvt Ltd Vanenburge Software India Pvt Ltd Cognizant Technology Solutions

The Kumaraguru College of Technology, located in the vicinity of the CHIL-SEZ is a reputed private Engineering College offering Under-Graduate and Post Graduate courses, spread over 150 acres and housing about 1.5 million sq. ft. of built up area. KCT has five academic blocks housing its different departments.

The administrative building, known as Dr.Mahalingam Vigyan Bhavan, is a symbolic architectural building of the institution and houses the administrative block, library, seminar hall complex (central wing), department of Computer Application, KCT Business School (left wing), Research cell and some other offices (right wing). The premises also include hostels having more than 750 rooms. The college has a number of air conditioned spaces as listed below.

- Library: Mahatma Gandhi Central Library is housed on the first floor of the Dr. Mahalingam Vigyan Bhavan and has an area of 16945 sq. ft.
- Hostels: Has two distinct sections for male and female students. The gents' hostel comprises four blocks with total of 445 rooms with a capacity to accommodate 1335 students. The Ladies hostel has a total of 329 rooms in its three blocks with a capacity to accommodate 987 students.
- Auditorium: Air-conditioned auditorium with a seating capacity of 1800 persons
- Aruljothi Dhyana Mandapam: An octagonal shaped air-conditioned meditation space
- Seminar Halls: Four A/C seminar halls each with 250 seating capacity are located in this building. In addition, four other seminar halls each of 120 seating capacity are located in various academic blocks.

The KCT houses the KCT Tech Park and also houses the Software Technology Park India campus which has an area of 200,000 sq. ft.

Figure 32: Kumaragaru College of Technology

Selection criteria for CHIL-SEZ site:

CHIL-SEZ site

Technical requirements	1. The CHIL – SEZ site has substantial cooling demand and uses 8 nos. of 400 TR (Air Cool de Screw Type) 2. The site offers sufficient diversity and may be able to provide continuous cooling demand
Availability of anchor loads with continuous load and diverse buildings can be connected	The site has a good mix of diverse building uses such as a large commercial space for IT companies, large residential developments and a sprawling educational campus located close to each other. Anchor load is available in the form of CHIL-SEZ. This is a potential district cooling retrofit case.
Potential for longer-term network expansion	The site is located in the rapidly developing IT corridor of Sarvanapatti outside the city. The area is expected to generate substantial employment and witness substantial mixed-use development.
Existing situation of buildings	Most of the buildings have been constructed
Influence from local government	The local government can help facilitate dialogue with the relevant businesses

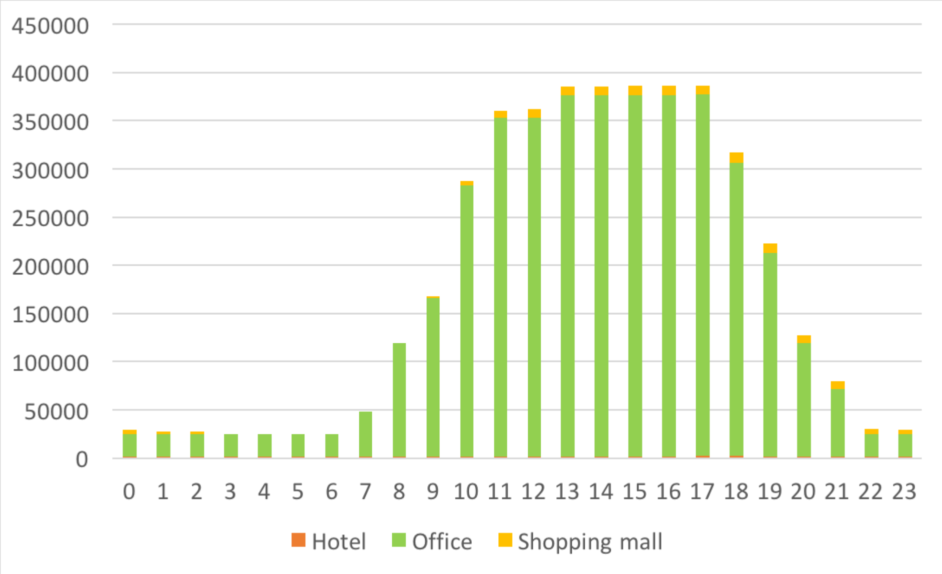
11.3.2 Delivering district cooling in CHIL-SEZ

Buildings served and cooling load

The total built-up area is estimated at 18,849,978 sq. ft (1,751,222 m^2) and the split by building type is: 97% offices, 2% retail and 1% hotel. This includes the following developments: KCT Tech Park, Kumaraguru College of Technology, Cognizant, Bosch, India Land and Dell.

According to the input data, the hourly cooling demand profile in the area, as served by a district cooling system, is shown in Figure 33 below.

Figure 33: Hourly cooling demand profile of district cooling system



Characteristics of the district cooling plant

According to the modelling results, the district cooling plant characteristics would need to be as listed below.

Table 17: District cooling plant

Installed Cooling Capacity	386,479	kW
	109,889	RT
District cooling plant built-up area	27,225	sq. m
Outdoor space for cooling towers	8,712	sq. m
DC plant land requirement	16,335	sqm

The investment of district cooling system is calculated as below.

Table 18: District cooling system investment

DC system investment	Rs.	USD
DC plant	14,651,834,534	219,777,518
Land	557,017,209	8,355,258
Network	1,318,665,108	19,779,977
Sum	**16,527,516,851**	**247,912,753**
Investment per TR	**150,402**	**2,256**

The results of annual cooling supply amount and operation fee for water and electricity are listed below.

Table 19: Annual cooling supply and operation fee

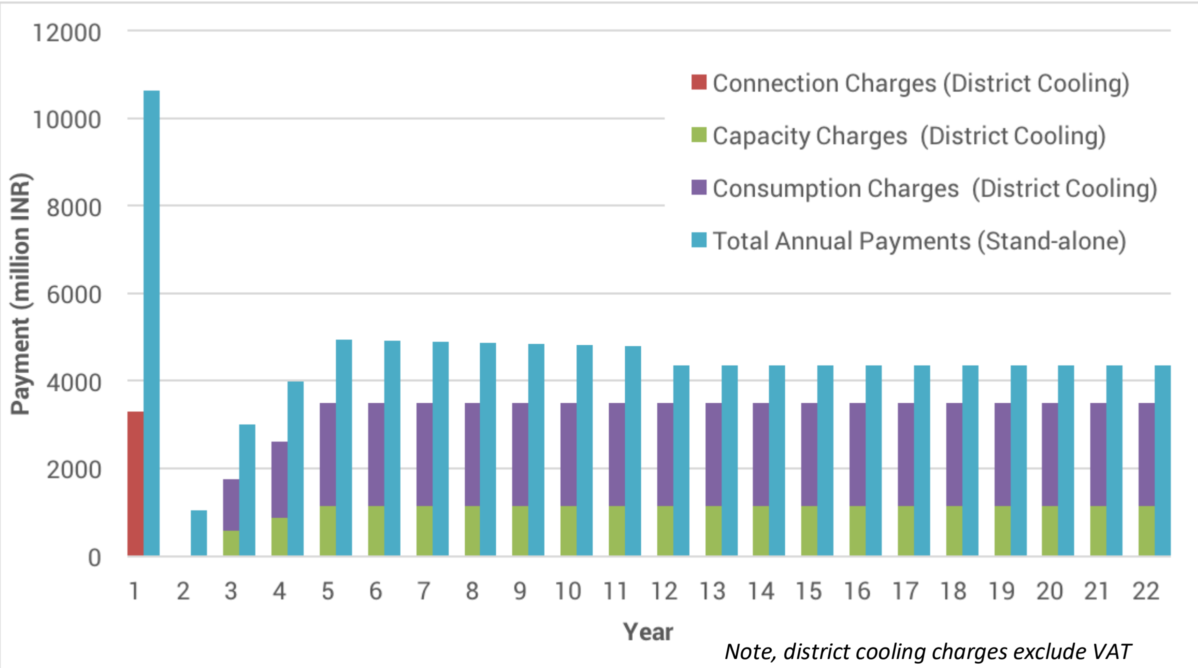
Annual cooling supply	kWh	381,270,892
Annual electricity consumption	kWh	108,407,987
Annual electricity fee	Rs.	1,235,162,867
	USD	18,527,443

Annual water consumption	m^3	3,122,150
Annual water fee	Rs.	1,092,752,514
	USD	16,391,288

Financial results

The economic analysis shows that when a metering charge equal to 0.15 USD/TR.h (10.0 INR/TR.h) is charged, the IRR of this project reaches 11% with a payback period of 15 years. This value is used as a baseline in this project for further economic analysis. As described in Section 11.2, this metering charge has been set to be 20% below the stand-alone costs for cooling. In reality, in order to attract and secure customer connections, the metering charge may be lower, lowering the IRR but ensuring load risk is minimised. Figure 34 shows the total payments made by all stand-alone consumers if they were to connect to district cooling or use their stand-alone systems.

