DISTRICT ENERGY IN CITIES INITIATIVE

UN environment

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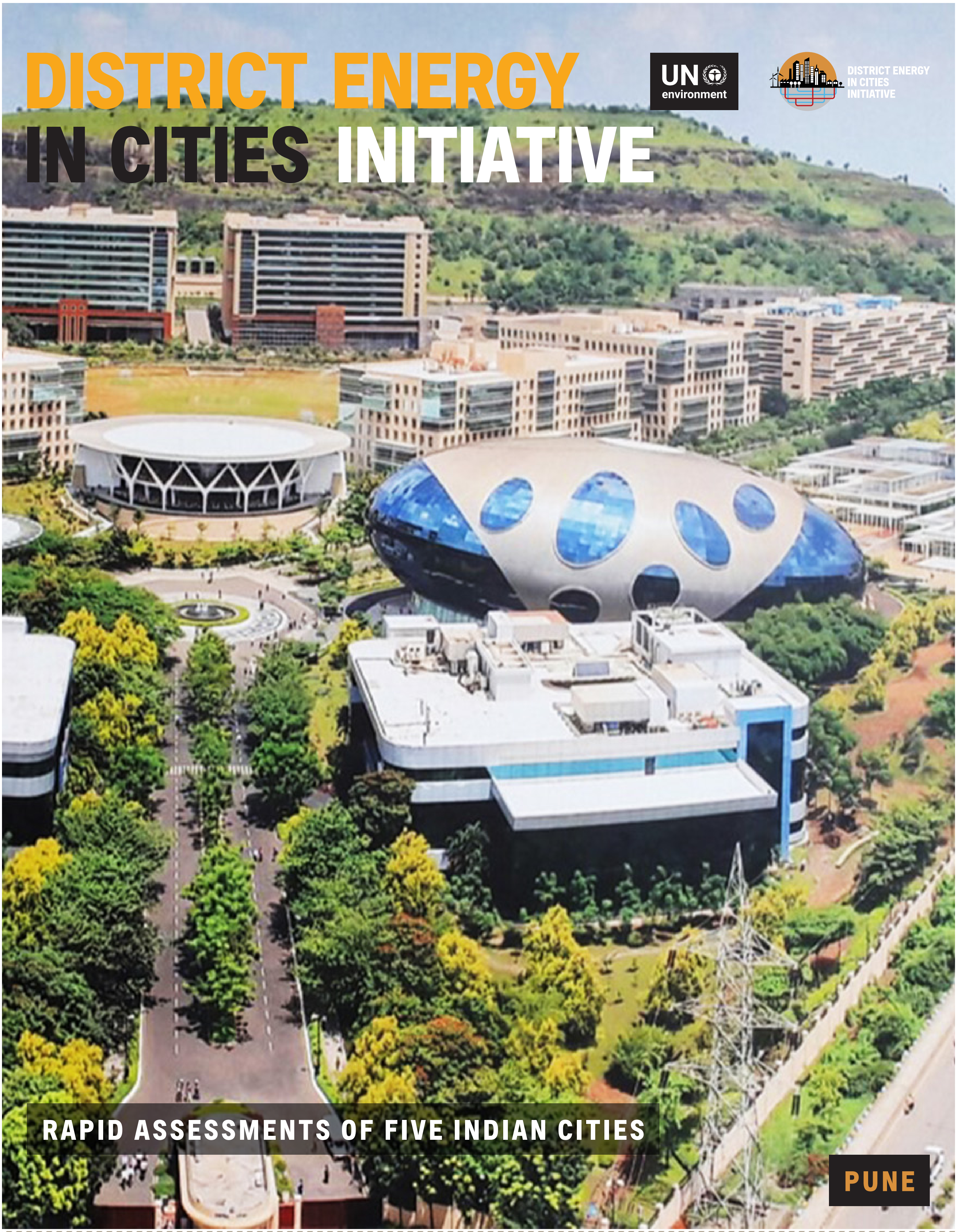

RAPID ASSESSMENTS OF FIVE INDIAN CITIES

PUNE

COPENHAGEN CENTRE ON ENERGY EFFICIENCY
SEforALL EE HUB

ICLEI Local Governments for Sustainability

EESL

Contributing to:

SUSTAINABLE ENERGY FOR ALL

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

The project team appreciates the vision shown by the Pune Municipal Corporation for agreeing to be a part of the District Energy in Cities Initiative. We are grateful for all the support extended by the Municipal Corporation and its departments to this exercise, in particular the Water Supply Department, Electrical Department, Town Planning Department, Buildings Department.

We extend our sincere thanks to administrators, government departments and stakeholders including the Pune Smart City Development Corporation Limited, Maharashtra State Electricity Distribution Company Limited – Pune office, Prayas (Energy Group), R.S Kulkarni and Associates, Indian Society of Heating, Refrigerating & Air-conditioning Engineers (ISHRAE) - Pune Chapter, Panchshil Realty, Amanora Park Town, Magarpatta City, AG Constructions, and Pune Premium Properties, whose inputs and contribution to data collection have been invaluable to the successful completion of the district cooling rapid assessment in Pune and the compilation of this document.

The Initiative

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

For more information and contact details please visit districtenergyinitiative.org

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1. Introduction

This report contains the rapid assessment of the Indian city of Pune undertaken alongside four other district cooling rapid assessments of Bhopal, Coimbatore, Thane and Rajkot. This report sets out a high-level analysis of the current impacts of space cooling in Pune, 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 Pune 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

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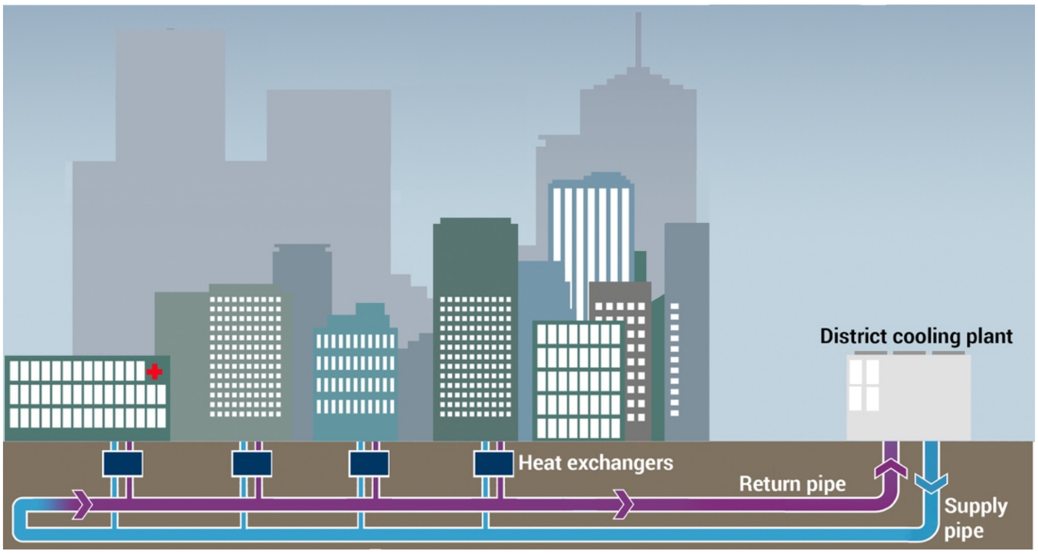
[1] For more information and contact details please visit www.districtenergyinitiative.org
[2] Available from www.districtenergyinitiative.org

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 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

Pune is actively engaged in pursuing sustainable, low emission development and the local government is particularly innovative and forward-looking with regards to green building policies and using its planning authority to promote sustainability. Pune is one of 20 cities selected for the first round of funding under the Government of India's Smart Cities Mission.

Pune is the ninth-most populous city in India and the second largest city in the state of Maharashtra after the state capital city of Mumbai. Pune city is the administrative headquarters of the Pune district. Over the recent years, the city's character has changed. From a former educational and administrative centre, Pune is now one of the most attractive business centres in the state as well as the country. Pune is a major Information Technology (IT) and Information Technology enabled services (ITeS) destination, which is accelerating real estate growth and ranks second in India in terms of economic value of software exports (Times of India, July 2015).

There are two governing bodies within the Pune urban agglomeration area, the Pune Municipal Corporation (PMC) and the Pune Metropolitan Region Development Authority (PMRDA). The PMC administers the city area spanning 243.8 sq. km. The PMRDA has been setup recently in the year 2015 and is responsible for planning and development of the urban agglomeration, spread over 6,700 sq. km.

Pune city has put forth ambitious commitments for renewable energy integration, particularly for solar energy. The city is actively undertaking interventions to promote uptake of renewable energy solutions. The PMC has placed high emphasis on promoting green buildings across the city through policy instruments such as the Eco-housing Programme and the national Green Rating for Integrated Habitat Assessment (GRIHA).

Table 1: City at a Glance

Particulars	Details
Area	243.8 sq. km.
Population	3,115,431
Population Density	12,777 persons per sq. km.
Local Economic Base	IT Services, Manufacturing (Auto and Engineering), Education
Average Temperature	24.1°C
Average Relative Humidity	66.4%
Average Rainfall	625 mm

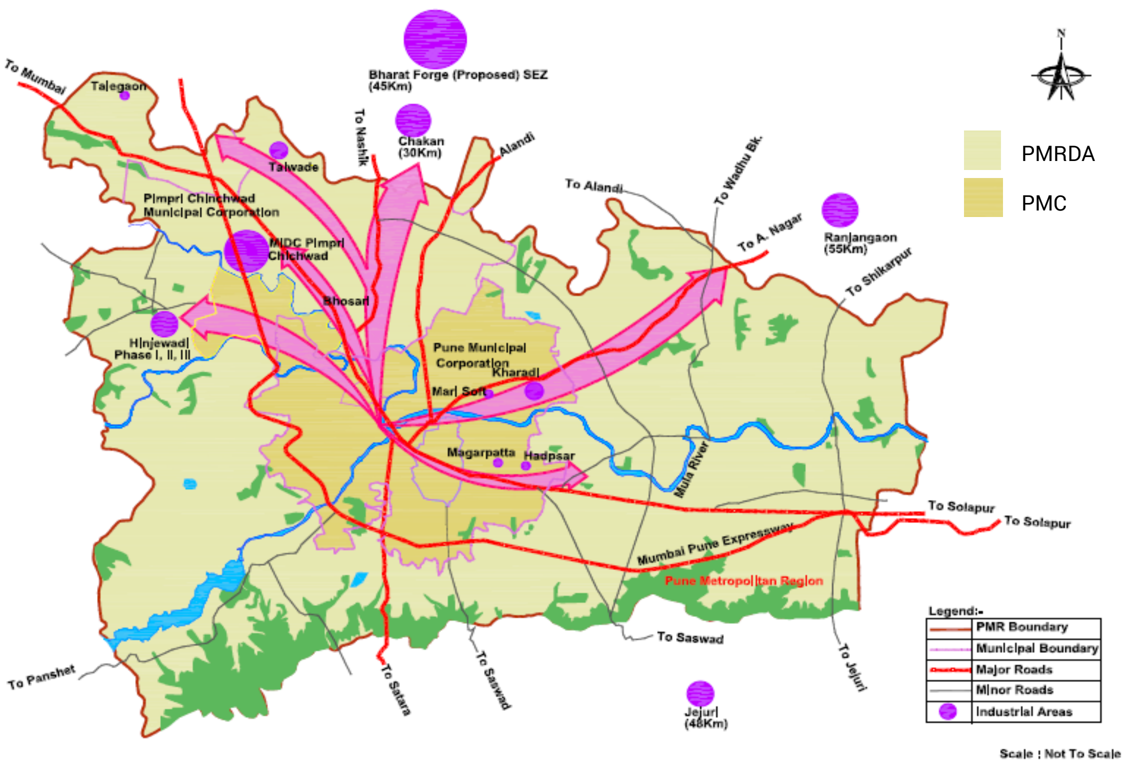
3.2. Location and Natural Environment

3.2.1. Geographical Location

Pune city lies in the eastern belt of the state of Maharashtra between 18°32' North latitude and 72°51' East longitude. Pune is situated at an altitude of 560 meters above sea level. The city is bound by the Thane district to the north-west, the Raigad district to the west, the Satara district to the south, the Solapur district to the south-east, and the Ahmednagar district to the north and north-East. It is situated at the confluence of the rivers Mula and Mutha (Pune Municipal Corporation, 2007).

The city is well connected to major Indian cities by both rail and road. Pune has an international airport at Lohegaon, situated at a distance of 10 km towards its north-east, and is connected via air to all major Indian cities and international destinations. A new international airport for the city has been proposed and approved for construction at Purandar (Times of India, October 2016), located at a distance of about 20 km to the south of the city.

Figure 1: Regional linkages and area of Pune City

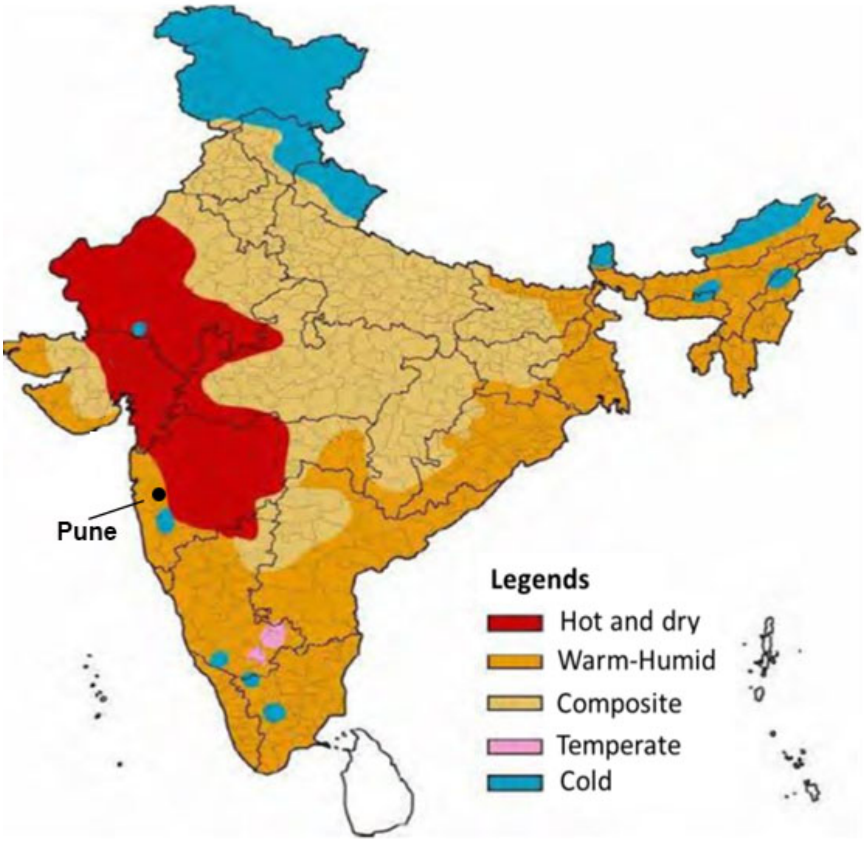


Source: (Comprehensive Mobility Plan for Pune City, 2008)

3.2.2. Climate

The city has a tropical wet and dry climate, with three distinct seasons: summer, monsoon and mild winter. The height above sea level and the leeward location with reference to the Western Ghats contribute to the city's relatively moderate and pleasant climate. The average daily temperature recorded in Pune is 24.1°C and average relative humidity is 66%. Summers in Pune start from March to May, with maximum temperatures ranging from 35 to 39°C. The warmest month in Pune is April. The nights are usually cool due to Pune's high altitude.

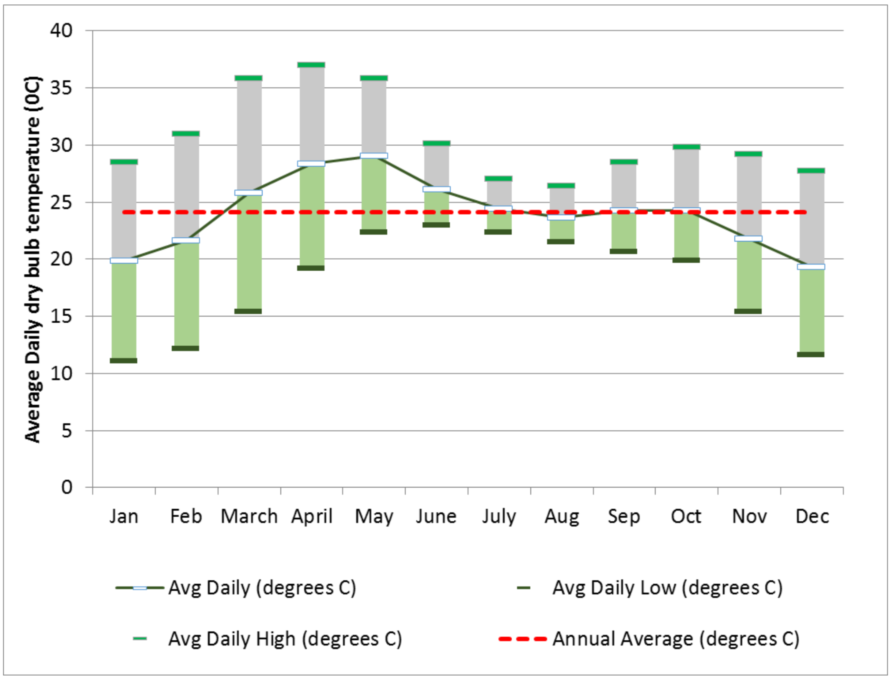
Figure 2: Climate Zones of India



Source: (ECBC , 2017)

The city receives annual rainfall of 625 mm, mainly between the months of June to September as a result of the South-West monsoon. The weather during this period is very pleasant with temperatures ranging from 20°C to 28°C. The winter sets in during the month of November and lasts till mid-February. The average maximum daily temperature during this period is approximately 29°C while the average minimum daily temperature ranges between 10°C to 15°C.

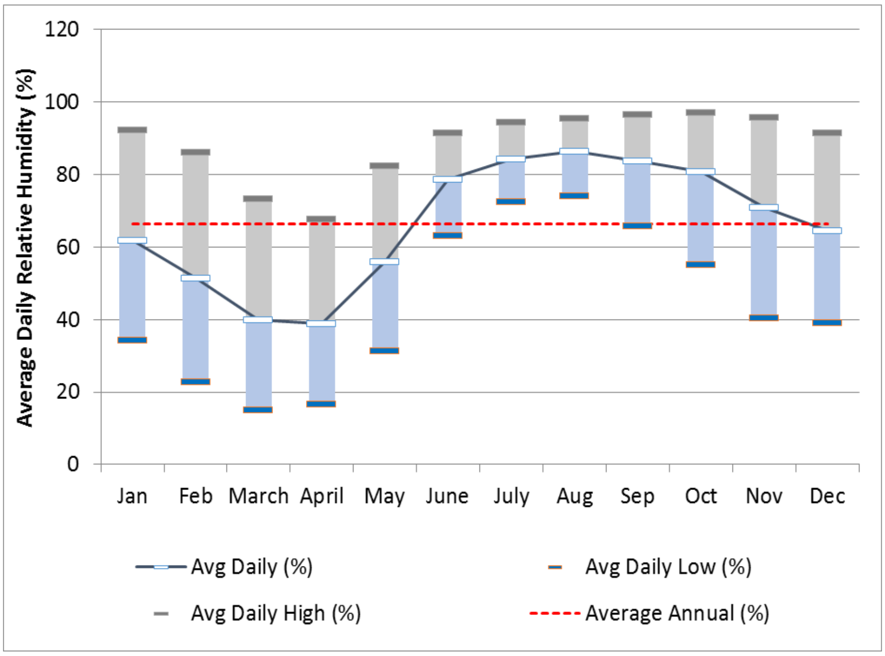
Figure 3: Month wise average daily temperature variation with respect to annual average temperature for Pune city (1982-2006)



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

The annual average relative humidity stands at 66.4 percent. The months of June to November are observed to have higher humidity as compared to the average, with the relative humidity going up to 97.2 percent in the month of October.

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



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

The Maharashtra State Action Plan on Climate Change indicates that weather patterns are projected to change across the state and for Pune city as well. Temperature and rainfall is projected to increase across the state of Maharashtra in the time period up to 2080, to varying extents across different regions in the state[3]. The projected rise in annual mean temperature is expected to be around 1.15 °C -1.28 °C for Pune by the year 2030 as compared to baseline of 1970-2000 (The Energy and Resources Institute, 2014). Therefore, Pune's energy consumption for space cooling is expected to rise in the coming years.

The total number of Cooling Degree Days (CDD)[4] for Pune is 1,154 (for base temperature of 23°C). There is noticeable difference in the CDDs between the winter months of December, January, and February and the summer months of March, April, and May, with the CDDs rising sharply in the summer. Other cities have developed successful district cooling projects with far lower CDDs.

The climate of Pune 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 Pune is examined further in Section 9.

3.2.3. Soil Conditions

Pune's soil conditions are characterized by slightly deep well drained, fine, calcareous soils on very gently sloping lands with mesas and buttes with moderate erosion. Pune city is largely underlain with hard rock (Deccan Trap basalt) and basaltic lava flows. The soil texture contains alluvial deposits of sand, gravels, fine silts and clays along the bank of the rivers. The thickness of this type of soil varies from 8 to 18 meters. The soil texture of the remaining city is made of silicates, phyllosilicates, and okenite group with basalts containing dykes and laterites (Maharashtra Remote Sensing Applications Centre (MRSAC), Nagpur) .

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

3.2.4. Surface and Groundwater Availability

Pune has two major water bodies, the Mula River and Mutha River which dissect Pune city. The Mutha River and the Mula River both flow from the western side of Pune and converge near the centre of the city and then continue to flow towards the east. The Pashan Lake, Katraj Lake and the Snake Park Lake are three important lakes in the city.

The surface water resources in the city are polluted due to disposal of untreated wastewater directly into the surface drains and water bodies. Although 97 percent of Pune's population is served by the sewerage network, up to 355 million liters per day (MLD) of wastewater from

[3] Projections for temperature and rainfall have been undertaken for three time periods - 2030s, 2050s and 2070s. The projection for the 2030s is the average of projections for the period between 2021-2040. Similarly, the projection for the 2050s is the average of projections for the period 2041-2060 and that for the 2070s is the average of projections for the period 2061-2080.

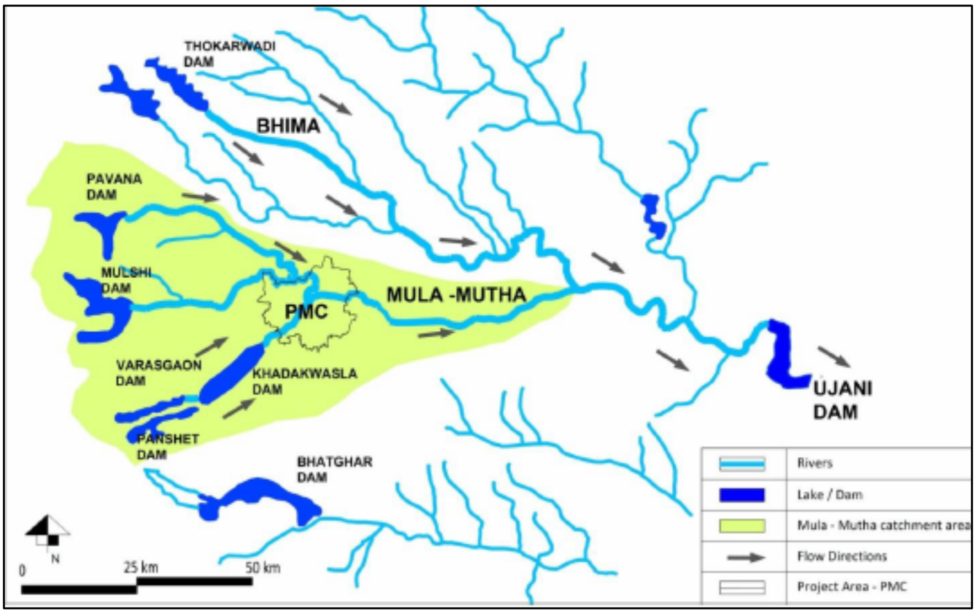
[4] Cooling Degree Days (CDD) is a measure of how much (in degrees) and for how long (in days), the outside air temperature is above a given level of comfort (base temperature) for which cooling is required. The higher the CDD, more is the cooling required. The base temperature selected is 23°C and has been chosen to enable international comparison.

sources located along the banks is discharged into the Mula-Mutha River. The biochemical oxygen demand (BOD) level of the two rivers ranges from 50 to 80 milligram per liter (mg/l) (Pune Municipal Corporation, 2014) (for more detail see Figure 46, Figure 47 and

Figure 48 in Annex). While this polluted water might not be fit for drinking purposes, the 2011 Pune City Sanitation Plan, does indicate that the water of the Mula River and the Mutha River is fit for other purposes such as agriculture, industrial cooling and process water (Pune Municipal Corporation, 2011). In Pune's smart city plan (see Section 5.1), water is a key sector to be addressed and the Plan includes objectives on improving access to clean water in Pune and reducing water stress.

The city sources its water supply from the Khadakwasla Dam which is located on the Mutha River at a distance of 12 km from the city. The water sources in Pune are highly dependent on the monsoon. The city faces water shortages in summers, particularly in times of inadequate monsoons.

Figure 5: Pune Location in North Bhima River Basin



Source: (Pune Municipal Corporation, 2012)

The rivers in Pune, 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 (Vinaya V. Fadtare and T.T. Mane, 2007). However, temperatures may be lower at deeper points of the river and further analysis should be undertaken during pre-feasibility stage of projects, particularly for projects near the riverfronts. This analysis should also account for the possible environmental benefits and impacts that can come from rejecting waste heat into rivers.

Ground water is an important water source catering to the water demand of various sectors in Pune. Due to the ever-increasing use of groundwater, the city's groundwater levels have dropped by more than 8.75 meters in recent years (Pune Municipal Corporation, 2012). There are examples of the 'free cooling' from groundwater being used for district cooling systems (Cleaner Production Germany, 2017), however analysis of this is outside the scope of this assessment.

The wastewater generation in Pune is about 575.2 MLD against the installed treatment capacity of 527 MLD, as of year 2012. Thus, there is a gap of 48 MLD in the treatment of wastewater. There are nine sewage treatment plants in the city. The sewage network coverage is 97.6% against the standard of 100% in Service Level Benchmark (SLB) (Pune Municipal Corporation, 2012).

The cost of water is quite high in Pune, between INR 700 (11 USD[5]) to INR 800 (12 USD), and is charged per cubic meter of water along with a substantial connection fee. In addition, district cooling service providers would also have to bear the cost of construction or any civil work for getting a water connection (Kulkarni, 2015). 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 Pune that have centralized cooling use a mix of air-cooled chillers and water-cooled chillers.

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

3.2.5. Air Quality

The transportation and industrial sectors are the key pollution sources impacting Pune's air quality. The concentration of nitrous oxide (NOx) and sulphur dioxide (SO_2) are found to be within the permissible limits, however, the concentration of Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM) exceeds the acceptable limits, largely owing to the growing vehicular population and traffic in the city (Pune Municipal Corporation, 2015-16).

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

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

3.2.6. Energy consumption

Pune is a fast-growing city and electricity demand is expected to reach 12.8 TWh per year with peak electricity demand of 2.1GW by March 2017. The industrial sector consumes 36% of this electricity, followed by the residential sector (29%), the commercial sector (22%) and others (13%). LPG is often used for cooking and transport is predominantly based on fossil fuels.

