DISTRICT ENERGY IN CITIES INITIATIVE

UN environment

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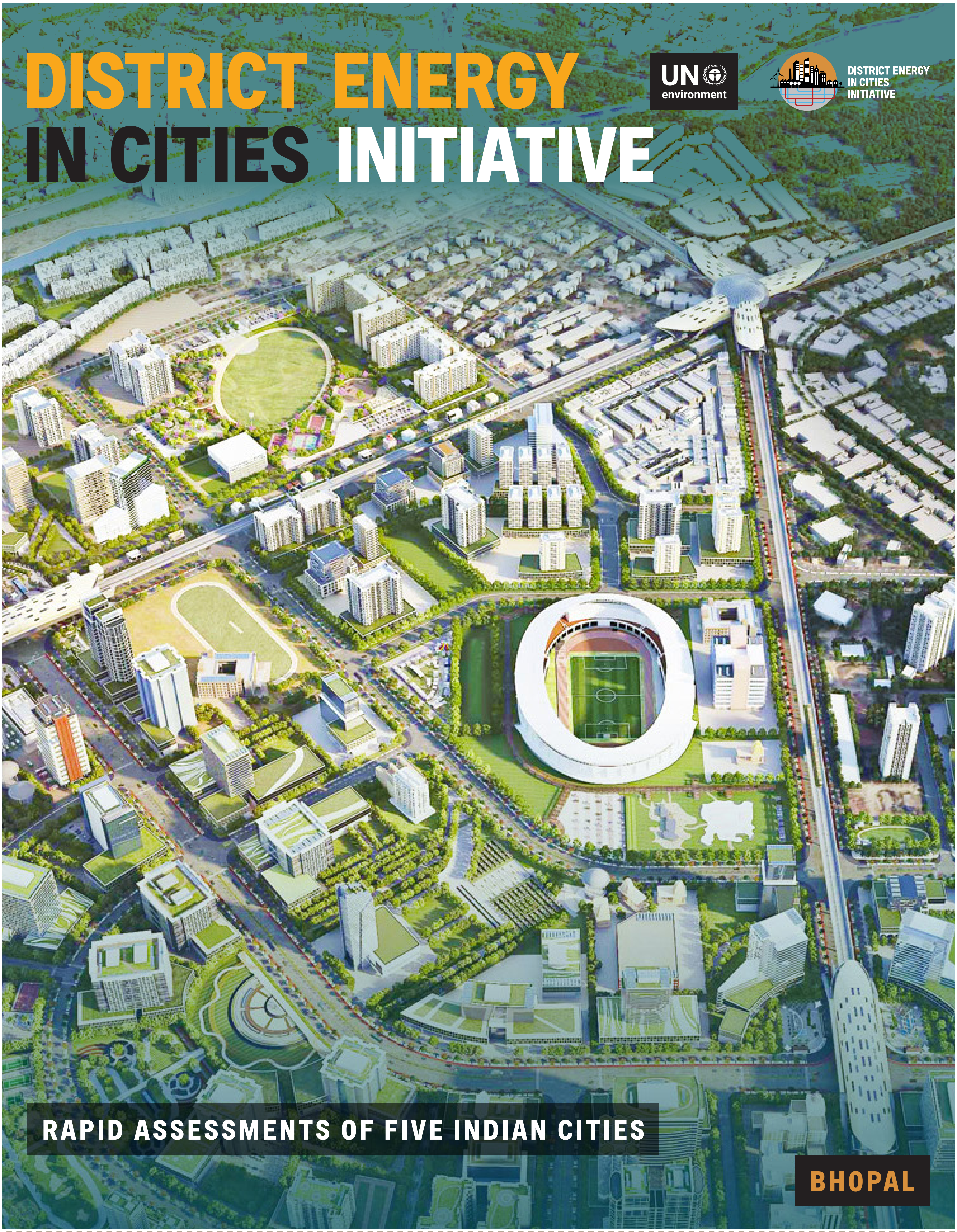

RAPID ASSESSMENTS OF FIVE INDIAN CITIES

BHOPAL

COPENHAGEN CENTRE ON ENERGY EFFICIENCY
SEforALL EE HUB

I.C.L.E.I 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 Bhopal Municipal Corporation for agreeing to be a part of the District Energy in Cities Initiative. We are grateful for all the support extended by the Municipal Corporation and its departments to this exercise.

We extend our sincere thanks to administrators, government departments and stakeholders including the Bhopal Smart City Development Corporation Limited, Directorate of Urban Administration and Development of the State Government of Madhya Pradesh, Directorate of Town and Country Planning (Madhya Pradesh), Madhya Pradesh Central Region Electricity Distribution Co. Limited – Bhopal office, Tata Consulting Engineers, Madhya Pradesh State Electronics Development Corporation Limited, Deepmala Infrastructure Private Limited, Blue Star – Air Conditioning Systems, CREDAI- Bhopal Chapter, Environmental Planning & Coordination Organisation, whose inputs and contribution to data collection have been invaluable to the successful completion of the district cooling rapid assessment in Bhopal 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 Bhopal undertaken alongside four other district cooling rapid assessments of Coimbatore, Pune, Thane and Rajkot. This report sets out a high-level analysis of the current impacts of space cooling in Bhopal, 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 Bhopal 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, neighbourhood energy systems etc. Confusingly 'district' has different meanings worldwide and the authors note that in India it can mean a jurisdiction far larger than a city. 'District' when used in the context of the District Energy in Cities Initiative refers to a city district, i.e. a neighbourhood. UN Environment in its report 'District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy' explains the technology options in detail, as well as the benefits, policies (national and local) and business models[2].

District Energy Systems for Cooling and its Benefits

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

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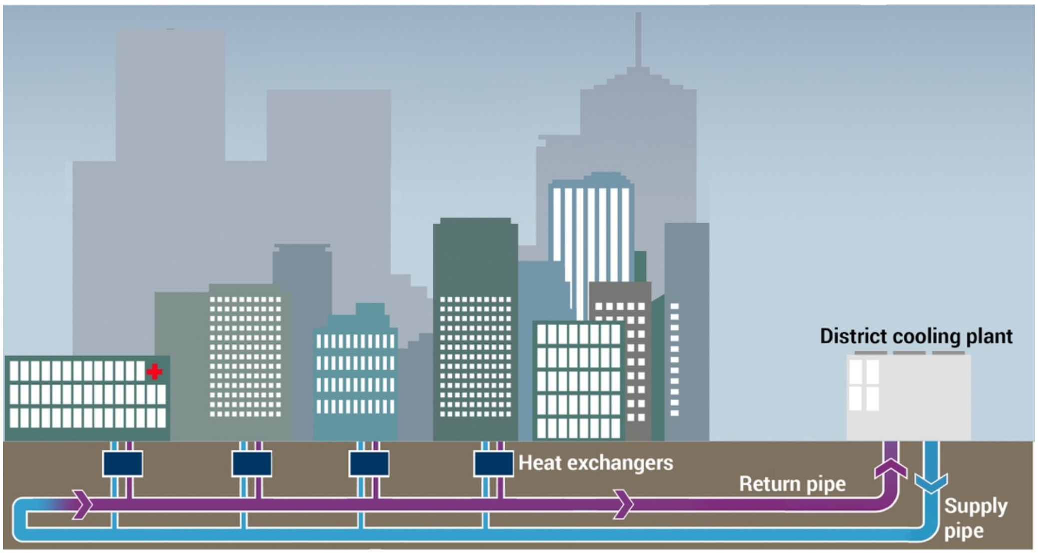
[1] For more information and contact details please visit www.districtenergyinitiative.org
[2] Available from www.districtenergyinitiative.org

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

Bhopal is the capital city of the state of Madhya Pradesh located in the central part of the state. It is the second largest city in the state and is a major hub for educational, administrative, political and industrial activities. Bhopal is strategically located at the centre of India and has good rail, road and air connectivity with the rest of the country. Also, being the capital city of the state, Bhopal drives the region's economy and hence attracts special attention from the government. These aspects have contributed to Bhopal being viewed as an attractive investment destination. Bhopal houses more than 1,200 Micro, Small & Medium

Enterprises (MSMEs), with notable investments in electrical machinery and transport equipment business. A number of key national and State level government institutions operate from the city. Various prominent research and academic institutes and health centres exist in the city.

The city is spread across an area of 285.9 sq. km and is governed by the Bhopal Municipal Corporation (BMC), which looks after the public services and development within the city limits. The Bhopal Development Authority (BDA) is responsible for planning and co-ordination of development activities in the large Bhopal Planning area, which comprises of the area under the jurisdiction of the BMC and the surrounding areas influenced by Bhopal city.

Bhopal is one of the first 20 cities selected to be developed as a Smart city under the Government of India's Smart Cities Mission. Under the area based development component of its Smart City Plan, targeting pilot-scale transformation of a specific area within the city, Bhopal strives to unlock the value of sub-optimally utilized land parcels in the T.T. Nagar area in the city through a 'redevelopment driven urban overhaul' and transform this area into a compact, mix-use based, sustainable urban habitat. The city is also keen to promote compact transit-oriented development and has prepared a plan for the same.

Table 1: City at a Glance

Particular	Details
Area	285.9 sq. km.
Population	1,798,218
Population Density	6,290 persons per sq. km.
Local Economic Base	Manufacturing and Engineering (particularly electrical goods and transport equipment), Tourism, Administrative Sector, Services
Average Temperature	25.3°C
Average Relative Humidity	55%
Average Rainfall	1200 mm

3.2 Location and Natural Environment

3.2.1 Geographical Location

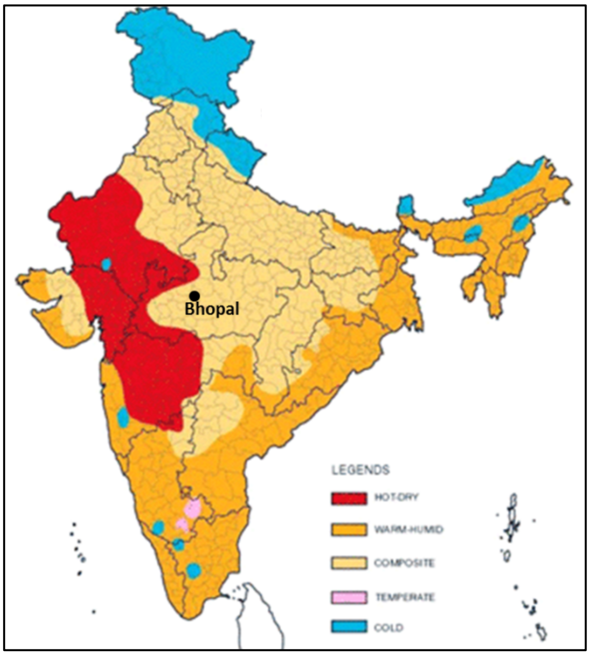
Bhopal is located on a hilly terrain within the Malwa Plateau and lies between the geographical coordinates of 23°16' North latitude and 77°22' East longitude. Because of its physiography and location, it is well connected to cities that surround it and other states in India. The city is well connected by road to major centres in the state and to other cities across the country. The rail network connects the city with major cities such as Delhi, Nagpur, Chennai, Hyderabad, Bangalore and Trivandrum. The city is also well connected with major cities of the country such as Delhi, Mumbai and Indore via air.

Figure 1: Geographical Location of Bhopal City

3.2.1.1 Climate

Bhopal city has a humid sub-tropic climate with mild and dry winters, a hot summer and a humid monsoon season. Bhopal lies in the composite climate zone of India which is characterized by hot and dry climate with high level of humidity during monsoons. The average daily temperature recorded in the city is 25.8°C. The presence of a number of lakes in the city makes the weather relatively pleasant, especially during the evenings.

Figure 2: Climate Zones of India

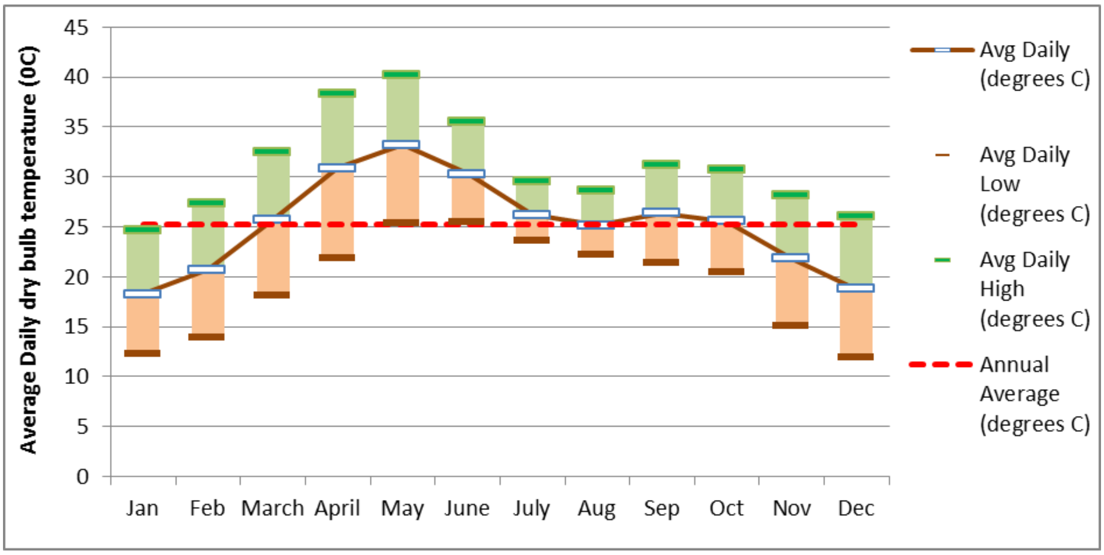


The daily temperature starts rising from the month of April, with relatively higher temperatures experienced up to the end of the summer season in June (see Figure 3). The maximum daily average temperature and minimum daily average temperature during summer is 40.2°C and 25.4°C respectively. The weather conditions in the summer months are generally hot and dry, with low relative humidity (see Figure 4).

Bhopal experiences moderate rainfall during the period from June to October, with rainfall predominant during July and August. The average number of rainy days is approximately 40 days per year and the average annual rainfall is 1200 mm. Relative humidity rises significantly in the monsoon period and the average daily maximum relative humidity exceeds 90% during the months of July and August. The daily average relative humidity stands at 86.6% during the month of July.

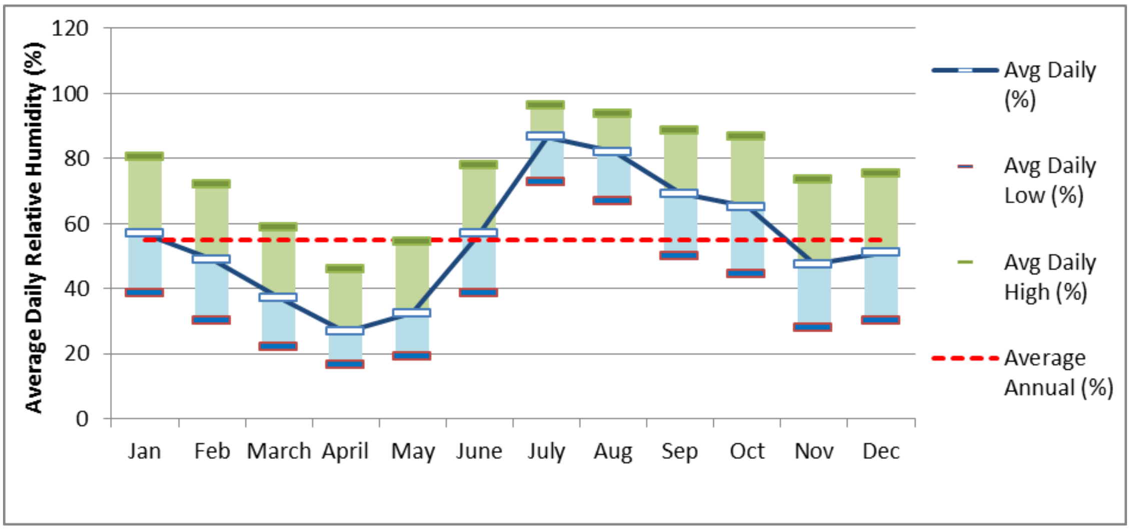
The winter season starts from the month of November and continues until February. During winters, the minimum daily average temperature drops to 11.9°C in the month of December while the maximum daily average temperature recorded is 24.7°C in January. The daily average relative humidity is lower as compared to the monsoon months and ranges from 47.6%-56.9% during the winter months.

Figure 3: Month wise average daily temperature variation with respect to annual average temperature for Bhopal city (1991-2006)



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

Figure 4: Month wise average daily relative humidity variation with respect to annual average relative humidity for Bhopal city (1991-2006)



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

The Madhya Pradesh State Action Plan on Climate Change includes climate projections for 2030s (2021 to 2050) and 2080s (2071 to 2098) as compared to the baseline of 1970s (1961-1990). A 1.8 to 2°C rise is expected in the average daily maximum temperatures across the state by 2030s and the average daily minimum temperature is anticipated to rise by 2 to 2.4°C across the state in the same period. An increase of 3.4 to 4.4°C is expected in the average daily maximum temperature and a rise of 4.4°C is expected in the average daily minimum temperature during the 2080s. Given this projected rise in temperature, it can be expected that Bhopal's space cooling demand will increase in the near future.

The total number of Cooling Degree Days (CDD)[3] for Bhopal is 1,585 (for base temperature of 23°C) for the year 2014-15. There is a 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. The CDDs have a positive correlation with the electricity consumption (see Section 1.7). Other cities have developed successful district cooling projects with far lower CDDs.

3.2.2 Soil Conditions

Bhopal city is located in a hilly terrain with uneven elevation, which slopes towards north and southeast. The underlying soil found in the Bhopal region is largely red sandstone strata, with the depth of the rock varying according to the slopes. The top portions of the hills consist of hard red soil, mixed with basaltic boulders. Black cotton soil is seen at various depths from 1 m to 3 m.

The soil condition should be further considered during the pre-feasibility stage of project development as poorer, unstable soil conditions can lead to higher district cooling network

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

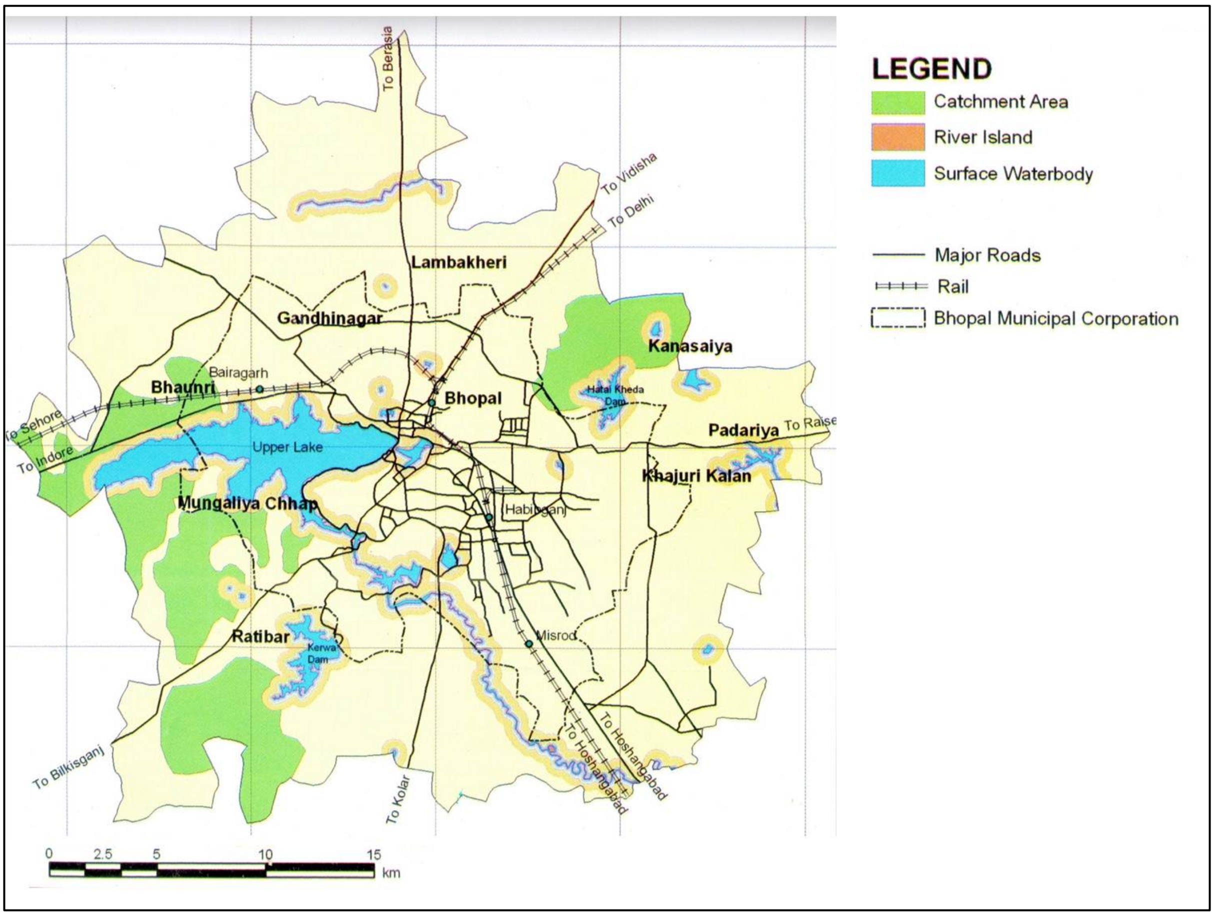
installation costs. Soil conditions are not expected to significantly affect the commercial viability for district cooling barrier in Bhopal but should be further analyzed at more detailed stages of project development.

3.2.3 Surface and Groundwater Availability

Bhopal is known as the city of lakes and houses a number of water bodies which includes the famous Bhoj Wetland (i.e. the Upper Lake and Lower Lake). There are about 18 lakes in and around the city. The water quality in the lakes in Bhopal has been deteriorating over time due to increasing discharge of untreated sewage and solid waste dumping. Efforts undertaken towards the conservation and management of the Upper Lake and the Lower Lake has have increased their water availability.