Figure 34: Cost comparison for consumers in CHIL-SEZ for district cooling vs. stand-alone systems



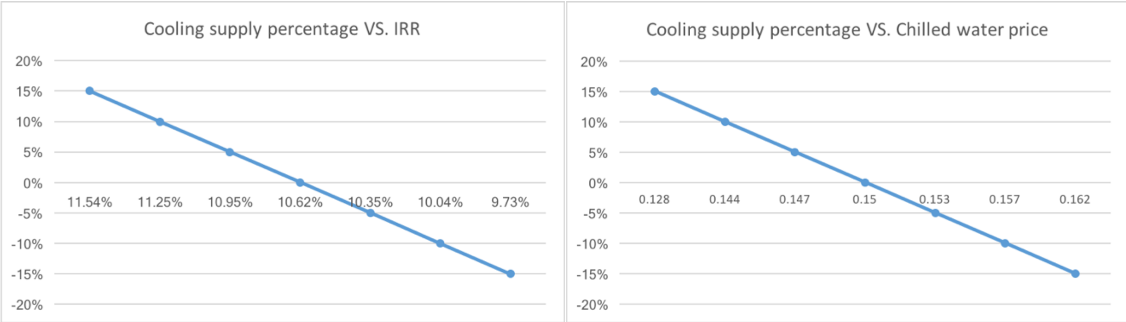
Sensitivity analysis

In this section, the results of a sensitivity analysis examining the impact of VAT

- Sensitivity analysis on cooling demand

The sensitivity analysis results of cooling demand, from +15% to -15%, are shown in the figure below.

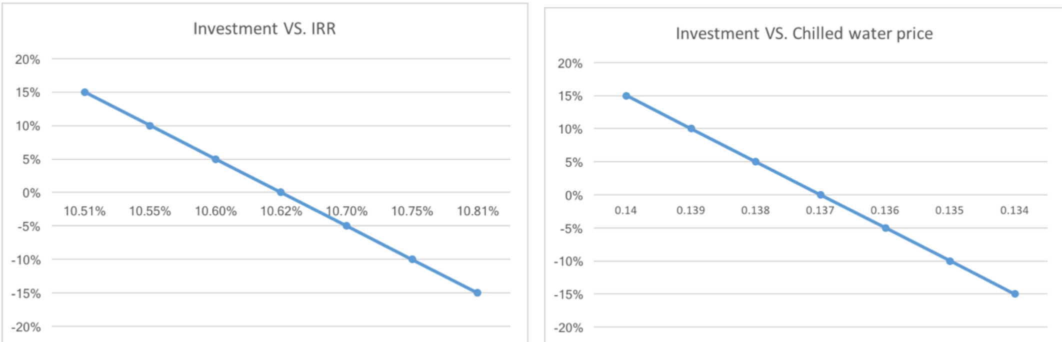
Figure 35: Sensitivity analysis results of changing cooling demand in CHIL-SEZ



➢ Sensitivity analysis on capital costs

The sensitivity analysis results of investment, from +15% to -15%, are shown in the figure below.

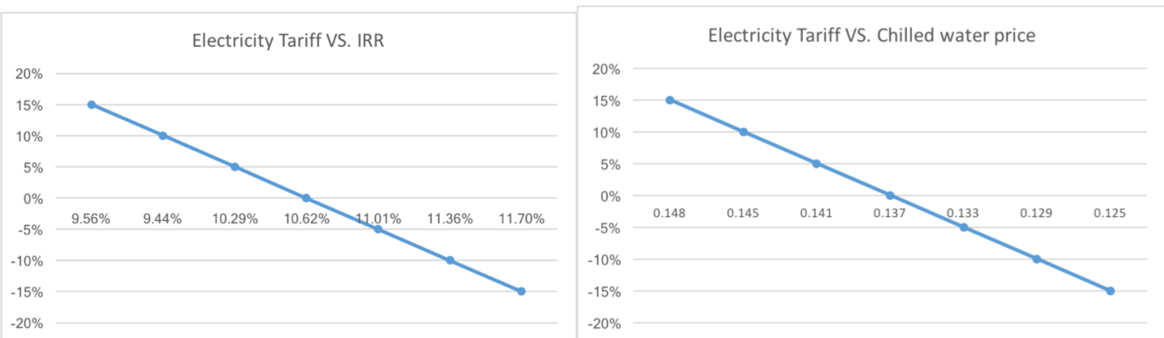
Figure 36: Sensitivity analysis results of changing capital costs in CHIL-SEZ



➢ Sensitivity analysis on electricity tariff

The sensitivity analysis results on electricity tariff, changing the tariff paid by the district cooling system by +15% to -15%, are shown in the figure below. The tariff paid for by stand-alone systems was not changed.

Figure 37: Sensitivity analysis results of changing electricity prices in CHIL-SEZ



➢ Sensitivity analysis on reduced VAT payments.

VAT payments that could be charged to a district cooling system are not included in the analysis as they are currently unknown. To account for this, a conservative 'buffer' has been set so that the annual payments made to a district cooling system are 20% below stand-alone payments (this is also described in previous sections). Some countries (e.g. France) have lowered VAT on district energy systems to help promote the technology and some argue that district energy systems should not be subject to high rates of VAT as it can make it more difficult to compete with stand-alone consumers who only pay VAT on electricity, and not on the cooling they produce.

Given that the IRR in Coimbatore is relatively low, the VAT (which could be set at state-level like for electricity) could be set at a relatively low value to encourage district cooling projects. The below analysis shows what happens to the IRR when the buffer zone of 20% is reduced[35] by adjusting the chilled water price:

Buffer between DC payment and stand-alone payment	Chilled water price (USD/TR.hr)	IRR	Payback period
20%	0.137	10.62%	15 years
10%	0.163	13.0%	13 years
0%	0.189	15.2%	11 years

Comparing with all these three groups of figures, it can be found that the values of chilled water price and IRR are most sensitive to the change of electricity tariff and to a lesser extent, cooling demand. They are not quite as sensitive to the change of capital costs. The IRR is very sensitive to the VAT set, indicating that VAT could be used to increase the IRR for district cooling in Gujarat.

The viability of connecting thermal energy storage to the CHIL-SEZ project is presented in Section 11.4 below.

The specific benefits of connecting the CHIL-SEZ to district cooling are presented in Section 11.5 below.

Recommendations for CHIL-SEZ

- Project pre-feasibility of the CHIL-SEZ is recommended and further consultation with the private developer. The private developer could offer district cooling as a service, providing better cooling for customers and receiving long-term steady revenues from the real estate project. The private developer could use district cooling to attract tenants seeking sustainable premises.
- Project re-design and pre-feasibility is needed to identify commercially viable solution. Low power prices make business case of district cooling difficult in Coimbatore as energy efficiency does not deliver returns as in other cities. Project re-design could explore:
    - reducing capital cost of district cooling below that of stand-alone
    - increasing connection charges paid by building owners to above 20% of initial CAPEX
    - identify low-cost financing

[35] Strictly speaking the buffer zone cannot be considered the same as VAT as any VAT payments paid on electricity by the district cooling system may be reimbursed in lieu of VAT on chilled water. As such, a VAT on chilled water of 20% may only need a buffer of 10-15%, dependent on the VAT rate on electricity. However, we have set the buffer at 20% to keep analysis conservative and given the fact that some cost reduction to consumers should still be considered.

- ensure VAT on chilled water is low
- special electricity tariffs provided

As the project is outside Coimbatore city's jurisdiction, the wider planning bodies at the metropolitan and state-level could use their significant planning authority to promote centralised cooling and district cooling, possibly through increased FAR allowances. This could be linked to existing benefits provided as it is a SEZ.

11.3.3 Site 2: CODISSIA Trade Fair Complex and TIDEL Park

1. The CODISSA Trade Fair Complex is a renowned trade fair centre and exhibition venue located on the Avinashi road in Coimbatore. The Avinashi road is a prominent location in the city having a diverse mix of commercial, residential, educational, and retail developments.

   The complex spans 1.7 million sq. ft. and has 5 air conditioned halls spread over 204,000 sq. ft. for conducting indoor events, seminars and meetings. Floor area of exhibition halls is around 200,000 sq. ft. The complex also has open space of over 200,000 sq. ft. to host large outdoor events.

Table 20: Specifications of the site

Facilities & Services	Area (sq. ft.)	Room Size	Room Height (sqm)
Hall A	26,900	2500	50m x 50m
Hall B	53,800	5000	100m x 50m
Hall C	26,900	2500	50m x 50m
Hall D	53,800	5000	100m x 50m
Hall E	43,040	4000	100m x 40m
Exhibition Hall	202,288	18800	
Open Air theatre	21,520	2000	
Open Ground Space	204,440	19000	

Figure 38: CODISSIA Trade Fair complex

Figure 39: CODISSIA Trade Fair complex layout

TIDEL Park

The TIDEL Park is a 7-storey IT-SEZ on Avinashi Road located behind Coimbatore Medical College. TIDEL Park is spread over 9.5 acres, with a total built-up area of 1.7 million sq. ft. The site has a central air conditioning system with 4000 TR Chillers and Thermal Energy storage of 6000 TR.

The park has a 30m wide approach road from the Avinashi Road (NH-47). The Wipro campus is located on the western side of the site while on the eastern side are TCS and HCL campuses. The TIDEL Park has achieved occupancy of 90%, with around 45 clients (including 17 SMEs) occupying a space of 821,00 sq. ft., out of the total IT space of 914,000 sq. ft.