3.2.7. Greenhouse gas emissions

Pune completed a GHG baseline study (The Energy and Resources Institute, 2012) in 2012, in total the city emitted 4.66 Mt CO_2 eq. in 2010-11 and the proportions of various sectors are shown below in Table 2. Pune's GHG emissions inventory captures emissions from use of different fuels in the city. The GHG inventory, however, does not cover emissions from refrigerants.

Table 2: Pune's CO2 emissions 2010-2011

Sector	Proportion
Residential	31.60%
Transport	18.70%
Commercial	9.50%
High-tension Electricity	24.10%
Waste	7.10%
Industrial	7.90%
Others	1.20%

3.3. Socio Economic Status

3.3.1. Population

The population of Pune city is about 3.12 million persons and has increased by about 22.7 percent from year 2001 (National Census, 2011). The population density in Pune is 12,777 persons per sq. km. The population in the wards situated in Pune's eastern side has almost doubled in the last few years, mainly due to the growth in the IT industry in this area. The resident population is expected to reach by 2020, 6.5 million persons and increase nearly

50% in the subsequent 20 years, rising to 8.59 million persons by 2041 (Pune Municipal Corporation, 2012).

The total number of slums in Pune is 564, with 353 declared or notified slums and 211 undeclared or not notified slums. 28 percent of the city’s households reside in slums. As of 2010-11, the annual per capita income for Pune was INR 127,000 (USD 1,905) (USDA Foreign Agricultural Service, 2015).

3.3.2. Local Economy and Real Estate Growth

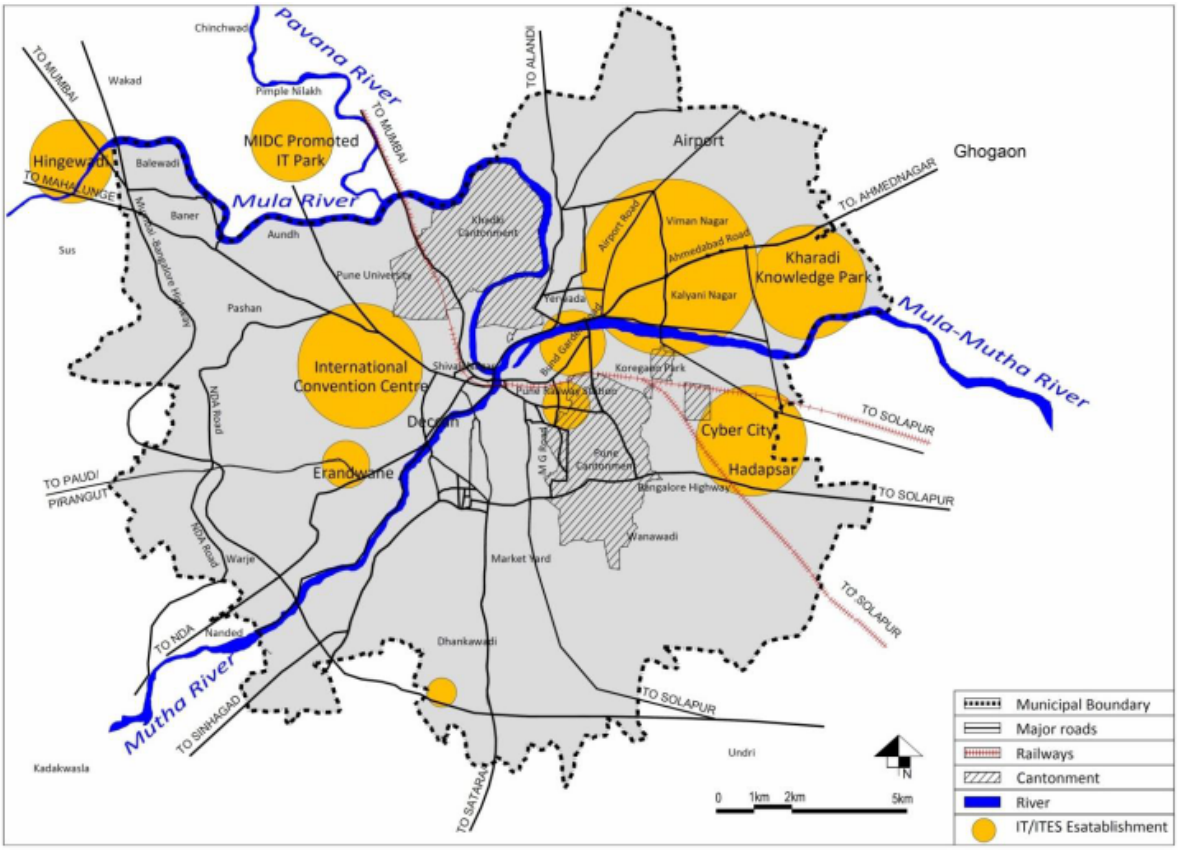
A strong industrial base and sound infrastructure have made Pune city and its suburban region one of the most attractive investment hubs in Maharashtra state and has been attracting investments from across the world. A study conducted by the Maharashtra Industrial Development Corporation (MIDC) in 2010, confirms that Pune city, including the larger urban agglomeration, is the most preferred investment destination in the state after Mumbai, having 35 registered IT Parks (2010) and 16 notified Special Economic Zones (SEZ).

Pune serves as a base for various large and small units operating in sectors such as auto components, engineering, IT/ITES, BPO, biotechnology, pharmaceuticals and food processing. In the large scale sector, industries like manufacturing textiles, pharmaceuticals, biscuits and chocolates, electrical and electronic goods, diesel engines, machine tools, automobiles, paper and its products, etc. are established in and around Pune. Figure 6 shows some of the IT and ITeS zones in Pune.

Pune city has emerged as an ideal destination for the IT/ITES sector and houses a large number of IT companies. Many leading software businesses such as Infosys, Wipro, IBM, Satyam, and Accenture among others have established operations in Pune. Pune’s bio-technology industry has been growing and the city contributes to 13 percent of the state’s biotech revenues. Pune is also a successful start-up destination, with more than 400 local start-ups (Pune Smart City Development Corportion Ltd., 2017). Pune is a well-known educational hub in India, accommodating more than hundred educational institutes and nine universities. The city attracts a large number of students from all over India.

Pune’s economy and rapid growth, particularly in the service and IT sector, make district cooling highly viable. Offices based in Pune, some of which have 24-hour operations,could anchor district cooling projects, by providing a steady load for a district cooling system, that could then serve other buildings in a mixed-use zone, lowering risks and costs. Pune already has a private district cooling system serving this high-tech industry.

Figure 6: IT Establishments in Pune



Source: (Pune Municipal Corporation, 2012)

4. Stakeholder Mapping

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

Institution type	Agency	Specific functions and role with relevance to district cooling
City Planning Authority	• Pune Municipal Corporation (PMC) • Pune Metropolitan Regional Development Authority(PMRDA) • Pune Smart City Development Corporation Ltd. (PSCDCL)	**Mandate and Functions:** • **PMC**: The PMC is the main planning authority for the city of Pune. PMC 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. PMC 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. PMC plays the role of planner, controller and implementer within its jurisdiction. • **PMRDA**: The PMRDA engages in long term planning, promotion of new growth centres, implementation of strategic projects and financing infrastructure development for the larger Pune Metropolitan Region. In particular, the PMRDA 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 Pune Metropolitan Region. • **PSCDCL**: The key responsibility of PSCDCL is to oversee the planning and execution of Smart City plan for Pune city. This includes the implementation of proposed smart and sustainable solutions throughout the city as well as in the area based development. PSCDCL's main focus remains on improvement of urban infrastructure and

Institution type	Agency	Specific functions and role with relevance to district cooling
		governance while addressing priority areas outlined in the Smart city plan. **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

Institution type	Agency	Specific functions and role with relevance to district cooling
		loads with high cooling demand to assist viability of district cooling • Facilitate stakeholder coordination, raise awareness and acceptance
Real Estate, Property Developers and related Institutions	• The Confederation of Real Estate Developers Associations of India (CREDAI) – Pune Metro • Panchsheel Group • Kumar Properties • Pride Purple Group • Paranjape Schemes Construction Limited • DSK Developers • Yoggav Infra Llp. • Synefra Infrastructures Pvt. Ltd. • Kolte Patil Developers Ltd.	**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, Pune Centre • Architects, Engineers & Surveyors' Association, Pune • The Institution of Engineers (India), Pune Local 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

Institution type	Agency	Specific functions and role with relevance to district cooling
		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 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

Institution type	Agency	Specific functions and role with relevance to district cooling
		• 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)	• 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 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.

Institution type	Agency	Specific functions and role with relevance to district cooling
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. **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	• Maharashtra Chamber of Commerce Industries and Agriculture (MCCIA) • Deccan Chamber of Commerce Industries & Agriculture (DCCIA) • The Hinjewadi Industries	**Role with respect to district cooling:** • Identify existing and upcoming large scale industrial developments such as IT, business and manufacturing hubs/parks, special economic zones in and around the city with high cooling demand and potential for district cooling integration • Share information on typical cooling demand for different industry building types in the city in consideration of the local climate, building use, envelope and size, and

Institution type	Agency	Specific functions and role with relevance to district cooling
	Association (HIA) • Hadapsar Industries Association	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
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), Pune Chapter	**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

Pune 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. Pune already has a private district cooling system and has established an innovative green building programme. 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 PMC are described below.

5.1. Pune Smart City

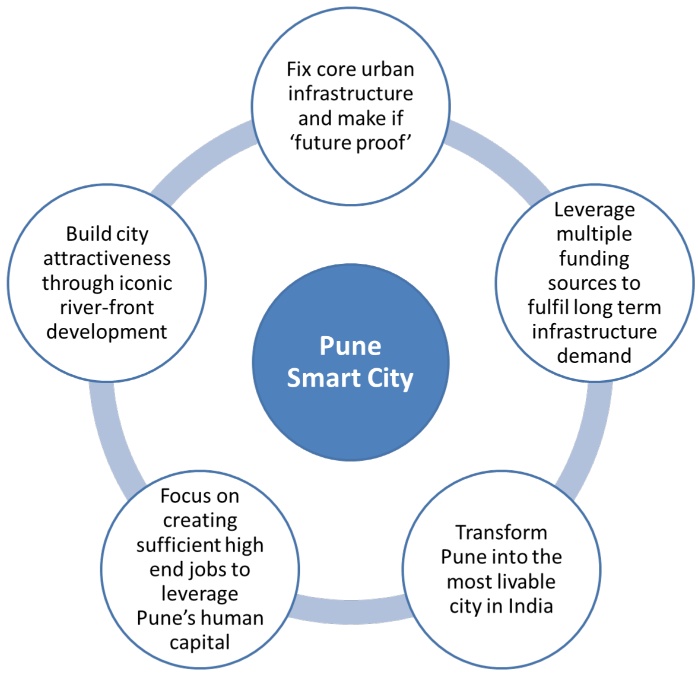
Pune is one of 10 cities from the state of Maharashtra to be shortlisted amongst 100 cities to be developed as Smart Cities under the Government of India's Smart Cities Mission. Based on a competitive evaluation of its Smart City proposal, Pune has been ranked 2nd in the initial list of 20 cities to be taken up for funding in the first round of the Mission.

Pune outlines the following vision in its Smart City proposal-

"Leveraging its rich **cultural and natural heritage**, **strong human capital** and **strong business environment** as key strengths, Pune **aspires to become the most liveable city** in India by solving its **core infrastructure** issues in a **future proof** way and by making its neighbourhoods **beautiful, clean, green and liveable**".

Pune's vision is based on five key underlying strategies, which are driven by aspirations of the administration and even more so by the city's community, given the effective civic engagement undertaken by the PMC. The PMC designed a tailored and strategic approach for civic engagement and received 3.5 million inputs from the community to help shape Pune's vision and priorities. Pune gives due consideration to the creation of 'future proof infrastructure' in its vision and considers sustainability (including smart energy solutions) as a key aspect to help improve its 'liveability'.

Figure 7: Priority Strategies for Pune Smart City



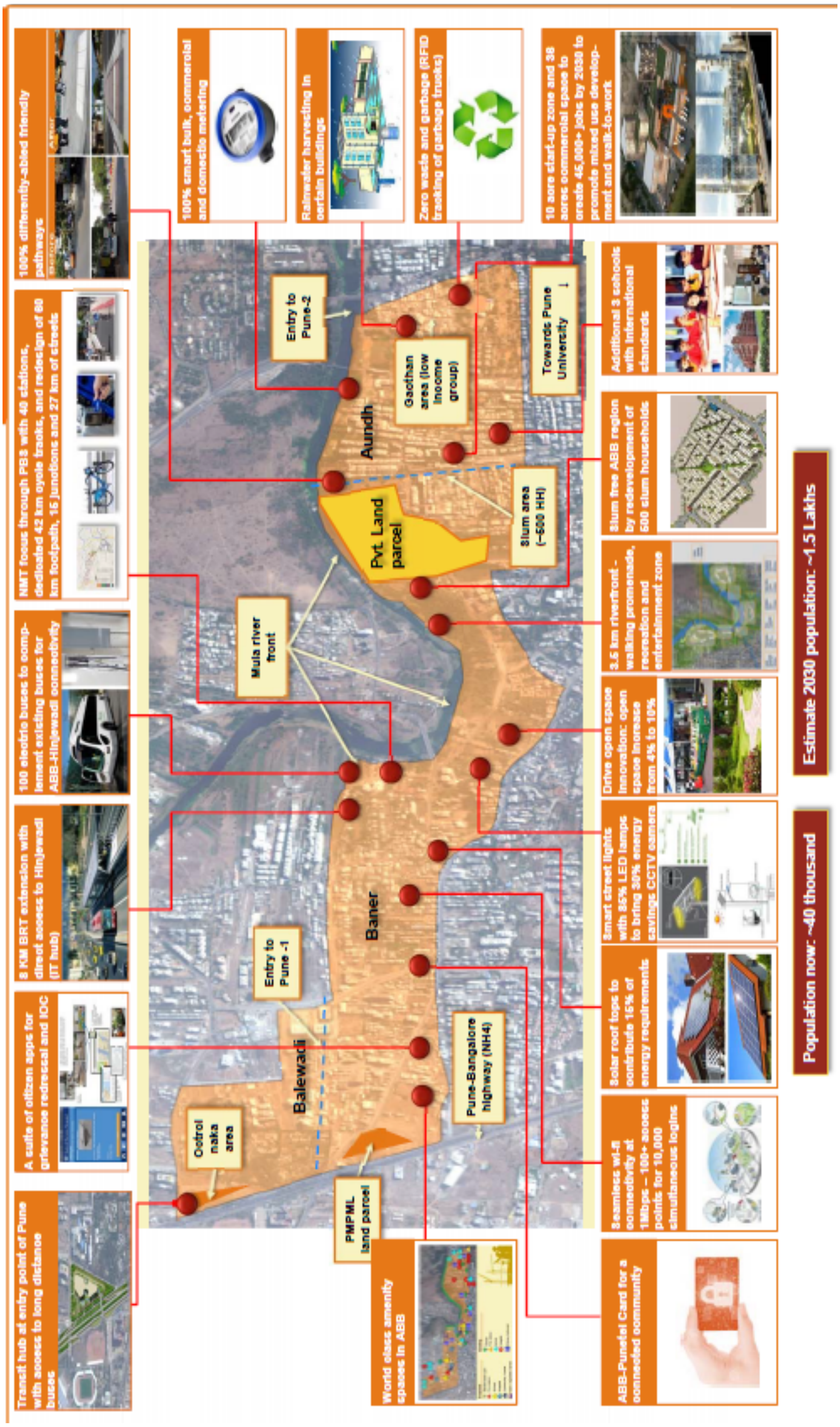
Pune has outlined smart solutions within a **Pan-city proposal** covering the whole city and also an **Area-based Development**[7] **proposal** covering an urban area called Aundh-Baner-Balewadi. The estimated cost of the Smart City Plan is INR 34.8 billion (522 million USD).

Under its **Pan-city proposal** which outlines smart solutions to be implemented across the city, Pune intends to address challenges in the priority areas of transportation and water and introduce smart technologies for these sectors. Full detail on these strategies is provided in Annex 14.1.

Under the **Area-based Development proposal** in its Smart City Plan, Pune aspires to create a model neighborhood having 'livability' and 'sustainability' that matches global standards. This will be achieved by fully deploying all 24 smart city features in a "future ready" manner in the selected local area of Aundh-Baner-Balewadi (MoHUA, 2015). The vision is to implement strategic initiatives to fully transform liveability across all dimensions in this pilot area and subsequently replicate these across the city (See Figure 8).

[7] 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.

Figure 8: Integrated Solutions Proposed for the Aundh-Baner-Balewadi Area



Source: (Pune Smart City Proposal , 2015)

The intent towards developing the Aundh-Baner-Balewadi area to be future ready stems from the area's expected four-fold population growth by 2030 (from 40,000 persons at present to 160,000 persons). Pune also aims to create 45,000 jobs in a mixed land-use zone which will include an incubation or a start-up hub spread over 10 acres (0.04 sq. km) and a commercial space spread over 36 acres (0.14 sq. km). In its effort to improve sustainability in the Aundh-Baner-Balewadi area, Pune aims to undertake the following smart energy interventions (Detailed Plan to transform Pune into a World Class Smart City, 2015)

- Implementing a smart grid for 100 percent coverage of power supply
- Installing solar roof tops to contribute to 15 percent of the energy requirements
- Strengthening the transmission and distribution system to reduce the power distribution losses by 30 percent under the Government of India's Integrated Power Development Scheme

Pune city has also started the process of establishing a Public-Private Partnership (PPP) project to ensure 24x7 electricity supply with significant improvements in energy efficiency in the Aundh-Baner-Balewadi pilot area. The project is estimated to cost about INR 800 Million (USD 12 million) (PPP projects in Smart Cities , 2017).

Section 11.5 provides a more detailed analysis of Aundh-Baner-Balewadi, including costs and benefits of district cooling against business-as-usual, as well as possible business model and policy options. The results of this assessment show that district cooling would be commercially viable in Aundh-Baner-Balewadi and could deliver significant environmental and economic benefits.

The Pune Smart City Development Corporation Ltd. (PSCDCL), a special purpose vehicle (SPV) headed by the serving municipal Commissioner of Pune, has been setup in early 2016 for implementation of Pune's Smart City plan. The total estimated cost of Pune's Smart City proposal is INR 29.32 billion (USD 439.8 million), of which INR 22 billion (USD 330 million) is for the area based development and INR 6.71 billion (USD 100.6 million) for the pan-city initiative respectively. The total capital expenditure and operational expenditure of the Pune's Smart City plan is estimated to be INR 23.70 billion (USD 355.5 Million) and INR 5.80 billion (USD 87 million) respectively.

As part of the Smart City Plan, the PSCDCL has launched the 'Pune-Maximum Solar City initiative' to promote and facilitate adoption of solar rooftop systems[8]. Under this initiative, Pune aspires to deliver 200 MW or more of rooftop solar capacity across the city by the year 2020 and become a 'Maximum Solar City', thereby contributing to India's goal of developing 100 GW of solar and 40 GW of rooftop solar capacity by the year 2022. Fifty rooftop solar projects have been launched in the city in mid-2016 under this initiative and 2,031 kW of rooftop solar capacity has been added as of February 2017 (Pune - Maximum Solar City, 2016) and (Pune Smart City Development Corportion Ltd., 2017)

[8] Under the Pune-Maximum Solar City initiative, the PSCDCL will undertake measures such as deployment of solar rooftop on PMC buildings, creating awareness amongst citizens about solar rooftop, and facilitating solar rooftop net metering arrangements in the city.

Box 1: Smart city recommendations

Pune's Pan-city proposal emphasises future-proofing of infrastructure, local jobs, the delivery of smart-energy solutions and improving 'liveability'. For many cities, district cooling delivers a solution to these, providing a smart, high-quality cooling service that is more insulated against future prices shocks in the electricity market and generates local income and jobs. With increasing affluence, cooling demand in Pune is expected to increase. This increase is demanded by consumers wanting a more 'liveable' city, but without planning prior to construction, the city could miss opportunities for efficient, innovative and cost-effective cooling solutions. Pune's Pan-city proposal could incorporate smart solutions to space cooling more explicitly, including district cooling and justify this inclusion against smart city objectives such as sustainable water consumption and future-proofed infrastructure.

Pune's Aundh-Baner-Balewadi presents an ideal opportunity to test district cooling in Pune and demonstrate innovative new policies and business models that will promote it. The emphasis Pune places on the replicability of Aundh-Baner-Balewadi to other parts of Pune and other cities is very important. Cities around the world that want to accelerate efficient cooling in their city typically select a zone with high potential and significant municipal control to demonstrate district cooling. Some cities explicitly have in their strategy and in their city targets to demonstrate district cooling in one particular area – recognising this as a strong first step, and announcing such an intention would send a strong signal to investors and building developers that Pune is serious about this technology.

The rapid real estate growth planned in Aundh-Baner-Balewadi will have significant cooling demand, and the emphasis on smart energy solutions for the area, particularly related to efficient and reliable delivery of power, further highlight the important role district cooling could play. District cooling can incorporate thermal storage and trigeneration to help balance power demand and can also centralise significant amounts of power demand, lowering the size of power connections needed for individual buildings (which no longer produce their own cooling), this balancing and centralisation of demand lowers required investment in power infrastructure in an area and makes delivering the smart grid concept easier and reducing distribution losses. Furthermore, the centralising of power demand, so that one district cooling operator purchases the power needed for cooling reduces power costs and enables easier contracting for direct supply of renewable power. For example, Pune could set up a single contract to supply solar power to the district cooling plant (using municipally owned solar power), resulting in a whole city-area benefiting from cooling powered by the sun.

As more information becomes available with regards to the detailed plans for redevelopment of this area, detailed costs and impacts of district cooling against the business-as-usual case can be examined. If possible, district cooling concepts should be incorporated into the design stage of the Area. The Smart City SPV (PSCDCL) could be supported to undertake such an analysis along with the power utility PPP to be established. The SPV could coordinate development of district cooling within the smart

city area, and promote its replication across each city. Furthermore, the SPV, the PPP looking at power supply and/or the city would all be natural direct investors into the district cooling project given the significant public benefits of the district cooling system. In particular, the PPP could justify investment in district cooling by the reduced investment costs in power infrastructure it would deliver. The city could also 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.)

Transport links planned in Aundh-Baner-Balewadi should be coordinated with district cooling rollout and the creation of new underground piping for sewage and power creates opportunities to lay district cooling systems at the same time, if the requisite cooling demand is available or coming up. This significantly lowers costs and disruption but relies on district cooling being analyzed before other utilities are laid. PSCDCL could lead such coordination in Aundh-Baner-Balewadi and the wider city, and this is examined in Section 11.5.

The PSCDCL could also promote district cooling explicitly, just like the Solar City Initiative, through a targeted Initiative on the technology designed to raise awareness to building developers and other stakeholders and help catalyse projects. A dedicated team within PSCDCL could receive international training on district cooling and work to establish district cooling under Pune's Smart City Plan.

Given its close proximity to the PMC, PSCDCL could lead stakeholder coordination on district cooling in Aundh-Baner-Balewadi and Pune more generally – bringing together the necessary stakeholders to identify and promote projects, coordinate earthworks and area-redevelopment to minimise district cooling costs, ensure inter-department coordination in the PMC to remove barriers to district cooling and develop new policy. Such stakeholder coordination will be vital to achieving the potential of district cooling in the city.

5.2. Pune's Solar City Master Plan

In 2016, Pune was selected as a 'Solar City' under the 'Solar Cities Programme' of the Ministry of New and Renewable Energy (MNRE) (The Indian Express, 2016). The PMC has recently initiated work to develop a comprehensive Solar City Master Plan under this national programme[9]. The plan will target a minimum of 10 per cent reduction in fossil energy demand in each city through a combination of renewable energy and energy efficiency measures to be implemented across the residential, commercial and institutional, industrial and municipal sectors.

[9] The Solar Cities Programme initiated by the MNRE in 2008, aims to empower local governments in India to address energy challenges in urban areas by providing support to ULBs for the preparation and implementation of a detailed Master Plan to promote and implement renewable energy and energy efficiency applications.

Development of the Solar City Master Plan for Pune will be undertaken in collaboration with all the major stakeholders in the city. This will require an integrated urban planning approach, which simultaneously involves reducing the reliance on fossil fuel through the application of energy conservation and efficiency measures and by complementing the conventional energy generation with the renewable energy. The Solar City Master Plan will help the city in taking targeted action and contribute to Pune's goals outlined under the 'Pune- Maximum Solar City initiative'.

Box 2: Solar City Program Analysis

The Solar Cities Programme'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 upcoming 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. The design 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, would be to calculate the beneficial impact of district cooling on energy consumption and identify the benefits and linkages to Pune's policy goals (e.g. Pan-City goals from the Smart City Mission such as sustainable water consumption; meeting 10% energy consumption reduction target; implementing smart grid; and facilitating renewable energy targets under the Pune-Maximum Solar City initiative).

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 Pune 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 11.2 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 Pune are being offset by installation of low efficiency space cooling elsewhere in the city.

5.3. Pune's Voluntary Initiatives

Pune has always been regarded, as far as sustainable initiatives are concerned, as a pro-active and forward-looking city. The PMC has been documenting and publishing an annual Environmental Status Report for the last 15 years, making it one of the few local governments to do so in the country. The PMC has undertaken a number of actions on its own accord to adopt renewable energy and energy efficiency measures in its own buildings and facilities. This includes installation of solar water heating systems (SWHS), solar photovoltaic (PV) systems, and energy efficient appliances in its hospitals, crematoriums, and administrative buildings. The PMC has also retrofitted its street lighting with LED lamps and setup bio-methanation plants to treat bio-degradable municipal waste (WWF - India, 2016).

The PMC has installed a solar PV system of 12 kW capacity on its main administrative building in the year 2012-13. This system generates about 100 kWh of power every day and is used for operation of pump sets. SWHS having a cumulative capacity of 33,500 litres per day (LPD) have been installed by the PMC at its various buildings. About 1,317 streetlights are being operated through power generated at 17 biogas plants installed across city. The plants generated about 528,805 kWh during the period from October 2015 to September 2016. A 5 metric tonne capacity biogas plant installed at the Yerwada Jail supplies biogas to its kitchen for cooking purposes.

In the year 2012, Pune has voluntarily accounted its baseline GHG emissions. As per the assessment, Pune city's total GHG emission amounted to about 4.7 million tonne of carbon-dioxide equivalent (tCO_2e) in the year 2010-11, with per capita emission of 1.46 tCO_2e (The Energy and Resources Institute, 2012). Electricity consumption by high tension consumers, which mainly includes large scale commercial, industrial, and residential buildings along with public service facilities, is the largest source of GHG emission from electricity use in the city.

Increasing public awareness on renewable energy and energy efficiency also ranks high on the PMC's agenda. An Energy Park has been established at Peshave Park in coordination with the Maharashtra Energy Development Agency and another is proposed at the Ram Tekadi hill in Hadapsar. The PMC has also been participating in the World Wide Fund's (WWF's) Earth Hour City Challenge[10] to showcase its action towards addressing sustainability locally and to inspire cities across the globe. The PMC has prioritized tapping of solar energy and intends to further setup rooftop solar power systems in its own buildings and facilities, to be financed through the PMC as well as the private sector (see sections 5.5.4 and 5.5.5 for more details).

[10] The Earth Hour City Challenge is a year-long competition among cities where participants are evaluated by an international jury of experts based on their performance, commitments and initiatives towards climate change.