The various lakes in Bhopal are unlikely to be able to provide significant 'free cooling' to district cooling systems as their temperatures are too high, as seen in the case of Bhopal's Upper Lake for which the surface water temperature ranges from 19^{0}C to 38^{0}C across the year (Vijay K. Dwivedi and V.K. Chaubey, 2007). Temperature at the bottom of the lake ranges from 17^{0}C to 37^{0}C. Further analysis should be undertaken during pre-feasibility stage of district cooling projects to account for the possible environmental benefits and impacts that can come from rejecting waste heat into the water bodies, particularly for projects in the vicinity of these water bodies.

Figure 5: Major water bodies in Bhopal



Bhopal city's water demand is about 360 Million liters per day (MLD). The majority of Bhopal's water demand is met by two surface water sources - the Upper Lake, located within the city and the Kolar reservoir which is located at a distance of 44 km from Bhopal. The city has recently begun sourcing water from the Narmada River, located at a distance of 67 km from the city. Groundwater extracted through private tube wells, dug wells and hand pumps supplements water supply from the surface water sources. Groundwater is available at a depth of 4 m to 6 m below ground level (bgl) in the southern part of the city during the pre-monsoon season while in the northern part of the city groundwater is available at depths ranging from 6 m to 10 m (Central Ground Water Board, 2011). There are examples of the 'free cooling' from groundwater being used for district cooling systems, however this analysis is outside the scope of this assessment (Cleaner Production Germany, 2017). Irregular supply and unequal distribution of water is an issue, especially during the summer season when the groundwater levels drop. Regular water supply is a challenge, especially for recently developed neighbourhood such as the ones in Kolar Road and BHEL which have inadequate water supply connections and do not have daily supply of water. Bhopal has 8 sewage treatment plants (STPs) which treat 80% of the city's wastewater.

The cost of water is INR 14.3 (USD 0.22) for commercial connections and INR 20 (USD 0.30) for industrial connections and is charged per kiloliter 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. 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[4]. Existing buildings in Bhopal that have centralized cooling use a mix of air-cooled chillers and water-cooled chillers (see Section 1.8).

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

3.2.4 Air Quality

The annual average concentration of sulphur dioxide (SO_2) and nitrous oxide (NO_2) in Bhopal are found to be within the permissible limits prescribed by the National Ambient Air Quality Standards based on data recorded by three air quality monitoring stations in the city (Sadhana Chaurasiaa, Pragya Dwivedi, Ravindra Singh, Anand Dev Gupta, 2013). However, the particulate matter 10 PM_{10} concentration is observed to be 173 ug/m^3- which is nearly three times the permissible limit of 60 ug/m^3. This can be attributed to the large number of vehicles and re-suspension of natural dust around the areas with pre-dominant industrial and commercial activities. The city does not have other significant pollution sources such as

[4] 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)

electricity generation from coal-fired power stations or independent power producers. Information on air pollution from point sources is not available for the city.

Table 2: Ambient Air Quality in Bhopal City (2012)

Location of Air Quality Monitoring Station	SO_2 (ug/m^3)	NO_2 (ug/m^3)	PM_{10} (ug/m^3)
Hamidia Road, MP Hastshilp Vikas Nigam	2	21	214
CETP Govindpura	2	20	178
Nutan Subhash School, T.T. Nagar	2	21	127
Permissible Limits as per National Ambient Air Quality Standards	**40**	**50**	**60**

Source: (Central Pollution Control Board, 2014)

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

3.3 Socio Economic Status

3.3.1 Population

The population of Bhopal city is about 1.79 million persons and has increased by 24% from year 2001 (National Census, 2011). Bhopal's population density stands at 6,290 persons per sq. km. With the city expanding outwards, the population in peripheral areas such as Neori, Misrod and BHEL extension has increased in recent years.

According to Bhopal's City Development Plan there are about 380 slum settlements in the city. However, a survey conducted by Oxfam in 2006 puts the figure closer to 542[5]. About 26% of the city's population resides in slums (Smart Cities India, 2017)

3.3.2 Local Economy

The economy of Bhopal is driven primarily by cotton, electrical goods, jewellery, cloth weaving, and chemical industries, with about 1,200 MSMEs located in and around the city. Bharat Heavy Electricals Limited (BHEL), one of India's largest manufacturing and engineering units, is located in Bhopal. In the recent years, Bhopal has seen the decline of traditional industries especially the engineering support and component manufacturers.

With the city housing about 200 banks and insurance companies, 36 hotels and restaurants, 100 hospitals, over 1500 educational institutions, the service sector is becoming increasingly important and employs a significant share of the city's population. Bhopal being an administrative capital has a sizeable workforce employed in Central and State

[5] City Profile- Bhopal Municipal Corporation a report prepared by All India Institute of Local Self-Government for Support to National Policies for Urban Poverty Reduction

government services. The state economic development policy envisions for Bhopal to be developed as a centre for education. There is a concentration of educational establishments at all levels and a large number of schools, training institutions and colleges that have been established in last few years in the city. Nationally renowned research facilities and academic institutions such as Indian Space Research Organization's Master Control Facility, All India Institute of Medical Sciences, the National Law Academy, and the School of Planning and Architecture among others are housed in the city. The Madhya Pradesh State Electronics Development Corporation Ltd. (MPSEDCL) has set up a large Software and Hardware Technology Park in the city, wherein multinational companies such as Taurus Microsystems, Fujitsu and Genpact are expected to set up their operations.

4 Stakeholder Mapping

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

Institution Type	Agency	Specific functions and role with relevance to district cooling
City Planning Authority	• Bhopal Municipal Corporation (BMC) • Bhopal Development Authority • Directorate of Town and Country Planning, Madhya Pradesh	**Mandate and Functions:** • **BMC:** The BMC holds the primary responsibility to provide and maintain the public services within the city limits. The BMC is also responsible for implementation of proposals made in the Development Plan and for maintaining the infrastructure developed by BDA, once it gets transferred to BMC. The Planning and Rehabilitation Department of the BMC is responsible for issuing licenses and providing building permissions for all developments in the city. Water supply in Bhopal city is looked after by Public Health Engineering Department (PHED) of Madhya Pradesh as well as Bhopal Municipal Corporation. The PHED is responsible for planning, design and construction of water supply and sewerage projects in Bhopal and subsequently transfers these assets to the BMC for operation and maintenance post construction. • **BDA:** The BDA is responsible for planning and co-ordination of development activities in the large Bhopal Planning area, which comprises of the area under the jurisdiction of the BMC and the surrounding areas influenced by Bhopal city. BDA is the main implementing agency of the master plan and development plan prepared for the Bhopal planning area. The BDA conceives, promotes and monitors the key projects for developing new growth centres along with provision of basic infrastructure and amenities to these areas. The BDA also engages in projects that bring about improvement across sectors such as roads, transport, housing, water supply, and environment in the region. • **Directorate of Town and Country Planning, Madhya Pradesh:** The key responsibilities of this agency include preparation of Master plans, Development plans, and regulations for building development within each land use zone. • **Bhopal Smart City Development Corporation Limited (BSCDCL):** BSCDCL is a special purpose vehicle that has been established to plan, design, implement, coordinate, and monitor the Smart City projects in Bhopal. This includes the implementation of proposed smart and

Institution Type	Agency	Specific functions and role with relevance to district cooling
		sustainable solutions throughout the city as well as in the area based development. **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 Transit Oriented Development Plan etc. • Leverage its role in city master planning to help identify strategic high density mixed-use zones and building clusters (existing and planned), key economic sectors with opportunities for district cooling network development • Share information such as city plan(s) detailing zones, existing and future development density, building locations, building use etc. to help determine demand density and new network designs and assess feasibility • Facilitate planning and implementation of district cooling infrastructure by identifying strategic location and securing land for district cooling production facilities, assisting in excavation permits and rights of way for laying district cooling pipelines, co-ordinating schedules with other planned infrastructure and building construction • Use the existing local regulatory framework for urban development and buildings such as building permits, bye-laws and development control regulations, building efficiency standards to develop complementary policies to encourage district cooling development and adoption • Share data on local government buildings and utilities, offering connections to local government buildings such as large hospitals, office buildings to act as anchor loads with high cooling demand to assist viability of district cooling • Facilitate stakeholder coordination, raise awareness and acceptance
Real Estate, Property Developers and related institutions	• Confederation of Real Estate Developers Associations of India (CREDAI), Bhopal Chapter • Macker Real Ventures • Mahindra Builders	**Mandate and Functions:** CREDAI is an institution that represents interests of the real estate developers and provides a forum to disseminate information and share best practices and technologies in building design and construction. CREDAI's Bhopal Chapter facilitates coordination between government bodies, real estate developers and consultants and also provides inputs to policy development relating to housing and development. **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

Institution Type	Agency	Specific functions and role with relevance to district cooling
	• Bhoomi Group • Fortune Builders • Gammon India	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 programs 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, Bhopal Centre • Council of Architecture, Bhopal • The Institution of Engineers (India), Bhopal	**Mandate and Functions:** Promote interests of architects and promote best practices in urban planning and architecture. Enable exchange of knowledge and present a platform to share new techniques, technologies and developments in the field of civil engineering. **Role with respect to district cooling:** • Identify existing and upcoming large scale high rise buildings and developments in the city with potential for district cooling integration • Share information on typical cooling demand for different building types in the city in consideration of the local climate, building use, envelope and size, and prevalent cooling technology in use and its cost • Provide technical inputs on integrating district cooling in the prevalent building design and 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	• Madhya Pradesh Madhya Kshetra Vidyut Vitaran Co. Ltd. (i.e. Madhya Pradesh Central Region Electricity Distribution Co. Ltd.)	**Mandate and Functions:** The Madhya Pradesh Madhya Kshetra Vidyut Vitaran Co. Ltd is responsible for electricity distribution of electricity in Bhopal. It is also responsible for planning the electrical infrastructure to strengthen the electricity distribution network, to reduce the electricity downtime and enhance reliability. This agency also collects the energy consumption charges from end users as per the tariff stipulated by the Madhya Pradesh Electricity Regulatory Commission and works to promote energy conservation and energy efficiency. **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

Institution Type	Agency	Specific functions and role with relevance to district cooling
		• Assist in identification of buildings / consumers with high load and energy demand • Share information on infrastructure status or augmentation required in the local electricity network to support the required power demand of the district cooling production plant. • Share information on existing and future tariff structure (fixed, variable, time of use) for different consumer categories, any incentives for electricity conservation to assist in design of district cooling system, assess commercial visibility and establish pricing levels for the district cooling service for different consumers.
State Designated Energy Agency	• Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL)	**Mandate and Functions:** MPUVNL is responsible for implementation of energy conservation and energy efficiency programs across the state of Madhya Pradesh. It is a state nodal agency for disbursement of central financial assistance for renewable energy projects including solar PV. The MPUVNL is responsible for developing, implementing and promoting energy efficiency and conservation in different sectors through enabling policies and programs. MPUVNL also engages in conduct energy audits and feasibility studies for renewable energy projects. **Role with respect to district cooling:** • In its role as the nodal energy agency for the State, MPUVNL 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
Environmental Planning and	• Madhya Pradesh Pollution	**Mandate and Functions:** • **MPPCB**: MPPCB is responsible for enforcement of environmental legislation with respect to prevention and

Institution Type	Agency	Specific functions and role with relevance to district cooling
Pollution Control	Control Board (MPPCB) • Environmental Planning & Coordination Organisation (EPCO)	control of pollution relating to air, water, noise and waste. MPPCB 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 MPPCB is responsible to plan and execute programs for the prevention, control or abatement of pollution. It also regulates and monitors discharge and treatment of sewage or trade effluent and performance of air pollution control systems. • **EPCO**: EPCO is an autonomous organization established by the Housing and Environment Department of the Government of Madhya Pradesh that works closely with the State Government in formulation and implementation of environmental policy for the state. EPCO also provides technical and implementation support for projects related to environmental conservation in the state. EPCO is the designated state nodal agency for climate change and also provides technical and implementation support for environment and climate change related projects in the state. EPCO also has core competence in sustainable architectural and urban design and also engages in generating public awareness on aspects of environment and climate change. **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	• Govindpura Industries Association • CII – Bhopal • Mandideep Association of All Industries • Federation of M.P. Chambers of Commerce	**Mandate and Functions:** Bhopal's industry associations are concerned with representing and highlighting the issues concerning industry sector. These institutions provide a platform for industry owners to exchange ideas and promote best practices. **Role with respect to district cooling:** • Identify existing and upcoming large scale industrial developments such as IT, business and manufacturing hubs/parks, special economic zones in and around the city with high cooling demand and potential for district cooling integration

Institution Type	Agency	Specific functions and role with relevance to district cooling
	and Industry (FMPCCI)	• Share information on typical cooling demand for different industry building types in the city in consideration of the local climate, building use, envelope and size, and prevalent cooling technology in use and its cost • Provide inputs on existing enabling provisions and how existing industrial policy and regulatory frameworks can be used to promoting district cooling in large industry related developments • Share information on potential waste heat sources (from industries such as foundries that exist in the city), availability of gas/biogas, existing and planned large industrial developments with high cooling demand, existing cooling technologies in use • Facilitate coordination and awareness generation for industries
Designers, manufacturers, installation contractors for chillers and cooling system	• Gentech Engineering Services • Snowcool Engineers	**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

5.1 Bhopal Smart City

Bhopal is one of seven cities from the state of Madhya Pradesh 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, Bhopal figured in the initial list of 20 cities to be taken up for funding in the first round of the Mission.

The vision outlined in Bhopal's Smart City Plan is
"Transforming Bhopal, a City of Lakes, Tradition and Heritage, into a ***leading destination for Smart connected and eco-friendly communities*** *focused on* ***Education, Research, Entrepreneurship and Tourism****".*

Bhopal envisages advancing its economic growth by leveraging its strengths and tapping existing opportunities to advance its industry and business potential and to promote the city as hub for education and tourism. The city also places emphasis on improving environmental sustainability by promoting holistic planning, mix-use development, green spaces, and efficient technologies. Bhopal has outlined smart solutions within a **Pan-city proposal** covering the whole city and also an **Area-based Development[6] proposal** covering a neighbourhood called T.T. Nagar. The estimated cost of the Area-based development project amounts to INR 14,435 million (USD 220 million) while the proposals related to the Pan-city development are estimated to cost INR 12,752 million (USD 196 million) (City Wise Projects under Smart Cities Mission, 2017). A special purpose vehicle, the Bhopal Smart City Development Corporation Limited (BSCDCL), has been established to plan, design, implement, coordinate, and monitor the Smart city projects in Bhopal.

Under the **Pan-city plan**, Bhopal focuses on use of smart technologies to enable the BMC to undertake centralized governance of the city . In this regard, emphasis is laid on developing smart apps and MIS to assist centralized control, management and city governance and to add an information and communication technologies (ICT) layer to smart waste management practices. The intelligent street lighting solutions which include retrofit of energy efficient LED street lights, smart lighting systems with remote scheduling and monitoring, interactive digital signage for traffic, surveillance cameras, Wi-Fi hotspots, and street parking sensors; address aspects of energy efficiency, safety and connectivity in the city.

As part of its **Area Based Development Plan**, the T.T, Nagar area has been selected for redevelopment into a smart area wherein old buildings will be demolished with new apartments and commercial centres coming up in their place. A few buildings that have been already been constructed in this area such as the Model school, Platinum Plaza, the T.T. Nagar Sports complex, college buildings and hospitals, along with a few other private

[6] 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.

structures will be retained. The aim is to transform this area into an eco-friendly and sustainable urban habitat. The area is located in the southern part of the city in between existing commercial zones and covers an area of about 380 acres. The surrounding commercial zones act as catalysts for initial investments in real estate. The area-based development of north and south TT Nagar is designed to unlock the value of underutilized government land that exists within the city. New building developments that come up will follow a transit oriented development model and will have a mix of compactly developed residential and commercial areas. Of the proposed land use, 32% is allocated for residential developments, 16% for commercial developments, and 4.7% for public and semi-public uses. 30% of the land area is designated for roads and utilities. To promote compact development and maximize the value and utilization of available land, the permissible FAR for developments that fall under the TOD zone in this area is 3.0.

Furthermore, at least 80% of the buildings in the area-based development are planned to be green and energy efficient buildings. All upcoming buildings in the T.T. Nagar area will have to get mandatory pre-certification from LEED/GRIHA (Gold/Silver rating) and will also need to obtain a final certification, in order to receive building occupancy permits. The existing buildings that are retained and do not undergo redevelopment in the T.T. Nagar area would have to upgrade to receive green building certification. These rating systems would ensure that buildings incorporate essential elements such as energy efficient design and operation, reduced water consumption, and rain water harvesting among others. Bhopal has also placed emphasis on sustainable power generation through solar energy and has signed two memorandum of understanding (MOU)s with Solar Energy Corporation of India (SECI) and MPUVNL, the state nodal energy development agency, to install solar rooftop capacity of 3 MW and 1 MW respectively.

In order to enhance liveability and sustainability of urban infrastructure across the city, the BSCDCL and the BMC are engaged in preparation of a 'Blue and Green' Master Plan for the city which will entail components such as

- creation of green and blue spaces across the city
- promoting sustainable water management
- achieving 100% green buildings and green neighbourhood planning in a phased manner maximizing utilization of land parcels
- implementing innovative solutions, incentives and standards for sustainable energy management

Unlocking the value of underutilized land parcels and promoting high density mixed-use residential and commercial districts through the TOD concept are key strategies outlined in Bhopal's Smart City plan. This provides a promising platform for such large and diverse building types to come up in a compact manner within the city, which in turn improves the commercial viability of district cooling and lowers the environmental impact of the new development. Urban redevelopment projects, such as the T.T. Nagar project, which focuses on mixed-use and dense development, offer opportunities to integrate district cooling from the planning stage of redevelopment. Connecting to the district cooling network will enable new buildings to achieve sustainable space cooling and improve their 'green' credentials. The existing buildings such as the Platinum Plaza, the T.T. Nagar Sports complex, educational institutions and hospitals can subsequently be connected to the district cooling network.

Box 1: Smart city recommendations

Bhopal'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 buildings and future-proofed infrastructure.

Bhopal's T.T, Nagar area presents an ideal opportunity to test district cooling in Bhopal and demonstrate innovative new policies and business models that will promote it. The replicability of T.T, Nagar area to other parts of Bhopal 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 Bhopal is serious about this technology.

The rapid real estate growth planned in T.T, Nagar area will have significant cooling demand, and district cooling can deliver efficient and reliable power. District cooling can incorporate thermal storage and tri generation 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, Bhopal 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 could be supported to undertake such an analysis. The SPV could coordinate development of district cooling within the smart city area, and promote its replication across each city. Furthermore, the SPV and/or the city would all be natural direct investors into the district cooling project given the significant public benefits of the district cooling system. The city 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. use of wastewater recycling, solar cooling, waste-to-energy connection etc.)

Transport links planned in T.T, Nagar area 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 analysed before other

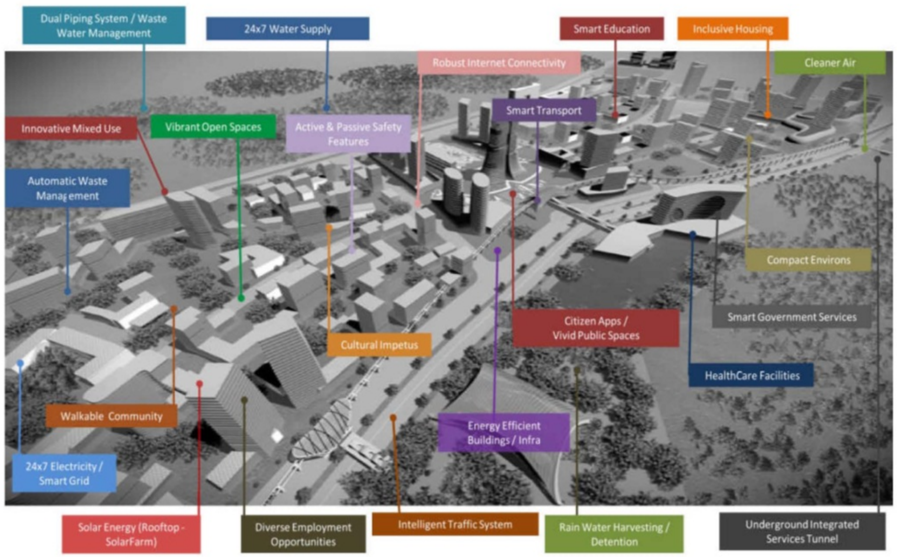
utilities are laid. The Smart City SPV could lead such coordination in T.T, Nagar area and the wider city, and this is examined in Section 1.10.1.

The Smart City SPV 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 the Smart City SPV could receive international training on district cooling and work to establish district cooling under Bhopal's Smart City Plan.

Given its close proximity to the city, the smart city SPV could lead stakeholder coordination on district cooling in TT Nagar area and Bhopal 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 BMC 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.

Figure 6: Proposed Area Based Development Smart Components

Area Based Development – Smart Components



2. IDENTITY & CULTURE
Bhopal's rich Identity & Culture will be exhibited & preserved with the Cultural Hub to provide access to diverse cultural opportunities. Cultural Alley will provide pedestrian friendly public space with public art & performing areas, providing Creative Impetus to public.

3. ECONOMY & EMPLOYMENT
Masterplan would provide numerous employment opportunities to create a inventive-innovative economy providing prospects for employment to young generation. It aims to create multiple hubs & zones catering to various industries & research centres for future growth and employment.

4. EDUCATION
Multiple educational facilities of varied scale, serving not just the inhabitants of the Smart City but also the surrounding areas, a mix of Public & Private providing **equal learning opportunity** to students from all economic backgrounds.

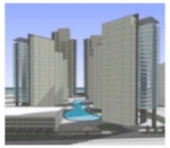
5. HEALTH
Development would constitute combination of **affordable healthcare** options with mix of Super Speciality Public & Private Hospitals,with world class.

6. MIXED USE
The Masterplan envisages various Hubs (Theme Based Mixed Development) to facilitate providing opportunity to new sectors of economy, providing diverse set of functions/ providing lively, comfortable and sustainable lifestyle to residents & community.

