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District energy in cities initiative

Rapid assessments of five Indian cities - Executive summary

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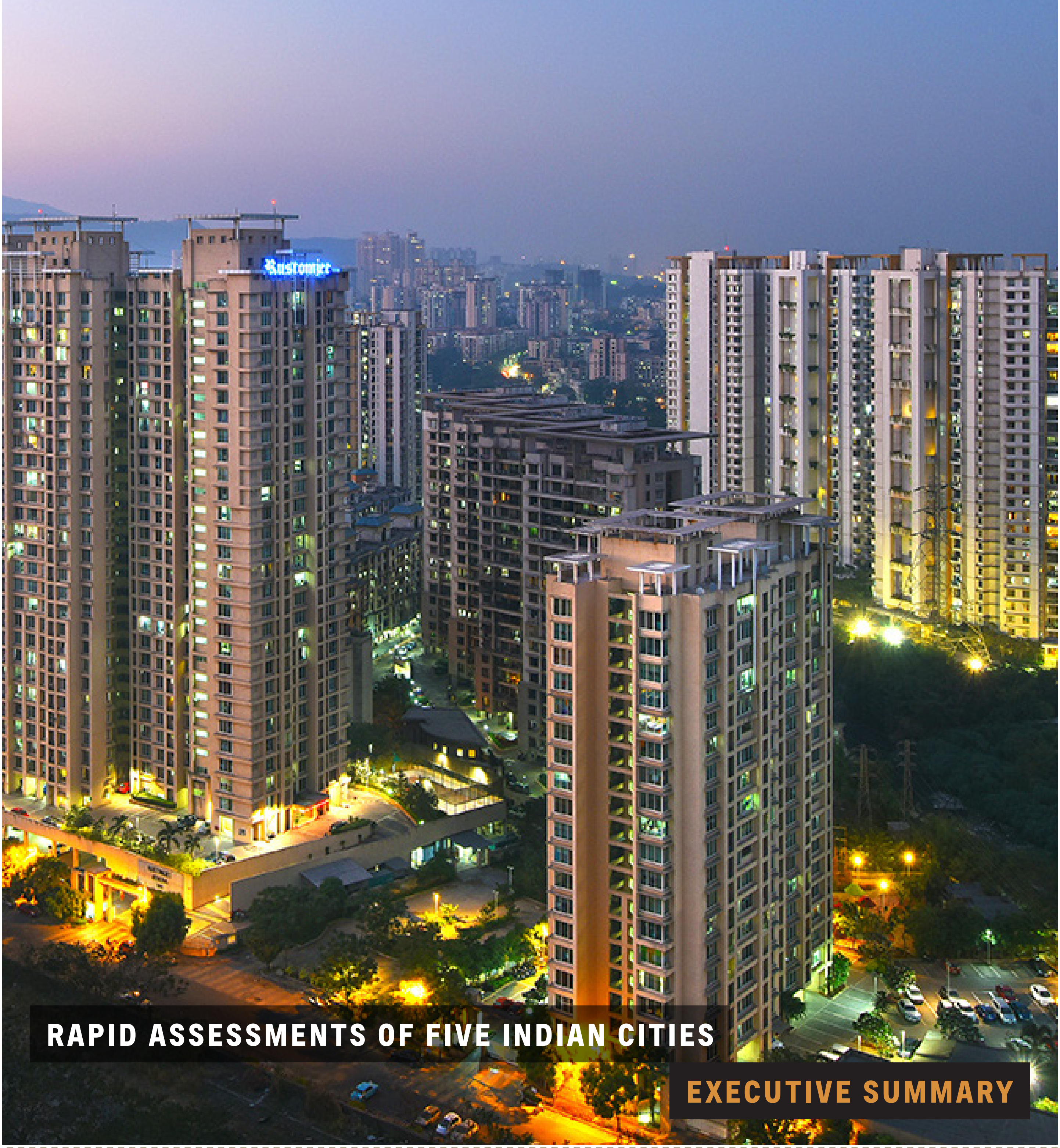

RAPID ASSESSMENTS OF FIVE INDIAN CITIES

EXECUTIVE SUMMARY

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 all 5 Municipal Corporations that took part in this study and for agreeing to be a part of the District Energy in Cities Initiative. We are grateful for all the support extended by the Municipal Corporations and their departments to this exercise. We extend our sincere thanks to administrators, government departments and stakeholders across all five cities whose inputs and contribution to data collection have been invaluable to the successful completion of the district cooling rapid assessment in Thane and the compilation of this document.

The Initiative

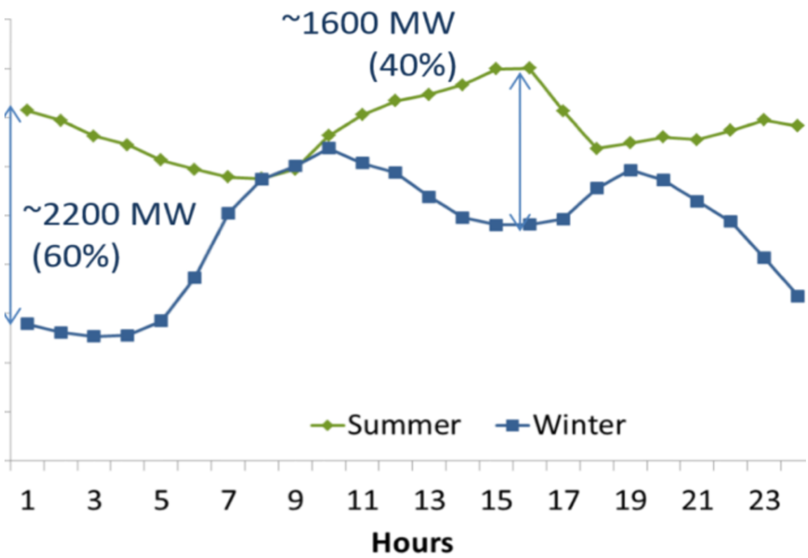
The District Energy in Cities Initiative is a multi-stakeholder partnership coordinated by UN Environment, with financial support from the Global Environment Facility and the Governments of Denmark and Italy. As one of six accelerators of the Sustainable Energy of All (SEforAll) Energy Efficiency Accelerator 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

Today, 30% of Indians live in cities and it is estimated that by 2050, this figure will reach 50% [1]. Cities are the powerhouses of India's economy and will contribute nearly 70% of the country's GDP by 2030 [2]. Rapid urbanisation and rising income levels means the real-estate market is one of the largest in the world and responsible for 8% of India's GDP, growing to a potential 17% by 2025% [3]. Cities consume 80% of India's electricity demand [4] and an increasingly significant contributor, albeit well hidden, is electricity demand for space cooling.