Box 3: City leadership

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

If the demonstration project were to be partially owned by PMC (or the smart-city SPV or smart grid PPP) then it could later be privatized once commercial viability is proven, creating a profit for Pune. 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, Pune 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).

Pune 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, Pune 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 Pune. This could be undertaken by the SPV established to deliver the Smart City Plan - PSCDCL. The unit would present the potential cost savings, environmental benefits and any local incentives available; and provide locally-relevant information to potential district cooling customers or developers to encourage connection and development of networks. This could include making available best practice assessment methodologies, tools to rapidly analyse cooling costs, sample contracts, previous feasibility studies and demonstration project results – including PMC's experiences and savings from connecting to district cooling[11]. Also important are formal and informal networks and contacts between, for example, municipal employees or officials and state utilities, building developers and housing associations.

Pune 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

[11] The District Energy in Cities Initiative will support a pilot city and with the pilot city ground-test methodologies, tools, procurement processes etc. adapted to the Indian context and later promote these to other cities.

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 PSCDCL and incorporated with the 'sustainable energy delivery unit'.

Pune can promote district cooling development and ensure strong analysis of district cooling opportunities by undertaking and maintaining a GIS energy mapping[12] of the city incorporating spatial analysis of cooling demand, upcoming building developments (for example those shown in Section 10.1) and assessments of renewable and waste heat options (see Section 10.2). This could also be used as a public awareness tool to help the city explain planned actions on district cooling and can help identify potential district cooling projects, renewable interconnection, opportunity zones for district cooling and as such can be used to develop long-term city plans on district cooling. Finally, such a tool could also be used to help Pune undertake other spatial analysis related to the energy sector, such as delivering smart grid, resource mapping and targeted building efficiency programmes. Box 10 describes further how such a mapping could be developed.

[12] The District Energy in Cities Initiative will support one pilot city to establish a GIS based energy map which will be maintained, owned and updated periodically by the pilot city. The software will be open source and the methodologies and training associated made available to all cities.

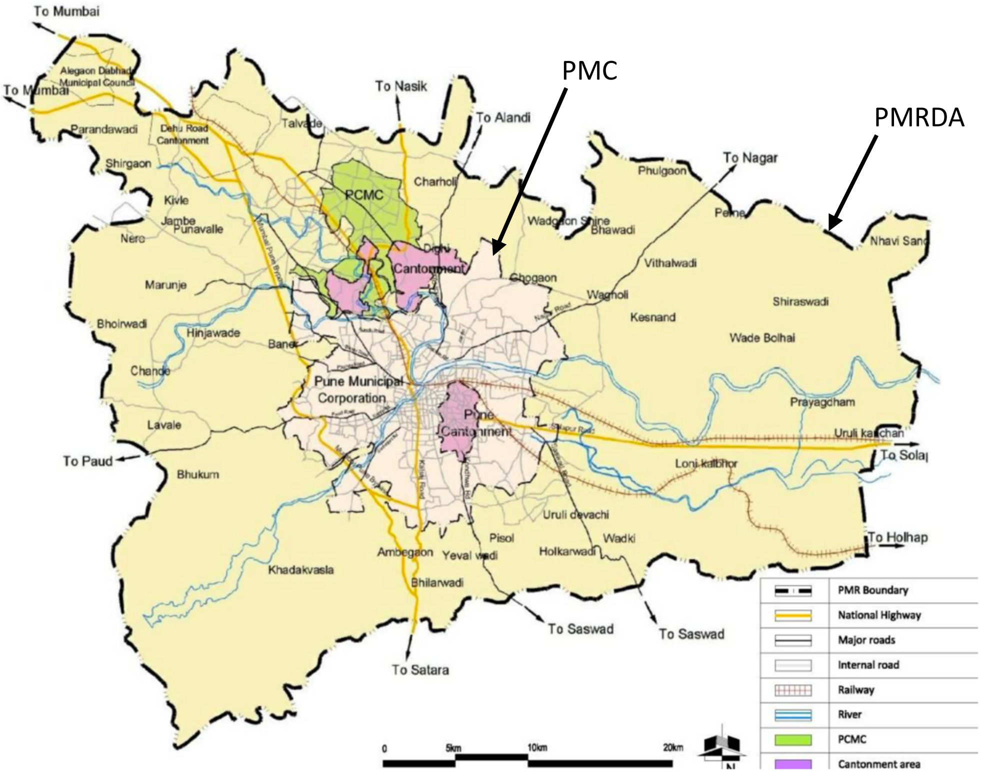
6. Local Policies and Legal Framework

6.1.Planning Authority and Framework

PMC is responsible for preparing the city's Development Plan - a strategic plan that steers planning, land use zoning and infrastructure development in Pune city. Pune city's administrative boundaries were expanded in 2001 to include 23 neighbouring villages (in parts). This increased the city area from 138.38 sq. km to 243.84 sq.km (Pune Municipal Corporation, 2007). The Development Plan for the former city area has been published in the year 2012 and was prepared for a horizon of 20 years (2007-2027), in line with the Maharashtra Regional and Town Planning (MR&TP) Act, 1966.

An additional Development Plan, exclusively addressing the fringe areas that have been added to the city, has been prepared and submitted to the Maharashtra State government for approval as of March 2017. Figure 9 shows the boundary of the PMC and the boundary of Pune's Metropolitan Region, which is the administrative boundary of PMRDA.

Figure 9: Map showing the jurisdiction boundary of PMC and PMRDA



Source: (Pune Municipal Corporation, 2012)

The Development Plan outlines the proposed land use zoning along with activities permitted in the defined zones in order to regulate and guide development of all sectors over a period of 20 years. The Plans also broadly prescribes the planning norms and development controls which have been made in compliance with the various plans and policies applicable in Pune

City. In the Development Plan, the former city area, is divided into six sections (called 'sectors'), each having a specific plan in consideration of the population distribution and projections, density, social and physical amenities required and their spatial distribution.

Building development in the city with regards to development densities, floor area ratios and built-up area, and other related norms and guidelines applicable for the proposed land use zoning and classification is regulated by the Development Control and Promotion Regulations (DCPR) for Pune Municipal Corporation, 2017. The DCPR is described in more detail in Section 6.2 and Table 29.

The existing land use distribution indicates that about 42 percent of Pune city's land area is covered with residential developments (see Table 3). About 12 percent of the city's total land area falls under the reserved, forest, and agricultural category, with the share being particularly high in the fringe areas. Public and semi-public uses such as utilities and services, government offices, and educational institutes occupy a significant share of the city's area at 7.4%.

Table 3: Existing Land Use for Former City Limits and Newly added Areas in Pune City

Land Use Category	Area in sq. km (2001)			Share of Total area (%)
	Former City Limits	Newly added Fringe Areas	Total Area	
Residential	50.5	53.2	103.7	42.5
Commercial	2.3	1.6	3.9	1.6
Industrial	7.2	2.6	9.9	4.1
Public and Semi Public[13]	15.2	1.4	16.7	6.8
Public Utilities[14]	1.3	0.0	1.4	0.6
Transport	22	9.8	31.8	13.0
Reserved, Forest and Agriculture	2.3	26.7	29.1	11.9
Water Bodies	12	2.5	14.5	6.0
Hills and Hill Slopes	12.4	0.0	12.5	5.1
Recreational[15]	12.7	7.8	20.4	8.4

Source: (Pune Municipal Corporation, 2011)

The land use zoning proposed in 2007 for the former city limits, envisaged to accommodate a projected population of 3.3 million persons in the year 2027, is shown in Table 4 Envisaging the future demand for housing, close to a third of the former city limits is earmarked for residential land use. A significant area continues to be reserved for public and semi-public

[13] 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

[14] Public utilities includes area for (a) power receiving station/substation, (b) water supply system, (c) sewerage and garbage disposal system, (d) police station, (e) Public parking, (f) cemetery / cremation ground, (g) bus station, fire brigade station and other public utilities as per requirements

[15] Recreational land use refers to a statutory common open space allocated in the planning of any layout or group housing scheme or any campuses, exclusive of margins and approaches.

uses. The share of land area proposed under industrial and commercial uses in the core city or former city limits is relatively lower. This is possibly due to industrial and commercial developments being expected to be concentrated around the city's suburban areas, outside the former city limits, in the coming years, in line with the peripheral growth that the city has witnessed.

Table 4: Proposed Land Use for the Former City Limits of Pune City

Land Use Category	Area in Former City Limits (sq. km) (2027)	Share of Total area (%)
Residential	47.4	32.1
Commercial	1.9	1.3
Industrial	2.8	1.9
Public and Semi Public	19.5	13.2
Defence	16.4	11.1
Transport	20.2	13.7
Forest and Agriculture	4.9	3.2
Water Bodies	7.0	4.7
Hills and Hill Slopes	8.4	5.71
Recreational	10.2	6.9
Others	9.0	6.1

Source: (Pune Municipal Corporation, 2007)

Note: *Proposed land use is available for the former city limits for the year 2027. The Development Plan and proposed land use for the new areas (addition of 23 villages in 2001) is to be finalized at present.*

The Development Plan of the former city area includes special provisions for the Pune metro rail project, a transport hub and expansion of main roads. Dense and compact development has been proposed in the transit oriented zone along the city's planned metro and bus rapid transit system (BRTS). Redevelopment of existing properties aged 30 years and above is planned.

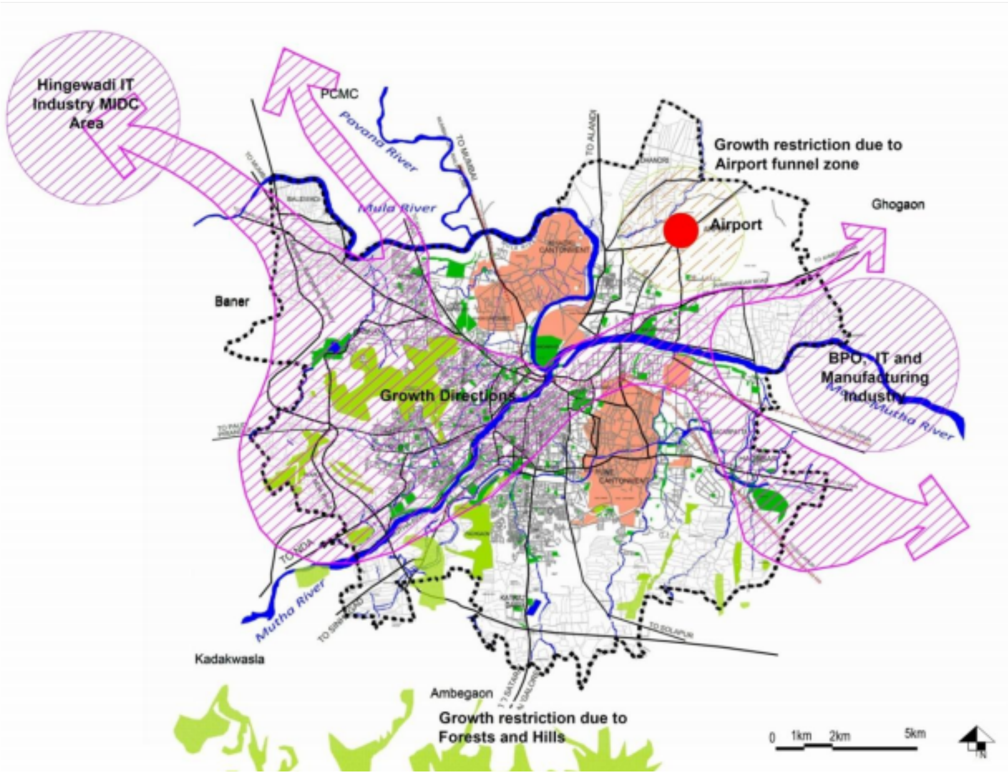
Over the years, Pune's spatial growth has taken place in the pattern of concentric rings. In the recent decades, the city's peripheral growth has been primarily driven by the development of IT industry and the growth in the automobile sector which forms a major portion of the industries in Pune and the surrounding Pune Metropolitan Region (PMR). The core city centre is a high-density zone wherein majority of the land use is being utilized for residential properties and commercial activities. The city centre is congested with its narrow roads and lack of open spaces. The core area is unable to accommodate the growing population and the increased demand for housing, commercial spaces, transportation network and facilities. As a result, such developments have sprung up in the adjoining suburbs and the city has expanded outwards. While urban sprawl has taken place in all directions, Pune's key growth corridors lie towards the north-west, east and south-east directions, triggered mainly by the IT industry in Hinjewadi, the automobile industry in Pimpri

Chinchwad, and the business process outsourcing (BPO), IT and manufacturing industry in Hadapsar respectively (see

Figure 10). Areas located in and around these growth corridors are witnessing significant mixed-use development comprising of residential, commercial and industrial uses[16].

Growth towards the southern side is constrained by the existing hilly terrain in this direction. There is restriction of growth in the north-east due to the presence of the airport. Pimpri Chinchwad, a neighbouring twin city governed by the Pimpri Chinchwad Municipal Corporation, lies adjacent to Pune towards the north and north-east direction. Thereby, some of the corresponding areas located towards the north-eastern direction of Pune and undergoing rapid development fall under the jurisdiction of the Pimpri Chinchwad Municipal Corporation.

Figure 10: Pune City Growth Corridors



Source: (Comprehensive Mobility Plan for Pune City, 2008)

A study conducted to forecast Pune metropolitan area's urban growth for the year 2030 also indicates a higher probability of Pune's expansion occurring towards the North and East direction as compared to the other directions (Lakshmi Kanta Kumar N; Nikhil G Sawant; Shamita Kumar, 2011). The study also indicates that rural areas located in the Urli Kanchan, Wagoli, Rahu, and Talegaon Dhamdhere revenue areas lying to the east of Pune city are key potential growth pockets for Pune's urban development in the future. This is owing to the presence of major transport corridors such as the Pune- Ahmednagar State Highway (SH-

[16] Pune Municipal Corporation (2008): Comprehensive Mobility Plan for Pune City

27) and the Pune-Hyderabad National Highway (NH-9) in and around these areas and due to the greater availability of flat ground as compared to the western and southern parts of Pune.

Section 10.1 details specific growth corridors, townships and developments that are to be developing the coming years, as identified in planning documents and by the city, and how they present an opportunity for district cooling.

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

The new townships, growth pockets, IT-hubs and urban redevelopments could provide strong catalysts for new district cooling systems in Pune. Depending on whether developments fall under the planning authority of PMC or PMRDA, authorities can encourage building developers to assess and develop district cooling.

PMC and PMRDA use zoning to influence development in the city by defining different land uses in different zones. Through zoning, PMC and PMRDA 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.

PMC 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, PMC could make space available where energy centres could be placed in public buildings or otherwise.

PMC 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). Upcoming townships or IT parks would be examples of 'high priority zones' given these are mixed-use developments with high cooling demand. The city could then attach specific conditions to building permits within these zones. PMC 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, PMC 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 PMC and international experts. In particular, ensuring high-quality of assessments given the lack of district cooling experience in India will be important[17].

Similarly, requests for re-zoning by building developers above a certain size could provide an opportunity for Pune to accelerate district cooling. PMC could permit re-zoning under the condition that the developer meets stricter operational/primary efficiency building standards[18] and/or evaluates the potential for district cooling and if techno-economically feasible, then establishes district cooling systems.

PMC can use the planning process to put in place specific connection policies (of different buildings types) in the high priority areas. Furthermore, PMC 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, PMC 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 system is more likely to be established in the longer-term once district cooling has been demonstrated.

In Pune, urban redevelopment is planned in existing urban areas, such as the highly dense core city centre which will see an increase in density as population increases and old buildings are redeveloped. Urban redevelopment projects often have significant influence from local authorities, such as Pune's Aundh-Baner-Balewadi smart city area (see Section 5.1), with huge levels of redevelopment and application of higher sustainability standards on buildings these projects 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, PMC 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 PMC to step-in and work with developers to ensure district cooling is appropriately assessed.

[17] 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.

[18] 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.

Finally, as a provider of utility services such as water and sanitation, PMC has the authority over the installation of new utility lines such as district cooling pipes. The development of the transit orientated zone in Pune, with metro rail, road expansion and BRTS, provide ideal catalysts for district cooling network development which can be installed at the same time as new transport infrastructure, dramatically lowering costs.

6.2. Building Regulations & Certifications

The planning department of the PMC is responsible for preparation of required plans, guidelines and regulations in order to steer and regulate the city's development. Development in the city takes place in accordance with the proposed land use zoning, norms, and regulations outlined in the Development Plans and the Development Control and Promotion Regulations for Pune Municipal Corporation (DCPR), 2017, both prepared by the PMC. The DCPR, 2017 guides building construction and development activities in Pune city including

- Site requirements, which are supposed to be in compliance with the development plan and in harmony with the natural features
- Regulations on location with respect to the main road and street access
- Regulations on division and sub-division of plots, regulations on the open area, Floor Space Index (FSI) and built-up area for all building types
- Details on land use classification and permitted uses
- Details on structural requirements, utility services, safety requirements, etc.

Under the DCPR, the permissible basic floor space index (FSI), permissible Transferable Development Rights[19] (TDR) loading, and additional FSI[20] availed on payment of premium varies based on the width of the adjoining road where the building development is located (see Table 28). The base FSI permissible for buildings located on roads having width below 9 m is 1.5. For buildings located on roads having width above 9 m, the permissible FSI is 2.0. An additional FSI of 0.25 can be purchased by paying an applicable premium charge for locations where road width exceeds 12 m. Further, using the TDR mechanism a maximum FSI of up to 3.0 can be availed at locations near major roads in the city, thereby promoting dense development.

The DCPR, 2017 encourages densification in the city by allowing a FSI of 4 for buildings to be constructed along transit-oriented development (TOD) zones, including mass transit such as the metro rail and the BRTS. To promote large IT related developments, an additional FSI of up to 200 percent over and above the basic permissible FSI is granted to all registered public and private IT/ITES parks. The additional FSI will be granted by charging a premium

[19] 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.

[20] Additional FSI can be availed by the developer by paying a certain charge depending on the zone.

of 30 percent of the prescribed land rate (Information & Technology & Information Technology Enabled Services (IT/ITES) Policy, 2015).

Box 5: Incentivizing district cooling through density bonuses

Pune 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 (e.g. through building certification schemes such as Eco-housing certificates, GRIHA or LEED). Several cities around the world are actively promoting district energy using this urban planning tool. Pune already provide FSI bonuses linked to sustainability criteria and district cooling could be an extension to this (see below).

Solar water heating

To promote uptake of solar energy across the city, installation of solar water heating systems (SWHS) or rooftop solar photovoltaic (PV) systems has been made mandatory for all types of buildings to be constructed on plot area more than 4,000 sqm. Provisions for SWHS or solar PV systems have to be shown in building plans in order to obtain planning approvals for new buildings.

National building certification

The PMC has adopted the **Green Rating for Integrated Habitat Assessment** (GRIHA)[21], a national green rating system to promote sustainable building construction in the city. The GRIHA rating system consists of 34 criteria addressing various green building concepts, including energy efficiency and efficient space cooling. While statistics on the uptake of the GRIHA system in Pune city are not available, the PMC is taking efforts to boost its adoption. As per the DCPR 2017, the PMC is offering FSI based incentives of 3 to 7 percent on the basic FSI for new building development projects that receive GRIHA certification (see Section 6.4). The incentive offered is based on the star rating that is awarded to the building under the GRIHA guidelines. Furthermore, it is mandatory that all upcoming public-sector buildings should have GRIHA certification[22]. GRIHA may not effectively account for the benefits of

[21] GRIHA is a rating tool that helps people assesses the performance of their building against certain nationally acceptable benchmarks. It evaluates the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'. It was adopted as the national rating system for green buildings by the Government of India in 2007

[22] The DCPR, 2017 mandates that all new buildings belonging to government, semi- government, local bodies, and public sector undertakings should have a certification of GRIHA 3-star rating or Indian Green Building Council (IGBC) Silver rating or an equivalent rating at a minimum.

buildings connecting to district cooling, if this is the case, Pune could ensure that FSI incentives linked to GRIHA are also made available to district cooling connected buildings.

Box 6: District cooling ready buildings[23]

Pune could adapt the DCPR 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 and GRIHA mandates and could be initially applied to public buildings (as is done for GRIHA certification). 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 Pune and applied to multiple building types. In this way, even if buildings operate their own chillers, eventually they could be connected into a district cooling system. In some cities, buildings that already have their own chillers can still be connected into the district cooling network – the network operator can use their chiller to feed the building and the wider district cooling network – a more efficient and cost-effective use of the chiller. Building developers could also be given flexibility under the DCR if they develop district cooling.

Pune already uses zoning to apply specific planning conditions, primarily conditions surrounding land-use. Mandates for connection to district cooling systems in high priority zones (or development of district cooling), could be exercised through adaptation of the DCPR. 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.

City-level green building policy

The PMC is actively implementing voluntary policy initiatives to promote green buildings. The DCPR, 2017 includes provisions related to the **Eco-housing Policy**[24] which has been adopted by the PMC in April 2005 in order to promote sustainability and energy efficiency in buildings. (Times of India, 2009) The PMC's **Eco-housing Cell** is also undertaking eco-housing demonstration projects to promote uptake further. Buildings with Eco-housing certification receive rebates from the PMC on floor premium charges (for detail see section 6.4). Furthermore, such buildings are more attractive to potential owners and/or tenants and may reach a higher market price.

The assessment criteria for Eco-housing certification include 88 measures in total (voluntary and mandatory) spanning eight focus areas: site planning , environment architecture,

[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.

[24] The Eco-housing Policy has been adopted by PMC to promote the adoption of environmentally friendly practices, energy efficient products and appliances, and green construction techniques in buildings with support of United States Agency for International Development (USAID), the Science and Technology park (Scitech Park) and the International Institute for Energy Conservation (IIEC).

efficient building materials, water conservation, energy-efficient lighting, solar water heating, waste segregation, and other innovative eco-friendly technologies[25]. The key Eco-housing provisions that promote adoption of renewable energy and energy efficiency include:

- All electrical systems to meet minimum efficiency criteria as specified by Energy Conservation Building Code 2006 (use of high efficiency pumps, motors, transformers etc.)
- Renewable energy technologies such as solar and wind should be installed

Table 5: Eco-housing Projects and Certification Status

Particulars	Status
Total built up area in sqm under eco-housing certification	14.59 million sq. ft.
Completed projects	3
Projects awarded provisional certificate	45
Projects yet to get provisional certificate	15

Source: (Science and Technology Park, University of Pune, Pune, 2017)

An analysis of Pune's Eco-housing Policy could be undertaken to ensure that district cooling connected buildings do not lose out on meeting the certification and system-wide benefits of district cooling systems are accounted for, including: improved energy efficiency, incorporation of renewables, reduced water consumption, wastewater reuse and refrigerant reduction.

6.3.Legislation relating to Space Cooling

Pune's DCPR, 2017 includes provisions that address the structural aspects and placement of air conditioning installations. The DCPR does not adequately include requisite legislation or guidelines to promote efficient space cooling.

The Eco-housing policy does address energy efficiency in heating, ventilation and air conditioning (HVAC); however, this is limited to encouraging the use of BEE 4 star rated energy efficient HVAC systems.

The GRIHA rating system through its criterion no. 14 focuses on minimizing the energy performance index (EPI) of buildings, a parameter that efficient space cooling systems can have significant impact on. It should also be noted that this criterion carries the highest number of points – 16 points out of 100 points in total - as compared to other criteria in the GRIHA, and thereby significantly impacts the GRIHA rating score awarded to buildings. The corresponding clauses and points awarded under criterion 14 are as follows:

Criterion 14– 'Optimize energy performance of building within specified comfort limits'

- **Mandatory clause**

[25] The Eco-housing scheme incorporates a 1000-point system which incorporates 88 measures and every measure is assigned 'points' depending on its impact on environment, and its relevance to local conditions. A minimum of 500 points is required to qualify for Eco housing certification. Eco-housing certification will be based on document submissions and site visits by a validating team. Based on the total points achieved as a result of measures implemented with due compliance, the building is awarded a corresponding rating and receives the Eco-housing certificate. The rebate that can be availed depends on the rating that the building receives.

- Compliance with the ECBC, 2007 (6 points)
- Compliance with thermal comfort condition as per the National Building Code, 2005 and minimum benchmark index as per GRIHA (2 points)

- **Non-mandatory/optional clause**
  - Every 10% reduction in EPI in the building under a specified category shall fetch additional 2 points, going up to a maximum of 8 points awarded for a 40 percent reduction in the EPI (2–8 points)

Over the years, Pune city has leveraged its local policy regulation and is utilizing mechanisms such as the GRIHA and Eco-housing schemes for promoting sustainable design and construction practices, energy efficiency and renewable energy in buildings. By mandating GRIHA for public buildings and providing GRIHA-linked FSI bonuses (see Section 6.2) Pune does have indirect legislation aiming to improve space cooling. Given this fact, and based on discussions with the stakeholders and city government officials, it would be appropriate to say that Pune city is willing to engage with all concerned partners including international institutions and technical experts to explore incorporation of legislation related to space cooling, including promotion of technologies such as district cooling.

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. 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 Pune at present.

Box 7: Ensuring the ECBC promotes district cooling growth

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

The adoption of new guidelines provides an opportunity for Pune to ensure that efficiency improvements to buildings that connect to district cooling are acknowledged in its local building regulations. Pune 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, Pune could ensure that any benefits and incentives linked to the

ECBC are also made available to a district cooling demonstration project. Such incentives and benefits have not yet been defined, but some other states in India that have notified ECBC have developed rating systems and incentive schemes based on compliance with the standards within ECBC (e.g. the State of Andhra Pradesh) (Pacific Northwest National Laboratory, 2016)**.**

6.4.Incentives and Subsidies

As indicated in section 6.2, the PMC offers incentives to buildings that comply to the Eco-housing norms. Depending on the rating that the building development project receives, a concession of 10 to 50 percent on the total premium charges payable to the PMC is offered. As much as 25 percent of the applicable rebate will be given while the building proposal is approved and the rest can be claimed after the project is completed and certified (Pune Mirror, 2015).

To further promote green buildings, the PMC offers FSI based incentives (density bonus) of 3% to 7%for GRIHA certified green buildings (see Table 6). The Bank of Maharashtra, a leading nationalized bank in India, has also announced a rebate of 0.25 percent in the interest rate on housing loans for Eco-housing projects (International Institute for Energy Conservation (IIEC, n.d.). Furthermore, the PMC also offers a discount of 5 to 10 percent in municipal taxes (excluding water tax and government taxes) for residential properties adopting solar energy based systems and rain water harvesting.

Table 6: FSI based Incentives offered by the PMC for Green Buildings

Green Building Rating received	Applicable FSI incentive
GRIHA 3-Star/ IGBC Silver or Equivalent rating	3% additional FSI on basic FSI
GRIHA 4-Star/ IGBC Gold or Equivalent rating	5% additional FSI on basic FSI
GRIHA 5-Star/ IGBC Platinum or Equivalent rating	7% additional FSI on basic FSI

Source: (Development Control and Promotion Regulation for Pune Municipal Corporation , 2017)

These actions amply demonstrate that the PMC is committed towards promoting sustainable practices and technologies in buildings and is willing to use enabling policy regulation and incentives to help accelerate adoption of the same. The PMC's efforts in this regard have helped to generate awareness and build momentum over time, as seen in the adoption of Eco-housing certificate (see Table 5 for more details). PMC can build upon existing incentives and support programmes, such as FSI incentives and municipal taxes to promote district cooling in the city.

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 11.8. 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.

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.

Pune could use its on-going 'Pune-Maximum Solar City initiative' to support district cooling. By selling municipally owned solar power directly to a district cooling project, PMC could 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, city-owned waste-to-energy (WTE) plants 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 a WTE plant.

