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Rapid assessments of five Indian cities - Rajkot

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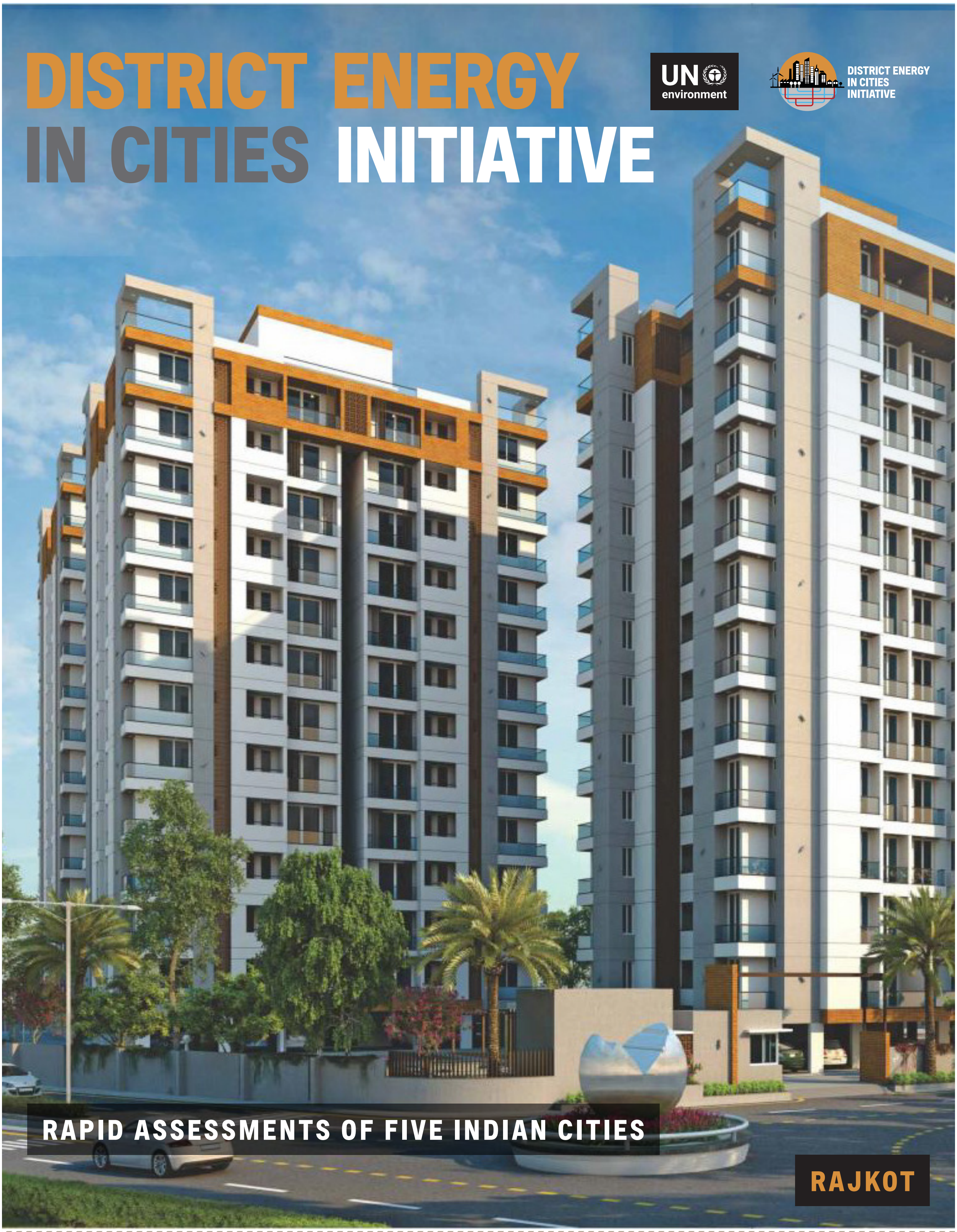

RAPID ASSESSMENTS OF FIVE INDIAN CITIES

RAJKOT

COPENHAGEN CENTRE ON ENERGY EFFICIENCY SEforALL EE HUB

I·C·L·E·I Local Governments for Sustainability

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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 Rajkot 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 are also thankful to the State Government of Gujarat for its support.

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The Initiative

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

For more information and contact details please visit districtenergyinitiative.org

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1 Introduction

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

2 Background on district cooling

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

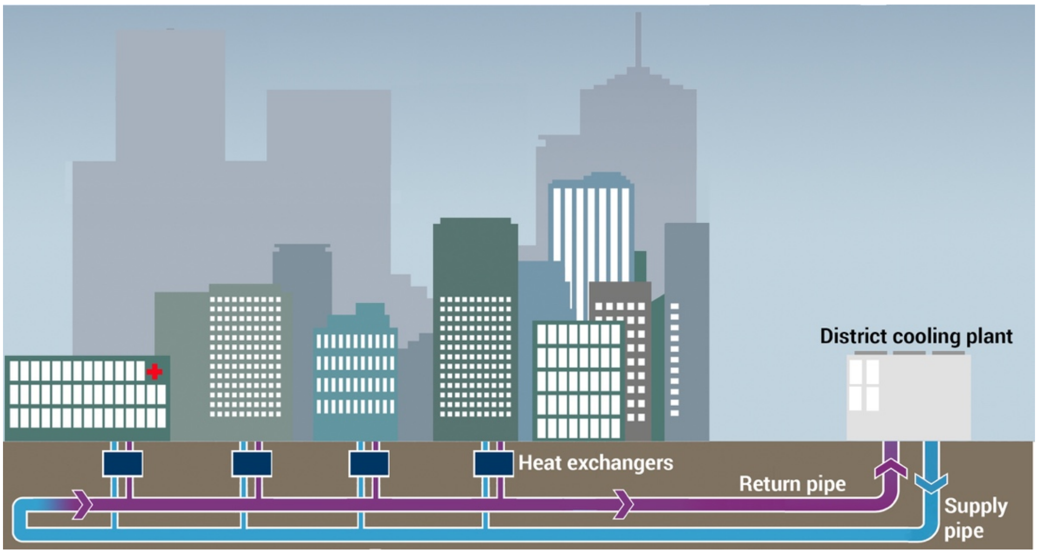
There is no fixed term used worldwide for 'district energy systems', and the authors note the following as being used worldwide: district cooling systems, district heating systems, community cooling/heating, heat networks, cool networks, decentralized energy systems, heat grids, CHP networks, trigeneration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

District Energy Systems for Cooling and its Benefits

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

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

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

Rajkot is working with various international agencies to achieve its sustainability goals through improving energy efficiency in buildings and in various public services, promoting green buildings across the city, and maximizing the use of renewable energy. Rajkot has been shortlisted as one of 100 Smart cities under the Government of India's Smart Cities Mission.

Rajkot is the fourth largest city in the state of Gujarat, housing a population of nearly 1.3 million as of 2011 and is ranked 22nd in the list of fastest growing cities and urban areas from 2006 to 2020 around the globe.

The development of the city has been historically driven by industrial activity. Rajkot is a major industrial centre known for manufacturing bearing, diesel engines, cutting appliances, watch and automotive parts, forging industries, casting industries, and machine tools manufacturers. The city has more than 40,000 enterprises providing direct employment to 105,959 persons (RMC, 2016). With increasing industrial, trade and commerce activity, there has been tremendous growth in the population and a change in lifestyles of the resident population.

There are two governing bodies within the Rajkot urban agglomeration area, the Rajkot Municipal Corporation (RMC) and the Rajkot Urban Development Authority (RUDA). RMC administers an area of 104.86 sq. km and RUDA governs the development and planning of the 54 villages located in the vicinity of the RMC jurisdiction, covering a total area of 686 sq. km (including RMC area).

Table 1: City at a Glance

Particulars	Details
Area	129 sq. km.
Population	1,346,000
Population Density	12,289 persons per sq. km.
Local Economic Base	Forging industries, Casting industries, Bearing, diesel engines, cutting appliances, watch and automotive parts, and machine tools manufacturers
Average Temperature	Minimum Average – 21.5 Maximum Average – 34.9
Average Relative Humidity	60.72%
Average Rainfall	500 mm

3.2 Location and Natural Environment

3.2.1 Geographical location

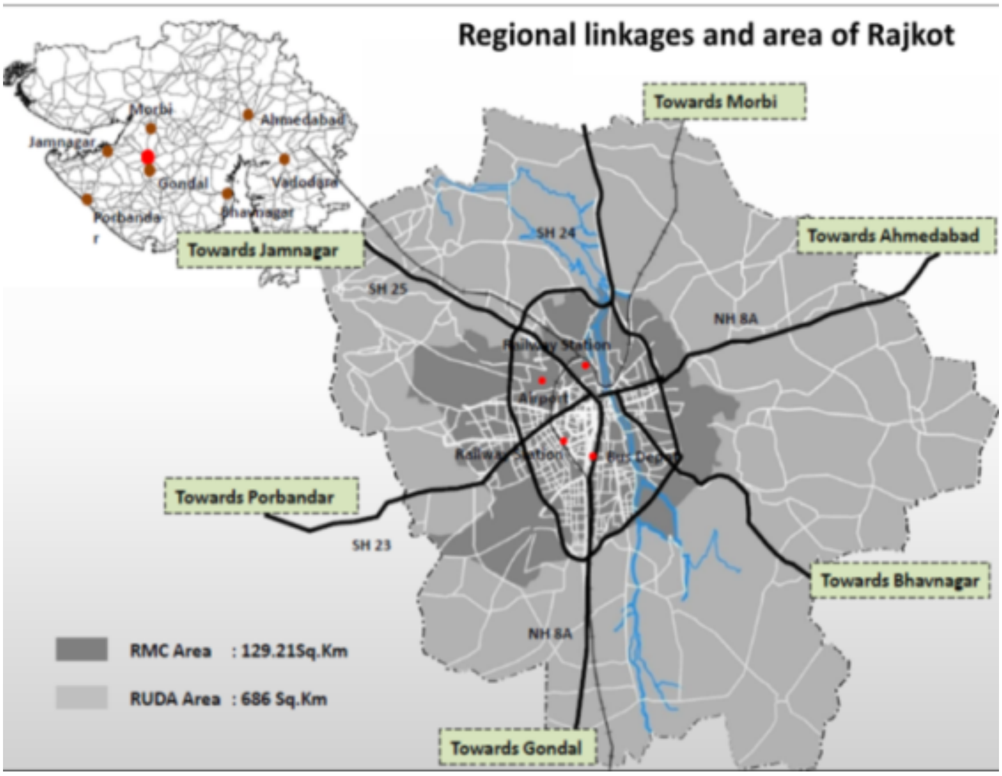
Rajkot is located in the Western part of India at a distance of 245 km from the state capital Gandhinagar, at the centre of the peninsular Saurashtra region in the central plains of Gujarat state. The city is situated at a height of 138 meters above mean sea level and is located on the banks of the Aji River and Nyari River. Rajkot lies between latitude 20.18 N and longitude 70.51 E.