The area of a typical floor is 202,665 sq. ft. and the building is designed as three blocks and ten modules of office space per floor. The TIDEL Park building is a G+ 4 structure with three basements with a floor to floor height of 3,650 mm. The total height of the building is 20.5m above ground level. Office spaces are located from the first floor up to the fourth floor.

The IT Building has the following common facilities on the Ground Floor:

1. Cafeteria / Food Court with kitchen facilities with seating capacity of about 1,000 persons.
2. Customer Conference Rooms (video conference) / Training Centre.
3. Post Office, Medical Stores, Banks & Insurance.
4. ATMs, Telephones, Meeting rooms, EPABX, Mail Box, Book store.
5. Travel Desk, Mail & Courier Service, Cloak room, Doctor's room & Fitness / health centre.
6. Confidential Store, Bonded warehouse.
7. 24 x 7 - Maintenance staff / Facility manager.
8. Usability Lab, Console room, Business Centre.
9. Security & Fire prevention/ Central Services.

The Basement has space for support facilities such as Engineering store and M/E services and common spaces for contract staff.

- Electrical: Power supply by 5 Nos. x 2500 KVA Transformer from TNEB sub-station (110/33 KV)
- Backup Diesel Generators: 100% backup power by 5 Nos. x 2000 KVA DG Sets.
- Intelligent Building Management Systems (IBMS)
- Exteriors: Structural Glazing System, the wall cladding with Aluminium Composite Panel (ACP) & Granite and Entrance Lobby glazing with sliding door.

Figure 40: Location of TIDEL Park

Table 21: Lease structure for TIDEL Park

Short Term Lease Structure	
Particulars	Values
Lease Term	5 to 9 Years
Rentals	Rs.25 per sq. ft. per month
Refundable Security Deposits	6 months rental
O&M	Rs.5.51 per sq. ft. per month (2013-14)
Air Conditioning	Rs. 6 to 7 per sq. ft. per month
Energy	Rs. 6 to 7 per sq. ft. per month
Total Facility Cost	Rs. 42 to 44 per sq. ft. per month
Concessional rent for 50,000 Sq. ft and above	Rs.23 / - per Sq. ft per Month

Long Term Lease Structure:				
Lease Term	15 Years	20 Years	25 Years	30 Years
Rental (Per sq. ft.)	2548	2943	3215	3402
Avg. monthly rental	14.16	12.26	10.72	9.45
O&M	Rs.5.51 per sq. ft. per month (2013-14)			
Air Conditioning	Rs. 6 to 7 per sq. ft. per month			
Energy	Rs. 6 to 7 per sq. ft. per month			
Total Facility Cost	Rs. 42 to 44 per sq. ft. per month			

Figure 41: Occupancy at TIDEL Park

TIDEL PARK COIMBATORE LTD. (As on 28.1.16)

FLR	MODULES 1	2	3	4	5	6	7	8	9	10	Vacant space
IV	SKAVA	STATE STREET	NAME CHEAP	VISION ARY	17,165	ACCESS HEALTH		DEVELOPMENT CENTRE (Launch Mid 2016)			17,165
III	CAMERON				SOLITON	CAMERON	TECHN OSOFT	NEXT	ASEC	TEXILA	0
II	STATESTREET HCL				BOSCH	STATE STREET HCL	BOSCH				0
I	TIDEL, ASEC	KAVIN	MERRILL	EXTERRO	VISIONET	S&T	PAYODA	SKAVA	PAYODA		0
Gr.	OWLER, AARBEE	KOVAI, INFORMATION	SRJ, CREGEN	BOSCH	ENVISION, INDMAX, PROLOGIQ	KMIT	SMEs and Support Services				0

Development Centre – 68,645 Sq.ft

- ⇒ Total IT Space : 9.14 Lakh Sq.ft
- ⇒ Space Concluded : 8.21 Lakh Sq.ft
- ⇒ % concluded : 90%
- ⇒ Balance Space : 17,165 Sq.ft

Figure 42: Photographs of TIDEL Park

Site selection criteria for CODISSIA Trade Fair Complex and TIDEL Park

CODISSIA Trade Fair Complex and TIDEL Park	
Technical requirements	1. The TIDEL Park has substantial cooling demand and uses a 4000 TR water cooled chiller and thermal energy storage of 6000 TR 2. Cooling demand for the CODISSIA Trade fair complex is significant
Availability of anchor loads with continuous load and diverse buildings can be connected	The site has a good mix of diverse buildings such as trade centre, large IT office space and educational institutes. Anchor load is available in the form of the TIDEL Park, which has 914,000 sq. ft. of floor space and a cooling load of 4,000 TR.
Potential for longer-term network expansion	The site is located on the Avinashi road having a diverse mix of commercial, residential, educational, and retail developments
Existing situation of buildings	The buildings have already been constructed. The TIDEL Park uses centralized air conditioning
Influence from local government	The CCMC can be a main stakeholder to facilitate further dialogue to demonstrate the viability and benefits of establishing a district cooling network in the city. The CCMC can also help integrate policies, regulations and incentives in its local development regulations to promote uptake of district cooling.

11.3.4 How district cooling could be retrofitted into the area

Since these two sites are located in proximity to one another (approximately 1-1.5km apart dependent on route), it may be possible to combine them to consider a district cooling system for the whole area. According to the information obtained by local partners and satellite images, there is lots of greenfield sites between the two existing buildings. If a pre-feasibility study indicates that it is possible to have district cooling even with the lower power prices in Coimbatore, the future development of nearby buildings should include a highly diverse mix of commercial, educational, residential and retail ones to ensure commercial viability.

Both of the buildings of CODISSIA Trade Fair Complex and TIDEL Park have installed centralized air conditioning system. Furthermore, the building of TIDEL Park even has a thermal energy storage (TES) system. Meanwhile, the TIDEL Park buildings have high occupation and have a very clear leasing structure, which is clearly stating the air-conditioning fee on the basis of square feet monthly.

There are several technical options for district cooling system development in the region, mainly for upgrading the cooling systems with higher efficient ones in the future.

For the local urban planning authority, in order to secure the cooling demand of district cooling system, some regulations of the regions nearby these buildings are required:

1) As much as possible, the greenfield sites adjacent to these existing buildings should be set aside for commercial buildings
2) The FAR of this area should not be less than 2.5 to encourage dense development
3) Extra space for a chilled water network should be considered in all road development and space should also be set aside along the main road.
4) The land for a district cooling plant should be reserved. However, the plant can be constructed completely underground with some open space used for cooling towers. Or the plant could be integrated with other public service facilities, such as bus terminals etc.

The retrofitting of this urban area to have district cooling could take place as follows:

- **Step 1:** When new, high potential development begins in the area, construct pipelines to connect the chillers inside existing buildings. The district cooling system can use these existing chillers to cool the existing buildings and to produce chilled water during off-peak periods, which for the existing buildings is principally during the night time. The chilled water produced during off-peak hours can be stored in thermal storage (TES) located inside the district cooling plant or together with the existing TES system in TIDEL Park and used to supply cooling for new or nearby end-users during peak periods. A prefeasibility study should be taken to compare the cost-effectiveness of different kinds of TES systems, including chilled water, ice ball and ice coil technologies.
- **Step 2:** When the operational efficiency of existing chillers begins to fall, slowly replace the existing chillers with chilled water supplied by the district cooling system.
- **Step 3:** Install new chillers with higher efficiency in district cooling system to supply chilled water for both existing buildings and new buildings.

By combining the existing chillers to the district cooling system and connecting the already-occupied buildings, the level of investment needed will be over a longer period than for a totally new district cooling system which may make financing easier, while the income of district cooling system is somehow secured. A deep dive for this potential technical solution should be undertaken and the real cooling demand for these existing buildings should be monitored to better understand the profitable potential of district cooling system development. And the district cooling system should seek for possible connections with other existing buildings as well, like the medical college.

11.4 The potential of thermal energy storage (TES)

Thermal energy storage (TES) is considered to be one of the energy efficient technologies used in many modern district energy systems. TES can reduce the costs of operation and at the same time dramatically lower peak power demand, securing upstream benefits such as reduced grid investment and grid stress. However, due to the extra investment required for TES (on average, systems with TES have a 20%-40% higher CAPEX than a normal district cooling system), it is often required to lower the electricity tariff, especially the off-peak price, to make TES cost-effective. This lowering of the off-peak price to ensure TES is cost-effective can be justified by utilities and tariff regulators as TES lowers the power demand during peak periods, playing an important role in balancing the power system and lowering overall system costs.