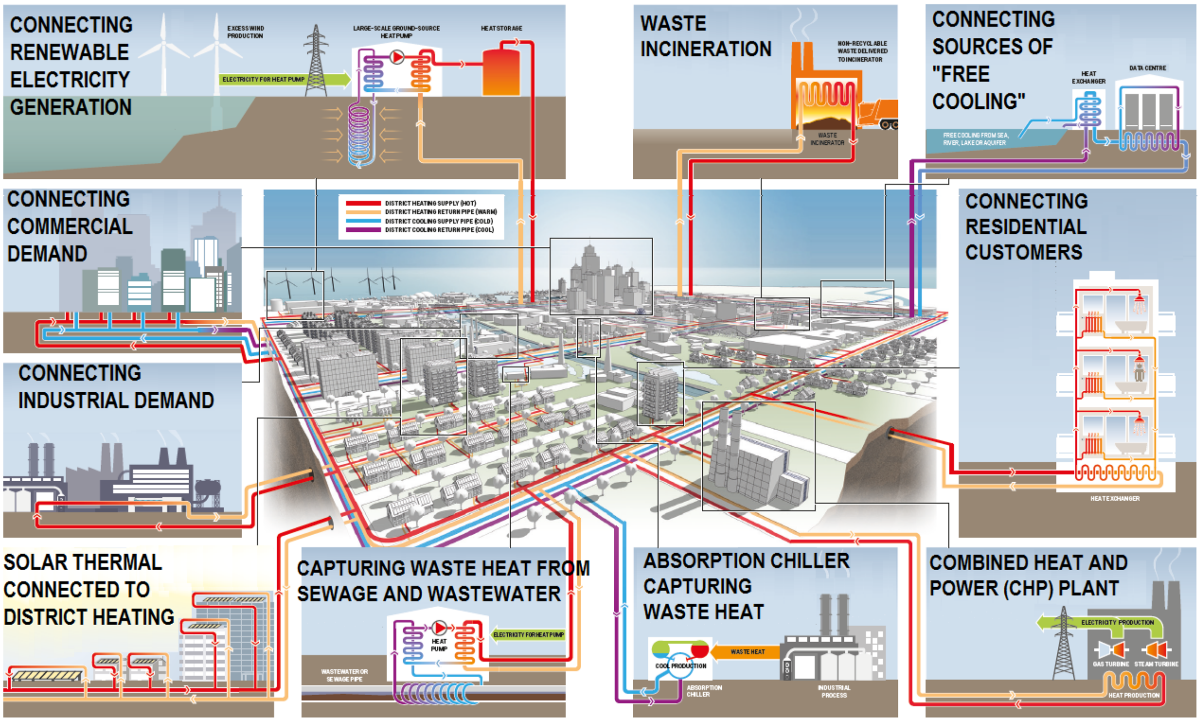
In Delhi, space cooling already contributes at least 40% of the peak load in summers and air conditioning is primarily responsible for the seasonal variation in electricity demand [5]. This demand for space cooling is having huge impacts both economically and environmentally with significant investments in the electricity system needed to meet this growing power demand, coupled with rising emissions of CO_2 and refrigerants and increasing use of potable water for cooling. The concentration of cooling demand in cities, the increasing attention of city governments on sustainability and the rapid growth of city real estate risking significant infrastructure lock-in makes city action on space cooling critical.

Figure 1: Average Hourly Power Demand in Summer and Winter for Delhi [5]



Globally, cities are turning towards district energy systems to provide their heating, cooling and hot water. Such systems are becoming the new norm for modern, smart cities given their ability to integrate multiple sectors, incorporate large scale renewables and waste heat, lower electricity demand for cooling by up to 50%, shift peak demand for electricity and deliver improved and lower cost heating or cooling for customers [6]. There are very few district cooling systems in India, but the potential of this technology to serve India's burgeoning cities is enormous. Analysis represented in these reports shows that for many real-estate developments, district cooling systems are cheaper, can deliver significant returns to project owners (up to 15-17% - see page 8 onwards) and a significant improvement environmentally on current cooling technologies.

Figure 2: District energy systems for a smart city: improving efficiency, connecting renewables and integrating sectors [6]



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 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. 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.

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

Introduction to the cities

Bhopal: Major hub for educational, administrative, political and industrial activities. Strategically located at the centre of India, Bhopal has strong transport connections with the rest of the country. As the state capital, Bhopal drives the state of Madhya Pradesh's economy and the city is viewed as an attractive investment destination.

Coimbatore: The city is the second largest in the state of Tamil Nadu and is a major industrial center and a renowned IT and educational hub in the state. The city is witnessing significant growth in residential as well as commercial and service sector related development. The city has a relatively pleasant climate and space cooling is not universal in all building types.

Pune: Formerly an educational and administrative centre, Pune is now one of the most attractive business centres in India and a hub for the IT industry, leading to rapid growth in the real estate market. Pune uses highly innovative policy instruments to promote sustainability such as the city's Eco-Housing Programme.

Rajkot: Rajkot is a major industrial centre known particularly for manufacturing, forging industries and casting industries. With increasing industrial, trade and commerce activity, there has been significant growth in the city focused through effective planning policy along the major arterial roads. Rajkot is a pilot city of the Sustainable Energy for All (SEforALL) Building Efficiency Accelerator.

Thane: Economic growth in Thane has been driven mainly by the IT industry, helped by Thane's vicinity to Mumbai, which has led to a rapid expansion in commercial, retail and residential real estate. Thane aims to become 'carbon neutral' in it city operations and has demonstrated solar cooling and storage of cooling.

Table 1: Overview of city characteristics [7]

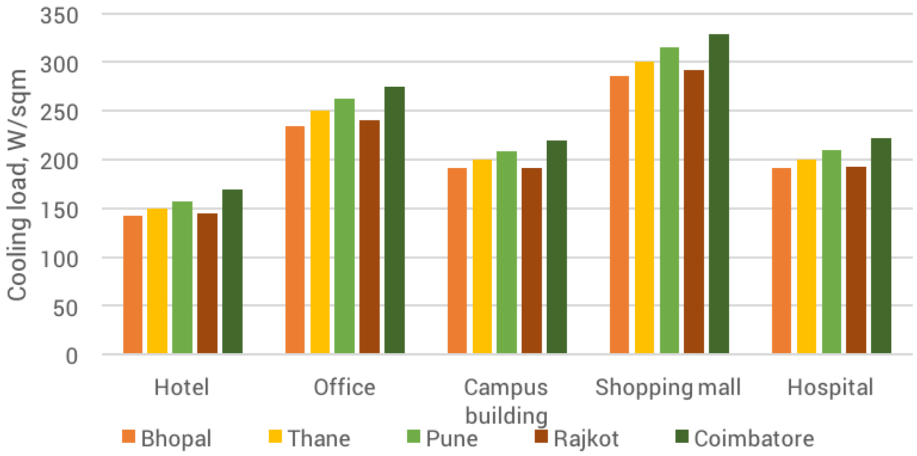
	Bhopal	Coimbatore	Pune	Rajkot	Thane
Population (2011)	1,798,218	1,610,000	3,115,431	1,346,000	1,840,000
Population growth	2.2%	1.6%	8.5%	4.3%	3.8%
Population density (persons per sqkm)	6,290	6,300	12,777	12,289	14,360
Main economic activities	Manufacturing (electrical, transport equipment), Tourism, Administrative, Services	Manufacturing (Textile, Engineering, IT), Education, Healthcare	IT Services, Manufacturing (Auto and Engineering), Education	Industry incl. forging and casting; manufacturing incl. bearings, car parts, and machine tools	IT Services, retail, service sectors, education
Average temperature	25°C	29°C	24°C	27°C	27°C
Average humidity	55%	66%	66%	61%	72%

	Bhopal	Coimbatore	Pune	Rajkot	Thane
Annual cooling degree days (base 23°C, year 2016)	1,530	1,623	1,194	1,952	1,969
Annual electricity demand	1.5 TWh	2.3 TWh	4.9 TWh	1.5 TWh	1.75 TWh
Electricity demand growth	6.9%	15.7%	8.6%	6.1%	3.7%
GHG emissions (tCO_2 per capita)	Not available	2.44	1.46	1.32	1.05

Climate and cooling demand

The relatively high average temperatures and humidities shown in Table 1 indicate that in all cities there is a suitable climate to support district cooling systems. However, space cooling is dependent on more than climate. Building efficiency, building occupancy and affordability are all significant drivers of air conditioning and make calculating cooling demands for generic building archetypes very difficult. Building occupancy and interior heat gain have a higher impact on cooling demand, especially for commercial buildings, than climate. Figure 2 shows the calculated variation in cooling load by city for different building archetypes. Cooling load will vary significantly from building-to-building, but these values have been used as an approximate guide during the rapid assessments.

Figure 2: Variation by city of cooling load for five building archetypes* [8]



** internal calculations Based on recommendations from handbooks of ISHRAE and ASHRAE (see full report)*

More accurate cooling load analysis will be needed at more detailed stages of project assessments as overestimated cooling load of buildings can significantly impact the profitability of district cooling. Cooling loads should be based on real cooling data obtained from metering where possible.