7. COMPACTNESS
Proposal has been designed to create compact, dense & Walkable City. The whole development is Transit Oriented Development within 5min (400m) walk of any Transit Station (BRT/LRT).

8. OPEN SPACE
Development is planned as green, walkable and cycle friendly development. It provides a variety of open spaces, design aims to create an Eco-Loop connecting major open spaces & waterbodies.

9. HOUSING & INCLUSIVENESS
It has been designed as mixed-use, high-density district that provides more options for city living meaning that more people can live near their work place. It will have a range of housing choices to ensure a broad population can be housed.



10. TRANSPORTATION & MOBILITY
The Site is served with 4 BRT Stations on the Northern Periphery & 3 LRT Stations on the Southern Periphery, and whole development has 5 mins. Accessibility. Vehicles are restricted to a 4- Lane Service Road periphery road on Site to give access to Development on the edge.

11. WALKABILITY
Development is inter-connected with multiple Pedestrian/Greens Linkages & Dedicated Cycle-Tracks at an Interval of max. 150 metres connecting all parcels to Major Plaza & Green Spaces. Bikeshare & Cycle Stands are provided at all Transit Stations.

12. I.T. CONNECTIVITY
Development would have fibre-optic connectivity to each household & office to provide super high-speed connectivity to every inhabitant as well as will have provision for Public Wi-Fi system in all public plaza/areas.

13. INTELLIGENT GOVT. SERVICES
Bhopal Smart City would have Government Services available through e-governance model already being implemented in State of Madhya Pradesh. In addition to these, certain hyper-local facilities would be provided within Shivaji Nagar Re-development which would then be extended to across the city.

14. ENERGY SUPPLY
Captive Gas based Power Plant with Grid Backup for 24x7 Power Supply. Solar power systems will meet 10% of the area's demand with Smart/Net Metering. The Smart Grid and distribution would ensure Snag free distribution.

15. ENERGY SOURCE
All buildings within Shivaji Nagar Redevelopment would have to meet 15% of there energy demand from Solar Energy with Rooftop Photovoltaic along with Building Intergrated Photovoltaics (BIPV).

16. WATER SUPPLY
The Smart City would be provided be 24/7 Water Supply. Water would be treated to best of International Standards and supplied by Municipal Corporation.

17. WASTE WATER MANAGEMENT
Run-off Water from the site would be drained with help of natural slope of the site and stored in Waterbodies on the site, all building would have rain water harvesting system to improve Ground Water Table.

18. WATER QUALITY
Sewage & Waste Water from whole development would be transported thru Sewage Pipe to Central Sewage Treatment Plant on the Eastern Periphery of the development. The processed water would be re-used for Landscape Irrigation & Flushing Water requirement.

19. AIR QUALITY
Transit Oriented Development with max. no. of people using Public Transport reducing need for Private Vehicles reducing Air Pollution. Vehicle Free Development reducing overall Air Pollution within the development with discouragement to usage & ownership of Private Vehicles with high parking and access charges.

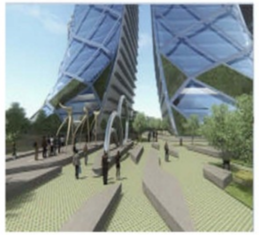
20. ENERGY EFFICIENCY
Bhopal Smart City would be a highly energy efficient urban zone, all street light would be LED based with Solar Panels, Smart Grids would be used to contain Transmission & Distribution Losses, All Buildings would have to meet Green Building standards such as LEED, GRIHA, GREENMARK etc.

21. UNDERGROUND ELECTRIC WIRING
Common services Tunnel for various services including Electrical Wiring which will provide Easy Access to Integrated Underground Utility Service (Electrical, communications, hot and cold water, centralize cooling system, pneumatic refuse collection pipes, gas pipes, sewer lines).

22. SANITATION
The development will have multiple Public Toilets integrated with Retail facilities so that Public Areas are free of Open defecation/urination. The development would also have a centralized STP for treating Sewage.

23. WASTE MANAGEMENT
The Bhopal Smart City will have Automatic Waste Collection System or Pneumatic refuse conveying system (S), which is a type of waste disposal system that uses air to move refuse through pipes to collection points. Waste Bins would be provided with sensors for proactive management.

24. SAFETY
The development would have combination of Active & Passive Security Features. Passive Crime Prevention techniques include AGU's (Activity Generating Uses) at Ground Floor Level to keep it active for majority of time and under regular public surveillance.



5.2 Bhopal's Solar City Master Plan

Bhopal has been selected by the Ministry of New and Renewable Energy (MNRE) to be developed as a Solar City under the Development of Solar Cities Programme. Bhopal's Solar City Master Plan developed under this programme targets to reduce the energy consumption by 17% by the year 2018, through adoption of renewable energy and improved energy efficiency.

The total energy savings planned in the period of 2013-18 and 2018-23 amount to 166.6 Million kilowatt hours (Million kWh) and 228.9 Million kWh respectively. 66% of the targeted energy savings are from increased use of renewable energy, planned through interventions including installation of solar water heating systems and solar PV systems in residential, commercial and public buildings, and through adoption of biogas gasifier systems. About 34% of the saving are targeted to result from energy efficiency interventions such as promoting the use of star rated equipment's and automatic street lighting control, and adoption of green building codes such as GRIHA and LEED. The residential sector has the highest scope for energy savings through renewable energy and energy efficiency interventions, followed by the municipal and the commercial sectors. The total investment for a period of ten years is estimated to be INR 11,810 million (USD 183 million).

Table 3: Sector-wise Targets for Renewable Energy and Energy Efficiency for Bhopal

Sector	Energy Saving Target (2013-18)		Energy Saving Target (2018-2023)	
	Million kWh	**Percent Share**	**Million kWh**	**Percent Share**
Renewable Energy	**109.5**	**66%**	**147.7**	**65%**
Residential	97.3	89%	123.9	84%
Commercial	8.5	8%	9.9	7%
Municipal	3.3	3%	13.8	9%
Energy Efficiency	**57.1**	**34%**	**81.2**	**35%**
Residential	42.2	74%	67.6	83%
Commercial	2.3	4%	2.2	3%
Industrial	0.3	1%	0.9	1%
Municipal	12.2	21%	10.5	13%
Total	**166.6**	**100%**	**228.9**	**100%**

The target to achieve a minimum 10% reduction in conventional energy consumption under the cities is not an obligatory target. It is seen that the implementation of the Solar Master plans in nearly all the Solar Cities in India has been quite unsatisfactory in terms of physical progress and meeting the large scale sector-wise targets owing to a number of barriers[7]. In the case of Bhopal, the Solar Master Plan has been approved by the MNRE but no funds have been sanctioned for implementation of the plan till date and thereby progress in terms of implementation has been slow, with no significant impacts evident in the city in terms of

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

increased renewable energy use or energy efficiency. The Solar City Programme, however, has provided a platform to motivate and enable the city to assess current and future energy demand and undertake strategic planning for promoting and implementing interventions to reduce energy demand. The programme has helped to create an eco-system for increased adoption of renewable energy and energy efficient technologies by end-users.

Box 2: Solar City Program Analysis

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

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

The first step to set such goals and/or justify the inclusion of district cooling in the Solar City Master Plan, is to calculate the beneficial impact of district cooling on energy consumption and identify the benefits and linkages to Bhopal's policy goals (e.g. Pan-City goals from the Smart City Mission such as green building targets; meeting 10% energy consumption reduction target etc.).

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

5.3 Bhopal's Voluntary Initiatives

Bhopal has been undertaking initiatives to address energy consumption and climate mitigation initiatives. Bhopal has previously engaged in the Cities for Climate Protection Campaign (CCP)[8], an international initiative that strived to reduce GHG emission and air pollution in cities through appropriate local interventions. Actions undertaken by Bhopal under this initiative include reducing energy bills for water pumping include replacement of pump sets and installing capacitors at eight pumping stations, and at four-hundred mini pumping units. The BMC implemented a corresponding maintenance program to address leakages and reduce friction in the pumping system. The BMC also focused on increasing energy efficiency in public street lighting by removing redundant lamps in high-mast lighting at traffic intersections, installing daylight sensors to automate streetlight operations, and replaced 150 watt high pressure sodium vapour (HPSV) lamps in residential colonies with 75 watt HPSV lamps.

As part of the Smart City Plan, the BSCDCL and BMC are working in partnership with the SECI to install solar rooftop systems having a capacity of 3 MW at public hospitals, private education institutes, orphanages, NGOs, religious places and for domestic use. Bhopal has also recently signed an MOU with the MPUVNL for the implementation of 1 MW rooftop PV system in Bhopal. Solar PV rooftop systems of 35 kW capacity have been installed at the main BMC administrative building (The Free Press Journal, 2017).

Box 3: City leadership

Bhopal is showing leadership on a range of sustainability issues, particularly piloting and advocating for clean, innovative technologies. Bhopal could similarly provide leadership to the district cooling sector, helping to pilot and promote this technology. Bhopal's promotion and involvement in an early demonstration project will be particularly important. Bhopal could finance and/or attract concessional finance to a demonstration project in the TT Nagar Smart City Area 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 Bhopal then it could later be privatized once commercial viability is proven, creating a profit for Bhopal. 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, Bhopal 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).

[8] ICLEI's CCP Campaign helped local governments directly influence and control many of the activities that lead to global warming and air pollution, through various sectoral projects related to land use policies, infrastructure and other service provisions, transportation management systems, building codes, and waste management

Bhopal 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, Bhopal 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 Bhopal. This could also be undertaken by the SPV established to deliver the Smart City Plan. The unit would present the potential cost savings, environmental benefits and any local incentives available; and provide locally-relevant information to potential district cooling customers or developers to encourage connection and development of networks. This could include making available best practice assessment methodologies, tools to rapidly analyze cooling costs, sample contracts, previous feasibility studies and demonstration project results – including BMC's experiences and savings from connecting to district cooling[9]. Also important are formal and informal networks and contacts between, for example, municipal employees or officials and state utilities, building developers and housing associations.

Bhopal 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 roadworks in order to save costs and minimize disruption. This group could also be consulted on new policies, plans and financing instruments designed to support district cooling. This is a key best practice from cities worldwide. This group could also be led by the SPV established to deliver the Smart City Plan and incorporated with the 'sustainable energy delivery unit'.

Bhopal can promote district cooling development and ensure strong analysis of district cooling opportunities by undertaking and maintaining a GIS energy mapping[10] of the city incorporating spatial analysis of cooling demand, upcoming building developments and assessments of renewable and waste heat options. 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 Bhopal 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.

6 Local policies and legal framework

6.1 Planning Authority and Framework

The key institutions that play a key role in the planning and management of Bhopal are:

[9] 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.

[10] 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.

- **The Directorate of Town and Country Planning, Madhya Pradesh** is responsible for the preparation of Master plans, Development plans, and regulations for building development within each land use zone.
- **The Bhopal Development Authority (BDA)** is the main implementing agency of the master plan and development plan prepared for the larger planning area (including Bhopal city and its surrounding area). The BDA conceives, promotes and monitors the key projects for developing new growth centres along with provision of basic infrastructure and amenities to these areas. The BDA also engages in projects that bring about improvement across sectors such as roads, transport, housing, water supply, and environment in the region.
- **The Bhopal Municipal Corporation (BMC)** holds the primary responsibility to provide and maintain the public services within the city limits. The BMC is also responsible for implementation of proposals made in the Development Plan and for maintaining the infrastructure developed by BDA, once it gets transferred to BMC. The planning and rehabilitation department of the BMC is responsible for issuing licenses and providing building permissions for all developments in the city.

Development in Bhopal is currently guided by the Bhopal Development Plan, 2005. The Development Plan is a macro level strategic plan that defines the direction of growth and visualizes the citywide infrastructure for the larger urban agglomeration. It contains detailed analysis of availability of existing physical and social infrastructure facilities and carrying capacity of city, and includes policies for densification/re-densification, renewal/redevelopment and congestion. 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 draft City Development Plan, 2021 has been prepared by the BMC for the area under its jurisdiction, in accordance with the Development Plan, 2005. This plan aims to overcome the deficiencies and gaps in various sectors while also addressing issues in the areas of urban governance, finance and management. The draft City Development Plan 2021, however, has been put on hold by the State Government at present and is yet to be approved and will be operationalized subsequently.

Land use zoning, development density, building heights and other development and building related guidelines in the city and the planning area are regulated by the Madhya Pradesh Bhumi Vikas Rules, 2012 developed by the Directorate of Town and Country Planning.

6.2 Existing and Proposed Development

The municipal area of Bhopal spans 286 sq. km. which includes all the developed areas, water bodies, agricultural land, and other land uses. The planning area as per the Bhopal Development Plan, 2005 is 601 sq. km. This planning area was increased to 806 sq. km. in year 2006 and includes Bhopal city along with its areas of Bairagarh, BHEL Township, Kolar Nagar, and 135 urban and rural villages in its vicinity. The Development plan, 2005 guides land use planning and development in the Bhopal planning area or the larger urban agglomeration. A separate Master Plan, outlining planning and development for Bhopal city limits, has not been prepared. Therefore information on the existing and proposed land use for the city limits is not available.

Residential developments account for 49% of the developed land parcels in the Bhopal planning area. Being the capital city and administrative centre of the state, institutional developments have a notable share of 20% in Bhopal's developed land area. The land use envisioned in the Development Plan, 2005 has not been fully realized at present. The existing area under developments in commercial and industrial sectors is observed to be much lesser as compared to that planned in the Development Plan, 2005. In the yet to be approved Draft Development Plan, 2021, it is envisioned that the area under developed land will double as compared to the developed land area at present.

Table 4: Existing and Proposed Land Use for Bhopal Planning Area

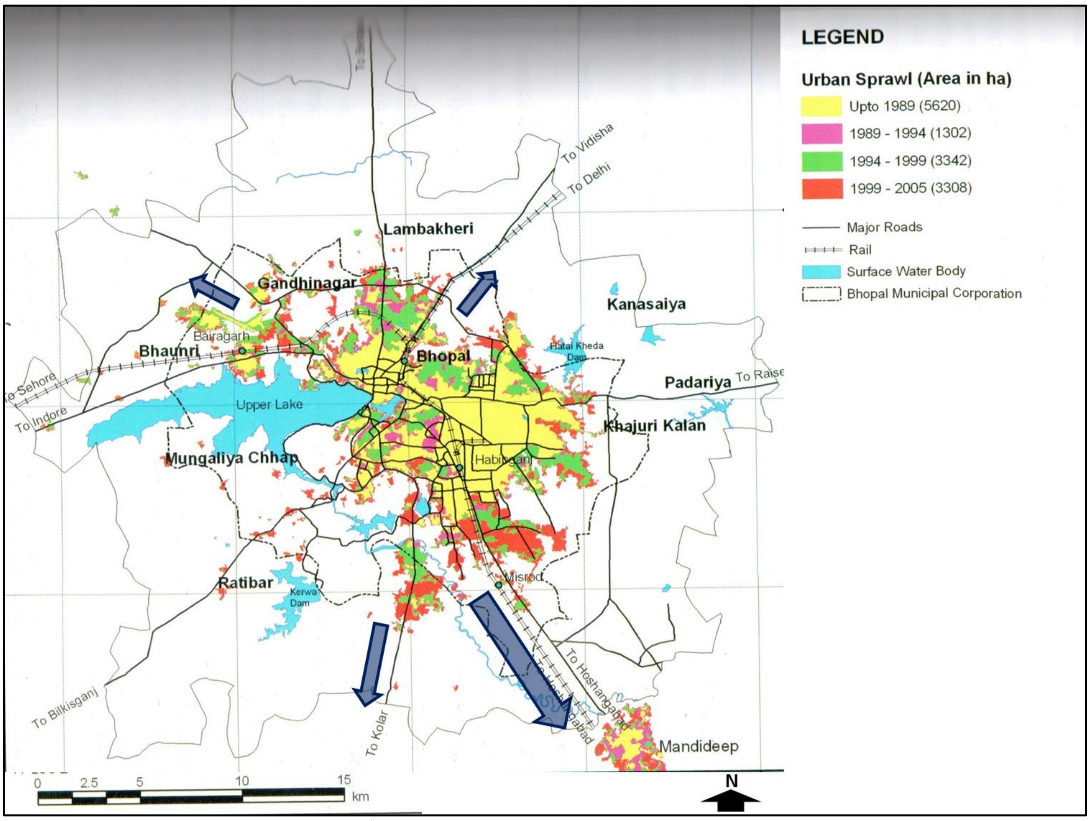
Land Use	Existing Land Use (2011)		Proposed Land Use (Development Plan,2005)		Proposed Land Use (Draft Development Plan 2021)	
	Area (sq. km)	Percent Share	Area (sq. km)	Percent Share	Area (sq. km)	Percent Share
Residential	91.66	48.9%	81.90	46.48%	193.82	53%
Commercial	3.34	1.78%	6.50	3.71%	13.21	3.61%
Public Semi-public (PSP)[11] & Public Utilities & Facilities (PUF)[12]	38.99	20.83%	17.46	9.96%	54.93	15.03%
Industrial	7.38	3.94%	13.89	7.93%	11.14	3.05%
Transportation	32.60	17.42%	26.00	14.85%	13.94	3.81%
Recreational[13]	13.21	7.06%	29.25	16.71%	78.63	21.50%
Total developed area (excluding undeveloped area)	**187.17**	**100%**	**175.00**	**100%**	**365.67**	**100%**

Spatially, the city is observed to be expanding towards the south and south-east direction along the Hoshangabad road. The ease of transportation, availability of even terrain, and proximity to the city's Habibganj railway station are the major factors responsible for this growth. The type of development observed in this area is mostly residential and commercial and shopping malls, retail spaces, office complexes have come up along the main roads. Slight development is also observed in the north-west direction towards Gandhinagar. The type of building development observed to be coming up in this area includes educational

[11] Public and Semi Public use zone includes government/semi-government/public offices, government land use, police station, education and research, health and socio-cultural and religious use activities.
[12] Public Utilities and Facilities use zone includes public utilities and services such as water treatment plants, sewage treatment plants, electric sub-stations, trunk line corridors, telephone exchange, fire control stations and solid waste disposal and processing sites
[13] Recreational use zone refers to playgrounds, stadium, sports complex, public open spaces such as parks and gardens, multi-open space, and lake front development.

institutes, government offices and IT/ITES companies. The vast expanse of the Upper Lake restricts the westward growth of the city.

Figure 7: Urban Sprawl of Bhopal City



A Transit Oriented Development (TOD) Plan has been recently prepared for the city in 2016, in line with the draft TOD policy developed for the state of Madhya Pradesh. TOD corridors are typically high-density compact developments along the transit corridors. Bhopal's TOD Plan was prepared with the aim of developing city level policy recommendations that will enable implementation of TOD oriented planning principles in the ongoing Bhopal Master Plan update and metro rail detailed project report preparation. The proposed recommendations integrate both the BRT and metro rail, along with maximizing the development potential along its transit corridors. The plan promotes mixed land use, greater floor-area ratio[14] (FAR) and compact development.

The total area proposed under standard TOD zone[15] in Bhopal is about 128 sq. km. which is 16% of the total planning area. Bhopal's TOD plan has categorized station areas along the proposed transit corridor into six different typologies based on an assessment of existing conditions and future development potential. The plan recommends land use mix for TOD

[14] FAR refers to the total floor area of a building (including the space covered by all the floors in a building) divided by the total area of land plot on which the building is being built. Town Planning Schemes and Development Plans outline different FAR values for different areas to guide development densities. The F.A.R. value, when multiplied with the plot area gives us the maximum floor area that can be constructed for a building in the plot. This is subject to satisfying other conditions such as land allocation for parking, setbacks, access width etc. A higher FAR value will lead to higher density of development.

[15] Refers to an area within a 300m wide belt (5 minute walk) on both sides of centre line of Bus Lane in BRT corridor or right of way of other public transport routes or an area within 800m (10 minute walk) radius from the center of a MRT Station or BRT Station.

specific to the context of each of these typologies (see Table 4 and Figure 9). The development context has also been identified for the station areas, in terms of whether these are green field areas or existing areas that need to be taken up for redevelopment or built-up infill development[16] (see Figure 10). The permissible FAR that can be utilized by buildings in the TOD zone ranges from 2.0-3.0, depending on the specific zone where the building is to be constructed. An additional FAR of 1.0 can be obtained through the through Transfer of Development Rights[17] (TDR) mechanism.