6.5. Demonstration Projects

A number of renewable energy and energy efficiency initiatives have been undertaken by the PMC in recent years. In due recognition of its local action to address energy consumption, the PMC has received the Energy Conservation award from the Ministry of Power, Government of India in 2008-09. Some of the key actions undertaken by the PMC include:

- Use of energy efficient feeder panels for street lighting has helped realize energy saving of 25 percent
- Installation of automated timers for all streetlights has led to energy saving of 10 percent
- Around 5,500 SWHS have been installed in PMC buildings and facilities such as hospitals and crematoriums
- Use of energy efficient star rated electrical appliances in the PMC buildings, hospitals and crematoriums
- PMC has installed soft starters/variable frequency drives resulting in energy saving of 10 percent
- A 12 kW solar PV system, consisting of 48 solar panels of 250 W each, has been installed at the PMC's main administrative building
- A dedicated 'Energy Saving Cell' has been established in the PMC in 2014

- The PMC has taken steps to start energy audit of all its buildings from hospitals, schools, gardens in the city
- About 50,000 LED street lighting fixtures have been retrofitted at a cost of about INR 500 million (USD 7.5 million). Retrofits for an additional 70,000 LED streetlights to reduce energy consumption by 40% through a shared savings based PPP project are underway

To promote adoption of solar rooftop projects under the 'Pune-Maximum Solar City initiative', awareness generation meetings have been conducted in the smart city pilot area of Aundh-Baner- Balewadi. The PSCDCL, the nodal agency responsible for implementing Pune's Smart City Plan, is partnering with government agencies such as the MSEDCL and the Maharashtra Energy Development Agency as well as renowned think tanks such as the Pune International Centre and Prayas Energy Group for implementation of this initiative. The PSCDL will assume the role of a facilitator to promote solar rooftop net metering arrangements in the city. As indicated earlier, 50 roof top solar projects have been launched in mid-2016 under the 'Pune-Maximum Solar City initiative'.

Box 8: Pune as a demonstrator

PMC'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 PMC and its experience in coordinating relatively large sustainability programmes. Building on this leadership, PMC can develop a demonstration project on district cooling as well as establish a 'sustainable energy delivery unit' (or incorporate it into existing untis such as the smart city SPV or the Energy-Saving Cell) as described above in Box 3, both of which are a best practice for scaling DES.

6.6.Project Financing

Leveraging finance from different funding sources forms a key underlying strategy of Pune's Smart City vision. Pune's Smart City proposal evidently intends to utilize the funding opportunities available under different programmes and schemes of the Government of India such as the Swachh Bharat Mission, Integrated Power Development Scheme (IPDS), Indian Smart Grid Mission, Digital India Mission, Atal Innovation Mission, Housing for All, and the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) to meet the city's goals. The activities proposed under Pune's Smart City plan have been aligned considering the timeline and resource availability of the aforementioned schemes in order to realize maximum benefits in the stipulated time frame.

The PMC has demonstrated leadership by utilizing its own funds to implement a number of renewable energy and energy efficiency interventions. The PMC strongly believes in working with a range of partners including government agencies such as the Maharashtra Energy

Development Agency, international and national technical institutions and think tanks, and the private sector to effectively leverage finance as well as technical expertise. The PMC has been piloting initiatives along with these partners and subsequently scaling these up by mobilizing different sources of funding in planned manner. For instance, energy efficient luminaires and day light sensors were previously installed on a pilot basis for 500 existing street lighting poles in the city, with technical support provided by The Energy and Resources Institute (TERI) and financial support from the WISIONS initiative[26]. The PMC has subsequently spent about INR 500 million (USD 7.5 million) to replace 50,000 of its conventional street lights with LED luminaires in a phased manner since the year 2011. In 2014, the PMC has installed solar streetlights in slums. The PMC had allocated a budget of INR 10 Million (USD 150,000) for installation of 160 streetlights, each for INR 62,000 (USD 930) for this activity. Based on experiences and successful demonstration of these pilots, the PMC is now going for large scale LED street lighting retrofits. Replacement of 70,000 conventional streetlights with LED lamps through a shared savings based PPP project is currently underway in the city as of March, 2017.

The PMC, in association with Solar Energy Corporation of India (SECI), has planned to install roof top solar PV systems of cumulative capacity of 1 MW across 19 of its buildings. This project will be implemented with a private agency under the Renewable Energy Service Company (RESCO) model and therefore the PMC will not bear any upfront capital expenditure for these solar PV systems. A long –term power purchase agreement will be signed between the private agency and the PMC at a mutually agreed tariff. The PMC also intends to invest its own funds to install about 825 kWp of net-metering based roof top solar PV systems across all the major municipal buildings in Pune (Electrical Department, Pune Municipal Corporation, 2016). It is evident that the PMC is willing to collaborate with a variety of partners and to explore different financing mechanisms and business models for implementation of clean and efficient technological solutions in the city.

Box 9: Financing district cooling

PMC 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 PMC and other stakeholders including local financiers to be able to deliver and finance a district cooling project. Analysis of how PMC and other Indian cities have handled similarly large

[26] "WISIONS of sustainability" is an initiative by the Wuppertal Institute supported by the Swiss-based foundation ProEvolution. The WISIONS initiative has been actively promoting the introduction of sustainable energy solutions and resource efficiency since it was launched in 2004.

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[27].

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

- PMC 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). The model of PMC's participation in a PPP to deliver smart grid in the Smart City area could be built upon but needs to be further analysed - there are specific benefits of incorporating electricity utilities into district cooling models as described below. PMC 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

[27] 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.

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 both in development, operation, financing and legal contracting. 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 Pune 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 Pune

- **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 city 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.
- **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.

- **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.
- **Difficulty in retrofitting existing building developments:** Most of the core city area in Pune, having a highly dense and mixed-use settlement, is already developed. 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. Thus, retrofitting existing development with district cooling systems is a challenging prospect. 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.
- **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.
- **Rate of development:** The fast pace of the real-estate sector 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.
- **High cost of** land in Pune: Land cost in the city is very high, about INR 5,000/sq. ft. (75 USD/sq. ft.) and can go up to INR 8,000 /sq. ft. (120 USD/sq. ft.). While this may increase CAPEX costs for district cooling plants, it can also incentivise building density and encourage developers to look for ways to maximise their land-use – such as by saving floorspace by eliminating chillers and cooling towers and connecting to district cooling.
- **Water availability:** Water availability in the city is highly dependent on the monsoon. In such a scenario where there is water shortage and a large number of users, non-availability of water throughout the year would pose a challenge for implementing water based district cooling system. The cost of water is quite high in Pune. INR 700 (10 USD) to INR 800 (12 USD) is charged per cubic meter of water along with a substantial connection fee. Besides this, the district cooling service provider will also have to bear the cost of construction or any civil work for getting the water connection

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

Barrier	Type of barrier	Degree
Limited data/information for district cooling project planning	Technical	High
Limited awareness and lack of local technical expertise on district cooling	Technical & Institutional	Medium
Lack of enabling local regulations/policies and financial incentives to promote district cooling	Regulatory	Medium
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 Pune

9.1.The extent of air-conditioning in Pune

Pune has witnessed remarkable economic growth in the past few years. The city's diverse economic base has contributed to rising income levels and changing lifestyles, thereby leading to increased penetration of air conditioners across households in the city.

Centralised cooling systems are being commonly used to provide thermal comfort in IT and business parks, hotels, hospitals and shopping malls across the city. Information collected from mid to large size developments such as Hotel Marriot, ICC Mall, Amonora Park Town Mall, Tech Mahindra campus, and the Eon Free Zone, indicates that either air cooled or water cooled central air conditioning systems are being used to cater to sizeable cooling demand. Centralized precision cooling units help maintain optimum temperatures of data centers and are indispensable to the way data centers are run in IT offices of all sizes in Pune.

Box 10: Identifying opportunities for district cooling

In order to assess the scale of cooling in Pune, effectively promote and plan for district cooling and identify potential district cooling projects, a GIS energy mapping of Pune 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). PMC will need to play a crucial role in encouraging and supporting building owners to install meters and ensure these can be monitored. PMC can lead by example and support the installation of meters in some public buildings[28], this could build on the energy audits started by PMC on public buildings described in Section 6.5.

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 Pune (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 Section 11.2 which should be built-upon in the future in Pune[29].

The combination of improved mapping, data and benchmarks will enable a full analysis on the current and longer-term impacts of space cooling in Pune, justifying new policies, technologies and investments. These impacts are likely to intensify with increasing population, increasing wealth and new business developments. Section 1.7.3 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 Pune, 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[30], essentially meaning the

[28] 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.
[29] 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.
[30] 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%.

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 Pune

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.

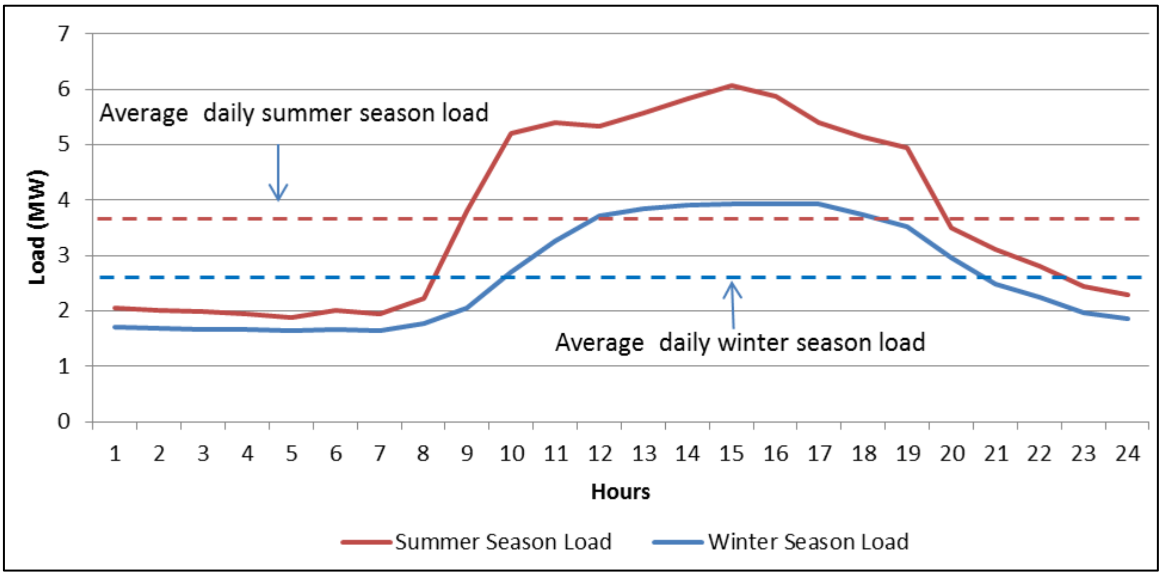
24-hour load variation for two building types

To understand seasonal variation in hourly power demand, data related to electrical demand over a period of 24 hours has been acquired from the MSEDCL[31]. Two indicative feeders have been selected, supplying electricity largely to a residential area and a large IT campus to understand the hourly load pattern. 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.

For the IT campus, it can be observed that the demand is lowest in the early hours from 0100 to 0700 hours and it escalates sharply thereafter during the business hours, before dipping towards the end of the day (see Figure 11). For the 24 hour periods shown, the average demand across the selected day in summer is nearly 40% higher than that in the winter day. While demand in the afternoon in the winter day is more or less constant, the summer demand is seen to rise in the afternoons from 1200 to 1800 hours. Peak load on the selected summer day is 1.5 times higher than during the winter day. This discernible rise in demand during the summers can be attributed to increased cooling load.

[31] The purpose of these graphs is to demonstrate the strong difference between the seasons for these two feeders, however the data is not necessarily representative of the average summer or winter profile.

Figure 11: Hourly Load Profile for an IT campus in Pune from two sample days in winter and summer, 2016

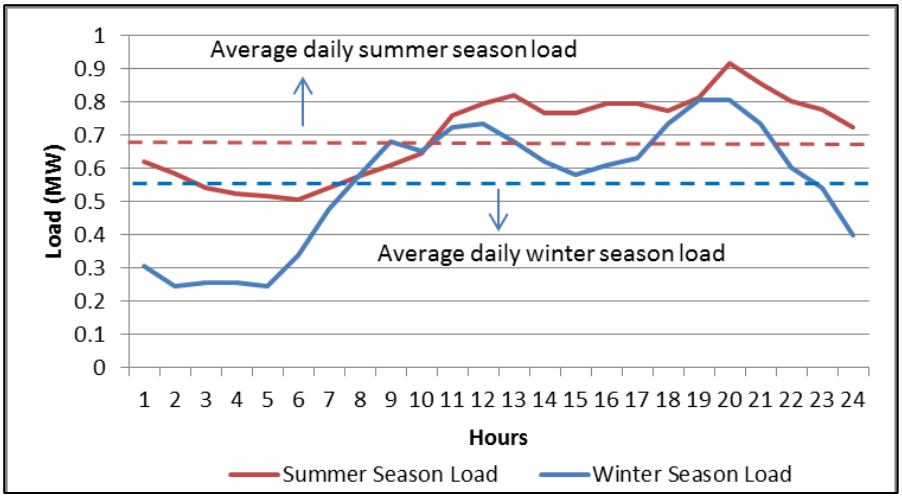


Source: Analysis based on data from (MSEDCL, 2016)

The residential load profile is notably different and reflects the time of maximum occupancy of the consumer (see

Figure 12). During the late evenings and night when occupancy is higher, demand increases whereas during the day time the demand is lower. Increased demand in the morning and evening in the winter can be attributed to increased requirement for hot water and indoor lighting as compared to the summer season. The average daily for the summer day selected is 27% higher as compared to the winter day. Night time demand is considerably higher in the summer as compared to the winter, most likely due to increased cooling load. Demand during the afternoons in the summer day from 1200 to 1800 hours is also much higher as compared to the winter. Based on the seasonal load profile, majority of the increased power demand can be attributed to increased need for space cooling and thermal comfort in the summers for Pune.

Figure 12: Hourly Load Profile for a predominantly residential area in Pune from two sample days in winter and summer

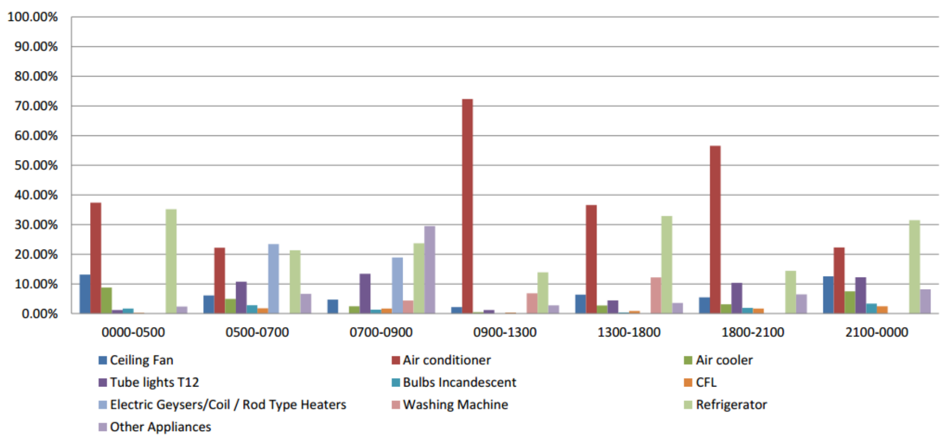


Source: Analysis based on data from (MSEDCL, 2016)

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[32] indicates that air conditioning contributes prominently to peak demand throughout the day in households during the summer season (see Figure 13). 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.

Figure 13: Operating Hours of Residential Appliances - Summer Season

[32] 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.



9.3.Impacts of cooling on electricity consumption

The MSEDCL is the utility responsible for distribution of power in Pune city. Electricity consumption in Pune in the year 2015-16 was 4,916 million kWh. A significant change can be observed in the pattern of electricity consumption within the city in the past few years. The consumption has increased by over 1,671 million kWh in the period between the years 2010 to 2015, amounting to an annual growth of about 8.6 per cent.

Over 40% of Pune city's electricity consumption is observed to be on high tension distribution lines (see Table 7). The high tension network primarily caters to large commercial (such as IT Parks) and industrial properties and public utilities (water works, sewage treatment plants). The residential sector accounts for about 37% of the total electricity consumption, followed by the commercial sector which has a share of over 13%

Table 7: Total Electricity Consumption in Pune City, 2015-16

Consumer Category	Electricity Consumption (Million kWh)	Percentage Share (%)
High Tension Consumers[33]	2,041.6	41.5
Residential	1,848.9	37.6
Commercial[34]	665.0	13.5
Industrial (Low Tension)[35]	272.1	5.5
Street Lighting	61.1	1.2
Public Service[36]	20.1	0.4
Public Water Works	2.4	0.1

[33] Includes consumers with more than 100 kW sanctioned load including Industrial, Commercial, Public Services, Bulk supply (Group Housing Society & Commercial Complexes), Temporary Supply, Agriculture, Public Water Works and Sewage Treatment Plants, Railway Traction

[34] 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

[35] Includes consumers having low tension connections such as IT/ITeS units, flour Mills, Ice factories, Milk Processing/Chilling Plants (Dairy), Engineering Workshops, Garment manufacturing units, LPG/CNG, bottling plants, Brick Kiln, Food Processing units and others

[36] Includes Schools and Colleges; Health Care facilities, such as Hospitals, Dispensaries, Clinics, Primary Health Care Centres, Diagnostic Centres and Pathology Laboratories; Libraries, offices of Government and Municipal/ Local Authorities/ Local Self-Government bodies

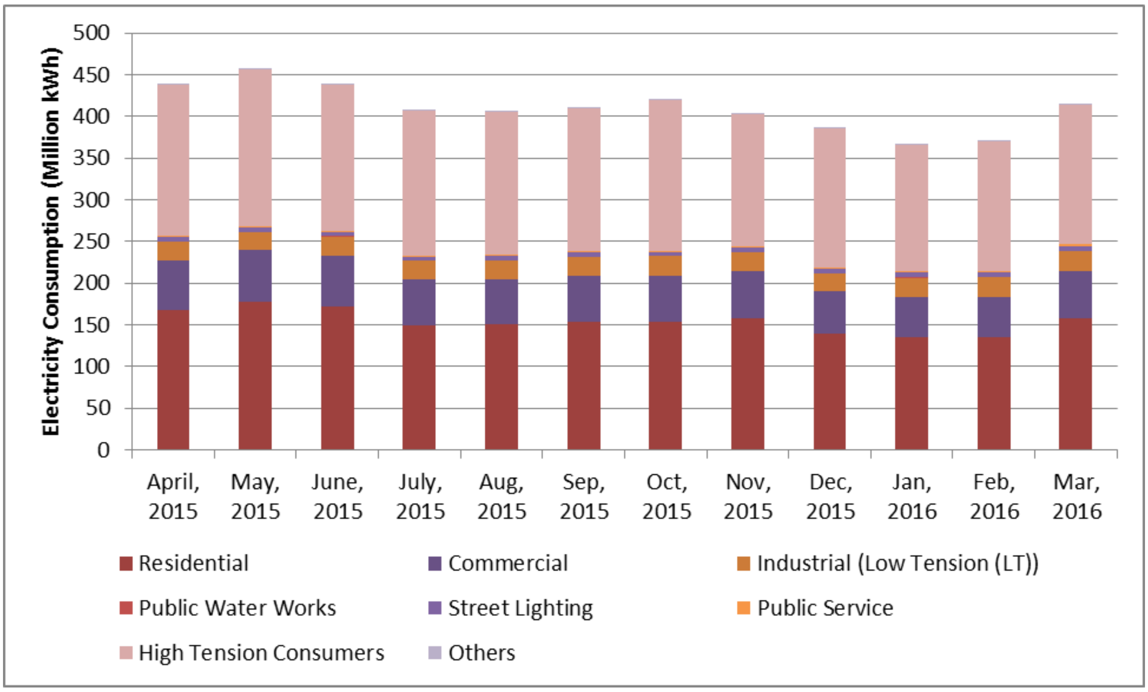
Consumer Category	Electricity Consumption (Million kWh)	Percentage Share (%)
Others[37]	4.9	0.1
Total	**4,916.1**	**100**

Source: (MSEDCL, 2016) Regional Office- Pune

Monthly electricity consumption can be very useful in understanding minimum and peak consumption in cities and the seasonal variations therein. Electricity consumption is seen to rise during the monsoon months when humidity or the level of thermal discomfort is high, starting with the months of March and April and peaking during the month of May (see Figure 14). Energy consumption by high tension consumers and the residential sector is consistently higher during the summer and monsoon months (March- June) as compared to the winter months. While other consumer categories show a similar trend, the seasonal variation is comparatively lesser in these sectors.

While the rise in monthly power consumption can be potentially linked to higher cooling demand, it is difficult to extract the full impact of space cooling from the monthly power consumption. Other loads in a city can be seasonal such as lighting and refrigeration and monthly data cannot demonstrate the full impact of cooling on peak demand and thus on power infrastructure, as peaks due to cooling are averaged with period when cooling is used less. Given the predominantly urban setting of Pune city, there is little irrigation pumping. The seasonal variation in electricity consumption is likely to be predominantly caused by space cooling (including fans, desert water coolers, air conditioners and chillers). Demand for lighting may slightly increase during the monsoon season, when hours of daylight are diminished, however it is not expected to create a significant seasonal variation.

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

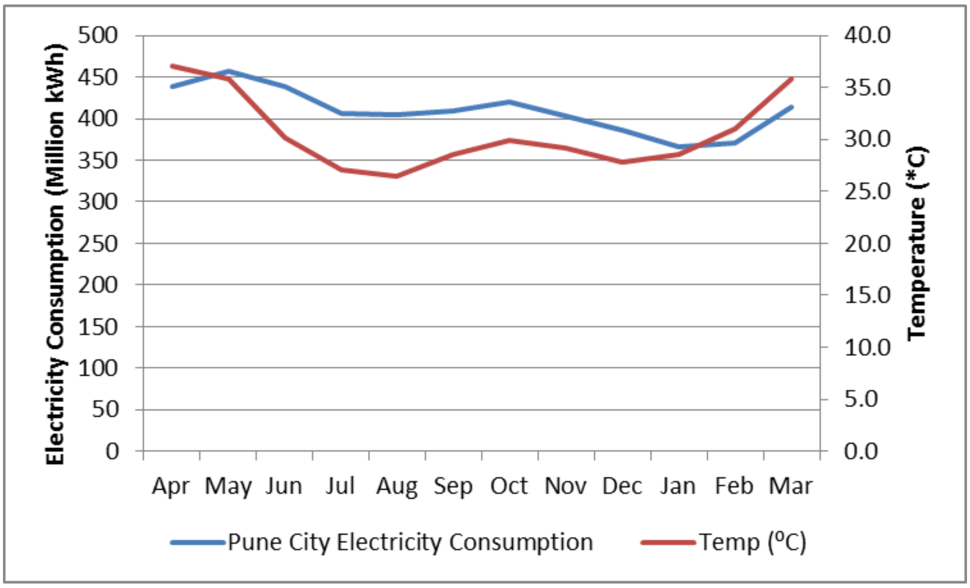


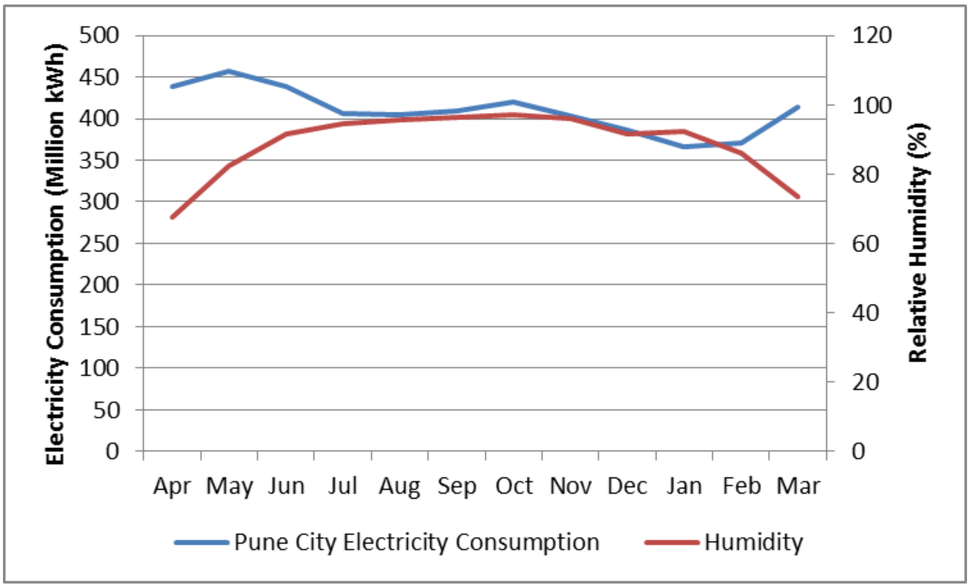
[37] Includes hoarding and advertisement, crematorium/Burial Grounds, and Temporary Connections

Source: Analysis based on data from (MSEDCL, 2016), Regional Office, Pune

Error! Hyperlink reference not valid.A positive correlation is observed between electricity consumption and monthly temperature, with the electricity consumption increasing when temperature is increasing.

Figure 15: Relationship between Monthly Temperature/Relative Humidity and Electricity Consumption for Pune City (2015-16)





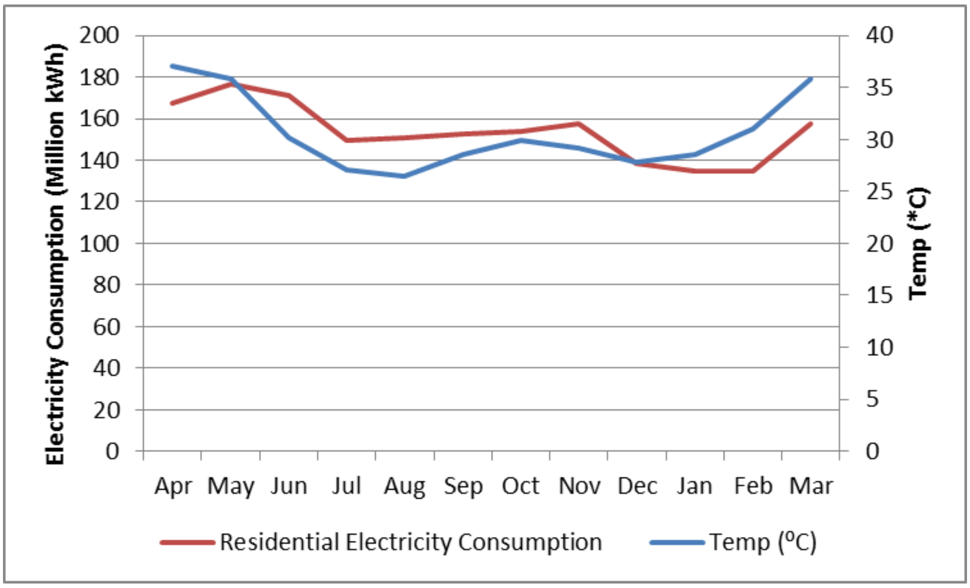
Source: Analysis based on data from (MSEDCL, 2016), Regional Office – Pune and (IMD, 2015-16)

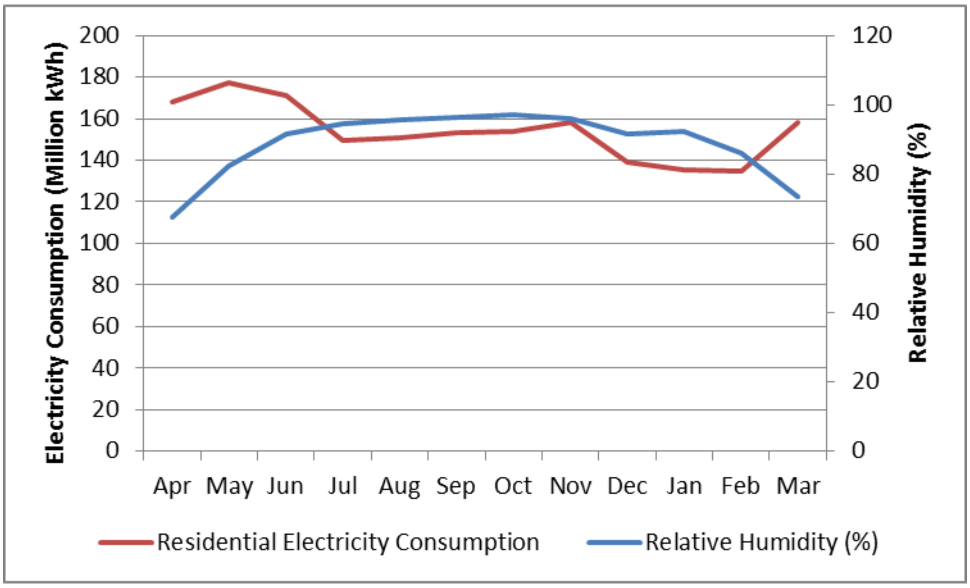
9.4.Sector-wise Analysis of Cooling Demand

1.1.1.1 Residential Sector

The electricity consumption in households is increasing by 14 per cent from the month of May up to October as compared to the yearly average, with consumption peaking in the month of May. About 13 per cent of Pune's households have sanctioned load more than 2 kW and consume substantial amounts of electricity. The seasonal load ratio for the residential sector is nearly 30 per cent.

