DISTRICT ENERGY IN CITIES INITIATIVE

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RAPID ASSESSMENTS OF FIVE INDIAN CITIES

THANE

COPENHAGEN CENTRE ON ENERGY EFFICIENCY SEforALL EE HUB

ICLEI Local Governments for Sustainability

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Contributing to:

SUSTAINABLE ENERGY FOR ALL

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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 Thane undertaken alongside four other district cooling rapid assessments of Bhopal, Coimbatore, Pune and Rajkot. This report sets out a high-level analysis of the current impacts of space cooling in Thane, 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 Thane to help realize 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].

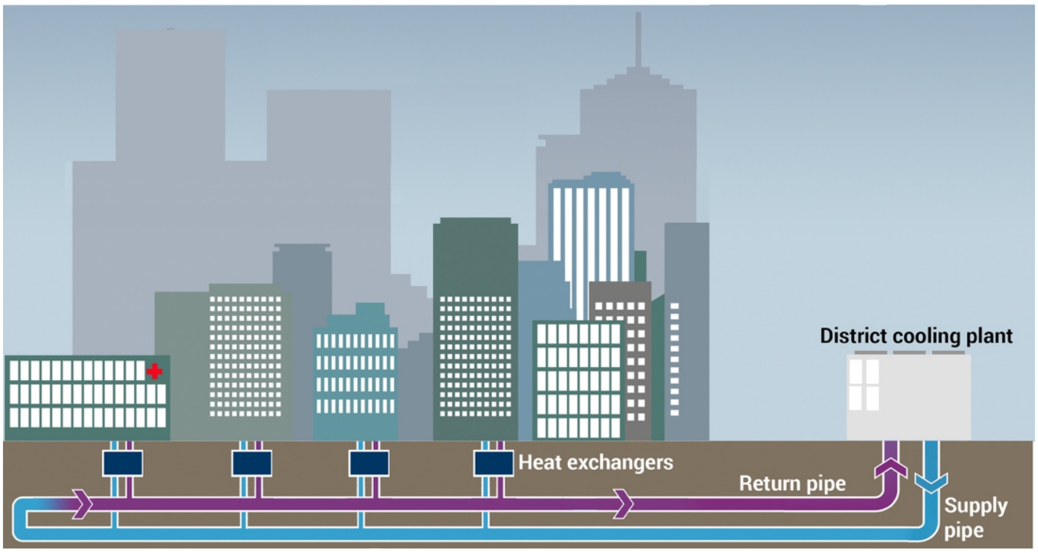
There is no fixed term used worldwide for 'district energy systems', and the authors note the following as being used worldwide: district cooling systems, district heating systems, community cooling/heating, heat networks, cool networks, decentralized energy systems, heat grids, CHP networks, trigeneration networks, community cooling, community heating, neighborhood 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 neighborhood. 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, and have large-scale thermal storage, leading to more efficient, reliable and environmentally friendly cooling in buildings. By cooling several buildings in a city

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

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 analyzed 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

Thane is actively engaged in pursuing sustainable, low emission development and the local government aims to become 'carbon neutral' in its city operations. In mid-2016, Thane was selected for development as a Smart City under the Government of India's Smart Cities Mission.

Thane city, located in Maharashtra state, is the second largest city in terms of population in the Mumbai Metropolitan Region with approximately 1.8 million inhabitants. The city is the administrative headquarters of Thane District and is adjacent to the megacity of Mumbai, which is located directly to the southwest of Thane city. Thane, also known as the Lake City, is one of the fastest growing cities in India and has experienced rapid demographic and economic growth in the past decade.

Economic growth in Thane has been driven mainly by the IT industry, helped by Thane's vicinity to Mumbai, which has led to a rapid expansion in population as well as commercial and residential real estate and associated consumer-oriented services. This growth is accompanied by increasing energy demand, in particular for space cooling, which for many businesses is a necessity, given the hot and humid climate of Thane.

The Thane Municipal Corporation (TMC) administers the city area spanning 128.23 sq. km. The Mumbai Metropolitan Region Development Authority (MMRDA), responsible for regional planning and development of the Mumbai urban agglomeration (4,355 sq. km), is also responsible for the planning and development of certain areas within Thane city.

Table 1: City at a Glance

Particulars	Details
Area	128.23 sq. km.
Population	1,841,488
Population Density	14,360 persons per sq. km.
Local Economic Base	IT Services, retail, service sectors, education
Average Temperature	28°C
Average Relative Humidity	72%
Average Rainfall	2500-3000 mm

3.2 Location and Natural Environment

3.2.1 Geographical location

Thane city is spread across an area of 147 sq. km and is 19 km inland, on the west coast of India. Abutting the north-eastern boundary of Greater Mumbai, it is about 34 km from the Central Business District (CBD) of Mumbai. The city is located at 72°-50' North latitude and 19°-10' East longitude.

Thane is well connected by road, not only to other areas of MMR, but also to other regions in the state and to other states. Thane is also well served by a rail network and has three suburban railway stations, including one major railway station. The Central Railway's main lines passing through the city connect the city to the north-north east and south-south east parts of India. It is connected by the local suburban train to other cities in the Greater Mumbai region including Mumbai, Kalyan-Dombivli and Navi Mumbai. The domestic and international airports located in Mumbai are at a distance of approximately 20 km from Thane.

Figure 1: Location of Thane District in Maharashtra and Mumbai Metropolitan Region (MMR)

3.2.2 Climate

The climate in Thane is predominantly warm, sultry and humid. Although temperatures are not very high in summer, the prevalent weather condition is uncomfortable due to high humidity. May is the hottest month with the monthly average daily maximum temperature reaching as high as 32°C, coupled with a relative humidity of about 60% during daytime.

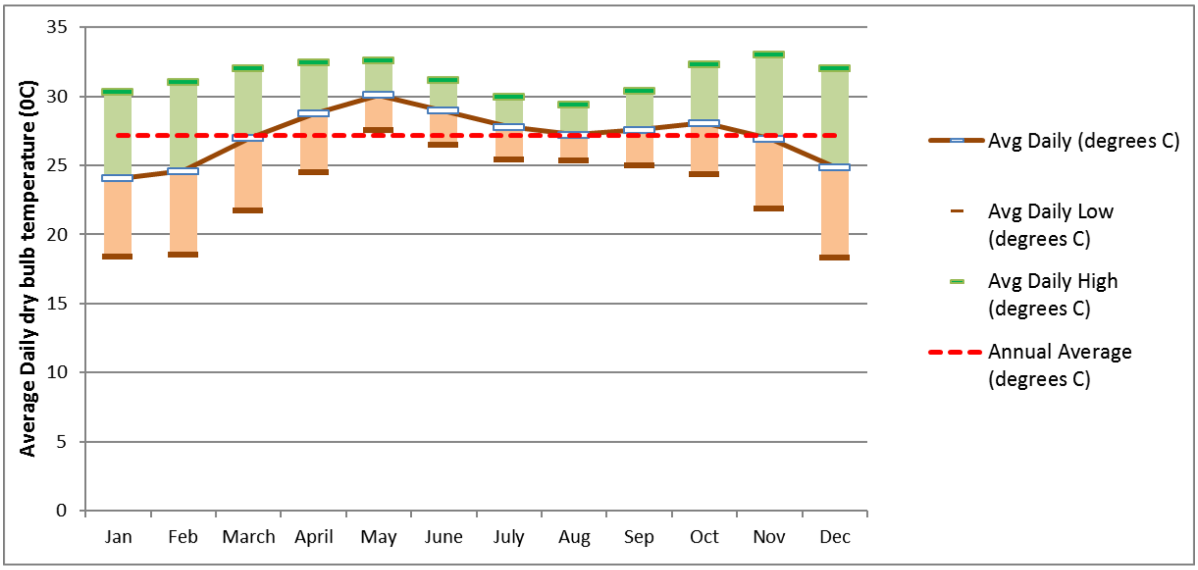
The average daily temperature of the city ranges from 24°C to 32°C (see Figure 2). Higher temperatures are recorded during the summer months between March to June, peaking in the month of May. The maximum daily average temperature is seen to rise from October to December (also known as the October heat), post the monsoon months. Average relative humidity in Thane is 72%, contributing to significant demand for space cooling. The lowest daily average relative humidity of 57-60 % is recorded during the winter season. During the monsoon season the relative humidity peaks, with an average daily high of over 90% in the month of July (see Figure 3).

The total number of Cooling Degree Days (CDD)[3] for Thane is 2,150 (considering a base temperature of 23°C). The CDD are consistently high for most of the year and have a positive correlation with the electricity consumption (see Section 9). Other cities have developed successful district cooling projects with far lower CDDs.

[3] 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 23°C and has been chosen to enable international comparison. For many buildings, air conditioners will maintain temperatures higher than this. For example, based on information received as part of the rapid assessments, a particular mall in Thane maintains a temperature of 24°C and operates its chillers for 10 hours per day for the whole year

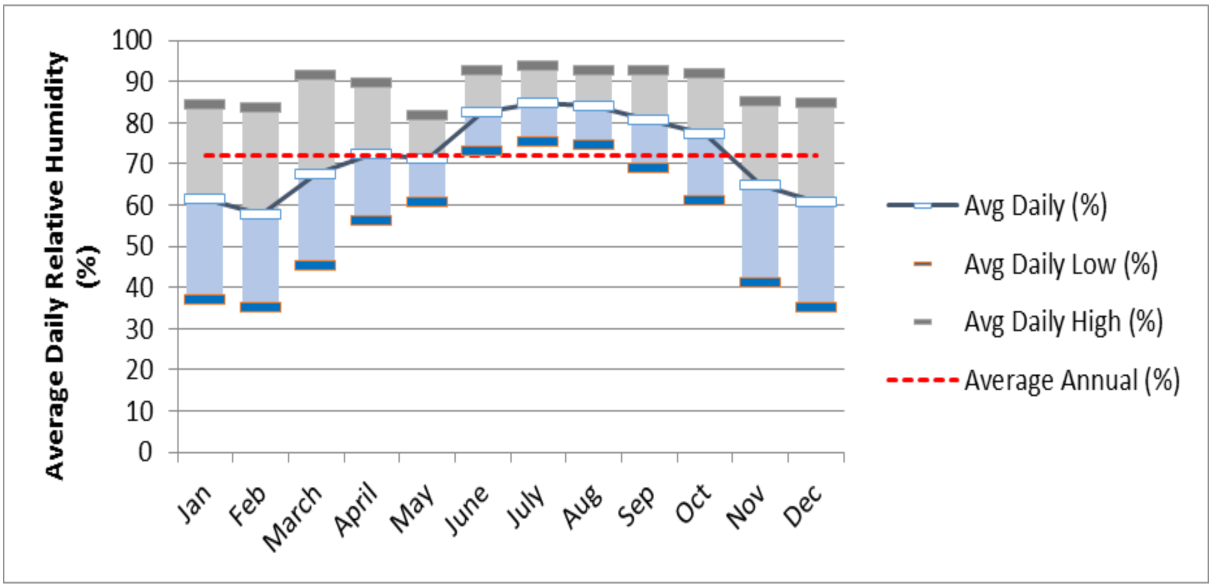
The hot and humid climate of Thane gives rise to a significant use of space cooling year-round making the city highly suitable for district cooling. The use of space cooling in Thane is examined further in Section 9.

Figure 2: Month wise average daily temperature variation with respect to annual average temperature for Thane city (1982-2006)



Source: Analysis is based upon the data from (ASHRAE, 2009)

Figure 3: Month wise average daily relative humidity variation with respect to annual average relative humidity for Thane city (1982-2006)



Source: Analysis is based upon the data from (ASHRAE, 2009)

3.2.3 Soil Conditions

Most of the soil crust in the Thane region is synthesized from Basaltic rocks. Within Thane city, black soil containing sulphur is predominantly observed (District Collectorate Thane, 2016). Infrastructure development in the city has resulted in compacted top soil layers.

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

3.2.4 Surface and Groundwater Availability

Thane city is known for its lakes, with around 33 lakes present within the city limits. The Thane creek, a part of the estuary of the Ulhas River, is the major water body flowing through the city. The Ulhas River mainly depends on the monsoon, receiving most of its water from the South-West monsoon during the months of June to October. The TMC has been continuously undertaking efforts towards integrated conservation and beautification of the lakes in the city.

The numerous lakes and the Thane creek that exist in Thane 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 approximately 25°C-27°C[4]. 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.

Figure 4: Ulhas River and Thane creek

Source: (TMC, 2010)

Water supply for Thane is sourced mainly from the Bhatsa River located at a distance of approximately 60 km from the city. TMC supplies 460 million litres per day (MLD) of water to the city, with about 200 MLD supplied from the TMC's water treatment plant at Temghar and the rest from other sources (see Table 2). Thane currently has sufficient water to meet its demand till the

[4] Water temperature measurements for lakes available at http://www.iosrjournals.org/iosr-jestft/papers/vol8-issue5/Version-4/I08544650.pdf and temperature measurements for the creek available at https://www.omicsonline.org/open-access/impact-of-construction-and-reclamation-activities-on-the-water-quality-of-the-thane-creek-centralwest-coast-of-india-1410-5217-7-163.pdf

year 2020. Unequal distribution of water across the city is concern, with supply ranging from 2-24 hours a day.

Table 2: Sources of Water for Thane Municipal Corporation

Sr. No.	Water supplied by	Water allocated (MLD)
1	Water Supply Scheme by TMC	200
2	Municipal Corporation of Greater Mumbai	60
3	Maharashtra Industrial Development Corporation (MIDC)	80
4	Shahad-Temghar Water Supply Authority (STEM)	122

Source: Water Supply Department (TMC, 2016)

Thane city generates around 343 MLD of wastewater, which is treated through the TMC's sewage treatment plants (STPs) and discharged into the Thane creek. The TMC has prioritized collection and treatment of all the wastewater generated in the city so as to improve the water quality of the Thane creek and its lakes. The TMC is also undertaking efforts to promote recycling and reuse of treated wastewater. Various commercial and large residential complexes in Thane are recycling and reusing wastewater. TMC also intends to promote decentralized treatment and reuse recycling of wastewater. Under its Smart City proposal, the TMC is also looking to frame a policy to promote wastewater reuse and recycling (see Section 5.1for more details).

The cost of water is INR 40 (0.60 USD)[5] per m^3 (or kiloliter) of water and this is charged alongside a substantial connection fee. In addition to these costs, district cooling service providers would also have to bear the cost of construction or any civil work for getting a water connection. 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 Thane that have centralized cooling use a mix of air-cooled chillers and water-cooled chillers (see Section 9.1 for more details).

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 would likely need further treating at the district cooling plant. The costs of using TSE or water from local water bodies in Thane are beyond the scope of this analysis but should be considered in future pre-feasibility studies of district cooling.

[5] Throughout the report an exchange rate of 1Rs=0.015 USD is used
[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)

3.2.5 Air Quality

Transportation and construction activity are the major sources of air pollution in Thane city. The city does not have other significant pollution sources such as electricity generation from coal-fired power stations or independent power producers. Since almost all of the industries within the city have been either shut down or shifted to locations outside the city, there is negligible pollution from industrial sources. Concentrations of respirable suspended particulate matter (RSPM) are observed to exceed prescribed National Ambient Air Quality Standards and are on the rise due to increased traffic congestion, road works, building construction and the high use of coal in street-side food vendors. The concentration of pollutants such as nitrous oxide (NOx) and sulphur dioxide (SO_2) are found to be within limits.

Table 3: Ambient Air Quality in Thane City (2013 and 2014)

Sr. No.	Monitoring Station	Pollution level in city (January-December 2013)			Pollution level in city (January-December 2014)		
		RSPM ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NOx ($\mu g/m^3$)	RSPM ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NOx ($\mu g/m^3$)
CPCB Standard (Annually)		**60**	**50**	**40**	**60**	**50**	**40**
1	Kopari Ward Office	120.50	17.75	32.42	106.00	21.00	61.00
2	Shahu Market	123.92	18.08	34.00	104.00	21.00	62.00
3	GlaxoSmithKline, Pokhran Road	107.92	15.75	29.67	130.00	20.00	59.00

Source: (TMC, 2014)

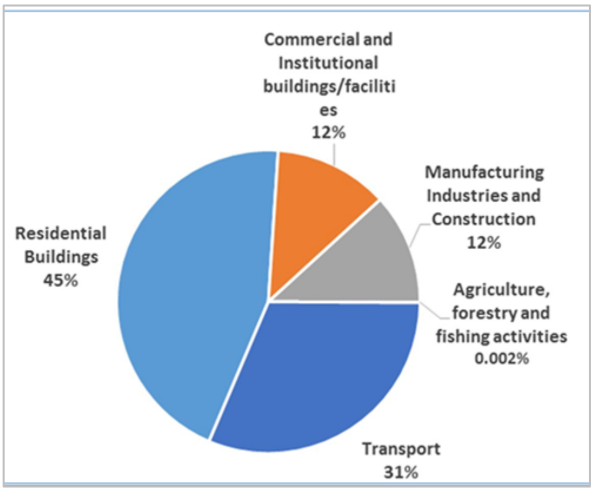
It is not expected that district cooling will have a significant impact or benefit on local air quality in Thane. However, improving the efficiency of electricity through district cooling could have upstream benefits on air quality outside of Thane by reducing the need for new power plants or the use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

3.2.6 Energy consumption

45% of Thane's total energy demand[7] stems from the residential sector, driven predominantly by the use of electricity and to a lesser extent by the fuels used for cooking. The transport sector is the second largest energy consumer, accounting for 31% of Thane's total consumption. Commercial and institutional buildings/facilities account for 12% of the city's energy consumption, with industries having a similar share as well (see Figure 5 below).

Figure 5: Sectoral share of Energy Consumption in Thane, 2012-13

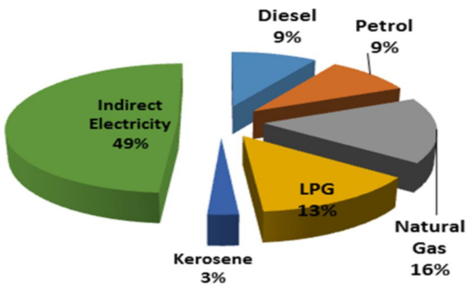
[7] A total of 11,398,774 GJ of energy was consumed in Thane in the year 2012-13 with the average per capita energy consumption at 5.80 GJ



Source: (ICLEI South Asia, 2016)

Electricity is the predominant final energy type in Thane and accounts for 49% of the city's final energy mix, typically being used for meeting the electricity demand in commercial and residential buildings[8]. Natural gas has a share of 16% and liquefied petroleum gas (LPG), which is mainly used for cooking, has a share of 13%. Diesel and petrol each account for 9% of the total energy mix. Use of natural gas, diesel and petrol is mainly associated with the transport sector.

Figure 6: Share of Energy Sources in Thane's Energy Mix, 2012-13



Source: (ICLEI South Asia, 2016)

3.2.7 Greenhouse gas emissions

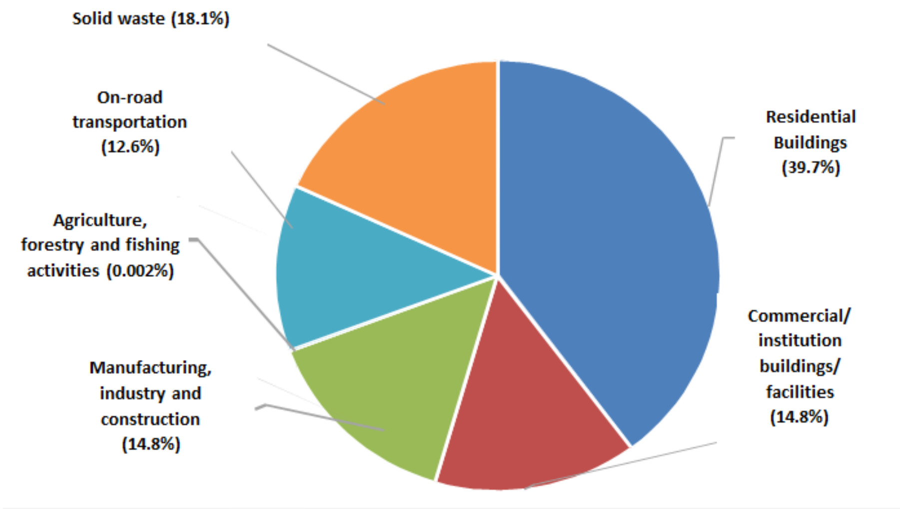
Thane city's GHG emissions amounted to 2.07 million tonnes of carbon dioxide equivalent (CO2eq.) in the year 2012-13, with the average per capita GHG emission at 1.05 tonnes of CO_2eq. Thane's GHG emissions inventory captures emissions from use of different fuels in the city. The GHG inventory, however, does not cover emissions from refrigerants. Thane aims to become 'carbon neutral' in its city operations but has not set a specific timeline.

It is seen that residential buildings have the highest contribution to GHG emissions (39.7%), with the commercial and industrial sectors accounting cumulatively for about 30% of the city's GHG emission (see Figure 7). With regard to emissions from different energy sources that are used in

[8] 53% of the city's electricity was consumed by buildings in the year 2014-15 showing nearly 4% increase in the consumption (Section 1.9.1 provides detailed analysis on the sectoral electricity consumption in Thane city for the year 2014-15).

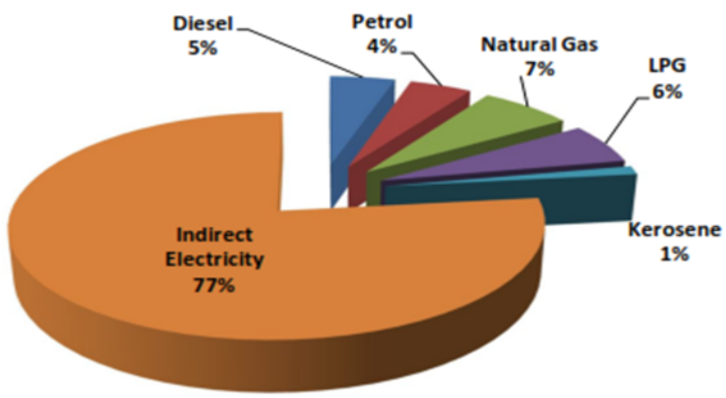
the city, electricity use contributes to 77% of the total emissions. The contribution from other energy sources including natural gas (7%), LPG (6%), diesel (5%), petrol (4%) and kerosene (1%) is far lower.

Figure 7: Sectoral Share of GHG Emission in Thane, 2012-13



Source: (ICLEI South Asia, 2016)

Figure 8: Share of GHG Emission by Energy Source, 2012-13



Source: (ICLEI South Asia, 2016)

3.3 Socio-economic Status

3.3.1 Population

As per National Census 2011, Thane city's population is 1.84 million. The decadal growth rate of Thane from year 2001-2011 is estimated to be 45.85% (Census of India, 2011). The city is expected to continue witnessing a significant growth of population in the years to come, which will contribute further to the rapid pace of building development seen in the city.

The city's slum population has also grown rapidly. There are 252 slums in the city, catering to the housing needs of a population of 0.98 million slum dwellers who constitute nearly 53.80% of Thane city's population. Migration of workers from rural areas of Maharashtra state as well as from other parts of the country is one of the major challenges faced by the city.

3.3.2 Local Economy and Real Estate Growth

Thane is one of the fastest developing cities in India and is witnessing substantial growth and increasing demand in the commercial and realty sectors due to its proximity to Mumbai. Due to this increasing demand, commercial and consumer-oriented services e.g. malls, shopping complexes, commercial hubs, hospitality services are increasing rapidly in the city. Thane district is the second largest contributor to Maharashtra state's economy (13.1%) after Mumbai (22.1%), with the adjoining Thane-Belapur-Kalyan areas emerging as a major industrial belt. Thane district's gross district domestic product stood at INR 1794.8 billion (USD 26.9 billion) in 2012-2013, increasing by over 3 times from a value of INR 540.52 billion (USD 8.1 billion) in 2004-2005. Thane is an emerging destination for the IT/ITES sector and associated residential and retail developments including large commercial spaces and malls. Thane has been identified as one among 11 emerging real estate markets for occupiers in India. (Jones Lang Lasalle Meghraj, 2010)

The employable population in Thane depends largely on the huge employment market in Mumbai. Industrial development in Thane has slowed down in recent times due to increased operational costs in the fast-developing urban setup of the city and industries are moving out of the city towards newly developing industrial belt of Bhiwandi-Kalyan-Badlapur, located at a distance of 15-20 km from the city.

Economic growth in the last couple of decades has been driven by many IT industries being established in the city, and spatial and development policies pursued by the State Government of Maharashtra have also contributed to economic development. The IT/ ITES sector is growing rapidly in Thane, with the city being the preferred location to set up IT industries, after the cities of Pune and Mumbai. The key reasons for Thane's transformation into an IT/ITeS hub are availability of young and qualified workforce besides excellent transportation network, social infrastructure and low cost of operations as compared to the neighboring city of Mumbai. Existing IT parks/hubs include complexes such as the Hiranandani Business Park, Ashar IT Park, Neptune Element in Wagle Industrial Estate area, and hubs such as Sigma IT Park and Loma IT Park on the Thane-Belapur Highway.

Figure 9 shows the location of major existing and upcoming IT/ITES, commercial (offices, hotels, retail mall, and hospitals), and residential projects in Thane. A particularly important IT zone is around the former Wagle Industrial area which includes a number of prominent IT/ITES developments, business parks and commercial offices including the Ashar IT park, Neptune Element, and the Sun Infotech park among others.