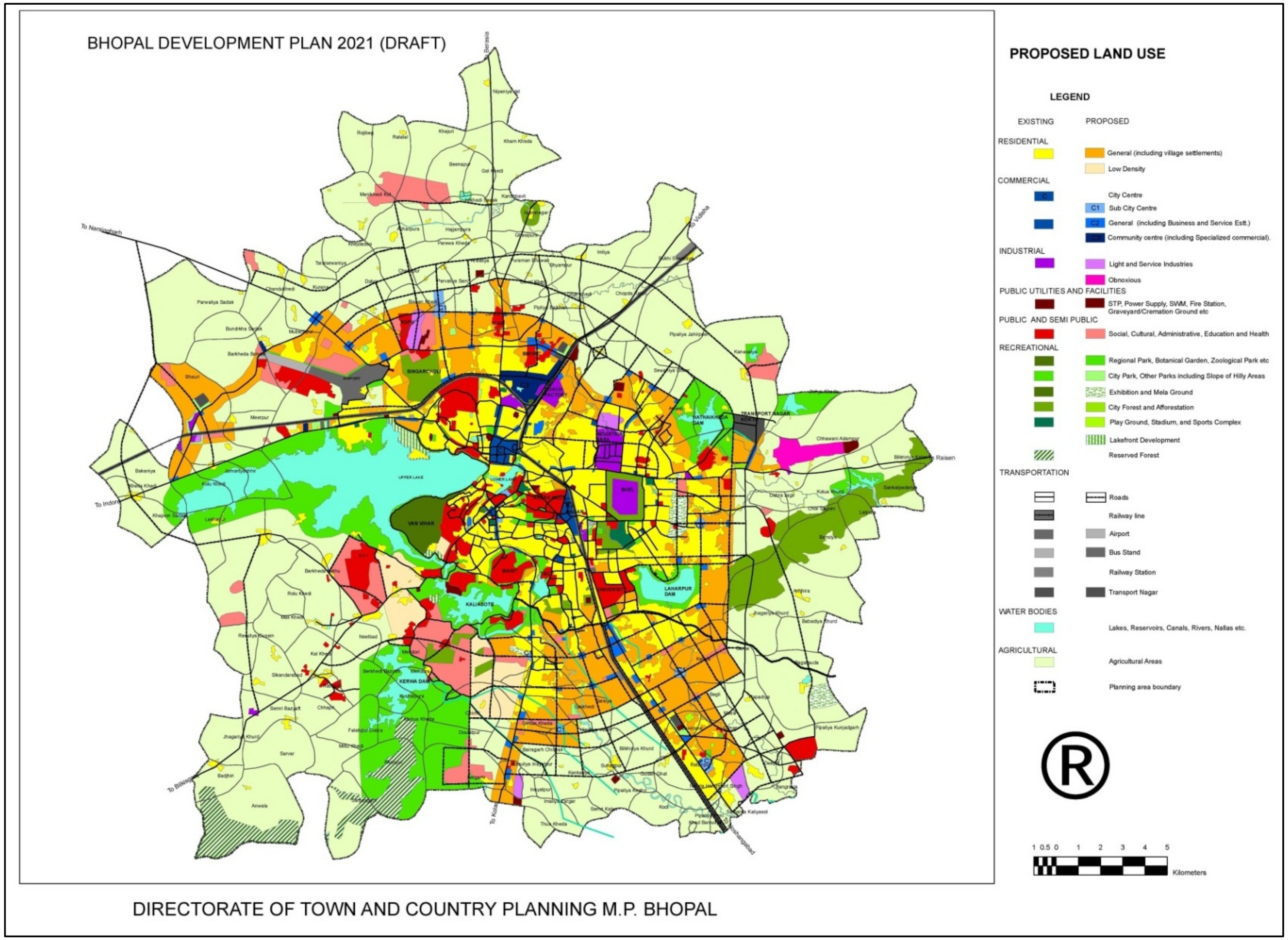
Table 5: Recommended land use mix to promote transit oriented development for different development typologies in Bhopal

Typology	Character of existing land use mix and development type	Recommended land use mix for TOD
Mixed Use Commercial Centre	Predominantly commercial activities on the ground floors along the main roads supported by moderate residential and institutional uses	Residential: 30-40% Commercial: 30-50% Public/semi-public and others: 10-20%
Mixed Use Neighbourhood	Predominantly residential districts supported by moderate mix of retail and public facilities	Residential: 50-70% Commercial: 20-30% Public/semi-public and others: 10-20%
Employment Centres	Significant centre of economic and community activities including offices, institutions, entertainment and a moderate mix of retail and residential uses	Residential: 30-40% Commercial: 10-20% Public/semi-public and others: 30-50%
Retail Destinations	Predominantly commercial and retail uses (>75%) with a moderate mix of residential uses within a 400 m radius	Residential: 30% Commercial: 50-60% Public/semi-public and others: 10-20%
Heritage Precincts	Old parts of the city with significant historical, cultural and architectural characteristics and including moderate to low-density mix of public/semi-public and cultural uses. Some residential and local-retail is also supported	Residential: 30-40% Commercial: 10-20% Public/semi-public and others: 10-20% Heritage areas: 20-30%
Transit Interchanges	Significant hubs of transport activity with moderate- to high-density mix of industrial, commercial, employment, public/semi-public, cultural and residential uses	Residential: 30-40% Commercial: 10-20% Public/semi-public and others: 10-20% Transportation: 20-30%

[16] Infill development focuses on developing vacant or underutilized land in previously developed areas using the existing infrastructure to serve the new development.

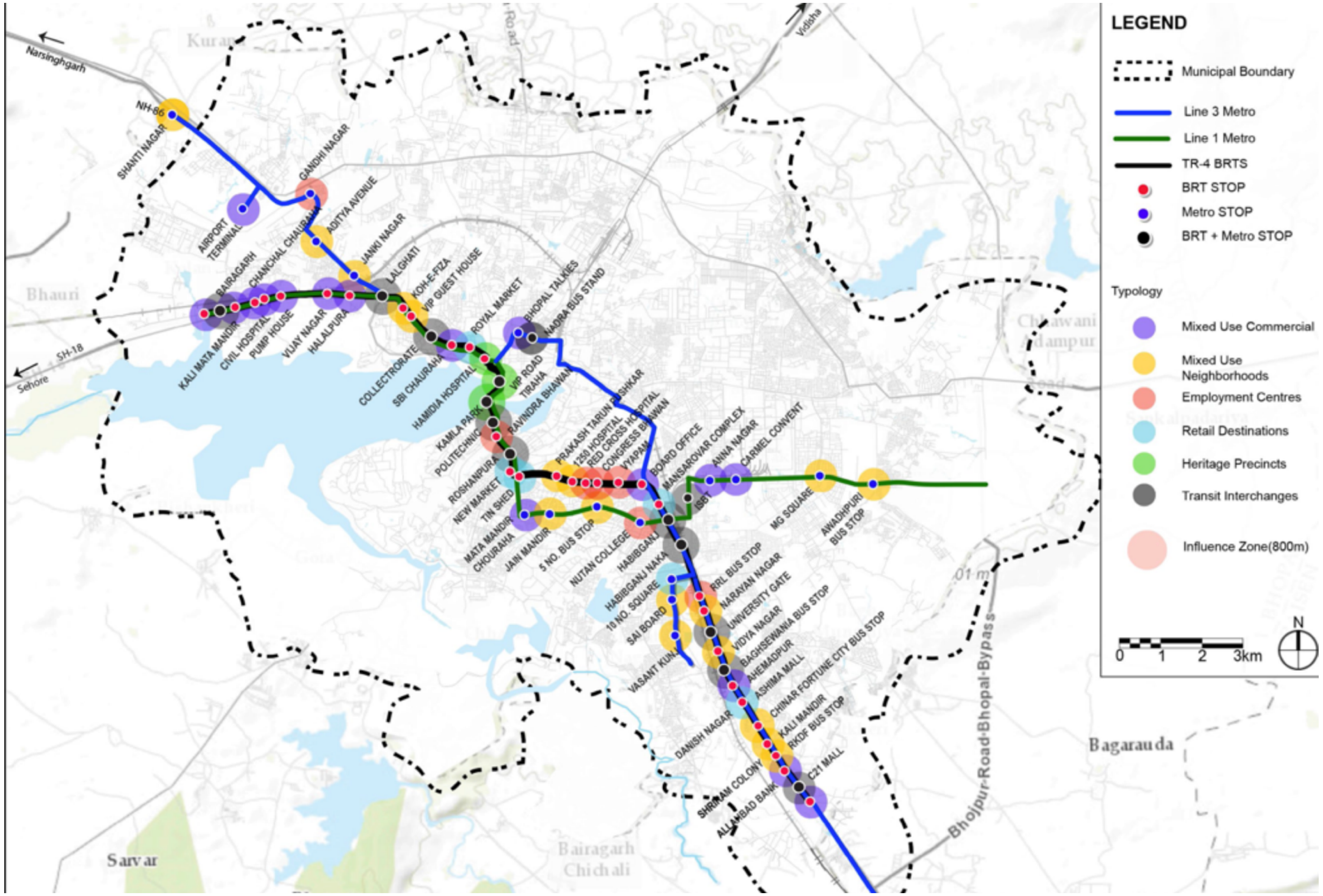
[17] TDR is a mechanism to facilitate the acquisition of land for public infrastructure development activities such as road widening, metro rail projects, etc. Under the TDR scheme, a property owner whose land is reserved for public purposes gets a development rights certificate from the local government (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.

Figure 8: Map of Proposed Land-use for Bhopal City - 2021



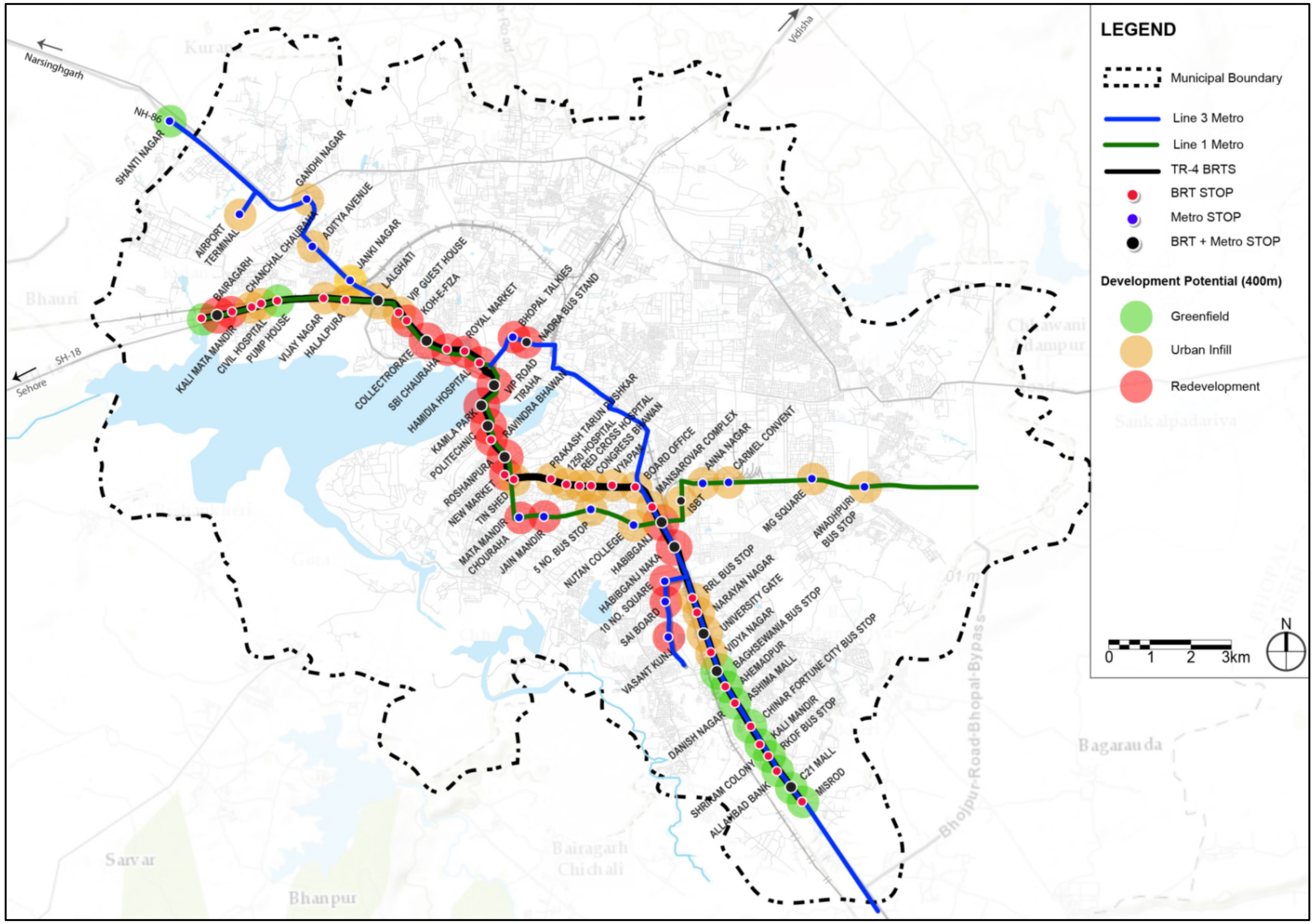
Source: (Bhopal City Development Plan, 2021)

Figure 9: Proposed Station Development Typologies in Bhopal's TOD Plan



Source: (TOD City Specific Plan – Bhopal, 2017)

Figure 10: Proposed Development Context for Station Areas in Bhopal's TOD Plan



(Source: (TOD City Specific Plan – Bhopal, 2017)

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

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

Bhopal 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, Bhopal could make space available where energy centers could be placed in public buildings or otherwise.

BMC and BDA can use their zoning authority to create 'high priority' and 'medium priority' zones for district cooling, based on data from GIS energy mapping (recommended in Box 3 and described further in Box 10) recommendations from urban planners and using benchmarks for district cooling viability (e.g. cooling demand density). The city could then attach specific conditions to building permits within these zones. Bhopal 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, BMC 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 BMC and international experts. In particular, ensuring high-quality of assessments given the lack of district cooling experience in India will be important[18].

Similarly, requests for re-zoning by building developers above a certain size could provide an opportunity for Bhopal to accelerate district cooling. State government, BDA or BMC could permit re-zoning under the condition that the developer meets stricter operational/primary efficiency building

[18] 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.

standards[19] and/or evaluates the potential for district cooling and if techno-economically feasible, then establishes district cooling systems.

Bhopal can use the planning process to put in place specific connection policies (of different buildings types) in the high priority areas. Furthermore, Bhopal 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, BMC could use its regulatory authority to enforce that after the investor /operator has gained its return on investment at a certain percentage, it has to then share the profits with consumers ensuring that they too benefit from the efficiency gains of DC. Such a licensing scheme is more likely to be established in the longer-term once district cooling has been demonstrated.

In Bhopal, urban redevelopment is planned in existing urban areas, such as the TT Nagar Area, with huge levels of redevelopment and application of higher sustainability standards on buildings. Such urban redevelopment projects often have significant influence from local authorities and can have district cooling concepts incorporated from the start of development, for example setting aside land specifically for use by a district cooling plant, developing buildings with centralized cooling and in a phased approach that could match district cooling construction. In addition, BMC 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 BMC to step-in and work with developers to ensure district cooling is appropriately assessed

6.3 Building Regulations and Certifications

Building development in Bhopal city is presently regulated by the Madhya Pradesh Bhumi Vikas Rules, 2012 which lays down the development control norms and general building requirements in terms of building height, ground coverage, and FAR for all land uses. The permissible FAR as per the development rules have been given in Table 6. The permissible FAR for residential areas is 1.25. For residential group housing which refers to large residential complexes, the FAR ranges from 0.75 to 2.0 depending upon the residential density and the extent of allocated land parcel that is covered by the building. The FAR for commercial areas ranges from 1.25 to 2.5 based on the category of the commercial building. The norms for industries can be relaxed by state government on recommendation of industries department wherever required. To promote large IT industry in the city, an additional FAR of up to 100% is allowed for software developments.

[19] 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.

Development of buildings in the TOD zone**Error! Bookmark not defined.** is regulated by the M adhya Pradesh State TOD policy and guided by Bhopal's TOD plan. As per Madhya Pradesh's TOD Policy, buildings to be developed in the TOD zone can utilize a maximum FAR of 3.0 (with maximum ground coverage of 40% and a maximum density of 2000 persons per hectare). An additional FAR of 1.0 can be availed through Transfer of Development Rights[20] (TDR) mechanism, thereby promoting dense development. A premium charge will have to be paid for FAR that is availed in addition to existing permissible FAR of 3.0.

Table 6: Use-wise Permissible FAR applicable in Bhopal

Use Zone	Maximum Permissible FAR	Details	
Residential	**1.25**	-	
Residential – Group Housing	**0.75 - 2**	**Depending on the density and ground coverage**	
		Density (persons/ha)	**Maximum Coverage (%)**
	0.75	125	25
	1.25	250	30
	1.50	425	33
	1.75	500	35
	2.00	625	35
Commercial	**1.25 - 2.5**	**Depending on the type of commercial centre**	
	1.25	Convenience Shopping Centre	
	1.50	Local Shopping Centre	
	1.75	Community Centre	
	2.00	Sub-city Centre	
	2.50	City Centre	
Public Semi-public	**1**	Includes Administrative areas, education and research, health, social and cultural buildings	
Industrial	**1 – 1.5**	Depending on the plot area with 60% maximum ground coverage	
	1.25	Up to 0.10 hectare	
	1	Above 0.10 hectare	

[20] TDR is a mechanism to facilitate the acquisition of land for public infrastructure development activities such as road widening, metro rail projects, etc. Under the TDR scheme, a property owner whose land is reserved for public purposes gets a development rights certificate from the local government (equivalent to the reserved land portion) upon surrendering the property to the public body. The rights/certificate can then be utilized either for the remaining portion of the same property or elsewhere or sold to property developers who wish to use the development rights to undertake additional construction on their property.

Use Zone	Maximum Permissible FAR	Details
	1.5	For industry with minimum plot area of 0.15 hectare and ground coverage 50%

(Source: Madhya Pradesh Bhumi Vikas Rules, 2012)

Box 5: Incentivizing district cooling through density bonuses

Bhopal could use the existing administrative structure of increase FAR allowances 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 FAR. 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 FAR bonus could become increasingly difficult, could be linked more generally to building efficiency (for example through building certification schemes such as GRIHA or LEED). Several cities around the world are actively promoting district energy using this urban planning tool. Other cities in India, such as Pune and Rajkot, already provide FSI bonuses linked to sustainability criteria[21]. Furthermore, the Bank of Maharashtra, a leading nationalized bank in India, has announced a rebate of 0.25 percent in the interest rate on housing loans for projects that are Eco-housing certified in Pune[22] – the bank could similarly develop incentives for green building certifications in Bhopal.

6.4 Legislation relating to Space Cooling

The existing development and building regulations in Bhopal need to be strengthened to have an increased emphasis on energy efficiency in buildings and particularly for space cooling. The guidelines and provisions in the local regulations largely address merely the structural aspects and placement of air conditioning installations and place little emphasis on improved efficiency or standards for cooling.

However, Bhopal recognizes the need to address this gap and promotion of green and energy efficient practices in buildings forms a key strategy in Bhopal's Smart City plan. In the area based development proposed for the T.T. Nagar area in Bhopal's Smart City Plan, upcoming buildings will have to get obtain LEED/GRIHA green building certification (minimum Gold/Silver rating). Already constructed buildings in this area would need to undertake upgrades and interventions to obtain green building certification. The BSCDCL and the BMC are engaged in developing a 'Blue and Green' Action Plan, which will provide a blueprint to establish green

[21] Buildings with Pune's Eco-housing certification receive rebates from Pune Municipal Corporation (PMC) on additional floor space charges. The PMC also offers additional FSI of 3 to 7 percent for GRIHA certified green buildings.
[22] For more information see: http://www.iiec.org/index.php/iiec-news/162-eco-housing-gains-market-acceptance-and-bank-support-in-maharashtra-india-.html

buildings across the city in a phased manner, and implement innovative solutions and standards for sustainable energy management.

The MPUVNL is actively promoting building energy efficiency in the state of Madhya Pradesh through capacity building and awareness generation campaigns. The MPUVNL has also undertaken demonstration projects on the implementation of the Energy Conservation Building Code (ECBC), which sets energy efficiency standards for building energy use in large commercial buildings, including that for space cooling. Although efforts in this regard are observed at the state level to an extent, the city of Bhopal is not implementing this building code at present.

In order to manage peak load, time of day tariffs are levied for consumers connected to high tension power lines, which typically comprises of industries or large building developments. In order to dis-incentivize energy consumption during the peak period, a surcharge of 5% is levied on the applicable energy charges for high tension consumers between 1800-2200 hours. To incentivize energy consumption during the off-peak hours from 2200-0600 hours, a reduction of 15% on the energy charges is applicable for high tension end-users.

Box 6: District cooling ready buildings[23]

Bhopal could 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 building efficiency mandate being applied on the TT Nagar area. 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 Bhopal 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.

Mandates for connection to, or development of, district cooling systems in high priority zones, such as TT Nagar should also be explored. 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.

Box 7: Ensuring the ECBC promotes district cooling growth

Adopting the ECBC will be a major step for delivering sustainable buildings in Bhopal. Its adoption 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.

[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.

The adoption of new guidelines provides an opportunity for Bhopal to ensure that efficiency improvements to buildings that connect to district cooling are acknowledged in its local building regulations. Bhopal can adapt ECBC requirements to ensure DC connected buildings meet ECBC requirements. 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, Bhopal 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)**.**

6.5 Incentives and Subsidies

At present, Bhopal city does not offer any incentives to promote green buildings, renewables or efficient space cooling. While municipal tax related incentives are seen to be an effective mechanism to promote investment in renewable energy and green buildings, these are lacking in the city as well. Madhya Pradesh's new Energy Policy, 2016 offers 30% capital cost related financial assistance to consumers for installing rooftop or ground-mounted solar PV systems.

Bhopal is keen to promote sustainable practices and technologies in buildings, as seen from the proposed mandate on green building certification for new and existing buildings located in the area based development project under Bhopal's Smart City initiative. Bhopal's local authorities are keen to promote green building certification across the entire city. The proposed requirement for green building certification can be leveraged to promote assessments of district cooling feasibility and ensuring impacts and incentivize connecting to the district cooling network.

6.6 Demonstration Projects

BMC has been open to adoption of new technologies for addressing energy consumption and improving service delivery. A few unique projects initiated by the BMC include:

- A solar PV system of 35 kW, operating on net-metering mechanism, has been installed on the BMC main administrative building.
- About 20,000 street lights in Bhopal city are being replaced with LED streetlights through a PPP project under the Smart City Plan. This project is expected to help realize energy savings of 60%. 400 smart poles will be installed, equipped with CCTVs and digital connectivity for surveillance, traffic control, parking management, and remote control and monitoring capabilities.
- Installation of 1 MW solar PV system through a PPP-based RESCO mode is planned at Lake-side VIP road and power evacuation to grid with a long term Power Purchase Agreement.

Solar rooftop PV systems with a cumulative capacity of 3 MW are planned to be installed in association with SECI.

- Energy efficiency measures in 80% of the BMC's buildings will be implemented through the BMC's own funds under the Smart City Plan

Box 8: Bhopal as a demonstrator

BMC'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. Building on this leadership, BMC can develop a demonstration project on district cooling as well as establish a sustainable energy delivery unit as described above in Box 3, both of which are a best practice for scaling DES.

6.7 Project Financing in Bhopal

Bhopal intends to leverage funds available under the current programmes and schemes of the Government of India as well as state government to finance development and implementation of projects outlined in its Smart City Plan. The funds are expected to fuel city's growth through programs. The activities proposed under Bhopal's Smart Cities Plan are designed to achieve convergence in terms of activities and goals with key programmes such as 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), and the Solar Cities Program. Leveraging opportunities for private sector investment forms a key strategy in Bhopal's Smart City Plan.