The city is well connected to major Indian cities by rail, air and road as indicated below

- By Air: Rajkot's domestic airport is located at a distance of 2.5 km from the core area of the city. Daily flights connect Rajkot to the cities of Mumbai, Ahmedabad and Bhavnagar.
- By Rail: The city is also connected by broad gauge railway lines to Delhi and Mumbai, the national and commercial capitals of India.

By Road: Rajkot is well connected with the entire Saurashtra-Kutch region and other states through National and State Highways. It has one national highway (NH-8) connecting Ahmadabad and Gondal to Rajkot whereas three state highways i.e. SH -23, 24 & 25 connecting Jamnagar, Porbandar and Morbi to the city. Regional linkages and area of Rajkot city are shown in Figure 1.

Figure 1: Geographical Location, Regional Linkages of Rajkot City

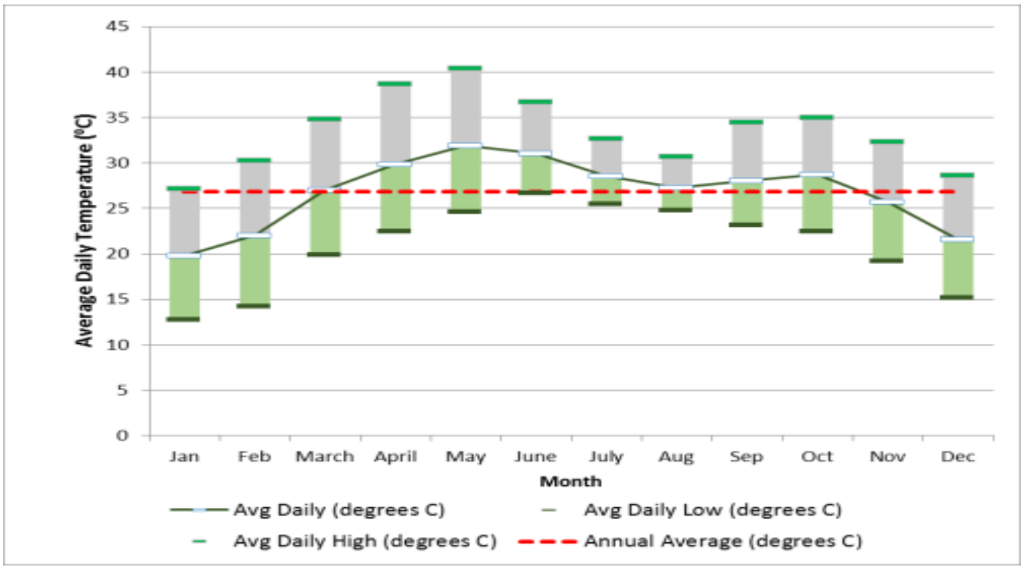


3.2.2 Climate

Rajkot falls under India's hot and dry climatic zone. Rajkot has a semi-arid climate, with hot, dry summers. Rajkot experiences three distinct seasons of summer, monsoon and winter. The average maximum and minimum temperatures recorded over the last 40 years are 43.5^{0}C and 24.2^{0}C respectively. The average annual rainfall is 500 mm. However, the city has received lower than normal rainfall in 20 of the last 60 years. Summer season extends from the months of mid-March to mid-June, with temperature ranging between 24°C and 42°C. In the months of winter lasting from November to February, the temperature varies between 10°C and 22°C, resulting in pleasant winters.

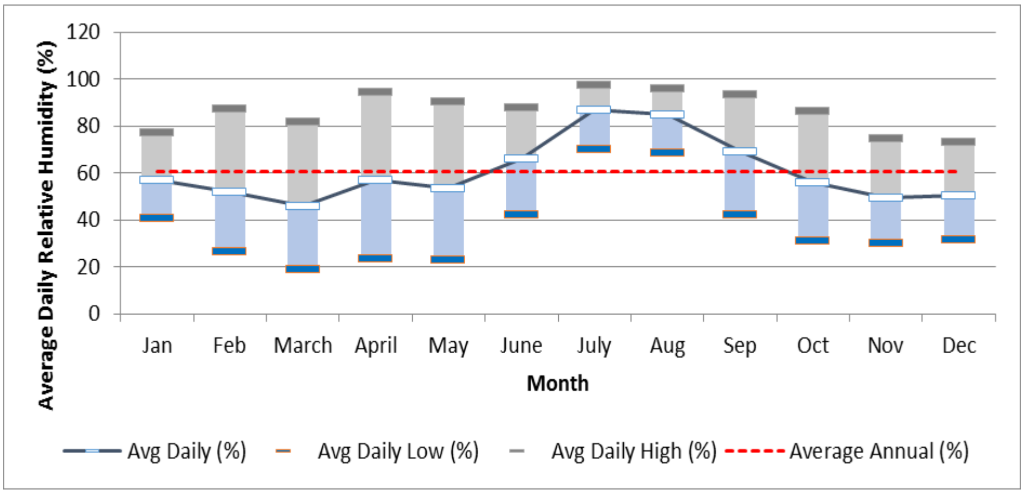
In the summers, the temperature in the city rises from mid-February onwards and peaks in mid-May, with the average daily maximum temperature rising to 42^{0}C. The average daily temperature of the city ranges from 20°C to 32°C (see Figure 2). Rajkot city has hot and humid weather conditions for about 8 months in the year. Relative humidity is significantly high during the summer season, increasing from mid-May onwards, and continues to rise in the monsoon season during the months of July to October, peaking in mid-September. Average relative humidity in Rajkot is 60%. The minimum and maximum humidity of 65 to 85% is above the annual average in the months of June, July, August and September (See Figure 3).

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



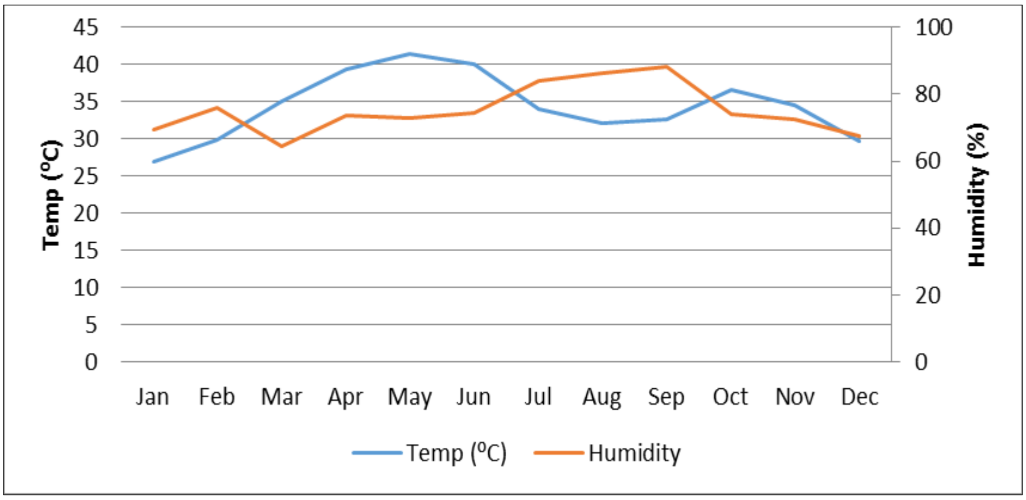
Source: Analysis based on data from (ASHRAE, 2009)

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



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

Figure 4: Monthly Average Relative Humidity and Temperature for Rajkot City (2015)



Source: Analysis based on weather data received from (IMD, Rajkot Airport Station, 2015)

Analysis undertaken on the past trends of temperature and rainfall using the India Meteorological Department's (IMD) thirty year gridded data as part of Gujarat State Action Plan on Climate Change , indicates an increase of 0.11° C in Gujarat state's mean maximum temperature over the period from 1969-2005 (Government of Gujarat, 2014). Based on analysis of data recorded by weather monitoring stations over the period from 1969-2008, the report further indicates that the increase in temperatures is higher over the Saurashtra region, wherein Rajkot is located, as compared to other regions of Gujarat. Seasonal rainfall and rainfall extremes have also shown an increasing trend in the past decade for the Southern Gujarat region and the Saurashtra region. The temperature is projected to increase in the range of 1.5 to 2.5^{0}C on an average for the state of Gujarat by year 2030 as compared to baseline year 1970.

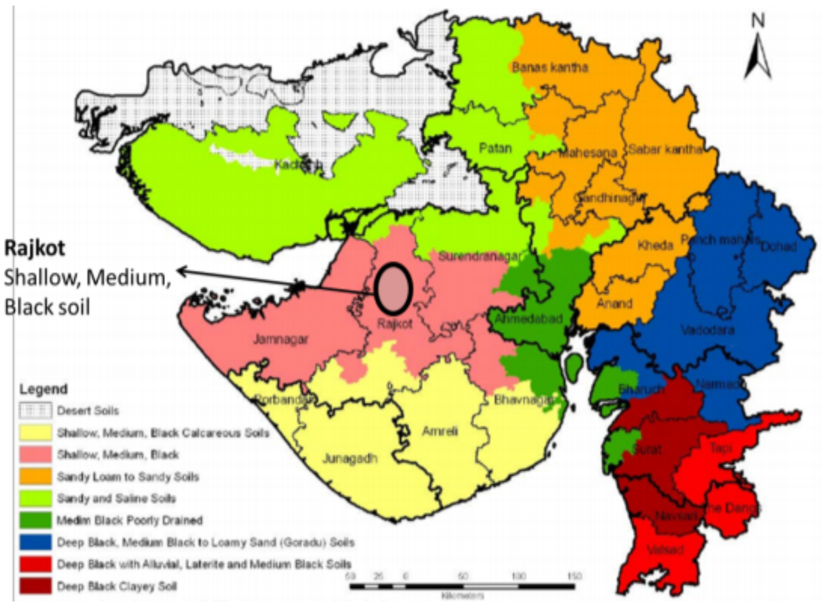
The total number of annual cooling degree days (CDD)[3] for Rajkot is 1,952 (considering a base temperature of 23^{0}C). The cooling degree days are high in the summer months and observed to be largely consistent between the months of June to October. Given that Rajkot's average temperature is projected to rise in the coming years, the cooling demand will increase in the city. Other cities have developed successful district cooling projects with far lower CDDs.