The Ghodbunder road (marked on Figure 9) is another prominent location due its strategic location as an arterial road that not only connects Mumbai's two main nodes - the eastern and western express highway joining the two ends of Mumbai, but also connects other nearby cities such as Nashik, Pune and Ahmedabad. The Ghodbunder road stretch has witnessed notable development in the last decade in particular, and houses major commercial office spaces such as the iThink-IT

Park, the Tata Consultancy Services offices at Pokhran road no. 2, G Corp Tech, and the Kalpataru Prime among others. A number of residential projects have come up and continue to come up in this area. The Ghodbunder road also houses a number of shopping malls and entertainment zones such as the R-mall, Viviana Mall, the Lakecity Mall along with large hospitals and hotels.

The Hiranandani Estate located in Thane west, is a large integrated township that houses mixed-use development including office spaces, residential apartments, hospital, educational facilities, restaurants and entertainment spaces. The Hiranandani Business Park is a key location in the Hiranandani Estate, housing major corporate offices. Tata Consultancy Services has also leased about. 2 million sq. ft. of land for 15 years for a large office space and is planning to lease an additional 2 million sq. ft. of office space in the near future. The Hiranandani Estate includes a number of green field sites intended to house high density development in the coming years.

In the future, it is expected that major IT/ITES and corporate offices, residential apartments (both affordable and high-end luxury apartments), and integrated townships may come up in areas such as Wagbil, Kavesar, Kasarvadavali, Patlipada, Brahmand, Koshet in Thane West. Future development may also be seen along the Mumbai-Nashik Highway passing through Thane. There are large parcels of land and slum areas available which are likely to be developed further. A proposal wherein the Mumbai Metropolitan Regional Development Authority (MMRDA) will develop 72 acres of land in Thane's Kharegoan area as a Peripheral Business District, on the lines of the iconic Bandra Kurla Complex in Mumbai, is under consideration.

The Maharashtra Industrial Development Corporation (MIDC) area that is located in nearby Navi Mumbai has many prominent IT/ITES and corporate offices such as Reliance, Wipro, Reliable Tech Park, MindSpace, Sigma & Loma IT, Dhirubhai Ambani Knowledge Park, thereby driving development in its proximity.

Major urban redevelopment is also planned in the dense city centre around Thane Railway Station as part of Thane's Smart City proposal. This redevelopment is presented in detail in Section 1.3.1.

New growth pockets, integrated townships, IT-parks and urban redevelopments could provide strong catalysts for new district cooling systems in Thane. Section 6 examines some of the policy interventions that could bring about such systems and Section 11 examines specific projects and their commercial viability.

Figure 9: Map Showing major existing, ongoing and future development in Thane and beyond

Existing IT/ITES & Biz Park/offices | Existing Projects (commercial & high end Residential) | Ongoing Projects | Proposed Projects | Future Developmental areas

Source: Mapping and analysis by TMC and ICLEI South Asia

4 Stakeholder Mapping

Local stakeholders and their potential roles in the development and deployment of district cooling initiatives in Thane are listed as below.

Institution type	Agency	Mandates and Role
City planning and policy relevant interventions	• Thane Municipal Corporation (TMC) • Mumbai Metropolitan Regional Development Authority (MMRDA) • Thane Smart City Development Corporation Ltd. (TSCDCL)	**Mandate and Functions:** • **TMC:** The TMC is the main planning authority for the city of Thane. TMC 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. TMC 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. TMC plays the role of planner, controller and implementer within its jurisdiction. • **MMRDA:** The MMRDA engages in long term planning, promotion of new growth centres, implementation of strategic projects and financing infrastructure development for the larger Mumbai Metropolitan Region. In particular, the MMRDA conceives, promotes and monitors the key projects for developing new growth centres and brings about improvement in sectors like transport, housing, water supply and environment in the Mumbai Metropolitan Region. The MMRDA is also involved in rental housing projects in the MMR region which also includes Thane. • **TSDCL:** The key responsibility of TSDCL is to oversee the planning and execution of Smart City plan for Thane city. This includes the implementation of proposed smart and sustainable solutions throughout the city as well as in the area based development. TSDCL's main focus remains on improvement of urban infrastructure and governance while addressing priority areas outlined in the Smart city plan.

Institution type	Agency	Mandates and Role
		Role with respect to district cooling: • 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. • 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 • 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 • 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 • 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 • 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 high cooling demand to assist viability of district cooling • Facilitate stakeholder coordination, raise awareness and acceptance • Lead implementation of district cooling through public private partnership funding mechanisms
Real Estate, Property Developers	• Maharashtra Chamber of Housing Industry (MCHI), Thane Unit • Hiranandani Group	**Mandate and Functions:** The MCHI is an institution that represents interests of the real estate developers as and when new regulations pertaining to real estate development

Institution type	Agency	Mandates and Role
and related Institutions	• Sheth Corp • Lodha group • Rustomjee • Wadhwa Group • Runwal group • The Puranic Group • Godrej properties • Dosti Group • Acme Group • VBHC Value Homes private limited	are concerned. MCHI is majorly associated with promotion of best practices and technologies in building design and construction. MCHI works towards raising awareness among the general public, real estate and construction industry while providing them with detailed information on new developments in and around Mumbai and the MMR. **Role with respect to district cooling:** • 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 • Provide inputs on practical issues, risks and possible enabling policies and programmes with regards to district cooling integration and market acceptance • Provide information relating to prevalent cooling technology and infrastructure in the real estate market • Facilitate measurement and monitoring of baseline cooling demand in buildings to assess feasibility for district cooling
Architects, Building Design and Civil Engineering related Institutions	• Indian Institute of Architects, Thane and Mumbai Centre • The Institution of Engineers (India), Mumbai • Indian Institute of Architects, Thane Centre	**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, technologies and developments in the field of civil engineering. **Role with respect to district cooling:** • Identify existing and upcoming large scale high rise buildings and developments in the city with potential for district cooling integration • 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 • Provide technical inputs on integrating district cooling in the prevalent building design and

Institution type	Agency	Mandates and Role
		other practical aspects in terms of expertise, market acceptance etc. • Provide inputs for promoting district cooling through existing or new building design and efficiency standards/regulations
Electricity Distribution company and regulator	• Maharashtra State Electricity Distribution Company Limited (MSEDCL) • Maharashtra Electricity Regulatory Commission – A tariff regulatory for state.	**Mandate and Functions:** • The MSEDCL is responsible for distribution of electricity that it receives from public and private power producers to end-consumers. It is also responsible for planning the electrical infrastructure to strengthen the electricity distribution network, to reduce the electricity downtime and enhance reliability. MSEDCL collects the energy consumption charges from end users as per the tariff stipulated by Maharashtra Electricity Regulatory Commission. MSEDCL works to promote energy conservation through demand side management and also supports implementation of the solar roof-top net metering program through facilitation of infrastructure for net-metering. **Role with respect to district cooling:** • 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 • Assist in identification of buildings/consumers with high load and energy demand • Share information on infrastructure status or augmentation required in the local electricity network to support the required power demand of the district cooling production plant • 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	Maharashtra Energy Development Agency (MEDA)	**Mandate and Functions:** • MEDA is responsible for implementation of energy conservation, renewable energy and energy efficiency programs across the state of Maharashtra. It is a nodal agency for

Institution type	Agency	Mandates and Role
		disbursement of central financial assistance/subsidies for renewable energy projects including solar PV. MEDA is responsible for developing, implementing and promoting energy efficiency and conservation in different sectors through enabling policies and programs. **Role with respect to district cooling:** • In its role as the nodal energy agency for the State, MEDA can assist in promoting district cooling by formulating and implementing enabling policy, regulations and schemes for the same • 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. • Could provide additional funding or grants from state funds, particularly to support project feasibility of district cooling • Share information on existing and planned renewable energy generation in the city for integration with district cooling • Generate awareness on district cooling among local stakeholders through targeted programmes.
Regional Pollution control board	Maharashtra Pollution Control Board (MPCB)	**Mandate and Functions:** • MPCB is a legislative body in Maharashtra that implements a range of environmental legislation with respect to prevention and control of pollution relating to air, water, noise and waste. MPCB 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 MPCB is responsible to plan and execute programs for the prevention, control or abatement of pollution. The MPCB regulates and monitors discharge and treatment of sewage or trade effluent and performance of air pollution control systems.

Institution type	Agency	Mandates and Role
		Role with respect to district cooling: • Identify potential waste heat sources in the city for use in the district cooling system • Share information on potential sources of water (e.g. location, temperature, depth, quality) for use in the district cooling network • 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	• Thane Small Scale Industries Association (TSSIA) • Thane Belapur Industries Associations	**Mandate and Functions:** • TSSIA as well as Thane Belapur Industries Association are industry bodies concerned with representing and highlighting the issues concerning the industries in Thane. These institutions provide a platform for industry owners to exchange ideas and promote best practices. **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

Institution type	Agency	Mandates and Role
Designers, manufacturers, installation contractors for chillers and cooling system	• M/s Thermax D. Limited • Danfoss India • M/s Energetic Consulting Private Ltd. • Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE), Thane Chapter • Btech Corporation, Thane • Vertiv Corporation, Thane	**Role with respect to district cooling:** • Provide inputs on energy audit of the buildings, practical issues and associated risks with regards to district cooling integration and market acceptance • Provide support/guidance for Conceptualization, planning and implementation of DCS project • Provide first-hand experience on technical aspects and local regulations towards HVAC and consequently district cooling.

5 City Strategies and Initiatives

Thane 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 TMC 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. This means that the true impact of space cooling is not fully understood, solutions are deployed that may be less cost-effective and opportunities are missed for sector integration and use of local renewables. Key strategies and initiatives undertaken by the TMC are described below.

5.1 Thane Smart City

Thane is one of 10 cities from the state of Maharashtra to be shortlisted amongst 100 cities to be developed as Smart Cities under the Government of India’s Smart Cities Mission.

The city’s vision framed under the Smart City proposal states that:

“Thane city shall reclaim its rich waterfront and lakes and weave it into the tapestry of everyday life of citizens to provide them with a distinct urban experience that is a class apart from others.

It shall be a city where the mind is free and, comfort and safety are assured, drawing a wave of creative employment opportunities; where all irrespective of their age, ability, gender or income are able to access all that the city has to offer”.

The vision for Thane consists of five key thematic areas which have been developed based on an exhaustive strengths, weaknesses, opportunities, and threats (SWOT) analysis and inclusive engagement and consultation with citizens. The key sub-goals defined under the thematic areas are listed in Table 4 below (see Annex 14.1 for more details). Thane’s Smart City proposal outlines ambitious goals for energy such as increasing the share of renewable energy by 50% through implementation of the city's Solar City Master Plan and other initiatives undertaken in partnership with citizens and the private sector. It also places emphasis on the reuse and recycling of wastewater and strives towards improving water quality of the creek. The city's intent to promote the IT/ITES industry and to become an educational hub is expected to drive additional building development and ensuing cooling demand in these sectors in the coming years.

Table 4: Key themes and Sub-Goals of Thane City outlined under Smart City Proposal

Key Themes	Sub-Goals
A Green Waterfront City	• Expanding public access to the lakes, waterfront and waterways on public and private property • Improving creek water quality
A Smart and Safe City	• Reducing unaccounted water losses (includes water lost due to leakages and consumption that is not charged) from 37% to levels below 20% through a comprehensive water audit, SCADA, smart metering and monitoring • Providing 100% online coverage of municipal services through both online portals and mobile applications
A Sustainable Economic Base	• Development of infrastructure and services to the IT/ITES industry and education sector
A Livable city which provides its citizens with appropriate basic infrastructure	• Increasing share of renewable energy by 50% through implementation of the solar city masterplan and other initiatives in partnership with citizens and the private sector • Recycling and reuse of treated wastewater • Promoting decentralized waste water treatment by commissioning 100 MLD of STPs having individual capacities of between 1-5 MLD • Decentralized SWM by ensuring that decentralized waste management units process 100% of biodegradable waste

Thane has outlined smart solutions within a **Pan-city proposal** covering the whole city and also an **Area-based Development[9] proposal** covering a centrally located urban cluster around the Thane railway station and the Kisan Nagar area. The estimated cost of Thane's Smart City proposal is INR 66,300 million (USD 0.995 billion), of which INR 57,300 million (USD 860 million) pertains to Area Based Development and INR 9,000 million (USD 135 million) is for the Pan-city proposal (TMC). The Thane Smart City Limited (TSCL), a special purpose vehicle (SPV), has been established for the implementation of the projects envisaged under Thane's Smart City Plan. Details of the proposed projects and corresponding costs for Thane's Smart City proposal are provided in Annex 14.2.

As part of the **Area Based Development proposal**, Thane has proposed rejuvenation of its city center area (spread over 1070 acres or 4.33 sq. km) which involves two broad initiatives:

[9] As per the Smart City Mission Guidelines issued by the Government of India, cities selected under the Smart City Mission are supposed to include a Pan-city proposal and an area based development proposal –targeting to develop specific areas of the city through three strategic options - retrofitting, redevelopment and green field development.

- ***Retrofitting an area of 1000 acres (4.04 sq. km) around the Thane Railway Station (see** Figure 10**):*** The city of Thane has grown organically through transit-oriented development taking place around the Thane railway station. The areas in this vicinity are typically core city areas wherein the road network is inadequate to support the increasing commuter load, with approximately 0.65 million commuters travelling daily and leading to heavy traffic congestion. Further the congested slum and dilapidated building clusters house over 50% of the city's population. These clusters are deficient in amenities, have poor sanitary conditions and have outpaced the reach of the service network and development of public amenities. The 32 km long creek line is at risk of encroachment from development as a result of the rapid growth of population in the city. The key interventions proposed include:
    - creation of a multimodal transit facility (SATIS East), a new suburban station between Thane and the suburb of Mulund lying to the north-east of Mumbai;
    - improvement of the Thane railway station;
    - waterfront development and bio-remediation of an existing lake;
    - upgradation of the sewerage and drainage networks; and
    - LED street lighting retrofits.
- ***Redeveloping a 70-acre residential cluster (see** Figure 11**):*** aims to rehabilitate over 50,000 households situated in the Kisan Nagar area which is characterized by densely populated (3,000 persons/hectare) and mixed-use development with inadequate road widths, lack of public amenities and open spaces and dilapidated, unauthorized multi-storey buildings and slums. The area based development proposal mainly involves redevelopment of 100% of the buildings spread across 70 acres of land into certified green buildings (utilizing solar photovoltaic systems, LED street light, waste water recycling), to create 10% of open space, adequate road layout plan and adequate and accessible public amenities such as water supply and sewerage networks.

Thane, in its Smart City Plan, has proposed setting up 2 MW of rooftop solar power plants at an estimated cost of INR 140 million (USD 2.1 million) and implementing an energy efficient LED street lighting project at an estimated cost of INR 270 million (USD 4.1 million) within the Area Based Development.

Box 1: Smart city recommendations

The Area Based Development site in Thane offers potential opportunities to test the integration and promotion of district cooling, particularly given the redevelopment of large land areas into mixed use modern buildings with an emphasis on sustainability. 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 both area based development 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 analyzed 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).

Figure 10: Proposed Area Based Development in Thane

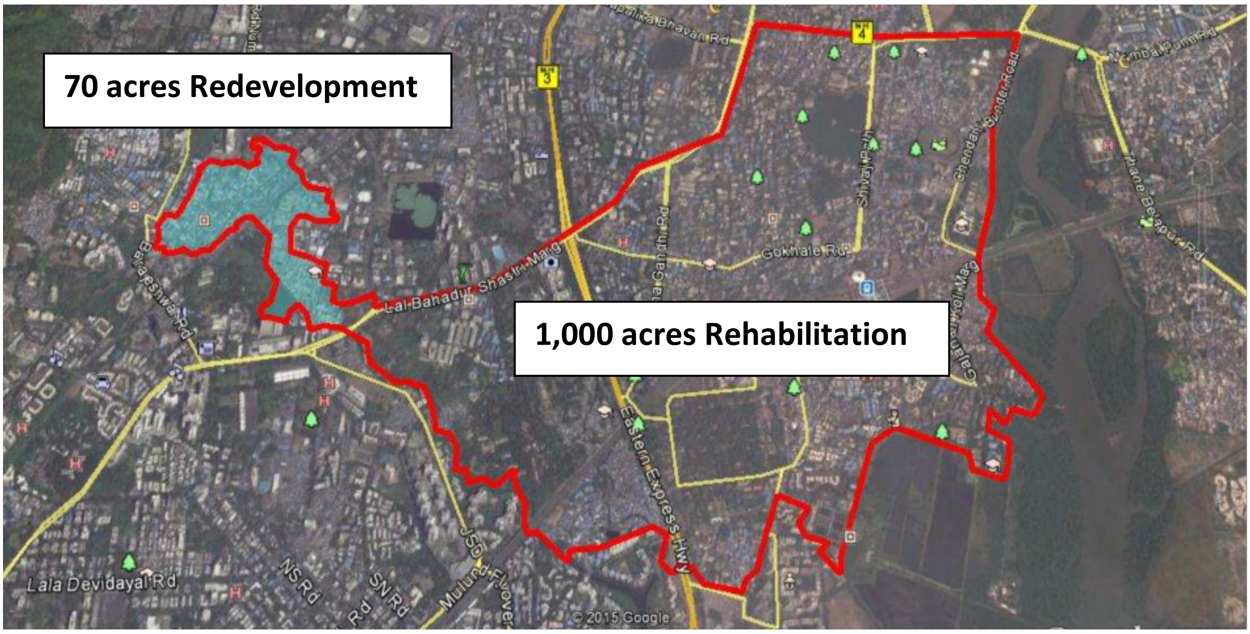
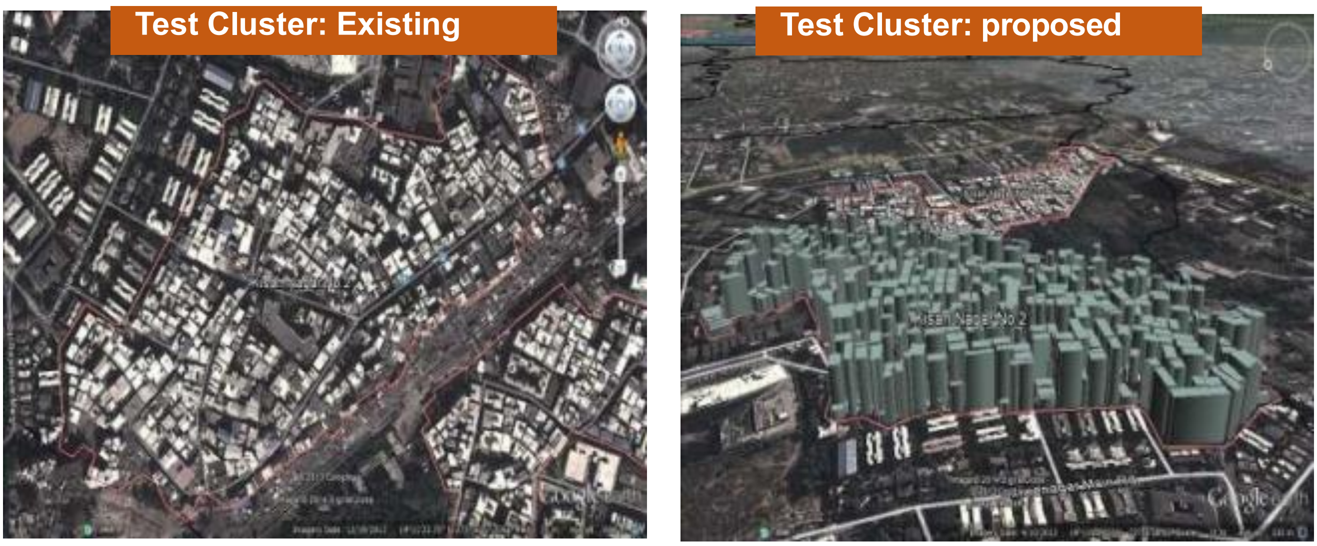


Figure 11: Smart Cluster-70 acres Redevelopment



5.2 Thane's Solar City Master Plan

Thane is one of 15 'pilot solar cities' selected under the Solar City Programme of the Ministry of New and Renewable Energy (MNRE), which includes a total of 60 cities. Thane has prepared a Solar City Master Plan with a target to achieve a 10% reduction in conventional energy consumption (about 230 million kWh) over a 5-year period from 2008-2013. Although the implementation of the Master Plan has been slower than anticipated in Thane, as with nearly all the cities participating in the Solar City Programme, it has served as a catalyst for local planning and policy actions that promote energy efficiency[10]. The programme has enabled cities like Thane to assess current and future energy demand and to develop a number of planning measure to promote renewable energy and energy efficiency technologies[11].

Table 5 outlines the targets set for renewable energy and energy efficiency across the residential, municipal, and commercial and institutional sector. TMC also took leadership and generated awareness on energy efficiency by undertaking action in its own buildings and operations, including through the sizeable targets laid out for the municipal sector. Therefore, TMC recognizes the importance of the Solar Master plan as an overarching strategy to drive action and reduce conventional energy use across sectors in the city, as is also emphasized in the Smart City plan, which continues to build on the city's solar plan.

Table 5: Sector-wise Targets for Renewable Energy and Energy Efficiency for Thane

	Renewable Energy Strategy		Energy Efficiency strategy	
Sectors	Conventional Energy replaced with RE (Million kWh)	Contribution to the Renewable Energy Target (%)	Total Energy Savings (Million kWh)	Contribution to the Energy Efficiency Target (%)
Residential	103.30	71%	110.05	65%
Commercial & Institutional	7.39	5%	25.89	15%
Industrial	1.66	1%	5.79	3%
Municipal	33.27	23%	28.62	17%
Total	**145.63**	**100%**	**170.35**	**100%**

[10] 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.

[11] Various alternate energy based solutions like solar water heaters, solar photovoltaic, and biogas have been proposed for residential, commercial and institutional, industrial and municipal buildings. Similarly, energy efficiency measures such as the use of energy efficient lighting, energy efficient appliances (including efficient air conditioners for space cooling) and energy savers have also been recommended in these sectors.

Source: (TMC, 2008)

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 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 Thane's policy goals (e.g. Pan-City goals from the Smart City Mission such as developing infrastructure and services to for the IT/ITES industry and education sector; meeting 10% energy consumption reduction target; municipal carbon neutral target; target of increasing renewables by 50%; and zonal building efficiency and renewable energy targets under the Smart City Mission).

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 Thane 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 presented in Section 9 will be important, including linking the analysis to politically important topics such as PV installations, clean water and smart infrastructure. For example, whether the benefits of new solar PV installations in Thane are being offset by installation of low efficiency space cooling elsewhere in the city.

5.3 Thane's Voluntary Initiatives

Thane has been a frontrunner in implementing renewable energy and energy efficient technologies in India. The TMC has demonstrated leadership and undertaken various renewable energy measures in its own buildings such as installation of 197 kW of solar photovoltaic systems in its main administrative building, zonal offices, and schools. Funds are allocated in its municipal budget for undertaking similar projects in the near future. Solar water heaters have been installed in hospitals owned by TMC. Energy efficiency measures undertaken by the TMC in its own buildings and facilities include retrofitting of conventional street lights with LED street lights, installation of energy efficient water pumps, and retrofit of energy efficient appliances and lighting. The TMC duly recognizes the opportunities to reduce energy use in space cooling applications as well and has implemented a thermal storage system in an auditorium and has installed a renewable energy based air conditioning system at a TMC hospital. A detailed list of TMC's interventions in renewable energy and energy efficient technologies, including the auditorium and hospital, is presented in Section 6.4 and further in Annexures 14.7 and 14.8.

The TMC has been engaging in voluntary international initiatives on the energy and climate change agenda with different partners such as the British High Commission (BHC)[12], the European Commission, and the Climate Group among others. TMC has leveraged opportunities offered in terms of technical support, knowledge exchange, and networking through these partnerships. For instance, the TMC partnered with the Climate Group, the Bureau of Energy Efficiency (BEE), and the Maharashtra Energy Development Agency (MEDA) to install around 300 LED street lights on a pilot basis, resulting in 50 percent energy savings. The success of the project led to the installation of 1100 LED lights by the TMC in localities housing lower income groups, implemented through funds allotted for social development.

Through the European Commission funded Urban-LEDS programme[13], Thane is actively engaged in pursuing low emission development by assessing its baseline energy use and GHG emissions (not including refrigerants). Thane has a voluntary target, under the Urban LEDS programme, of a cumulative reduction of 0.62 million tonnes of CO_2^{eq} (30% of baseline emissions in 2012-13) to be reduced by the year 2019-20. Thane has identified a set of priority low emission strategies and is undertaking a range of pilot actions at the local level, in alignment with the city's plans and vision. Pilot projects implemented include installation of net-metering based solar PV system, LED retrofit of 12,000 street lights, installation of smart and energy efficient appliances and lighting in buildings.

Box 3: City leadership

Thane is showing leadership on a range of sustainability issues, particularly piloting and advocating for clean, innovative technologies. Thane could similarly provide leadership to the district cooling sector, helping to pilot and promote this technology. Thane's promotion and involvement in an early demonstration project will be particularly important. Thane 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.