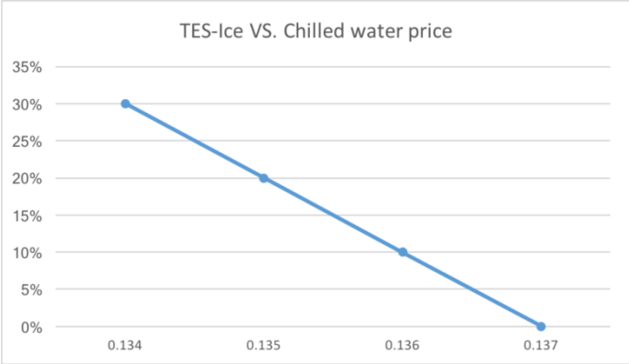
Based on the current electricity tariff in Coimbatore and the situation of this project, ice storage is considered as a potential TES technology to use in a district cooling system because it has the highest cooling storage density amongst the TES technologies and as such requires far less land as compared to chilled water storage. Due to lack of information on similar projects in India, the cost of such a system are estimated based on applications in nearby countries, like China, Malaysia and Singapore. The extra costs of ice storage are listed below in **Error! Reference source not found.**. The COP of ice storage under off-peak period is set to be 1.76 KW/TR. For example, if a 10,000TR district cooling plant wanted to have 20% TES ice storage an additional investment of 3.2 million USD (1,631USD/TR x 20% x 10,000TR) would be required.

Table 22: Investment costs for various elements of an ice-storage system

TES-ICE		Chiller	Ice coil	Cooling Tower	Pumps	Heat exchanger	Control system	Construction	Other	Sum
Increased investment	USD/TR	280.0	280.0	120.0	150.0	180.0	125.0	170.0	25%	1631
	USD/kW	79.6	79.6	34.1	42.6	51.2	35.5	48.3	25%	464

The results for different coverage ratios of ice TES for peak load periods, ranging from 0% to 30%, are shown below in Figure 43 as tested on the CHIL-SEZ project. This shows that the application of TES results in a slightly lower chilled water price under a fixed IRR.

Figure 43: Sensitivity analysis results of coverage ratio of ice TES for peak period



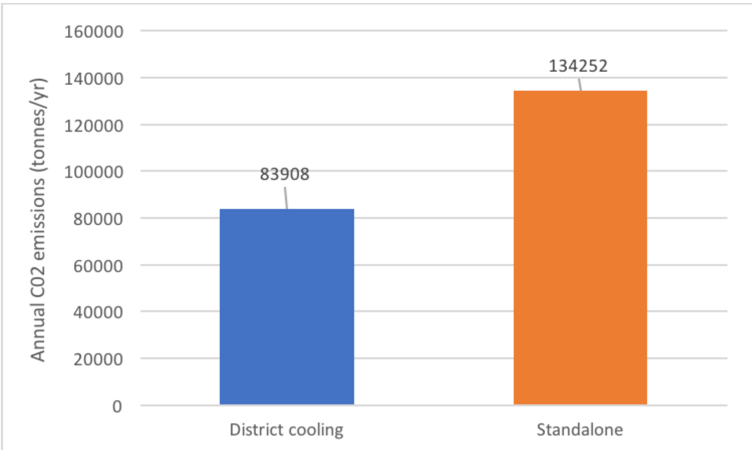
Centralised thermal storage and the increased peak shaving it can achieve is one of the key benefits of district cooling. While the results show that TES would be cost-effective, it is highly recommended that this analysis is repeated in more detail during a pre-feasibility study of a specific phase of CHILE-SEZ development. It may be that given the low IRR of the project, additional investment for TES cannot be justified – in such a case, in order to make the TES system cost-effective so that the whole electrical grid can benefit from the peak load shifting, it would be suggested to establish a special subsidy on the electricity price for the off-peak period for TES.

11.5 Benefits of district cooling

Environmental benefits

Because district cooling systems can save electricity and water during operation and improve management and use of refrigerants they have significant benefits for the environment. Conservative estimates for CO_2 savings from the CHIL-SEZ project are 50345 tons per year[36], as shown below in Figure 44. Due to a lack of data for CO_2 emissions for water supply, this contribution is not included.

Figure 44: CO2 emission comparison for stand-alone and district cooling in CHIL-SEZ



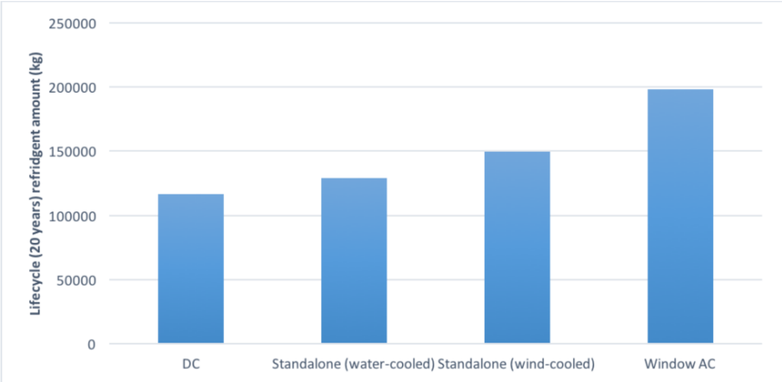
Electricity savings of 65.0GWh of electricity annually (33% reduction from stand-alone) are expected.

[36] Calculated using: http://www.carbon-calculator.org.uk/

The CO_2 savings and electricity savings can be increased significantly by connecting renewable and waste heat resources.

The district cooling system can also contribute to refrigerant phasing out, due to reduced cooling capacity in the whole district. Over the lifetime this is expected to be 12.03 tonnes, as compared to water-cooled chillers. The calculated results are shown below.

Figure 45: Lifecycle refrigerant comparison for district cooling vs. stand-alone solutions in CHIL-SEZ



This graph does not account for the increased refrigerant leaks that can occur for stand-alone chillers and air conditioners through poor operation and maintenance and shows only the refrigerant requirements for well-maintained systems. Refrigerant reduction can be increased even further by using renewable resources, like absorption chillers connected to waste heat, to replace baseload chillers in the district cooling system. For example, Paris through the use of free-cooling and improved management and use of refrigerants has reduced refrigerant consumption relative to stand-alone chillers by 90%.

In general, for electricity-based district cooling systems without thermal energy storage, Coimbatore can expect the following environmental benefits (these are also set out for the generic project above). It should be noted that the inclusion of renewable and waste heat sources could reduce electricity demand and subsequent CO_2 emissions by more than 50%. Thermal energy storage with an electricity-based district cooling system could reduce peak power demand by up to 50% relative to stand-alone chillers, dependent on the size of TES.

Table 23: Environmental benefits of an electricity-based district cooling system

CO_2 savings	30-35%
Life cycle refrigerant saving (20 years)	10-15%
Water savings (compared to water-cooled chillers)	15-20%
Electricity demand reduction.	30-35%
Peak power demand reduction	30-35%

Economic and social benefits

For end-users of cooling services, the annual payment for cooling is critical. For the district cooling system in CHIL-SEZ, end-users can be charged less for cooling than they would if they were using stand-alone systems. As described in Box 10, the service and reliability of cooling will be improved, end-users do not have to maintain complex cooling systems, buildings can have improved environmental credentials or certifications, space can be made available on rooftops and in basements (as cooling system would now be outside the building) for solar power, roof terraces, basement leisure centres etc. and buildings would require a smaller power connection, saving money.

The district cooling operator can to an extent lower tariffs for different end-users to ensure their connection if their costs for stand-alone cooling are lower than those presented in Figure 34 above. The district cooling operator and end-user can typically have a dialogue to ensure both agree that district cooling is providing a more cost-effective service. As different building types may be subject to differing electricity tariffs (for example public buildings and residential buildings will pay lower electricity tariffs) such negotiation and flexibility in tariffs is crucial. If Coimbatore has a stake in the district cooling project, or is providing specific incentives, it could influence expansion of the network to include socially and economically important buildings such as new hospitals, schools, campuses, public offices etc.

Furthermore, by delivering energy efficiency, district cooling can retain wealth in the local economy with lower electricity payments made to the state level and jobs created in the city.

12 Summary and Conclusion

From the high-level analysis conducted in this assessment, it is concluded that district cooling would not be commercially viable in Coimbatore unless power prices paid for district cooling projects can be lowered or the VAT paid on chilled water removed or other major incentives provided. For well-designed projects with a high share of office space, such as CHIL-SEZ there is potential and the city should pursue a pre-feasibility study of this site. District cooling can deliver significant benefits to the environment, consumers and the local economy which may not be priced into commercial business models – these benefits could justify provision of incentives in Coimbatore to accelerate district cooling.

Coimbatore can build upon the examples of other cities globally that have promoted district energy successfully; across these cities the role of local government is crucial and will require dedicated human resources in CCMC to work on the range of best practices recommended throughout this report. The risk can be that without strong local government intervention, district cooling systems are isolated, do not expand and do not reach their full potential of incorporating renewables and efficient solutions.

Dedicating human resources in local governments can be difficult due to tight city budgets; if Coimbatore can monetise direct benefits from district cooling, this increased human resources can be justified. This could be through direct participation of CCMC in the business model of district cooling or indirectly, for example through solar sales to the district cooling provider or concession fees if a concession area is established.

The role of national and state-level government and institutions in district cooling will be hugely significant. Across the world, interventions of higher levels of government have been crucial to accelerate district energy. This can include: removing regulatory or policy barriers that may occur during subsequent stages of project development, incentivising project development through grants and provision of expertise, setting guidelines of when district cooling should be assessed and incorporating district energy under national strategies and initiatives.