3.2.3 Soil Conditions

The soil of the entire Rajkot area can be broadly classified as medium black to shallow black (See Figure 5). These soils have been formed from granite and gneiss parent materials. The depth of the topsoil is generally 25 cm to 50 cm deep and is underlain with soft rock and hard rock formations. The soil surface is clayey in texture. It contains 40 to 70 percent clay minerals. The soil in Rajkot is poor in drainage and neutral to alkaline in reaction.

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

Figure 5: Soil Map of Gujarat



Source: (Gujarat Ecology Commission)

3.2.4 Surface and Groundwater Availability

Rajkot is situated on the banks of River Aji. With the city situated in an arid zone, monsoons in Rajkot are irregular and erratic. The Narmada River, located 600 km away, is the main

[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 18^{o}C and has been chosen to enable international comparison. For many buildings, air conditioners will maintain temperatures higher than this.

source of water over the course of the year, catering to more than 90 percent of Rajkot's water demand at times (RMC, 2016). The city also relies to a certain degree on the local water supply sources such as the Nyari dam, Aji dam, Bhadar dam, Lalpara Lake, and Randarda Lake, especially in and around the monsoon season. Although there are local water sources located at relatively short distances from Rajkot, it is not cost effective to source water from these sources given the poor water quality and the ensuing need for considerable treatment before its use. Considerable variation in the per capita availability of water has been observed due to inadequate availability of water.

Table 2: Sources of Water for Rajkot Municipal Corporation

Sr. No.	Name of Source	Type	Distance from City Area (km)	Total Water supply capacity (MLD)
1	**Aji-1 + Narmada at Aji**	Dam+Canal	0	110
2	**Lalpari + Randarda**	Lake	0	6
3	**Bhadar-1**	Dam	65	50
4	**Nyari-1**	Dam	18	35
5	**Nyari-2**	Dam	24	7.5
6	**Narmada at Raiyadhar WTP**	Canal	6	35
Total				243.5

Source: (RMC, 2012)

As indicated earlier, the soil stratum in the Rajkot region is made of hard rock. Moreover, confined aquifer is thin. Hence, the availability of ground water for potable use in Rajkot is limited. The seasonal availability of ground water also varies widely, fluctuating between 1.8 to 12 m. The quality of ground water is poor as well (see Annexure 2.1 for more details). The ground water occurs below the water table and in confined conditions. The depth of tube wells used to abstract groundwater ranges from 30 to 120 m below the ground level, whereas depth of the water level ranges from 20 to 100 m below the ground level. During the monsoons ground water is available for extraction, due to rainfall in the upstream catchment areas of River Aji. The water level in the aquifers declines in seasons when Rajkot receives normal to below normal rainfall.

Rajkot generates about 190 million litres per day (MLD) of wastewater. The wastewater collection network caters to 75 percent of Rajkot's population at present. The existing wastewater treatment capacity stands at 95.5 MLD and thereby only 50 percent of the city's wastewater is treated. Currently two activated sludge process based sewage treatment plants (STP) are operational with 10 sewage pumping stations. One STP of 44.5 MLD capacity is located at Madhapar and the other STP of 51 MLD capacity is located at Raiya, both lying towards the western part of the city.

Rajkot is addressing the gap in its sewage treatment, with two STPs having a cumulative treatment capacity of 126 MLD expected to be operational at Gauridhar and Raiyadhar by mid-2017. It is also proposed to demolish the existing 44.5 MLD sewage treatment plant at

Madhapur, which is quite old, and construct a new 80 MLD sewage treatment plant based on SBR technology in its place. Consequently, the city will have a cumulative wastewater treatment capacity of around 272 MLD; sufficient enough to treat all of the city's wastewater generated. Rajkot is keen to promote improved water management and reuse of treated wastewater. A 50 MLD tertiary water treatment plant is proposed in the premises of the STP at Raiya to reuse treated wastewater. Also, lake water conservation and water reuse is proposed in area development plan under Rajkot's Smart City proposal.

The numerous lakes that exist in Rajkot city and the surrounding area, are unlikely to be able to provide significant 'free cooling' to district cooling systems as their temperatures are too high, at approximately 21°C-23°C[4] (Bhadja & Vaghela, 2013). However, temperatures may be lower at deeper points of these water bodies and further analysis should be undertaken during pre-feasibility stage of projects and city-wide assessments, particularly for projects in the vicinity of these water bodies. This analysis should also account for the possible environmental benefits and impacts that can come from rejecting waste heat into the water bodies. 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. Existing buildings in Rajkot that have centralized cooling use a mix of air-cooled chillers and water-cooled chillers (see Section 1.7.1).

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

3.2.5 Air Quality

Manufacturing industries, foundry units and vehicular emissions are the major pollution sources impacting air quality in Rajkot. The city does not have other significant pollution sources such as electricity generation from coal-fired power stations. Rajkot has two ambient air quality monitoring stations for monitoring its air quality (See Table 3). The concentration of pollutants such as sulphur dioxide (SO2), nitrous oxide (NOx) and ozone (O_3) in the city is found to be within permissible limits. The concentration of particulate matter 10 (PM10) in Rajkot city varies from 60 to 160 microgram per m^3, exceeding the permissible limit of 60 microgram per m^3 prescribed by the National Ambient Air Quality Standards[5]. Information on pollution from point sources is not available for the city.

[4] Water temperature measurements for Lalpari lake is available

[5] The National Ambient Air Quality Standards are prescribed by the Central Pollution Control Board, Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India

Table 3: Yearly Average Air Quality Recorded in Rajkot, 2014-15

Location in Rajkot	PM 10	PM 2.5	SO_2	NOx	O_3	CO
Nr. Sardara Corporation Amul India Ltd.	89	32	13.3	20.3	10.6	1.41
GPCB Office	82	31	12.3	19	11	1.33

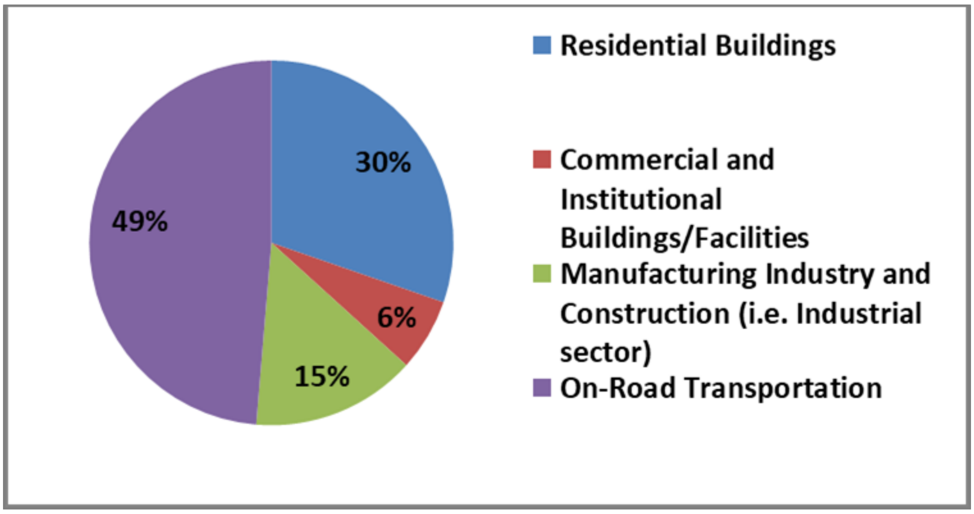
Source: (Gujarat Pollution Control Board, 2015)

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

3.2.6 Energy consumption

49% of Rajkot's total energy demand[6] stems from the transport sector. The residential building sector is the second largest energy consumer, accounting for 30% of Rajkot's total consumption driven predominantly by the use of electricity and to a lesser extent by the fuels used for cooking. Manufacturing industry & construction sector and Commercial and institutional buildings/facilities sector account for 15% and 6% of the city's energy consumption respectively (see Figure 6).

Figure 6: Sectorial share of Energy Consumption in Rajkot (2015-16)

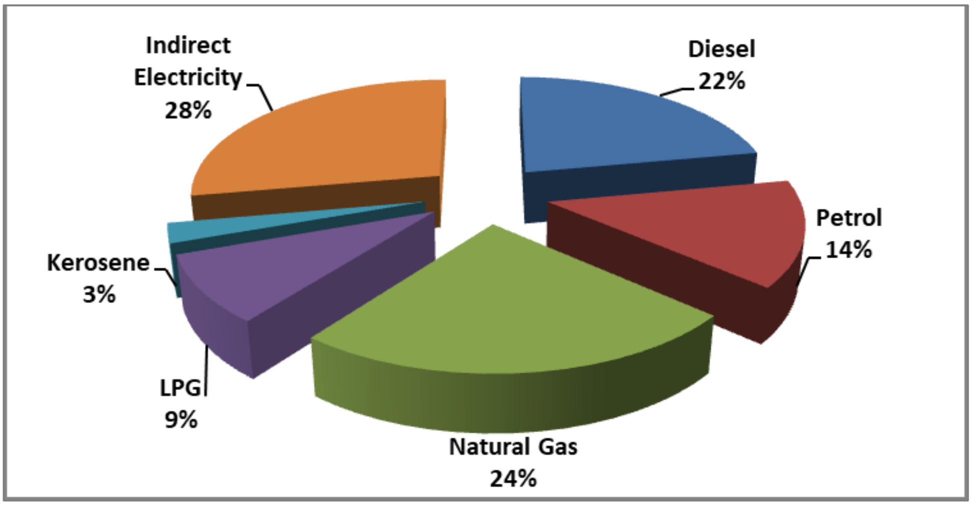


Source: (ICLEI South Asia, 2017)

[6] A total of 15,716,335 GJ of energy was consumed in Rajkot in the year 2015-16 with the average per capita energy consumption at 11 GJ.

Electricity is the predominant final energy type in Rajkot and accounts for 28% of the city's final energy mix, typically being used for meeting the electricity demand in commercial and residential buildings[7]. Natural gas (including piped natural gas) has a share of 24% of the total energy mix. Diesel and petrol account for 22% and 14% respectively of the total energy mix. Use of natural gas, diesel and petrol is mainly associated with the transport sector. Liquefied petroleum gas (LPG), which is mainly used for cooking, has a share of 9%.