District cooling systems can only connect to buildings with centralised cooling systems (air-cooled or water-cooled). Centralised cooling of buildings is not necessarily the norm and varies significantly dependent on the city's climate, building size and also on the sector. Small-scale commercial and residential buildings are unlikely to have centralised cooling, for public offices it varies significantly and large-scale commercial, offices, hotels and hospitals all tend to have centralised cooling. All cities could promote centralised cooling in areas of high district cooling potential.

Residential buildings were not included in final project designs in these rapid assessments, although they were considered, especially luxury apartments in the vicinity of other building types. There are multiple reasons for this principally: residential buildings have lower cooling consumption compared to commercial buildings; residential buildings are unlikely to be developed with centralised cooling systems; they often access a subsidised, lower electricity tariff than commercial rates; individual homes have varying preferences for thermal comfort; and multiple apartments are more difficult to bill for cooling demand.

Growing electricity demand

Electricity consumption in all the cities is distinctly seasonal and in direct correlation with humidity and/or temperature. This seasonality is expected to be predominantly caused by space cooling and will only grow as demand for air conditioning increases, increasing the difference between peak and off-peak electricity demand. Furthermore, from consultations in the cities, it is known that large offices, retail and some hospitals will be using air conditioning year-round (see Korum Mall example in Table 3).

Table 2 shows the difference between the highest and lowest monthly consumptions in each city and Figure 3 shows the profile of electricity and temperature in Bhopal. The peak of electricity consumption is actually in July as this month has the highest average relative humidity at 90% (rather than May which experiences highest average temperature).

Table 2: Difference between highest and lowest monthly electricity consumption [9]
Figure 3 Bhopal monthly consumption and monthly average temperature [10]

	Highest monthly consumption (GWh)	Lowest monthly consumption (GWh)	Percentage increase from baseload
Bhopal	147.92	95.39	55%
Coimbatore	204.01	184.13	11%
Pune	457.02	366.9	25%
Rajkot	143.97	101.94	41%
Thane	256.597	180.205	42%

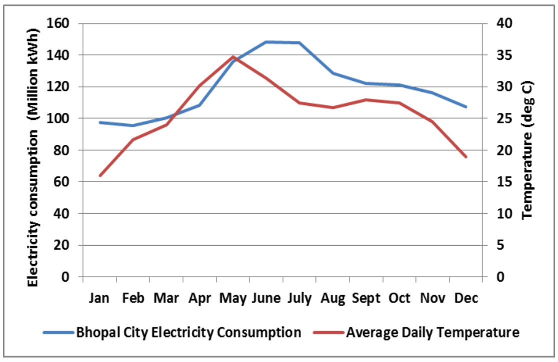


Table 2 and Figure 3 only show total monthly consumption as no data was made available for hourly or daily electricity demands. It can be expected that comparisons of peak power demand (i.e. in MW) and typical baseload power demand will yield higher percentage differences. The impacts of such seasonality are enormous with state utilities having to make significant investments in power system upgrades to meet the peak power demand caused by space cooling.

In India and in other countries, it is difficult to analyse cooling demand as it is hidden inside electricity data. There also no general metrics for estimating the cooling demand of a single building. This means that the impacts of cooling demand are relatively hidden, making evidence based policy on the sector more difficult to achieve. It is recommended that a national study on current and future impacts of cooling is developed and a national institution identified to improve monitoring and reporting of cooling demand. Such a national could build on state-level studies.

Table 3: Building example: Korum Mall, Thane [11]

Specification	Details
Installed Capacity	2,400 tons of refrigeration (TR)
Floor space cooled	325,608 sqft (30,250 sqm)
Peak power consumed by cooling system*	1.3 MW
Summer/Winter monthly electricity consumption	407 MWh / 256 MWh
Annual electricity consumption	3600 MWh
CO2 emissions due to space cooling*	2786 tCO_2/yr

** Calculated*

Archetype analysis

Between the cities, cooling demand, dense developments, electricity price and the proclivity of buildings to use centralised cooling are the main factors in determining the commercial viability of district cooling. Water price, land cost and labour cost also have an effect but it is significantly less.

Figure 4: Comparison of time-averaged electricity prices across all cities as paid by district cooling plants and stand-alone commercial cooling systems [8]

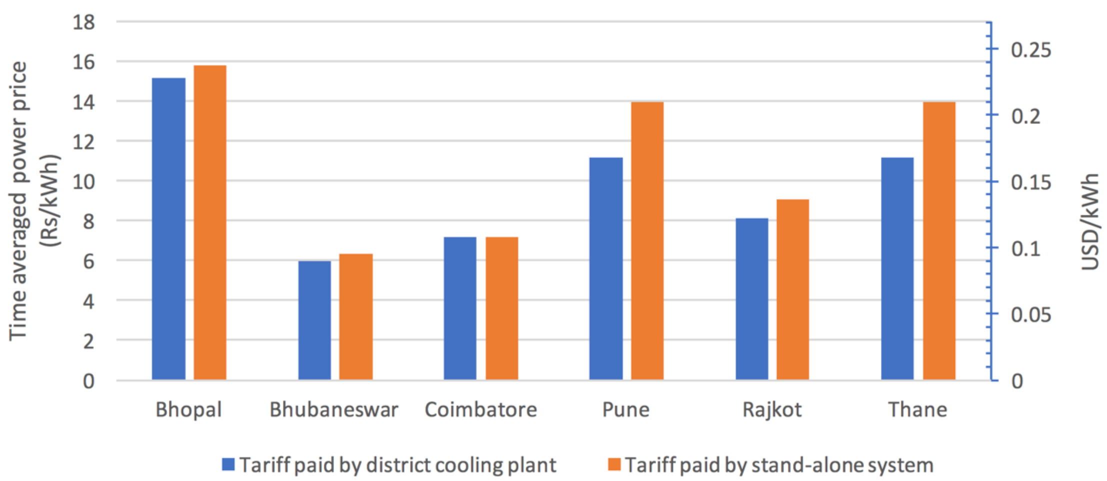
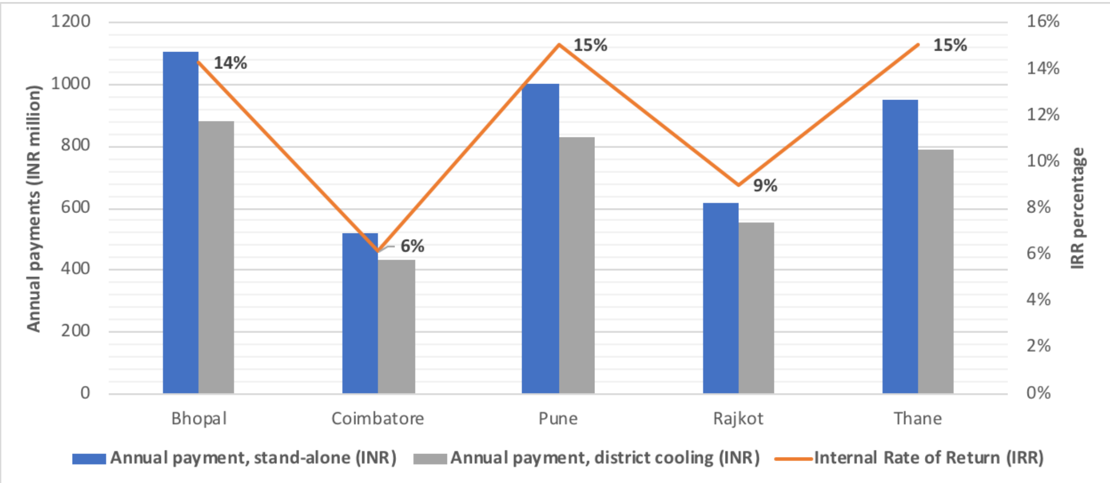


Figure 5 and table 4 below, shows the baseline assumption and findings for a typical mixed-use development across the cities served by an electricity-based district cooling system. The prices paid for cooling vary by city primarily due to the varying electricity prices in each city.