The BMC has been exploring new avenues in technology adoption using its own funds. Recently, it installed a net-metering based solar PV system worth INR 1.9 million (i.e. USD 29,000) of capacity 35 kW on its main administrative building. The BMC has also signed a MOU with MPUVNL, the nodal energy development agency for Madhya Pradesh State, for implementation of rooftop solar PV systems of 1 MW capacity in the city. MPUVNL will be assisting the BMC with regard to technical aspects and the solar PV systems will be installed on the lake-side VIP road through a PPP, including the BMC and a private agency. The implementation will be based on the RESCO model, with the public entity not making any upfront investment. A long-term power purchase agreement will be signed between the private agency installing the system and the public entity procuring the power at a mutually agreed tariff.

Bhopal is also implementing a PPP based smart poles and intelligent street lights project in India under the Smart City initiative. This project comprises of two components – 1) Installation of 400 smart poles across the city and 2) Replacement of 20,000 existing conventional street lights with energy efficient LED street lights. The project will be implemented on a Design, Finance, Build, Own, Operate & Transfer (DFBOOT) model. Bhopal is leveraging private investment of INR 6,900 million (USD 105 million), which covers capital expenditure and operation and maintenance for a period of 15 years. The project component covering LED streetlight replacement will be on a shared savings basis, with the resulting energy saving realized being shared between the private entity and the BMC.

Box 9: Financing district cooling

BMC 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 BMC and other stakeholders including local financiers to be able to deliver and finance a district cooling project. Analysis of how BMC and other Indian cities have handled similarly large infrastructure projects should be done and lessons learnt for district cooling. National support programmes and entities could be made available and international expert law firms, consultancies, multi-lateral development banks and international district cooling operators should be used to help smooth the financing and handling of district cooling, which will be crucial during the 'demonstration phase' of this technology[24].

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

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

- EESL / ESCO model

These are elaborated as follows

- Bhopal 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). Bhopal could also be involved in a joint cooperation model with the private sector and invest into helping the project succeed through their strong planning authority, and coordination and by encouraging connection which would lower risks and thus financing costs. In return, the city can direct the private sector to achieve specific environmental or social objectives, or have special tariffs for poor segments of society, and/or sit on board for the utility.
- The Ministry of New and Renewable Energy (MNRE) could provide a portion of the funds needed for district cooling demonstration projects as a loan or grant from existing central government schemes. The State Government, including State Renewable Energy Development Agencies (such as MEDA), could also provide additional funding or subsidy from state funds. Such support could be crucial in the roll-out of district cooling, helping to lower risks and the cost of financing for district cooling demonstrations. Such support would only be required in the initial period and could be slowly phased out.
- It could be extremely beneficial to district cooling in India if state electricity utilities were incorporated into the business model as they have power to scale-up the district cooling model across multiple cities and can internalize the power system benefits – including the investment in upstream infrastructure. However, tight utility budgets and a disincentive to invest in measures that reduce demand make their investment unlikely. But if the business model is designed correctly, district cooling could provide an alternate revenue stream for them. Further, where capital budgets allow, utilities can host an ESCO model for district cooling where they can expand the number of consumers while reducing demand.
- Bringing building developers into the business model has been successful in other countries as they control the development timetable. However, many want a quick 'out' so they can invest capital elsewhere, but some may like the steady returns post-sale. Some developers could become multi-utility providers, particularly in integrated townships, providing services for their properties such as water, waste, power, cooling (e.g. Dubai).
- EESL could build upon its ESCO model used for small-scale appliances and expertise in efficiency projects to develop a business model for investing and operating district cooling projects – this has huge potential as EESL has a large amount of capital, well-developed existing programmes related to cooling, a desire to export abroad and strong links to utilities and cities. EESL's expertise in district cooling could be boosted through

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

- There is little expertise in India regarding district cooling. Bringing in international private sector to invest in and/or operate projects would help to transfer knowledge and capacity to the local stakeholders and ensure initial projects are of a high quality – extremely important in such a nascent market which needs to establish a strong reputation. International private sector also has significant levels of capital and can invest significantly. However, the risk assessment of Indian cities and projects may not be favourable and the returns demanded may be too high. International private sector can also be brought in to operate systems, directing investments without risking significant amounts of their own capital.
- Smart City SPVs. The SPVs being established to deliver the Smart City Plans could provide a useful conduit for district cooling investment. The SPVs will be attracting investment from external parties and would manage building development and utility development in an area, helping to lower risk for the DC project. However, this would require cities incorporating district cooling into their Smart City plans as a priority. In Bhopal 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 Bhopal

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

- **Unavailability or limited access to relevant information for district cooling project planning:** Limited data exists on cooling demand, existing energy baselines and prevalent technology and appliance use for space cooling, and decentralized chilled water systems installed across the city. Sub-metering to enable assessment of cooling loads is absent in the city's buildings and thus crucial baseline data on cooling demand and hourly load patterns required to assess detailed feasibility of district cooling is not readily available. In addition, there is no quantitative and spatial data on potential waste heat 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. While the BMC was keen to integrate district cooling into the Smart City redevelopment project at T.T. Nagar which demonstrates awareness within the local authorities in Bhopal, limited awareness on district cooling exists amongst other stakeholders in the city. Given that Bhopal's climate is not hot and humid for a large part of the year; public perception may not be favourable towards adoption of centralized air conditioning systems and incurring related costs, particularly in residential and smaller commercial developments.

- **Lack of local technical expertise**: Lack of in-house experience within the BMC and the BSCDCL 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. This factor also contributed to the BMC not going ahead with integrating district cooling concepts in the Smart City redevelopment project. Considerable efforts will need to be undertaken to enhance local capacity and expertise for implementation.
- **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. Also requisite provisions in Bhopal's local building and development regulations and incentives to promote efficient space cooling in buildings are lacking. The BMC however is keen to promote green buildings and compact mix-use development through its TOD plan, which can be leveraged to enable district cooling development.
- **Difficulty in retrofitting existing building developments:** Building developers in Bhopal have faced difficulties in convincing occupiers to pay for maintenance costs incurred for the central air conditioning units installed in the existing establishments such as malls. Integrating district cooling in existing buildings is a challenge since it is likely that potential consumers will be reluctant to incur costs for any internal structural changes. It may prove difficult for building developers and managers to convince occupiers to make such changes. Further, the networks for utilities and services have already been laid along with the transportation network in existing brownfield developments. Limited information is available on buildings having centralized chilled water system in the city. However, urban redevelopment projects such as the T.T. Nagar redevelopment under the Smart City Plan offer promising opportunities to integrate district cooling at an early stage of redevelopment and subsequently connect to existing buildings.
- **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. Building developers in the city have expressed concerns over the higher maintenance and manpower cost associated with the chilled water based systems. Additional costs incurred for maintenance of ceilings due to leakage of moisture along the pipelines circulating chilled water has been cited as one of barriers.

- **Lack of financing and project development experience**: The city and local stakeholders do not currently have the 'district cooling specific' experience to support a project from concept to construction, including feasibility studies, tendering, financing, business model design, procurement, negotiations, contracting and construction. Local financing institutions are unlikely to have the required experience to provide the complex finance required to district cooling projects which can have long returns and high initial investments.

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

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

9 Space Cooling in Bhopal

Bhopal city experiences a pleasant climate most of time through the year due to presence of lakes in and around the city. Use of desert water coolers is predominant in households in the city, with use of air conditioning not too prevalent traditionally. Use of air-conditioning is seen to be rising of late, driven by changing lifestyles and increasing affordability. Approximately 300-400 individual air conditioners are sold per month by each of the 50-60 air conditioning vendors operating in the city[25]. Sales of air conditioners go up to 2,500-3,000 units per month during the peak summer months.

With growing commercial and institutional activities in the city, space cooling demand in large commercial, retail and institutional buildings is being increasingly met by centralized air conditioning systems. Recently constructed shopping malls in Bhopal such as the DB City Mall and the Aashima Mall have centralized water-cooled air conditioning systems. The air

[25] Discussions with locally based Blue Star air-conditioning systems retailer in Bhopal.

conditioning system in Aashima Mall has chillers with a cumulative capacity of 1500 TR. A centralised air conditioning system of 340 TR capacity is planned to be installed at the extension building that is presently under construction for the Vallabh Bhawan, the Secretariat of the State Government, housing a number of key administrative offices and departments.

The section 1.7.2 analyses the variation in the seasonal electricity consumption with respect to the weather conditions in the city and attempts to bring out the possible impact of space cooling on the consumption pattern. It is however difficult to establish clear linkages between the variations in the consumption pattern and increasing use of air conditioning given the limited information available on the prevalence of air conditioning systems, technologies in use, and cooling demand across the year for different building types.

9.1 Electricity Consumption

Distribution of power in Bhopal is handled by the state distribution utility, Madhya Pradesh Madhya Kshetra Vidyut Vitaran Co. Ltd. (Madhya Pradesh Central Region Electricity Distribution Co. Ltd.) Electricity consumption in Bhopal is growing rapidly at an annual growth rate of nearly 7%, with the city consuming 1,450 million kWh of power in the year 2014-15.

The increase in the electricity consumption over the years can be attributed to the increasing consumption in residential and commercial sectors which is observed to be increasing at an annual growth rate of 8.8% and 5.9% respectively (see Table 7). The residential sector is the largest end-use power consumer and accounts for 44.4% of Bhopal's total electricity consumption. Consumers that include large facilities for public water supply and treatment and irrigation, residential bulk consumers (grouped housing apartments), railway traction, hoarding and advertisements, and seasonal connections account for 22.4% of the city's power consumption. Commercial consumers that include office spaces, retail stores, large shopping malls, public/semi-public and institutional buildings, commercial complexes account are a key-end use category, accounting for 16.7% of the total electricity consumed. Low tension and high tension industrial connections have a share of about 14% in Bhopal's electricity use.

Table 7: Sector-wise Electricity Consumption

Consumer Category	Electricity Consumption (Million kWh)					Annual Growth Rate	Percent Share (2014-15)
	2010-11	2011-12	2012-13	2013-14	2014-15		
Residential	**465**	**484**	**521**	**559**	**650**	**8.8%**	**44.4%**
Commercial[26]	169	174	184	197	213	5.9%	16.7%
Industrial (HT)[27]	30	30	30	29	28	-1.8%	2.0%
Industrial (LT)	151	159	162	166	176	3.9%	12.2%

[26] Includes offices, shops, show rooms, hospitals and medical care facilities (private and public), public and semi-public buildings, wedding halls, hotels/restaurants, cinemas, automobile maintenance centres, banks and ATMs, and sports clubs/facilities.

[27] Includes energy consumed for factory and lighting in the offices, main factory building, stores, canteen, residential colonies of industrial units such as flour Mills, Ice factories, Milk processing/chilling plants (Dairy), Engineering Workshops, Garment manufacturing units, LPG/CNG, bottling plants, Brick Kiln, and Food Processing units. This also includes compound lighting, common and ancillary facilities such as water supply and wastewater treatment in the premises of the industrial units.

Consumer Category	Electricity Consumption (Million kWh)					Annual Growth Rate	Percent Share (2014-15)
	2010-11	2011-12	2012-13	2013-14	2014-15		
Residential	**465**	**484**	**521**	**559**	**650**	**8.8%**	**44.4%**
Public Water Works	29	26	17	23	23	-2.1%	1.6%
Agriculture Metered	7	8	7	8	8	2.5%	0.6%
Street lighting	31	30	28	34	30	0.01%	2.2%
Others[28]	228	255	284	301	322	9%	22.4%
Total	**1,110**	**1,167**	**1,234**	**1,318**	**1,450**	**6.9%**	**100%**

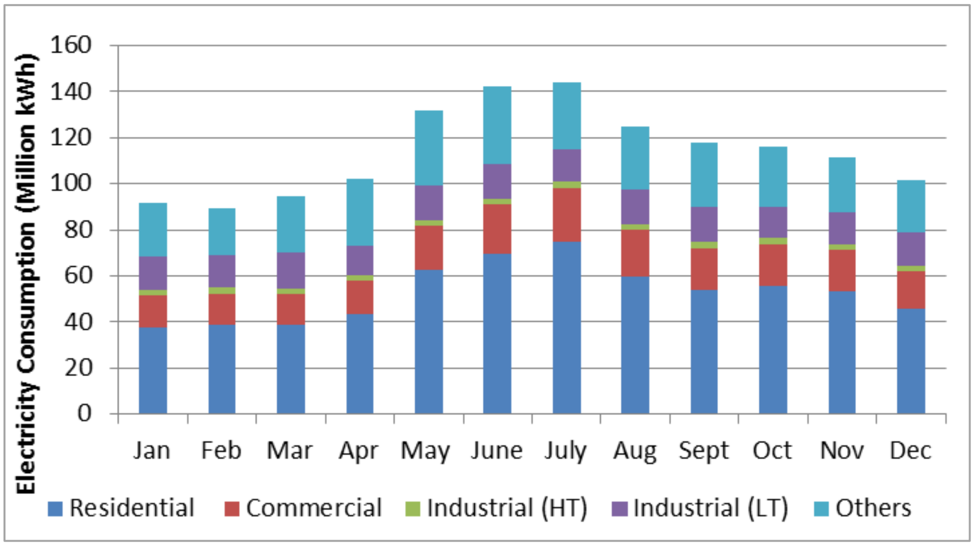
Source: Data received from (Madhya Pradesh Madhya Kshetra Vidyut Vitaran Co. Ltd., Bhopal Office, 2016)

Monthly electricity consumption can be very useful in understanding minimum and peak consumption in cities and the seasonal variations therein. The electricity consumption is observed to rise during the months of May, June and July, when the weather conditions are hot and humid (see Figure 14). This is driven by increased consumption by the residential and commercial consumers during this period. The peak monthly consumption of 148 million in June is 44% higher than the total power consumption in the winter month of February. The consumption dips in the period from December to February when the city experiences the winter season.

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 Bhopal 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. A positive correlation can be observed in the seasonal electricity consumption and the cooling degree days (CDD) (see Figure 15). The number of CDD is higher in the summer months where electricity consumption is also observed to be increasing.

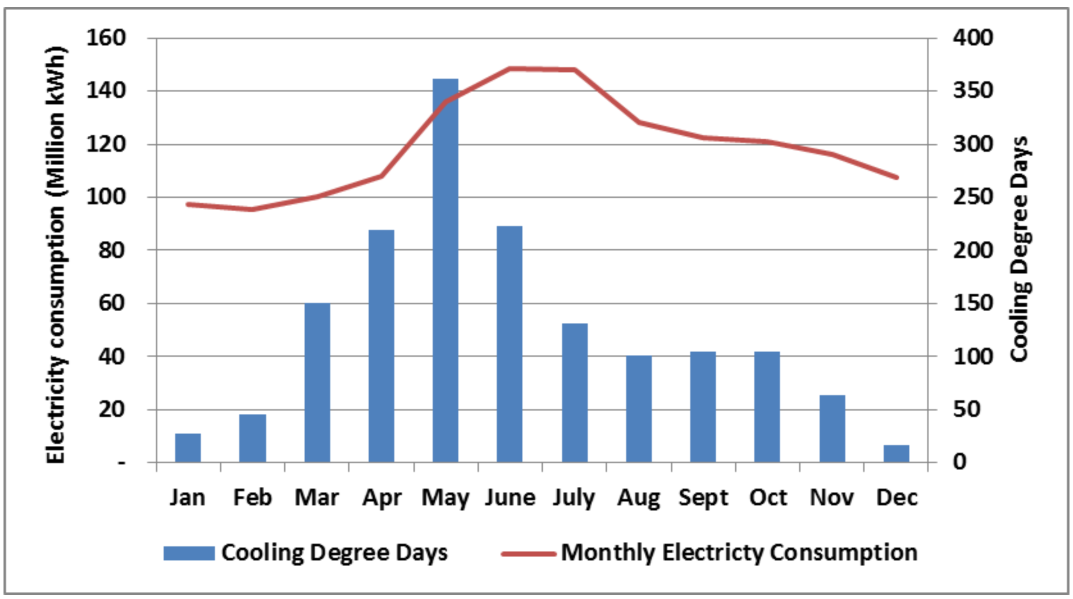
Figure 11: Sector-wise Monthly Electricity Consumption (2014-15)

[28] Includes large public water works and irrigation, , large residential users (group housing), railway traction, hoarding and advertisements, crematoriums, temporary connections, seasonal loads etc.



Source: Analysis based on data from (MPMKVVCL, Regional Office, Bhopal, 2016)

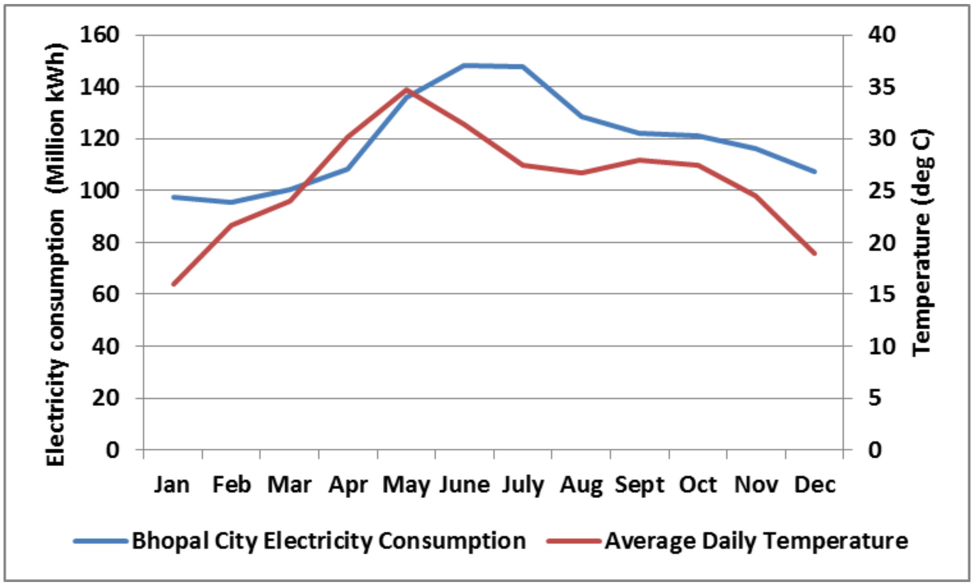
Figure 12: Monthly Cooling Degree Days for Bhopal City (2014-15)

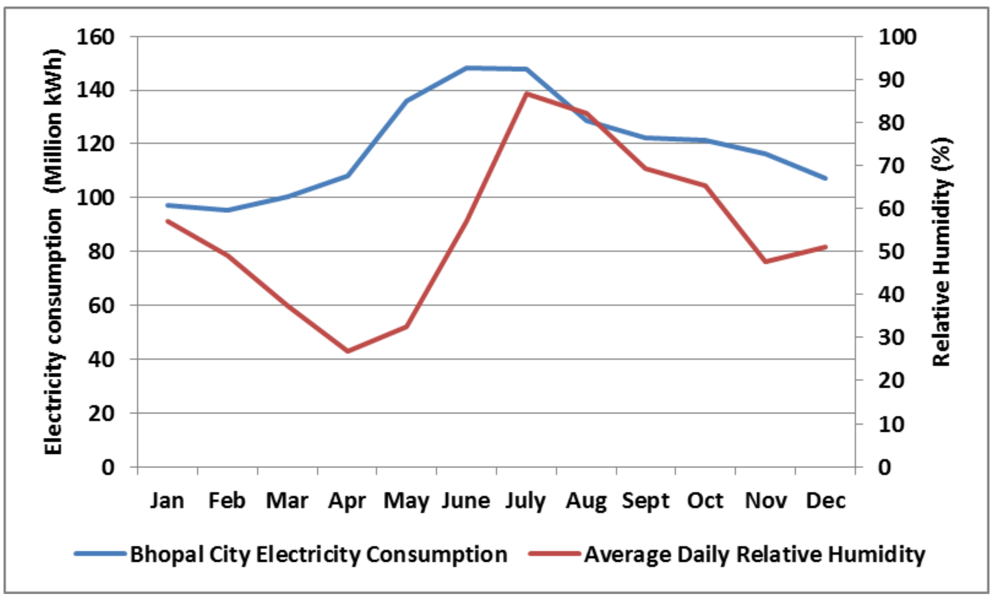


Source: Analysis based on data from (MPMKVVCL, Regional Office, Bhopal, 2016)

A positive correlation is also observed between trend of monthly electricity consumption and monthly temperature and relative humidity, with the consumption increasing with rising temperature and humidity (see Figure 16).