Figure 7: Share of Energy Sources in Rajkot's Energy Mix



Source: (ICLEI South Asia, 2017)

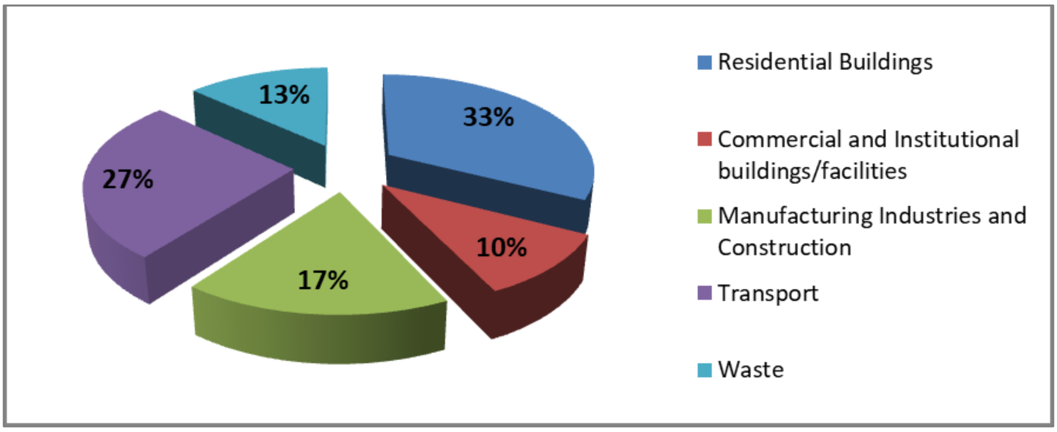
3.2.6.1 Greenhouse gas emissions

Rajkot city's GHG emissions amounted to 2.01 million tonnes of carbon dioxide equivalent (CO_2eq.) in the year 2015-16, with the average per capita GHG emission at 1.40 tonnes of CO_2eq. Rajkot's GHG emissions inventory captures emissions from use of different fuels in the city. The GHG inventory, however, does not cover emissions from refrigerants.

It is seen that residential buildings have the highest contribution to GHG emissions (33%), followed by transportation sector (27%), manufacturing industries and construction (17%), waste sector (13%) and commercial and institutional buildings/ facilities sector (10%) (see Figure 8). With regard to emissions from different energy sources that are used in the city, electricity use contributes to 57% of the total emissions followed by Diesel (15%), Natural Gas (12%), Petrol (9%), LPG (5%) and Kerosene (2%) (see Figure 9)

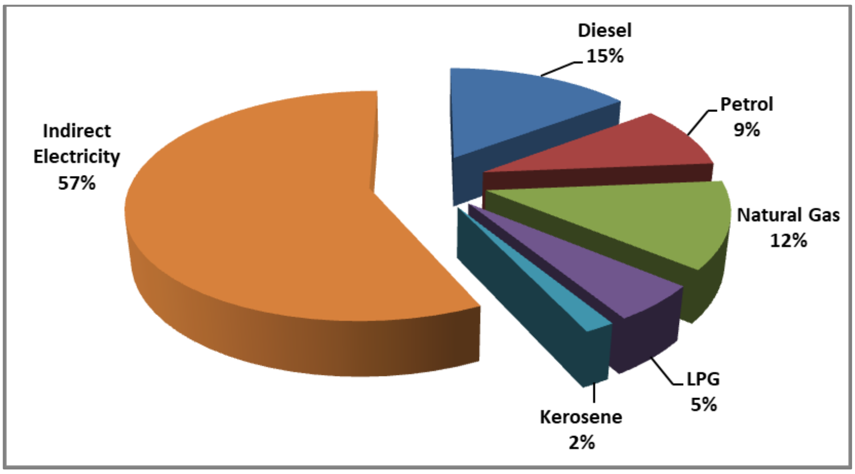
Figure 8: Sectorial Share of GHG Emission in Rajkot

[7] Residential buildings and commercial & institutional buildings/ facilities consumes 50% and 20% of the city's total electricity consumption in the year 2015-16



Source: (ICLEI South Asia, 2017)

Figure 9: Share of GHG Emission by Energy Source



Source: (ICLEI South Asia, 2017)

3.3 Socio-economic Status

3.3.1 Population

The population of Rajkot city is 1.28 million persons as of year 2011 (Census of India, 2011). The population has grown at decadal growth rate of 28.3 percent since 2001. The population growth in the previous decade was influenced largely the expansion of the city area i.e. the area governed by the RMC. The population density of Rajkot city is 12,289 persons per sq. km as of 2011. The maximum density of 32,053 people per sq.km has been observed in ward (i.e. administrative division) no. 22 and the lowest density of 6,167 persons per sq.km in ward no. 3. The average household size for Rajkot is 4.23 persons per household. Slums and economically weaker sections (EWS) have higher household size whereas other income groups have a household size of nearly 4 persons (UNEP, 2014). According to socio-economic survey conducted by RMC in 2012-13, there are a total of 124 slum pockets in the city which cover about 5.5 percent of the city's area. These slums house 45,562 households and 188,465 persons, indicating that 14.6 percent of city's population resides in slums (CEPT

University). Over past decade, there has been a decrease of 6.8 percent in the slum population.

The projected population for Rajkot city in 2031 (based on 2011 population) is estimated to be 3.1 million persons. As per survey done during Low Carbon Comprehensive Mobility Plan, Rajkot's average monthly income stands at INR 22,000 (USD 340) per household. Households located along the recently developed areas such as Kalawad Road, Racecourse Road, Raiya Road have high monthly incomes ranging from INR 30,000 to INR 50,000 (USD 465 to USD 770) or more[37]. Whereas, areas near Gondal road in the south or those located to the north of Hospital Chowk largely have households with middle income levels, ranging from INR 10,000 to INR 30,000 (USD 155 to USD 465) [37]. The old city areas as well as developments on the eastern side of the River have monthly incomes up to INR 10,000 (around USD 155) and are considered as low income groups. The economically weaker sections, comprising of the population below poverty line, have monthly incomes ranging between INR 1,000 to INR 2,500 (around USD 16 to USD 38)[37].

3.3.2 Local Economy and Real Estate Growth

Rajkot is an industrial town and two industrial areas and three major industrial estates, housing more than 26,000 industrial units, surround the city. There are two main industrial estates in the city, the Aji Industrial Estate and the Bhaktinagar Industrial Estate (RMC, 2016). The city is a major industrial centre known for manufacturing bearing, diesel engines, cutting appliances, watch and automotive parts, forging industries, casting industries, and machine tools manufacturers. Rajkot has more than 40,000 enterprises providing direct employment to 105,959 persons[42]. Due to its strategic location, Rajkot has become a major trade centre in the Saurashtra region for agriculture products. The major industry types in Rajkot are as follows:

- Oil Engine & Machine Tools
- Foundry industry
- Engineering and automobile industries
- Castor oil industries
- Gold and silver jewellery
- Handicrafts

Skill training for the local workforce is provided through 74 colleges located in the city. The city has two polytechnic colleges (diploma training based) and 13 Engineering colleges. Rajkot is also famous for its gold and silver jewelry.

The growth of Rajkot city and its surrounding urban agglomeration in the past decade has been influenced by the expansion of the area under the RMC and RUDA jurisdiction, undertaken in order to accommodate the increasing urban population and development. Rajkot has witnessed significant development within the city limits as well as in the newly added areas within the larger RUDA area. The residential area in Rajkot city has increased from 40.5 percent in 2001 to 52.4 percent in 2011 while that in the RUDA area has more than

doubled (see Section 1.4.1 for more details). Around 40,000 residential properties are being built in the city every year (Business Standard, 2013).

While the city has grown in all directions along the highways, most of the residential and commercial growth is occurring on its western side. Residential development is also expected to occur in the southern direction due to industrial development in surrounding areas. The presence of natural geographical barriers such as the Aji River and water bodies has restricted the growth of the city on the eastern side and in some portions on the northern side (UNEP, 2014).

A noticeable difference exists in the typology of development taking place on the eastern and north-western side of Rajkot as well. The eastern and central part of the city is characterized by low-rise apartments, informal housing, and small scale retail and commercial shops. The relatively recently developed areas around major arterial roads and important nodes such as the Kalavad Road, Jamnagar Road, Raiya Road and the 150 feet ring road, located in the northwest part of the city, are characterized by a mix of large scale retail and commercial development that typically includes shopping malls, complexes with cinema theatres, office complexes and business parks along with premium high-rise residential apartments with a range of amenities including centralized air-conditioning. A number of educational institutes are located on Rajkot's western and northern side (Rajkot Urban Development Authority, 2016). The city's bus rapid transit system (BRTS) corridor has been developed along this stretch and as a result the real estate value has appreciated significantly in these areas and will continue to do so in the coming years as well.

Rajkot is also promoting compact development and coordinated planning of land use and transportation. Transit Oriented Zones[8] (TOZ) and polycentric zones[9] have been identified in the city, to be taken up for development over the existing Residential and Commercial zones and encouraging compact mixed use development[10](See Figure 12). A TOZ covering an area of about 34.5 sq. km has been proposed around the potential transit corridor along the outer Ring Road in the city, in close proximity to the BRTS (see Figure 12). Sustainable transit oriented densification is proposed by incentivizing development of additional floor space along the transit corridors. The maximum permissible FSI[11] in the TOZ shall be 3.75, with a base FSI[12] of 1.8 and the remaining FSI can be availed by paying a charge. Developments

[8] Transit Oriented Zoning is an effective planning tool to promote compact, transit oriented development within walking distances of public transit routes such as BRTS and Metro.

[9] The traditional structure of cities has been of the Monocentric type, typically having a high density commercial core/centre surrounded by residential suburbs which tends to increase travel distances and add to congestion due to tidal commuting flows. With rapid urbanization in the recent decades, cities are witnessing polycentric development- wherein jobs and amenities are distributed rather more uniformly across the built up area, leading to decentralized concentration of numerous small- and medium-size centers, frequently organized around a compact city center, forming large urban agglomerations. Polycentric corridors or nodes recognize this polycentric pattern of growth and is an effective tool to promote compact development around existing highways connecting the larger urban agglomeration.

[10] The TOZ and polycentric corridors are limited to areas which were not in the developable zone in the previous Development Plan and are both along the 75 m wide ring road with 500 m buffer on both the sides, making the entire corridor 1,075 m wide.

[11] The maximum permissible FSI is the sum of permissible FSI and chargeable FSI.