Table 4: City comparison for mixed-use development archetype [12]

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
Discount on annual operating cost for connecting to district cooling system[1]	20% relative to stand-alone costs		
Total connection fees paid by all consumers	20% of upfront district cooling investment		
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%		

Figure 5: Comparison of IRR in each city and of the annual district cooling payments made by consumers vs. payments by those using stand-alone systems.[2]



With such returns on investment, from a fast comparison of one development archetype, it can be seen that given favourable financing support district cooling projects would be profitable to investors, beneficial to the environment and lower-cost to the consumers.

1 The district cooling charges do not include VAT as information on chilled water VAT was unavailable. Electricity VAT varies by state. As such a 20% ceiling was added to ensure that even if DC payments had to increase by 20% to pay sales tax, the system would still be better value for customers.

2 The Internal Rate of Returns (IRR) calculated are the project IRRs, i.e. they are independent of financial structuring and debt to equity mix

Although some cities it is far easier to make a return from district cooling, none of the cities should rule the technology out as in all cities, a well-designed district cooling system with supportive policies and incentives could be a better option than stand-alone systems for many development types, especially under the framework of smart city. The district cooling system is considered as smart energy with high operation efficiency. To ensure commercial viability, detailed feasibility studies need to be undertaken of projects and for greenfield projects district cooling to be considered as early in the development cycle as possible.

Project analysis

Within each city, in-depth consultations have been held with local stakeholders to raise awareness of district cooling and identify upcoming urban developments that could incorporate district cooling as a demonstration project. Some existing developments have also been selected and analysed as if the site had been developed with district cooling from the beginning. Below one project from each city is presented and further projects are detailed in the full reports. Large projects will in reality be developed over numerous phases as buildings are developed, as such investments will be spread out significantly. Recommendations are targeted at specific cities, but many will be relevant across all cities [13]

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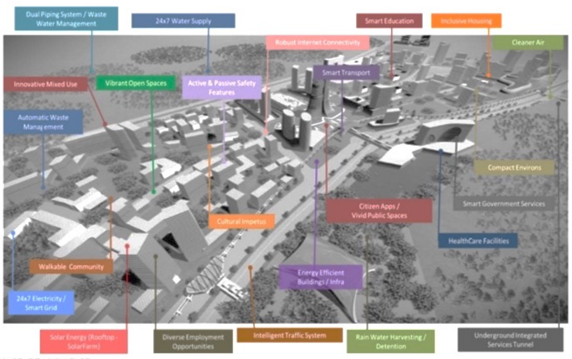
<tr><td rowspan="7">
</td><td>Bhopal</td><td>T.T. Nagar Smart City Area</td></tr>
<tr><td colspan="2">A 380-acre site selected by Bhopal as the area based development under the Smart City plan. Development has already begun on portions of this project.</td></tr>
<tr><td colspan="2">Built-up area assessed for district cooling:
12.9% Hotel, 61.4% Office, 8.6% shopping mall, 17.1% hospital,
Total built-up area: 820,299 sqm</td></tr>
<tr><td colspan="2">Capacity of district cooling system: 38,924 TR</td></tr>
<tr><td colspan="2">IRR and payback: 15%, 11 years</td></tr>
<tr><td colspan="2">Total investment: INR 5.9 billion, $ 88 million</td></tr>
<tr><td colspan="2">Benefits: 17 ktCO_2/yr reduction; 22 GWh/yr of electricity saved; 6.5 tonnes of refrigerant saved over project life cycle</td></tr>
<tr><td colspan="3">Important features:
• 80% green & efficient buildings target
• Planned buildings are mandated to get LEED/GRIHA
• Existing buildings must upgrade to receive green building certification.</td></tr>
<tr><td colspan="3">Next steps:
• Detailed project pre-feasibility undertaken immediately before development accelerates, particularly on the area of phase II of the adjacent Shrishti CBD project which is up for development in 2018 and will include a new mall and 5-star hotel. Focus on non-residential buildings.
• Detailed design of district cooling system incorporated into the smart city plan
• Extend mandates on the zone to require connection to district cooling and showcase how district cooling can help meet LEED standard.
• Require district cooling evaluation in buildings' refurbishment plans in order to receive certification.</td></tr>
</table>

Coimbatore	CHIL-SEZ, Saravanapatti
A 250 acre integrated township just outside of Coimbatore with IT/ITES. Some buildings have already been constructed.	
Built-up area assessed for district cooling: 0.9% Hotel, 97.2% Office,1.9% shopping mall Total built-up area: 1,751,222 sqm	
Capacity of district cooling system: 109,889 TR	
IRR and payback: 11%, 15 years	
Total investment: INR 16.5 billion, $248 million	
Benefits: 50 ktCO_2/yr reduction; 65 GWh/yr of electricity saved; 12 tonnes of refrigerant saved over project life cycle	

Important features:

- The area is an IT Special Economic Zone (SEZ) and will have be an integrated township with commercial offices, apartments, hotel, hospital, entertainment complex and malls
- The site is privately owned and being privately developed
- The site is outside the city limits and falls under the jurisdiction of the regional development authority rather than the city's municipal corporation
- 25% of the SEZ is already operational with major buildings using centralised cooling

Next steps:

- Project pre-feasibility of the CHIL-SEZ is recommended and further consultation with the private developer. The private developer could offer district cooling as a service, providing better cooling for customers and receiving long-term steady revenues from the real estate project. The private developer could use district cooling to attract tenants seeking sustainable premises.
- Project re-design and pre-feasibility is needed to identify commercially viable solution. Low power prices (see Figure 4) make business case of district cooling difficult in Coimbatore as energy efficiency does not deliver returns as in other cities. Project re-design could explore:
    - reducing capital cost of district cooling below that of stand-alone
    - increasing connection charges paid by building owners to above 20% of initial CAPEX
    - identify low-cost financing
    - ensure VAT on chilled water is low
    - special electricity tariffs provided
- As the project is outside Coimbatore city's jurisdiction, the wider planning bodies at the metropolitan and state-level could use their significant planning authority to promote centralised cooling and district cooling, possibly through increased FAR allowances. This could be linked to existing benefits provided as it is a SEZ.

Pune	Blue Ridge Township, Hinjewadi
138-acre integrated township that includes a SEZ and caters the IT sector. Phase II of the development is currently under construction	
Built-up area assessed for district cooling: 5.9% Hotel, 42% Office, 2.2% shopping mall, 42% IT office, 7.9% school Total built-up area: 181,289 sqm	
Capacity of district cooling system: 10,539 TR	
IRR and payback: 14%; 12 years	

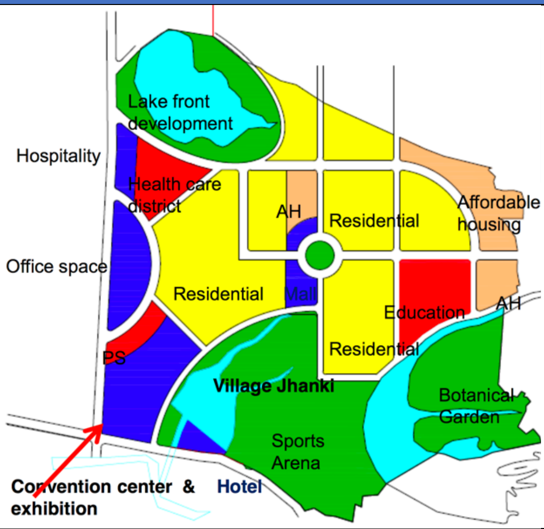
	Total investment: INR 1.6 billion, $24 million
	Benefits: 3.2 ktCO_2/yr reduction; 4.2 GWh/yr of electricity saved; 1.3 tonnes of refrigerant saved over project life cycle

Important features:

- Given the rapid mixed-use development taking place in the Hinjewadi area and the large cooling demand of the IT offices in the area, some of which operate 24-hours a day, favourable conditions exist for establishment of district cooling networks.
- Treated wastewater at the site could be used for district cooling
- Zonal development enables application of policies and incentives to the zone

Next steps:

- As 70% of the construction in the township had been completed as of March 2017 and all construction will be finished by the end of 2018, it is unlikely that district cooling will be used in Blue Ridge unless further development occurs. Blue Ridge was selected to demonstrate the viability of district cooling in an integrated township in Pune, for which there are many upcoming.
- It is recommended that Pune city and the metropolitan authority require district cooling assessments in upcoming townships, SEZs and in the city's smart city area. These assessments should be undertaken by experienced consultancies and should begin as early in the project cycle as possible. Where district cooling is shown to be commercially viable, the city can use its various planning powers to encourage district cooling development.
- PMC could explore how its GRIHA and Eco-housing policy could be extended to incentivise district cooling
- Building developers can benefit significantly from developing district cooling, enabling them to sell a service that provides long-term steady revenues.