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





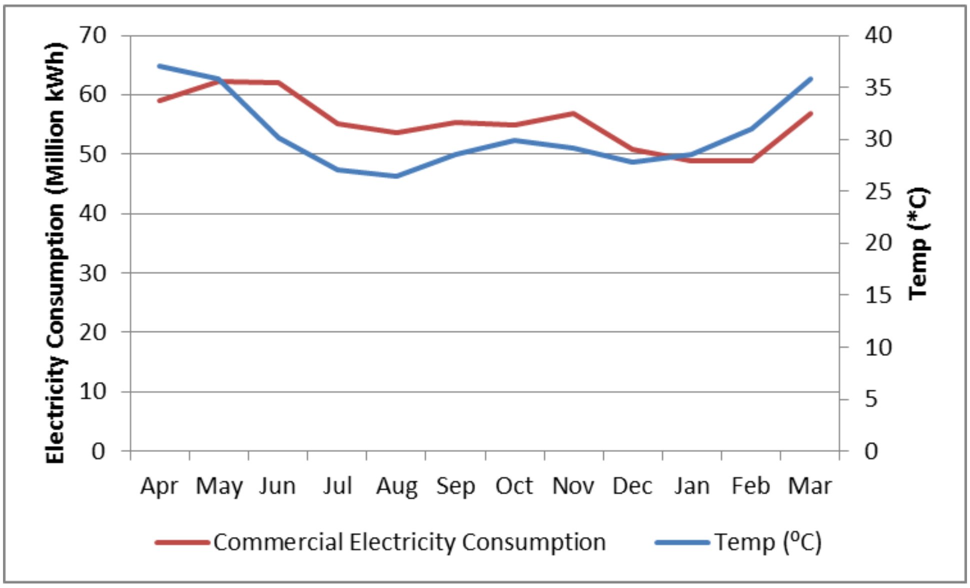
Source: Analysis based on data from (MSEDCL, 2016), Regional Office – Pune and (IMD, 2015-16)

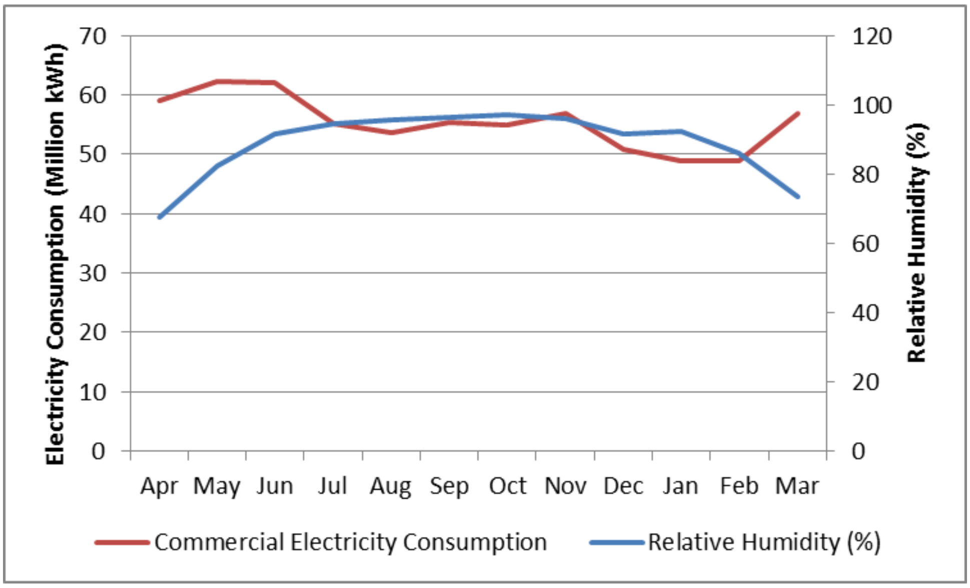
1.1.1.2 Low Tension Consumers in the Commercial Sector

Power consumption by consumers with low tension connections in the commercial sector[38] increases by about 20 percent from February onwards and has a consistently high pattern between the months of February to May.

Figure 17: Relationship between Monthly Temperature/Humidity and Electricity Consumption for Commercial Sector (2015-16)

[38] 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





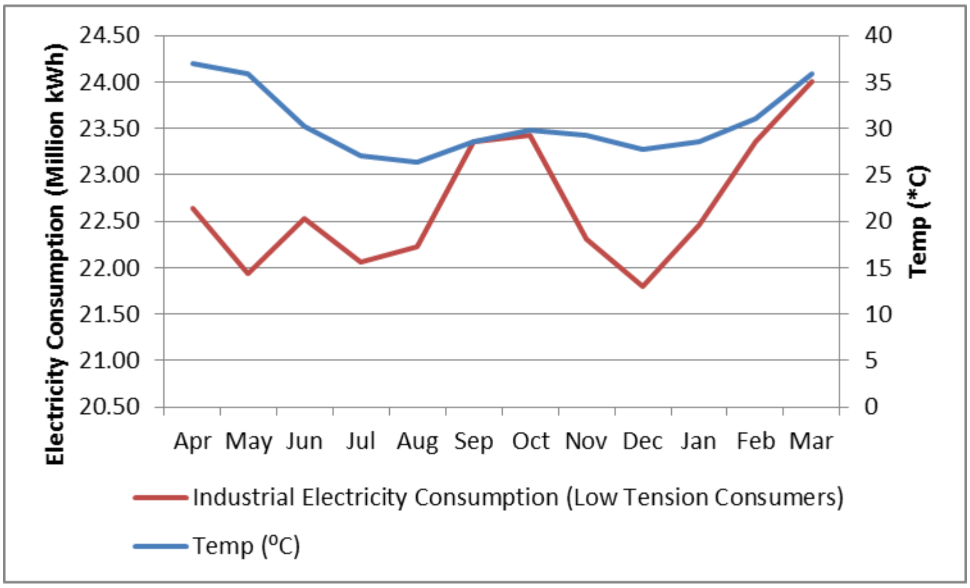
Source: Analysis based on data from (MSEDCL, 2016), Regional Office – Pune and (IMD, 2015-16)

1.1.1.3 Low Tension Consumers in the Industrial Sector

Electricity consumption by low tension industrial consumers[39] increases between the months of August to September and between December to March, peaking in the month of March.

Figure 18: Relationship between Monthly Temperature and Electricity Consumption for Industrial Sector (LT) (2015-16)

[39] Includes consumers having low tension connections such as IT/ITeS units, flour Mills, Ice factories, Milk Processing/Chilling Plants (Dairy), Engineering Workshops, Garment manufacturing units, LPG/CNG, bottling plants, Brick Kiln, Food Processing units and others

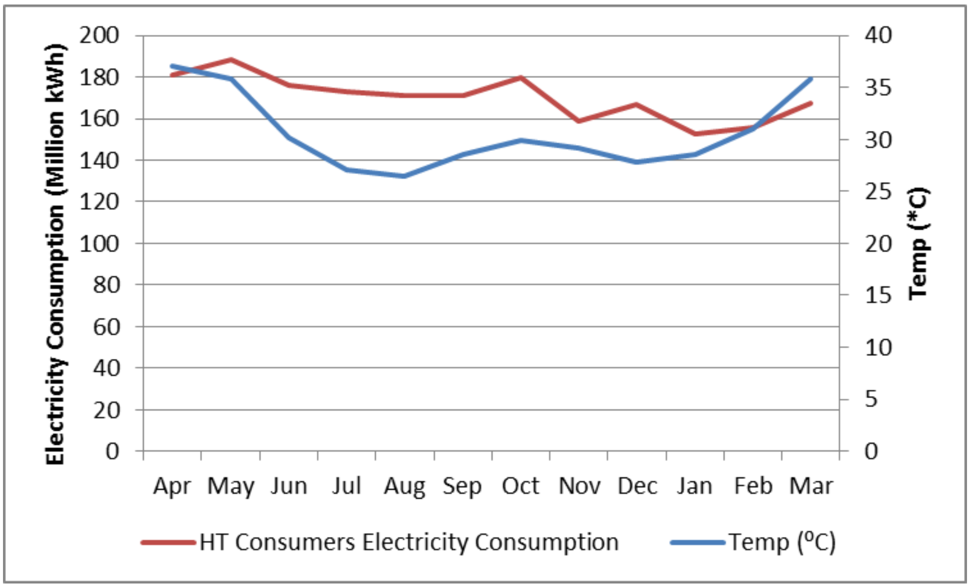


Source: Analysis based on data from (MSEDCL, 2016), Regional Office – Pune and (IMD, 2015-16)

1.1.1.4 High Tension Consumers in the Commercial, Industrial and Other Sectors

Electricity consumption by high tension consumers[40] rises during the summer months remains relatively higher between the months of March to November and peaks during summer months of May and June. The seasonal load for the high tension consumers is 21 per cent.

Figure 19: Relationship between Monthly Temperature and Electricity Consumption for High Tension Consumers (2015-16)



Source: Analysis based on data from (MSEDCL, 2016), Regional Office – Pune and (IMD, 2015-16)

[40] Includes consumers with more than 100 kW sanctioned load including Industrial, Commercial, Public Services, Bulk supply (Group Housing Society & Commercial Complexes), Temporary Supply, Agriculture, Public Water Works and Sewage Treatment Plants, Railway Traction

10. Opportunities for District Cooling in Pune

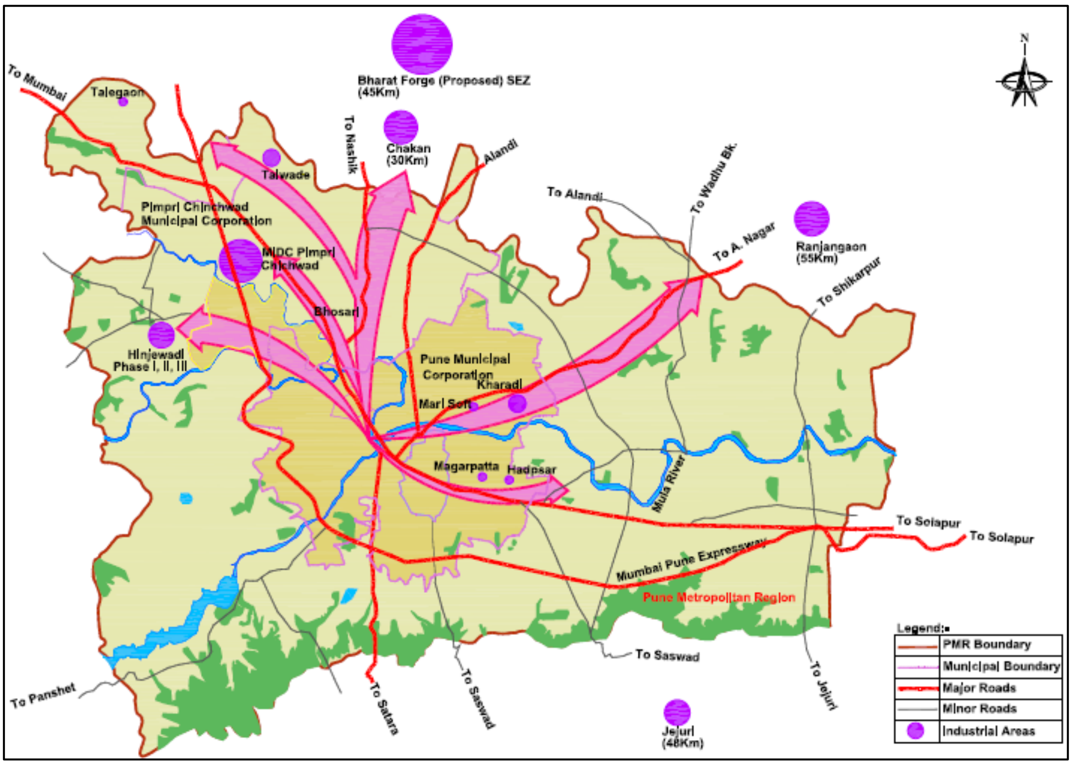
10.1. Real estate development

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

Pune has been historically known as a cultural and educational hub, which to a certain extent it still is. However, in less than two decades, Pune has transformed into an IT and manufacturing hub and is one of the fastest growing cities in India. The city has been experiencing rapid economic growth and development in the past few years, which coupled with changing lifestyles, is leading to an annual growth in power demand of approximately 8.6% (see section 9.3).

Pune houses a large number of IT/ITeS companies and the sector is the largest contributor to office space demand in the city (Knight Frank, 2015). The city accounts for 10 percent of the total occupied office space in India (Knight Frank, 2016). Over the last 10 years, Pune's employment hubs have moved away from the traditional central business district areas such as Bund Garden Road, Deccan and Senapati Bapat Road, towards the peripheral business districts such as Hinjewadi, Kharadi, Hadapsar, and Wakad which are located along city's growth corridors towards the north-west, east and south-east directions. Development in east Pune is being driven by a mix of Banking, Financial Services and Insurance (BFSI), IT and business process outsourcing (BPO) industries in Kharadi, Viman Nagar, Magarpatta Cyber City and Kalyani Nagar and the manufacturing hub of Ranjangaon. In the western part of Pune, development is being largely driven by the demand emerging from the IT hub and SEZ's concentrated in Hinjewadi (ICICI Property Services, 2015). Most of incremental office space supply is expected to come up in the same locations in the coming years (Knight Frank, 2016).

Figure 20: Map showing future developments in Pune



Source: (Pune Municipal Corporation, 2012)

A number of integrated townships are coming up in Pune's peripheral areas to cater the ensuing residential demand[41]. Some of the large on-going and completed townships projects in Pune and around include the Amanora park township (spread over 400 acres), Blue Ridge township at Hinjewadi (spread over 106 acres), Megapolis at Hinjewadi (spread over 150 acres), Life Republic at Hinjewadi (spread over 421 acres), Oxford city at Mauje Lavlhe (spread over 675 acres), and Pride World City at Charholi (spread over 400 acres). Apart from self-sustaining infrastructure, these integrated townships also offer a walk-to-work concept since these are either house commercial office spaces or are in close proximity of centres of business. The township projects tend to include multiplexes, hospitals, restaurants, schools, club houses, and health club facilities along with residential buildings. Such mixed-use development delivers a diverse set of consumers to aid feasibility of implementing district cooling. However, townships that have low proportions of commercial buildings could make the profitability of district cooling more difficult.

With Pune having a large commercial base and offering significant employment opportunities, the city ranks fourth in the year 2013 in country in terms of market potential for growth of the retail sector (Jones Lang Lasalle, 2014). The Hadapsar area, which lies towards the east of Pune, has also witnessed major retail development with presence of landmark shopping malls such as the Amanora Mall and the Magarpatta Seasons Mall.

[41] As of year 2012, around 25 townships are expected to come up in and around of Pune city, out of which 6 have already started taking shape.

Similarly, Hinjewadi which lies to the north-west of the city is also witnessing high growth in retail establishments. A study on the Mall Stock and Supply Trends in India conducted by Jones Lang LaSalle in 2013 indicates that Pune's mall space is rapidly increasing at the rate of 15.5% per year (JLL, 2013). A number of these large retail spaces are utilizing centralized air conditioning systems to meet their space cooling demand.

The PMC is actively leveraging its regulatory framework to promote building energy efficiency and reduced resource consumption through the GRIHA and Eco-housing schemes. Building developers are increasingly incorporating energy efficiency and renewable measures into building designs, aiming to reduce energy expenses. As indicated in section 6.4, the PMC is offering higher FSI and encouraging densification in large IT parks, near major roads, and in the influence zone along the planned metro corridor in the city. Pune's growth is also expected to be impacted positively by the proposed Delhi Mumbai Industrial corridor (DMIC)[42]. Pune lies within the corridors influence area and will be impacted by development of new export-oriented industries and special economic zones (SEZs), augmentation of existing industrial estates, and development of knowledge hubs, integrated townships, and feeder road links.

The upcoming Pune international airport could also provide an opportunity for integration of a district cooling system as in the case of Delhi International Airport Terminal 3. The outlook for Pune's real estate remains positive and the city is poised to accommodate a number of compact mixed-use developments, having large and sufficiently large cooling demand. The city potentially offers significant opportunities for integrating district cooling networks to meet its cooling demand in the long term, particularly in zones where a number of large IT/ITeS parks or campuses, offering large potential anchor loads, exist or will come up.

Building developers in Pune 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.

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, Pune has opportunities to develop district cooling using innovative renewable technologies in addition to electricity based chillers. These renewable or low-carbon options include: direct use of municipally-owned solar electricity by the district

[42] The DMIC is a planned industrial development project between India's capital city of Delhi and the financial hub of Mumbai. The project is estimated to cost about USD 90 billion and is planned as a high-tech industrial zone spread across seven states, including 24 industrial regions, eight smart cities, two airports, five power projects, two mass rapid transit systems, and two regional hubs.

cooling project, solar and/or biogas cooling through absorption chillers, waste-to-energy plants. The temperatures of the Mula River and Mutha River are expected to be too high for use as 'free-cooling', groundwater free cooling may be available but requires further analysis (see Section 3.2.4**Error! Reference source not found.**). No information on geothermal potential was available.

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 Pune (see Section 3.2.4), lowering water stress from cooling, helping meet Pune's water scarcity challenge. High-level analysis of the power prices in Pune has indicated that thermal storage (TES) is unlikely to be cost-effective for electricity-based district cooling, unless the difference between peak and off-peak tariffs is increased.

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

11. Techno-economic analyses of district cooling in Pune

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

11.1. Development of evaluation tool

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

- **Sub-model 1: Input**

The required input data includes:

1) built-up area of building types in the area planned for district cooling implementation
2) occupancy of building types
3) development timeline for different buildings
4) electricity and water tariffs charged to stand-alone buildings and a district cooling project
5) cooling demand per m^2

6) operational parameters including annual average COP and EFLHs[43]

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

[43] 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.

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 Pune

Cooling demand

As explained in Box 10, no benchmarks for building cooling demand or consumption are available in the city of Pune. 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, 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 14.3 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 8: Assumptions of cooling demand

	Hotel	Office	Shopping mall	Hospital	Residential Apartment	Campus building
W/sqm	158	263	315	209	131	209

Equipment costs

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

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

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

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

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

- Land cost for district cooling plant: 512 USD/ m^2 (34,133 INR/ m^2) (estimated)
- Distribution network cost (including pipes, metering, insulation and installation): 180 USD/TR[44] (12,000 INR/TR)
- FAR of cooling plant: 2

Cooling system characteristics

The cooling systems operates with different portions of loads (full or part load) throughout the year. According to site visits of buildings and district cooling experience in other countries, the annual average Coefficient of Performance (COP) of each cooling system[45] is estimated as following (the chilled water temperature is 5/13 ℃):

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

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

[44] 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.

[45] 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.

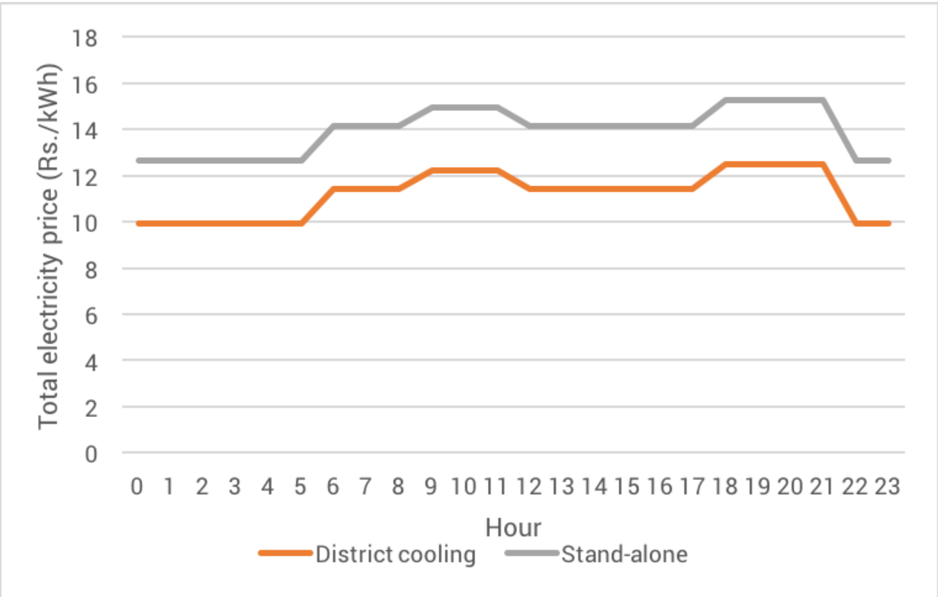
The operation of the district cooling and stand-alone systems for a given cooling load can, for high-level analyses, be characterised by the Equivalent Full Load Hours (EFLH). EFLH is the number of hours a cooling source has to operate at full capacity installed to produce the same amount of cooling 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 Pune is conservatively estimated as 1950 hours.

Operation and Maintenance costs

Electricity tariffs are calculated from Maharashtra State Electricity Distribution Company limited (MSEDCL) tariffs and presented in

Figure 21. 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.

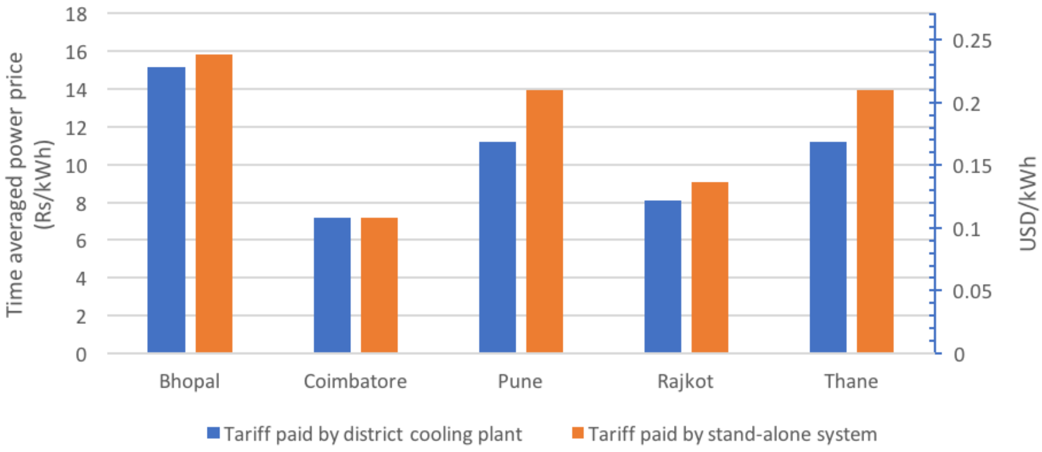
Figure 21: Electricity prices in Pune (Energy charge fee)



(Source: Based on tariff orders from MSEDCL)

Compared to the other cities assessed in India, Pune has relatively high electricity prices, as can be seen in Figure 22. 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. Pune has the same prices as Thane as they are in the same state.

Figure 22: Comparison of time-averaged electricity prices across all cities as paid by district cooling plants and stand-alone commercial cooling systems



(Source: Analysis based on tariff orders 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 23, 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 23.

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

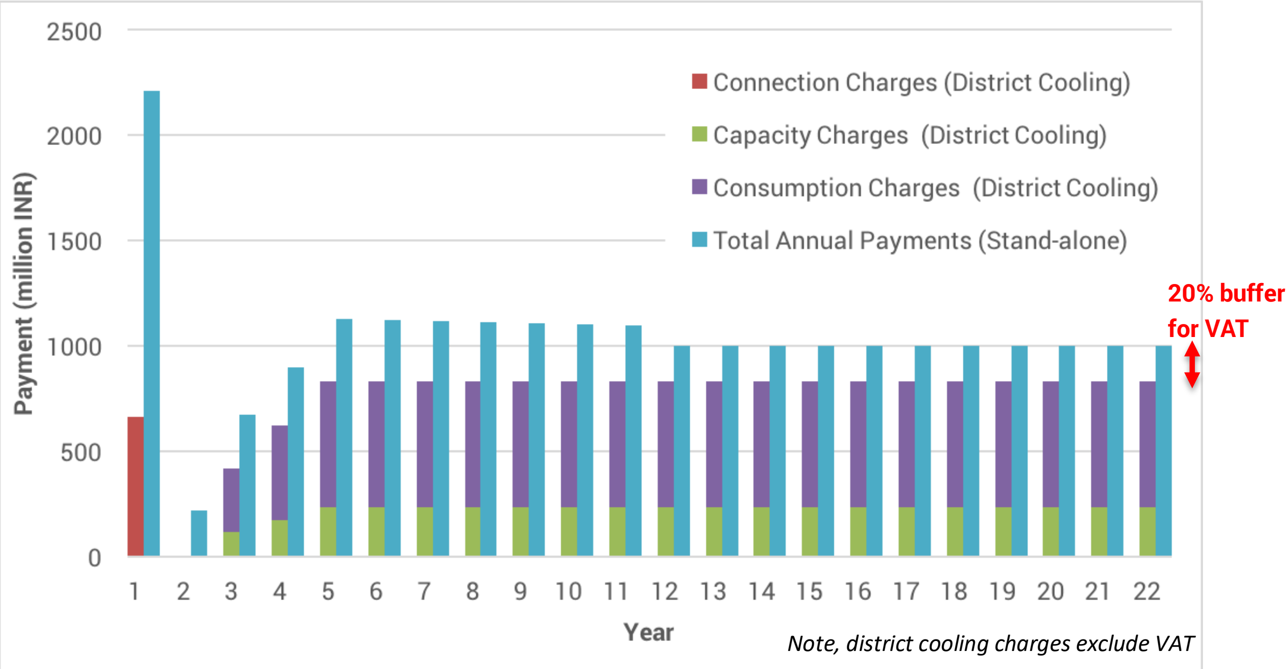
Through analysis of projects across all five cities, a development archetype was chosen that could be used as a typical development to enable comparison across all cities. The make-up of this archetype is shown in Table 11 below, it is mixed-use with multiple buildings with centralised cooling.