[12] The Base FSI is FSI which is permissible for different zones. In certain zones, developers can avail additional FSI by pay a certain charge depending on the zone.

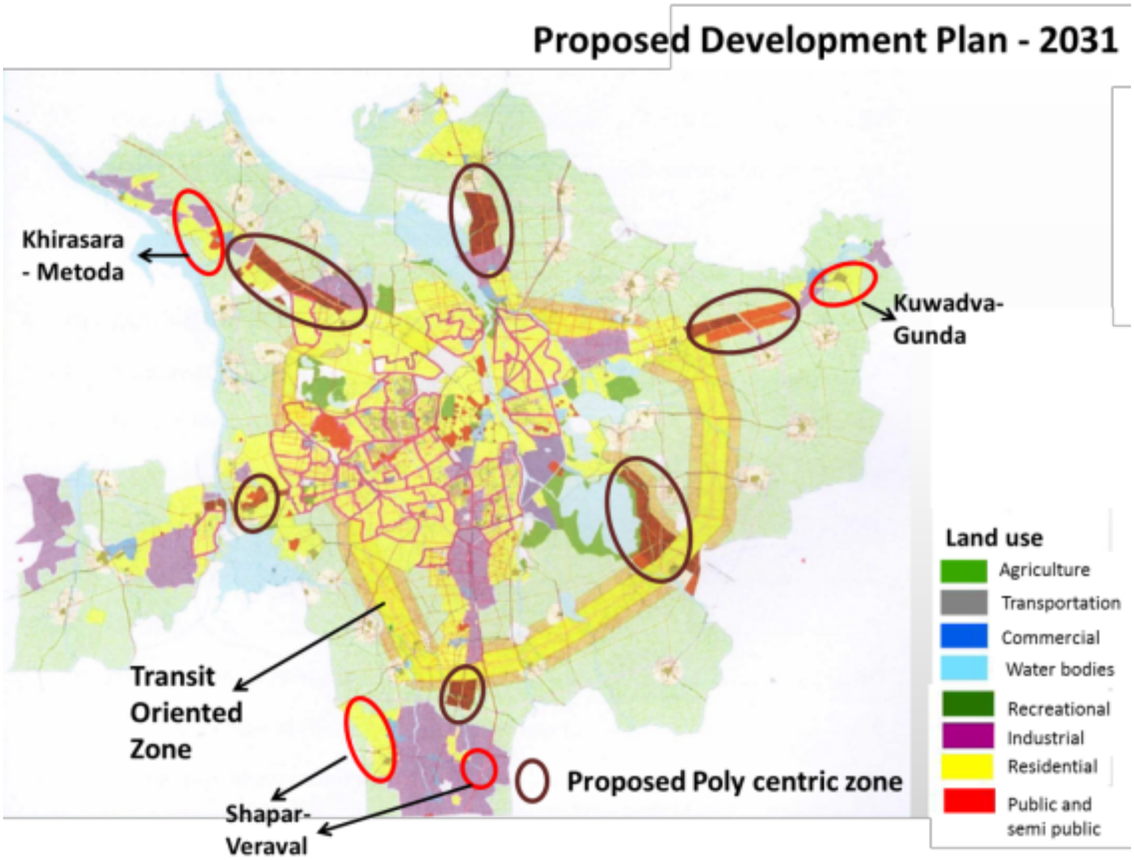
proposed in the TOZ will be fast-tracked by enforcing the Town Planning Scheme[13] or similar land development mechanisms in this zone.

In the same vein, polycentric corridors have also been identified to promote compact development around existing highways in the city (see Figure 10). These areas have been identified based on the recommendations of a study conducted by Centre for Environmental Planning and Technology (CEPT) University for Rajkot city and its peripheral areas. Polycentric corridors are proposed along all the six existing highways in the city, covering about 1,170.53 sq. m of area (superimposed on the base zones). Similar to the TOZ, densification of such polycentric corridors is proposed to be achieved under the Development Plan 2031 by incentivizing development of additional floor space along the corridors, with a maximum permissible FSI of 4.0 (see section 1.4.2 for more details).

Three growth centres of Shapar – Veraval, Khirasara – Metoda and Kuwadva – Gunda are identified in close proximity to the city and around industrial clusters, to support future population growth as indicated in Figure 12. It is proposed to develop additional zones around the existing industrial areas to utilise large tracts of vacant land in order to accommodate future population in these areas. Areas in the western part of the city such as the Kalawad road, Race course road, and Raiya road, accommodate a significant portion of high income population and are rapidly developing areas, lying in close proximity to the BRTS route and with a focus on transit oriented development. Mixed and compact land use is also proposed for the Area Based Development in the west zone of the city under Rajkot's Smart City plan (see section 1.3.1 for more details). The proposed TOZ and polycentric growth corridors will further promote densification and compact development in Rajkot.

[13] The basic concept of Town Planning Schemes is pooling together all the land under different ownerships and redistributing it in a properly reconstituted form after deducting the land required for open spaces, social infrastructures, services, housing for the economically weaker section, and road network. This process enables the local authority to develop land without fully acquiring it and gives it a positive control over the design and the timing of the urban growth.

Figure 10: Proposed Development Plan – 2031, Rajkot



Source: Adapted from (Rajkot Urban Development Authority, 2016)

4 Stakeholder Mapping

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

Institution type	Agency	Mandates and Role
City planning and policy relevant interventions	• Rajkot Municipal Corporation (RMC) • Rajkot Urban Development Authority (RUDA) • Rajkot Smart city Development Ltd. (RSDL)	**Mandate and Functions:** • **RMC:** The RMC is main planning authority for the city of Rajkot. RMC is responsible for providing basic infrastructure services including water supply, drainage, roads, street lights, waste management, slum management planning for economic and social development, development planning, regulation, control and coordination of urban growth within the territorial jurisdiction of the city. Zoning and mandating the type of land use over its entire jurisdiction is one of its key functions. RMC is also responsible for the

Institution type	Agency	Mandates and Role
		provision of basic services and civic amenities to the citizens along with the preparation and execution of infrastructural development projects. RMC plays the role of planner, controller and implementer within its jurisdiction. • **RUDA:** RUDA oversees the planning and development of larger Rajkot Urban Agglomeration area (including Rajkot city) including long term planning, promotion of new growth centres, implementation of strategic projects and financing infrastructure development for the Rajkot Urban Agglomeration area. RUDA is responsible for the preparation of a physical plan for the development of the Rajkot Urban Agglomeration; preparation and implementation of town planning schemes; monitoring and controlling of the development activities in accordance with the Development Plan. • **RSDL:** The key responsibility of RSDL is to oversee the planning and execution of Smart City plan for Rajkot city. This includes the implementation of proposed smart and sustainable solutions throughout the city as well as in the area based development. RSDL's main focus remains on improvement of urban infrastructure and governance while addressing priority areas outlined in the Smart city plan. **Role with respect to district cooling:** A. Integrate district cooling development as a focus area in the city's long-term vision and strategy through policy and planning frameworks such as the Master Plan, Smart City Plan, and Low Emission Development Plan etc. B. Leverage its role in city master planning to help identify strategic high density mixed-use zones and building clusters (existing and planned), key economic sectors with

Institution type	Agency	Mandates and Role
		opportunities for district cooling network development C. Share information such as city plan(s) detailing zones, existing and future development density, building locations, building use etc. to help determine demand density and new network designs and assess feasibility D. Facilitate planning and implementation of district cooling infrastructure by identifying strategic location and securing land for district cooling production facilities, assisting in excavation permits and rights of way for laying district cooling pipelines, co-ordinating schedules with other planned infrastructure and building construction E. Use the existing local regulatory framework for urban development and buildings such as building permits, bye-laws and development control regulations, building efficiency standards to develop complementary policies to encourage district cooling development and adoption F. Share data on local government buildings and utilities, offering connections to local government buildings such as large hospitals, office buildings to act as anchor loads with high cooling demand to assist viability of district cooling G. Facilitate stakeholder coordination, raise awareness and acceptance H. Lead implementation of district cooling through public private partnership funding mechanisms
Real Estate, Property Developers and related Institutions	• Rajkot Builders Association • Gandhi Realty group • Samvedna Builders Pvt. Ltd. • Kotecha Builders Pvt. Ltd. • Shyamal Builders	**Mandate and Functions:** Rajkot Builders Association is an association of builders with an objective to provide a platform to real estate developers to promote best practices and technologies in building design and construction by organizing various seminars and debates, to advise and assist the builders/ developers in technical, non-technical and legal matters. **Role with respect to district cooling:**

Institution type	Agency	Mandates and Role
		• Identify existing and upcoming large scale high rise buildings and mixed-use developments in the city with potential for district cooling integration, share information on property and building plan, floor space, utilities and cooling technology for the same • Provide inputs on practical issues, risks and possible enabling policies and programmes with regards to district cooling integration and market acceptance • Provide information relating to prevalent cooling technology and infrastructure in the real estate market • Facilitate measurement and monitoring of baseline cooling demand in buildings to assess feasibility for district cooling
Architects, Building Design and Civil Engineering related Institutions	• The Indian Institute Of Architects (IIA), Saurashtra Region • Association of Consulting Civil Engineers (ACCE), Rajkot • AMA Architects • MaST Designs and Architecture	**Mandate and Functions:** • Promote interests of architects- learning as well as practicing – and promote best practices in urban planning and architecture. Enable exchange of knowledge and present a platform to share new techniques, technologies and developments in the field of civil engineering. **Role with respect to district cooling:** A. Identify existing and upcoming large scale high rise buildings and developments in the city with potential for district cooling integration B. Share information on typical cooling demand for different building types in the city in consideration of the local climate, building use, envelope and size, and prevalent cooling technology in use and its cost C. Provide technical inputs on integrating district cooling in the prevalent building design and other practical aspects in terms of expertise, market acceptance etc. D. Provide inputs for promoting district cooling through existing or new building

Institution type	Agency	Mandates and Role
		design and efficiency standards/regulations
Electricity Distribution company	Paschim Gujarat Vij Company Ltd. (PGVCL)	**Mandate and Functions:** • The PGVCL is responsible for distribution of electricity that it receives from public and private power producers to end-consumers. It is also responsible for planning the electrical infrastructure to strengthen the electricity distribution network, to reduce the electricity downtime and enhance reliability. PGVCL collects the energy consumption charges from end users as per the tariff stipulated by Gujarat Electricity Regulatory Commission. PGVCL works to promote energy conservation through demand side management and also supports implementation of the solar roof-top net metering program through facilitation of infrastructure for net-metering. **Role with respect to district cooling:** A. Share information on baseline and future energy and cooling demand, daily, seasonal and annual load profile, power availability for specific locations/consumers and for the city B. Assist in identification of buildings/consumers with high load and energy demand C. Share information on infrastructure status or augmentation required in the local electricity network to support the required power demand of the district cooling production plant D. Share information on existing and future tariff structure (fixed, variable, time of use) for different consumer categories, any incentives for electricity conservation to assist in design of district cooling system, assess commercial viability and establish pricing levels for the district cooling service for different consumers