From analysis across the cities assessed in India under the District Energy in Cities Initiative it is clear that district cooling's time has come in India. With the correct incentives and well-designed projects, Coimbatore has an opportunity to be at the forefront of this technology's advancement and could set an example to cities across India and internationally on how to develop, promote and benefit from district cooling. As a signed-up city of the District Energy in Cities Initiative, Coimbatore will be supported by a range of cities, industry, academia, NGOs and banks committed to seeing district energy's success in India and globally.

13 Recommended Next Steps for CCMC

Throughout this rapid assessment, policies and actions have been recommended to CCMC that will help to accelerate district cooling in the city through improved coordination, mapping, project identification, policy development and incentive setting. These recommendations build on best practices identified in 45 champion cities for district energy around the world and published in the 2015 UN Environment report 'District Energy in Cities: Unlocking the Potential for Energy Efficiency and Renewable Energy' which is available online[37].

The recommended next steps to Coimbatore are summarised below. Further detail can be found in the report:

CHIL-SEZ as a demonstration project

- Project pre-feasibility of the CHIL-SEZ is recommended and further consultation with the private developer. The private developer could offer district cooling as a service, providing better cooling for customers and receiving long-term steady revenues from the real estate project. The private developer could use district cooling to attract tenants seeking sustainable premises.
- Project re-design and pre-feasibility is needed to identify commercially viable solution. Low power prices (see Figure 4) make business case of district cooling difficult in Coimbatore as energy efficiency does not deliver returns as in other cities. Project re-design could explore:
    - reducing capital cost of district cooling below that of stand-alone

[37] Available from: http://www.districtenergyinitiative.org/publications

    - increasing connection charges paid by building owners to above 20% of initial CAPEX
    - identify low-cost financing
    - ensure VAT on chilled water is low
    - special electricity tariffs provided
- As the project is outside Coimbatore city's jurisdiction, the wider planning bodies at the metropolitan and state-level could use their significant planning authority to promote centralised cooling and district cooling, possibly through increased FAR allowances. This could be linked to existing benefits provided as it is a SEZ.
- Stakeholder consultations to identify potential business models and develop a procurement plan
- Dependent on the chosen business model, attract funding for a feasibility study (e.g. multi-lateral development banks, state and national-level grants etc.)

Based on a full project pre-feasibility of the CHIL-SEZ site Coimbatore and analysis of whether incentives such as reduced power prices or a VAT rate lower than 20% on chilled water are feasibly, Coimbatore should make a decision on whether to promote district cooling in the city, if it does, the following city-wide actions are recommended:

City-wide actions (short-term)

- Establish a multi-stakeholder coordination group (Box 3)
- GIS energy mapping and development of district cooling benchmarks including metering of cooling demand (Boxes 3 and 9)
- Analysis of business-as-usual cooling demand and impacts as well as district cooling's potential to meet city goals and objectives, including Smart City Plan and Solar City Master Plan
- Identify opportunities and establish 'high priority' and 'medium priority' zones to promote district cooling (Box 4)

City-wide action (medium-term)

- Establish a 'sustainable energy delivery unit' or include within the Smart City SPV
- Support piloting of innovative district cooling applications, e.g. Thermal Energy Storage (TES), waste heat connections, solar power and Treated Sewage Effluent to reduce water consumption
- Incorporation of district cooling into existing city strategies and targets. Set targets specifically for the district cooling sector (Box 3)
- Apply specific conditions on building permitting in zones through the DCR (Box 4 and Box 6)
- Consider developing density bonuses using FSI premium payments in DCR (Box 5)
- Mandate that specific building types are developed as 'district cooling ready' (Box 5)
- Use public buildings to anchor new district cooling development (Box 4)
- If required, establish franchise zones or concession areas for district cooling (Box 4)

14 Annexures

14.1 Power tariff structure applicable in Coimbatore

Table 24: TNEB Revised Tariff rates with effect from 23.05.2016 payable by the Consumer for Coimbatore City

Tariff	Category of Consumers & slabs		Energy Charges (Rs/unit)	Fixed Charges for two months(Rs)	Energy Charges (Rs/unit) Govt's subsidy	Fixed Charges for two months(Rs) after Govt's subsidy
	Domestic , Handloom, Old age homes, Consulting rooms, Nutritious Meals Centres etc.					
	Consumption up to 100 units bi-monthly					
	(100 units free scheme)	0-100 units	3.00	30/service	0	0
	Consumption above 100 units and up to 200 units bi-monthly					
	(100 units free scheme)	0-100 units			0	
		101-200 units	3.25	30/service	1.50	20/service
#I-A	Consumption above 200 units and up to 500 units bi-monthly	0-100 units			0	
	(100 units free scheme)	101-200 units	3.50		2.00	
		201 to 500 units	4.60	40/service	3.00	30/service
	Consumption above 500 units bi-monthly					
	(100 units free scheme)	0-100 units				
		101-200 units	3.50		0	
		201 to 500 units	4.60		3.50	
		above 500 units	6.60	50/service	4.60	
					6.60	50/service
	For Handlooms in residence, 0 to 200 units bimonthly is free.					

	(Above 200 units bi-monthly, the corresponding slab in the domestic tariff is applicable)					
*I-B	Huts in village panchayats, TAHDCO:- Till installation of meters (Fully subsidized by the Govt.)		0	290/service	0	0
	On installation of meters (Fully subsided by the Govt.)		4.95	0	0	0
I-C	L.T. Bulk supply to residential Colonies of Railway, Defense , Police quarters etc.		4.60	120/service	4.60	120/service
II-A	Public lighting by Govt./Local bodies, Public water supply, Sewerage etc.,		6.35	120/kW	6.35	120/kW
II-B(1)	Govt and Govt. aided Educational Institutions, Govt. Hospitals and Research labs, etc.		5.75	120/kW	5.75	120/kW
II-B(2)	Private Educational Institutions & Hostels		7.50	120/kW	7.50	120/kW
#II-C	Actual Places of Public worship(Bi-monthly)	0-120 units	5.75	120/kW	2.85	120/kW
		Above 120 units	5.75	120/kW	5.75	120/kW
III-A(1)	Cottage and Tiny Industries, Agricultural and allied activities, Sericulture, Floriculture,					
	Horticulture and Fish/Prawn culture etc. (up to 10HP)(Bi-monthly)	up to 500 units	4.00		4.00	
		above 500 units	4.60	40/kW	4.60	40/kW
# III-A(2)	Power Looms (up to 10 HP) incl. Winding etc.(Bi-monthly)	up to 500 units	5.20		0	0
	(750 units bimonthly is free)	501-750 units	5.75		0	0

		751-1000 units	5.75	120/kW	2.30	
		1001-1500 units	5.75		3.45	70/kW
		above 1500 units	5.75		4.60	
	Industries(Not covered under LT-III-A(1) & III-A(2)) , If the connected load of all		6.35		6.35	70/kW
III-B	industries in LT-III-A(1) & III-A(2) exceeds 10HP, welding sets and IT services etc.,					
	Agricultural, sericulture, floriculture, horticulture and fish/prawn culture etc., -			Rs.2875/HP/		
	Till installation of meters (Fully subsidized by the Govt.)		0	Annum	0	0
*IV	On installation of meters (Fully subsidized by the Govt.)		3.22	0	0	0
	Commercial (Not covered under LT-I-A, I-B, I-C, II-A, II-B(1), II-B(2), II-C,					
	III-A(1), III-A(2), III-B, IV and VI)					
	consumption up to 100 units bi-monthly	0-100 units	5.00	140/kW	5.00	140/kW
V	consumption above 100 units bi monthly	(for all units)	8.05	140/kW	8.05	140/kW
VI	For temporary activities, construction of buildings and Lavish illumination, additional					
	construction of beyond 2000 square feet in the premises of an existing consumer.	12.00		690/kW	12.00	690/kW

14.2 Details of CCMC's Funding Sources for Project Implementation

For meeting the funding requirement for implementing various projects, the main financial sources identified by CCMC includes:

a) Funding schemes by Central and State Government
   - Funding for smart city projects under the Smart City Mission (including grant funding from Government of India and matching funds from the State Government)
   - Funding allocated under the AMRUT Mission by the State Government for specific project components related to water supply and sewerage;
   - Funding allocated under the Swacch Bharat Mission (SBM) for sub-components such as the solid waste management and integrated waste to energy plants;
   - Funding under the Solar City Mission of MNRE for solar panel on rooftops of public buildings in Coimbatore;
   - Funding from devolution of 14th Financial Commission to the State Government;

b) Revenue surplus of CCMC or CCMC's own Funds

c) Projects on Public Private Partnerships (PPP)

14.3 Details of provision of Coimbatore GDCR with regards to energy efficiency and space cooling in buildings

Table 25: Permissible FSI for new development/re-development in Coimbatore (2002-2021)

Development Zone	Maximum permissible FSI	Maximum height of building
Residential	1.5	15 m or G+3 or stilt+4 floors
Group development[38]	1.5	G+2 or stilt+3 floors subject to a maximum of 12 m, 3.5 m on either side
Multi-storied buildings	1.5 - 2.5 maximum depending on building category which is based on the plot size and width of the road adjacent to the site	Exceeding 15 m or G+3 or stilt+4 floors and going up to G+8 or 60 m height subject the plot size and width of the road adjacent to the site
Commercial	1.5	15 m or G+3 or stilt+4 floors
Institutional zone, educational, Public and semi public	1.5	15 m or G+3 or stilt+4 floors
Hospital buildings	1.5 + 0.25 additional FSI	
Industrial	1	15m
IT development	1.5 times of the FSI ordinarily permissible for the respective zone	

[38] Signifies development that accommodates residential, commercial or institutional use in two or more block of buildings in a particular site

Source: (General Development Control Regulation, 2010)

'All centrally air conditioned buildings shall have their own waste water reclamation plant and use reclaimed wastewater for cooling purposes.'