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

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 Pune and the payback period is 11 years.

Figure 23: 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 Pune with favourable financing, district cooling projects would be profitable to investors, beneficial to the environment and lower-cost to the consumers.

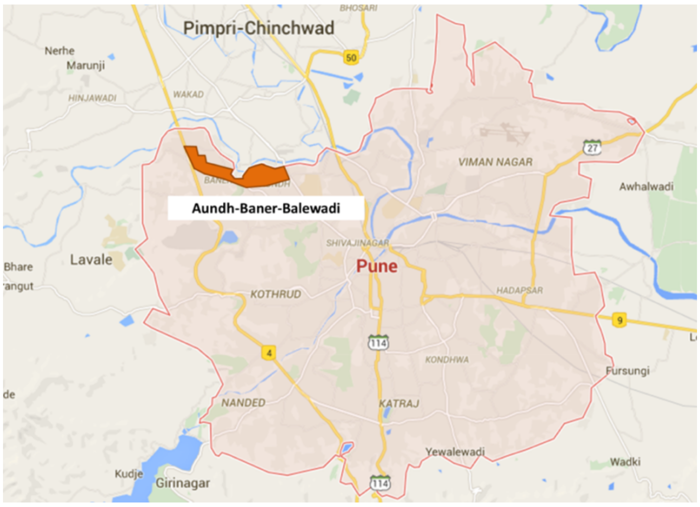
11.4. Selection of Probable Project Sites

The following section presents some of the sites that have been identified and assessed for district cooling potential in Pune. Existing and proposed developments are included but not all include cost-benefit analyses. Site 1 is the Smart City Area, identified as high-priority by the city for district cooling assessment. Site 2 examines the Blue Ridge development an IT/ITeS SEZ with township that is already mostly constructed on the periphery of Pune. Other similar SEZs are also shown to demonstrate the large scale real estate projects Pune is attracting. Much of the future development in Pune with a high potential for district cooling would be like Site 2, and the recommendation to incorporate district cooling early in the design phase is emphasised. The pace of real estate in Pune is also a major challenge, identifying sites that are early enough in the planning system to be able to have district cooling which aren't just conceptual is difficult. Site 3 has not been developed and will be an integrated township and it is hoped the lessons from Site 2 can be applied in the development of Site 3.

11.5. Site 1: Aundh-Baner-Balewadi Area (brownfield/redevelopment)

A 900-acre (3.6 sq. km.) area of Aundh-Baner Balewadi is being developed as a pilot smart area under the Area based development component of Pune's Smart City Plan, this is also described in Section 5.1. This area is located at the entry point to the city from Mumbai. It comprises of a 3.5 km river front, high-rise buildings, slums, old villages, a sports stadium, IT industry and educational institutes. With its proximity to the IT hub of Hinjewadi, this location is a catchment zone for the IT sector. The location of the site has been marked in the map below.

Figure 24: Location of Aundh-Baner-Balewadi Area



11.5.1. Site 1: Collected data and site details

The population in this area is expected to grow by 4 times from 40,000 at present to 150,000 by the year 2030. The area has a large amount of vacant land, wherein mixed-use and compact development is planned. This will include a start-up zone spread over an area of 10 acres (0.04 sq. km) and commercial space spanning 36 acres (0.14 sq. km) these are expected to be ready by the year 2019. A transit hub, 3 multi-speciality hospitals, and 3 international schools are proposed as well. Existing development in the area includes offices, commercial spaces, educational and health facilities in close proximity. The existing slums in the area are proposed to be redeveloped. A detailed plan of current and proposed development is not available.

Figure 25: Existing and Proposed Amenities in the Aundh-Baner-Balewadi Area

Source: (Pune Smart City Proposal , 2015)

The site is located along the Mutha River which can potentially provide fresh water for the district cooling network, subject to the water quality and obtaining requisite permissions from the local government and other relevant authorities. Test conducted on the water quality of the Mula – Mutha River at Aundh indicate that the water quality is within the permissible limits prescribed under the standard A-IV of the Maharashtra Pollution Control Board, thereby making the fresh water fit for agriculture, industrial cooling and process water uses. About 10% of the waste water generated from the site is proposed to be recycled and used for consumption in parks and construction activities. This treated wastewater could potentially be reused in the district cooling network. A sewage treatment plant is located close to the site at Baner and its capacity is proposed to be augmented to treat the waste water from this site. Reuse of storm water has also been planned at the site.

Table 12: Selection criteria for Site 1

Technical requirements	A range of developments are proposed for this site that will have high cooling loads in centrally cooled buildings.
Availability of anchor loads with continuous and/or large demand and diverse buildings can be connected	More detail is needed on the proposed start-up zone (floor space of 0.44 million sqft.) and commercial space (floor area of 1.57 million sqft.) but they could have extended operating hours if they are in the service sector. Planned hospitals could serve as anchor. If the transit hub were to have space cooling it could also be a significant anchor load. The high-share of residential planned for this zone is unlikely to be connected.
Potential for longer-term network expansion	An initial starter network would have potential to expand in the zone given the expected population growth and amenities in this area.
Existing situation of buildings	Some existing buildings in the zone have centralised cooling and can be connected e.g. IT office spaces, commercial and retail spaces, hospitals.
Influence from local government	The overall development and proposed initiatives for this site have been drawn up by the PMC. The PSCDCL, which is responsible for implementation of Smart City plan across Pune city and in the Aundh-Baner-Balewadi area, is headed by the serving Municipal Commissioner of the PMC. The PMC is well represented in the governing body of the PSCDCL. Thus, the local government exerts a high degree of influence over the project and controls development in and around this site and can potentially intervene to help integrate district cooling.

11.5.2. Site 1: How district cooling could be developed in the Aundh-Baner-Balewadi Area

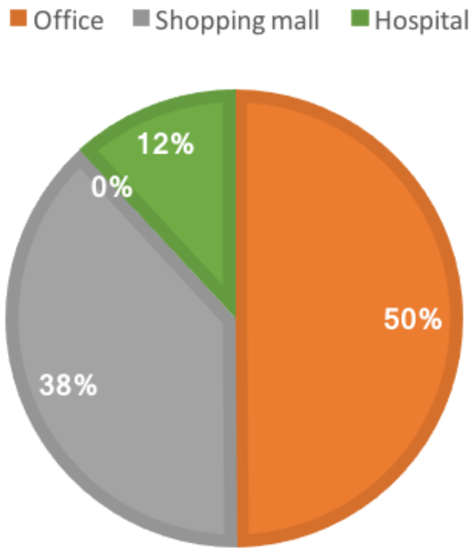
The potential for district cooling in Aundh-Baner-Balewadi has been analysed below. No plans for specific building locations have been made available, as such, based on the information supplied a potential project has been defined including the start-up zone, commercial zone and a hospital.

Buildings served and cooling load

The total built-up area is estimated at 2,279,029 sq.ft (211,729 m^2) and the split by building type is shown in .

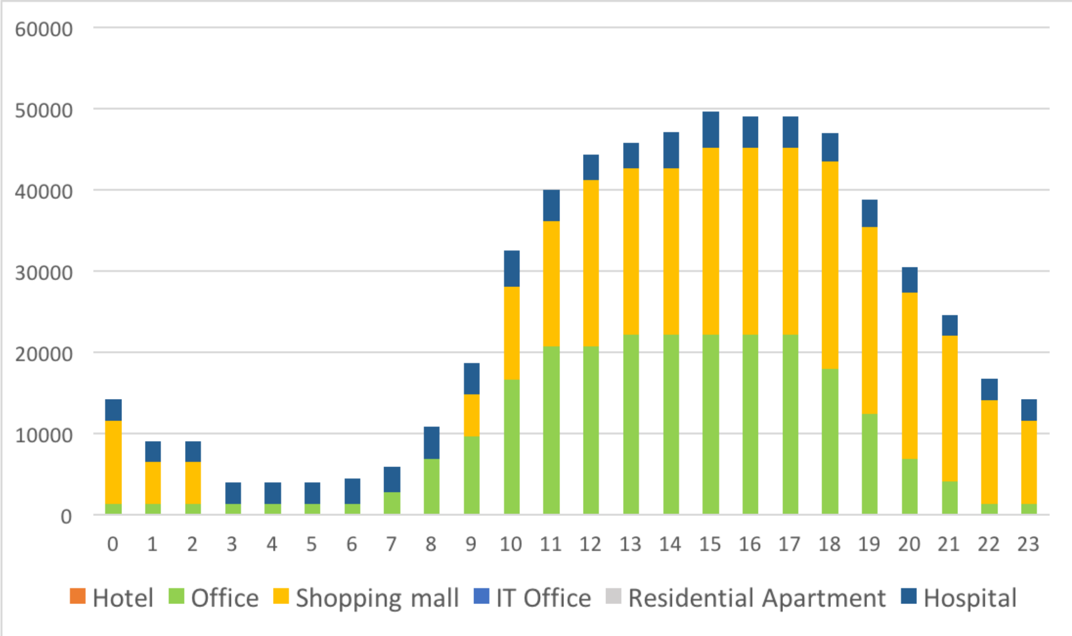
Figure 26. This is based on information received that the start-up zone will have 0.44 million sq. ft. (40,900 m^2) of floor space and a commercial space having 1.57 million sq. ft. (146,000 m^2) The start-up zone is presumed to have cooling demand similar to office space and the commercial space is presumed to have floor space characterised by 50% office and 50% retail mall. A large hospital of approximately 700 beds with a floor space of 269,000 sq.ft (25,000 m^2) is presumed to connect.

Figure 26: 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 27 below.

Figure 27: 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 13: District cooling plant

Installed Cooling Capacity	49637	kW
	14113	RT
District cooling plant built-up area	3497	sq. m
Outdoor space for cooling towers	1119	sq. m
DC plant land requirement	2098	sq.m

The investment of district cooling system is calculated as below.

Table 14: District cooling system investment

DC system investment	Rs.	USD
DC plant	1,881,776,702	28,226,651
Land	71,539,301	1,073,090
Network	169,359,903	2,540,399
Sum	**2,122,675,906**	**31,840,139**
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 15: Annual cooling supply and operation fee

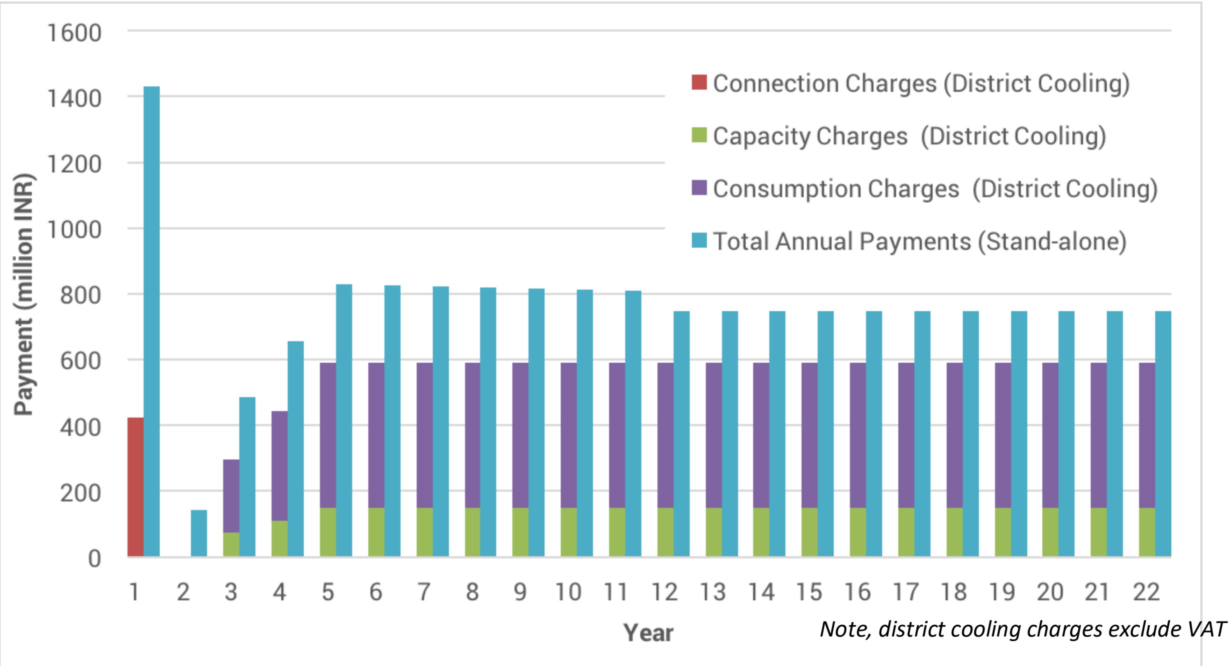
Annual cooling supply	kWh	55,040,113
Annual electricity consumption	kWh	15,649,734
Annual electricity fee	Rs.	173,842,384
	USD	2,607,636
Annual water consumption	m^3	450,712
Annual water fee	Rs.	105,917,397
	USD	1,588,761

Financial results

The economic analysis shows that when a metering charge equal to 0.22 USD/TR.h (14.7 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 28 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 28: Cost comparison for consumers in Aundh-Baner-Balewadi for district cooling vs. stand-alone systems



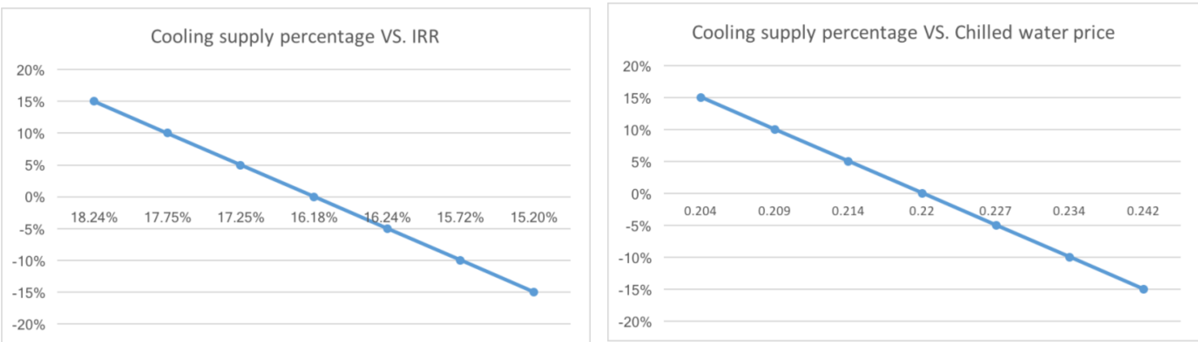
Sensitivity analysis

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 0.22USD/TR.h (14.7 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.

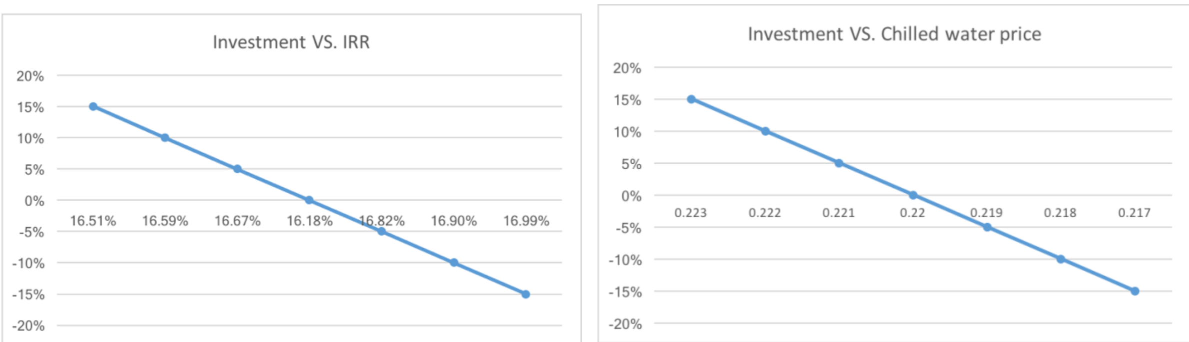
Figure 29: Sensitivity analysis results of changing cooling demand in Aundh-Baner-Balewadi



- Sensitivity analysis on capital costs

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

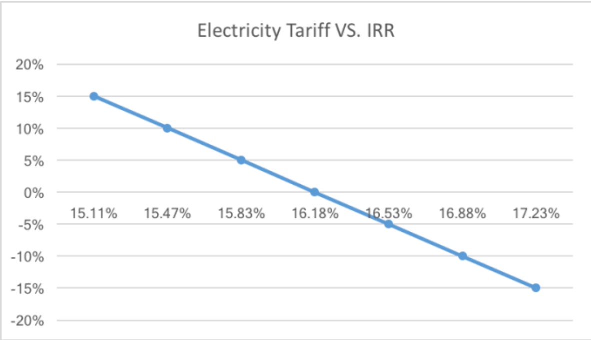
Figure 30: Sensitivity analysis results of changing capital costs in Aundh-Baner-Balewadi

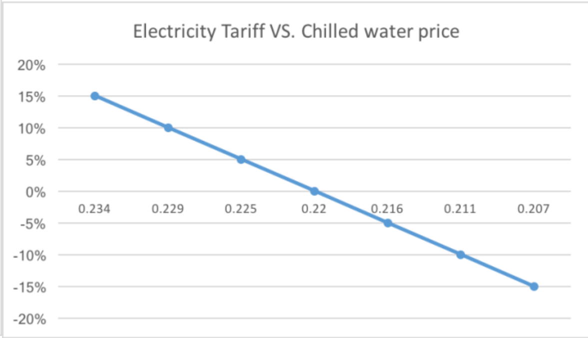


- Sensitivity analysis on electricity tariff

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 31: Sensitivity analysis results of changing electricity prices in Aundh-Baner-Balewadi





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 Aundh-Baner-Balewadi area is presented in Section 11.8 below.

The specific benefits of connecting the Aundh-Baner-Balewadi area to district cooling are presented in Section 11.9 below.

Box 11: Recommendations for Aundh-Baner-Balewadi Smart City Area

Given the commercial viability of district cooling assessed above, PMC could direct PSCDCL to incorporate district cooling into the design of the smart city area, particularly focusing on the planning of non-residential buildings likely to have centralised cooling, the placement of utilities, incorporation of existing buildings, identification of land for a district cooling plant. It may be that given the size of the area, multiple district cooling networks are establish that could later interconnect.

District cooling system(s) can be integrated into the initial stages of development of the Smart City Area, targeting the start-up zone and commercial space that is planned. The network(s) can subsequently be expanded to connect the diverse mix of proposed and existing buildings in the area in particular hospitals, transit hub, retail areas etc. If building layouts for the start-up zone and commercial zone are already developed, a project pre-feasibility should be undertaken. If not, then an experienced international district cooling engineer can provide inputs to zonal design including FSI and building mix that will benefit district cooling. It is highly recommended that these initial zones are assessed for district cooling potential as soon as they are planned and district cooling concepts considered early on in their design.

The consultancy undertaking a pre-feasibility 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. The consultancy should assess the use of Treated Sewage Effluent in district cooling systems.

In parallel, PMC should work with an independent consultancy to identify the level of incentives necessary to ensure the Smart City is established with district cooling. These incentives are described in preceding sections but these could include: property tax rebates; low-cost provision of solar electricity; provision of low-cost land (for a district cooling plant), water and wastewater; density bonuses; negotiation of improved off-peak electricity tariff; accounting for district cooling in buildings' environmental credentials etc.; low interest loans attracted from the state-level. If the pre-feasibility study identifies significant connection risk, or that long-term expansion would be unlikely, PMC could examine the use of connection policies such as requiring other buildings in the Area to assess district cooling connection (see Box 4) and/or mandating centralised cooling in non-residential buildings (see Box 6).

Finally, the investment interests of PMC, the PPP handling smart grid in the area, the SPV, buildings developers and future building owners 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.

PMC should prioritise the Smart City Area for demonstration of district cooling as the district cooling concept aligns well with the vision of the Smart City, the area is designed to test new policies and technologies for future replication and PMC has significant planning control over the area.

11.6. Site 2: Blue Ridge, Hinjewadi (Brownfield site)

11.6.1. Site 2: Collected data and site details

Blue Ridge is a mixed-use township located near the phase-I of Hinjewadi, the IT hub of Pune. The township consists of a Special Economic Zone (SEZ) and residential spaces spread across 138 acres (0.558 sq. km). The SEZ covers an area of 38 acres and the rest of the land is allocated for residential and related development. The total built-up area at this site is estimated to be around 65 acres.

The IT/ITeS SEZ will be spread across a floor area of 3 million sq. ft. Phase-I of the Blue Ridge SEZ approximately has 1.45 million sq. ft. of leasable space and is already operational, housing large IT/ITeS companies such as Accenture, Cisco Systems, L&T Infotech Ltd., Persistent Sytems among others. Phase-II of the SEZ is currently under construction and will comprise three buildings with approximately 1.5 million sq. ft. of total built-up area.

A total of 31 towers having about 5000 apartments are planned within the Blue Ridge township. Construction of about 70 percent of the Blue Ridge project has been completed as of February 2017 and all construction is expected to finish by end of 2018[46]. Construction of 14 towers has been completed and the units in these towers have been occupied. The rest of the towers are at various stages of construction[47].

The Blue Ridge township includes a number of amenities such as a centralised business centre with conference and training rooms, food courts of approximately 40,000 sq. ft. floor space, fitness centre, shopping mall, multiplex, a 5-star hotel, and a golf course. The Blue Ridge Public School located within the campus is currently operational. The township has well laid out roads and also includes a captive 200 kVA power substation, a water treatment plant, and a wastewater treatment plant. Wastewater is being reused and recycled for landscaping purposes.

Other buildings including the IT/ITeS office spaces of Cognizant and M-Tech, and the educational campuses of the Symbiosis Institute of International Business and the Symbiosis Centre for Information Technology, located to the north of the Blue Ridge township can potentially be served by the district cooling network as well. The Hinjewadi area has developed rapidly since the establishment of the Rajiv Gandhi Infotech Park in the year 1998. At present, two phases of Infotech Park are operational and the third one is still under construction.

Vacant land is available near the site towards the East and West that could be developed, into another township or SEZ or a further phase of this development.

[46] Information received from the project developer, Paranjape Schemes (Construction) Ltd.
[47] Tower 18 to 23 are under construction while towers 15, 16,17 have not been launched as yet.

Figure 32: Location of Blue Ridge, Hinjewadi

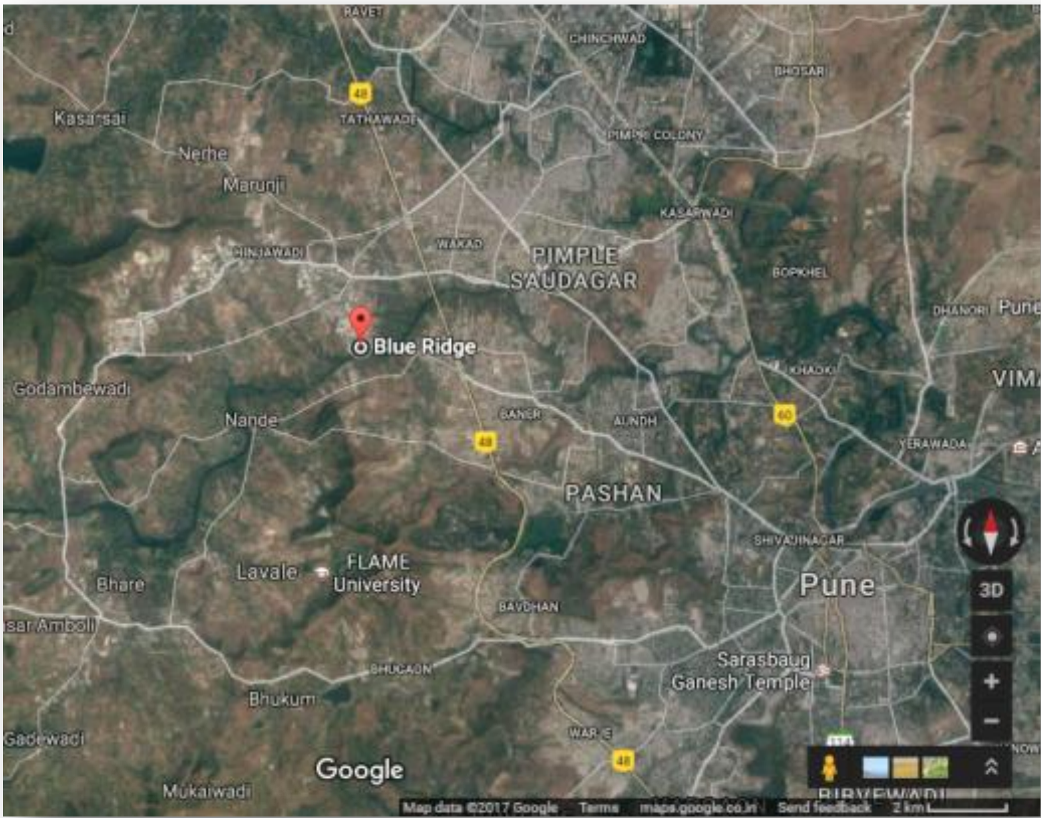


Figure 33: Blue Ridge, Hinjewadi Site Plan

Figure 34: 3D Images of Blue Ridge, Hinjewadi

Site selection criteria for Blue Ridge, Hinjewadi:

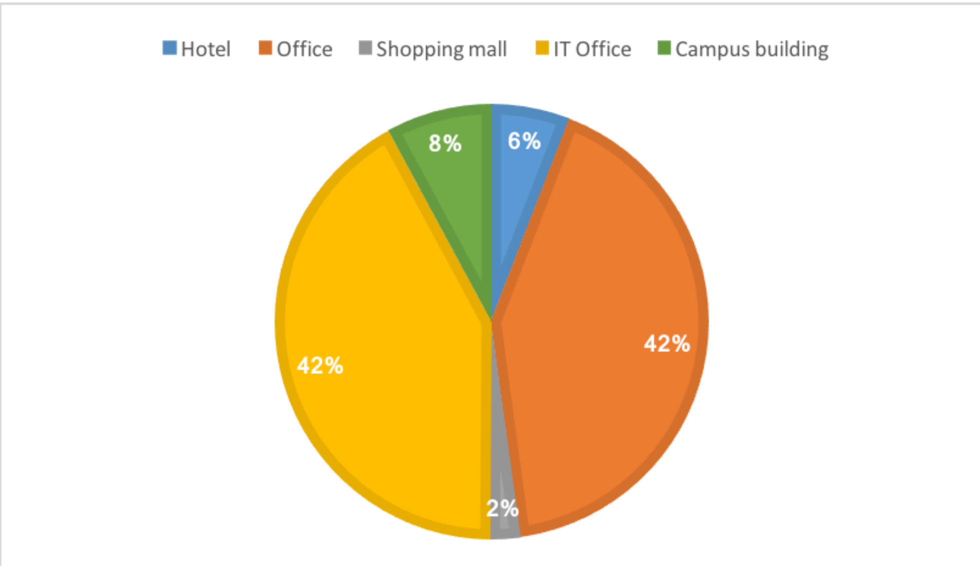
Technical requirements	The significant size of the township, compact development and emphasis on IT/ITeS sector would have made it ideal for district cooling. A significant amount of the site has already been constructed and the fast-pace of the rest of the site under construction (completed by 2018) make incorporating district cooling into the buildings identified very difficult in the short-medium term as buildings have already invested in chillers. Vacant land is available near the site towards the East and West that could be developed with district cooling. If development is near enough, the new network could connect existing buildings in Blue Ridge when their chiller systems need replacing. Treated wastewater available at the site could be partly used in the district cooling network.
Availability of anchor loads with continuous load and diverse buildings can be connected	The significant cooling demands of existing/upcoming IT/ITeS office spaces, which are operational across the day and often the night, make for strong anchor loads. Cooling of data centres housing servers of the IT/ITeS companies should be investigated further and could be served by district cooling. Other anchor loads include: the business centre, hotel, shopping mall and multiplex
Potential for longer-term network expansion	The site is located in the Hinjewadi, which is the IT hub of Pune city. This area has developed rapidly in the recent years and is witnessing a diverse mix of commercial, residential, educational, and retail developments coming up. Significant potential exists to develop

	district cooling networks in upcoming phases of the Hinjewadi IT park which in the future could connect existing buildings
Existing situation of buildings	70% of the construction in the Blue Ridge township has been completed and all construction is expected to be completed towards the end of the year 2018.
Influence from local government	The PMC can leverage its relationship with the relevant building developers, businesses, the Hinjewadi Industries Association, and other stakeholders to help facilitate further dialogue to demonstrate the viability and benefits of establishing a district cooling network. The PMC can also help integrate policies, regulations and incentives in its DCPR, particularly in large IT/ITeS developments wherein large and continuous cooling demand exists, to promote uptake of district cooling.