Rajkot	Raiya Area
494 acre Raiya area is the area-based development for Rajkot's Smart City Plan and is greenfield project yet to begin construction	
Building mix assessed for district cooling: 3% Hospital, 26% shopping mall, 58% office, 13% IT office Total floor area: 249,841 sqm	
Capacity of district cooling system: 15,068 TR	
IRR and payback: 10%, 15 years	
Total investment: INR 2.3 billion, $33 million	
Benefits: 6 ktCO_2/yr reduction; 7.7 GWh/yr of electricity saved; 2.2 tonnes of refrigerant saved over project life cycle	

Important features:

- Raiya area is the Area-based Development proposal in Rajkot's Smart City Plan
- The site assessed is a 30-acre business park to house banking and financial services, IT/ITeS, and retail space. A 36-acre convention and exhibition centre is also planned as well as educational facilities, a sports arena and a hospital.
- The project will be dense, with a maximum FSI of 4, and house approximately 100,000 people
- Zonal targets of 80 percent buildings should be energy efficient and green building; 20% of the area's energy supply being renewable including 6.4 MW of solar PV.
- 70% of the surrounding land in the same ward is vacant, promising potential for long-term expansion of district cooling

Next steps:

- Detailed project pre-feasibility undertaken and realistic development timeline determined, particularly identifying initial buildings to be developed
- IRR is sensitive to project design (compare with Figure 5) and district cooling will not be suitable for the whole site (particularly some residential areas which were not included). But with innovative incentives the IRR could be sufficiently high to allow district cooling to serve the majority of buildings. Further, given the relatively lower power prices in Rajkot, careful project planning to ensure low capital costs will be required.
- Use opportunity of greenfield development to push sector integration – wastewater reuse and direct use of renewable power in particular. Also, if the planned waste-to-energy plant could be located near to the smart city area
- Expand mandate on centralised HVAC systems in hospitals to other building types in this zone to enable future connection to district cooling.
- Consider expanding existing policies on FAR bonuses and property tax rebates to district cooling connected buildings

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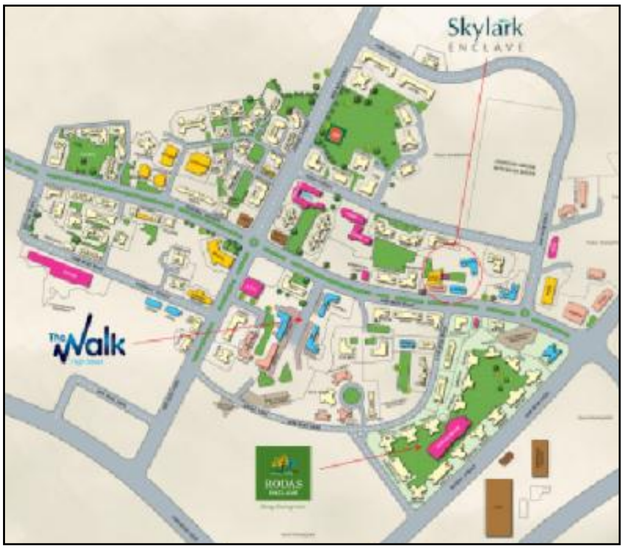
<tr><td rowspan="7">
</td><td>Thane</td><td>Hiranandani Estate</td></tr>
<tr><td colspan="2">300-acre integrated township built by the Hiranandani Group. This is a fast expanding, mixed-use development with a business park</td></tr>
<tr><td colspan="2">Building mix assessed for district cooling: 1.7% Hotel; 59% Office, 19.7% shopping mall, 19.7% campus building
Total floor area: 277,120 sqm</td></tr>
<tr><td colspan="2">Capacity of district cooling system: 16,100 TR</td></tr>
<tr><td colspan="2">IRR and payback: 17%, 10 years</td></tr>
<tr><td colspan="2">Total investment: $36.3 million</td></tr>
<tr><td colspan="2">Benefits: 5.8 ktCO_2/yr reduction; 7.5 GWh/yr of electricity saved; 2.6 tonnes of refrigerant saved over project life cycle</td></tr>
</table>

Important features:

- The township is already partially constructed and is expanding fast with a significant number of greenfield sites intended to house high density development in the coming years
- Mixed-use development including offices, residential, hospital, educational facilities etc. The township includes the Hiranandani Business Park which includes major corporate offices.
- Hiranandani is a major, national building developer, meaning replication potential of the project is significant
- Thane municipality has indicated willingness to incentivise district cooling development through municipal taxes, provision of lower cost land and direct provision of low-cost, municipally-owned solar electricity.

Next steps:
- Detailed project pre-feasibility undertaken quickly to fit into development schedule of building developer.
- Separate analysis with the city of Thane to identify and design specific policy mechanisms and incentives to ensure district cooling is developed
- Slow expansion of district cooling across the site could be possible
- Building developer could use the district cooling projects environmental credentials to promote the site and attract tenants
- Given the emphasis on reuse and recycling of wastewater in the smart city plan, identify opportunities for wastewater reuse in this zone for district cooling

Prospects of renewable technologies

The above financial analysis has focused on electricity-based district cooling systems, i.e. systems that use highly efficient electric chillers to produce cool centrally. However, all of the cities have opportunities to develop district cooling using innovative renewable technologies. The most likely renewable or low-carbon options include: direct use of municipally-owned solar electricity by the district cooling project, solar thermal cooling, biogas, gas tri-generation and waste-to-energy plants. All of the cities have rivers or lakes; however, the temperatures are expected to be too high for use as 'free-cooling'. No information on geothermal potential was available and so has not been considered.

Recommendations:
- More detailed city-wide assessments and pre-feasibility studies of projects include assessment of local renewable opportunities, which could improve the commercial viability of projects due to the lower running costs of such renewables.
- Undertake an energy mapping of the city incorporating spatial analysis of cooling demand and assessments of renewable and waste heat options[3]

Prospects of innovative technologies

There are also opportunities for innovative technologies to be used with the district cooling systems. Many of the cities reported significant water stress and have policies in place for wastewater reuse including within some of the smart city proposals. By centralising the production of chilled water, district cooling can make use of Treated Sewage Effluent instead of potable water, lowering water stress from cooling. If water costs are high, such as in Pune and Rajkot, this can lower the costs for the district cooling network.

Analysis of the power prices in each city 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, potentially through a special, lower off-peak tariff being provided to district cooling plants. This would allow introduction of TES to a district cooling system, reducing peak power demand by up to 50% compared to a stand-alone system. District cooling networks that incorporate renewables such as waste heat would likely also install thermal storage to maximise use of the low operating cost, renewable cooling.