[12] The TMC participated in a project "Carbon emissions reduction through city level local action plans by integrating renewable energy and energy efficiency measures into city activities" implemented by ICLEI South Asia in collaboration with BHC. The project involved assessment of energy consumption and GHG emission within the city and preparation of a comprehensive city action plan to address the same.

[13] The Urban-LEDS project was an international programme implemented in select cities from emerging economy countries of Brazil, India, Indonesia and South Africa, to enhance the transition to low emission urban development by integrating low-carbon strategies into the local development planning process. Thane was one of two Model cities in India that engaged in this programme along with six other Satellite cities. The programme was implemented from 2012-2016.

If the demonstration project were to be partially owned by Thane then it could later be privatized once commercial viability is proven, creating a profit for Thane. 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, Thane 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).

Thane 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, Thane 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 Thane. This could also be undertaken by the SPV established to deliver the Smart City Plan. 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 analyze cooling costs, sample contracts, previous feasibility studies and demonstration project results – including TMC's experiences and savings from connecting to district cooling[14]. Also important are formal and informal networks and contacts between, for example, municipal employees or officials and state utilities, building developers and housing associations.

Thane 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 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 road works 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'.

Thane can promote district cooling development and ensure strong analysis of district cooling opportunities by undertaking and maintaining a GIS energy mapping[15] of the city incorporating spatial analysis of cooling demand, upcoming building developments (for example those shown in Section 3.3.2) 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 Thane undertake other spatial analysis related to the energy sector, such as delivering smart grid, resource mapping and

[14] 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.

[15] 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.

targeted building efficiency programmes. Box 10 describes further how such a mapping could be developed.

6 Local Policies and Legal Framework

6.1 Planning Authority and Framework

There are two main authorities in Thane which are involved in the planning and development of infrastructure related activities for the city. These are:

- Mumbai Metropolitan Region Development Authority (MMRDA)
- TMC

The MMRDA engages in long term planning, promotion of new growth centres, implementation of strategic projects and financing infrastructure development for the larger Mumbai Metropolitan Region. The Regional Plan provides for a strategic framework of MMR's sustainable growth. MMRDA is also involved in rental housing projects in the MMR region which also includes Thane (MMRDA, 2013).

TMC is the main planning authority for the city of Thane. TMC 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. TMC is also responsible for the provision of basic civic amenities to the citizens along with the preparation and execution of infrastructure development projects. Thus, TMC plays the role of planner, controller and implementer within its jurisdiction.

Development in Thane is currently guided by the Development Plan of 2003 which is a strategic framework prepared to regulate and guide land-use and infrastructure development over a period of 20 years. The plan details the quantity of land utilization for various uses, their functional interrelationship, and social and environmental considerations. The Plan also broadly prescribes the planning norms and development controls that will apply in the city.

The Town Planning Department of TMC is responsible for development and implementation of the Development Plan and holds the responsibility of issuing building approvals within the city.

The total area under the jurisdiction of TMC is 128.23 sq. km out of which 59 sq. km (47%) is developable area, 36 sq. km (36%) is non-developable (zoned as forest and defence) while the remaining 32 sq. km (24.9%) is green area. For planning purpose the city is divided into 11 spatial sections (called 'sectors'). Across these sectors are 804 reserved 'sites'.

Table 6: Broad Zoning of Sanctioned Development Plan

Sr. No.	Zoning	Area (sq. km)	Percentage share (%)
1	Area under Residential Zone	26.66	20.78
2	Area under Industrial Zone	12.54	9.78
3	Area under Reservation	12.68	9.88
4	Area under Road	7.43	5.79
5	Defense Area	1.22	0.95
6	Forest area	35.60	27.76
7	Green Zone Area	32.12	25.05
Total		**128.23**	**100**

Source: (TMC, 2016)

Section 10.1details some of the upcoming developments in Thane identified in planning documents and by the city and explores their opportunity for district cooling.

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

TMC uses zoning to influence development in the city by defining different land uses in different zones. Through zoning, TMC 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.

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

TMC 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. TMC 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, TMC 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 TMC and international experts. In particular, ensuring high-quality of assessments given the lack of district cooling experience in India will be important[16].

Similarly, requests for re-zoning by building developers above a certain size could provide an opportunity for Thane to accelerate district cooling. TMC could permit re-zoning under the condition that the developer meets stricter operational/primary efficiency building standards[17] and/or evaluates the potential for district cooling and if techno-economically feasible, then establishes district cooling systems.

TMC can use the planning process to put in place specific connection policies (of different buildings types) in the high priority areas. Furthermore, TMC 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, TMC 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 Thane, urban redevelopment is planned in existing urban areas, such as the highly dense city centre around Thane Railway Station (see Section 1.3.1), with huge levels of redevelopment and application of higher sustainability standards on 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, TMC 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 TMC to step-in and work with developers to

[16] 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.

[17] 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.

ensure district cooling is appropriately assessed – this could be the case for the multitude of large stand-alone buildings along Ghodbunder Road.

Through consultations with TMC as part of the District Energy in Cities programme, TMC has indicated that parcels of undeveloped land adjacent to existing developments such as along Ghodbunder Road 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 11.5.2.

Finally, as a provider of utility services such as water and sanitation, TMC has the authority over the installation of new utility lines such as district cooling pipes. During consultations, TMC has indicated that it can fast-track permissions needed for installation of piping and road works and can coordinate to ensure other utilities are installed in parallel. In addition, TMC may enter into a PPP to deliver a waste-to-energy (WTE) plant in Thane. TMC could use its planning authority to ensure the WTE is constructed so that waste heat capture is achievable by a district cooling demonstration project. TMC could also promote building development relatively near the vicinity of the WTE[18] plant (location is fixed at Dayghar) that could use the waste heat for a district cooling system.

6.2 Building Regulations and Certifications

The TMC is the deemed planning authority for Thane city. The Development Control Regulation (DCR), 1994 (updated in 2004), prepared by the TMC, regulates and lays out guidelines for land use zoning, density, floor space index (FSI)[19], building heights and other development and building related guidelines in Thane city. The Town Planning Department of the TMC holds the responsibility of issuing building approvals within the city.

Under the DCR, the permissible basic floor space index (FSI), permissible Transferable Development Rights[20] (TDR), and additional FSI[21] availed on payment of premium for the building development on a given plot varies based on the width of the adjoining road and the specific spatial planning sector wherein the plot is located. The permissible base FSI in the city for different types of land uses is 1.0. To encourage densification and development in underutilized areas and promote redevelopment within dense areas in Thane, additional FSI up to a maximum of 0.3 can be

[18] While some WTE are placed even 20 km away from the district energy systems that will use their heat it is far better to be able to serve demand that is close to the WTE as transmission pipes are expensive and their construction difficult to coordinate.
[19] FSI is the ratio of the built-up space on a plot to the area of the plot. FSI is a common variable used in the development control norms by cities to define and control the extent of built-up area on a plot. FSI is therefore an instrument used to regulate the pattern of development with regards to urban form and space.
[20] TDR is a mechanism to facilitate the acquisition of land for public infrastructure development activities such as road widening, metro rail projects, etc. Under the TDR scheme, a property owner whose land is reserved for public purposes gets a development rights certificate from the local government (equivalent to the reserved land portion) upon surrendering the property to the public body. The rights/certificate can then be utilized either for the remaining portion of the same property or elsewhere or sold to property developers who wish to use the development rights to undertake additional construction on their property.
[21] Additional FSI can be availed by the developer by paying a certain charge depending on the zone over and above the base FSI.

purchased if the adjoining road has a minimum width of 9 m. Further additional floor-space can be obtained through the TDR mechanism up to a maximum level that depends on the width of the adjoining road. More details on the DCR, including specific FSI achievable in Thane, can be found in Annexure 14.3.

Box 5: Incentivising district cooling through density bonuses

Thane could use the existing administrative structure of 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 and Rajkot, already provide FSI bonuses linked to sustainability criteria[22]. Furthermore, the Bank of Maharashtra, a leading nationalized bank in India, has announced a rebate of 0.25 per cent in the interest rate on housing loans for projects that are Eco-housing certified in Pune – the bank could similarly develop incentives for green building certifications in Thane'. (International Institute for Energy Conservation (IIEC, n.d.)

Solar Water Heating

In order to promote adoption of solar water heating systems, the State and the local building regulations have been amended to include mandates for installation of solar water heating systems in new as well as in existing buildings (see Annex 14.5 for the provisions that have been made in the DCR). The mandate has been linked to approvals sought for new buildings, with provisions made for solar water heating system required to be shown as part of any plans submitted for building planning permission. This mandate has resulted in about 6 million liters per day (LPD) of solar water heating capacity being installed in the city.

Box 6: District cooling ready buildings[23]

Thane could adapt the DCR 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 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 Thane and applied to multiple building types. In this way, even if buildings operate their own chillers, eventually they could be connected into a district

[22] Buildings with Pune's Eco-housing certification receive rebates from Pune Municipal Corporation (PMC) on additional floor space charges. The PMC also offers additional FSI of 3 to 7 percent for GRIHA certified green buildings.

[23] District cooling ready buildings: i.e. use centralised cooling systems with sufficient space left for chilled water pipes to connect the cooling system inside the building to outdoor pipelines as well as space for metering and a heat exchanger.

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 DCR if they develop district cooling.

Thane already uses zoning to apply specific planning conditions; primarily conditions surrounding land-use (see Section 6.1). Mandates for connection to, or development of, district cooling systems in high priority zones, as discussed in Section 6.1, could be exercised through adaptation of the DCR. 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

Thane 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. However, such a policy is under-development and the adoption of the Energy Conservation Building Code (ECBC) and its mandates on buildings will be a major step towards having such a policy.

6.2.1 Legislation relating to space cooling

Mandates for efficient space cooling are presently lacking in Thane's DCR. The existing guidelines and provisions in the development control regulations largely address the structural aspects and placement of air conditioning installations, with very little focus in terms of improved efficiency or standards for cooling (see Annex 14.6 for provisions on air conditioning in the DCR).

The Energy Conservation Building Code (ECBC), formulated in 2007, is India's first building energy code and targets building energy efficiency. The ECBC addresses the design of new, large commercial buildings (having a connected load of 100kW or contract demand of 120 KVA and above) and aims at optimizing the energy demand in buildings, including that for space cooling. This includes minimum standards on building envelopes and HVAC system efficiencies (see Section XX of the national analysis for more information on ECBC). Presently, the state of Maharashtra has modified the ECBC to suit its local or regional climatic conditions; however, a notification mandating compliance with the ECBC for large commercial buildings has not been issued as yet. As a result, the ECBC mandate is not under enforcement in Thane city at present. Given the numerous large scale commercial developments underway in Thane, the TMC is keen to promote green buildings and adopt the ECBC code[24] once this is notified.

Box 7: Ensuring the ECBC promotes district cooling growth

Adopting the ECBC will be a major step for delivering sustainable buildings in Thane. Its adoption will involve incorporating the ECBC into the DCR for Thane, establishing guidelines for how ECBC will be enforced in the city and building capacity in the city to enforce the new requirements. This

[24] In order to build local capacity to adopt and implement the ECBC, the TMC has participated in training programmes conducted by the Bureau of Energy Efficiency and has also organized a workshop with Maharashtra Energy Development Agency (MEDA).

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 Thane to ensure that efficiency improvements to buildings that connect to district cooling are acknowledged in its local building regulations. Thane 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, Thane 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)

6.3 Incentives and subsidies

TMC offers a 10% rebate in property tax to existing residential buildings that have installed solar assisted water heating systems. This has resulted in about 6 million LPD of solar water heating capacity being installed in the city. While the TMC does not offer incentives for green buildings or for efficient space cooling at present, it is exploring provision of incentives for green buildings under Thane's Smart City plan. 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.

During consultations conducted as part of the District Energy in Cities programme, TMC indicated its willingness to offer incentives to support and promote district cooling projects in the city. Development of such incentives will require detailed cost-benefit analyses. The city is interested to explore a similar model to their Solar Water Heaters programme, providing a property tax rebate for district cooling connection perhaps combined with a mandate on developers to assess district cooling development. Furthermore, the city is interested in setting aside parcels of public land for use by district cooling stations at a reduced cost and also adjusting water tariffs to support the business cases of demonstration projects.

Time of day tariffs are levied by the Maharashtra State Energy Distribution Company Limited (MSEDCL) with the intent to shift the load from the morning peak (0900 hours – 1200 hours) and evening peak (1800 hours – 2200 hours) to the night off-peak period (2200 hours – 0600 hours) and the afternoon hours. Around the world, such time of day tariffs often incentivize building-level and district-level storage of cool water for use during peak hours. In Maharashtra, initial and high-level analysis indicates that the peak to off-peak ratio may not significant enough for thermal storage to be financially viable on a district cooling network, this is explained further in Section 11.7. Thermal storage can deliver some of the main benefits of district cooling and so thermal storage incorporation should be analysed in all project pre-feasibilities.

While Thane has an innovative building-level thermal storage system in an auditorium (see Section 6.4 below) and hospital, stakeholder consultations and initial analysis indicate this is unlikely to be a commercially viable technology in Thane under current power prices. In some markets (e.g. in Malaysia), special tariffs are developed for district cooling storage projects that improves the commercial viability of such projects. In effect, these special tariffs increase the peak to off-peak ratio and this is justified by the significant upstream investment savings that can be achieved through such power system balancing and load shifting. To support district cooling market development MSEDCL along with Maharashtra Electricity Regulatory Commission (MERC) could consider special tariff provisions for district cooling and building-level storage projects.

Consultations with TMC have revealed the city's willingness to increase solar PV capacity to support district cooling. By selling municipally owned solar power directly to a district cooling project, TMC may be able to lower electricity costs by 30% for the project and guarantee a price for its solar PV projects. This would be a highly efficient use of the renewable energy and mutually beneficial – the district cooling project provides a means to centralize electricity demand from multiple buildings meaning one sole buyer of electricity for cooling. One sole buyer is much easier to set up a solar purchase agreement than multiple buyers.

Similarly, a planned 10MW waste-to-energy (WTE) plant (described in Box 4) could provide low-cost power directly to a district cooling project and also provide waste heat for a very low cost. Such waste heat is unlikely to otherwise be utilized and its use would improve the environmental credentials of the WTE plant.

6.4 Demonstration Projects

Thane city has been very proactive in trialing new innovative low carbon initiatives, assessing their effectiveness, and up-scaling such initiatives subsequently. This strategic vision of the TMC is well complemented by sound technical capacity and has enabled the TMC to effectively develop and implement a number of projects to help realize energy savings as follows:

- Replacement of 12,000 conventional street lights with energy efficient light emitting diode (LED) street lights is being done at present by engaging an Energy Saving Company (ESCO), with expected energy savings of about 60%.
- TMC has installed energy efficient devices in its office buildings, with about 3,000 conventional 80 W ceiling fans replaced with energy efficient 5 star rated ceiling fans of load 50 W, resulting in reduction in energy consumption by 270,000 kWh annually. Around 6,000 conventional T12 and T8 tube lights in TMC offices have been replaced with efficient T5 tube lights which have led to energy savings of 360,000 kWh annually. This initiative is being extended to other public buildings such as schools, hospitals, and auditoriums.
- 36,500 LPD of solar water heating systems have been installed in TMC buildings such as maternity homes and staff quarters, which has led to energy savings of 38,000 kWh per annum. 76,000 LPD of solar water heating systems have been installed in new residential buildings constructed by the TMC for its urban poor population.

- Solar PV systems in excess of 200 kW capacity have been installed by the TMC in its main administrative building, various zonal offices and its schools, which includes net-metering based systems as well.
- TMC has installed a bio-methanation plant of about 15 tonnes capacity at the Chatrapati Shivaji Maharaj (CSM) hospital. The plant produces 600 m^3 of methane gas per day, which is being supplied to a 50 kVA biogas genset for electricity generation and is also fed to the solar AC backup boiler. About 800 kWh of electricity is generated every day. In addition, 2 bio-methanation plants of 5 tonne capacity each have been installed in residential complexes.

The TMC has also implemented initiatives related to efficient space cooling at the Kashinath Ghanekar Auditorium and at the CSM hospital.

- **Thermal storage for centrally air-conditioned Auditorium**: The TMC has considerably improved the energy performance of its central air-conditioning plant at Kashinath Ghanekar Auditorium, with energy savings of 30% realized, accruing monetary savings of INR 1.4 million annually. A thermal storage system has been put in place to store ice with ice balls during off-peak time (10 pm to 6 am) and use it during peak time in combination of chillers when necessary. This has helped in shifting energy demand to off-peak hours. Existing inefficient compressors having specific energy consumption of 1.8 kW per TR (kW per tons of refrigeration) by energy efficient screw compressors having specific efficiency 0.8 kW per TR. The use of CFC based refrigerants has been eliminated as well.
- **Renewable energy based air-conditioning plant:** A 160 TR capacity solar based air conditioning system has been installed by the TMC at its CSM hospital and is partly meeting the cooling demand of the hospital building. Solar parabolic concentrators have been installed and the existing chillers replaced by a double effect vapor absorption machine. A diesel fired boiler has been replaced by agro residue based briquette fired boiler. Steam generated through the solar concentrator as well as through the briquette-fired boiler is used for laundry purpose, for sterilization, and further for air conditioning through the vapour absorption machine (VAM) which uses lithium bromide solution to produce chilled water. The interventions have resulted in energy saving of nearly 1 million kWh per year and monetary savings of INR 7 million per annum. The hospital also has a bio-methanation plant that feeds the solar cooler (see above). This hospital is examined in further detail in Section 11.4 and its details are available in Annex 14.8. Further details of project interventions undertaken by the TMC are available in Annex 14.7.

Box 8: Thane as a demonstrator

TMC'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 TMC and its experience in coordinating relatively large sustainability programmes. Building on this leadership, TMC can develop a demonstration project on district cooling as well as establish a sustainable energy delivery unit as described above in Box 3, both of which are a best practice for scaling DES.

6.5 Project financing in Thane

The TMC has indicated its willingness to explore innovative financing and business models for district cooling projects and also to extend financial support, to the extent possible. These could include providing low-cost electricity from its 10MW solar PV plants, land for district cooling plants, low-cost water and property tax rebates and are discussed in Section 6.3 above.

The administrative agencies in Thane have been leveraging finance from different sources to implement projects in key sectors. They understand the complementarity that exists between various Central and State government programmes and place high emphasis on integrated planning to maximize funding opportunities available. The TMC has been utilizing funds available under various programmes and schemes that include the Smart Cities Mission, the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Integrated Urban Development Mission, and the Solar Cities Programme for implementation of infrastructure and energy projects. TMC also utilizes its own funding sources for project financing, as indicated in Table 7 for key energy related project areas for year 2016-17. TMC has worked closely with international agencies to leverage funding support for demonstration projects apart from technical support. Annex 14.4 provides more detail on the different funding sources used by Thane.

The TMC has also implemented various projects with a public private partnership (PPP) model and has gained considerable experience in leveraging private sector expertise and investment. The LED streetlight retrofit project covering 12,000 street lights, is being implemented through a shared savings based ESCO model. The ESCO will finance and implement the project and also be in charge of operation and maintenance (O&M) and monitoring, reporting and verification (MRV) post-installation. The ESCO will receive a share of the accrued monetary savings from the TMC, to recover its investment. The TMC will be signing an energy savings performance contract with the ESCO for a period of 7 years, with the ESCO offering guaranteed energy savings to the TMC. The ESCO will be implementing the project under the Design, Finance, Build, Own, Operate and Transfer (DFBOOT) model. A third-party auditor will certify the established baseline and accrued energy savings. Key ongoing projects along with their implementation modality are listed in Table 7 below.

Table 7: Details of Budget Allocation made by TMC for financial year 2016-17 for Energy Project Areas

Sr. No.	Projects	Allocated Budget	
		Million INR	Million USD
1	Capital work for energy efficiency projects	5	0.08
2	Projects under Solar City Master Plan	15	0.23
3	Solar City cell	5	0.08
4	Solar system in Municipal schools	25	0.38
5	New demonstration project (Solar concentrator based HPSV system)	5	0.08
Total		**55**	**0.83**

Source: (TMC, 2016)

Table 8: Details of Implementation model and TMC's contribution for Energy projects currently under implementation

Sr. no.	Details of Low emission initiative	Year	Allocated budget/financial contribution by TMC	Status	Implementation Model
1	A 10 MW Solar photovoltaic to be installed at various locations in TMC area	2016	-	ongoing	PPP
2	10 kW micro-hydro power project	2016	-	ongoing	PPP
3	Operation of 100 electric buses	2016	-	ongoing	PPP
4	LED retrofit of 12,000 existing street lights	2016	TMC funds (partly) (street light maintenance fund)	ongoing	ESCO
5	8 municipal buildings to be made net zero with total installed solar PV capacity of 136 kW (with net-metering)	2016	TMC funds (budgetary allocated under energy efficiency projects)	ongoing	TMC's own initiative
6	SPV system in municipal school buildings	2016	TMC funds	ongoing	TMC's own initiative
7	Solar Concentrator based HPSV system	2016	TMC funds	ongoing demonstration project	TMC's own initiative
8	Waste-to-energy plant (1000 TPD municipal waste to be treated)		TMC funds (partly)	ongoing	PPP

Source: (TMC, 2016)

Box 9: Financing district cooling

TMC 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 TMC and other stakeholders including local financiers to be able to deliver and finance a district cooling project. Analysis of how TMC 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[25].

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
- EESL / ESCO model

These are elaborated as follows:

[25] 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.

- TMC 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 TMC has a tight city budget and no precedent of previously guaranteeing or providing loans the latter is more likely. TMC 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 MEDA), 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 have 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 Thane 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 Thane

The key barriers towards implementation of district cooling projects in Thane are:

- **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 centralised 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.
- **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**: Lack of in-house experience within the TMC and a general lack of local technical expertise specific to implementation of district cooling systems would impact the pace of design and construction for any district cooling projects. However, it is evident from past experiences that TMC is proactive in trialling new technology for demonstration and then scaling up the same while absorbing technical know-how and learnings.
- **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. The TMC has shown willingness to devise such enabling instruments to promote district cooling projects.

- **High cost of land in Thane:** The real estate prices in Thane are very high and almost comparable to Mumbai and are rising. This can inhibit deployment of district cooling systems. While this may increase capital expenditure (CAPEX) costs for district cooling plants, it can also incentivize building density and encourage developers to look for ways to maximize their land-use – such as by saving floor space by eliminating chillers and cooling towers and connecting to district cooling.
- **Difficulty in retrofitting existing building developments:** Considering the highly dense and mixed-use development in Thane city, which has already taken place in prominent areas in the city, retrofitting buildings to have centralised air conditioning is difficult as potential consumers will be reluctant to incur costs for any internal structural changes. It may prove difficult for building developers and managers to have agreements with occupiers to make such changes. The networks for utilities and services have already been laid along with the transportation network, meaning sections of roads would need to be dug-up to lay district cooling pipes. Limited information is available on buildings having centralized chilled water system in the city, making identifying retrofit projects harder. A key concern highlighted during consultations was that building developers or owners who have already invested in centralized chillers in existing projects 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. However, one significant benefit is that the buildings already exist and their cooling load known, lowering load uncertainty for a district cooling project.
- **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.
- **Rate of development in Thane:** The fast pace of the real-estate sector in Thane provides some challenges in that a district cooling project would have to align with this pace. Furthermore, detailed building plans and HVAC system designs may only be made available later in the project at which point it may be too late to incorporate centralised cooling and/or ensure connection to district cooling.

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

Table 9: The key barriers towards the implementation of district cooling in Thane city

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
High cost of land	Financial	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
Fast-pace of real estate	Technical	Medium

9 Space cooling in Thane

Thane being in the hot and humid climatic zone of India faces daily climatic conditions which are not within the desired thermal comfort zones, necessitating the use of air-conditioners and ceiling fans for space cooling. Furthermore, building envelopes and building occupancy are major drivers of air-conditioning demand.

9.1 The extent of air-conditioning in Thane

Overall, air conditioning has found takers in all types of buildings in the city and the hot and humid conditions of Thane (see Section 3.2.2) along with the rapid development witnessed by the city are making it the norm to install air conditioning, particularly in new developments.

Non-residential

Large-scale commercial buildings, offices, retail malls, hospitals, and business and IT parks in Thane widely use air-cooled or water-cooled centralized air conditioning systems for space cooling. 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[26]. Data or benchmarks relating to the size and costs of systems installed is also unavailable although consultations with stakeholders and building owners in Thane 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.

[26] 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).

Residential

In the case of the residential sector, the higher and the upper medium income group mostly uses split air conditioners throughout the year. Many residential township developers are offering apartments with split air-conditioning as an add-on facility in order to attract customers, thereby contributing to rising air-conditioning loads. In 2009, the neighboring city of Mumbai used 40% of its electricity demand for space cooling with an air conditioner market penetration of only 16% (Times of India, 2009). According to a survey conducted as a part of Thane's Solar City Master Plan, the ownership of air-conditioning is found to be 43% in Thane while ceiling fans are used by 100% of the surveyed population. The authors are not aware of any current or planned residential buildings in Thane using centralized cooling.

Box 10: Identifying opportunities for district cooling

In order to assess the scale of cooling in Thane, effectively promote and plan for district cooling and identify potential district cooling projects, a GIS energy mapping of Thane 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 8. 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). TMC will need to play a crucial role in encouraging and supporting building owners to install meters and ensure these can be monitored. TMC can lead by example and support the installation of meters in some public buildings[27].