Figure 13: Relationship between Electricity Consumption Monthly Temperature/Relative Humidity for Bhopal (2014-15)





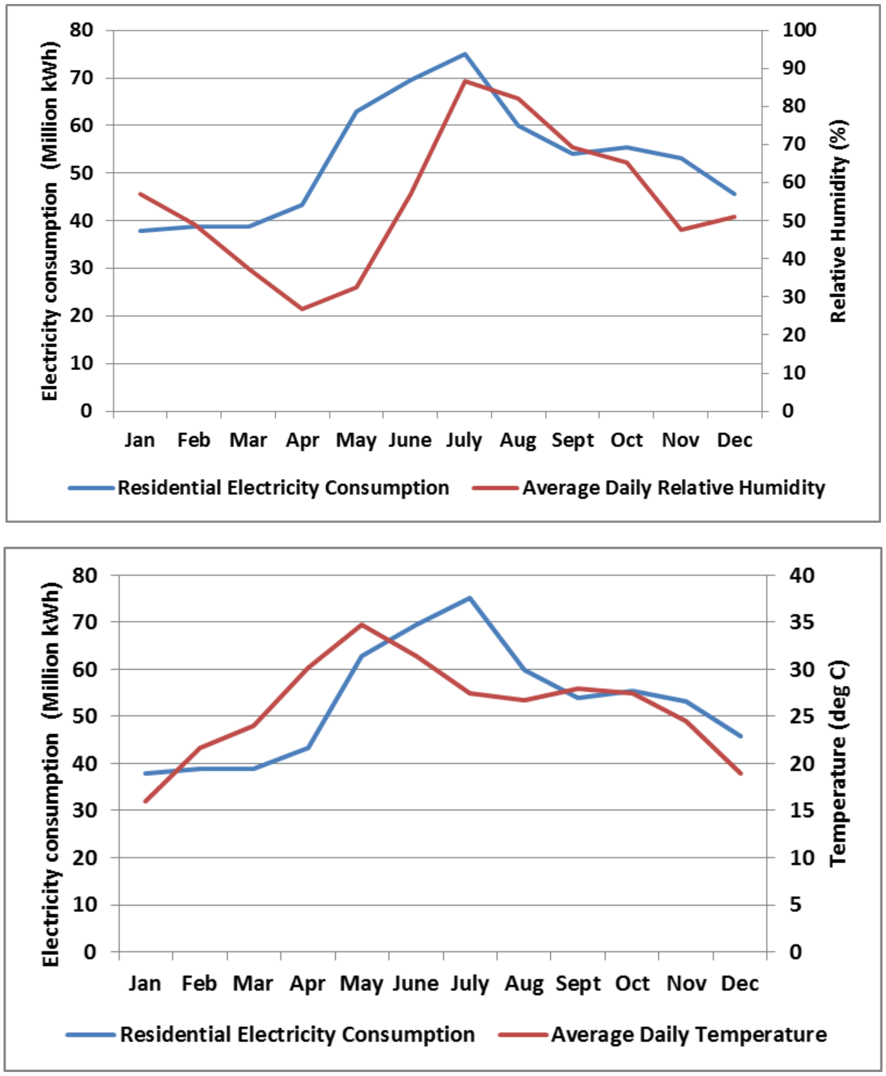
Source: Analysis based on data from (MPMKVVCL, Regional Office, Bhopal, 2016)

9.2 Sector-wise Analysis of Cooling Demand

9.2.1 Residential Sector

The seasonal variation in electricity consumption in the residential sector, similar to the total consumption pattern, rises in the months of May, June, July and August due to the rising temperature and relative humidity. Peak consumption in the month of July is about 42% higher than the average monthly power consumption.

Figure 14: Relationship between Residential Electricity Consumption Monthly Temperature/Relative Humidity for Bhopal (2014-15)



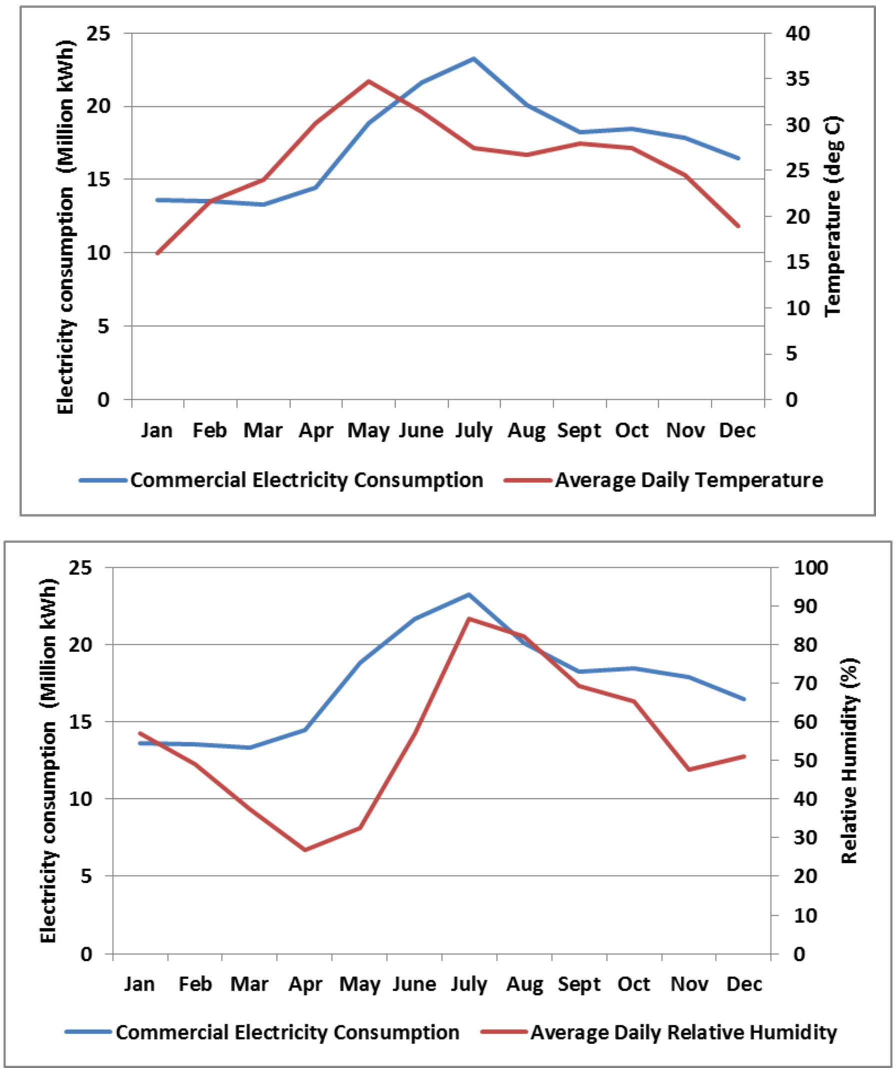
Source: Analysis based on data from (MPMKVVCL, Regional Office, Bhopal, 2016)

9.2.2 Commercial Sector[29]

Electricity consumption in the commercial sector rises during the period from May to August due to higher temperature and relative humidity. The peak power consumption in July is 33% higher than the average monthly consumption.

[29] Includes offices, shops, show rooms, hospitals and medical care facilities (private and public), public and semi-public buildings, wedding halls, hotels/restaurants, cinemas, automobile maintenance centres, banks and ATMs, sports clubs/facilities.

Figure 15: Relationship between Commercial Electricity Consumption Monthly Temperature/Relative Humidity (2014-15)

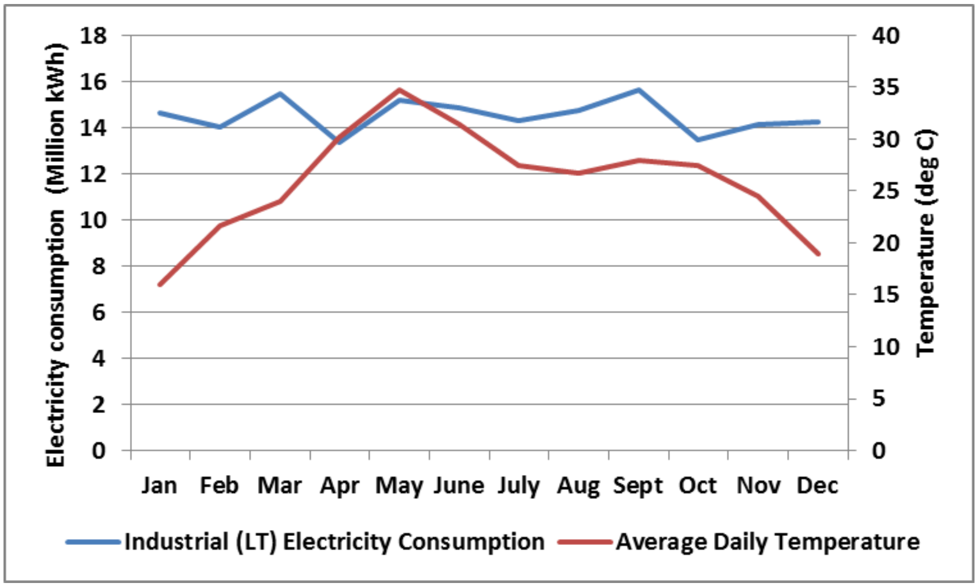


Source: Analysis based on data from (MPMKVVCL, Regional Office, Bhopal, 2016)

9.2.3 Low Tension Consumers in the Industrial Sector

Seasonal variation in electricity consumption by industrial consumers connected to low tension connections is less with a slight increase in the months of March, June and September. The consumption pattern in the industrial sector is not impacted by the weather conditions in the city.

Figure 16: Relationship between Industrial Low-Tension Electricity Consumption and Temperature in Bhopal (2014-15)



Source: Analysis based on data from (MPMKVVCL, Regional Office, Bhopal, 2016)

Box 10: Identifying opportunities for district cooling

In order to assess the scale of cooling in Bhopal, effectively promote and plan for district cooling and identify potential district cooling projects, a GIS energy mapping of Bhopal is recommended (also described in Box 3). This would help to resolve some of the barriers linked to a lack of data described earlier. 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). Bhopal will need to play a crucial role in encouraging and supporting building owners to install meters and ensure these can be monitored. Bhopal can lead by example and support the installation of meters in some public buildings[30].

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

[30] 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.

for Bhopal (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 Error! Reference source not found. **which s hould be built-upon in the future in Bhopal**[31]**.**

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

No examples of residential buildings with centralized HVAC were identified in Bhopal, 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[32]**, essentially meaning the same installed district cooling chillers that serve offices during the day could also serve residential buildings at night.**

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

10 Opportunities for District Cooling in Bhopal

Section 1.9 describes typical project types that can lead to profitable district cooling schemes. Vital to such projects is new developments, high cooling load density, diversity of consumers and a focus on commercial, institutional and industrial developments.

The real estate market in Bhopal has witnessed considerable growth in recent years, leading to rising investments in real estate projects[33]. Bhopal city is witnessing rapid expansion towards the south and south-east direction, with large commercial developments such as malls, hotels, office spaces, and residential townships cropping up in these areas. This development is driven by good connectivity, availability of land with even terrain, and proximity to the city's Habibganj railway station. The development of the transit corridors in these areas, the bus rapid transit system (BRTS) and the planned light metro rapid transit system (MRTS), has also influenced

[31] 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.
[32] 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%.
[33]making it an ideal destination for investors

growth positively. Such rapid development and changing lifestyles in Bhopal is leading to an annual growth of nearly 7% in Bhopal's power demand. Air conditioning systems in the existing commercial establishments such as Aashima Mall, Hotel Jehan Numa and the State IT Centre in the city, operate round the year to cater to space cooling requirements.

Bhopal has placed high emphasis on promoting compact and mixed-use development to maximize land utilization. Under Bhopal's Smart City area based development project targeting redevelopment of T.T. Nagar, area will be converted to prime residential and commercial Central Business District (CBD). Integrated townships such as the Shristi CBD, which is coming up in the vicinity of the T.T. Nagar Smart city area, house mix-use developments that include residential buildings, commercial offices, shopping malls, hotels among others. The implementation of Bhopal's TOD plan will further promote high-rise, mixed-use and compact development in the TOD influence zone, lying along the transit corridors across the city. The TOD zone covers about 16% of the total planning area and all vacant land parcels in the TOD zone have to be utilized for building development within a span of 5 years. The expected mix-use development in such areas offers promising opportunities for integrating district cooling by offering large and diverse consumers, thereby improving the commercial viability of district cooling. However, mix-use developments that have low proportions of commercial buildings could make the profitability of district cooling more challenging.

Additional FAR is being offered for the IT sector to promote investments in the sector. This policy boosts potential for the growth of the IT sector and given that such developments will have higher densities due to higher FAR, this offer opportunities for district cooling development. The Madhya Pradesh State Electronics Development Corporation is developing a large software and electronic hardware technology park in the vicinity of the Bhopal airport. The technology park is expected to house a number of prominent firms and will attract a sizeable workforce and drive development in the area.

Bhopal potentially offers notable opportunities to integrate district cooling networks to meet its cooling demand in the long term, particularly in mixed-use areas in and around the TOD zones, wherein a number of large offices, commercial complexes, shopping malls and residential townships will come up. A key factor to be assessed is whether sufficient space cooling demand exists throughout the year in Bhopal. Section 1.10 examines the high-level feasibility of some areas with mix-use developments and large anchor loads, located in and around Bhopal, for district cooling. The local authorities in Bhopal are keen to integrate district cooling in large developments as well. The BMC has explored integration of a district cooling system in the Smart city ABD area of T.T. Nagar, with preliminary assessments related to technology and costs conducted for 18,000 TR system. However, the BMC subsequently dropped this project from the proposed interventions due to uncertainty regarding financing of the sizeable investment required, and lack of local private technology providers with expertise and experience of implementing district cooling networks.

Building developers in Bhopal 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.

11 Techno-economic analyses of district cooling in Bhopal

This section presents the project analysis of district cooling undertaken in Bhopal including description of the modelling, a generic development archetype tested across all the cities and the sites that have been selected in Bhopal 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[34]

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

7) capital and operating cost assumptions on stand-alone cooling systems, district cooling plants, land and network

8) CO_2 emission baseline.

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

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

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

1) End-users description. Built-up areas are broken down into percentage of different building types, so that the end-user types can be better understood.

2) Cooling demand. The hourly cooling demand of typical design day in the region is presented.

3) District cooling plant requirements, including installed cooling capacity, district cooling plant built-up area, outdoor space for cooling towers and the total estimated cost for district cooling plant.

4) Operation and Maintenance costs (O&M) for both of district cooling system and standalone system, including annual cooling supply, annual electricity consumption and fee, annual water consumption and fee, and finally total operation fee. This will show the annual cost savings of the district cooling system relative to standalone systems.

5) Environmental benefits from the district cooling system, including reduction of annual CO_2 emissions, life-cycle refrigerant reduction, reduced water consumption relative to water-cooled stand-alone systems

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

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

1) Tariff structure for district cooling including connection charge, capacity charge and chilled water price
2) End-user discount for using district cooling – the annual payments of an end-user for district cooling are kept below the annual payments for an end-user using a stand-

alone system. This discount is fixed across all the five cities at 20% and acts as a buffer in case VAT is applied to district cooling sales

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

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

11.2 Assumptions used in Bhopal

Cooling demand

As explained in Annex 15.2, no benchmarks for building cooling demand or consumption are available in the city of Bhopal. 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 and stakeholder consultations 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 15.2 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.

Table 8: Assumptions of cooling demand

	Hotel	Office	Shopping mall	Hospital	Residential Apartment	Campus building
W/sqm	142	235	286	192	117	191

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. **Error! Reference source not found.** summarises these assumptions.

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

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

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

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

- Land cost for district cooling plant: 512 USD/ m^2 (34,133 INR/ m^2)
- Distribution network cost (including pipes, metering, insulation and installation): 180 USD/TR[35] (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. The annual average Coefficient of Performance (COP) of each cooling system[36] 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

[35] 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.

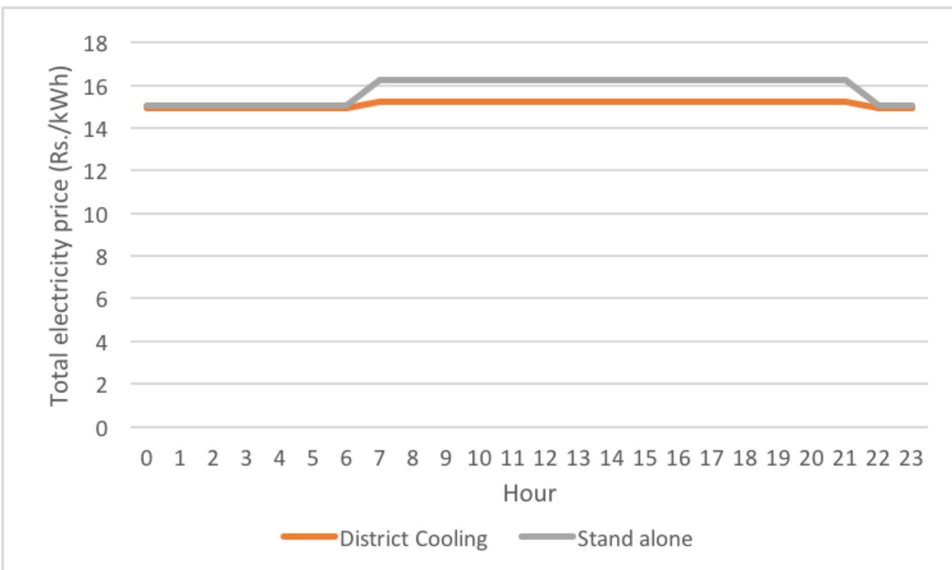
[36] The annual COP presented here is equivalent to the annual average electricity used to produce one refrigeration ton of cooling (including electricity consumption of chillers, pumps and cooling towers). Chillers, pumps and cooling towers have different efficiencies under different loads. Normally, 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 Bhopal is conservatively estimated as 1950 hours.

Operation and Maintenance costs

Electricity tariffs are calculated from Madhya Pradesh Central Region Electricity Distribution Co. Ltd. tariffs and presented in **Error! Reference source not found.**. District cooling plants are e xpected to access slightly lower overall electricity tariffs due to their higher voltage connections (as they are able to centralise multiple cooling loads from different buildings) and they come under a different consumer type.

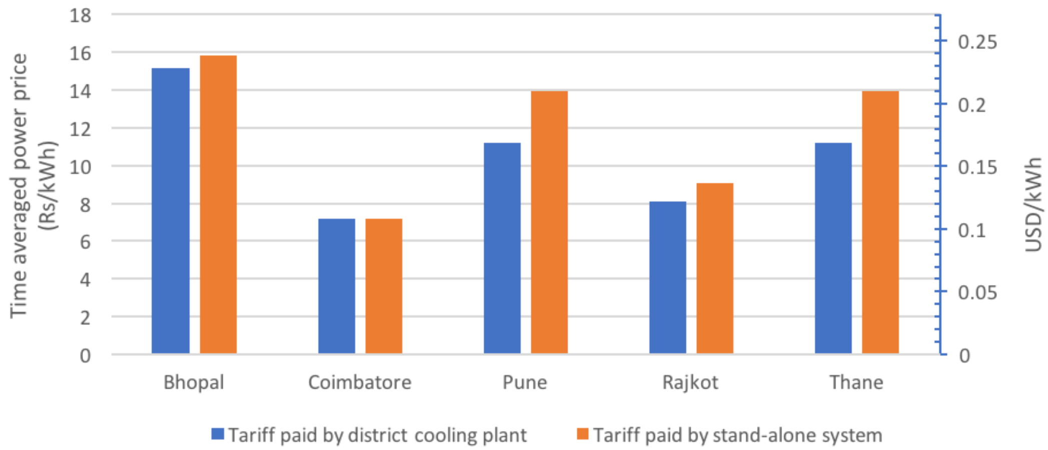
Figure 17: Electricity prices in Bhopal (Energy charge fee)



Source: Based on tariffs charged by from (Madhya Pradesh Madhya Kshetra Vidyut Vitaran Co. Ltd., Bhopal Office, 2016)

Compared to the other cities assessed in India, Bhopal has high electricity prices, as can be seen in **Error! Reference source not found.**. This helps the business model for district cooling a s it makes being energy efficient in cooling more profitable, even if upfront costs are higher for efficient solutions like district cooling.

Figure 18: Comparison of time-averaged electricity prices across all cities as paid by district cooling plants and stand-alone commercial cooling systems



(Source: Analysis based on tariffs charged by 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 **Error! Reference source not found.**, the 20% buffer is shown b y 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 **Error! Reference source not found.**.

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

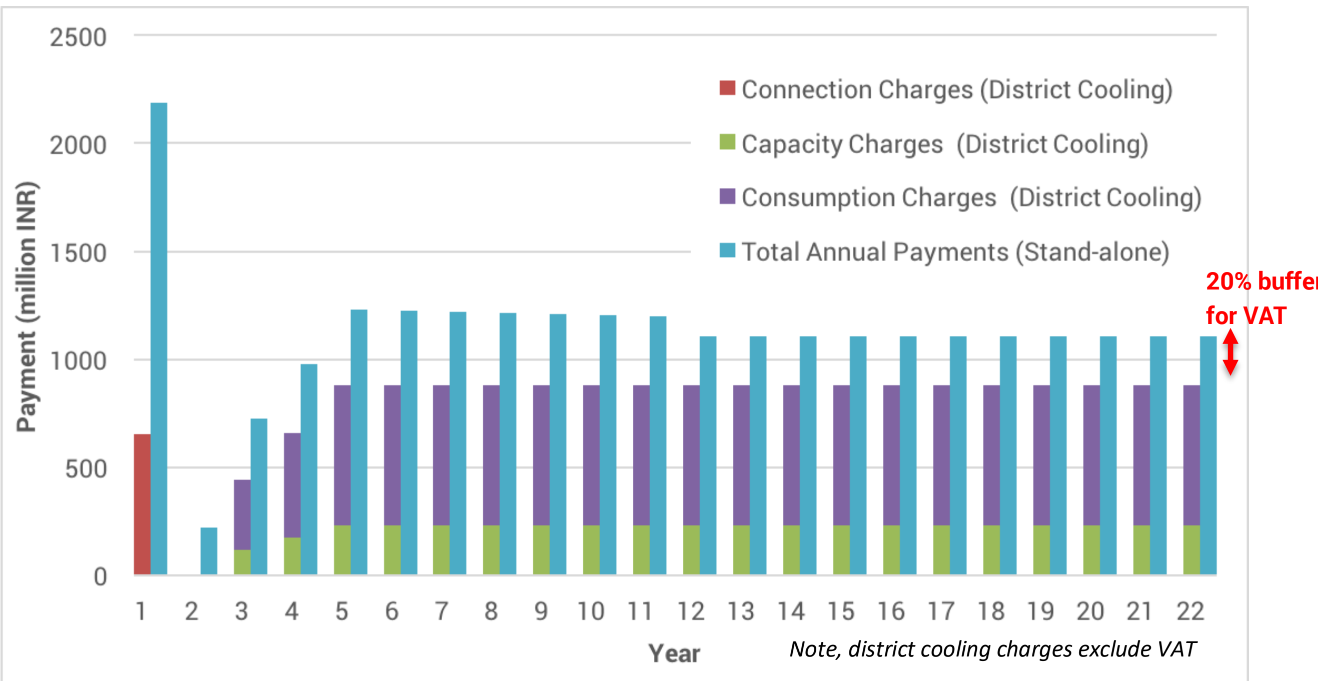
Through analysis of projects across all five cities, a development archetype was chosen that could be used as a typical development to enable comparison across all cities. The make-up of this archetype is shown in **Error! Reference source not found.** below, it is mixed-use with m ultiple buildings with centralised cooling.

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

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 14% in Bhopal and the payback period is 12 years.