14.4 Information Collected

Table 26: Weekly weather data for Coimbatore (2015)

Std wk	Date	Rain (mm)	Temperature (C)			RH %		Wind speed (kmph)	Sun shine (hrs)
			Max	Min	Grass min	700	1400		
1	Jan 01-07	3.7	29.1	18.8	14.6	86.9	47.1	5.4	290.5
2	Jan 08-14	1.3	29.3	18.9	14.9	87	46.4	5.2	294.8
3	Jan 15-21	3.4	29.8	18.5	14.1	86.8	44.7	5.6	302.8
4	Jan 22-28	0.1	30.5	17.7	14.8	86.2	37	5.6	326
5	Jan 29-04	0.5	31.1	18.2	14.5	85.1	36.9	5.5	315.2
6	Feb 05-11	1	31.7	19	14.7	82	38.2	6	311
7	Feb 12-18	2.7	32.6	19.7	13.4	83.1	35.6	5.8	307.7
8	Feb 19-25	3.7	33.4	19.7	15.6	81.5	34.6	5.9	339.8
9	Feb 26-04	2.5	33.9	19.6	15.5	79.7	30.3	6.5	334.1
10	Mar 05-11	7.2	46.9	19.7	15.6	79.9	31.2	6.2	331
11	Mar 12-18	2.9	34.6	21.1	16.6	80.7	31.9	6	328
12	Mar 19-25	1.5	35.6	21.5	17.5	81.1	31	5.9	331.6
13	Mar 26-04	2.8	35.7	22.3	18.4	81.7	33.5	6.2	322.4
14	Apr 02-08	6.5	35.6	23	20.1	81.4	36.4	5.9	306.3
15	Apr 09-15	9.8	35.2	23	20.1	82.9	39	5.7	308.4
16	Apr 16-22	17.7	35.5	23.3	20.6	83.1	40.1	5.9	316.5
17	Apr 23-29	11.7	35.6	23.8	20.7	82.9	40.5	5.8	318.5
18	Apr 30-06	18.5	35.4	23.7	20.8	83.4	43	5.8	307.5
19	May 07-13	15.9	35.5	23.5	21	82.8	41.1	6.1	313.6
20	May 14-20	16	34.9	23.6	20.9	80.9	43.7	8.2	311.2
21	May 21-27	11.9	34.8	23.9	20.9	81.2	45.7	8.1	307.9
22	May 28-03	7.8	34.3	23.4	21	81.1	49	8.9	305.4
23	June 04-10	6.6	32.7	23.4	20.9	78.8	51.4	12.6	281.2
24	June 11-17	6.5	31.7	23.3	20.4	75.4	53.1	16.8	267.5

Std wk	Date	Rain (mm)	Temperature (C)			RH %		Wind speed (kmph)	Sun shine (hrs)
			Max	Min	Grass min	700	1400		
25	June 18-24	8.4	31.5	23.2	20.5	75.6	53	18.1	278
26	June 25-01	12	31.4	22.9	20.7	77.1	52.8	18	284.1
27	July 02-08	13.7	31.8	22.6	20.5	79.2	51.3	15.7	276.5
28	July 09-15	14	31.2	22.7	20.4	79	53.4	16.6	261.9
29	July 16-22	8	30.7	22.7	20.4	77.9	55	16.2	265
30	July 23-29	13.6	30.8	22.2	20.5	81.4	55.2	14.9	258.3
31	July 30-05	6.4	31.2	22.7	20.4	80.8	53.7	14.6	259.9
32	Aug 06-12	7.9	31	22.4	20.2	80.4	54.7	15.1	263.1
33	Aug 13-19	9.7	31.4	22.6	20.1	78.9	53.7	15.7	270.8
34	Aug 20-26	9.5	31.7	22.2	19.9	81.7	53	12	276.1
35	Aug 27-02	7.2	31.5	21.9	20.1	84.1	50.9	11.7	295.4
36	Sep 03-09	6.1	32.2	21.9	19.4	83.4	48.7	10.4	302.2
37	Sep 10-16	13.8	32.2	21.9	19.7	83.9	50.3	8.8	307.7
38	Sep 17-23	19.2	32.3	22	19.6	84.8	52.2	8.7	294.5
39	Sep 24-30	23.8	31.9	21.9	19.6	86.5	52	7.3	283.3
40	Oct 01-07	26.1	31.3	22	19.9	86.7	58.1	9.1	270.5
41	Oct 08-14	31.6	31.3	22	19.2	87.3	55.4	5.5	284.6
42	Oct 15-21	40.1	31.1	21.5	20.1	88.4	56.1	4.8	270.4
43	Oct 22-28	43.5	30.4	21.4	19.4	89.5	59.6	4.5	270.6
44	Oct 29-04	41.6	28.4	21.5	19.5	88	60.6	4	269.6
45	Nov 05-11	39.5	29.1	21.1	18	89.1	63	4.2	264
46	Nov 12-18	33.4	29.6	20.8	18.1	87.5	57.8	3.9	286.2
47	Nov 19-25	26.8	29.4	20.7	18	88.4	56.2	4.3	265.3
48	Nov 26-02	11.8	29.2	19.3	17	87.7	54	4.5	288.1
49	Dec 03-09	22.2	28.6	19.3	16.3	88.3	54.6	5.3	288.3
50	Dec10-16	41.4	28.8	18.9	15.7	88.2	51.2	4.7	290.8
51	Dec 17-23	4	28.5	18.7	14.9	86.8	50.9	5.2	277.4
52	Dec 24-31	6.2	29	19.3	15.2	87.5	50	5.2	294.9

Source: (Tamil Nadu Agriculture University, Coimbatore, 2016)

Table 27: Monthly weather data for Coimbatore (Average over 1940-1990)

Month	Mean Temp °C		Mean Rainfall (mm)	Mean Number of Rain Days	RH (%)	Evapo-ration (mm)	Wind velocity (km/hr)	Sun-shine hours	Solar radiation (Cal/cm²/ day)
	Temp Minimum	Temp. Maximum							
Jan	17.9	29.4	14	0.7	61	4.3	5.4	8.7	469.5
Feb	18.5	31.8	9.2	0.6	55	5.1	5.5	9.5	491.6
Mar	20.5	34.5	17	1	50	6.2	7.6	9.9	483.6
Apr	23.8	35.2	52.7	3.5	54	6.6	4.6	8.6	444.6
May	23.2	34	66.5	4.7	55	6.7	3.7	8.2	428.9
Jun	22.9	31.6	42.8	3.9	56	5.8	13.4	5.8	419.6
Jul	22.2	30.1	68.5	5.2	55	5.1	12.7	4.6	435.1
Aug	22.2	30.1	30.1	3.3	62	6.4	11.2	5.8	387.6
Sep	21.8	29.3	68	4.2	63	5.6	6	5.2	436.5
Oct	21.4	31.6	146	8.9	72	4.6	2.8	6.3	369.2
Nov	20.2	29.2	118	6.6	73	3.1	2.5	6.1	414.5
Dec	17.9	29.4	41.4	3.2	77	4.3	2.8	8.7	369.2
Year	21	31.5	674.2	45.8	61	5.3	6.5	7.3	429.2

Source: (Tamil Nadu Agriculture University, Coimbatore, 2016)

Table 28: Monthly mean maximum & minimum temperature and total rainfall based upon 1901-2000 data

Station Name	Month	Period	No. of Years	Mean Temperature oC		Mean Rainfall in mm
				Maximum	Minimum	
Coimbatore	January	1948-2000	53	30.2	18.1	6.6
Coimbatore	February	1948-2000	53	32.9	19.2	8.9
Coimbatore	March	1948-2000	53	35.5	21.3	12
Coimbatore	April	1948-2000	53	36.2	23.3	49.4
Coimbatore	May	1948-2000	53	34.7	23.3	68.8
Coimbatore	June	1948-2000	53	32	22.3	84.4
Coimbatore	July	1948-2000	53	30.8	21.7	34.3
Coimbatore	August	1948-2000	53	31.3	21.7	28.4
Coimbatore	Sept.	1948-2000	53	32.2	21.8	57.3
Coimbatore	October	1948-2000	53	31.3	21.8	136.7
Coimbatore	Nov.	1948-2000	53	29.9	20.6	119.3
Coimbatore	Dec.	1948-2000	53	29.1	18.8	40.8

Source: (Indian Meteorological Department, Pune, 2016)