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 Thane (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 as described in Table 11 which should be built-upon in the future in Thane[28].

The combination of improved mapping, data and benchmarks will enable a full analysis on the current and longer-term impacts of space cooling in Thane, justifying new policies, technologies and investments. These impacts are likely to intensify with increasing population, increasing

[27] 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.

[28] 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.

wealth and new business developments. Section 9.3 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 Thane, 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 and commercial buildings would have a lower diversity factor[29], 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 Thane

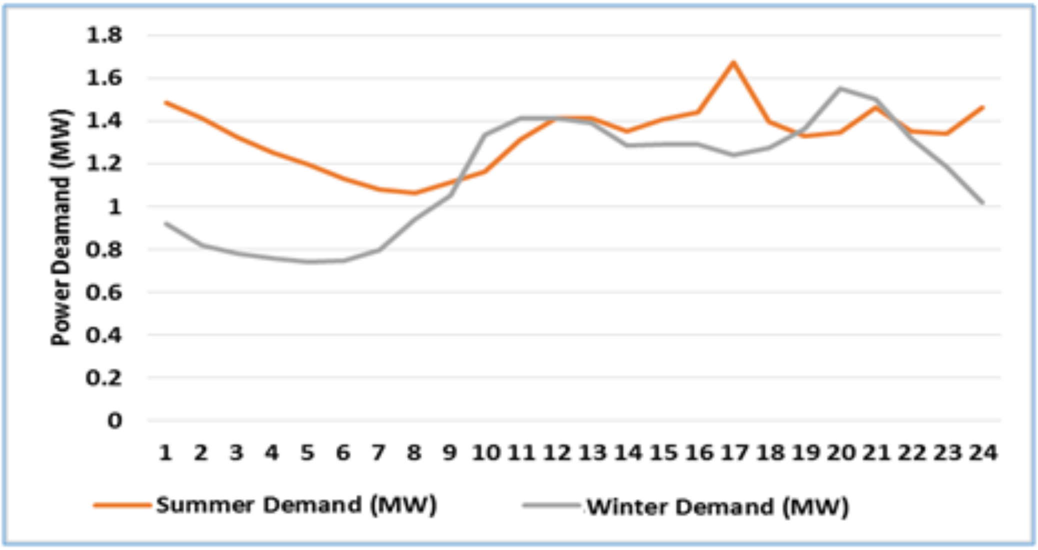
Interactions with stakeholders in Thane, including developers, owners and managers of commercial properties, business parks and residential apartments, confirmed that given the climate of Thane and the significant role building occupancy has on cooling demand, almost all the sectors require space cooling throughout the year, however the cooling demand rises sharply in the summer period. 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 was also not available from MSEDCL, except at the feeder level where individual 24-hour periods can be downloaded.

24-hour load variation for two building types

To demonstrate the range of electrical demand that can be seen over a period of 24 hours, data was acquired from the MSEDCL website. Two different feeders were considered which predominantly supplied power to a residential township and a commercial shopping mall respectively. The data downloaded was for a single 24-hour period in winter and in summer and so the data is not representative of the average summer or winter profile. The purpose of these graphs is to demonstrate the strong difference between the seasons for these two building types.

[29] 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%.

Figure 12: Hourly Load Profile for Commercial Shopping Mall in Thane from two sample days in winter and summer

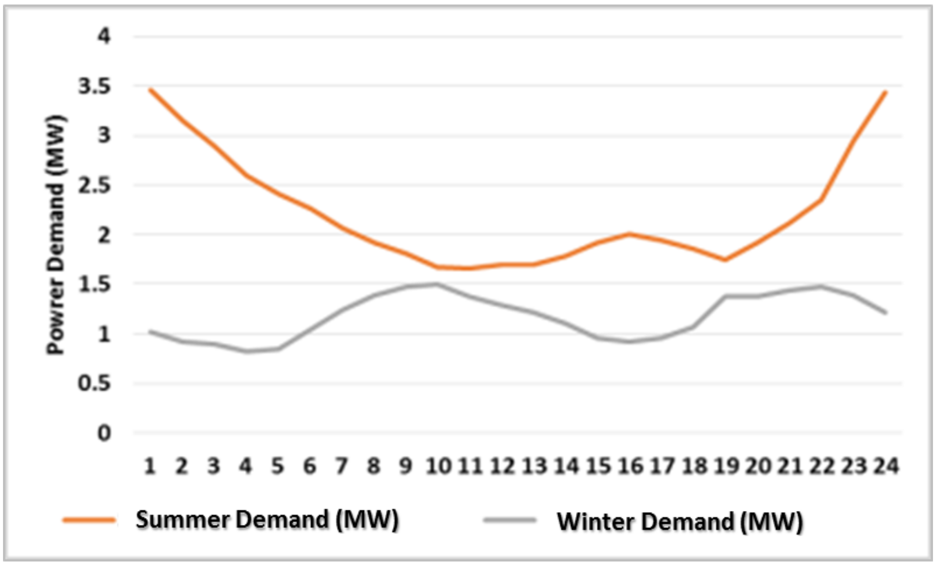


Source: Analysis based on the data from (MSEDCL, 2016)

For the commercial shopping mall, shown in Figure 12, it can be observed that the winter demand is lowest in the early hours from 0200 to 0600 hours and starts increasing from the start of the day and more or less remains same during the prime commercial hours, while dipping again towards the end of the day. Summer demand is higher than that in the winter, particularly overnight and in the afternoon from 1400 to 1800 hours. This can likely be attributed to increased space cooling load. Demand rises in the winter from 1900 to 2100 hours, this may be due to increased lighting demand as compared to summer. Overnight demand being higher in summer could indicate that the building is air-conditioned outside of operating hours. Relatively similar demands during the day in both winter and summer could indicate the significant impact higher building occupancy has on air-conditioning use.

As an example, Viviana Mall in Thane, which has a 4,185 TR capacity water chilled plant and 5 MVA of electrical load, consumes an average of 2200 kVA in winter and 3200 kVA in summer. This underlines the fact that the space cooling demand in the summer season in commercial buildings increases as compared to that in the winter season.

Figure 13: Hourly Load Profile for Residential housing complex in Thane from two sample days in winter and summer



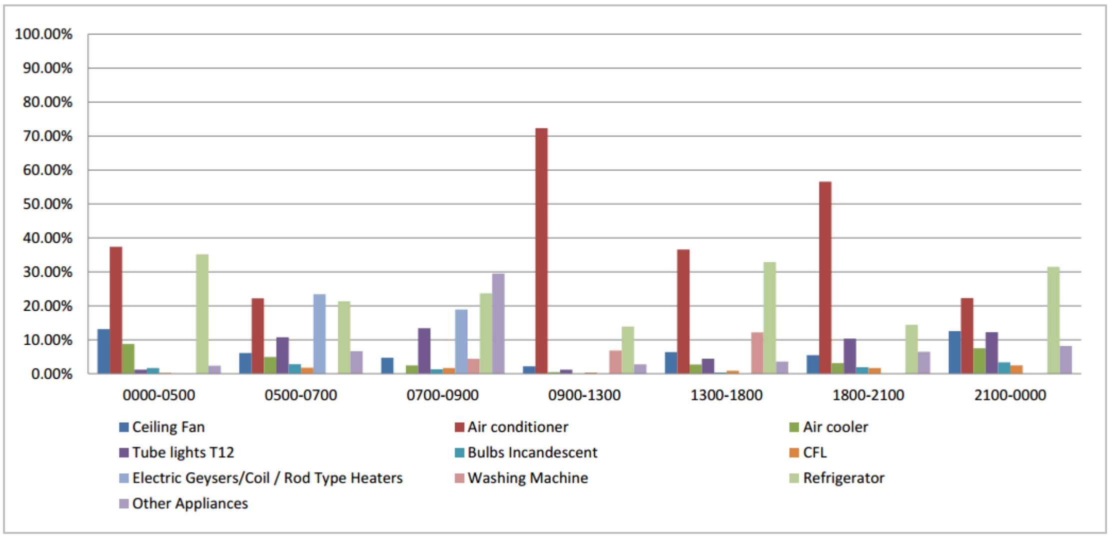
Source: Analysis based on the data from (MSEDCL, 2016)

The sample days from winter and summer used to illustrate residential load profiles show a distinct seasonal difference and the profiles reflect the time of maximum occupancy of the consumer. In summer, during the night when occupancy is higher, demand increases whereas during the day time the demand is lower. During winter, clearly less space cooling is needed during the night due to lower temperatures and humidity. The winter demand is about half of the summer demand. Night time demand is considerably higher in the summer season, rising as much as 3.5 times of the night time demand during winters. Demand during the afternoons in the summer from 1200 to 1800 hours is also much higher as compared to the winter season.

A load research survey and analysis conducted in 2015 by the Indian Institute of Technology, Mumbai and the Energy Efficiency Services Limited (EESL) for 22 power distribution circles of the MSEDCL across Maharashtra[30] indicates that air conditioning contributes prominently to peak demand throughout the day in households during the summer season (see Figure 14) (EESL, 2016). The study also indicates that use of air conditioning in households remains significant during the winter season between 0900-1300 hours and between 1800-2100 hours as well. While it would be useful to similarly assess impacts of appliance use on peak demand for the commercial properties and office spaces as well, studies reporting such analyses for the commercial sector in Maharashtra are not available.

[30] The load research survey and DSM Potential Assessment (Load Sector and End Use wise) was conducted in 2015. Under this study, hourly load data for the year 2013-14 had been collected from MSEDCL and then season wise, weekday and weekend wise MSEDCL load curve was prepared and analysed. As part of the feeder level data collection, data for hourly load data for 7 days of a month for entire financial year was collected from sub-stations, and based on feeder data collected, sector specific load curves have been prepared and analysed.

Figure 14: Operating Hours of Residential Appliances - Summer Season[31]



9.3 Impacts of cooling on electricity consumption

The MSEDCL is the distribution utility responsible for distribution of power in Thane city. The electricity consumption for Thane has been growing at an annual rate of 3.67%, with a total consumption of 1,754 Million kWh in the year 2014-15 (see Table 10).

The residential sector is the largest end-use consumer accounting for 53.2% of the total electricity consumption. Consumers connected to the high-tension network accounts for 20.2% of the city's power consumption. The high-tension consumers' category primarily includes large commercial and industrial properties such as IT offices, business parks, large shopping malls and commercial complexes having connected load of 150 kW and above. A decreasing trend is observed in the power consumption by high tension consumers primarily owing to the shifting of large scale industries to areas outside the city limits in recent years. Smaller scale commercial consumers connected to the low tension have a share of 13.5% in Thane's power consumption. Power consumption by the public sector and the public utilities through low tension and high-tension connections cumulatively account for 3.3% of the power consumption. Smaller-scale industrial consumers connected to the low-tension network account for 6.8% of the total electricity consumed.

Analyzing 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.

[31] The percentage refers to the percentage of time that the appliance is used for each time slot

Table 10: Year-wise Total Electricity Consumption for Thane City

Consumer Category	Electricity Consumption (Million kWh)				
	2011-12	2012-13	2013-14	2014-15	Percent Share (2014-15)
Residential	752.8	834.4	872.7	933.1	53.2%
Low Tension-Commercial[32]	213.5	229.1	232.8	236.7	13.5%
Low Tension-Industrial[33]	106.7	107.2	115.1	118.8	6.8%
High Tension -Consumers[34]	395.7	377.1	363.3	354.9	20.2%
Low Tension-Public Sector/Services[35]	28.9	29.1	28.8	32.2	1.8%
High Tension-Public Sector/Services[36]	10.0	19.5	25.3	27.1	1.5%
Others[37]	64.1	67.1	64.6	52.5	3.0%
Total	**1,571.7**	**1663.1**	**1702.0**	**1754.6**	**100.0**

Source: (MSEDCL, 2016)

Monthly electricity consumption can be very useful in understanding the seasonal consumption of electricity in cities. The monthly electricity consumption indicates that consumption is increasing in the summer period from March up to June in particular, with the highest monthly electricity consumption observed in the month of June, a rise of 42% compared to that in February (see Figure 15). Electricity consumption is consistently high throughout the monsoon months when humidity or the level of thermal discomfort is high and in the dry period beyond this season as well, with the months of July to November having similar levels of power consumption.

[32] Low Tension Commercial includes small-scale consumers having low tension connections such as film studios, cinemas and theatres (including multiplexes), offices, commercial establishments, marriage halls, hotels/restaurants, ice-cream parlours, coffee shops, internet/cyber cafes, telephone booths and fax /photocopy shops, automobile maintenance centres, banks and ATMs, sports clubs/facilities, etc.

[33] Low Tension Industrial includes consumers having low tension connections such as flour mills, engineering workshops, printing press, food processing units and others

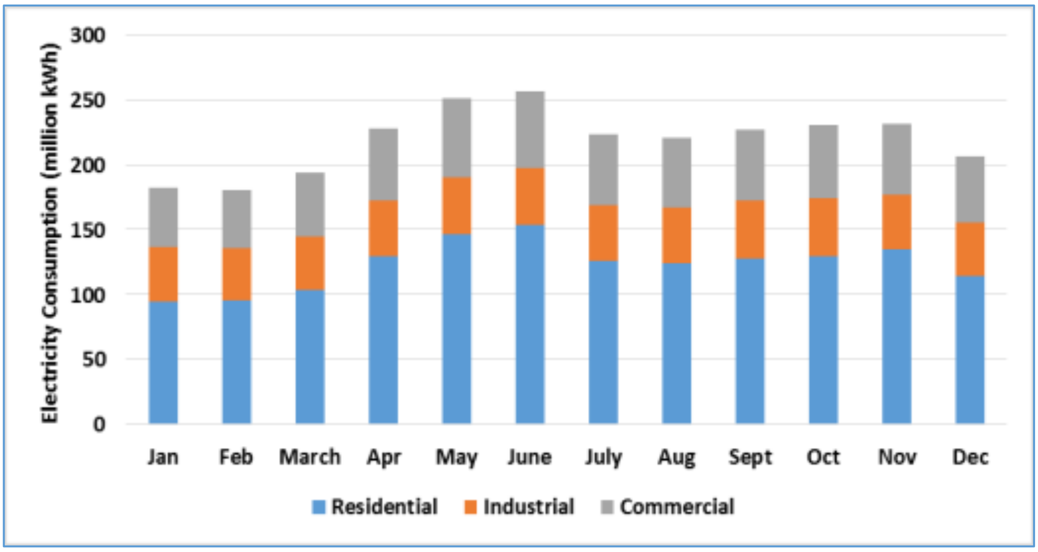
[34] High Tension Consumers includes large scale properties consumers with more than 150 kW sanctioned load such as large IT offices, business parks, shopping malls/complexes, large hotels, educational institutions etc.

[35] Low Tension-Public sector and services includes public water works, sewage treatment, street lighting, other public services, and public sector and government consumers such as educational institutes; public health care facilities, libraries, offices of Government and Municipal/ Local Authorities/Local Self-Government bodies

[36] High Tension-Public sector and services includes public water works, sewage treatment, other public services, public sector and government consumers such as educational institutes; public health care facilities, libraries, offices of Government and Municipal/ Local Authorities/Local Self-Government bodies

[37] Others include temporary supply, railway traction, hoarding and advertisement, crematorium/burial grounds, etc.

Figure 15: Sector-wise Monthly Electricity Consumption (2014-15)



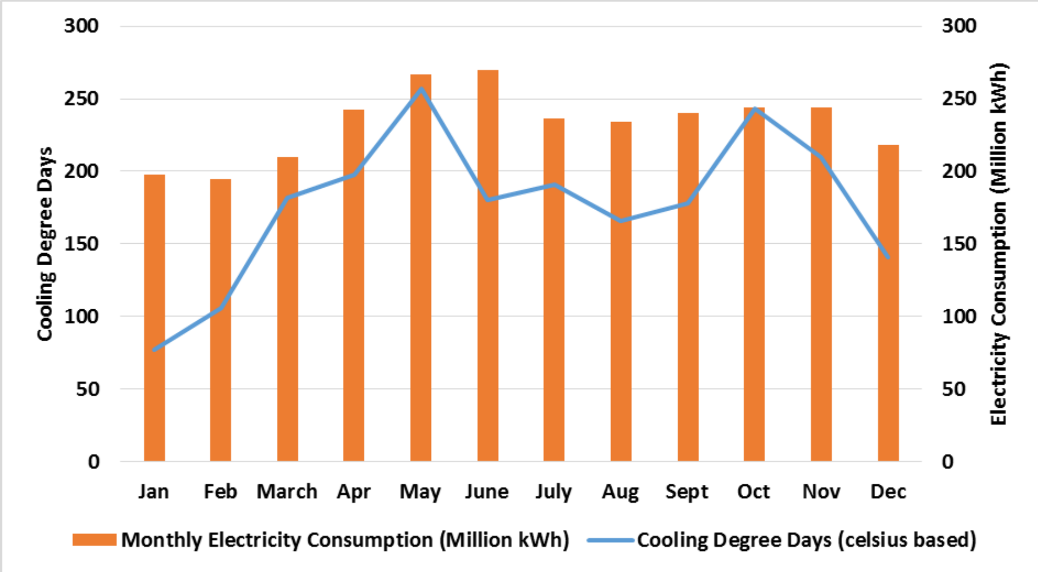
Source: (MSEDCL, 2016)

However, it is difficult to extract the full impact of cooling from monthly power consumption. Other loads in a city can be seasonal (e.g. lighting, refrigeration, irrigation pumping etc.) 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 periods in a month when cooling is used less. Furthermore, as described in Section 9.2, air conditioning is used throughout the year in Thane by all sectors, meaning the loads shown in January and February will still contain significant amounts of cooling demand.

Since humid climate conditions prevail in Thane, the seasonal variation in electricity consumption is likely to be predominantly caused by space cooling (including fans, air conditioners and chillers). Given the urban setting of Thane city, there is little irrigation pumping. Demand for lighting may slightly increase during the monsoon season, when hours of daylight are diminished, however it is not expected to create a significant seasonal variation[38]. The cooling degree days (CDD) for Thane are seen to rise during the summer season and are relatively high during the post-monsoon months of October and November as well (see Figure 16 – base temperature used for CDDs is 23°C). The trend of the cooling degree days is generally observed to have a positive correlation with the trend of power consumption.

[38] Electricity demand for lighting demand varies negligibly between winter and summer in Gujarat cities and this is also expected in Thane (Load Research Survey ,2010).

Figure 16: Relationship between Monthly Cooling Degree Days and Electricity Consumption for Thane City (2014-15)

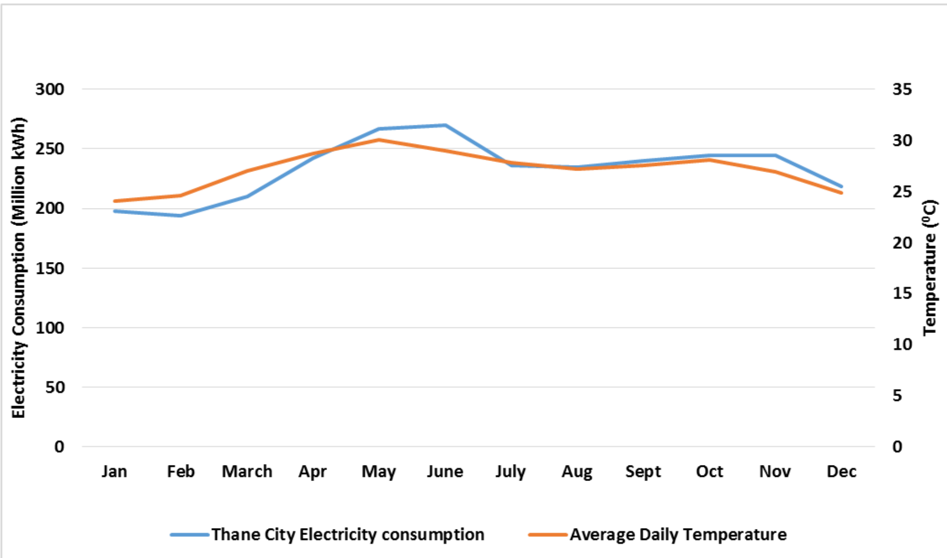


Source: Analysis based on data from MSEDCL, 2016 and degreedays.net Tool

The electricity consumption in the residential sector is seen to increase notably in the summer months. The commercial and industrial Sector show a similar trend, though the seasonal variation is comparatively lesser in these sectors, perhaps due to less seasonality in their cooling demand.

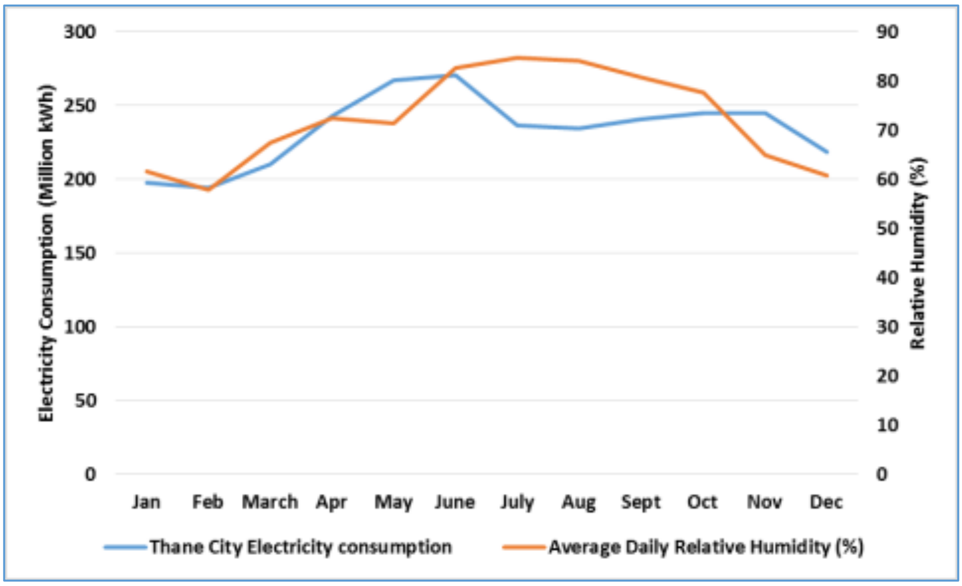
A positive correlation is observed between electricity consumption and the monthly temperature, with the power consumption rising when the temperature increases.

Figure 17: Relationship between Monthly Temperature and Electricity Consumption for Thane City



Source: Analysis based on data from MSEDCL, 2016 and ASHRAE, 2009

Figure 18: Relationship between Monthly Relative Humidity and Electricity Consumption for Thane City



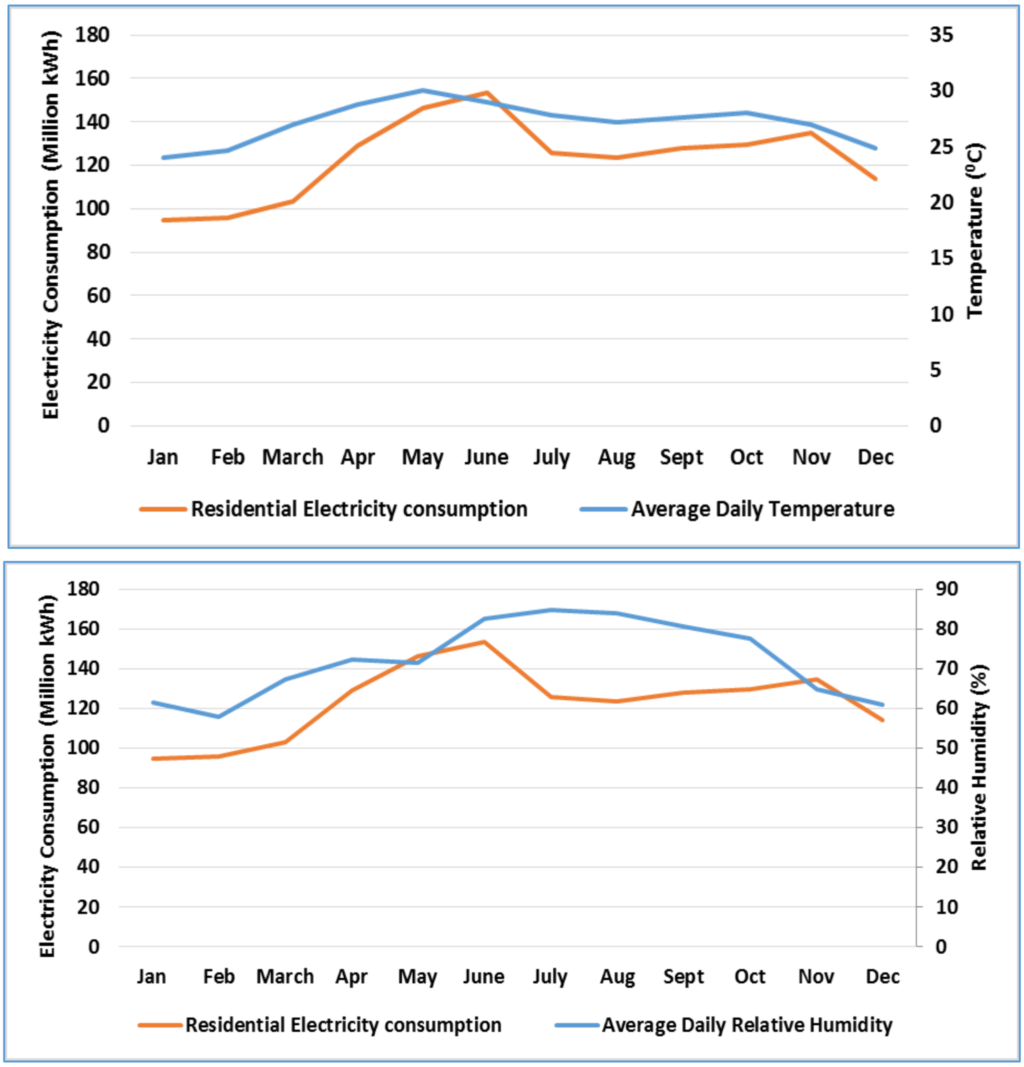
Source: Analysis based on data from MSEDCL, 2016 and ASHRAE, 2009

9.4 Sector-wise Analysis of Cooling Demand

9.4.1 Residential Sector

The electricity consumption in the residential sector during the peak summer period from May to June is about 40% higher as compared to that in the winter season, which can be correlated with increased demand for space cooling due to rising temperature levels. Household power consumption during the period between July to November remains relatively steady. The seasonal load ratio for the residential sector is 21%.