[3] The District Energy in Cities Initiative will support a pilot city to develop energy mapping and will make methodologies and tools available to all cities

Recommendations:

- As provider of multiple utilities and services, cities can show leadership by supporting planned district cooling projects to be more innovative by integrating multiple sectors. This could mean helping to remove barriers to reuse of wastewater
- Deeper feasibility assessment of TES in each city to indicate whether an off-peak tariff is needed to ensure TES is incorporated. City can recommend to state government and utility a lowering of off-peak tariff to reflect system benefits of reducing peak demand.
- Cities can make available results of existing demonstrators on thermal storage and highlight their economic effectiveness under current tariff regimes

Strategies and targets

Through various initiatives, all of the cities are placing significant emphasis on environmental sustainability through various strategies and targets. Many of cities are developing strategies and targets for specific zones or sectors (e.g. municipal buildings or residential) as shown in Table 5. Cities are addressing space cooling's impacts indirectly through measures on building efficiency, appliance efficiency and electricity decarbonisation. However, no city has explicitly incorporated cooling into its local energy strategies or targets meaning that the true impact of space cooling is not fully understood, solutions are deployed that are less cost-effective and opportunities are missed for sector integration and use of local renewables.

Table 5: Strategies, initiatives and targets within the cities [14]

	Bhopal	Coimbatore	Pune	Rajkot	Thane
Smart city	Green	Green	Green	Green	Green
Solar city program	Green	Green	Green	Green	Green
Baseline GHG assessment	Red	Green	Green	Green	Green
Low GHG plan / target	Red	Orange	Red	Green	Green
City-wide efficiency & renewables target	Green	Green	Green	Green	Green
Efficiency & renewable target by sector	Red	Green	Orange	Green	Green
Zonal renewable energy target	Red	Red	Green	Green	Green
Zonal building efficiency target	Green	Red	Red	Red	Green

Red: Not developed, Orange: Under development, Green: Existing policy

All of the cities are part of the Smart City Mission of the Ministry of Urban Development (MoUD) and the Solar City Programme of the Ministry of New and Renewable Energy (MNRE). These two initiatives can be used to explicitly address space cooling and promote district cooling and it recommended that district cooling is incorporated under these programmes in each city.

The Smart City Mission

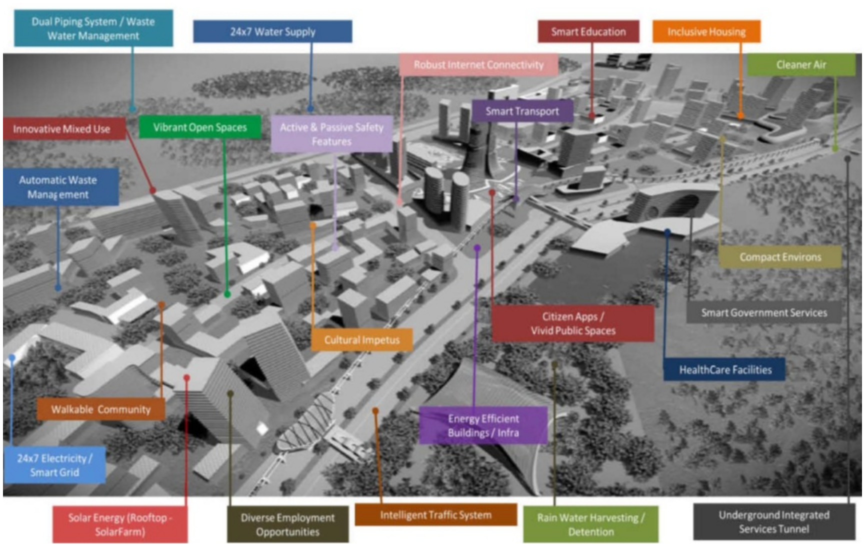
All cities have been shortlisted amongst 100 cities to be developed as Smart Cities under the Government of India's Smart Cities Mission. Bhopal, Coimbatore and Pune have been shortlisted into the top 20. Under the smart city proposals, cities are setting out their priorities and commitments to deliver smarter, more sustainable and liveable cities. The smart city proposals are holistic in nature and include various smart solutions addressing water, solid waste, sewage, energy, smart grid.

District cooling can help cities to integrate the priority sectors presented within their smart city proposals, improving environmental credentials and lowering costs. For example, district cooling systems can make use of surplus heat from waste-to-energy projects, help balance local electricity networks with cold storage and use Treated Sewage Effluent (TSE) as cooling water (as is done in the U.A.E). Many cities have established Special Purpose Vehicles (SPVs) to design and implement Smart City plans.

Recommendations:

- Smart city SPV, with support from district cooling engineers incorporate district cooling into the Pan-city proposals and the Area-based development proposal.
- The SPV could coordinate development of district cooling within the smart city area, and promote its replication across each city
- The SPV could be a direct investor into a district cooling demonstration project in some of the cities, dependent on progress on existing smart city proposals. In addition, SPVs could 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. residential connection to district cooling, use of wastewater recycling, solar cooling, waste-to-energy connection etc.)
- At the national level, the Smart Cities Mission could recognise district cooling as technology to integrate multiple aspects of smart cities and prioritise cities with district cooling concepts in their Smart City Plans.

Figure 6: Area-based development in Bhopal's Smart City proposal [15]



Solar city programme

All of the cities assessed are members of the Solar Cities Programme. This national programme aims to achieve a minimum 10% reduction in fossil energy demand in each city at the end of five years, through adoption of renewable energy technologies and implementation of energy efficiency measures. Each city develops a Solar Master Plan for meeting these targets and will receive investment from the state and national-level government to support the plan and leverage private sector interest.

Implementation of these master plans in most cities is observed to be quite slow due to a number of barriers[4]. The Solar City Programme has however provided an enabling platform for cities to assess current and future energy demand and undertake strategic planning for implementing interventions to reduce energy demand. The programme has helped to create an eco-system for adoption of renewable energy and energy efficient technology by consumers.

The Master Plan's combined approach of improving energy efficiency and unlocking renewables is a fundamental tenet of a modern district energy model and the Master Plans could therefore provide a policy framework to take action on district cooling. Modern district cooling systems maximise the use of renewables, both on the electricity system such as solar PV, but also directly connected to district cooling, such as industrial waste heat or waste-to-energy plants while also reducing primary energy consumption for cooling by up to 30-50%.

Recommendations:

- Master Plans could be used as overarching strategies by cities to take action on space cooling, particularly by promoting district cooling.
- Master Plans could indicate how district cooling meets specific city goals and targets (e.g. the share of total GHG reduction target to be met by district cooling) although revising these Master Plans in multiple cities may not be realistic, particularly as funding for their development has already been used.
- To evaluate along such goals or targets and justify city-action on district cooling, cities must first undertake holistic studies[5] on sustainable cooling, including: mapping of cooling demand and local renewable sources, impact analysis of cooling demand, cost-benefit analyses of different cooling technologies and the potential of district cooling to achieve city goals.
- Cities could use district cooling to attract investment into the Master Plans as the large-scale nature of district cooling projects and steady returns helps to attract different investor types.
- At the national level, it is recommended that targeted action on space cooling and district cooling is promoted through the Solar Cities Programme.

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[4] Barriers include: higher capital costs and delayed disbursement of funds, ineffective project planning and monitoring, ineffective procurement planning, inadequate institutional capacity and coordination, and low awareness with regards to energy efficiency and renewable energy.

[5] The District Energy in Cities Initiative will be adapting methodologies and tools to the Indian context to support a pilot city to undertake such a study.

Cities and their planning authority

Municipal corporations can effectively catalyze district cooling deployment first and foremost in their role as planner and regulator. In general, the cities assessed have sufficient authority over building permissions, land-use planning, zoning and building regulations to successfully promote district cooling. Many of the cities do have a larger metropolitan-level authority they work with to develop long-term development plans and promote high-growth, as such strong coordination will be necessary for policy development.