Figure 19: 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 Bhopal with favourable financing, district cooling projects would be profitable to investors, beneficial to the environment and lower-cost to the consumers.

12 Selection of Probable Project Sites

This section presents the potential sites that have been identified for assessing the high-level feasibility of deploying a district cooling system in Bhopal. The project sites have been identified based on discussions with the BMC and the BSCDCL. The potential project sites selected have diverse mix-use development with significant cooling demand and the presence of anchor loads. Ram bhawan

12.1 Site 1: TT Nagar Smart City Area

A 380 acre site in T.T. Nagar has been selected by the BMC to be taken up for area based development under the Smart City plan. The selected area is planned to be redeveloped into an all new smart area where old buildings will be demolished to give way to new apartments and commercial centres. However, a few existing buildings such as the Model School, Platinum Plaza, the T.T. Nagar Sports complex, educational institutes, hospitals, and other private structures will be retained.

Figure 20: Location of T.T. Nagar Smart City ABD Area

Source: (Bhopal Smart City Proposal, 2016)

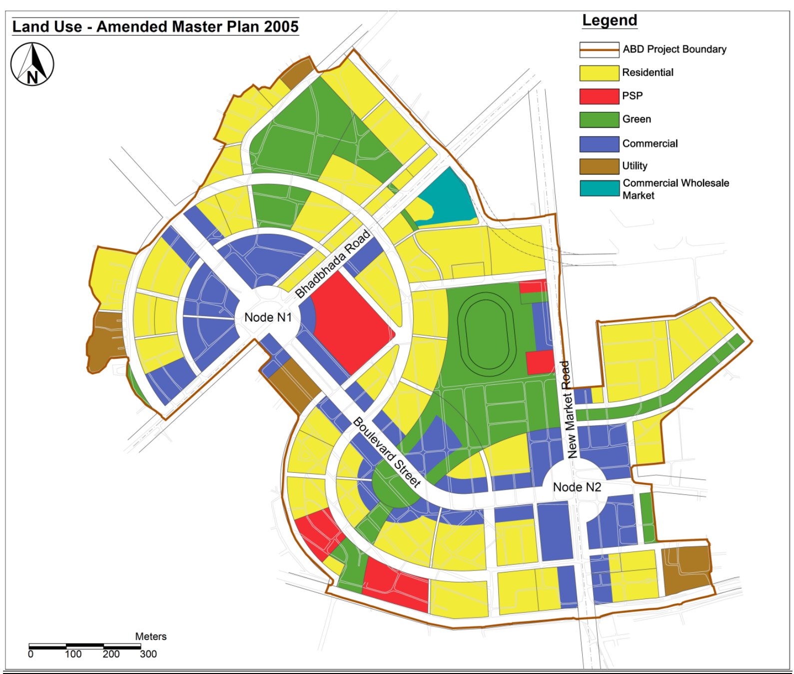
Most of the land area at this site is designated for residential use (32%). 16% of the site area is allocated for commercial use and 4% for public and semi-public use. Few existing vacant land parcels will be developed initially to shift the existing population and to re-develop the remaining areas. Majority of the commercial areas are planned along the TOD corridor. The plan has been developed in accordance with the Bhopal Development Plan, 2005 and the TOD plan.

Table 12: Proposed Land Use Allocation in T.T. Nagar ABD Area, Bhopal

Land use Categories	Share of proposed land use for the project area	Total Land Area on the site (acres)	Built-up Area (Million sq. feet)	Planned Population	Floating Population
Residential	32.4%	123.1	Not available	60,000	12,000
Commercial	16.3%	61.9	3.4	12,140	68,082
Public & semi-public	4.7%	17.9	4.6	43,200	
Multipurpose Open Spaces	16.4%	62.3	0.8	429	
Utilities	2.9%	11.0	-	-	-
Roads	27.2%	103.4	-	-	-
Total	**100%**	**380**		**55,769**	**80,082**

Source: (Bhopal Smart City Proposal, 2016)

Figure 21: Proposed Land Use Plan of T.T. Nagar Smart City Area



Source: (Bhopal Smart City Proposal, 2016)

The allowable FAR for the site varies is according to the road widths. The area under the TOD zone will have a FAR of 3.0 as per the TOD Plan.

Table 13: Proposed FAR for T.T. Nagar Smart City ABD Area

Sr. No.	Road Width (m)	Proposed Permissible FAR	Proposed Permissible Height (m)	Proposed Permissible Ground Coverage (%)
1	60	3.00	90	30
2	45	2.75	75	30
3	24	2.00	30	30
4	18	1.75	24	30

Source: (Bhopal Smart City Proposal, 2016)

A district cooling system of 18,000 TR size was planned to be integrated at this site. The system was planned to cover all residential and commercial areas. The district cooling system was envisaged to serve a built-up area of 109 acre in the first phase and 62.2 acre in the second phase. Based on initial quotations received from a few technology providers, the total estimated cost of the system was about INR 2,450 million (USD 37 million). However, this initiative was subsequently dropped from the proposed interventions due to uncertainty regarding financing of the sizeable investment required, and lack of local private technology providers with expertise and experience of implementing district cooling networks.

Table 14: Proposed District Cooling Plant Capacity

District Cooling System	Number of Plots covered	Total Built-up Area (sq. feet)	Capacity (TR)
DCS -1	10	4,774,176	11,500
DCS – 2	6	2,726,856	6,500

Source: Information received from (BSCDCL, 2016)

Shrishti CBD

The Shrishti CBD site includes a large-scale residential-cum-commercial project that is currently being developed at the south of T.T. Nagar in Bhopal. The site is covers an area of 15 acres and is located at the intersection of Link Road, Mata Mandir Road and New Market, adjacent to the Smart City ABD area. This project will be developed in two phases and its construction commenced in the year 2009. In phase-I (2009-2018) 5 residential buildings, 2 commercial office towers, and shopping arcades have been developed.

Figure 22: Location of Shrishti CBD site and the Adjacent T.T. Nagar Smart City Area

The five residential buildings are near completion and house about 288 apartments. The two office towers are near completion and will accommodate about 520 offices in total. The shopping arcade has 6 blocks with about 349 shops and is already operational. In Phase II of the project, planned to begin in 2018, luxury residential buildings, a shopping mall, and a 5-star hotel have been planned. Buildings constructed in phase I and phase II of this project will span a floor space of about 2 million sq. ft as indicated in Table 15. The plans for buildings to be developed in phase II are being redrawn and the built-up area for these buildings may be subject to changes accordingly. The allowable FAR for the site is 2.5 while for area lying in the TOD zone the FAR of 3.0 will apply. 8 sewage treatment plants having a total capacity of about 800 kiloliter per day have been planned to cater to all types of buildings at the site.

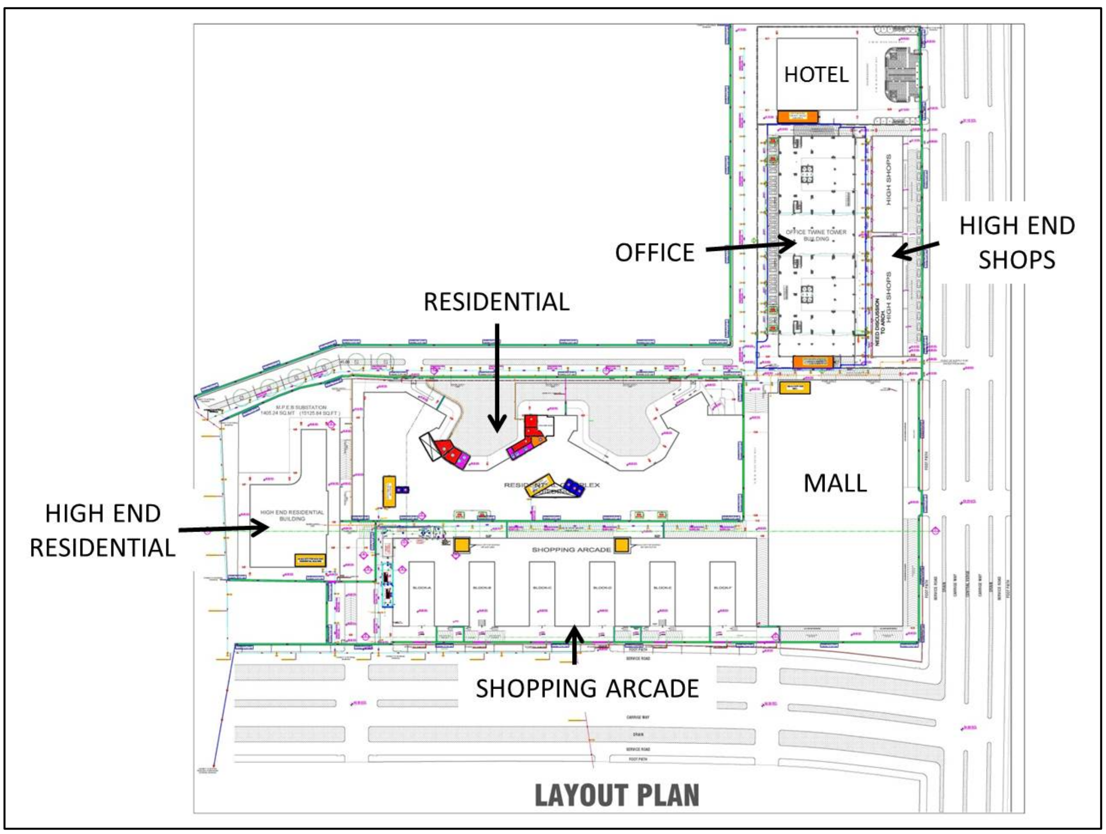
Table 15: Proposed Development and Built-up Areas for Shrishti CBD

Type	No. of Towers	No. of Floors	No. of Units	Built-up Area (sq. ft.)
Phase I				**1,236,231**
Residential	5	22	288	421,620
Commercial Office	2	18	520	516,029
Shopping Arcade	6	6-7	349	298,583
Phase II				**793,505**
Luxury Residential	1	22		154,023
Shopping Mall	1	-		276,990
Hotel	1	-		516,515
Total				**2,029,737**

Source: Data Collected from (Developer's Office, 2016)

Figure 23: Modelled Image of Shrishti CBD site

Figure 24: Layout Plan of Shrishti CBD site



Source: Data Collected from (Developer's Office, 2016)

Table 16: Site selection criteria for TT Nagar area with focus on Shrishti CBD

Site 1: T.T. Nagar Smart City area	
Technical requirements	The area will be undergoing redevelopment and high density mixed-use development is proposed for this site. The proposed new developments will include residential buildings, office complexes, a transit hub, shopping malls, exhibition centres with potentially significant cooling demand. Some of the developments such as include schools, educational institutes and hospitals which will not be redeveloped can also be potentially served by the district cooling system.
Availability of anchor loads with continuous load and diverse buildings can be connected	The site is envisaged to have a good mix of high density large scale residential, commercial and institutional developments which will offer diversity of space cooling demand. The commercial and public/semi-public buildings which are proposed to have floor space of 3.4 million sq. ft. and 4.6 million sq. ft. can serve as anchor loads for the district cooling network.
Potential for longer-term network expansion	The site houses mix-use developments in its vicinity including institutional buildings, educational institutes, hospitals and commercial spaces. Since the site will be redeveloped, district cooling concepts can be potentially integrated from the start of the redevelopment for the proposed commercial and institutional developments in particular. The network can subsequently be expanded to connect the diverse mix of proposed and existing buildings in and around the site.
Existing situation of buildings	Existing buildings in this area are proposed to be redeveloped, with new high density mix-use developments coming up in their place. Some of the already constructed buildings that are located at this site including educational institutes, a school, hospitals, a sports complex will be retained and not undergo redevelopment.
Influence from local government	The redevelopment and proposed initiatives at this site has been designed and planned by the BMC. Bhopal's Smart City SPV, BSCDCL, is responsible for implementation of the planned redevelopment at this site. 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.

Focus on: Shrishti CBD

Technical requirements	This integrated project, covering a cumulative floor space of 2 million sq. ft, is proposed to have a good mix of commercial and residential developments including 2 office towers, luxury residential apartments shopping complexes, and a hotel. These buildings can offer potentially significant space cooling demand.
Availability of anchor loads with continuous load and diverse buildings can be connected	The two office towers, and the proposed hotel and shopping mall are potential anchor loads. The site has a good mix of different building types with sufficient diversity of cooling demand.
Potential for longer-term network expansion	The site is located close to the T.T. Nagar site, which will undergo redevelopment and is envisaged to house large mix-use residential, commercial and institutional developments. Thus, there exists significant potential to link the district cooling network to new developments at T.T. Nagar site and the Shrishti CBD site.
Existing situation of buildings	The five residential buildings and the two office towers are near completion. The shopping arcade is already operational. Construction of the buildings planned under phase II including a shopping mall, a hotel and a luxury residential apartment is yet to begin.
Influence from local government	The area lies under the BMC jurisdiction and in close vicinity of Bhopal's Smart City pilot site. The BMC can leverage its relationship with the building developer, business and other stakeholders to help facilitate further dialogue to demonstrate the viability and benefits of establishing a district cooling network.

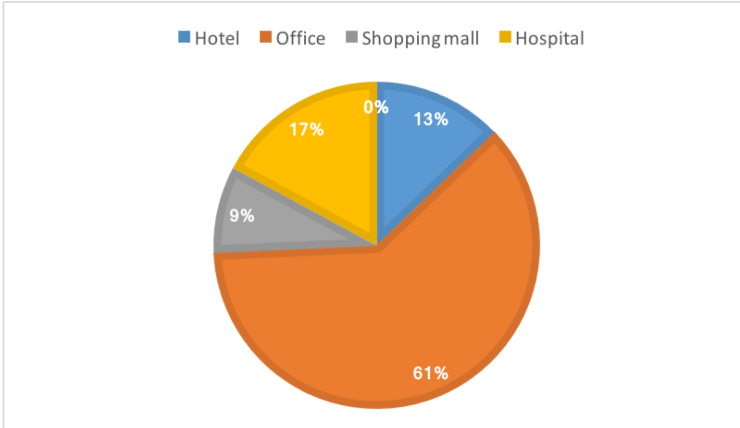
12.1.1 Site 1: Analysis of district cooling in TT Nagar Smart City Area

The mixed use and dense TT Nagar site can serve as demonstration project for district cooling Bhopal. Based on the available data, an analysis has been undertaken of a portion of the area's planned buildings, including the phase 2 development of the Shrishti CBD Site. This analysis is presented below.

Buildings served and cooling load

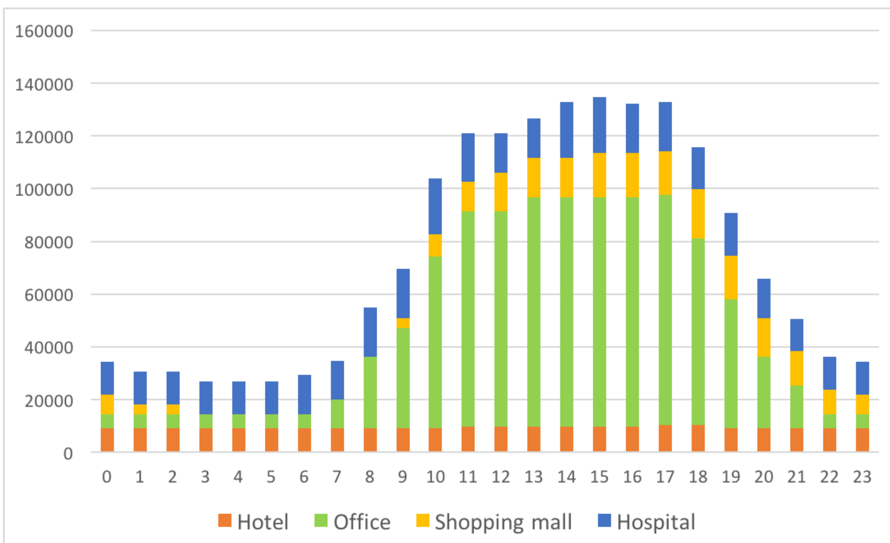
The total built-up area is estimated at 8,829,611 sq.ft (820,299 m^2) and the split by building type is shown below.

Figure 25: 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 28.

Figure 26: Hourly cooling demand profile of district cooling system



Characteristics of the district cooling plant

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

Table 17: District cooling plant

Installed Cooling Capacity	136,894	kW
	38,924	RT
District cooling plant built-up area	9,643	sq. m
Outdoor space for cooling towers	3,086	sq. m

DC plant land requirement	5,786	sq.m

The investment of district cooling system is calculated as below.

Table 18: District cooling system investment

DC system investment	Rs.	USD
DC plant	5,189,802,146	77,847,032
Land	197,300,147	2,959,502
Network	467,082,193	7,006,233
Sum	**5,854,184,486**	**87,812,767**
Investment per TR	**150,402**	**2,256**

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

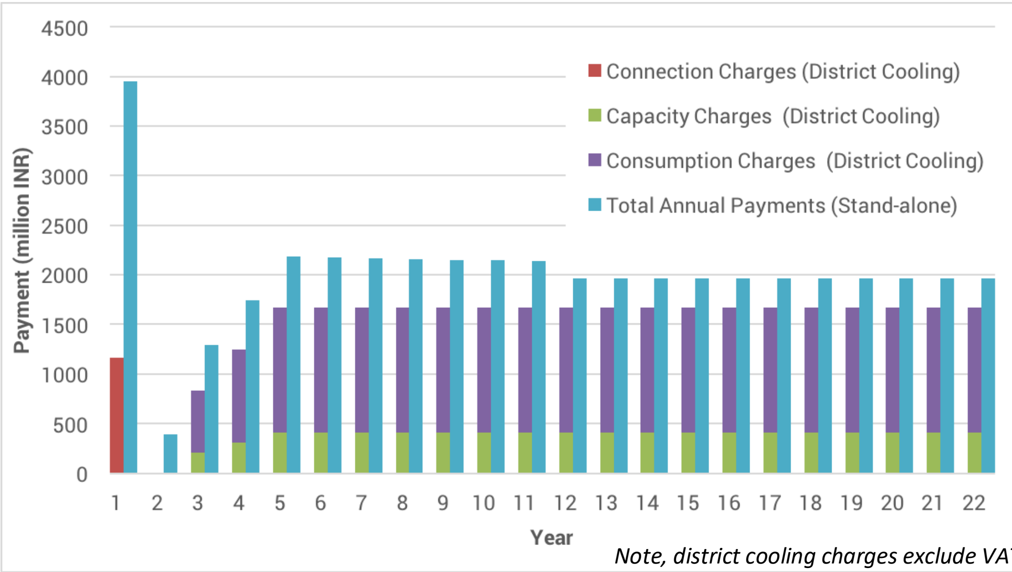
Table 19: Annual cooling supply and operation fee

Annual cooling supply	kWh	153,064,121
Annual electricity consumption	kWh	43,521,217
Annual electricity fee	Rs.	661,366,482
	USD	9,920,497
Annual water consumption	m^3	1,253,411
Annual water fee	Rs.	50,136,442
	USD	752,047

Financial results

The economic analysis shows that when a metering charge equal to 0.25 USD/TR.h (16.7 INR/TR.h) is charged, the IRR of this project reaches 15% with an 11 year payback period. 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 29 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 27: Cost comparison for consumers in TT Nagar Smart City Area for district cooling vs. stand-alone systems



The specific benefits of connecting the TT Nagar area to district cooling are presented in Section 1.10.1below.

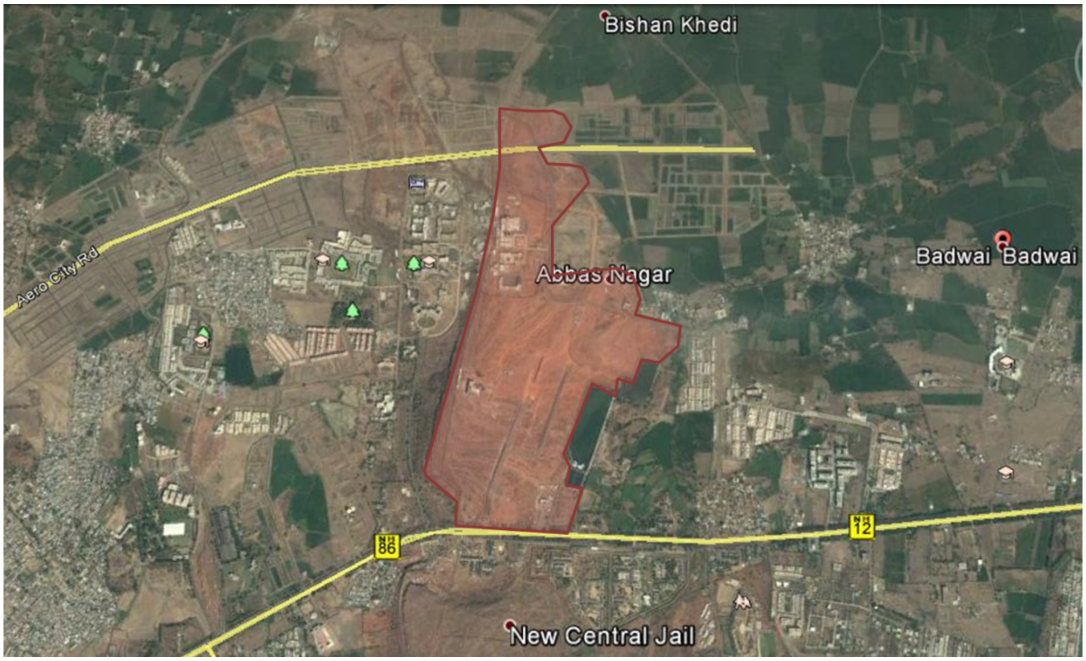
Recommendations for TT Nagar:

- 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.

12.2 Site 2: Software Technology Park – Badwai Village

Bhopal's first Software Technology Park has been set up by Madhya Pradesh State Electronics Development Corporation (MPSEDC) Ltd. in Badwai Village adjacent to the Rajiv Gandhi Proudyogiki Vishwavidyalaya. The Software Park covers an area of 212 acres out of which about 50 acres have been designated for electronic manufacturing companies.