Figure 19: Relationship between Monthly Temperature/Relative Humidity and Electricity Consumption for Residential Sector (2014-15)



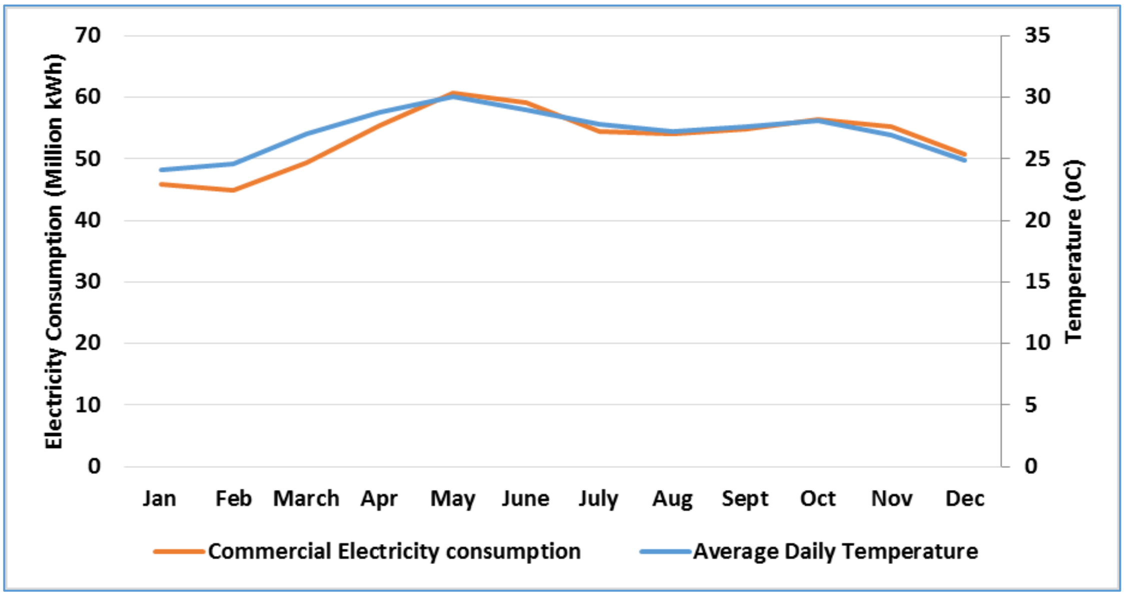
Source: Analysis based on data from MSEDCL, 2016 and ASHRAE, 2009

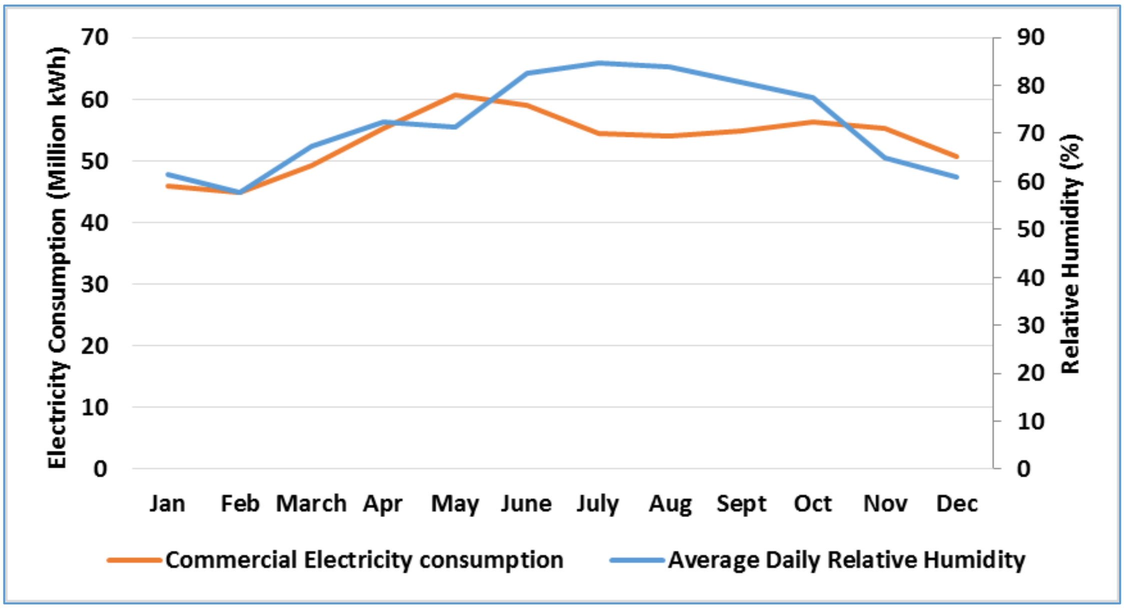
9.4.2 Commercial Sector

The seasonal load in the commercial sector[39] rises during the summer and is about 15% more than the base load across the year, while peaking to about 30% higher in the month of May. Monthly power consumption by small-scale commercial consumers depicts a close correlation with the average monthly temperature. The monthly power consumption for the large scale high-tension commercial consumers is not available.

[39] Includes commercial and business premises such as shopping malls and show rooms, marriage halls, hotels/restaurants, automobile maintenance centres, banks and ATMs, sports clubs/facilities

Figure 20: Relationship between Monthly Temperature/Relative Humidity and Electricity Consumption for the Commercial Sector





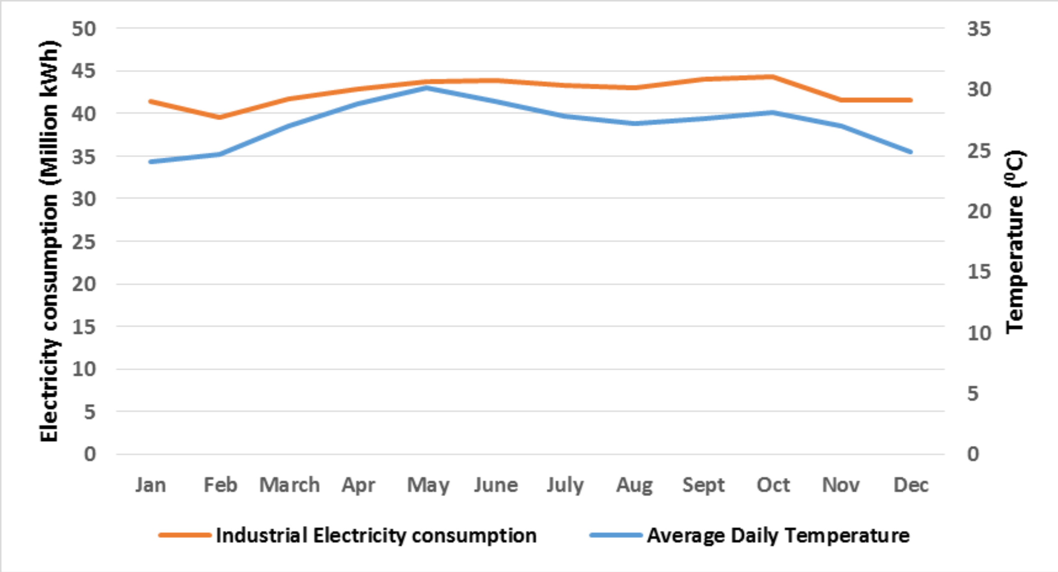
Source: Analysis based on data from MSEDCL, 2016 and ASHRAE, 2009

9.4.3 Industrial Sector

Electricity consumption in the industrial sector[40] peaks is seen to rise during the summer months and is quite consistent up to the month of November.

[40] Includes small-scale industrial units such as engineering workshops, printing press, food processing units

Figure 21: Relationship between Monthly Temperature and Electricity Consumption for Industrial Sector



Source: Analysis based on data from MSEDCL, 2016 and ASHRAE, 2009

10 Opportunities for District Cooling in Thane

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

Thane is a fast-developing hub for IT and IT related services along with rapidly expanding retail sector. Thane city is known as the dormitory city of Mumbai and is a favored destination for new residential real estate, in particular luxury apartments. As shown in Section 0 above, rapid development and economic growth is leading to an annual growth in power demand of 4.6%. Thane's electricity consumption is seen to rise by approximately 42% during the summer season, predominantly due to space cooling. This cooling demand is expected to grow given the rapid development, population influx and increasing incomes.

Thane is the fastest appreciating realty market in the metropolitan region of Mumbai, witnessing a quarter-on-quarter rise ranging from 3.4-14 across different localities in year 2015, mainly due to its good connectivity to Mumbai, Navi Mumbai, and other cities in the region (Square Yards, 2015). Key local real-estate developers such as Sheth Developers, Dosti Group, Rustomjee, Hiranandani, and Kalpataru are focusing on large-scale residential townships with high-rise structures. Prominent projects of these developers include Sheth Vasant Lawns, Dosti Vihar, Rustomjee Urbania, Hiranandani Estates, and Kalpataru Siddhachal. IT/ITeS companies constitute a major portion of the occupiers of commercial office spaces in the city. Thane has about 4.5 million sq.ft of premium (Grade A) office space which constitutes about 5.3% of the total stock of the city (Jones Lang La Salle), which includes commercial properties such as G Corp Tech Park, Kalpataru Prime, Dosti Pinnacle, Neptune Element, and the Hiranandani Business Park among others. With a limited number of large office occupiers, commercial office spaces largely cater to multiple occupiers, who either fully or partially occupy floors in commercial properties.

Proposed infrastructure projects such as the Thane-Kasarvadavli Metro and the Thane- Bhiwandi - Kalyan Monorail corridor are expected to further boost development in Thane by enhancing its connectivity. Residential developments will be driven by demand arising from the IT businesses in the city. The city's arterial Ghodbunder road has witnessed significant mixed-use development and hosts good commercial projects and office spaces along with a number of shopping malls, retail spaces and hotels in its vicinity. A number of these large commercial and retail spaces use centralized air conditioning systems to meet their space cooling demand, as seen in the properties in the vicinity of the Viviana mall area, a potential site selected for high-level feasibility of district cooling in this assessment. The Ghodbunder road is expected to drive development in the coming years as well due to new infrastructure development, availability of large parcels of land, a surge in commercial activities, and the IT zone in the Wagle Estate area. Other areas witnessing significant development include Old Thane, Pokhran Road, the Nashik Highway, and the Pune Highway.

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 11 examines the high-level feasibility of some areas with large IT based anchor loads and mixed-use development, located in and around Thane, for district cooling.

Building developers in Thane 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 Thane 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, Thane 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 include: direct use of municipally-owned solar electricity by the district cooling project, solar and/or biogas cooling through absorption chillers (see Section 11.4 and Annex 14.8) and the upcoming waste-to-energy project (see Box 4). The temperature of the Thane Creek is expected to be too high for use as 'free-cooling' (see Section 3.2.4). 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 Thane (see Section 3.2.4), lowering requirement of fresh water for cooling. High-level analysis of the power prices in Thane (presented in Section 11.7) 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 (see Section 0).

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 Thane

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

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[41]

[41] 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.

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**

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 Thane

Cooling demand

As explained in Box 10, no benchmarks for building cooling demand or consumption are available in the city of Thane. 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 Sections 11.5 and 11.6), 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.

Annex 14.10 details 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 11: Assumptions of cooling demand

	Hotel	Office	Shopping mall	Hospital	Residential Apartment	Campus building
W/sqm	150	250	300	200	125	200

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 12 summarises these assumptions.

Table 12: 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[42] (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 Thane buildings and district cooling experience in other countries, the annual average Coefficient of Performance (COP) of each cooling system[43] is estimated as following (the chilled water temperature is 5/13 ℃):

Table 13: 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 Thane is conservatively estimated as 1950 hours.

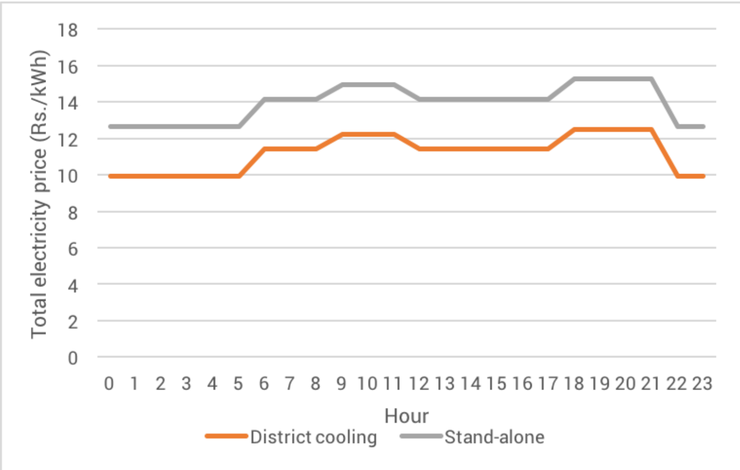
Operation and Maintenance costs

[42] 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.

[43] 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 Maharashtra State Electricity Distribution Company limited (MSEDCL) tariffs and presented in Figure 22. District cooling plants are expected to access slightly lower overall electricity tariffs due to higher voltage connections as they are able to centralise multiple cooling loads from different buildings. For district cooling system, it can employ high-voltage chillers (6KV or 11KV) so the tariff of High-Tension Industrial (HT I (A): Industry-General) is applied, while the tariff of High-Tension Commercial is applied to standalone systems according to information provided by local commercial users.

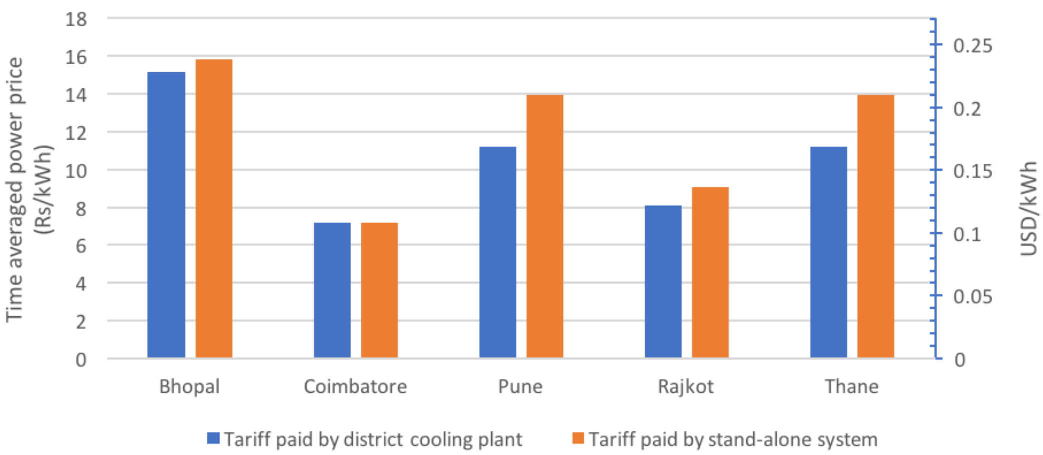
Figure 22: Electricity prices in Thane (Energy charge fee)



(Source: Based on tariffs charged by (MSEDCL Tariff Order, 2016)

Compared to the other cities assessed in India, Thane has relatively high electricity prices, as can be seen in Figure 23. This helps the business model for district cooling as it makes being energy efficient in cooling more profitable, even if upfront costs are higher for efficient solutions like district cooling. Thane has the same prices as Pune as they are in the same state.

Figure 23: 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 tariffs charged by from 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 24, 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 24

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.

11.3 Analysis of generic project archetype

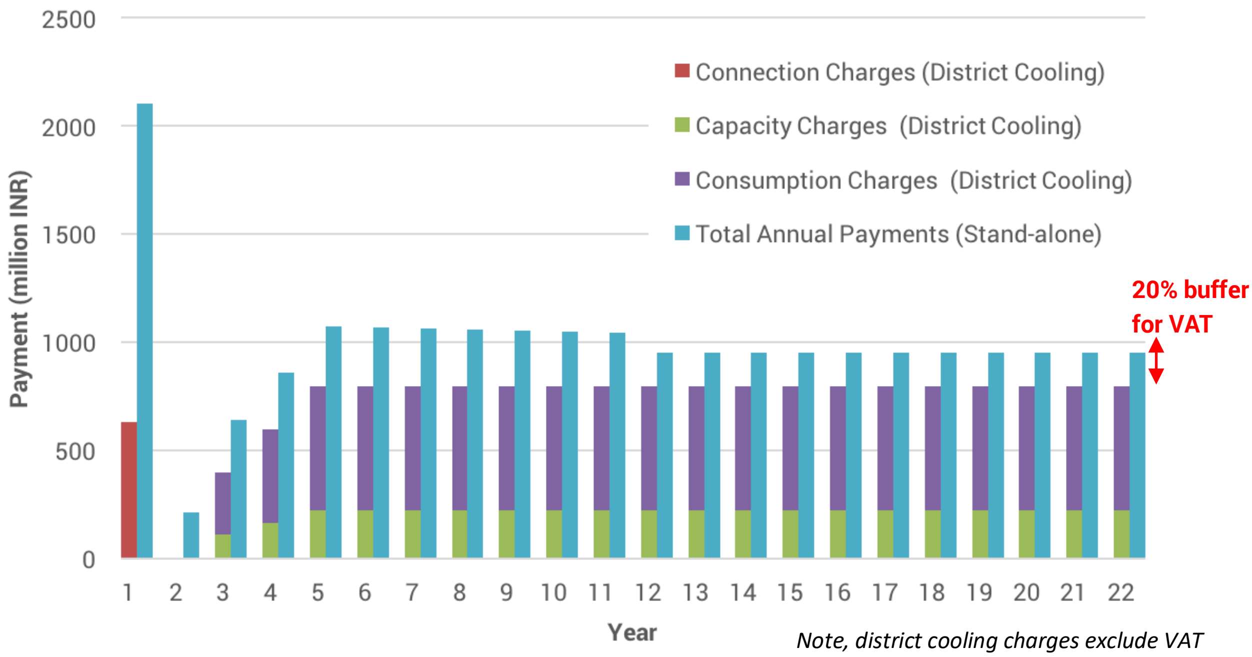
Through analysis of projects across all five cities, a development archetype was chosen that could be used as a typical development to enable comparison across all cities. The make-up of this archetype is shown in Table 14 below, it is mixed-use with multiple buildings with centralised cooling.

Table 14: Input data for a generic, mixed-use development archetype in Thane

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 15% in Thane and the payback period is 11 years.

Figure 24: 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 returns on investment it can be seen that in Thane with favourable financing, district cooling projects would be profitable to investors, beneficial to the environment and lower-cost to the consumers.

11.4 Selection of Probable Project Sites

Two potential sites for district cooling projects have been identified in Thane 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 upcoming) with significant cooling demand and the presence of anchor loads. As it is a retrofit project, financial analysis has not been undertaken on the Viviana mall area (site 1).

A third site was identified by the city: Chhatrapati Shivaji Maharaj Hospital and the Rajiv Gandhi Medical College owned by TMC, that uses extremely innovative solar cooling and biogas cooling (through absorption chillers). The peak load of this hospital complex is 400TR. The hospital is currently procuring additional chillers to replace backup chillers. Unfortunately, no significant new development has been identified in the vicinity of the hospital and the 400TR load of the hospital is unlikely to anchor a new commercially viable district cooling development in the short/medium term. It is recommended that a mapping exercise (see Box 3) includes this hospital and buildings around it to identify opportunities for small-scale district cooling when they arise. If a suitable building is located nearby, TMC could use the hospital complex to pilot small-scale district cooling with TMC likely being responsible for investment in the system. The hospital could 'share' renewable cool with buildings in the vicinity and could be used to test centralized cooling in buildings that may not typically have centralized cooling such as residential or schools. The technical specifications, costs and benefits of the hospital complex's renewable cooling system should certainly be examined and lessons applied into feasibility assessments of other projects. More detail on the hospital complex can be found in Annex 14.8.

11.5 Site 1: Viviana Mall Area (Brownfield/retrofit project)

Site 1 is a potential retrofit project located adjacent to Thane's Ghodbunder Road, which runs along the city and links the two main arterial roads of Mumbai, the Eastern Express Highway and the Western Express Highway. The Viviana Mall area is an ideal location for district cooling system due to the availability of diverse loads in close proximity. The key buildings with prominent cooling loads in the Viviana mall area include:

1. Korum Mall and Viviana Mall: Commercial shopping malls housing retail outlets, multiplex, restaurants, food court
2. Jupiter Hospital: a large super-speciality hospital
3. Fortune Park Lake City Hotel: a 4 Star hotel building
4. Avalon residential complex: an upcoming large high end residential project with space allocated for a commercial complex
5. Vasant Lawns residential complex: a prominent high-income housing complex
6. iThink IT park: an IT Park housing a large multinational company and IT/ITES offices
7. Tata Consultancy Services (TCS) Campus

Further details for each of these buildings are provided below in Section 11.5.1:

11.5.1 Site 1: Collected data and site details

Areas in the vicinity of the Ghodbunder road have witnessed tremendous development in recent years and house a number of schools and colleges, multi-specialty hospitals, large shopping malls, commercial offices and large-scale residential housing projects. The area contains a number of high-rise buildings, with many more expected to come up in the coming years.

Figure 25: Location of buildings under Pilot Site 1

Viviana Mall

The Viviana mall has nearly a million sq. feet of built space spread over a three-level complex on 50 acres of land. It is one of the largest malls in Thane and houses 150 retail stores for a range of consumer goods, a large multiplex with 14 screens, an entertainment center, restaurants, cafes, food court and a large supermarket.

Table 15: Details of the Floor space and Air Conditioning System at Viviana Mall

Specifications of Floor Space	**Area (sq. m.)**
Plot Area	93,114
Amenity Area	13,319
Permissible Area in I.T. Zone	677,751
Permissible Total Floor Area	60,878
Proposed Built Up Area of Mall	60,162
Specifications of the Air Conditioning System	**Details**
Type of Air Conditioning System	Central Water-Cooled Type
Installed Capacity	4,000 TR
Peak Consumption of System	3,500 TR
Consumption in Winter	1,000 TR
Consumption in Rainy Season	2,500 TR
Area to which Air Conditioning Supply provided	700,000 sq. ft. (approx.)
Number of Air Handling Units (AHUs)	250
Operating Hours	0800 hrs. to 0030 hrs. (16.5 hours)

Sources: Town Planning Department, TMC and Air conditioning details from Viviana Mall team

Figure 26: Photograph of the Viviana Mall

Source: (Sheth Developers, 2016)

Korum Mall

The Korum mall has a total built-up area of 1 million sq. ft. and retail built up area of 450,000 sq. ft. The mall has retail stores, a hypermarket, family entertainment center, and a four-screen multiplex with a seating capacity of over 1000 seats, and a food court.

Table 16: Details of Air Conditioning System at Korum Mall

Specifications of the Air Conditioning System	Details
Type of Air Conditioning System	Central Water-Cooled Type
Installed Capacity	2,400 TR
Peak Power Consumption of System	407033 kWh (Summer Season Monthly Consumption)
Electricity Consumption (yearly)	35,86,372 kWh
Yearly Operation and Maintenance Expenses	INR 41,50,000 (includes AMC and labour cost)
Power Consumption in Winter	255,945 kWh
Power Consumption in Rainy Season	379,974 kWh
Water Requirement (Yearly)	40,791 kL
Area to which Air Conditioning Supply is provided	325,608 sq. ft. (approx.)
Number of Air Handling Units (AHUs)	158
Operating Hours	10 hours

Sources: Town Planning Department, TMC and Air conditioning details from Korum Mall team

Figure 27: Photograph of the Korum Mall

Source: (Thane Property, 2016)

Jupiter Hospital

The Jupiter Hospital is multi-specialty tertiary care hospital of 325 bed capacity. This 7-storey hospital is spread over 3 acres of area. The Fortune Park Lake City hotel is located in the hospital premises.

Table 17: Details of the Jupiter Hospital

Plot Area	10,315 sq. m.
Amenity Area	519 sq. m.
Permissible Total Floor Area	18,567 sq. m.
Total Built Up Area	18,560 sq. m.
Height from Ground Floor to Terrace	44 m

Figure 28: Photograph of the Jupiter Hospital Building in Thane

Source: (Jupiter Hospital, 2016)

Fortune Lake City Park Hotel

The Fortune Park Lake City, is a 4-star rated premium business class hotel situated in the campus of Jupiter hospital. It includes 46 rooms, 5 conferencing and banquet halls with a seating capacity of 10 to 235 people. The hotel also includes a restaurant, a coffee shop and tea lounge. Since the Jupiter hospital and Fortune Lake City Park hotel are housed in the same location, a common HVAC system caters to these two buildings.