11.6.2. Site 2: Delivering district cooling in IT townships and SEZs

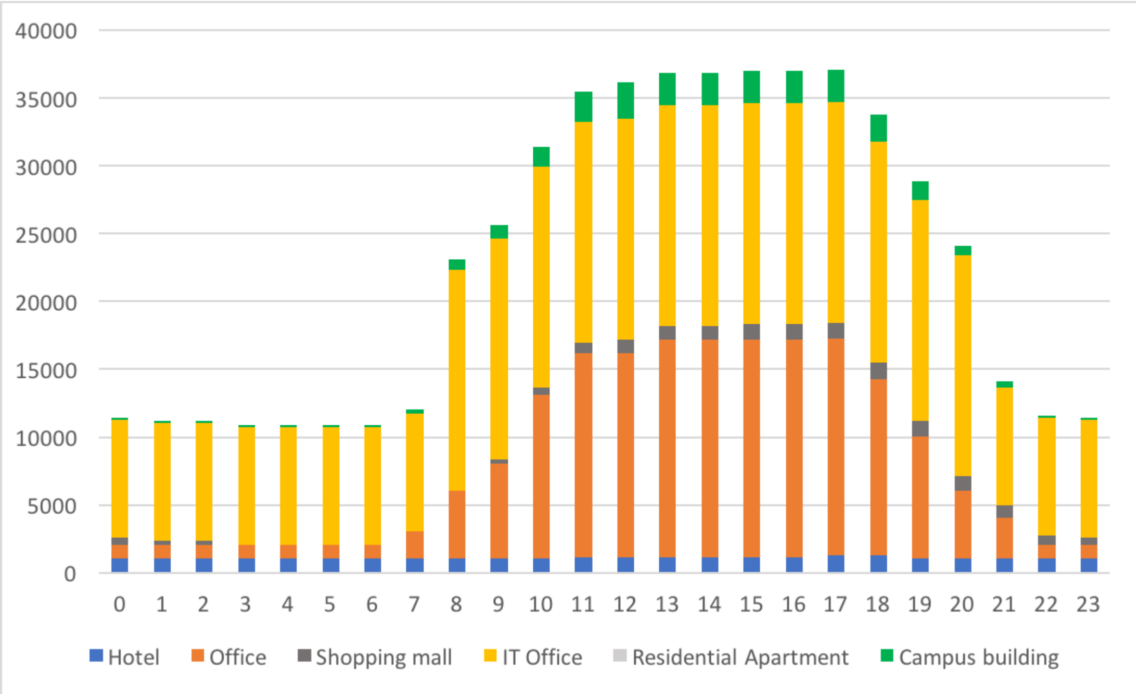
The Blue Ridge project has been used to undertake a general analysis of IT Townships and SEZs in Pune. The built-up area assessed for district cooling is 1,951,376 sq.ft (181,289 m^2) and the split by building type is shown in Figure 35. A new category of building has been added, IT Offices, which are presumed to have longer operating hours see Table 30 in the Annex.

Figure 35: 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 36 below.

Figure 36: 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 16: District cooling plant

Installed Cooling Capacity	37,066	kW
	10,539	RT
District cooling plant built-up area	2,611	sq. m
Outdoor space for cooling towers	836	sq. m
DC plant land requirement	1567	sq.m

The investment of district cooling system is calculated as below.

Table 17: District cooling system investment

DC system investment	Rs.	USD
DC plant	1,405,198,055	21,077,971
Land	53,421,263	801,319
Network	126,467,825	1,897,017
Sum	**1,585,087,143**	**23,776,307**
Investment per TR	**150,402**	**2,256**

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

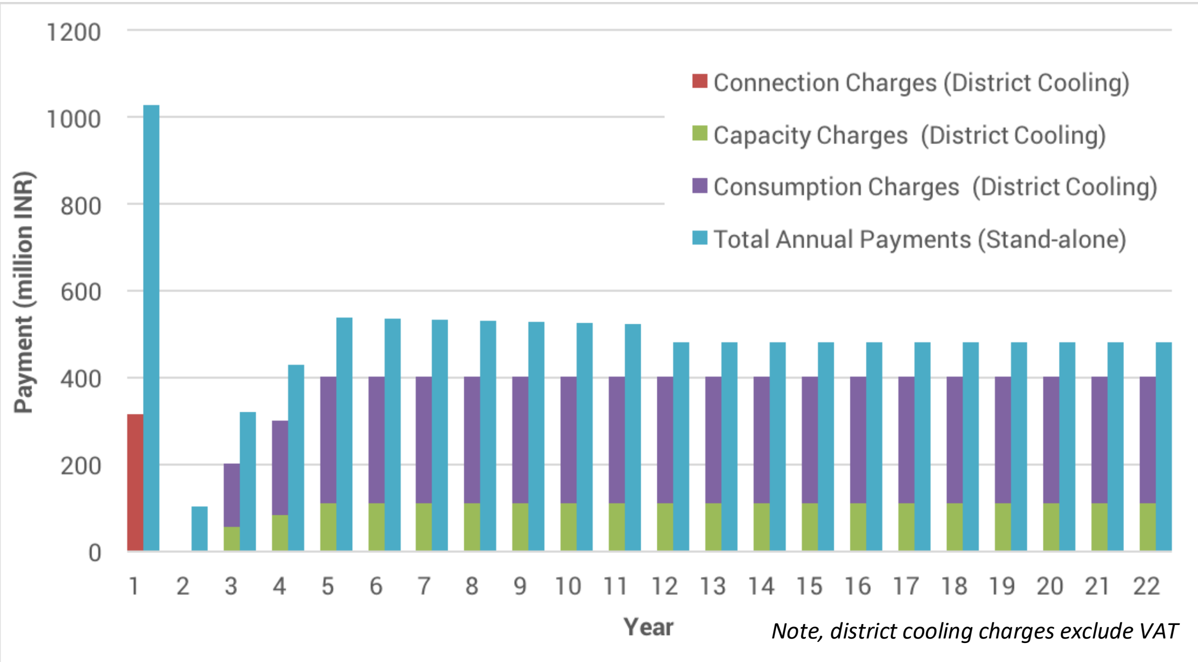
Table 18: Annual cooling supply and operation fee

Annual cooling supply	kWh	49,259,122.26
Annual electricity consumption	kWh	14,006,006
Annual electricity fee	Rs.	160,959,748
	USD	2,414,396
Annual water consumption	m^3	403,373
Annual water fee	Rs.	16,134,919
	USD	242,024

Financial results

The economic analysis shows that when a metering charge equal to 0.194 USD/TR.h (12.9 INR/TR.h) is charged, the IRR of this project reaches 14%. 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 37 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 37: Cost comparison for consumers in IT Township/SEZ for district cooling vs. stand-alone systems



The specific benefits of connecting an SEZ such as Blue Ridge to district cooling are presented in Section 11.9 below.

Two other large SEZs in the vicinity of Pune were identified for district cooling analysis and are shown below.

International Tech Park, Pune (Ascendas)

The International Tech Park Pune is a new 25-acre IT/ITES SEZ located within the Phase-III of the Rajiv Gandhi Infotech Park, Hinjewadi, Pune. This site is under construction and will offer 2.2 million sq. ft. of premium office space when fully completed along with its amenities. Had this site been designed with district cooling from the beginning, it is expected that significant cost savings and environmental savings could have been achieved by sharing load and capacity between buildings. However, not all buildings have been completed and buildings under construction could still be connected by a district coolng system if an assessment is started immediately. Potential retail developments nearby could also be connected to such a system or could even use one of the buildings' spare cooling capacity.

Figure 38: 3D Images of International Tech Park Pune (Ascendas)

E.ON Free Zone

The EON Free Zone is a large state-of-the-art IT/ITeS SEZ campus spread across 45 acres (0.182 sq. km) located in Kharadi, a business district in Pune's eastern IT corridor. Phase-I of the EON Free Zone has a total built up area of 4.5 million sq. ft.with a 15,000 TR cooling system and was completed in November, 2015. Construction of Phase-II of the EON Free Zone, spread over an area of 2 million sq. ft. is underway and expected to be completed by the year 2018. Some of the buildings of the EON Free Zone have recieved LEED 'Gold' certification and phase-wise certification is underway for the rest. Wastewater treated on-site is reused for flushing and landscaping purposes.

The site has other building developments next to it with signficant cooling demand like the World Trade Centre Complex. This complex consists of four towers in total, with three towers under construction and one tower operational at present. All towers will have a cumulative capacity of 4,900 TR. The land on the east side and south side of the site is vacant for new development to come up.

While the respective cooling systems of the E.ON Free Zone and the World Trade Centre Complex are likely highly efficient at the single-building level, international experience shows that the connection of these two systems could have yielded lower costs and improved environmental credentials. Further, the centralised nature of a district cooling system could save space in some of the buildings and also make the use of an innovative technology like Treated Sewage Effluent for cooling water possible. Further, the likely long-term development adjacent to this site could have been connected into the district cooling system.

District cooling could still be developed at this site if building owners are willing to expand existing systems and connect upcoming developments in the future.

Figure 39: 3 D Image of Eon Free Zone

Box 12: Incorporating district cooling into the design of SEZs and integrated townships

PMC and PMRDA can work to ensure that integrated townships, IT Campuses and SEZs on the periphery of Pune are developed and expanded with district cooling systems. Many of the planning policies presented in Box 4 can be used and PMC and PMRDA should identify which of these could catalyse district cooling development without impacting real estate development.

For future SEZs and townships, the potential of district cooling will be very high and will deliver significant benefits, PMC and PMRDA could consider mandating district cooling development in these zones (see Box 4). SEZs and townships typically have favorable planning conditions and taxes provided to them – incentives using these tools could work well.

For existing SEZs where development is ongoing, PMC and PMRDA can directly work with building developers to identify buildings due to be commissioned in the next 2-5 years and use these to start district cooling networks. Given the pace of real estate, building plans may not exist for such developments, but district cooling can be

incorporated early on in the design process, followed by a pre-feasibility study and can even connect some existing buildings that may have spare cooling capacity or need to replace their chillers. In parallel to city consultations, policies such as mandating new developments to assess district cooling development could be applied on the SEZs in order to accelerate this process (see Box 4).

The townships and SEZs that have been developed without district cooling will be in place for many years and will replace their chiller system multiple times throughout the buildings' lifetime. Even if small district cooling networks are started within or on the periphery of such townships with greenfield sites (e.g. to the west of Blue Ridge) eventually these will be able to slowly expand and cover the whole township, connecting buildings as their chillers need replacing. This model of connection is best practice internationally and is low-risk – the building to be connected already exists and its cooling demand is already known. In order to support this long-term expansion, PMC and PMRDA could consider setting franchise zones across the SEZ for these initial networks and mandating that existing buildings assess district cooling connection when they replace their chillers.

Pune could become a centre of excellence for how to deliver SEZs with sustainable cooling and could replicate its best practice rapidly across the region and India.

11.7. Site 3: Pride World City

The Pride World City is a mega scale integrated township project, spread across 400 acres (1.61 sq. km) and located in the north-east of Pune at Charholi. Pride World City has a long-term planning horizon and is envisaged to be ready by 2032. Along with residential apartments, an IT/business park, schools, multi-speciality hospital, mall and multiplex are envisaged to come up in this township. Construction of 18 residential towers having 13 floors and occupying 35 acres (0.14 sq. km) of land is underway as of March, 2017. The residential towers will house about 1,800 apartments.

The D Y Patil Knowledge city, an integrated educational campus housing engineering, architecture, and management colleges and hostels, is located near the site.

Land around this site is vacant, though this might partly be due to the proximity to the airport. Land parcels for development have been possibly allocated. This area has witnessed significant development in the recent past. A ring road is proposed near the site, which is likely to influence future development of the surrounding area positively.

Figure 40: Location of Pride World City

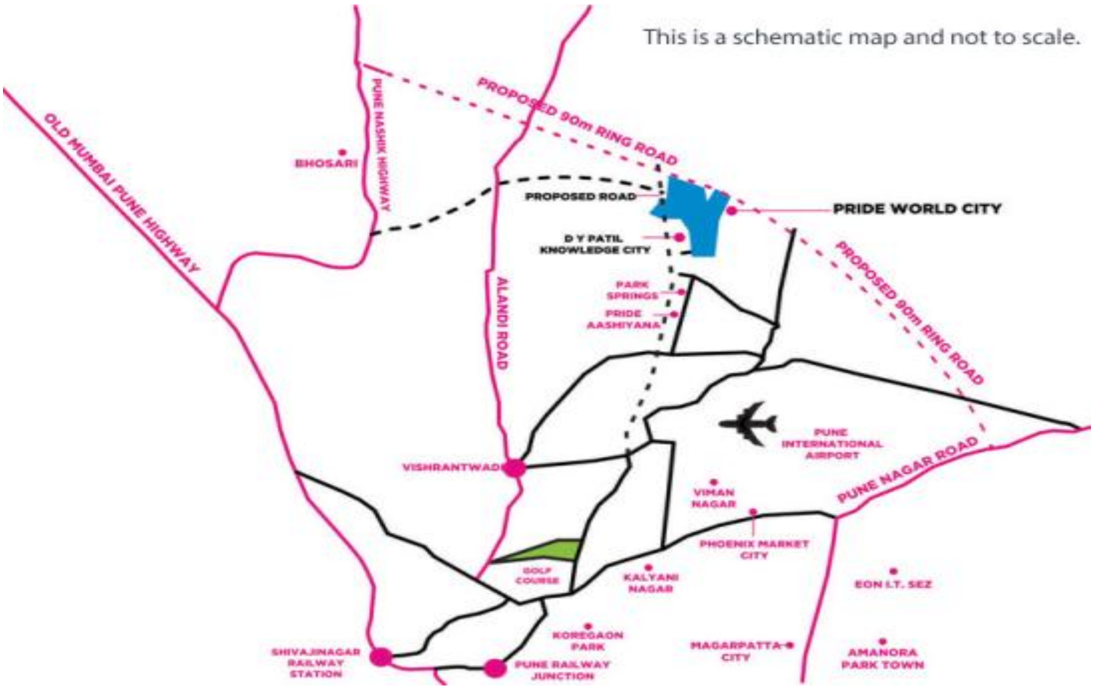


Figure 41: 3D Image of Pride World City, Charholi

Site selection criteria for Pride World City

Technical requirements	Given the scale of this integrated mixed-use township, the cooling demand in the different building typologies is expected to be significant.
Availability of anchor loads with continuous load	The site has a number of diverse buildings proposed that could serve as anchor loads such as the IT/business park, multi-speciality hospital, five-star hotel, multiplex.

and diverse buildings can be connected	
Potential for longer-term network expansion	Land around the site is largely vacant and with a transport corridor proposed, significant development can be expected in the areas around the site.
Existing situation of buildings	About 35 acres out of a total of 400 acres have been taken up for development and construction of 18 residential towers is underway as of March, 2017.
Influence from local government	The Pride World City falls under the jurisdiction of the Pimpri Chinchwad Municipal Corporation, the local government of Pune's neighbouring city of Pimpri Chinchwad which lies adjacent to Pune towards its north and north-east. The two local governments often work closely together for integrated planning and development in the larger Pune metropolitan region. The PMC can help facilitate further dialogue with the Pimpri Chinchwad Municipal Corporation. The Pimpri Chinchwad Municipal Corporation is similarly active on the local energy agenda and has been implementing the ECBC and GRIHA schemes through its regulatory framework.

Recommendations for Pride World City

The long-term planning horizon for this site offers promising opportunities for phased development of district cooling. Residential towers have already been constructed but any non-residential buildings in planning currently could be assessed for centralised cooling and district cooling. More information is required on the neighbouring education campus, but if it has centrally cooled buildings then this could serve as an anchor load for a new district cooling project. Such analysis should be undertaken by the project developer and the team promoting Pride World City, who should incorporate district cooling into the design of the whole site as early as possible. This could be a major selling point for the site, and given the long-time horizon of 2032, when sustainability and green buildings will likely have become a development norm, district cooling can future-proof the design, ensuring that properties in the future can have minimal environmental impact. Vacant tracts of land available could potentially be used to house the district cooling plant.

11.8. 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.

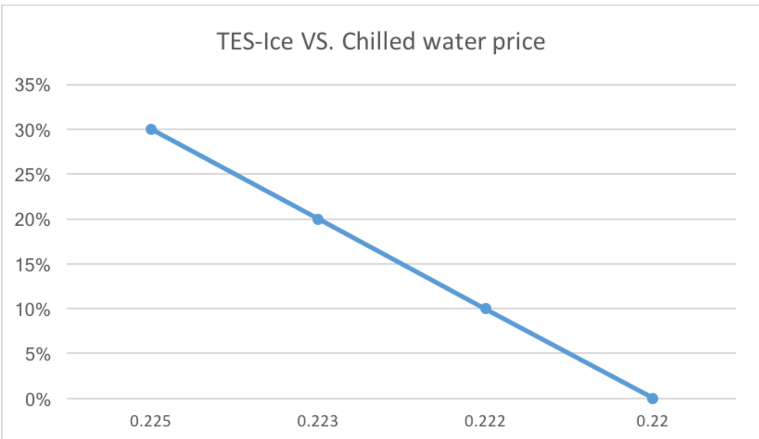
Based on the current electricity tariff in Pune and the type of projects assessed, ice storage is considered as a potential TES technology to use in a district cooling system because it has the highest cooling storage density amongst the TES technologies and as such requires far less land as compared 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 19. 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 19: 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 42 as tested on the Aundh-Baner-Balewadi 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 42: Sensitivity analysis results of coverage ratio of ice TES for peak period



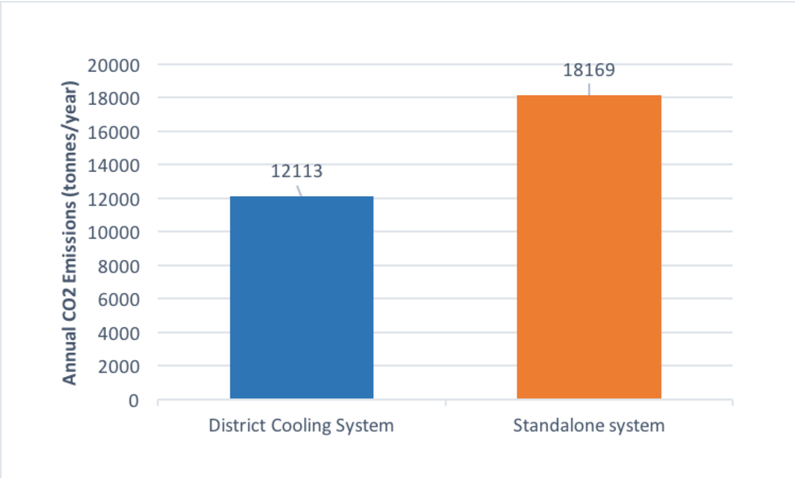
In order to make the TES system cost-effective so that the whole electrical grid can benefit from the peak load shifting, it is suggested to establish a special subsidy on electricity price of off-peak period for TES. Centralised thermal storage and the increased peak shaving it can achieve is one of 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.

11.9. 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 Aundh-Baner-Balewadi area are 6056 tons per year[48], as shown below in Figure 43. For the Blue Ridge project the savings are 3253 tons per year. Due to a lack of data for CO_2 emissions for water supply, this contribution is not included.

Figure 43: CO2 emission comparison for stand-alone and district cooling in Aundh-Baner-Balewadi



For the Aundh-Baner-Balewadi project electricity savings of 7.82GWh of electricity annually (33% reduction from stand-alone) are expected.

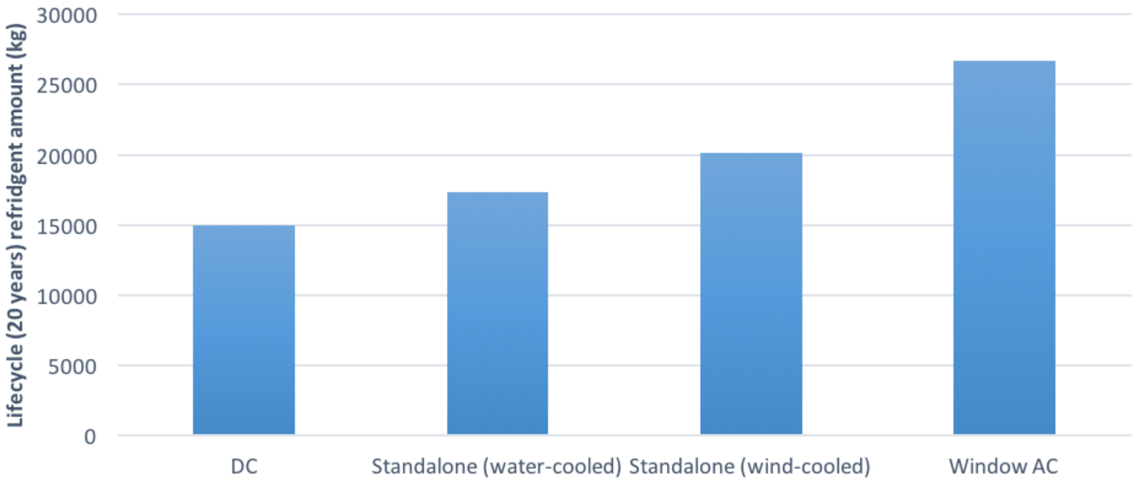
For the Blue Ridge project electricity savings of 4.2GWh of electricity annually (23% reduction from stand-alone) are expected.

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 the Aundh-Baner-Balewadi and the clustering and phasing of SEZs, it is expected that future phases would 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.

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

The district cooling system can also contribute to refrigerant phasing out, due to reduced cooling capacity in the whole district. Over the lifetime in Aundh-Baner-Balewadi this is expected to be 2.4 tonnes, as compared to water-cooled chillers. For the Blue Ridge project this is 1.3 tonnes. The calculated results for Aundh-Baner-Balewadi are shown below.

Figure 44: Lifecycle refrigerant comparison for district cooling vs. stand-alone solutions in Aundh-Baner-Balewadi



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, Pune 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 20: 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 systems analysed, 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 28 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 PMC 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 Pune for well-designed projects and can deliver significant benefits to the environment, consumers and the local economy. The climate, strong real estate growth (particularly in the IT/ITeS sector), clear existing impact of cooling demand and a local government willing to show leadership and demonstrate innovative technologies and policies to reduce the environmental impacts of the buildings sector, make Pune a high-priority city for demonstrating this technology.

Pune 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 PMC 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 Pune, this would be a missed opportunity.

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

Throughout this rapid assessment, policies and actions have been recommended to PMC that will help to accelerate district cooling in the city through improved coordination, mapping, project identification, policy development and incentive setting. These recommendations build on best practices identified in 45 champion cities for district energy around the world and published in the 2015 UN Environment report 'District Energy in Cities: Unlocking the Potential for Energy Efficiency and Renewable Energy' which is available online[49].

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

Aundh-Baner-Balewadi smart city area (see Sections 5.1 & 11.5 and Box 11)

- PMC directs smart city SPV to incorporate district cooling into the design and planning of the smart city area, particularly focusing on upcoming start-up zone and commercial zone
- Project pre-feasibility study including assessment of renewables, waste heat, smart grid synergies and Treated Sewage Effluent
- Stakeholder consultations to identify potential business models including the existing PPP for smart grid (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 PMC incentives and policies that can ensure project delivery including property tax rebates, provision of municipally owned solar power and provision of land (Section 6.4 and Box 11)

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

Blue Ridge project and existing SEZs/townships (Section 11.6 & Box 12)

- Work with building developers to identify projects to be commissioned in next 2-5 years on the periphery or within existing SEZs that can catalyse district cooling development
- Consider mandating that these projects incorporate district cooling in design (see Box 4) and undertake project pre-feasibility studies
- Support the slow expansion of these projects across the SEZ connecting existing buildings potentially with a franchise zones and mandates on buildings to assess connection

Future SEZs and townships (Section 11.7 & Box 12)

- Work with building developers early on to incorporate district cooling into SEZ design
- Consider mandating district cooling development for future SEZs and townships, supported by incentives linked to existing incentives for SEZs

City-wide actions (short-term)

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

City-wide action (medium-term)

- Establish a 'sustainable energy delivery unit' or include within the Smart City SPV
- Support piloting of innovative district cooling applications, e.g. Thermal Energy Storage (TES), waste heat connections, solar power (Section 10.2) and Treated Sewage Effluent to reduce water consumption (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 Eco-housing policy, GRIHA incentives and upcoming ECBC adoption promote district cooling development (Sections 6.2 to 6.4)

14. Annexes

14.1. Pune's Smart City Plan

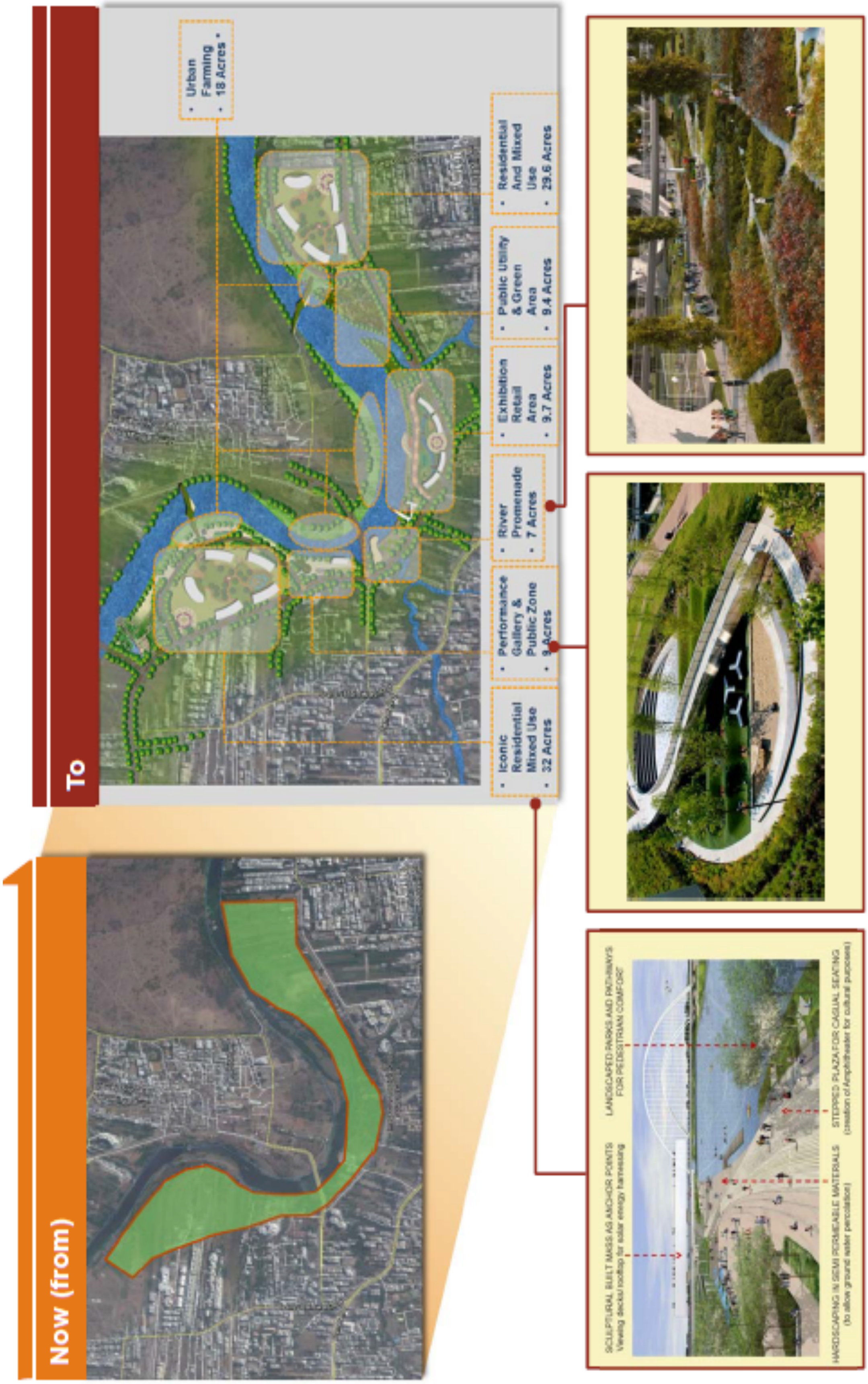
Under its **Pan-city proposal** which outlines smart solutions to be implemented across the city, Pune intends to address challenges in the priority areas of transportation and water and introduce smart technologies for these sectors. Key transportation based interventions proposed include deployment of vehicle health monitoring system for all the buses, real-time GPS tracking, and public information systems. The city also intends to implement interventions towards smart parking, adaptive traffic lights, and mobile based traffic applications. Key 'Smart Water' solutions planned to ensure 24x7 water supply to all citizens include installing smart metering at reservoirs and for end-users, utilizing helium leak detection system, conducting comprehensive GIS-based customer surveys to identify irregular connections, and use of Information and Communications Technology (ICT) for enhancing end-customer service.