Figure 28: Location of the Software Technology Park



MPSEDC has already developed an office area having about 100,000 sq. ft. of floor space. Few independent plots will be developed to be given on rent and will include amenities such as centralised air conditioning system, food court and café, business centre, private boardroom, a fitness club. Independent plots to be developed by the buyer are also available for purchase and will have facilities such as 18 meter wide roads, water supply, and power supply with back-up. The allocated areas for different types of plots and uses are indicated in the Table 20.

Table 20: Land Allocation in the Software Technology Park

Category	Type of Use	Land Area	
		Acre	Percent Share
Plots		**177.6**	**83.5%**
Plot Type A	Electronic manufacturing companies	45.2	25%
Plot Type B	IT	40.6	23%
Plot Type C	IT	58.7	33%
Plot Type U	Utility	5.4	3%
Plot Type G	Open Areas	27.7	16%
Roads		**35**	**16.5%**
Total		**212.6**	**100%**

Source: Information received from (MPSEDC, 2016)

According to the Madhya Pradesh IT, ITeS and Electronic System Design and Manufacturing (ESDM) Investment and Promotion Policy, 2016 the maximum allowable FAR is 2.5 and each plot should have at least 60% area under either of IT or ITeS or ESDM use. The site is located close to the Bhopal airport and thus each company or developer will be required to obtain height clearance from the Airport Authority of India. The details of plot sizes for different types of uses have been given in Table 21 in the Annexure.

The MPSEDC office has been nearly completed. Prominent companies have already started purchasing plots in the area. About 51 plots have been sanctioned out of a total of 105 plots. Two LED manufacturing units have already completed their construction. A sewage treatment plant having a capacity of 100 kLD is planned to be constructed at the site. There is scope to further expand the sewage treatment capacity to 500 KLD based on future requirements. Another sewage treatment plant having a capacity of 16.7 million liters per day is located close to the site.

Table 21: Site selection criteria for all the proposed Sites

Site 3: Software Technology Park – Badwai Village	
Technical requirements	The Software Park has about 100 acres and 45 acres of land allocated for IT businesses and electronic manufacturing companies respectively. The upcoming buildings have to occupy at least 60% of this land area. Given the large scale of this development, significant cooling demand is expected to exist for the ensuing large floor space housing IT/ITeS offices and the electronic manufacturing companies. The site has vacant land allocated for utilities, which can be used to house the district cooling plant.
Availability of anchor loads with continuous load and diverse buildings can be connected	The IT/ITeS businesses housed at the site will have continuous cooling demand through the day and are potential anchor loads for the district cooling system. Cooling will also be required for the data centres housing servers of the IT/ITeS companies and for the electronic manufacturing units that will come up.
Potential for longer-term network expansion	The area lies in the outer limits of Bhopal city near the city's airport. This area contains tracts of vacant land and with the development of this large scale software park, it is expected to see major development in the near future offering opportunities for network expansion.
Existing situation of buildings	This is a greenfield site, with most of the plots vacant at present and buildings yet to come up.
Influence from local government	This area lies outside the BMC jurisdiction. The BMC and the BDA can facilitate further dialogue with the MPSEDC to demonstrate the viability and benefits of establishing a district cooling network.

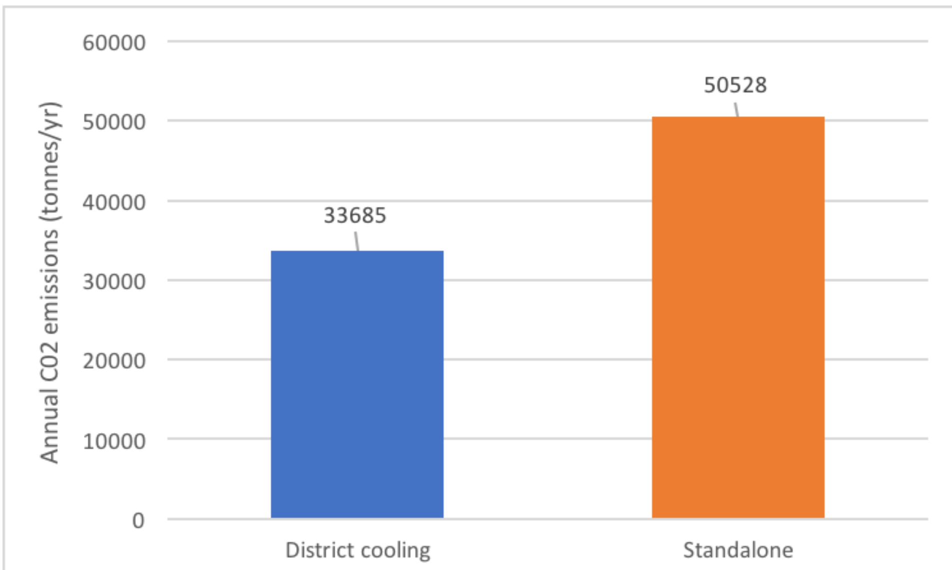
A financial analysis has not been undertaken of the Badwai village but given the fact this is a greenfield project with high planned shares of IT and ITeS offices and manufacturing sites that may require space cooling it is recommended that a district cooling pre-feasibility is undertaken to assess the project.

12.3 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 TT Nagar area are 16,843 tons per year, as shown below in **Error! Reference source not found.** (National Energy Foundation, 2001-17). Due t o a lack of data for CO_2 emissions for water supply, this contribution is not included.

Figure 29: CO2 emission comparison for stand-alone and district cooling in TT Nagar

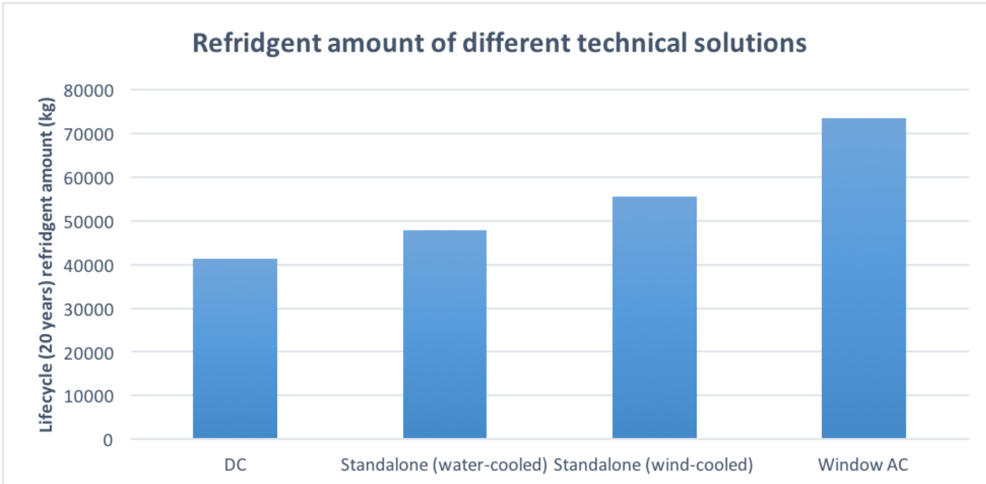


For the TT Nagar project electricity savings of 21.8GWh of electricity annually (33% reduction from stand-alone) are expected.

The CO_2 savings and electricity savings can be increased significantly by connecting renewable and waste heat resources. Furthermore, given the scale of the TT Nagar, 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.

The district cooling system can also contribute to refrigerant phasing out, due to reduced cooling capacity in the whole district. Over the lifetime in TT Nagar this is expected to be 6.5 tonnes, as compared to water-cooled chillers.

Figure 30: Lifecycle refrigerant comparison for district cooling vs. stand-alone solutions in TT Nagar



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, Bhopal can expect the following environmental benefits. 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 22: 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. 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 BMC 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.

13 Summary and Conclusion

From the high-level analysis conducted in this assessment, it can be concluded that district cooling is commercially viable in Bhopal for well-designed projects and can deliver significant benefits to the environment, consumers and the local economy. The climate, high potential smart city project, 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 Bhopal a high-priority city for demonstrating this technology.

Bhopal 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 BMC 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 potential in Bhopal, this would be a missed opportunity.

Dedicating human resources in local governments can be difficult due to tight city budgets; if Bhopal can monetise direct benefits from district cooling, this increased human resources can be justified. This could be through direct participation of BMC 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. Bhopal 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, Bhopal will be supported by a range of cities, industry, academia, NGOs and banks committed to seeing district energy's success in India and globally.

14 Next Steps

Throughout this rapid assessment, policies and actions have been recommended to BMC 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 (UNEP, 2015).

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

TT Nagar smart city area

- BMC 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. Side-by-side assessments of previous district cooling assessment that did not recommend DC should be made with the DC assessment in this report
- Stakeholder consultations to identify potential business models and develop a procurement 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.

- 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 BMC incentives and policies that can ensure project delivery
- Use the development in Shrishti CBD phase II to catalyse the district cooling network

Badwai village project

- Work with building developers to identify projects to be commissioned in next 1-5 years in the zone that can catalyse district cooling development
- Work with developers to ensure that these projects incorporate district cooling in design and undertake project pre-feasibility studies
- Identify incentives and mandates that can be applied on the zone to ensure district cooling development

City-wide actions (short-term)

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

City-wide action (medium-term)

- Establish a 'sustainable energy delivery unit' or include within the Smart City SPV
- Support piloting of innovative district cooling applications, e.g. Thermal Energy Storage (TES), waste heat connections, solar power and Treated Sewage Effluent to reduce water consumption
- Incorporation of district cooling into existing city strategies and targets. Set targets specifically for the district cooling sector (Box 3)
- Apply specific conditions on building permitting in zones to encourage DC
- Consider extending FAR allowance for DC connected buildings (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)

15 Annexures:

15.1 Information Collected

Table 23: Dry Bulb Temperature

Month	Avg Daily (degrees C)	Avg Daily Low (degrees C)	Avg Daily High (degrees C)	Record Low (degrees C)	Record High (degrees C)
Jan	18.27	12.29	24.71	11	29.8
Feb	20.70	13.86	27.40	11.9	31.1
March	25.72	18.08	32.45	13.2	39
April	30.88	21.87	38.32	15.6	42.4
May	33.23	25.41	40.20	21.2	43.3
June	30.27	25.44	35.53	22.7	43.5
July	26.22	23.63	29.54	21.6	33.7
Aug	25.18	22.23	28.60	20.5	31.1
Sep	26.36	21.37	31.22	20.2	34.6
Oct	25.58	20.42	30.78	17.9	33
Nov	21.84	15.06	28.19	13.2	30.2
Dec	18.80	11.91	26.04	9	29.4

Source (ISHRAE Weather Data Handbook)

Table 24: Wet Bulb Temperature of Bhopal

Month	Avg Daily (degrees C)	Avg Daily Low (degrees C)	Avg Daily High (degrees C)	Annual Average (degrees C)	Plus in low	Minus in high
Jan	18.27	12.29	24.71	25.25	5.98	6.44
Feb	20.70	13.86	27.40	25.25	6.84	6.70
March	25.72	18.08	32.45	25.25	7.64	6.72
April	30.88	21.87	38.32	25.25	9.01	7.44
May	33.23	25.41	40.20	25.25	7.81	6.97
June	30.27	25.44	35.53	25.25	4.83	5.26
July	26.22	23.63	29.54	25.25	2.59	3.31
Aug	25.18	22.23	28.60	25.25	2.95	3.43
Sep	26.36	21.37	31.22	25.25	4.99	4.86
Oct	25.58	20.42	30.78	25.25	5.16	5.20
Nov	21.84	15.06	28.19	25.25	6.77	6.35
Dec	18.80	11.91	26.04	25.25	6.89	7.24

Source: (ISHRAE Weather Data Handbook)

Table 25: Relative Humidity

Month	Avg Daily (%)	Avg Daily Low (%)	Avg Daily High (%)	Record Low (%)	Record High (%)
Jan	56.91	38.55	80.58	22	99
Feb	48.99	30.11	72.18	16	98
March	37.33	22.00	58.94	2	90
April	26.82	16.53	45.97	10	98
May	32.54	19.06	54.39	11	98
June	56.95	38.47	77.90	19	98
July	86.61	72.65	96.39	51	98
Aug	82.11	67.00	93.87	47	98
Sep	69.19	49.97	88.60	25	98
Oct	65.17	44.39	86.90	6	98
Nov	47.62	28.00	73.47	21	84
Dec	51.06	30.26	75.48	16	97

Source: (ISHRAE Weather Data Handbook)

Table 26: Consumer Category-wise Electricity Consumption for Bhopal City, 2014 (Million kWh)

Month	Residential	Commercial	Industrial (HT)	Industrial (LT)	Public Water Works	Agriculture Metered	Street lighting	Others
January	37.86	13.62	2.48	14.60	1.69	1.16	3.01	22.81
February	38.84	13.52	2.42	13.99	1.63	1.08	3.40	20.51
March	38.84	13.31	2.25	15.48	1.65	0.95	2.99	24.83
April	43.23	14.49	2.26	13.34	2.64	0.49	2.89	28.76
May	62.84	18.81	2.37	15.16	1.55	0.40	2.30	32.40
June	69.46	21.65	2.52	14.85	3.41	0.36	2.51	33.54
July	75.03	23.21	2.51	14.30	1.23	0.35	2.28	29.01
August	59.94	20.10	2.36	14.76	1.48	0.37	2.05	27.38
September	53.94	18.22	2.38	15.60	1.53	0.38	2.42	27.83
October	55.44	18.45	2.37	13.47	1.65	0.64	2.82	26.35
November	53.25	17.87	2.25	14.10	1.69	0.75	2.62	23.84
December	45.66	16.47	2.24	14.22	2.16	1.12	2.53	22.96

Source: (Madhya Pradesh Madhya Kshetra Vidyut Vitaran Co. Ltd., Bhopal Office, 2016)

Table 27: Plot sizes as per designated plot number at the Software Park in Bhopal

Plot Numbers	Land Use	Area (Acre)
A1-A40	Electronics manufacturing	45.23
B1-B54	IT	40.63
C1-C11	IT	10.32
U1-U3	Utility	5.39
G1-G7	Open area	27.74

Source: Data collected from the (Developer's Office, 2016)

Table 28: Applicable Electricity Tariff in Bhopal, 2017-18

Sr. No.	Category	Energy Charges (INR/ unit)	Monthly Fixed Charges	Minimum Charges
Low Tension Tariff Schedule				
1	**Tariff Schedule-- LV-1 DOMESTIC**	3.25	50 per connection	
2	**Tariff Schedule – LV-2 NON-DOMESTIC**			
2.1	Sanctioned load based tariff (only for connected load up to 20kW)			
	0 to 50 units	3.25	45 per kW	
	More than 50 units	3.65	80 per kW	
2.2	Connected Load based tariff			
	Demand based tariff (only for connected load above 10 kW and up to 20kW)	3.65	100 per KW or 80 per kVA of billing demand	
	Mandatory demand based tariff for connected load above 20 kW	3.65	100 per KW or 80 per kVA of billing demand	
	Temporary connections including Multi point temporary connection at low tension for festival/events*	4.40	100 per KW or 80 per kVA or part thereof of sanctioned or connected or recorded load, whichever is highest	
3	**Tariff Schedule – LV-3 PUBLIC WATER WORKS AND STREET LIGHTS**			
3.1	Public Water Works	4.15	NIL	300 per kW
3.2	Street light	4.15	NIL	300 per kW
4	Tariff Schedule – LV-4 : LT INDUSTRIAL			

4.1 a	Demand based tariff (for Contract demand up to 150 horsepower)	3.65	100 per kW or 80 per kVA of billing demand	
4.1 b	Temporary Connection	1.3 times the applicable tariff		
High Tension Tariff Schedule				
	Tariff Schedule – HV - 1 INDUSTRIAL AND NON-INDUSTRIAL			
1.1	Industrial			
	11 KV supply	3.70	170	
	33 KV supply	3.65	206	
1.2	Non-Industrial			
	11 KV supply	3.90	225	
	33 KV supply	3.80	240	
2	**Tariff Schedule – HV - 2 PUBLIC WATER WORKS**	3.60	175	
	11 KV supply	3.30	200	
	Tariff Schedule – HV - 3 SYNCHRONIZATION OF POWER FOR GENERATORS CONNECTED TO THE GRID			
	Generators for synchronization with Grid	7.50		

Source: (Madhya Pradesh Electricity Regulatory Commission, 2016)

15.2 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 29: 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 30: 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

15.3 Summary of meetings

Date	Meetings
January 6-7, 2016	Meetings were conducted with the following officials and stakeholders during a 2 day visit: • Mr. Tejasvi Naik, Municipal Commissioner, BMC • Mr. Lokender Thakkar, Environmental Planning & Coordination Organisation (EPCO) • Mr. Kanta Rao, Industries Commissioner, Directorate of Industries (DIC) • Mr. Rajesh Chaurasiya (Additional Chief Engineer and Additional Chief General Manager), Madhya Pradesh State Electricity Management Company • Mr. Khatri, General Manager, City Circle, Bhopal, M. P. Madhya Kshetra Vidyut Vitaran Co. Ltd. (i.e. Madhya Pradesh Central Region Electricity Distribution Co. Ltd.) • Priyanka Das, IAS, Additional Commissioner, Directorate of Urban Administration and Development, Madhya Pradesh • Mr. Tarun, Smart City Cell, BMC
February 20-24, 2017	• Ms. Chhavi Bhardwaj, Municipal Commissioner, BMC • Mr. Harshit Tiwari, Deputy Commissioner, BMC • Dr. Amit Gajbhiye, Director, State Institute for Town Planning • Mr. Chandramauli Shukla, CEO, Bhopal Smart City Development Corporation Limited (BSCDCL) • Mr. Ramji Awasthi, Executive Engineer, BSCDCL • Mr. Ankit Singhal, Senior Engineer – Civil, Tata Consulting Engineers (TCE) • Mr. Joy Mathew, General Manager, Madhya Pradesh State Electronics Development Corporation Ltd. (MPSEDC) • Mr. Saxena, MPSEDC • Mr. Rakesh Singh Rajput, Deputy Manager – MEP, Gammon, Deepmala Infrastructure Private Limited • Mr. Musheer Ahmed Baquai, Authorised Dealer, Blue Star – Air Conditioning Systems, Cooling Matrix • Mr. Neeraj Bhushan Macker, Promoter, Macker Real Ventures & Vice President, CREDAI • Mr. Hanif Khan, Senior Executive Sales and Marketing, Jehan Numa Palace

16 References

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

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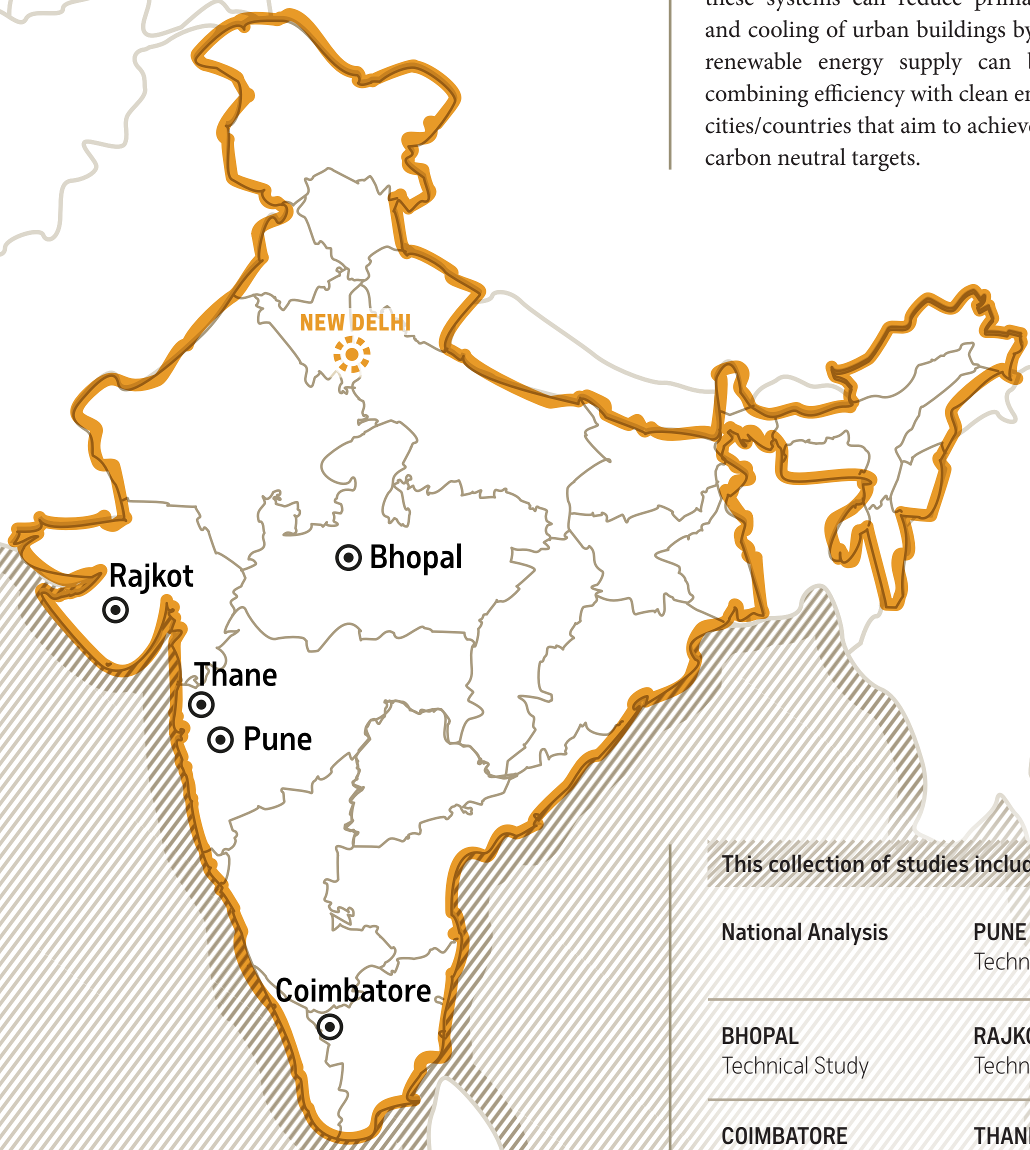
RAPID ASSESSMENTS OF FIVE INDIAN CITIES

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

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



This collection of studies includes

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

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