Table 18: Details of Central Air Conditioning System Jupiter Hospital and Fortune Lake City Park Hotel

Specifications of the Air Conditioning System	Details
Type of Air Conditioning System	Central Water-Cooled Type
Installed Capacity	972 TR
Annual Operation and Maintenance Cost	INR 3,536,289 (53,044 USD)
Annual Electricity Expenses (for HVAC only)	INR 3,656,250 (54,843 USD)
Peak Consumption of System	11,406 kW/day (Average in the month of May)
Consumption in Winter	7,818 kW/day (Average in month of January)
Consumption in Rainy Season	10,483 kW/day (Average in month of August)
Water Requirement for HVAC	2,250 kL (monthly)
Area to which Air Conditioning Supply provided	215,278 sq. ft. (approx.)
Number of Air Handling Units (AHUs)	AHUs 104 Nos & FCUs 240 Nos

Sources: Town Planning Department, TMC and Air conditioning details from Jupiter Hospital team

Vasant Lawns

Vasant Lawns is a luxury residential building project housing about 20 premium residential buildings, each about 30 storey high. The buildings largely house high income households. The project is spread over 2 acres and houses about 400 units in 6 residential towers. Common amenities include a club house which has an area of 15,000 sq. ft. It is observed during the site visit that most of the houses are equipped with individual split air conditioning units. A lack of centralized cooling means this building is unsuitable for district cooling.

Figure 29: Layout Plan of the Vasant Lawns Project in Thane

Source: (Sheth Developers, 2016)

iThink

iThink is a recently constructed IT Park housing major IT/ITES company offices. The IT park is spread over 5 acres, with a built-up area of about 850,000 sq. ft. The property is equipped with a state-of-the-art building management system to monitor all the important service equipment. iThink is a LEED certified project and is provided with centralised water cooled air-conditioning system. The installed capacity of the centralised air conditioning System is 2800 TR (700 TR x 4 Units) and the system operates for around 13 hours daily (0700 hrs to 2000 hrs).

Figure 30: iThink IT Park in Thane and Layout

Source: (Lodha Group, 2016)

Avalon (Township)

Avalon is an upcoming cluster of four 30-storey towers flanked by the Jupiter Hospital and spread over an area of 5.5 acres. The total residential floor space in the township will span 90,592 sq. ft. These premium residential apartments will be equipped with amenities such as clubhouse, banquet hall, squash court, a small theatre, business centre, and a gymnasium. The project will have an in-house sewage treatment plant and a water treatment plant which could potentially be investigated as a source of water for a district cooling plant. Designs of Avalon do not include centralised cooling, and the high share of residential load in this township make it unlikely to be part of a district cooling demonstration project.

Figure 31: Model of the Upcoming Avalon Township in Thane

Source: (Sheth Developers, 2016)

Other upcoming developments

Many more large-scale buildings are expected to be installed in this area over the coming years and the city has a significant role in controlling development in the area. However, given the fast pace of real-estate, little information is available on potential buildings at this stage.

11.5.2 Site 1: How district cooling could be retrofitted along the Ghodbunder road

There are several commercial buildings in this area which have installed centralized standalone cooling systems and are now operating. These stand-alone cooling systems have been operating for around 5-7 years and have reported annual average efficiencies of 0.8-1.5 kW/TR. There is likely significant load diversity between the different buildings as they all will have different operating hours and occupancy.

In this area, there is also greenfield land for potential development of commercial buildings, which could be future end-users for a district cooling system retrofitted into this zone. In order to make district cooling systems cost-effective in this area, there are several requirements for greenfield urban planning:

1) As much as possible, the greenfield sites adjacent to these existing buildings should be set aside for commercial buildings, such as shopping malls, hotels, offices, sports complexes or

public buildings that could have centralised cooling incorporated such as hospitals, government offices, schools, museums etc.

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 all 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 and used to supply cooling for new end-users during peak periods.
- **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, the level of investment needed will be over a longer period than for a totally new district cooling system which may make financing easier. A detailed pre-feasibility of this site is recommended including further stakeholder consultations to improve data collected and gauge interest for being connected to district cooling. This pre-feasibility study would also look at possible network configurations and planned developments.

TMC could support the project through the various incentives described in Section 0, in particular, providing low-cost solar electricity or WTE waste heat to lower costs and incentivise buildings to switch to district cooling. Furthermore, this project would require significant oversight from TMC to ensure the area is planned correctly (see above). Given the expected lower capital cost of this district cooling project as compared to greenfield and the significant city intervention and coordination required, having TMC or the Smart City SPV investing in this project as a PPP could be highly successful.

It is unlikely that any existing residential buildings, such as Vasant Lawns or Avalon Township in the area would be connected to district cooling.

Table 19: Selection criteria for Site 1

Technical requirements	Total cooling demand for site is approximately 7,372 TR (Viviana & Korum mall, Jupiter hospital and Fortune Lake City hotel). Cooling demand for most of the buildings is being met through chillers at present. This is a potential district cooling retrofit case. A vacant tract

	of land available at the site is owned by TMC and could potentially be used to house the district cooling plant.
Availability of anchor loads with continuous and/or large demand and diverse buildings can be connected	The site includes diverse buildings such as shopping malls, office space, hospital and hotel with a large floor space and significant cooling demand. The site thereby offers sufficient load diversity and may be able to provide continuous cooling demand.
Potential for longer-term network expansion	The area in the vicinity of the Ghodbunder Road houses mixed-use development including commercial offices, large-scale shopping malls, multispecialty hospitals, hotels, educational institutes and large residential townships. This area is developing rapidly and the expected high density mixed-use development offers opportunities for district cooling network expansion.
Existing situation of buildings	Most of the buildings at this site have been constructed already.
Influence from local government	The TMC can leverage its relationship with the relevant building developers, businesses, and other stakeholders to help facilitate further dialogue to demonstrate the viability and benefits of establishing a district cooling network. The TMC can also help integrate policies, regulations and incentives in its local development regulations to promote uptake of district cooling.

11.6 Site 2: Hiranandani Estate (Greenfield site)

The Hiranandani Estate is an upmarket condominium-style township built by the Hiranandani Group, one of the largest building developers in India, in the Patlipada area of city of Thane and spans across more than 300 acres.

The township includes the Hiranandani Hospital, the Hiranandani Foundation School (ICSE) and a club house along with shopping arcades, banks, cinemas, mega-markets, cafes, restaurants and its own transportation system connecting the township to Thane railway station. The township is characterized by wide roads, broad pavements and landscaping. The township has a Business Park which houses numerous multi-national companies and business process outsourcing (BPO) service providers. There are several ongoing residential and commercial projects under construction currently at the site. The Hiranandani Estate also has a bio-methanation plant.

11.6.1 Site 2: Collected data and site details

The locations of the buildings under consideration for district cooling assessment are given in the map below, with additional details provided for the buildings in subsequent sections.

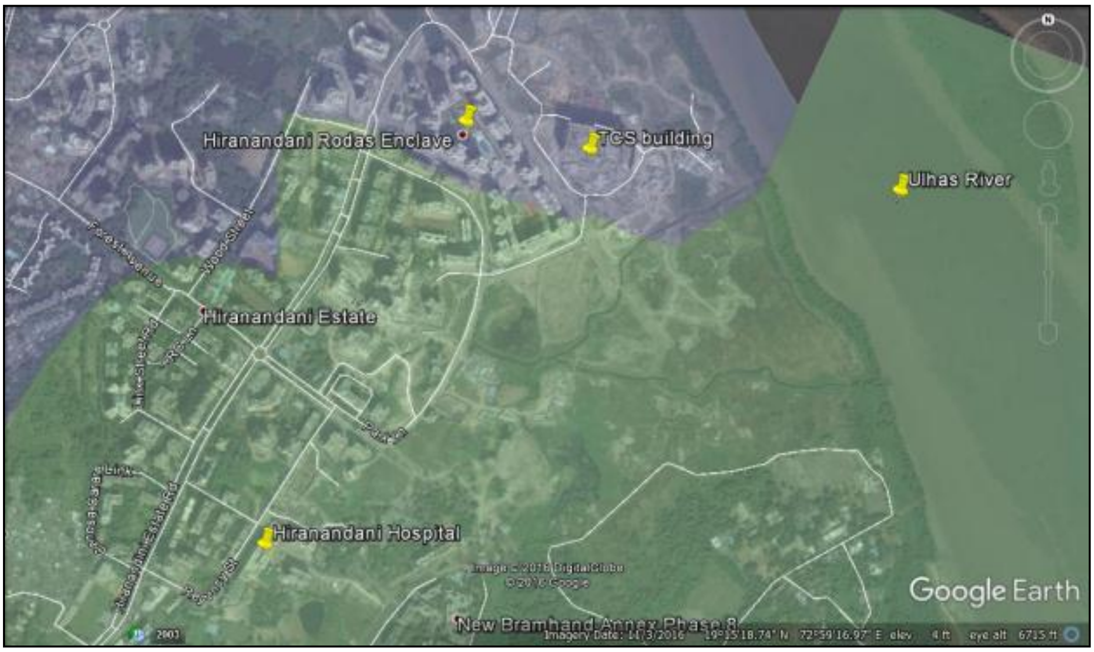
Figure 32: Layout of Hiranandani Estate

Source : (Rodas Enclave, 2016)

Figure 33: Pan view of Hiranandani Estate, 2016

Source: (Hiranandani Group, n.d.)

Figure 34: Location of potential buildings in Site 2



Rodas Enclave Township

RODAS enclave is residential township developed spanning an area of 25 acres and located in the vicinity of Ulhas River. This residential township has 18 residential buildings of 18, 24, and 31 floors that house lavish 2, 2.5, 3, 4 and 5 room luxury apartments. This development also includes a common clubhouse. The details of the residential towers of Royce, Marvela and Leona (housing 4 room houses) and the Bacilius tower (housing 5 room houses) are given in the Table 20 below.

Table 20: Details of Residential buildings

Township Name	Rodas Enclave, Hiranandani Estate
Number of Buildings	4 nos.
Name of building	Royce, Marvela, Leona and Bacilius
No. of storeys	31
No. of apartments	61 per building

Source: Rodas Enclave Team

Table 21: Details of Central Air Conditioning System for Residential buildings

Specifications of the Air Conditioning System	Details
Type of Air Conditioning System	High-wall Split AC
Centralised Cooling planned	No
Area to which Air Conditioning supply is planned	366,070 Sq.ft. approx.

Source: Rodas Enclave Team

Figure 35: Layout of Rodas Enclave residential township

Source: (Rodas Enclave, 2016)

Figure 36: Rodas Enclave residential township

Source: (Rodas Enclave, 2016)

Hiranandani Multi Specialty Hospital

The Hiranandani Multi Specialty hospital is a recently constructed 200-bed 6-storey hospital located in the Hiranandani Estate. The hospital is yet to be operationalized but a water-cooled centralized air conditioning system of 950 TR has been commissioned for this hospital with thermal storage.

Table 22: Details of Hiranandani Hospital

Particulars	Details
Number of Buildings	1
No. of storeys	Basement, Ground + 6 floors
Number of beds	200

Source: Rodas Enclave Team

Table 23: Details of Central Air Conditioning System of the Hiranandani Hospital

Specifications of the Air Conditioning System	Details
Type of Air Conditioning System	Water cooled (not commissioned)
Installed Capacity	950 TR installed (not commissioned)
Peak Consumption of System	961.5 TR (not commissioned)
Consumption in Winter	1,000 TR
Consumption in Rainy Season	2,500 TR
Area to which Air Conditioning Supply provided	244,786 sq. ft. (approx.)
Number of Air Handling Units (AHUs)	107

Source: Rodas Enclave Team

Figure 37: Photograph of the Hiranandani Multispecialty Hospital

Tata Consulting Services (TCS) Office Building

Tata Consultancy Services (TCS) has leased an office space of 1.9 million sq. ft. from the Hiranandani Group. The construction of this building has been recently completed and an Occupancy Certificate has been obtained from TMC. This 15-storey building is expected to accommodate about 30,000 employees.

Since the building has been constructed recently and design of the HVAC system is underway, information collection and the feasibility assessment for this particular building would have to be expedited for any possible district cooling implementation.

Table 24: Details of Central Air Conditioning System of TCS Building

Specifications of the Air Conditioning System	Details
Type of Air Conditioning System	Water & Air-cooled chillers and DX systems (Planned)
Installed Capacity	4050 TR installed (not completed)
Area to which Air Conditioning Supply provided	1,209,023 sq. ft. (approx.)
Operating Hours	24 hrs.

Source: Rodas Enclave Team

Figure 38: Photograph of the nearly completed TCS building and adjacent developments

Source: Site visit by Authors

Vicinity of TCS building

Adjacent to this TCS building are planned several other large developments which will be developed at a similarly fast pace, likely completing construction within the next 15-18 months. According to urban planning documents and architectural plans made available during site visits to Hiranandani Estate, a cluster of commercial buildings with FAR larger than 2.5 are planned in the greenfield area of the Estate in the immediate vicinity of the TCS building described above.

These planned buildings will be in close proximity and will include a combination of various building types including office, campus classroom, shopping malls etc. The office building is planned to be the same size as the TCS building described above.

Upcoming buildings are expected to include the following approximate built-up areas:

Office: 550,000 sq ft.

Campus classroom: 600,000 sq. ft.

Retail mall: 570,000 sq. ft.

This is a rapidly developing site and more details on building layouts and size will become available in the coming months.

11.6.2 Site 2: Delivering district cooling in a fast-paced, greenfield site

The development of Hiranandani Estate is very fast, during a site visit in July 2017, TCS buildings were expected to finish construction within the following 15 months. The Estate is ideal for district cooling implementation due to the fast-pace of development, helping to raise certainty of connection over a short period.

The Rodas Enclave township is assessed as unsuitable for district cooling connection due to the lack of centralised cooling and significant proportion of residential buildings. If new residential buildings are developed in Hiranandani Estate, TMC could request that centralised cooling is assessed, and if centralised cooling is better value for consumers, either Hiranandani could charge for cooling, the eventual building owner or tenant association could charge through rents or building charges or an ESCO such as EESL could recover cooling payments through reduced electricity expenditure.

The Hiranandani Hospital is suitable for district cooling, although its newly installed chillers make it unlikely to be connected to a district cooling network unless it can share chiller capacity with buildings in its vicinity.

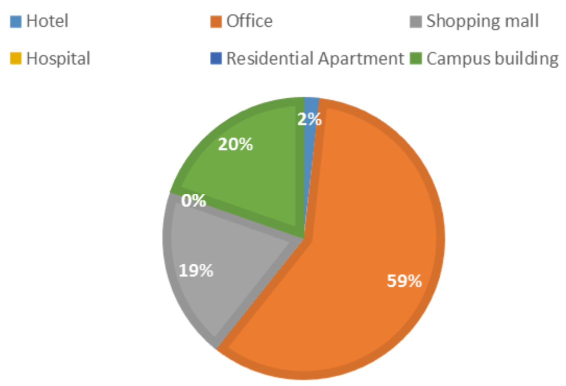
The TCS building and the buildings in its vicinity have been identified as a high potential project but district cooling development must match the fast-pace of the real estate development. This building cluster is analysed below and its potential is significant. The buildings have significantly different cooling load profiles enabling the project to reduce the cooling capacity required once connected to district cooling system due to diversity. Furthermore, the cooling demand of these commercial buildings is expected to be relatively constant throughout the cooling season due to relatively steady usage and building occupancy.

As such, the district cooling system analysed below is planned to supply chilled water to the TCS building and upcoming buildings in its vicinity.

Buildings served and cooling load

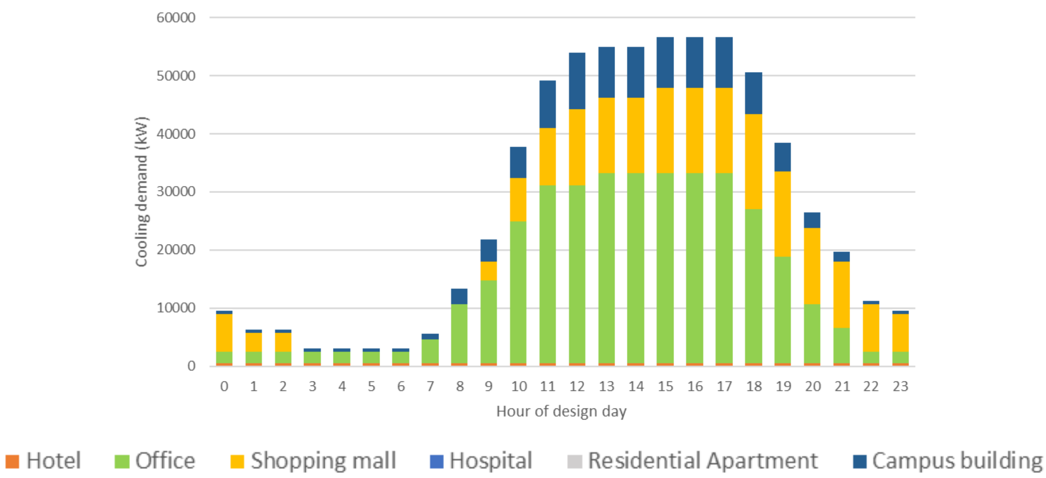
The total built-up area is estimated at 2,981,811 sq. ft (277,120 m^2) and the split by building type is shown in Figure 39 an existing hotel has also been added to the analysis.

Figure 39: Built-up area being analysed, by building-type



According to the input data, the hourly cooling demand profile in the area, as served by a district cooling system, is shown in Figure 40 below.

Figure 40: 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 25: District cooling plant

Installed Cooling Capacity	56633	kW
	16103	RT
District cooling plant built-up area	3989	sq. m
Outdoor space for cooling towers	1277	sq. m
DC plant land requirement	2394	sq. m

The investment of district cooling system is calculated as below.

Table 26: District cooling system investment

DC system investment	Rs.	USD
DC plant	2,147,035,617	32,205,534
Land	81,623,621	1,224,354
Network	193,233,206	2,898,498
Sum	**2,421,892,444**	**36,328,387**
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 27: Annual cooling supply and operation fee

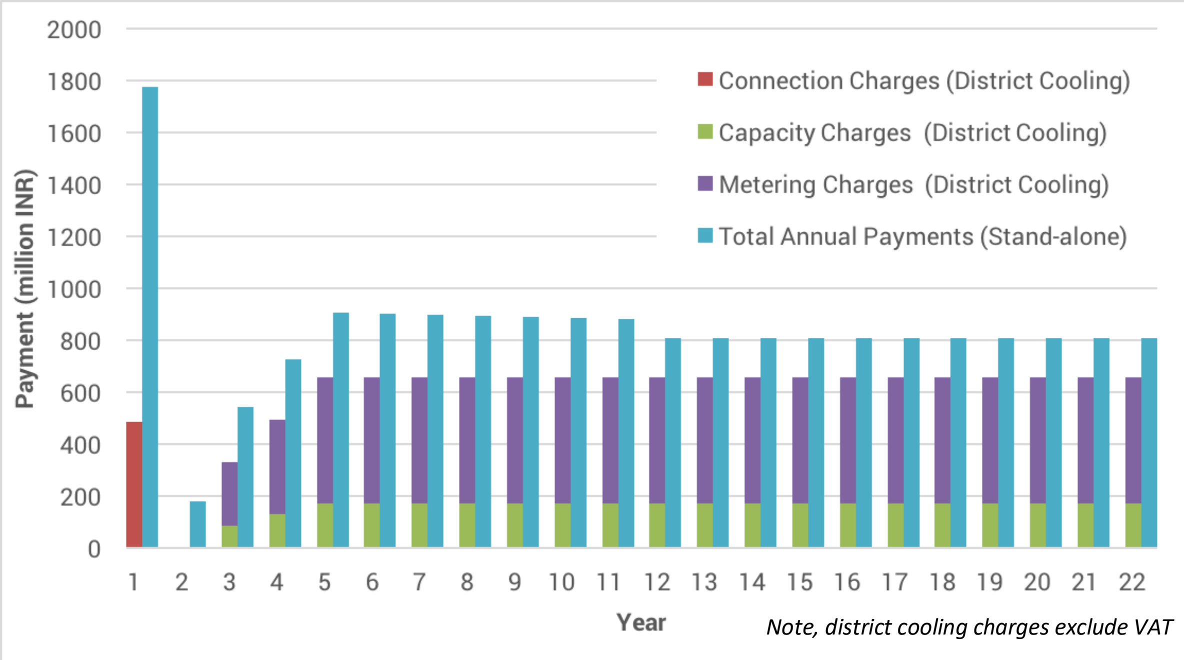
Annual cooling supply	kWh	52,971,387
Annual electricity consumption	kWh	15,061,526
Annual electricity fee	Rs.	175,333,729
	USD	2,630,006
Annual water consumption	m^3	433,772
Annual water fee	Rs.	17,350,878
	USD	260,263

Financial results

The economic analysis shows that when a metering charge equal to 0.233 USD/TR.h (15.5 INR/TR.h) is charged, the IRR of this project reaches 17%. 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 41 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 41: Cost comparison for consumers in Hiranandani Estate for district cooling vs. stand-alone systems



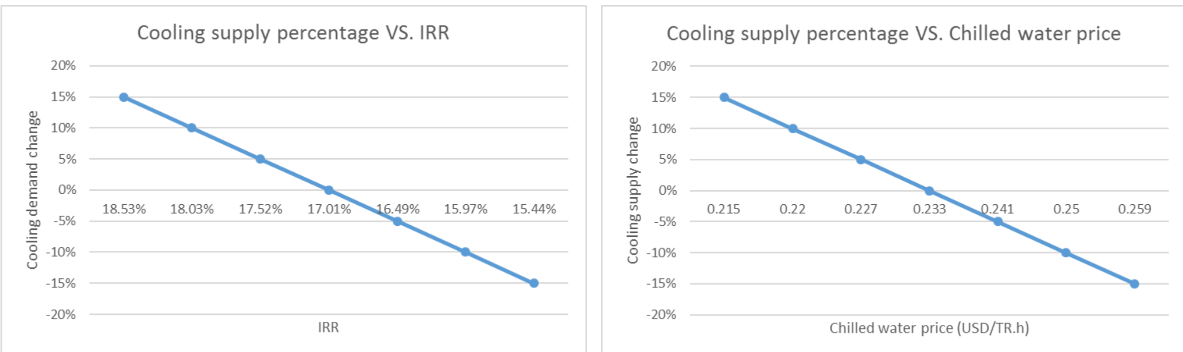
Sensitivity analysis

In this section, the results of a sensitivity analysis examining cooling demand, capital costs and electricity tariff are undertaken, changing these values from +15% to -15% so as to show the required change of chilled water price (metering charge) under fixed IRR and the changing IRR while keeping the chilled water price fixed at 0.233USD/TR.h (15.5 INR/TR.h). The 20% reduction below the stand-alone payment for VAT is maintained throughout.

- Sensitivity analysis on cooling demand

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

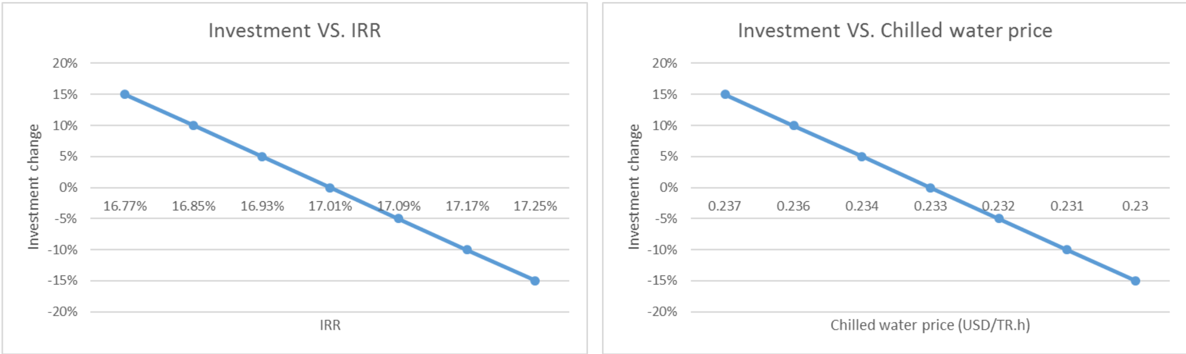
Figure 42: Sensitivity analysis results of changing cooling demand in Hiranandani Estate



➢ Sensitivity analysis on capital costs

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

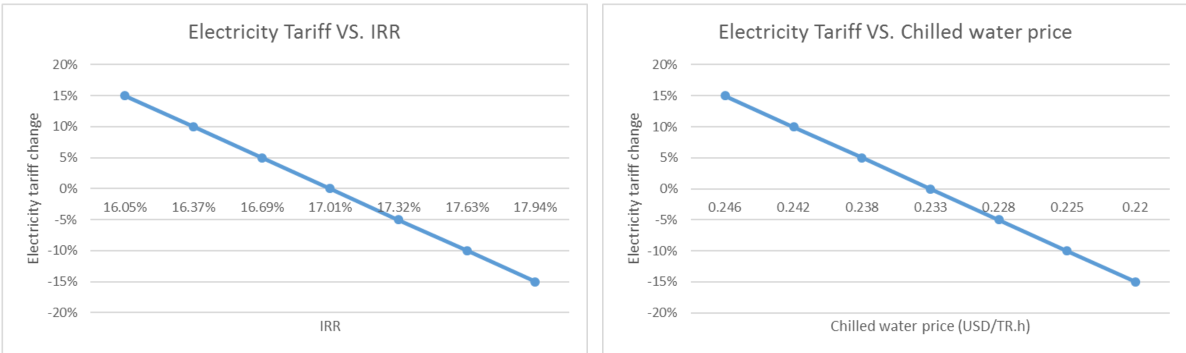
Figure 43: Sensitivity analysis results of changing capital costs in Hiranandani Estate



➢ 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 44: Sensitivity analysis results of changing electricity prices in Hiranandani Estate



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 cooling demand and electricity tariff, and are not quite as sensitive to the change of capital costs.