Table 29: Month-wise Maximum Temperature 0C in Coimbatore (2011-2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	30.1	31.6	33.5	33.4	34.2	30.7	30.7	31.5	31.9	31.6	28.7	29.3
2012	29.7	32.3	34.9	35.3	34.5	32.4	31.3	31.2	32.4	30.6	30.7	30.5
2013	31.6	31.9	34.2	35.9	35.4	30.6	30.1	31.3	31.2	31.5	29.8	29.2
2014	30.1	32.4	34.5	36.3	34.3	32.8	30.7	30.6	31.9	30.1	29.5	28.8
2015	30.1	32.2	34.5	34.3	32.7	32.3	32.2	32.3	33	31.6	28.6	29
2016	30.2	33.4										

Source: (Tamil Nadu Agriculture University, Coimbatore, 2016)

Table 30: Month-wise Minimum Temperature 0C in Coimbatore (2011-2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	19.0	18.4	20.7	22.9	23.0	23.0	23.2	22.9	22.2	22.6	20.8	19.1
2012	18.4	19.4	22.5	24.0	24.1	23.8	23.6	23.0	22.6	22.3	20.5	20.3
2013	19.0	20.7	22.8	24.5	24.5	23.3	23.2	22.6	22.6	21.7	22.3	19.8
2014	19.7	20.4	22.2	24.9	24.4	24.0	23.3	23.1	22.6	22.5	21.3	21.0
2015	19.5	20.0	23.1	24.0	23.5	23.7	22.9	23.2	23.8	23.3	22.0	21.5
2016	19.5	21.5										

Data Source: (Tamil Nadu Agriculture University, Coimbatore, 2016)

Table 31: Month-wise Relative Humidity (@ 0722 hrs) (%) (2011-2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	89	89	88	89	92	84	83	87	88	91	90	89
2012	89	83	84	86	87	78	79	83	84	87	89	85
2013	86	82	80	86	82	80	79	86	85	88	89	88
2014	84	79	74	81	85	78	78	84	85	93	90.1	88.5
2015	86	80	80	83	91	82	85	86	83	87	93	90
2016	86	81										

Source: (Tamil Nadu Agriculture University, Coimbatore, 2016)

Table 32: Month-wise Relative Humidity (@ 1422 hrs) (%) (2011-2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	44	40	35	49	52	57	57	57	59	59	61	52
2012	46	35	36	43	49	49	52	55	50	59	48	43
2013	35	38	37	42	45	57	61	55	58	57	59	51
2014	42	39	34	39.0	52	53	60	59	55	68	58	59
2015	47	35	35	47	61	55	50	51	47	52	71	62
2016	46	36										

Source: (Tamil Nadu Agriculture University, Coimbatore, 2016)

Table 33: Solar Radiation (cal.cm2/day) (2011-2016)

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2011	414.0	433.7	425.9	375.7	396.2	344.3	335.4	315.1	360.4	344.8	328.5	367.3
2012	416.3	420.2	416.8	369.6	379.1	368.0	354.1	318.8	364.1	301.6	391.3	381.5
2013	432.8	399.5	402.4	385.7	373.2	298.3	287.6	331.4	350.5	338.8	346.6	374.2
2014	406.3	400.0	413.3	380.7	352.6	395.4	415.8	322.3	360.8	290.5	310.5	304.3
2015	391.4	426.4	401.4	359.6	323.3	337.1	405.5	353.8	356.5	356.7	275.0	344.0
2016	385.0	413.1										

Source: (Tamil Nadu Agriculture University, Coimbatore, 2016)

Table 34: Monthly electricity consumption, Coimbatore Metro – 2015

Consumer Category	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
Domestic/Residential	57.43	56.54	56.47	56.64	57.15	59.85	59.7	59.34	60.5	61.67	63.13	62.33
Bulk Supply	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Local Body(St.Lt, Water Supply)	0.18	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.2	0.21
Govt Edn Institutions	3.72	3.64	3.63	3.69	3.79	3.92	3.95	3.88	3.85	3.88	3.88	3.89
Private Edn Institutions	0.31	0.32	0.32	0.3	0.21	0.22	0.33	0.31	0.33	0.33	0.33	0.33
Public Worship	0.77	0.78	0.79	0.71	0.5	0.52	0.78	0.75	0.79	0.78	0.79	0.8
Tiny Industries	0.16	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
LT Industries	25.92	26.1	26.13	26.76	27.49	28.44	28.64	28.13	27.93	28.1	28.13	28.2
Commercial	26.37	25.97	25.5	25.47	25.9	26.53	26.7	27.2	28.19	28.69	28.79	28.52
Temporary Supply	0.39	0.36	0.42	0.43	0.44	0.45	0.45	0.46	0.48	0.49	0.49	0.48
All Tariff	71.95	70.67	70.5	70.03	70.66	73.99	73.81	73.36	74.81	76.25	78.05	77.06
Total	**187.25**	**184.75**	**184.13**	**184.4**	**186.53**	**194.32**	**194.76**	**193.83**	**197.29**	**200.6**	**204.01**	**202.04**

Source: (TNEB Regional Metro Office, Coimbatore, 2015)

Table 35: List of Large Buildings Approved by the DTCP and LPA for the year 2016-17

Building/Name of the Person for Registration	Site Area in sq. m.	Administrative Ward Number	Location with respect to Area (Indicative Zone/Direction)	Location with respect to City limits
Commercial Buildings				
M/S. Alliance Mall Developers Coimbatore LPA/ Corporation, Co pvt. Ltd.,	99,550	29	Sivanandha Mills near Ganapathy – Sathy Road (North)	Within City Limits
Educational Buildings				
Mrs. Seema Senthil	13,800	98	Podanur near Pollachi Road (South)	Within City Limits
Mr.V.Narayanaswamy	25,535	Not applicable	Details insufficient	Out of City Limits
M/S. Madha	28,368	Not applicable	Details insufficient	Out of City Limits
Mr. P.Raju & Tmt, R.Vijayalakshmi Raju	31,577	45	Sanganoor, between Mettupalayam and Sathy Road (North)	Within City Limits
A.V.B. Matriculation Higher Secondary School	36,435	Not applicable	Details insufficient	Out of City Limits
M/S. Nehru College of Educational & Charitable Trust	69,200	93	Palakkad Road (South)	Within City Limits
Shri. SNS Charitable Trust	110,641	26	Mettupalayam Road (North)	Within City Limits
M/S. SNR Sons Charitable Trust	130,473	40	Avinashi Road(North East)	Within City Limits
M/S. PS Govindhasawamy Naidu & Sons Charities	134,344	38	Avinashi Road (North East)	Within City Limits
M/S/PSG & Sons Charities	146,008	Not applicable	Details insufficient	Out of City Limits
Managing Trustee, Kovai Kalaimagal Educational Trust	218,240	Not applicable	Details insufficient	Out of City Limits

Building/Name of the Person for Registration	Site Area in sq. m.	Administrative Ward Number	Location with respect to Area (Indicative Zone/Direction)	Location with respect to City limits
M/S.VLB Trust	234,155	91	Kuniamuthur, Palakkad Road (South)	Within City Limits
M/S. VLB Trust	311,053	91	Kuniamuthur, Palakkad Road (South)	Within City Limits
Managing Trustee, PSG & Son's Charities	516,383	38	Peelamedu, Avinashi Road (North East)	Within City Limits
Industrial Buildings				
M/s. Raja Magnetics Ltd.	17,550	Not applicable	Details insufficient	Out of City Limits
Mr. N.Govindarajan	37,796	Not applicable	Details insufficient	Out of City Limits
K.Srinivasan	40,850	Not applicable	Details insufficient	Out of City Limits
M/S. Global Textile Alliance India Pvt., LTD.	45,350	Not applicable	Details insufficient	Out of City Limits
M/s. Premier Fine Liners (P) Ltd.	248,799	71	Race Course (Centre)	Within City Limits
Residential Buildings				
C.S. Ramasamy	4,032	3	Meetupalayam Road (North)	Within City Limits
M/s.Marudham Developers	4,048	55	Papanakanpalayam, Avinashi Road (North East)	Within City Limits
M/s. Pricol Properties Ltd.,	7,287	40	Near Papanakanpalayam, Avinashi Road (North East)	Within City Limits
M/S. Aalayam Foundations Pvt., Ltd,	8,866	55	Papanakanpalayam, Avinashi Road (North East)	Within City Limits
Mrs. M.Kamalaveni	9,900	Not applicable	Details insufficient	Out of City Limits

Building/Name of the Person for Registration	Site Area in sq. m.	Administrative Ward Number	Location with respect to Area (Indicative Zone/Direction)	Location with respect to City limits
M/S. CASA GRANDE, SRI DWARAKA	9,983	59	Singanallaur, Trichy Road (East Direction)	Within City Limits
M/S. CASA GRANDE,	19,895	59	Singanallaur, Trichy Road (East Direction)	Within City Limits
V. Mohan, M.D	21,659	72	Near Anupperpalayam, Avinashi (Centre)	Within City Limits
M.s. Casagrande Coimbatore	41,333	59	Singanallaur, Trichy Road (East)	Within City Limits
V.S.Gokul	46,700	22	Saibaba Colony, Mettupalayam Road (North)	Within City Limits

Source:: (Town Planning Department, CCMC, 2016)

14.5 Assumptions used to calculate cooling load of buildings

In order to calculate cooling load, several assumptions have been made according to local standards or conditions. These assumptions can be verified and updated during later stages of pre-feasibility study or feasibility study