Institution type	Agency	Mandates and Role
State Designated Energy Agency	Gujarat Energy Development Agency (GEDA)	**Mandate and Functions:** • GEDA is responsible for implementation of energy conservation and energy efficiency programs across the state of Gujarat. It is a nodal agency for disbursement of central financial assistance/subsidies for renewable energy projects including solar PV. GEDA is responsible for developing, implementing and promoting energy efficiency and conservation in different sectors through enabling policies and programs. **Role with respect to district cooling:** A. In its role as the nodal energy agency for the State, MEDA can assist in promoting district cooling by formulating and implementing enabling policy, regulations and schemes for the same B. Coordinate with other State and Central government departments for implementation and promotion of energy efficiency programmes and technology (including district cooling). Create buy-in amongst such departments on district cooling development. C. Share information on existing and planned renewable energy generation in the city for integration with district cooling D. Generate awareness on district cooling among local stakeholders through targeted programmes.
Regional Pollution control board	Gujarat Pollution Control Board (GPCB)	**Mandate and Functions:** • GPCB is a legislative body in Gujarat that implements a range of environmental legislation with respect to prevention and control of pollution relating to air, water, noise and waste. GPCB 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 GPCB is responsible to plan and execute programs for the prevention, control or abatement of pollution. The

Institution type	Agency	Mandates and Role
		GPCB regulates and monitors discharge and treatment of sewage or trade effluent and performance of air pollution control systems. **Role with respect to district cooling:** A. Identify potential waste heat sources in the city for use in the district cooling system B. Share information on potential sources of water (e.g. location, temperature, depth, quality) for use in the district cooling network C. Provide inputs on potential environmental constraints, environmental permits and assisting in obtaining requisite clearances for construction and operation of the district cooling project
Industry related Institutions	• Aji GIDC industries association (AGIA) • G I D C Lodhika Industrial Association • Shapar Veraval Industrial Association • Gujarat Chamber of Commerce and Industries	**Mandate and Functions:** • Industrial Associations and Gujarat Chamber of Commerce and Industries are industry bodies concerned with representing and highlighting the issues concerning the industries in Rajkot and in state of Gujarat. These institutions provide a platform for industry owners to exchange ideas and promote best practices. **Role with respect to district cooling:** A. 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 B. 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 C. Provide inputs on existing enabling provisions and how existing industrial policy and regulatory frameworks can be

Institution type	Agency	Mandates and Role
		used to promoting district cooling in large industry related developments D. Share information on potential waste heat sources (from industries such as foundries that exist in the city), availability of gas/biogas E. Facilitate coordination and awareness generation for industries F. Provide input on how existing building designs can adopt district cooling facilities G. Provide inputs on adopting district cooling in future real estate project developments
Designers, manufacturers, installation contractors for chillers and cooling system	• Raj Cooling Systems Pvt Ltd, Rajkot • Isotherm Refrigeration Pvt Ltd, Rajkot • Natural Storage Solutions Pvt Ltd, Rajkot • Armec Cooling system Ltd, Ahmedabad	**Role with respect to district cooling:** A. Provide inputs on energy audit of the buildings, practical issues and associated risks with regards to district cooling integration and market acceptance B. Provide support/guidance for Conceptualization, planning and implementation of DCS project C. Provide first-hand experience on technical aspects and local regulations towards HVAC and consequently district cooling,

5 City Strategies and Initiatives

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

5.1 Rajkot Smart City

Rajkot is one of 100 Smart cities to be developed under the Government of India's Smart Cities Mission. The Smart City proposal developed by the RMC envisages Rajkot as a 'Sensitive & Sustainable, Modern, Affordable, Robust Infrastructure and Technology Driven' city in future, where all its citizens get an enabling environment to fulfill their dreams and aspirations by provision of quality infrastructure and efficient service delivery; a city where citizens actively collaborate with government to improve their lives and the future of the city.

Rajkot's Smart city proposal emphasizes the city's commitment to address its rising energy consumption by increasing renewable energy generation and improving building energy efficiency.

Rajkot has identified five core themes to achieve its vision – **Sustainable, Modern, Affordable, Robust Infrastructure and Technology Driven**, with priority goals and strategies further outlined. Under its **Pan-city proposal**, Rajkot has outlined implementation of various smart solutions across the city for different sectors (see Figure 11). The city has identified improving energy efficiency, promoting adoption of solar energy, and establishing a smart grid as key strategies under one of core sectors **Environment and Energy**. Rajkot has prioritized reuse of non-potable drinking water as well, which presents potential opportunities for its use in the district cooling networks, given the competing water uses and water scarcity in the city.

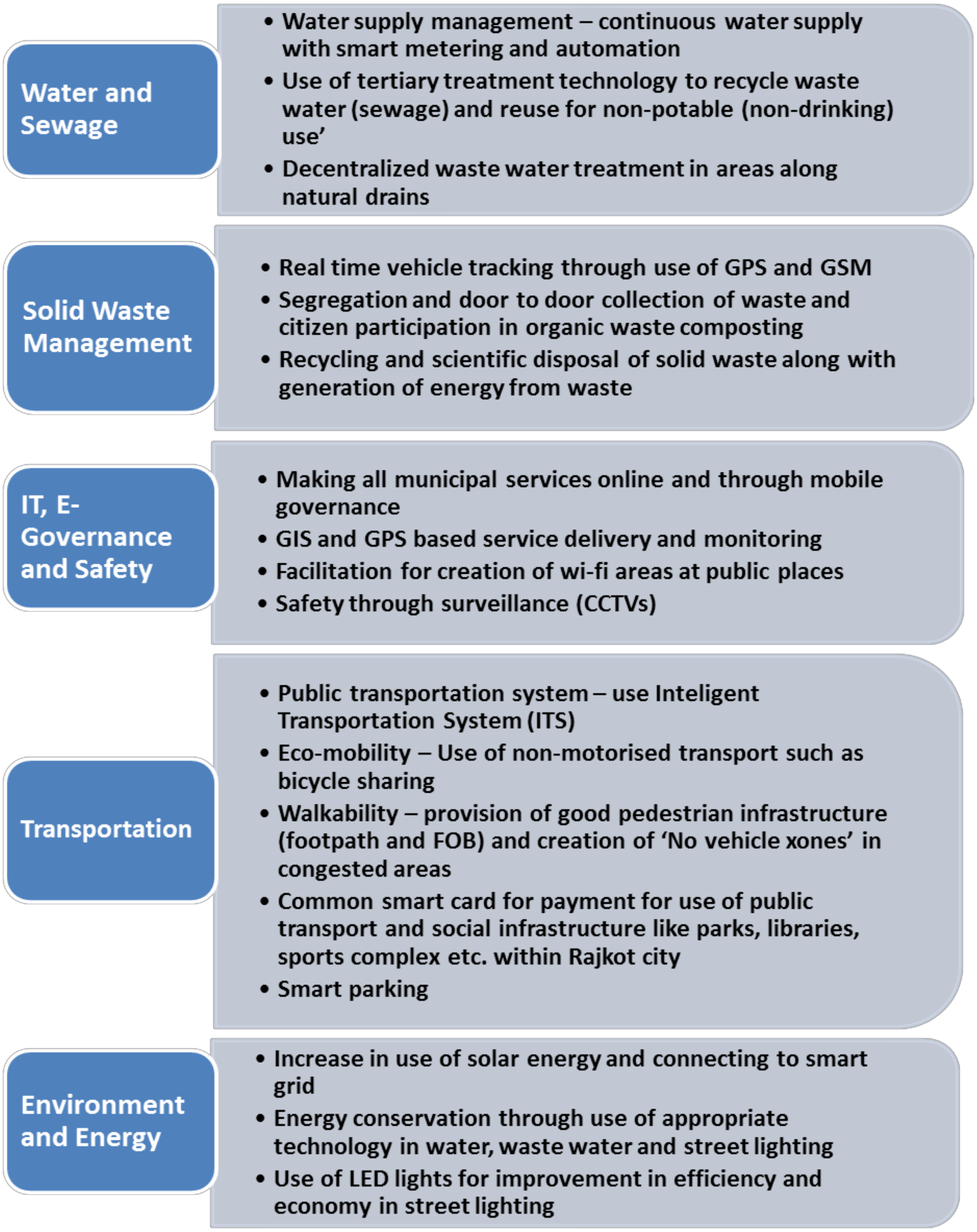
Under the Area-based Development[14] (ABD) proposal in its Smart City Plan, Rajkot will be going ahead with Greenfield development in the Raiya area spread over 2 sq. km, situated in ward no. 1 and in conjunction with the growth direction (west) of the city. Rajkot has selected this pilot green field zone to create a sustainable development model through effective land use planning. The location selected is situated close to Rajkot's BRTS corridor as well. The key elements outlined in Rajkot's Smart City Proposal to promote renewable energy and building energy efficiency for the Raiya area include-

- Assured electricity supply with at least 20%of the Smart City's energy requirement coming from renewable energy (solar power generation of 4.4 MW)
    - Grid connected solar panels with net metering across 18,000 households
    - Additionally, it is estimated that around 2 MW of solar energy will be generated through utilization of vacant land for installation of solar panels
    - Rooftop Solar PV (6.4 MW) connected to the smart grid supply grid
- At least 80% buildings should be energy efficient and green building
    - Appropriate amendments would be made in the development control regulations to mandate construction of energy efficient buildings (including residential, commercial and others)
    - Climate responsive design and active and passive solar architecture will be adopted in buildings along major streets
    - Constructing built up area along transit corridors having robust infrastructure to support compact development and eco-mobility
- Waste to Energy – A 130,000 MT capacity waste to energy plant is proposed which will generate 4 Megawatt (MW) of power annually

[14] 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.