The viability of connecting thermal energy storage to the TCS area in the Hiranandani Estate is presented in Section 11.7 below.

The specific benefits of connecting the TCS area in the Hiranandani Estate to district cooling are presented in Section 11.7.1 below.

Box 11: Recommendations for Hiranandani Estate

The TCS building and the buildings in its vicinity have been identified as a high potential project which need to have a pre-feasibility study completed immediately to ensure district cooling development can match the pace of real estate development. The consultancy undertaking such

a study should evaluate the benefits to different stakeholders, including direct benefits such as capital and operational cost reductions, but also indirect benefits such as improved cooling service, reduced maintenance, space being available on rooftops and in basements (as cooling system would now be outside the building) for solar power, roof terraces, basement leisure centres etc. as well as reduced size of power connection to buildings.

In parallel, TMC should work with the consultancy undertaking such a study to identify the level of incentives necessary to ensure this project is established with district cooling. These incentives are described in preceding sections but TMC has indicated that these could include: property tax rebates; low-cost provision of solar electricity; and provision of low-cost land (for a district cooling plant), water and wastewater. Other incentives could include: density bonuses; negotiation of improved off-peak electricity tariff; accounting for district cooling in buildings' environmental credentials etc. If the pre-feasibility study identifies significant connection risk, or that long-term expansion would be unlikely, TMC has shown willingness to examine the use of connection policies such as requiring other buildings in the Estate to assess district cooling connection (see Box 4) and/or mandating centralised cooling in non-residential buildings.

Finally, the investment interests of TMC, the Hiranandani Group and future building owners such as TCS need to be understood further and relevant business models discussed. Such business models could consider the expertise of international district cooling operators through management contracts or part/full ownership while also considering any domestic experience in district cooling.

TMC should prioritise Hiranandani Estate as the best chance for demonstrating district cooling in the city in the short-term.

11.7 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.

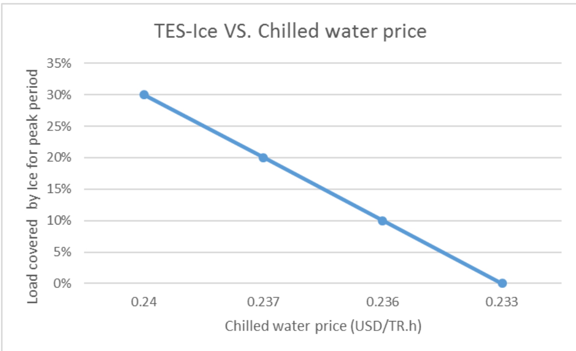
Based on the current electricity tariff in Thane and the situation of this project, ice storage is considered as a potential TES technology to use in a district cooling system because it has the highest cooling storage density amongst the TES technologies and as such requires far less land as compared 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 Table 28: Investment costs for various elements of an ice-storage systemTable 28. 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 28: 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 45 as tested on the Hiranandani site. This shows that the application of TES results in higher chilled water price under a fixed IRR. The reason is that the electricity price between off-peak and peak periods cannot cover the increased cost of TES.

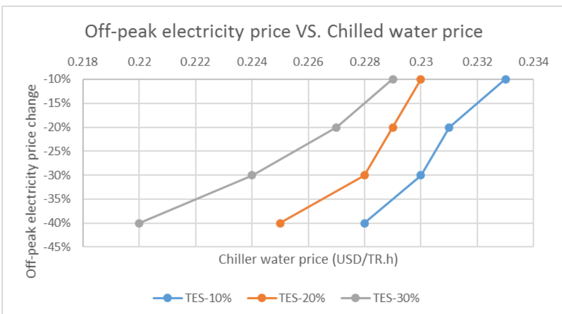
Figure 45: Sensitivity analysis results of coverage ratio of ice TES for peak period



In order to make the TES system cost-effective so that the whole electrical grid can benefit from the peak load shifting, it is suggested to establish a special subsidy on electricity price of off-peak period for TES. The economic analysis results of different subsidy percentage under different ratio of ice are shown below. All the cases shown have the similar IRR of 17%.

According to the results, at least 20% of subsidy on off-peak electricity price is required to make TES cost-effective as at this point the chilled water price is below the chilled water price for a system without TES (0.233 USD/TR.h).

Figure 46: Sensitivity analysis results of subsidy on off-peak electricity price



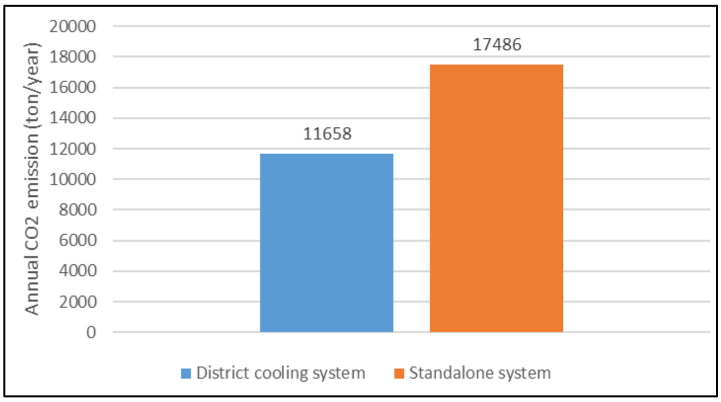
More detailed analysis should be undertaken as part of a demonstration project to confirm these findings. Centralised thermal storage and the increased peak shaving it can achieve is one of the key benefits of district cooling and the technology should not be ruled out of project pre-feasibility analysis, even with the current electricity tariff structure.

11.7.1 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 Hiranandani project are 6000 tons per year, as shown below in Figure 47[44]. Due to a lack of data for CO_2 emissions for water supply, this contribution is not included.

Figure 47: CO2 emission comparison for stand-alone and district cooling in Hiranandani Estate



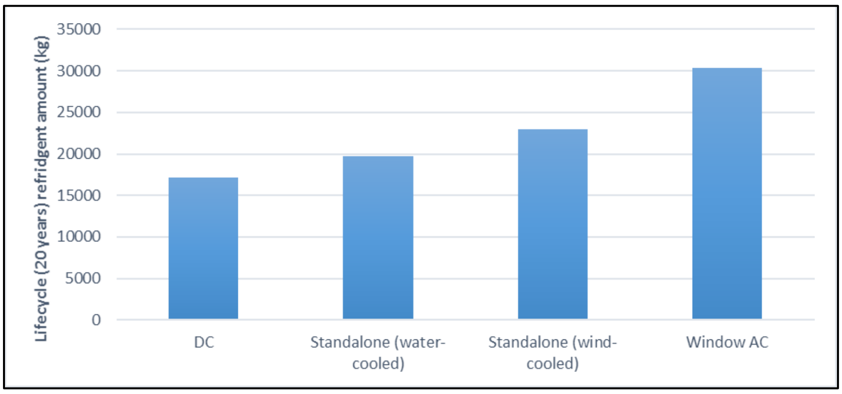
Electricity savings of 7.53GWh of electricity annually (33% reduction from stand-alone) are expected and a reduction in peak power demand of 9.2 MW (36% reduction from stand-alone.

The CO_2 savings and electricity savings can be increased significantly by connecting renewable and waste heat resources as described in Section 10.2. Furthermore, given the scale of Hiranandani Estate, it is expected that future phases of the site will be connected to the district cooling system and even some existing buildings could be connected in the long-term – this will further increase the CO2 savings and electricity savings.

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 4.4 tonnes, as compared to water-cooled chillers. The calculated results are shown below.

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

Figure 48: Lifecycle refrigerant comparison for district cooling vs. stand-alone solutions in Hiranandani Estate



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, Thane can expect the following environmental benefits (these are also set out for the generic project in Section 11.3). 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 29: 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 Hiranandani, 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 41: Cost comparison for consumers in Hiranandani Estate for district cooling vs. stand-alone systems

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 TMC 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 can be concluded that district cooling is commercially viable in Thane for well-designed projects and can deliver significant benefits to the environment, consumers and the local economy. The hot and humid climate, strong real estate growth (particularly in the service sector), clear existing impact of cooling demand and a local government willing to show leadership to accelerate district cooling, make Thane a high-priority city for demonstrating this technology.

Thane 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 TMC 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. Given the huge potential in Thane, this would be a missed opportunity.

Dedicating human resources in local governments can be difficult due to tight city budgets; if Thane can monetise direct benefits from district cooling, this increased human resources can be justified. This could be through direct participation of TMC 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. Thane 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, Thane 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 TMC

Throughout this rapid assessment, policies and actions have been recommended to TMC 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 ' (UNEP, 2015)' which is available online.

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

Hiranandani as a demonstration project (Section 11.6)

- Project pre-feasibility study including assessment of renewables and waste heat
- Stakeholder consultations to identify potential business models
- Work with district cooling experts to define TMC's role in a potential PPP (see Box 3 and Section 7) 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.)
- Independent analysis of TMC incentives and policies that can ensure project delivery including property tax rebates, provision of municipally owned solar power and provision of land (Section 0)

Viviana Mall area (Section 11.5)

- Project pre-feasibility study including assessment of renewables and waste heat
- Target adjacent land to include high potential real estate that can catalyse district cooling development
- Coordinate multiple stakeholders and manage discussions on potential business models

Smart-city area

- Smart City team to work with district cooling experts to identify possible district cooling projects in Area-Based Development and incorporate district cooling into area design

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)
- Identify how the planned WTE plant can catalyse district cooling development (Section 0)

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) (Section 11.7), waste heat connections, solar power (Section 10.2) and Treated Sewage Effluent (Section 3.2.4)
- 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)
- Ensure planned green building incentives promote district cooling development (Section 0)

14 Annexes

14.1 Key themes and Sub-Goals of Thane City outlined under Smart City Proposal

Key Themes	Sub-Goals
A Green Waterfront City which plans and implements initiatives that make it environmentally friendly and sustainable, while protecting and enhancing the existing green areas, waterfront and lakes	• expanding public access to the lakes, waterfront and waterways on public and private property • improving creek water quality • improving air quality in the city over ten years through real time monitoring and stringent enforcement of the 'polluters pay' principle • enhancing the quantum of breathing space in the city by increasing parks and recreational areas for citizens by 50%
A Smart and Safe city which focuses on a blend of innovative and practical technologies for better management and provision of services to citizens	• reducing NRW from 37% to levels below 20% through a comprehensive water audit, SCADA, smart metering and monitoring • providing 100% online coverage of municipal services through both online portals and mobile applications • developing a TMC Smart DigiCard (DigiThane) which serves as a single point access for all the services provided by TMC to the citizens • installing 2000 CCTV cameras across the city for ensuring safety & security, and increasing surveillance • increasing access of local residents and businesses to online services
A sustainable Economic Base by transforming Thane into a high-end services and education hub in the MMR	• development of infrastructure and services to the IT/ITES industry and education sector • leveraging ICT tools such as GIS to widen the property tax net and enhance collection
A Livable city which provides its citizens with appropriate basic infrastructure	• 24x7 water supply to all • 100% coverage of sewerage network in the city • promoting decentralized waste water treatment by commissioning 100 MLD of STPs having individual capacity of 1-5 MLD • recycle and reuse of treated wastewater • through Integrated Nalla Development Programme, ensuring sustainable urban drainage schemes • expanding and improving the public transport services • new suburban station between Thane and Mulund • smart parking solutions • non-motorized and public transport • dedicated pedestrian areas with segregation from motorized transport modes • Increasing coverage of door-to-door segregated waste collection to 80% by 2020 and incentivizing the same through property tax rebates • decentralized SWM by ensuring that decentralized waste management units process 100% of biodegradable waste • commissioning a centralized incineration based waste processing unit having a capacity of 600 MT at Daighar by 2018 • **Increasing share of renewable energy by 50% through implementation of the solar city masterplan and other initiatives in partnership with citizens and the private sector**

Key Themes	Sub-Goals
A Socially Responsive city that meets the social needs and aspirations of its citizens including vulnerable sections of society such as women, senior citizens, the differently abled and those residing in slums. The sub-goals include:	• affordable housing along with improved basic infrastructure and amenities to around 20% of the population residing in slums and dilapidated structures by leveraging policies such as Cluster Redevelopment, Affordable Housing and Inclusive Housing • affordable health care facilities and development of quality health care facilities • developing Thane as a Regional Education Hub • skill development initiatives for creating a skilled workforce matching the requirements of high end services and manufacturing sectors • supporting working women and senior citizens through development of working women's hostel, children's home old age home • various climate change resilience strategies to be undertaken such as tree plantation programme, mega mangrove plantation drive, biodiversity park, pumping station and tidal gates to prevent flooding.

14.2 List of Projects and Cost Estimates as per Smart City Proposal for Thane City

Sr. No.	Projects in Smart City	Cost (INR Crore)	Cost (INR Million)
Area Based Development (ABD)			
	Improving mobility		
1	New suburban station	289.00	2890.00
2	Multi-modal facility	267.00	2670.00
3	Teen haath naka junction improvement	239.00	2390.00
4	Parking management	27.00	270.00
5	Pedestrian improvements	23.00	230.00
	Inclusive housing for 11akh population		
6	70acre brownfield township	3974.00	3974
	Enhancing natural habitat to better lives		
7	3 lake front developments	16.00	160.00
8	1.5km waterfront development	224.00	2240.00
	Energy savings		
9	LED street-lighting	27.00	270.00
10	2MW solar roofing	14.00	140.00
	Improving infrastructure		
11	Water supply network remodeling	35.00	350.00
12	Sewerage works	25.00	250.00
13	Nalla works	49.00	490.00
14	Decentralized solid waste processing	21.00	210.00
15	Urban restrooms	5.00	50.00
Pan City			
	Digital Thane initiative		
16	Digi-card	28.00	280.00
17	Enterprise resource planning	12.00	120.00
18	City-wide CCTV and Wi-Fi	42.00	420.00
19	Online performance monitoring	83.00	830.00
20	Intelligent transport system	4.00	40.00

Note- *This only indicates cost of individual projects given in the SCP. The total value of SCP may additionally include other costs such as DPR preparation, PMC, O&M etc.*

14.3 Details of permissible Floor Space Index (FSI) as per Thane DCR, 1994

Thane's road width can be availed as per a recent amendment in January 2016 (see Table 31). The additional FSI[45] can be availed by residential, commercial, non- polluting industrial, and public and semi-public users[46]. For properties situated on roads having width less than 9 m, the base FSI of 1.0 would be applicable.

Table 30: Permissible and additional FSI in Residential, Commercial and Industrial Zones

Sector	Width of the access road of the plot	FSI Permissible[47] (Base)	Additional FSI
			On payment of Premium
1,2,3	9 m and more	1.0	0.2
4,5,6,8,9,10, and 11[48]	9 m and more	1.0	0.3

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

Further, a recent amendment notified in May 2015 outlines the maximum permissible TDR that can be utilized in a given plot, based on the width of the adjoining road (see Table 31). The maximum extent of built-up space on such plots (i.e. FSI loading limit) will be based on the summation of the base FSI, the applicable TDR, plus any additional FSI on payment of premium (if applicable to the sector in which the plot exists).

Table 31: Details of Maximum Permissible TDR based on Road width

Sr. No.	Plots fronting on Road width	Maximum permissible TDR Loading
1	9 m and above but less than 12 m	0.40
2	12 m and above but less than 18 m	0.65
3	18 m and above but less than 24 m	0.90
4	24 m and above but less than 30 m	1.15
5	More than 30 m	1.40

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

14.4 Details of TMC's Funding Sources for Project Implementation

For meeting the funding requirement for implementing various projects, the main financial sources identified by TMC 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 Integrated Power Development Scheme (IPDS) for specific projects based on DPR, prepared by Maharashtra State Electricity Distribution Company limited (MSEDCL) and approved by the Ministry of Power;
   - Funding under the Solar City Mission of MNRE for solar panel on rooftops of public buildings in Thane;
   - Funding for redevelopment of the Thane Railway Station under which the station building and commercial development will be carried out by Central Railways;
   - Funding from devolution of 14th Financial Commission to the State Government;

[45] Additional FSI permissible under this regulation shall be applicable on the gross plot area, after deducting Development Plan reservation. Additional FSI is optional and non-transferable and is to be used on the same plot.
[46] Public and Semi-Public land use includes Government, Semi-government, Local bodies and institution owned properties, and civic amenities and large infrastructure facilities of health, education, sports, cultural and social institutions
[47] Permissible FSI - Floor Space Index, which is permissible for different zones.
[48] Additional FSI not applicable for sector 7

- Funding of Safety and Security - City-wide Wi-Fi and CCTV will be taken up with District Planning Development Corporation (DPDC) funds and public private partnerships (PPP)

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

c) Projects on Public Private Partnerships (PPP).

14.5 Details of provision of Solar Water Heating system as per Thane DCR, 1994

(i) Solar Water Heating System is made mandatory for the following constructions or building types:

- Hospitals & Nursing homes
- Hotels, Lodges and Guest houses
- Hostels, school, colleges, Training Centres and other institutes
- Barracks of armed forces, paramilitary forces and Police
- Functional Buildings of Railway Stations like waiting rooms, retiring rooms, rest rooms and inspection bungalows and catering units.
- Community Centres, Banquet Halls, Barat Ghars, Kalyan Mandaps and buildings for similar use

(ii) New building development: all new buildings to be constructed shall have:

- provision for SWH system installation in an open sunny roof area
- Roof loading to be adopted in the building design shall be at least 50 kg/sq. m for SWH system installation
- SWH system integrated in the building design
- Shall have hot water line from rooftop and insulated distribution pipelines to each of the points where hot water is required.

(iii) For existing building subject to change in use to above said category, provision for SWH system installation is mandated if such buildings have already incorporated the hot water supply system

(iv) Capacity of SWH system in New residential buildings: The TMC has made SWH system mandatory for new residential buildings also for which the capacity is decided as 25 lit per day per capita. For different categories of buildings, the recommended capacity of SWH is given below:

Sr. No	Type of buildings	Capacity of SWH
1	Hospitals	100 litres per day per bed
2	Hotels	150 litres per day per capita
3	Hotels other than 5 stars	25 litres per day per capita
4	Canteen	As required
5	Laboratory and Research institutions	As required

14.6 Details for provision of Air Conditioning system as per Thane DCR, 1994

Air Conditioning: As per DCR the planning, design and installation of electrical installations, air-conditioning and heating work shall be carried out in accordance with part VIII-Building Service Section 2 - Electrical installations, Section 3 Air conditioning and Heating, of National Building Code of India. Some of the points for air conditioning are stated below:

- The ducting shall be constructed in accordance with IS1/655-1963 Metal Air Ducts (Revised)
- The materials used for insulating the duct system (inside or outside) shall be of non-combustible materials such as glass wool, spun glass with neoprene facing
- Area more than 750 sq. m on individual floor shall be segregated by a fire wall and automatic fire wall and automatic fire dampers for isolation shall be provided where the ducts pass through fire walls. The fire dampers shall be capable of operating manually
- Air ducts serving main floor areas, corridors, etc., shall not pass through the staircase enclosure
- The air handling units, shall as far as possible, be separate for each floor and air ducts forever floor shall be separate and in no way interconnected with the ducting of any other floor

- If the air handling unit serves more than one floor than proper arrangements by way of automatic fire dampers working on smoke detectors for isolating all ducting at every floor from the main riser shall be made and provision of automatic switch off arrangement
- The air filters of the air-handling units shall be of non-combustible materials
- The air handling unit room shall not be used for storage of any combustible materials
- Inspection panels shall be provided to facilitate the cleaning of ducts of accumulated dust and to obtain access for maintenance of fire dampers.

14.7 Low Carbon Projects implemented by TMC

1. **Energy efficiency in Street Lighting**: TMC has initially installed 300 LED street lights as a pilot initiative which resulted in 50% savings in electricity consumption with support from Climate Group and Bureau of Energy efficiency (BEE) in the year 2012. Currently TMC has retrofitted 7500 LED street lights. Taking this forward TMC is now undertaking retrofit of 12000 LED street lights. The contract has been allotted to Energy Saving Company (ESCO) selected through a competitive bidding process. The project will provide Thane city with a modern and reliable street lighting system, improving illumination levels and aesthetic appearance, enhancing public safety and security and is expected to result in an energy saving of at least 60 % annually. TMC is planning to undertake the retrofitting work of remaining street lights in the city with LED ones and has addressed this in the smart city proposal. This move is expected to significantly increase energy efficiency and also reduce the energy demand for municipal street lighting from 7 MW to 3 MW.

2. **Energy efficiency in Municipal buildings**: TMC has promoted energy efficiency in its buildings by installing LED tube lights, promoting star labelling programme for fans, ACs & geysers, and installing smart sensors in corridors, staircases, restrooms and near water coolers so that lights and fans automatically switch off when there are no people around. In its office buildings, approx. 3000 nos. of conventional 80 watt fans replaced with energy efficient 5 star rated fans of load 50 watt resulting in reduction in energy consumption by 2,70,000 kwh annually. Similarly, 6000 conventional T12 and T8 tube lights were replaced with T5 tube lights with electronic ballast resulting in reducing the electricity consumption by 3,60,000 kwh annually. This initiative is continuous and has extended to other municipal buildings such as schools, hospitals, auditorium, etc.

3. **Thermal storage for Central AC Auditorium:** The TMC has considerably improved the energy performance of its central air-conditioning plant at an auditorium, Gadkari Rangayatan (30% energy saving) by implementing energy efficiency measures and a demand side management measure, thermal storage system has been provided to shift the cooling energy demand to off-peak hours (10 pm to 6 am), accruing monetary savings of INR 1.4 million annually and eliminating the use of CFC based refrigerants. The specific measures mainly included:

    - provision of thermal storage system for shifting energy demand to off-peak hours (10 pm to 6 am)
    - replacement of existing inefficient compressors having specific energy consumption of 1.8 kW/Ton by energy efficient Screw Compressors having efficiency 0.8 kW per Ton
    - elimination of CFC based refrigerant banned by Kyoto Protocol
    - improved air-conditioning - as per ASHRAE Standard
    - use of screw Compressors with efficiency 0.8 kW per Ton

4. **Energy efficiency in water supply sector**: While augmenting the existing water supply scheme from 120 to 240 MLD the following measures were undertaken by TMC under Government of India JnnURM scheme to reduce the energy consumption:

    - existing pumps were replaced with new modified duty condition pumps by utilizing available motors
    - new BPT was taken at lower level (9m), to reduce the head on the pumps
    - originally 600 hp 2 pumps were delivering 120 MLD; whereas now 600 hp 3 pumps are capable to deliver 240 MLD
    - redesigning of Raw Water Pumps for reducing head
    - System Automation with Supervisory Control and Data Acquisition (SCADA) system from raw water lifting up to the distribution Reservoirs leading to real time online monitoring of the entire water supply system
    - use of VVFD for water pumps
    - energy savings about 33 %
    - monetary savings around INR 5.2 Million/annum

5. **Renewable Energy (Solar thermal) initiatives in Municipal buildings**: 36,500 LPD of Solar Water Heaters has been installed in municipal buildings such as maternity homes, staff quarters, etc. resulting in approx. savings of 38, 000 kWh of electrical energy per annum. Under Basic Services for Urban Poor (BSUP) scheme, 76,000 LPD of SWH system

were installed in newly constructed building for urban poor population residing in slums. This led to saving of 0.9 kWh of electricity per annum. Apart from this approx. 6 million LPD of SWH has been installed in the city.

6. **Renewable Energy (solar photovoltaic) initiatives in municipal buildings:** TMC has installed 61.5 kWp rooftop solar photovoltaic (SPV) system in its main administrative building. Further grid connected 136 kWp SPV system has been installed at various ward offices of TMC where provision for net metering has been done. Maharashtra Govt. recently announced the net metering policy for solar rooftop system and under pilot initiative out of 136 kWp installed capacity TMC had installed 25 kW_p Solar Net Metering at Vartak Nagar ward office. Once this becomes successful the remaining ward offices will be net metered. Apart from this under Urban LEDS (see section 5.4.3) initiative 15 kW grid connected SPV system has been installed. Thus, a total of 212.5 kW SPV system has been installed in various municipal owned buildings.
7. **Bio-methanation Plant: TMC** has commissioned 15 T capacity Bio Methanation Plant at Chatrapati Shivaji Maharaj (CSM) hospital. The Methane gas produced is being fed into 50 kVA Biogas Genset for electricity generation and also fed to the Solar AC backup boiler. The plant produces 600 m^3 methane gas per day. Electricity generated is 810 Units per day. In addition to this 2 units of 5 T capacity each has been installed in the residential complexes.
8. **Low Carbon Measures in Municipal school**: This project was implemented in Municipal owned School No. 107 at Vartak Nagar under Urban LEDS project with an aim to deliver a refurbished Zero Carbon School-the first of its kind in Thane by demonstrating application of innovative low emission measures in school buildings and make it a model school that could be replicable in other schools. The measures included:
    - Energy efficiency retrofit: installation of energy efficient 08 & 16 watt LED tube light and 35-watt ceiling fans, smart sensors in the class rooms as well as in the toilets.
    - Renewable energy measures: based on the load demand a 15 kW grid interactive SPV system was commissioned. An arrangement for cleaning of solar panels was provided
    - Other low emission measures: installation of smart distribution board, smart metering for real time monitoring of load, solar power and with remote data logging features, rain water harvesting system and tree plantation. The wiring of the entire building was changed so as to make it suitable for efficient working of the smart appliances. For waste management, two bins in each floor provided for collection of wet and dry waste.