All the cities have long-term Development Plans that detail land utilization and are used to regulate and guide development, often over a period of 20 years. The Plan also broadly prescribes the planning norms and development controls that will apply in the city.

Short/medium-term recommendations

- Cities can use their zoning authority to create high priority and medium priority 'zones' for district cooling, based on energy mapping and benchmarks for district cooling viability[6]. Tailored policies and incentives can then be applied to these zones similar to the current use by cities of Special Economic Zones or even Smart City areas.
- Cities can ensure that public buildings are established in high priority zones, such as hospitals, city control centres and public offices, that can 'anchor' new district cooling development by connecting a significant cooling demand and lowering risk through the participation of the public sector.

Long-term recommendations

- Cities can use Development Plans to promote district cooling in the long-term by ensuring new large developments and zones are mixed-use and dense.
- Cities can evaluate how different urban planning practices can be used to target district cooling and develop adapted policies dependent on these. For example, Transit Orientated Development (TOD), integrated townships and redeveloping around industrial areas.

Urban Planning Practices for District Cooling

Several types of development provide natural opportunities for district cooling. With TOD, district cooling networks can grow out linearly, boosted by the denser buildings promoted along the transit route (see Figure 7) and the cost reductions of simultaneously laying multiple utilities (including district cooling) as the transit route is developed. TOD is often combined with FAR incentives and these could be increased for district cooling connected buildings.

[6] The District Energy in Cities Initiative will be establishing such benchmarks in the pilot city and also making available similar benchmarks that are currently used or under development in countries such China, Malaysia, Egypt, U.A.E etc.

With integrated townships or Special Economic Zones (SEZ) the dense and mixed-use development, with often a single building developer, can make district cooling very attractive (see Figure 8). The well-defined zone can have targeted policies applied to (in addition to similar targeted economic policies which may already be in place). Furthermore, the relative independent utility services typical in such townships could make a multi-utility business model for district cooling more viable and technologies that integrate of sectors, e.g. wastewater reuse or tri-generation more viable.

Urban redevelopment in proximity to industrial areas (as is occurring in Rajkot) provides opportunities for the use of industrial waste heat in district cooling networks and also trigeneration opportunities as gas/biogas connections may be available and the industrial area may have a significant heat and/or power demand

Figure 7: Proposed Land Use Plan of T.T. Nagar Smart City Area, Bhopal [15]

Figure 8: EON Free Zone, a large integrated township and SEZ in Pune [16]

Cities are generally responsible for setting local building regulations and are using these as well as other planning tools and control over municipal taxes to promote sustainable construction and operation of buildings. Table 6 gives an overview of the different tools being used, or under development by the cities.

Table 6: Planning policies & incentives used by cities to promote sustainable development [14]

	Bhopal	Coimbatore	Pune	Rajkot	Thane
Mandates on solar water heating and/or PV by sector	Red	Green	Green	Green	Green
Mandates on centralised HVAC linked to FAR by sector	Red	Red	Red	Green	Red
Green building policy	Red	Orange	Green	Orange	Orange
Mandate on water re-use in centrally cooled buildings	Red	Green	Red	Red	Red
FAR payment reductions linked to sustainability /density bonus	Red	Red	Green	Green	Red
Property tax rebate for SWH installation	Red	Red	Green	Green	Green
City-level certification programme	Red	Red	Red	Green	Red
Direct investment in energy projects	Green	Green	Green	Green	Green
Using public buildings to demonstrate technology and business models	Green	Green	Green	Green	Green
Mandates on building certification	Orange	Red	Green	Red	Red

Red: Not developed, Orange: Under development, Green: Existing policy

Recommendations:

- Identify existing policy mechanisms used to promote sustainability, such as incentives under the Smart City Mission, and extend these to cover district cooling
- Mandate large new developments in 'high priority zones' submit an 'energy efficiency plan' that includes district cooling assessment in order to obtain a building permit. This could be an extension of mandates on building certification and solar hot water (SWH).
- Under such plans, 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, cities 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.
- Developments in 'medium priority zones' could have mandates on centralised cooling to make sure they are district cooling ready. The mandate could be applied through the Development Control Regulations similarly to SWH connection. This could be incentivised through FAR incentives etc.
- Requests for re-zoning by building developers could be permitted under the condition that the developer meets stricter building efficiency standards and/or assesses district cooling development and, if techno-economically feasible, establishes district cooling.

- Set district energy targets for municipal buildings and operations and mandate their connection. Private entities can use long-term customer service contracts from a municipality (e.g. 20-year offtake agreements) as security collateral on debt.
- Extend existing FAR incentives and property tax rebates in high priority zones for buildings that connect to district cooling.
- Ensure district cooling connected buildings are not excluded from municipal and state-level incentives linked to building certificates and also where certification is mandated.
- In the short/medium-term, national and state-level government can adapt incentives and mandates related to building certificates to account for district cooling.
- In the long-term, the national government could ensure that certification schemes are adapted to properly assess district cooling.
- Evaluate the benefits of designating areas as exclusive franchise zones for district cooling operators with well-designed consumer protections based on international experiences.
- Make available parcels of public land for use by district cooling stations at a reduced cost
- Adjust water tariffs to support the business cases of demonstration projects.
- Direct municipally owned renewable power to a district cooling demonstration project to lower power costs and to efficiently use the renewable power.

Energy Conservation Building Code (ECBC)

In general, local building regulations do not currently specify building efficiencies or equipment efficiencies. This will change once cities adopt the ECBC which will mandate commercial buildings to be developed with improved energy performance. Adopting the ECBC into local building regulations will be a major step for delivering sustainable buildings in all the cities. The process will involve establishing guidelines for how ECBC will be enforced in each city and building capacity in each city to enforce the new requirements. This will involve trainings to building assessors and developers as well as pilot buildings demonstrating the new guidelines.

Recommendations:

- 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.
- In the longer-term, cities could adapt ECBC requirements to ensure district cooling connected buildings meet ECBC standards. In the short-term, cities could ensure that any municipal, state-level or national benefits and incentives linked to the ECBC are also made available to a district cooling demonstration project.
- Cities could serve as a demonstration to other cities in India on how to adapt ECBC to appropriately reflect the benefits of district cooling. National government could promote such demonstration as ECBC is a national code.
- The national government could in the short-term adopt interim recommendations on how cities should assess district cooling connected buildings for ECBC compliance
- In the medium/long-term the national government could incorporate district cooling into future iterations of ECBC and recommended compliance guidelines and trainings

City leadership and awareness raising

The cities are showing leadership on a range of sustainability issues, particularly piloting and advocating for clean, innovative technologies. The cities could similarly provide leadership to the district cooling sector, helping to pilot and promote this technology.

Recommendations:

- Cities should establish and lead a multi-stakeholder coordination group of city departments, developers, utilities and building associations to ensure coordinated development of district cooling and to consult on new policies, plans and financing instruments. This group could also be led by the SPV established to deliver the Smart City Plan.
- Cities could finance and/or attract finance for a demonstration project which could be financially structured to demonstrate commercial viability and with results used to increase trust in the technology and legitimize a city-wide energy plan focused on scaling up district energy.
- Cities could provide their own buildings, or land under a concession contract, to create a PPP.
- In the long-term, cities could establish a 'sustainable energy delivery unit' that would be responsible for: promoting district cooling to companies and building developers keen to establish premises in their city; providing locally-relevant information (e.g. methodologies, tools, sample contracts, previous feasibility studies[7]) to potential district cooling customers or developers. Or such a unit could be incorporated into existing 'Solar City cells' under the Solar Cities Programme, which are responsible for generating awareness and promoting sustainable energy and building city capacity to design and lead energy projects.
- Cities could make space available for district cooling plants within their public buildings (e.g. in basement) or provide public land.

Business models and financing

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 and support the financing of district cooling, as shown in Table 7.