Occupancy

Table 36: Assumptions of Occupancy

Time	Hotel	Office	IT Office	Shopping mall	Hospital	Residential Apartment	Campus building
0	65%	5%	40%	40%	50%	90%	5%
1	65%	5%	40%	20%	50%	90%	5%
2	65%	5%	40%	20%	50%	90%	5%
3	65%	5%	40%	0%	50%	90%	5%
4	65%	5%	40%	0%	50%	90%	5%
5	65%	5%	40%	0%	50%	90%	5%
6	65%	5%	40%	0%	60%	80%	5%
7	65%	10%	40%	0%	60%	80%	10%
8	65%	25%	75%	0%	75%	50%	25%
9	65%	35%	75%	20%	75%	30%	35%
10	65%	60%	75%	45%	85%	30%	50%
11	70%	75%	75%	60%	75%	50%	75%
12	70%	75%	75%	80%	60%	60%	90%
13	70%	80%	75%	80%	60%	50%	80%
14	70%	80%	75%	80%	85%	30%	80%

15	70%	80%	75%	90%	85%	30%	80%
16	70%	80%	75%	90%	75%	30%	80%
17	75%	80%	75%	90%	75%	50%	80%
18	75%	65%	75%	100%	65%	60%	65%
19	65%	45%	75%	90%	65%	70%	45%
20	65%	25%	75%	80%	60%	80%	25%
21	65%	15%	40%	70%	50%	90%	15%
22	65%	5%	40%	50%	50%	90%	5%
23	65%	5%	40%	40%	50%	90%	5%

Building design parameters

Building efficiency and design parameters are presumed to follow the Energy Conservation Building Code (ECBC). For existing buildings, this is perhaps less realistic but planned buildings, which may be delivered when ECBC becomes mandatory for commercial buildings, are likely to be similar to these parameters. The buildings design index of envelope, lighting etc. are listed as below and set as the base requirement for future analysis. However, the parameters of some building types, like campus buildings and hospitals, were not available in the ECBC and the data for these is based on experiences in other countries, like China and the USA.

Table 37: Assumptions of building design parameters

	Hotel	Office	Shopping mall	Residential Apartments	Campus buildings	Hospital
Occupancy (m2/person)	8	10	4	30	6	3
Lighting (W/m2)	13	10	40	10	15	12
Appliance (W/m2)	16	20	10	10	10	18

		Hotel	Office	Shopping mall	Residential Apartments	Campus buildings	Hospital
Wall	U-value(W/(m2.K))	0.44	0.44	0.44	0.44	0.44	0.44
Roof	U-value(W/(m2.K))	0.261	0.409	0.261	0.409	0.409	0.409
Window	Window-wall Ratio (%)	40%	40%	40%	25%	40%	40%
	U-value(W/(m2.K))	3.3	3.3	3.3	3.3	3.3	3.3
	SHGC	0.25	0.25	0.25	0.45	0.25	0.25

14.6 Summary of meetings

COIMBATORE CITY VISIT: November 26-27, 2015

Participants from the Project Team:

- Mr. Moustapha Assayed, Technical Director, EMPOWER
- Mr. AshwaniGirdhar, Sales Manager, India, DANFOSS
- Mr. Sanjay Gupta, Sales Manager and DC, India, DANFOSS
- Mr. Sella Krishnan, Sr. Manager, Tamil Nadu Operations, ICLEI South Asia
- Ms. Rashmi Sinha, Manager, ICLEI South Asia
- Mr. Tejas Shinde, Sr. Engineer, ICLEI South Asia
- Mr. Nagendran, Project Officer, ICLEI South Asia

List of meetings conducted

- Meeting with Dr. K.Vijayakarthikeyan (I.A.S), Municipal Commissioner, CCMC
- Meeting with Mr G.Rajendran, City Engineer, CCMC
- Meeting with Mr. C. Basker, IC Centre for Governance
- Meeting with: Mr. Ranganathan, Consultants of Engineers/Architects
- Meeting with Mr. Asokan, District Environmental Engineer, Tamil Nadu Pollution Control Board (TNPCB), Coimbatore
- Meeting with Mr. Nandakumar, President, Indian Chamber of Commerce (ICC)
- Meeting with: Mr. Chandrasekar, Chief Engineer, Tamil Nadu Electricity Board (Distribution)
- Meeting with Mr. P.P.Subramanian, Electrical Consultant Engineer and Mr. M.S.Krishna Kumar, HVAC – Consultant, P.P Associates
- Site Visit to Prozone Mall

15 References

Significant information was obtained through long consultations with Coimbatore City Municipal Corporation and many local stakeholders. Below are some of the references used in this report.

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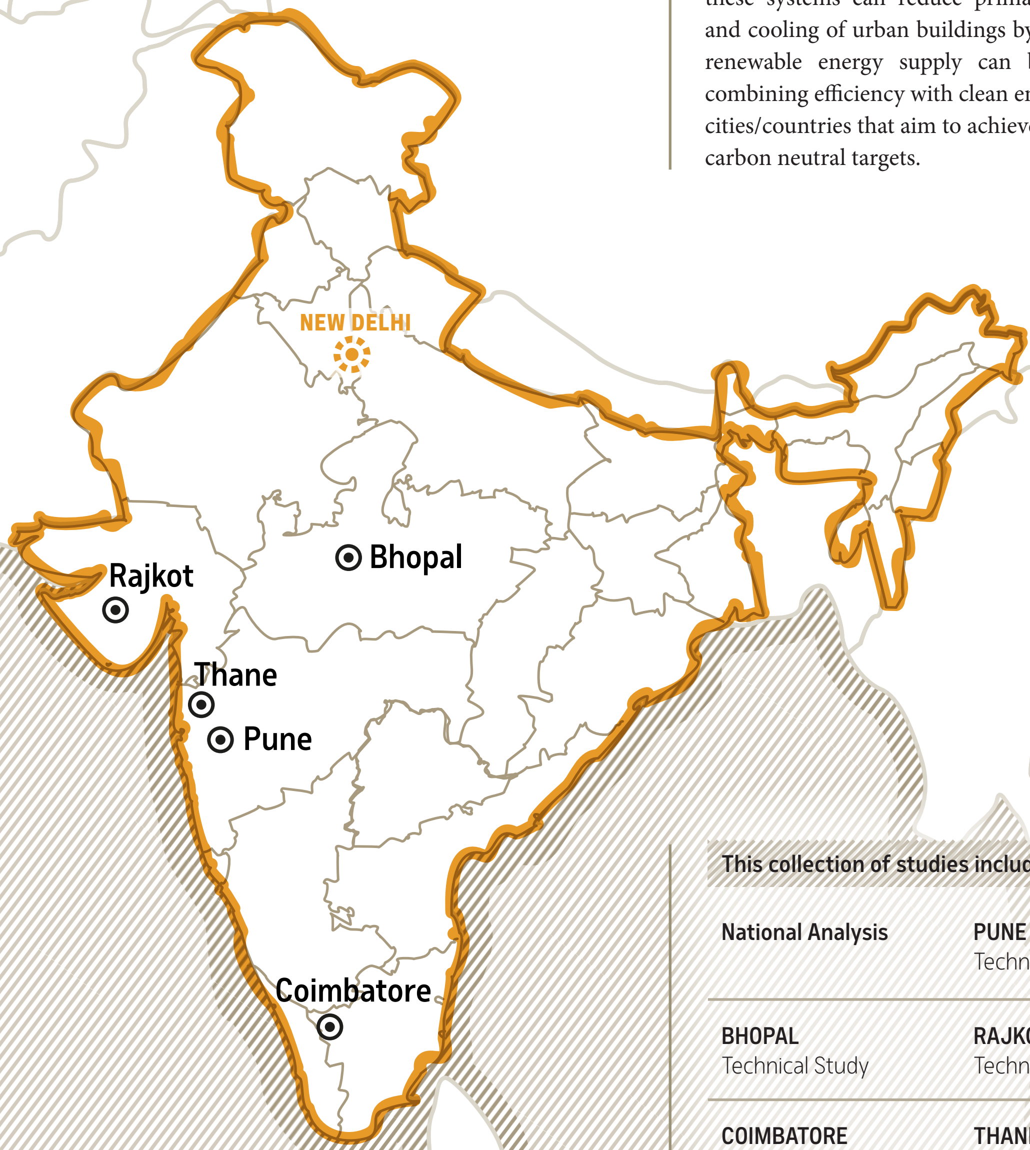
RAPID ASSESSMENTS OF FIVE INDIAN CITIES

The District Energy in Cities Initiative is a 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. District energy systems are intelligent energy infrastructure, efficiently integrating clean sources of energy for cost-effective heating and cooling.

Through economies of scale, diversity of supply, balancing and storage, these systems can reduce primary energy consumption for heating and cooling of urban buildings by up to 50%. High levels of affordable renewable energy supply can be integrated with district energy, combining efficiency with clean energy, making them a key measure for cities/countries that aim to achieve 100% renewable energy, clean air, or carbon neutral targets.



This collection of studies includes

National Analysis	**PUNE** Technical Study
BHOPAL Technical Study	**RAJKOT** Technical Study
COIMBATORE Technical Study	**THANE** Technical Study

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