    All these initiatives led to 65% reduction in base electrical load and improvement of 125 % over base illumination of 68 Lux. TMC has allocated INR 0.2 million for installation Solar system at Municipal schools for the year 2015-16.
9. **Renewable energy based AC plant (160 T):** Installed at CSM hospital owned by TMC (See Section 2.12.3 XX, one of the potential site proposed by TMC for DCS). The specific measures include:
    - use of solar parabolic concentrators
    - existing chillers replaced by Vapor Absorption Machine (VAM)
    - diesel fired boiler replaced by agro residue based briquette fired boiler. Biogas is also used as fuel
    - use of liquid desiccant technology for reduction of heat load
    - elimination of CFC based refrigerant
    - saving in energy – 0.97 million units per annum
    - saving in amount – INR 7 million per annum
10. **Waste-to-Energy project**: to dispose 650 Tons per day (TPD) of entire municipal waste to produce 8 to 10 MW power
11. **other energy efficiency and renewable measures:** undertaken by TMC from time to time includes:
    - providing automatic power factor correction panels for H.T. connections
    - providing energy saving equipment's for air conditioning system
    - use of Microprocessor based Almanac timers for precisely switching ON/OFF street lighting considering seasonal changes
    - use of energy efficient, optically well designed streetlight fixtures
    - Voltage dimming Panel for street lighting
    - pilot project of GSM based advanced street light management system including energy saving cum power conditioning features
    - replacing conventional pumps with energy efficient water pumps
    - Installation of solar blinkers 39 Nos. solar traffic signals 5 Nos. solar powered advertisement Kiosks
    - 138 Buses operating on CNG and 75 Buses on CNG being procured leads to 33% saving in Diesel cost & less maintenance, low noise, zero pollution
    - CNG refilling station installed at TMT depot
    - All TMC light vehicles converted into CNG
    - Crematorium working on Diesel converted in LPG

14.8 Site information: Hospital and Medical College owned by TMC

The Chhatrapati Shivaji Maharaj Hospital and the Rajiv Gandhi Medical College, both owned by the TMC, are situated in the same building. The 500-bedded hospital offers specialty and super-specialty services and includes support services such as laundry, boiler house, maintenance, mortuary, central medical store, kitchen facilities.

The TMC has installed a 160 TR solar power based Central AC Plant, which is partly serving the needs of cooling requirement of the hospital building. Steam generated through solar concentrator as well as through agro residue based, carbon neutral, briquette-fired boiler is used for laundry purpose, sterilization and further for air conditioning through double effect vapour absorption machine (VAM) which uses lithium bromide solution to produce chilled water. TMC has also commissioned 15 T capacity bio-methanation plant in the hospital premises. The methane gas that is generated is being fed into 50 kVA biogas genset for electricity generation and to the backup boiler for the solar air conditioner.

Space cooling demand during the daytime is met through central air conditioning provided through 2 vapour absorption systems of 80 TR each for 12 hours. Window and split air conditioners (179 in total) meet the cooling demand during the night time. 4 packaged units are in operation to provide air conditioning to the main operation theatre and the casualty department in addition. 3 conventional chillers of 90 TR each are functioning as standby systems for the central air conditioning. The TMC plants to install a screw chiller of 120 TR capacity to replace the existing conventional standby chillers. An additional vapour absorption machine along with a compressor is planned to be installed for an upcoming morgue in the hospital.

Table 32: Details of Chhatrapati Shivaji Maharaj Hospital & Rajiv Gandhi Medical College

Particulars	Details
Number of Buildings	3 buildings in total 1) Main Hospital Building 2) Girl's Hostel with Canteen 3) Post Mortem and Mortuary room
No. of storeys	Ground + 3 floors
Number of beds	501
Air conditioning system and energy sources	- Boiler 7 kg pressure 12 hr. daily working with capacity of 1200 kg (fuel used is biogas and green briquettes) - Standby boiler 7 kg pressure with capacity 600 kg (working as a standby for 1200Kg Boiler) - 2 Vapour Absorption Machines of 80 Ton each, working daily for 12 hours - 2 Transformers of 1000 KVA; max demand recorded is 531 KVA

(Source: Electrical department, (TMC, 2016)

Table 33: Details of Central Air Conditioning System of Chhatrapati Shivaji Maharaj Hospital

Specifications of the Air Conditioning System	Details
Type of Air Conditioning System	- vapour absorption system for central air conditioning - window and split ACs - Package units
Installed and planned Capacity centralized	Installed capacity: - 160 TR VAM based (currently in use) - 270 TR conventional Chiller (as Standby for VAM) Planned capacity - 120 TR Screw Chiller
Peak Consumption of System	- 160 TR (central air conditioning through VAM) - 37 TR (Window AC) - 125.5 TR Split AC
Area to which Air Conditioning Supply provided	25306 sq. ft. (approx.)

Number of Air Handling Units (AHUs)	8
Operating Hours	24 hrs.

(Source: Electrical department, (TMC, 2016)

Figure 49: Photograph of the Chhatrapati Shivaji Maharaj Hospital

(Source: Electrical department, (TMC, 2016)

Figure 50: Bio-Methanation Plant at Chhatrapati Shivaji Maharaj Hospital

(Source: Electrical department, (TMC, 2016)

14.9 Climate and electricity information collected

Table 34: Monthly average Temperature and Relative Humidity, Thane

Month	Avg Daily Low (degrees C)	Avg Daily High (degrees C)	Avg Daily (degrees C)	Avg Daily relative Humidity (%)
Jan	18.4	30.3	24.1	61.5
Feb	18.5	31.0	24.6	57.8
March	21.7	32.0	27.0	67.4
April	24.5	32.5	28.8	72.4
May	27.6	32.6	30.1	71.4
June	26.5	31.2	29.0	82.4
July	25.4	29.9	27.8	84.6
Aug	25.4	29.4	27.2	84.0

Month	Avg Daily Low (degrees C)	Avg Daily High (degrees C)	Avg Daily (degrees C)	Avg Daily relative Humidity (%)
Sep	25.0	30.4	27.6	80.6
Oct	24.4	32.3	28.1	77.4
Nov	21.9	33.0	27.0	64.9
Dec	18.4	32.0	24.9	60.8

Table 35: Yearly electricity consumption, Thane - 2015

Electricity Consumption in Thane City (Thane, Wagle Estate, Mumbra and Shil) (Million kWh)

Category	2010-11	2011-12	2012-13	2013-14	2014-15
Residential	712.55	753.94	834.7	872.14	932.4
Commercial	321.9	341.26	364.01	377.05	397.59
HT-Industrial	282.38	268.07	242.32	219.35	203.32
LT-Industrial	88.38	106.66	107.23	115.09	118.83
Powerloom	0	0.02	0	0	0
PWW	10.78	11.05	11.99	10.56	12.2
Street Light	21.02	27.9	28.22	27.93	26.6
Agriculture	0.09	0.12	0.05	0.09	0.17
Others	1.93	1.27	10.26	18.04	23.3
Railways	52.81	61.39	64.25	61.79	49.22
Total	1491.84	1571.68	1663.03	1702.04	1763.63

Table 36: Sector wise monthly seasonal and base load, Thane - 2015

Month	Residential		Commercial		Industrial		Total	
	Seasonal Consumption (GWh)	Base Consumption (GWh)	Seasonal Consumption (GWh)	Base Load Consumption (GWh)	Seasonal Consumption (GWh)	Base Load Consumption (GWh)	Seasonal Consumption (GWh)	Base Load Consumption (GWh)
Jan	94.782	97.934	45.850	46.677	41.509	97.934	182.140	185.479
Feb	95.795	97.934	44.915	46.677	39.495	97.934	180.205	185.479
March	103.224	97.934	49.265	46.677	41.664	97.934	194.153	185.479
Apr	129.205	97.934	55.332	46.677	42.901	97.934	227.439	185.479
May	146.430	97.934	60.638	46.677	43.827	97.934	250.895	185.479
June	153.649	97.934	59.010	46.677	43.938	97.934	256.597	185.479
July	125.509	97.934	54.342	46.677	43.315	97.934	223.166	185.479
Aug	123.614	97.934	54.104	46.677	43.098	97.934	220.816	185.479
Sept	127.781	97.934	54.776	46.677	44.099	97.934	226.657	185.479
Oct	129.708	97.934	56.318	46.677	44.382	97.934	230.408	185.479
Nov	134.827	97.934	55.192	46.677	41.599	97.934	231.618	185.479
Dec	113.948	97.934	50.763	46.677	41.608	97.934	206.318	185.479

14.10 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 37: Assumptions of Occupancy

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

10	65%	60%	45%	85%	30%	50%
11	70%	75%	60%	75%	50%	75%
12	70%	75%	80%	60%	60%	90%
13	70%	80%	80%	60%	50%	80%
14	70%	80%	80%	85%	30%	80%
15	70%	80%	90%	85%	30%	80%
16	70%	80%	90%	75%	30%	80%
17	75%	80%	90%	75%	50%	80%
18	75%	65%	100%	65%	60%	65%
19	65%	45%	90%	65%	70%	45%
20	65%	25%	80%	60%	80%	25%
21	65%	15%	70%	50%	90%	15%
22	65%	5%	50%	50%	90%	5%
23	65%	5%	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 38: 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

14.11 Summary of meetings

Date	**Meeting**
3rd December, 2015	Representatives from EMPOWER, ICLEI South Asia, Danfoss met with the following officials from Thane Municipal Corporation and stakeholders • Mr. Sanjeev Jaiswal (IAS), Municipal Commissioner, TMC • Mr. Sunil Pote, Deputy City Engineer (Electrical), TMC • Mr. Bhagwan Shirsekar, Independent Energy Expert The DES team also undertook a site visit to the Hiranandani Estate in Thane
05th August, 2016	DES Team conducted a stakeholders meeting at Commissioner office- meeting Room, TMC. The main aim of this meeting was to brief the stakeholders about the project and its progress made so far, to understand their perspective for further on-ground implementation and their willingness to participate, understand the barriers, etc. The following officials of TMC and other prominent stakeholders attended this meeting: • Mr. Sanjeev Jaiswal (IAS), Municipal Commissioner, TMC • Mr. Sunil Pote, Deputy City Engineer (Electrical), TMC

Date	Meeting
	• Mr. Sharad Pustake, Advisor to TMC-Energy Sector, Science and Technology Park, University of Pune • Dr. Sanjay Gopal, Associate Professor-Mechanical Dept., VJTI • Ms. Sharmishtha Mukerjee Shinde, Principal Architectural Consultant, Hiranandani Group • Mr. Caitano A. Sequeira, Project Engineer (HVAC), Hiranandani Constructions Pvt. Ltd. • Mr. Subhash Ahuja, Dy. General Manager, MEP Division, Viviana Mall • Mr. Ankit Thakker, General Manager, Jupiter hospital • Mr. Sanatan D. Jha, Dy. Manager- Electrical Engineer, Sheth Developers Pvt. Ltd. • Mr. Sanjiv Walke, Dy. Vice President-Liason, Lodha Developer • Mr. Sagar Pawar, Territory Manager-Cooling Sales, Thermax Limited • Mr. Rahul Agnihotri, Senior Manager, Meghraj Capital Advisors Pvt. Ltd. The team undertook a visit to the Chatrapati Shivaji Maharaj Hospital, Viviana Mall area, Korum mall, Jupiter hospital, Lodha IT park, Hiranandani estate, Raymond company land
25th- 27th July, 2017	A three day visit had been conducted by DES team members from UNEP and ICLEI South Asia to carry out the walk-through visit and verification of data collection. The following meetings and site visits were conducted with the during this visit: • Site visit with Mr. Zope from TMC to Chatrapati Shivaji Memorial Hospital Kalwa and Kashinath Ghanekar Auditorium, Thane • Mr. Bhaskar Jare, President and Mr. Nandakumar, Vice President, ISHRAE Thane Chapter • Mr. K. Ramachandran, ex-National President, ISHRAE; Mr. Bhaskar Jare, President, ISHRAE Thane Chapter; Mr. Sagar and Mr. Nandakumar Mahajan, , ISHRAE Thane Chapter • Mr. Sanjay Ahuja and Mr. Sonar, MEP Division, Viviana Mall and visit to the mall’s HVAC plant • Mr. Sanjeev Jaiswal (IAS), Municipal Commissioner, TMC • Mrs. Sharmishtha Mukharjee- Shinde, Chief Architect, Hiranandani Group

References

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

ASHRAE. (2009). *ASHRAE Handbook Fundamental.* Accessed from the Climate Consultant Tool developed by the Department of Energy, University of California, Los Angeles (UCLA).

Bhadja, P., & Vaghela, A. (2013). Assessment of Physico-Chemical parameters and Water Quality Index of Reservoir water. *International Journal of Plant, Animal and Environmental Sciences*.

Business Standard. (2013). *Rajkot realtors want Infra development in outskirts: RBA.* Retrieved November 2016, from www.business-standard.com: http://www.business-standard.com/article/companies/rajkot-realtors-want-infra-development-in-outskirts-rba-110122500012_1.html

Census of India. (2011). Retrieved December 2015, from Census of India: http://www.censusindia.gov.in/2011census/dchb/Maharashtra_A.html

Census of India. (2011). Retrieved May 2015, from Census of India: http://www.censusindia.gov.in/2011census/dchb/DCHB_A/24/2409_PART_A_DCHB_RAJKOT.pdf

CEPT University. (n.d.). *Slum free City Plan of Action (SFCPoA), Rajkot.* Rajkot: CEPT University.

District Collectorate Thane. (2016). *Thane District Profile*. Retrieved 2016, from District Collectorate Thane: http://www.thane.nic.in/htmldocs/DistrictProfile.html

EESL. (2016). *Load Research and DSM potential assessment (Load sector & End use wise).* Retrieved from http://dsm-india.org/wp-content/uploads/2016/12/PPT-EESL-IIT-MUMBAI-09122006_DHK.pdf

Goverment of Gujarat. (2013). *District Groundwater Brochre.*

Government of Gujarat. (2014). *State Action Plan On Climate Change.* Climate Change Department.

Gujarat Ecology Commission. (n.d.). Retrieved November 2016, from http://www.gujenvis.nic.in: http://www.gujenvis.nic.in/PDF/soil.pdf

Gujarat Lodhika Industrial Association. (2015). Gujarat Lodhika Industrial Association, Rajkot.

Gujarat Pollution Control Board. (2015). Retrieved November 2016, from www.gpcb.gov.in: http://www.gpcb.gov.in/ambient-air-quality-monitoring-programme.htm

Guttikunda, S., & Jawahar, P. (2011). *Urban Air Pollution Analysis in India.* New Delhi: UrbanEmissions.Info.

Hiranandani Group. (n.d.). *Thane the ideal luxury living residential destination*. Retrieved from Hiranandani Group: http://www.houseofhiranandani.com/blog/

ICLEI South Asia. (2016). *Thane City: Greenhouse Gas Inventory Report, 2012-13.*

ICLEI South Asia. (2017). *Rajkot City Greenhouse Gas Inventory Report 2015-16.*

IMD, Rajkot Airport Station. (2015). *Information collected from IMD, Rajkot.*

International Institute for Energy Conservation (IIEC. (n.d.). *Eco-housing Gains Market Acceptance and Bank Support in Maharashtra, India*. Retrieved from http://www.iiec.org/index.php/iiec-news/162-eco-housing-gains-market-acceptance-and-bank-support-in-maharashtra-india-.html

International Institute for Energy Conservation (IIEC). (n.d.). Retrieved November 2016, from www.iiec.org: http://www.iiec.org/index.php/iiec-news/162-eco-housing-gains-market-acceptance-and-bank-support-in-maharashtra-india-.html

Jones Lang La Salle. (n.d.). *Emerging Investment Hotspots.* Retrieved from http://indiainbusiness.nic.in/newdesign/upload/reports/CII%20-%20JLL_Report_on_Real_Estate_Sector.pdf

Jones Lang Lasalle Meghraj. (2010). *The Seven Stars of India.* Retrieved from http://www.jll.co.in/india/en-gb/Research/The_Seven_Stars_of_India_(L).pdf

Jupiter Hospital. (2016). Retrieved December 2016, from Jupiter Hospital: https://www.jupiterhospital.com/images/about/about_img_1.png

Lodha Group. (2016). *iThink Thane*. Retrieved from http://www.lodhagroup.com/ithink-thane/gallery.php

Mapping and analysis by TMC and ICLEI South Asia. (n.d.).

Ministry of New and Renewable Energy. (2012). *Development of Rajkot Solar City.*

MMRDA. (2013). Retrieved March 2016, from Mumbai Metropolitan Region Development Authority: https://mmrda.maharashtra.gov.in

MSEDCL. (2016). *Information collected from MSEDCL Thane Circle Office.* Thane Circle Office, Thane.

MSEDCL Tariff Order. (2016). Retrieved from http://mahadiscom.co.in/consumer/Comm_Cir_275.pdf

Pacific Northwest National Laboratory. (2016). *Implementing the Energy Conservation Building Code: Toolkit for Smart Cities.* Retrieved September 2017, from http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26000.pdf

Pacific Northwest National Laboratory. (2016). *Implementing the Energy Conservation Building Code: Toolkit for Smart Cities.* Retrieved September 2017, from https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26000.pdf

PGVCL. (2016). *Information collected from the power distribution company PGVCL, Rajkot.*

Rajkot Urban Development Authority. (2016). *Draft Comprehensive Development Plan 2031 (Second Revised) part I: Existing conditions, studies and analysis.*

Rajkot Urban Development Authority. (2016). *Draft Comprehensive Development Plan 2031 (Second Revised) part II: Planning proposals and recommendations.* Rajkot: Rajkot Urban Development Authority.

Rajkot Urban Development Authority. (2016). *Draft Comprehensive Development Plan 2031 (Second Revised) part III:General Development Control Regulation.* Rajkot: Rajkot Urban Development Authority.

RMC. (2012). *Preparation of Second Generation City Development Plan for RMC as well as RUDA.*

RMC. (2015). *Information collected from Town Planning Department, RMC, Rajkot.*

RMC. (2016). *Smart City Proposal - Rajkot City.*

Rodas Enclave. (2016). Retrieved from Rodas Enclave: http://www.rodasenclave.com/images/about/about2.jpg

Rodas Enclave. (2016). Retrieved December 2016, from Rodas Enclave: http://www.rodasenclave.com/

Sheth Developers. (2016). *Avalon Township*. Retrieved from http://www.shethcorp.com/images/project/Current/avalon/big-2.jpg; http://www.shethcorp.com/real-estate-projects/avalon-flats-thane.html

Sheth Developers. (2016). *Vasant Lawns*. Retrieved from http://www.shethcorp.com/images/project/Completed/vasant-lawns/layout-plan/lp-big.jpg

Sheth Developers. (2016). *Viviana Mall*. Retrieved from http://shethcorp.com/real-estate-projects/viviana-mall-stores-thane.html

Square Yards. (2015, July). *Mumbai Real Estate Overview*. Retrieved from http://www.squareyards.com/blog/wp-content/uploads/2015/08/Mumbai-Report.pdf

Thane Property. (2016). *Korum Mall*. Retrieved from Thane Property Website: http://thane-property.com/blog/korum-mall/

Times of India. (2009). *ACs eat up 40% of city's total power consumption*. Retrieved 2016, from http://timesofindia.indiatimes.com/city/mumbai/ACs-eat-up-40-of-citys-total-power-consumption/articleshow/5368121.cms

TMC. (2008). *Development of Thane as a Solar City.* Electrical Department, Thane.

TMC. (2010). *Environmental Status Report, Thane.*

TMC. (2014). *Environmental Status Report. Thane: 2013-14.*

TMC. (2016). *Draft Thane City Development Plan- 2031.*

TMC. (2016). *Information collected from Electrical Department, TMC.*

TMC. (2016). *Information collected from Town Planning Department, TMC.*

TMC. (2016). *Information Collected from Water Supply Department.*

TMC. (n.d.). *Thane Smart City Proposal.* Retrieved from http://smartcities.gov.in/upload/uploadfiles/files/Thane_projects.pdf

UNEP. (2014). *Low-Carbon Comprehensive Mobility Plan: 2011-2031.*

UNEP. (2015). *District Energy in Cities: Unlocking the Potential for Energy Efficiency and Renewable Energy.*

UNEP. (2015). *District Energy in Cities: Unlocking the Potential for Energy Efficiency and Renewable Energy.* UNEP.

USAID. (2010). *Load research for residential and commercial establishment in Gujarat - Final survey report, ECOIII project.*

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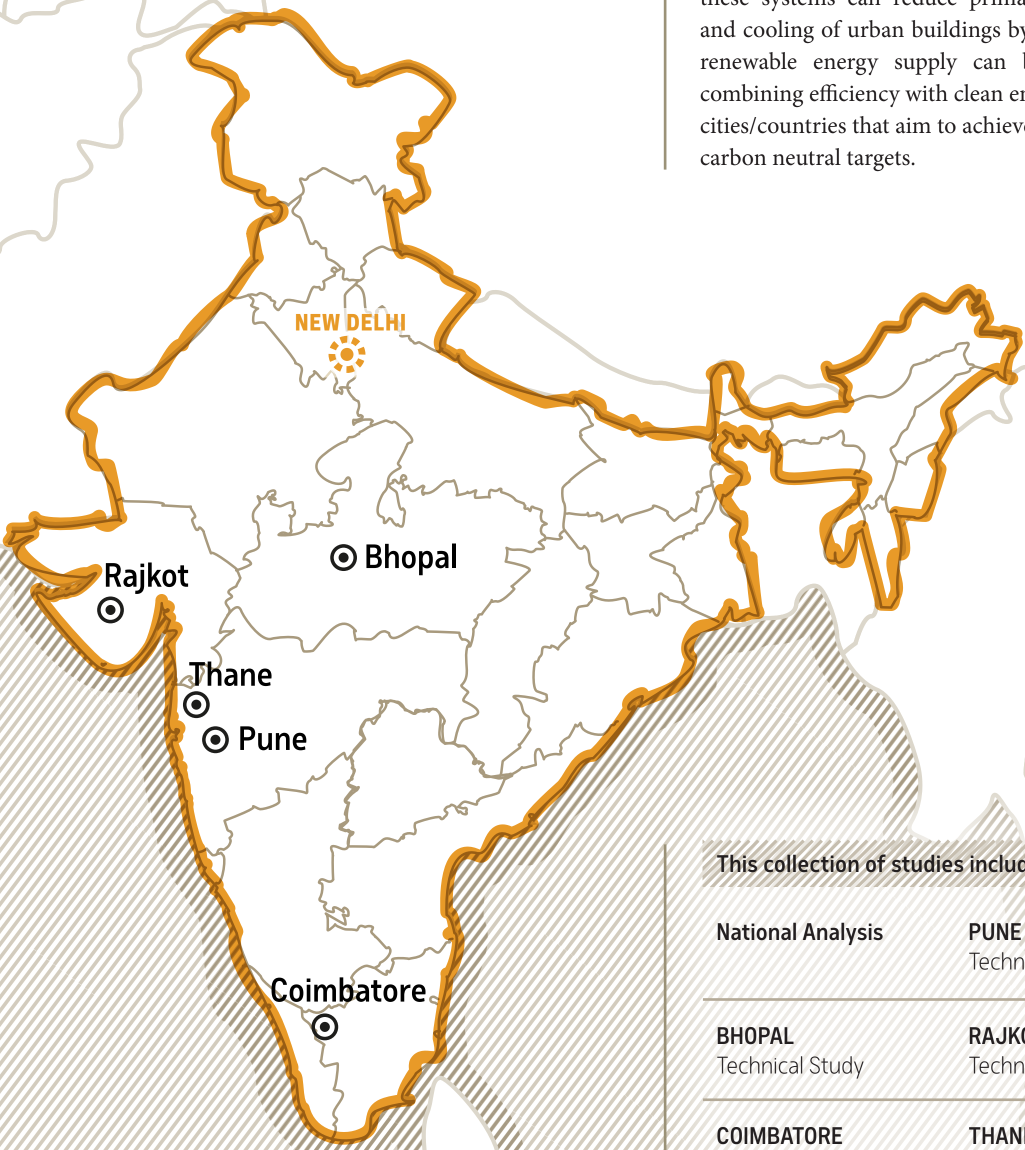
Through economies of scale, diversity of supply, balancing and storage, these systems can reduce primary energy consumption for heating and cooling of urban buildings by up to 50%. High levels of affordable renewable energy supply can be integrated with district energy, combining efficiency with clean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



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