[7] The District Energy in Cities Initiative is establishing a national programme to support cities to assess and deliver district cooling including promoting methodologies, trainings, tools and best practices

Table 7: Potential for investment from different stakeholders into district cooling systems

Municipalities	Cities could either make a direct investment or potentially have a partial stake based on the value of incentives they are willing to provide (e.g. land, access to energy sources, building connections, access to wastewater treatment plants). In this way, district cooling could operate under a PPP model. Cities could also enter into joint cooperation models with the private sector; helping the project succeed through strong planning authority, coordination, incentives and by encouraging connection. In return, the city can direct the private sector to achieve specific environmental or social objectives.
National and State Government	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, 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.
Utilities	It would 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. However, tight utility budgets and a disincentive to invest in measures that reduce demand can make their investment more difficult. District cooling could be presented to utilities as an alternative revenue stream and where capital budgets allow, utilities could host an ESCO model for district cooling where they can expand the number of consumers while reducing demand.
Building developers	Bringing building developers into the business model has been highly successful in other countries as they control the development timetable, helping lower load risk. However, many want a quick 'out' so they can invest capital elsewhere, but some may like the steady returns post-sale. Building developers could become interested in being multi-utility providers, particularly in SEZs or integrated townships.
International expertise	There is little expertise in India regarding district cooling. Bringing in international private sector to invest in and/or operate projects would help to transfer knowledge and capacity to the local stakeholders and ensure initial projects are of a high quality – extremely important in such a nascent market which needs to establish a strong reputation. This will include technical, commercial, financial and legal capacity building and knowledge transfer. International private sector has significant levels of capital to invest. 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 or manage systems, directing investments without risking significant amounts of their own capital.
International finance	District cooling projects are complex, have diverse risks and long returns and as such need complex financing mechanisms that may not be achievable using only Indian banks and investment funds. District cooling should attract international concessional finance such as from multi-lateral development banks given the technology's strong potential in India and environmental credentials. Such banks as well as other international banks and funds could support financial structuring of projects and build capacity in Indian banks to finance district cooling projects. Multi-lateral development banks with significant international experience in financing large infrastructure projects including district energy systems could be brought in at the feasibility stage to help structure commercially viable projects.

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. This could be in parallel to SPVs incorporating district cooling into their Smart City Plans as a priority.
EESL / ESCO model	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.

References

Significant information was obtained through long consultations with the municipal corporations, local development authorities and many local stakeholders. Below are some of the references used in this report

[1] *Population Projections for India and States 2001-2026*

[2] *India's urban awakening: Building inclusive cities, sustaining economic growth.* Mckinsey Global Institute, 2010

[3] Planning Commission, Government of India, 2015

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[5] *Accelerating Improvements in the Energy Efficiency of Room Air Conditioners (RACs) in India: Potential, Cost-Benefit, and Policies (Interim Assessment).* Prepared by Lawrence Berkeley National Laboratory for the U.S. Department of Energy. Abhyankar et al, 2016

[6] *District Energy in Cities: Unlocking the Potential for Energy Efficiency and Renewable Energy*. UN Environment, 2015 Available from: http://www.districtenergyinitiative.org/publications

[7] Data has been collected from cities, state utilities, ASHRAE publications of climate data, the 2011 census and cooling degree days are from: CoolingDegreeDays.com

[8] Calculations made by the report's authors using assumptions on building efficiency, building occupancy, heat-gain from appliance use and climate. The full reports explain the calculations in more detail.

[9] State electricity utilities have made this data available

[10] Madhya Pradesh Central Region Electricity Distribution Co. Ltd

[11] Data provided by Korum Mall, Thane. Calculations made by authors

[12] The full detail behind this archetype is explained in the reports. It has been selected as typical development archetype

[13] Data presented is calculated or has been made available from multiple sources including building developers, smart city planners, municipal corporations and building owners. Image credits: Bhopal Smart City Plan, CHIL-SEZ, Saravanapatti, Blue Ridge Township, Rajkot Smart City Plan, Hiranandani Developers

[14] Analysis by the authors based on city consultations

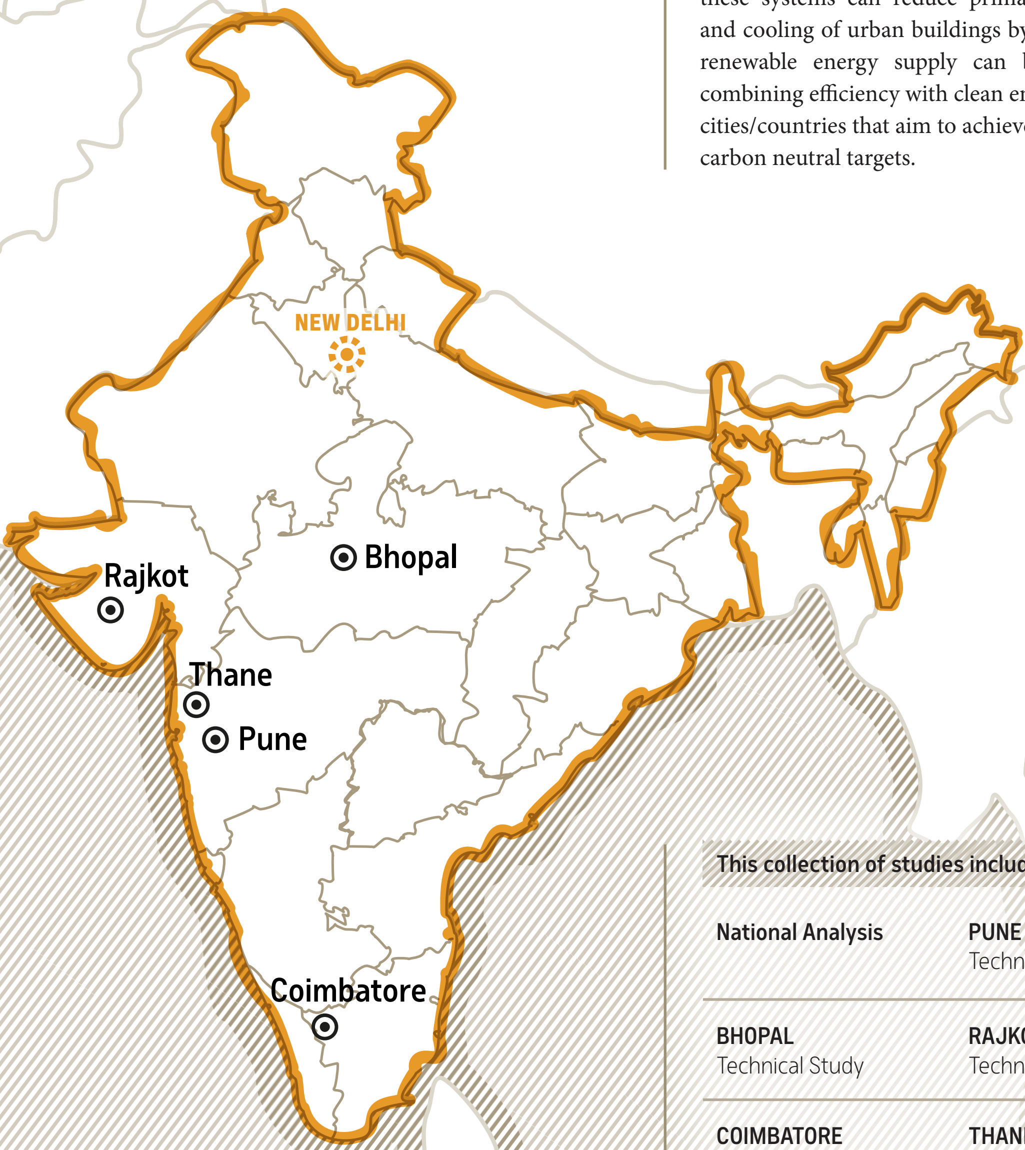
[15] Bhopal Smart City Plan

[16] E.On Free Zone, Pune. Image credit: Panchshil Realty

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

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