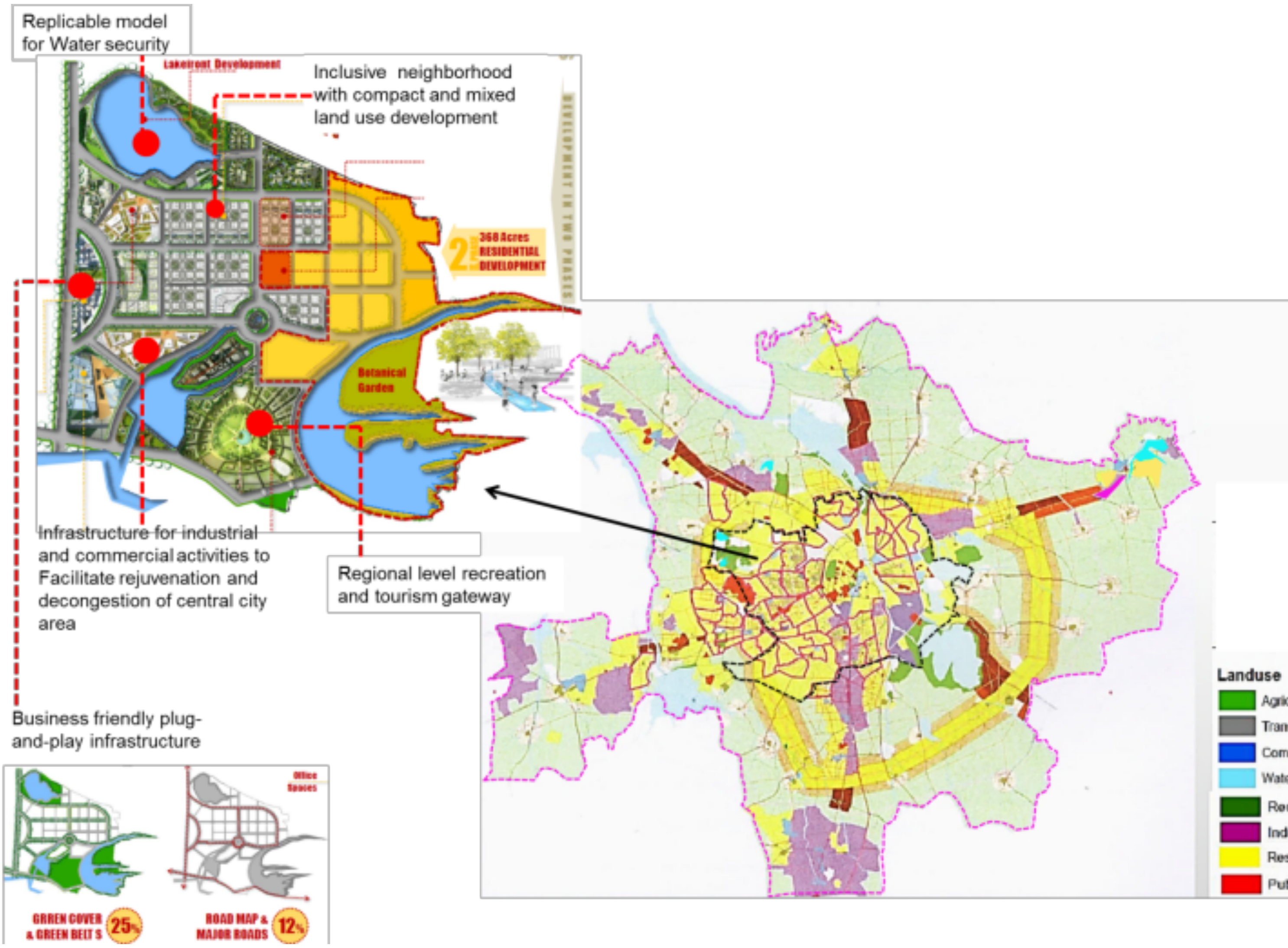
The total estimated cost of Rajkot's Smart City proposal is INR 26,230 million (USD 403 million), of which INR 4,455 million (USD 68.5 million) pertains to the Pan-city initiatives and INR 21,774 million (USD 335 million) is estimated for the Area Based Development. The Rajkot Smart City Development Ltd. (RSDCL), a special purpose vehicle (SPV) has been setup for implementation of Rajkot's Smart City plan.

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



Source: (RMC, 2016)

Figure 12: Proposed Area Based Development in Rajkot



Box 1: Smart city recommendations

The Area Based Development site in Rajkot offers potential opportunities to test the integration and promotion of district cooling, particularly given the high-density mixed land use development proposed within a largely green field area. Emphasis is also placed on promoting sustainability and maximum use of renewable energy for this site. The proposed business park spread over an area of 30 acres (0.12 sq. km), and the housing banking and financial services, IT/ITeS, and retail spaces and the convention and exhibition centre spread over 36 acres (0.14 sq. km) may have substantial demand for cooling to anchor the district cooling network (see section 1.9.5 for more details).

If possible, district cooling concepts could be incorporated into the design stage of the Greenfield Area since the local government will control development in and around this site. The RSDCL could be supported to undertake such an analysis. If district cooling is feasible, RSDCL could coordinate development of district cooling within the smart city area, and promote its replication across each city. Furthermore, RSDCL and/or the city could be a direct investor into the district cooling project, or provide finance and support for related projects. Also, opportunities exist to explore reuse of the treated waste water from the wastewater plant in the district cooling network as well along with the use of renewable energy and energy generated from waste to energy plant.

Furthermore, the RSDCL and/or the city could be a direct investor into the district cooling project, or provide finance and support for related projects such as key municipal buildings converting to centralised HVAC or demonstration projects with a particular social or environmental value that are deemed 'smart' (e.g. residential or the planned sports arena connecting to district cooling, use of wastewater recycling, renewable energy, waste-to-energy connection etc.)

There is significant potential for long-term expansion of the district cooling network in this site as this is green field and underground utilities such as water and sewage pipelines are yet to be laid. Also, significant transport links planned in this area based development sites need to be coordinated with district cooling rollout and the construction of underground utilities creates opportunities to lay district cooling systems at the same time, if the requisite cooling demand is available or coming up. District cooling should be analyzed before other utilities are laid. Furthermore, given that this site is located in Ward no. 1 which is proposed to be developed as a high-density transport corridor, with a permissible FSI going of up to 4.0, and is likely to be an important area for district cooling development as well (high priority zones).

5.2 Rajkot's Solar City Master Plan

Rajkot city is one of the cities selected under the Solar City Programme of the Ministry of New and Renewable Energy (MNRE). The city has prepared its Solar Master Plan which targets a total reduction of 10 percent in its energy consumption, potentially leading to savings of 290.44 Million kWh by the year 2013. The Solar Master Plan proposes achieve the target through use of various renewable energy and energy efficiency measures for

Residential, Commercial, Industrial and Municipal Sectors. Targets are set depending upon the existing trends, resources, and the potential for uptake of renewable energy and energy efficiency measures across various sectors. Different alternate energy options including solar water heaters, solar photovoltaic, and solar appliances have been proposed for residential, commercial and institutional, industrial and municipal buildings across the city. Interventions for improved energy efficiency such as the use of energy efficient lighting and appliances (including air conditioners) have also been recommended for these sectors.

The Municipal sector has the highest share of renewable energy related targets at 32 percent, followed by the industrial and residential sector (see Table 4). The higher municipal targets indicate the city's willingness to take action and demonstrate leadership by adopting renewable energy systems in its building and facilities. With regards to energy efficiency, the Residential sector accounts for 37 percent of the target. The Municipal sector and the Commercial and Institutional contribute to 27 percent and 22 percent of the energy efficiency target respectively.

Table 4: Sector-wise Targets for Renewable Energy and Energy Efficiency for Rajkot

Sector	Energy Saving Target (Million kWh)	% contribution to the Target
Renewable Energy	**148.23**	**48%**
Residential	43.52	29.35%
Commercial and Institutional	13.12	8.85%
Industrial	44.79	30.21%
Municipal	46.8	31.57%
Energy Efficiency	**158.86**	**52%**
Residential	58	36.59%
Commercial and Institutional	35	22.08%
Industrial	21.9	13.85%
Municipal	43.53	27.46%
Total	**307.09**	**100%**

Source: (Ministry of New and Renewable Energy, 2012)

The target to achieve 10% reduction in conventional energy consumption under the cities is not an obligatory target. It is seen that the implementation of the Solar Master plans in nearly all the Solar Cities in India has been slower than anticipated in terms of physical progress and meeting the large scale sector-wise targets owing to a number of barriers[15]. The Solar City Programme, however, has provided a platform to motivate and enable cities to assess

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

current and future energy demand and undertake strategic planning for promoting and implementing interventions to reduce energy demand. The programme has definitely helped to create an eco-system for adoption of renewable energy and energy efficient technology by consumers.

The RMC has assumed a leadership role and implemented a number of renewable energy based technologies in its buildings and facilities. Solar PV systems with a cumulative capacity of about 190 kWp of solar PV have been installed by the RMC in its office and school buildings. 125 kWp of solar PV systems are presently under installation in the RMC's buildings, civic centres, and swimming pools. In order to promote renewable energy uptake, the RMC has mandated installation of solar water heaters in new residential buildings through the General Development Control Regulations. A rebate in property tax of INR 2,500 (USD 38) and INR 5,000 (USD 77) for five years, to be availed by residential and commercial buildings respectively (existing as well as new buildings), has been put in place by the RMC to promote uptake of solar water heaters. The RMC has also taken several initiatives for awareness generation across the community through its Energy Park located at Race course ground. Awareness activities for use of various energy efficient and renewable energy appliances are being undertaken for school students and Residential Welfare Associations.

The RMC's intent to show leadership and generate awareness by undertaking action in its own buildings and operations is demonstrated by the sizeable targets laid out for the municipal sector. While the RMC has not been able to fully realize the ambitious targets outlined under the plan in the given period, it recognizes the importance of the Solar Master plan as an overarching strategy to drive action and reduce conventional energy use across sectors in the city, as is also emphasized in the Smart City plan.

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 in Rajkot.

Modern district cooling systems maximize the use of renewables or waste heat, including renewables connected to the electricity grid such as solar PV, as well as through direct connection to a district cooling system such as industrial waste heat or a waste-to-energy plant (connected to absorption chillers), while also reducing primary energy consumption for cooling by up to 30-50%. Many cities set district energy-specific goals in their strategies that are linked to broader energy targets, such as on energy efficiency, greenhouse gas emissions, fossil fuel consumption, or energy intensity. The update of Solar City Master Plan can indicate district energy goals such as: the share of total GHG reduction target to be met by district energy, 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 impact of district cooling on the energy consumption and identify the benefits and linkages to Rajkot's policy goals (such as: Pan-City goals from the Smart City Mission such as reduce use of conventional energy and increase in use of solar energy and connecting to smart grid; Area Based Development Goals from the Smart City Mission such as meeting at-least 20% of the energy requirement from renewable energy, 80% of the total buildings as green and energy efficient building target, building efficiency and renewable energy targets under the Smart City Mission), and 25% voluntary GHG emission reduction goal adopted by the RMC.