Table 21: Priority Strategies for the Transport and Water Sector in Pune Smart City

Transport and Mobility	Water and Sewage
Pune Smart Public Transport System • GPS and real-time monitoring of buses • Smart bus stops with public information systems • Real-time tracking of buses through mobile apps • Vehicle health monitoring	**24x7 Water Supply Pilot** • Customer survey on GIS platform
Smart Adaptive Traffic Management System • 319 Smart Traffic Lights • Pedestrian right of way buttons and emergency response system • PA system, solar powered systems	**Grievance redressal and Smart Customer Service** • Improve customer experience
Advance Traffic Management • Using E-Challan system • CCTV and Mobile GPS based traffic analysis • Intelligent road assistant management	**Smart Bulk Meters** • With SCADA • 100% Smart Metering for commercial establishment • Smart metering for domestic household through a "Give up water subsidy" campaign
	Leak Identification • Helium technology based leakage detection across 2688 km

Source: (Pune Smart City Proposal , 2015)

Figure 45: Proposed development in the Aundh-Baner-Balewadi ABB Area



14.2. Information Collected

Table 22: Dry Bulb Temperature

Month	Avg. Daily (degrees C)	Avg. Daily Low (degrees C)	Avg. Daily High (degrees C)
Jan	19.9	11.1	28.6
Feb	21.7	12.1	31.0
March	25.8	15.4	35.9
April	28.4	19.2	37.0
May	29.1	22.4	35.8
June	26.2	23.0	30.2
July	24.4	22.3	27.0
Aug	23.7	21.5	26.4
Sep	24.3	20.7	28.6
Oct	24.3	19.9	29.9
Nov	21.8	15.4	29.2
Dec	19.4	11.6	27.8

Table 23: Wet Bulb Temperature

Month	Avg. Daily (degrees C)	Avg. Daily Low (degrees C)	Avg. Daily High (degrees C)
Jan	14.6	10.0	18.3
Feb	14.4	10.3	17.6
March	15.8	11.7	18.7
April	17.8	14.1	20.3
May	21.6	19.3	23.5
June	23.1	21.5	24.5
July	22.3	21.2	23.5
Aug	21.9	20.7	23.1
Sep	22.0	20.0	23.7
Oct	21.5	19.4	23.3
Nov	17.7	14.6	19.9
Dec	14.7	10.4	18.4

Table 24: Relative Humidity

Month	Avg. Daily (%)	Avg. Daily Low (%)	Avg. Daily High (%)
Jan	61.7	34.2	92.3

Feb	51.3	22.7	86.0
March	40.0	15.1	73.3
April	38.8	16.6	67.6
May	55.9	31.4	82.3
June	78.7	63.2	91.4
July	84.1	72.5	94.4
Aug	86.4	74.0	95.5
Sep	83.6	65.7	96.4
Oct	80.9	55.0	97.2
Nov	70.8	40.4	95.8
Dec	64.6	39.0	91.6

Table 25: Consumer Category-wise Electricity Tariff levied by MSEDCL

Consumption Slab	Fixed/Demand Charge	Energy Charge (INR/kWh)
(A) Low Tension – Residential		
0-100 units	Single phase: INR. 60 per month Three Phase: INR 170 per month	3.0
101-300		6.73
301-500		9.70
501-1000		11.20
Above 1000 units (balance units)		12.48
(B) Low Tension – Non-residential or Commercial		
0-200 units per month	INR 190 per month	5.85
Above 200 units per month (only balance consumption)	INR 190 per month	8.38
(C) Low Tension – Industry		
0-20 kW		
0 to 200 units per month	250	6.09
Above 200 units per month (only balance consumption)	250	9.32
> 20 kW and ≤ 50 kW	250	9.98
> 50 kW	250	12.55
		7.01
TOD Tariffs (in addition to above base Tariffs)		
2200 Hrs-0600 Hrs.		-1.50
0600 Hrs-0900 Hrs. & 1200 Hrs-1800 Hrs.		0.00
0900 Hrs-1200 Hrs.		0.80
1800 Hrs-2200 Hrs.		1.10
(D) High Tension – Industry		
HT I-Industry		
(A) Industry General	INR 250 per kVA per month	7.07
(B) Industry Seasonal	INR 250 per kVA per month	7.67

TOD Tariffs (in addition to above base tariff) (in INR/kWh)		
0600 to 0900 Hours		0.00
0900 to 1200 Hours		0.80
1200 to 1800 Hours		0.00
1800 to 2200 Hours		1.10
2200 to 0600 Hours		-1.50
(E) High Tension – Commercial		
All units	250	11.40
TOD Tariffs (In addition to above base tariffs)		
2200 Hrs-0600 Hrs.		-1.50
0600 Hrs-0900 Hrs. & 1200 Hrs-1800 Hrs.		0.00
0900 Hrs-1200 Hrs.		0.80
1800 Hrs-2200 Hrs.		1.10

Source: (MSEDCL, 2016)

Table 26: Pune City Category-wise Electricity Consumption Data, 2015-16

Month	Residential	Commercial	Industrial (Low Tension (LT))	Public Water Works	Street Lighting	Public Service	High Tension Consumers	Others	Total
April, 2015	167.86	59.08	22.63	0.15	5.00	1.62	181.21	0.38	437.95
May, 2015	177.13	62.36	21.94	0.29	4.70	1.54	188.68	0.38	457.02
June, 2015	171.34	62.06	22.53	0.22	4.55	1.60	176.09	0.41	438.79
July, 2015	149.80	55.20	22.06	0.19	4.56	1.57	172.77	0.39	406.55
Aug, 2015	150.87	53.72	22.22	0.25	5.06	1.69	171.10	0.43	405.33
Sep, 2015	153.14	55.37	23.35	0.18	4.69	1.80	170.85	0.37	409.76
Oct, 2015	154.01	55.00	23.42	0.21	4.62	1.84	179.92	0.45	419.48
Nov, 2015	158.03	56.78	22.31	0.25	5.54	1.55	158.71	0.43	403.60
Dec, 2015	138.97	50.79	21.79	0.12	5.50	1.45	166.65	0.37	385.66
Jan, 2016	135.09	48.86	22.46	0.24	5.73	1.61	152.42	0.49	366.90
Feb, 2016	134.72	48.80	23.36	0.13	5.59	1.74	155.55	0.41	370.29
Mar, 2016	157.92	56.95	24.01	0.14	5.56	2.04	167.63	0.38	414.63
Total	1848.90	664.98	272.09	2.37	61.10	20.05	2041.58	4.90	4915.96

Source: (MSEDCL, 2016)

Figure 46: Dissolved Oxygen (DO) Level in Mula-Mutha River, 2008-2011

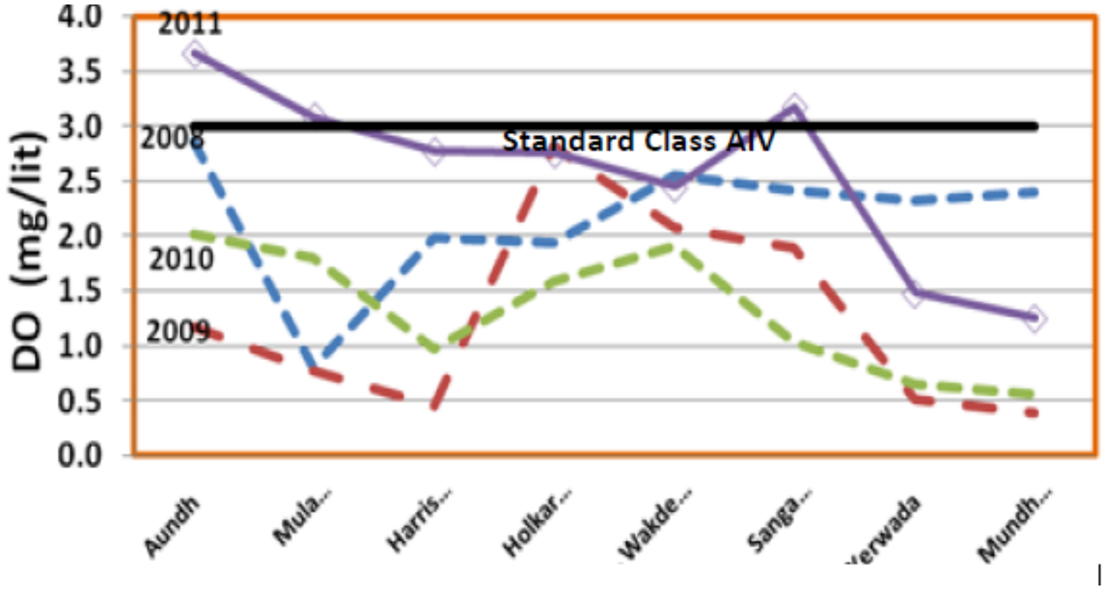


Figure 47: Bio-chemical Oxygen Demand (BOD) in Mula-Mutha River, 2008-2011

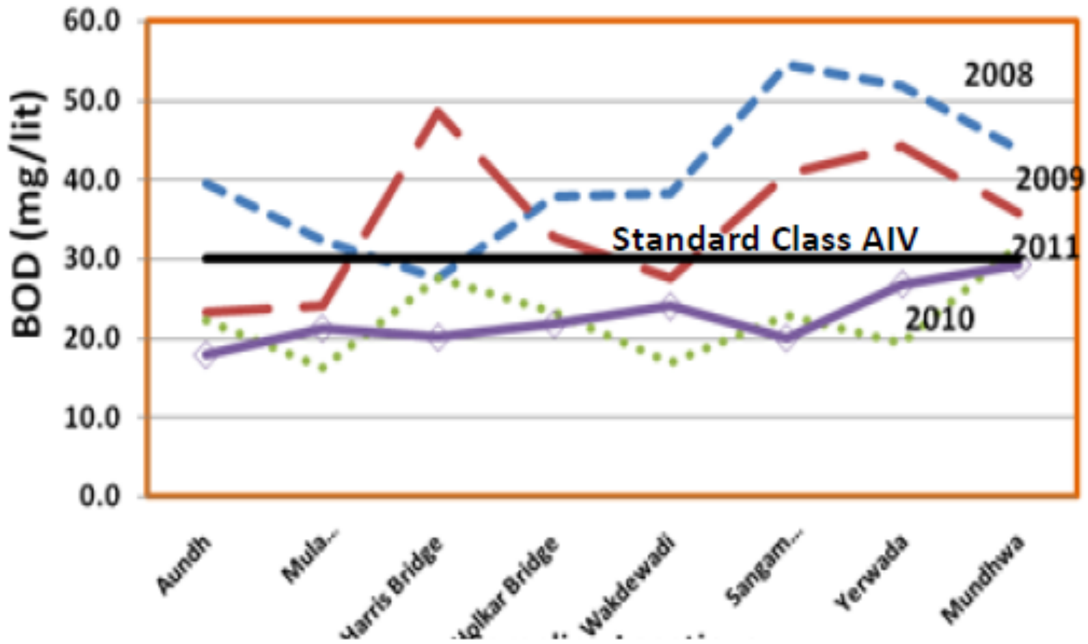


Figure 48: Chemical Oxygen Demand (COD) in Mula-Mutha River, 2008-2011

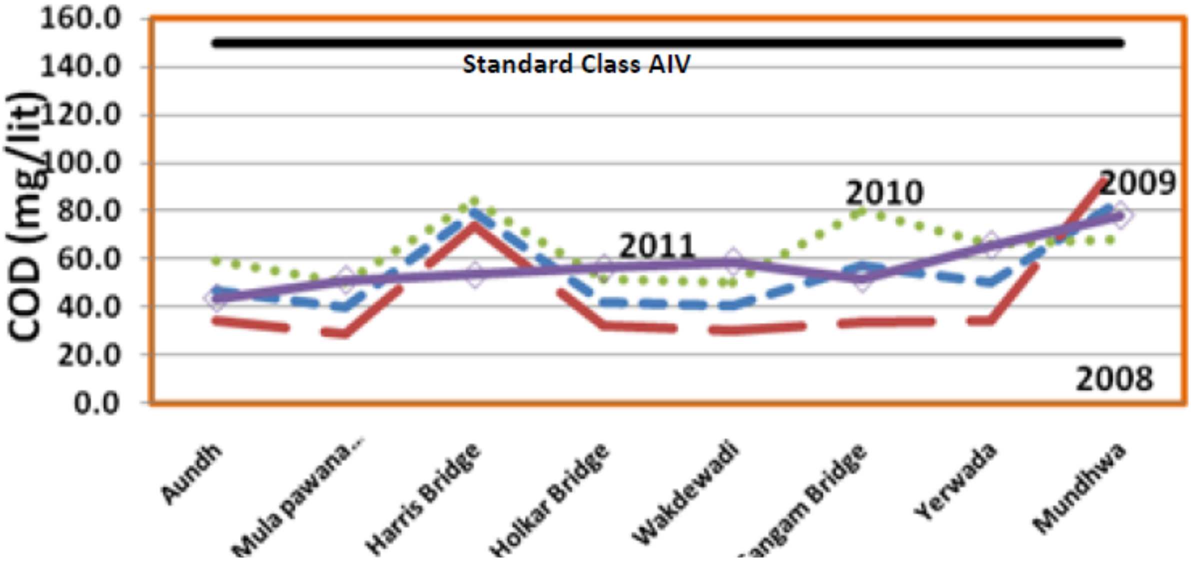


Table 27: Building Archetype Information for Pune

Site name	Total Floor Area (sq. ft.)	Ground floor area and number of floors (sq. ft.)	Size of HVAC system (RT)	Floor area to be cooled (sq. ft.)	Approx. Year of Installation	Existing /proposed cooling technology
Eon Free Zone, MIDC Kharadi Knowledge Park Pune.	Total Built-up area is 4.5 million sq. ft. across 5 clusters. Built-up area delivered: 4 million sq. ft. **Cluster A/B/C/D DETAILS** 1 million sq. ft./Each Cluster Wings 1 & 4 : 190,000 sq. ft. each Wings 2 & 3 : 290,000 sq. ft. each **CLUSTER - E DETAILS** Total built-up area : 500,000 sq. ft. (approx.)	Wings 1 & 4 : 2 lower ground floors, ground + 5 floors Wings 2 & 3 : 2 lower ground floors, ground + 7 floors CLUSTER - E : DEVELOPMENT DETAILS Levels : 4 lower ground floors, ground+7 floors	15,000 TR chiller plant capacity	3.15 Million Sq. ft.	Installation in 2008 One additional tower's chilling plant installation is under progress (as of Feb, 2017)	Air Cooled VRF System

	Cluster break-up : Cluster E comprises of two Wings Wing 1 & Wing 2 : 215,000 sq. ft. (approx.)					
Precision cooling for data centre at Tech Mahindra, Hinjewadi	3000 Sq. ft.	To be checked	105 RT	2100 sq. ft. (approx.)	To be checked	Air Cooled Precision Units.
ICC Mall, Senapati Bapat Road Pune, Maharashtra 411016	400000 sq. ft.	4 floor	1739 RT 600 tonnes approx. chilling plant capacity Water	280000 sq. ft.	On-going (will be completed in next 5 months)	Water Cooled Chilled Water System
J W Marriot, Senapati Bapat Road, Pune, Maharashtra 411053	Total built up area is 462848 sq. ft.	Ground floor built up area is 99027 sq. ft. 18 floor (basement+ terrace)	1440RT Four chiller plants with capacity of 350 RT each	370278 sq. ft.	2010	Water Cooled Chilled Water System In-campus STP water sourced for chilling plant. STP is of 350kl per day capacity.

Tech Mahindra Ltd, Hinjewadi Pune	853988 Sq. ft.	To be checked	3000 RT	To be checked	To be checked	Air Cooled VRV
Ruby Hall Clinic, 40, Sassoon Road, Pune, Maharashtra 411001	466675 Sq. ft.	Information expected in the coming week	3 chilling Plant in total in this site: 2 operation and 1 as standby 450 RT total capacity of three chilling plants	326672 sq. ft.	1997 installation	Water Cooled Chilled Water System

Table 28: Permissible FSI and TDR for plots in congested and non-congested area

Sr. No.	Road width in Meter	FSI Permissible (base)	Additional FSI on payment of premium	Maximum Permissible TDR	Maximum Permissible (FSI) on the plot
Congested areas					
1	Below 9 m	1.50	--	--	1.50
2	9 m and up to 12 m	2.00	--	--	2.00
3	12 m and up to 18 m	2.00	0.25	--	2.25
4	18 m and up to 24 m	2.00	0.25	0.25	2.50
5	24 m and up to 30 m	2.00	0.25	0.50	2.75
6	30 m and above	2.00	0.25	0.75	3.00
Non-congested areas					
1	Below 9.0	1.10	--	--	1.10
2	9 m and up to 12 m	1.10	0.30	0.40	1.80
3	12 m and up to 18 m	1.10	0.50	0.65	2.25
4	18 m and up to 24 m	1.10	0.50	0.90	2.50
5	24 m and up to 30 m	1.10	0.50	1.15	2.75
6	30 m and above	1.10	0.50	1.40	3.00

Source: (Development Control and Promotion Regulation for Pune Municipal Corporation , 2017)

Notes:

(1) For the other Non-Residential buildings (except Residential and Residential with mixed-use) the basic FSI for each type of building shall be 1.25

(2) Additional FSI up to 0.20 on payment of premium shall be allowed for the redevelopment of authorized residential buildings located on roads having width below 9 m, subject to condition that the construction redevelopment shall be allowed only if the building is more than 30 years old.

Table 29: Provisions in Pune's DCPR, 2017 with regards to energy efficiency and space cooling in buildings

Some of the provisions given in the DCPR, 2017 having relevance to air conditioning include

- Where the lighting and ventilation requirement are not met through day lighting and natural ventilation, the same shall be ensured through artificial lighting and mechanical ventilation as per the latest revision of National Building Code of India published by the Indian Standards Institution. In the case of special types of buildings requiring artificial lighting and air-conditioning for special types of manufacturing or other process, the requirements about natural day lighting and ventilation may be relaxed.
- No electrical shafts/panels/AC ducts or gas pipes etc. shall pass through or open in the staircases/stairways.
- The planning, design and installation of electrical installations, air-conditioning and heating work shall be carried out in accordance with Part VIII Building Services, Section 2- Electrical Installations, Section 3- Air-conditioning and Heating of National Building Code of India.
- The air handling of units shall as far as possible be separate for each floor and air ducts for every floor shall be separate and in no way interconnected with the ducting of any other floor

14.3. 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 30: Assumptions of Occupancy

Time	Hotel	Office	IT Office	Shopping mall	Hospital	Residential Apartment	Campus building
0	65%	5%	40%	40%	50%	90%	5%
1	65%	5%	40%	20%	50%	90%	5%
2	65%	5%	40%	20%	50%	90%	5%
3	65%	5%	40%	0%	50%	90%	5%
4	65%	5%	40%	0%	50%	90%	5%
5	65%	5%	40%	0%	50%	90%	5%
6	65%	5%	40%	0%	60%	80%	5%
7	65%	10%	40%	0%	60%	80%	10%
8	65%	25%	75%	0%	75%	50%	25%
9	65%	35%	75%	20%	75%	30%	35%
10	65%	60%	75%	45%	85%	30%	50%
11	70%	75%	75%	60%	75%	50%	75%
12	70%	75%	75%	80%	60%	60%	90%
13	70%	80%	75%	80%	60%	50%	80%
14	70%	80%	75%	80%	85%	30%	80%
15	70%	80%	75%	90%	85%	30%	80%

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

Building design parameters

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

Table 31: 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

14.4. Summary of meetings

Date	Meeting
23rd November, 2015	Representatives from EMPOWER, ICLEI South Asia, Danfoss met with Pune Municipal Corporation officials and Smart City Consultant
24th Nov, 2015	DES Team has met the following officials and held discussion on the potential of district cooling systems in the city of Pune: (1) Mr. R.S Kulkarni, ISHRAE Member and HVAC Expert (2) Mr. R.D Munde, Chief Engineer (Pune Zone), MSEDCL (3) Mr. Aditya Chunekar, Prayas (Energy Group)
25th Nov 2015	DES Team Site visit to Baner Area
24th to 27th January, 2016	Meeting were conducted by ICLEI South Asia team with • Mr. Shivaji Lanke, Engineer, Buildings Department, Pune Municipal Corporation • Prashant Waghmare, Town Planner, Town Planning Department, Pune Municipal Corporation • Anuja Gokhale, Smart City Team Member • Mr. Varun, Panchshil Realty • Mr. Pradeep Mishra, Amanora Park Town • Mr Malay Deshmukh, Magarpatta City • Mr. Ajit Gaikwad and Mr. Abhijeet Gaikwad, AG Constructions • Mr. Tanuj Nagrani, Pune Premium Properties

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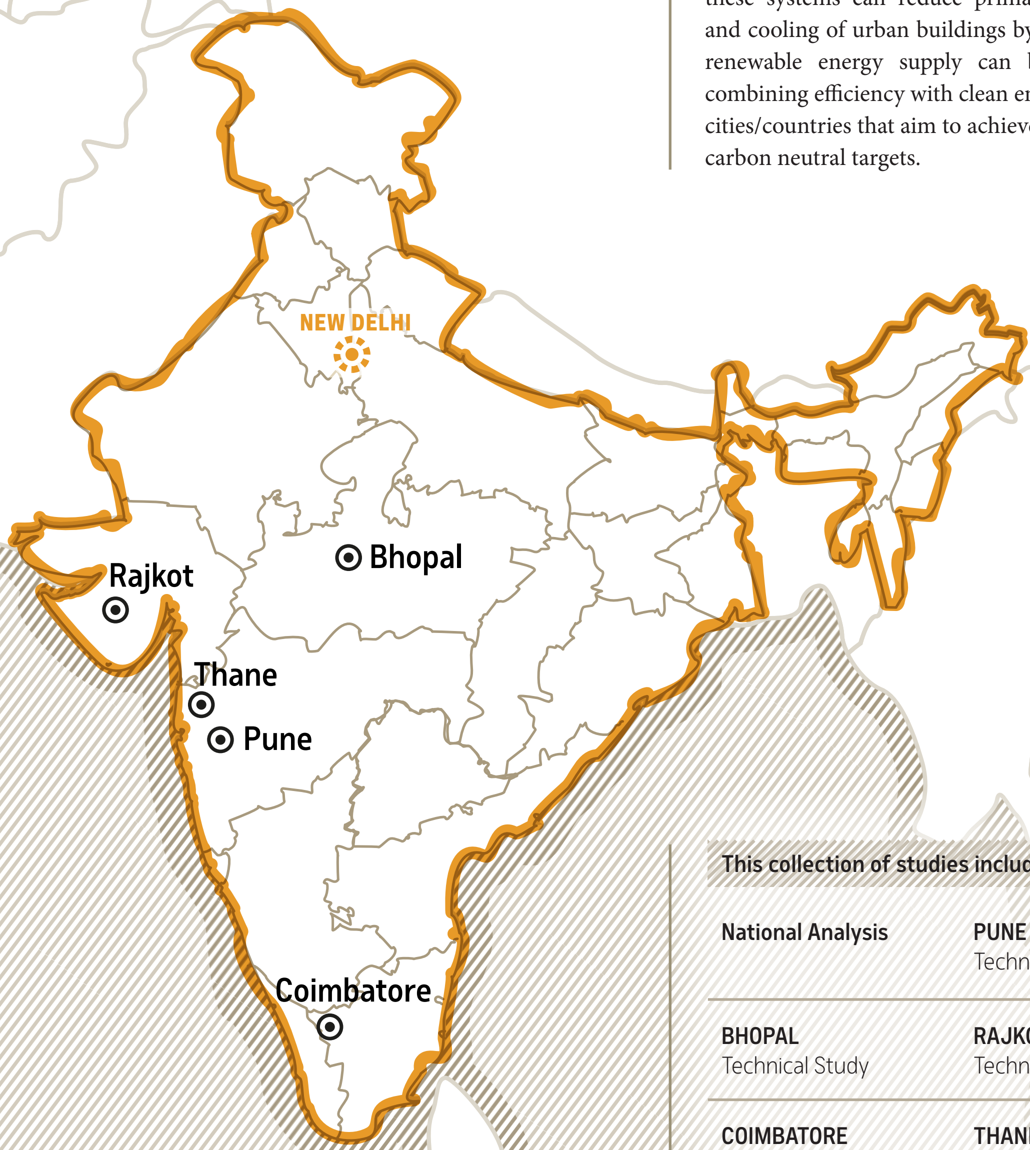
RAPID ASSESSMENTS OF FIVE INDIAN CITIES

The District Energy in Cities Initiative is a multi-stakeholder partnership that assists developing countries and cities to accelerate their transition to lower-carbon and climate resilient societies through promoting modern district energy systems. District energy systems are intelligent energy infrastructure, efficiently integrating clean sources of energy for cost-effective heating and cooling.

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



This collection of studies includes

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

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