Analysis of the current energy consumption of space cooling and its potential growth will be extremely important. Such analyses would help justify incorporating district cooling from air conditioning and electric chillers and future demand growth, the impact and benefits of using district cooling as compared to the baseline, and the role of district cooling in achieving city objectives under this Plan.

Building upon the rapid analysis of cooling loads in Section 9 will be important, including linking the analysis to politically important topics such as PV installations, clean water and smart infrastructure. For example, whether the benefits of efforts towards building efficiency and compact development are being offset by installation of low efficiency space cooling elsewhere in the city.

5.3 Rajkot's Voluntary Initiatives

Sustained engagement of Rajkot city in national and international climate and energy initiatives over a period of time has helped the RMC to imbibe knowledge and experience from best practices implemented by other cities. This has enhanced strategic capacity and Rajkot has been undertaking a number of strategic initiatives and actions to promote low carbon development and energy conservation.

Rajkot participated in the European Commission funded **Promoting Low Emission Urban Development Strategies in Emerging Economy Countries (Urban-LEDS)** programme from the year 2012 to 2016[16]. Under this voluntary programme, the city assessed its baseline greenhouse gas (GHG) emissions. The emission inventory does not include refrigerant emissions. Rajkot's Low Emission Development Plan, prepared as part of the Urban-LEDS programme, outlines various strategic measures to address rising energy consumption and

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

mitigate GHG emissions across sectors[17]. The plan also focuses on reducing energy use in buildings through measures such as energy audits, energy efficient appliance retrofits (including space cooling), and integration of renewable energy systems. Rajkot's city council has approved Low Emission Development Plan and voluntarily committed to reduce 25 percent of its GHG emission in the year 2019-20 as compared to that in the baseline year 2012-13.

Rajkot is one of six cities selected by the **Global Building Efficiency Accelerator Partnership**[18] for deeper engagement and support to improve building energy efficiency in the city. Under this initiative, Rajkot is presently receiving on-ground technical assistance to support a multi-stakeholder planning process and expand the city's capacity to focus on building efficiency solutions. Technical advisors are working directly with the city officials to help prioritize and develop local building efficiency policies and projects, including any reforms in the local building by-laws to promote energy efficiency in buildings. A Green building guidebook will also be developed for the city under this project. It is also proposed to setup an Energy Lab through which engineering and planning students can be integrated into RMC's regular city planning process and undertakes energy audits in municipal and private buildings. Students and academic institutions will be part of regular periodic monitoring, reporting and verification of various green buildings. Rajkot is one of four model cities currently participating in the **CapaCITIES project** (under the Swiss Agency for Development and Cooperation's (SDC) Climate Change Programme), which seeks to technically support and fast track implementation of mitigation & adaptation actions and also to develop climate resilience strategies for Rajkot.

Rajkot has effectively utilized and benefited from the technical expertise, knowledge exchange, networking, and peer learning opportunities offered by such international initiatives. As mentioned earlier, the RMC has voluntarily undertaken interventions to reduce energy consumption in its own buildings and across the city through renewable energy adoption (see Section 6.5).

Box 3: City leadership

Rajkot is showing leadership on a range of sustainability issues, particularly piloting and advocating for clean and innovative technologies and policy level interventions. Rajkot could similarly provide leadership to the district cooling sector, helping to pilot and promote this technology in high potential areas such as the proposed Smart City green

[17] Under the Low Emission Development Plan prepared for Rajkot city, the cumulative potential GHG emission reduction from the actions proposed across the various sectors (including residential, commercial and institutional, industrial, transportation) and for Municipal operations stands at 4,51,825 tonnes of CO2e, aggregating to about 25 percent of Rajkot's baseline annual GHG emissions in the year 2012-13.

[18] The BEA partnership supports the U.N. Sustainable Energy for All (SE4All) initiative that seeks to double the rate of energy efficiency by 2030. Under the partnership, participating cities and municipalities have committed to accelerate one policy, implement one project, and track progress on reducing their emissions from buildings by 2030. Policy actions could include establishing or updating building codes or putting in place incentives for use of new technologies. Projects could include retrofitting existing buildings such as hospitals, schools or government buildings; achieving green building certification; or establishing baselines for energy used in city buildings.

field development site. Rajkot's promotion and involvement in an early demonstration project will be particularly important.

Rajkot could finance and/or attract concessional finance to a demonstration project which could be financed using a commercial structure. This demonstration project could: showcase the business model and demonstrate commercial viability; build capacity; increase stakeholders' trust and confidence in the technology (e.g. Vancouver) and provide concrete data and experience and ultimately legitimize a city-wide energy plan focused on scaling up district energy.

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

In the medium-term, Rajkot 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 Rajkot. This could also be undertaken by RSDCL which has been 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 RMC's experiences and savings from connecting to district cooling[19]. Also important are formal and informal networks and contacts between, for example, municipal employees or officials and state utilities, building developers and housing associations.

Rajkot could also take leadership by setting a target that requires all public buildings or new buildings proposed in green field development, transit oriented zones and poly-centric zones to be connected to district cooling in the high priority zones. Similarly, new public/ private buildings could be mandated to have centralized cooling to ensure long-term district cooling connection.

Rajkot could promote 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

[19] 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.

cities worldwide. This group could also be led by RSDCL established to deliver the Smart City Plan and incorporated with the 'sustainable energy delivery unit'.

Rajkot can promote district cooling development and ensure strong analysis of district cooling opportunities by undertaking and maintaining a GIS energy mapping[20] of the city incorporating spatial analysis of cooling demand, locations with upcoming building developments (for example those shown in Section 10.1) and assessments of renewable and waste heat options (see Section 1.8.1). 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 Rajkot 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 RMC is responsible for the provision and maintenance of the city's civic infrastructure and its administration while the RUDA oversees the planning and development of larger Rajkot Urban Agglomeration area (including Rajkot city). The city is undertaking two types of planning, micro level planning and macro level planning. At the macro level, the urban planning is conducted in the form of city development plan, or simply a development plan for the entire city area or the development area. The second level is micro level urban planning, in the form of a Town Planning Scheme, which is prepared for smaller areas of the city, keeping in view the needs of such smaller areas. Town planning scheme is a micro level implementation of the larger development plan.

Rajkot has recently prepared its Second Revised Draft Development Plan, 2031. The Development Plan is a macro level strategic plan that defines the direction of growth and visualizes the citywide infrastructure for the entire development area. It has detailed analysis of availability of existing physical and social infrastructure facilities along with analysis of carrying capacity of city, and policies for densification/re-densification, renewal/redevelopment and congestion are also included. Issues such as disaster management, environment management, and heritage conservation are also being included in development plan. Broader level planning proposals are proposed in Development Plan prepared for the Urban Area. Development plan shows the broad areas under different land use zones, land reservations for roads and other different purposes. The Development Plans

[20] 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.

and town planning schemes are developed as per the provisions of the Gujarat Town Planning & Urban Development Act, 1976 and Gujarat Town Planning and Urban Development Rules, 1979. It is mandatorily revised every 10 years and may be revised whenever a need arises to respond to the changing context.

RUDA is responsible for the preparation of a physical plan for the development of the Rajkot Urban Agglomeration; preparation of draft town planning schemes; implementation of the revised town planning schemes; and monitoring and controlling of the development activities in accordance with the revised Development Plan, 2031. Density, floor space index (FSI), and land use are regulated by the Draft General Development Control Regulations of the Draft Development Plan-2031, prepared under the Gujarat Town Planning and Urban Development Act, 1976.

Rajkot's Second Revised Draft Development Plan, 2031 considers the demand of the projected population for the next two decades across the entire urban agglomeration area of 686 sq. km. under RUDA's jurisdiction, including the Rajkot city area. Based on the inventory of existing land use, about 89.14 sq.km of area under different land use zones in the city is still vacant and available for development. Further, existing areas which have been developed a long time ago are planned to be redeveloped. In order to optimize the utilization of these areas and to encourage development on this serviceable land, incentives have been provided for densification in the underutilized areas.

Table 5: Existing and Proposed Land Use for Rajkot City

Land Use for RMC limit (Rajkot City)	2001		2011		2031	
	Area (sq. km)	Share of each category (%)	Area (sq. km)	Share of each category (%)	Area (sq. km)	Share of each category (%)
Residential	42.47	40.5	55.02	52.4	62.28	59.4
Commercial	2.09	2	2.79	2.6	2.21	2.1
Industrial	6.28	5.9	7.38	7.1	6.35	6.1
Traffic and Transportation	14.00	13.3	16.50	15.7	data not available	data not available
Public and semi public[21]	1.49	1.4	2.49	2.3	3.05	2.9
Recreational Space[22]	1.23	1.2	5.23	4.9	5.17	4.9
Agriculture	9.95	9.5	8.00	7.6	0.69	0.7
Water bodies	2.36	2.3	2.36	2.3	2.36	2.3

[21] Public or semi-public land use refers to a building or a space owned and operated by Government, Semi-Government organizations, used or constructed or adapted to be used as an office or as a temple, hospital, college, school, public hall, public exhibition or other similar public purpose activities. This includes institutional buildings such as Police Station, Fire Station, Medical facility, Public Library, Civic Centre, and Ward and Zonal Offices constructed for relevant authorities.

[22] Recreational land use refers to public recreation areas or parks usually ornamented with plants and trees along with landscape furniture.

Vacant lands	15.1	14.4	-	-	-	-
Other	9.88	9.4	5.08	4.8	23.07	22.01

Source: *(Rajkot Urban Development Authority, 2016)*

Table 6: Existing and Proposed Land Use for Rajkot Urban Agglomeration under RUDA

Land Use for RUDA jurisdiction area (Urban Agglomeration)	2001		2011		2031	
	Area (sq. km)	Share of each category (%)	Area (sq. km)	Share of each category (%)	Area (sq. km)	Share of each category (%)
Residential	57.44	8.4	125.28	18.3	130.75	19.1
Commercial	5.43	0.8	8.27	1.2	6.24	0.9
Industrial	33.88	4.9	52.05	7.5	49.38	7.2
Traffic and Transportation	16.97	2.5	24.53	3.5	data not available	data not available
Public and semi public	6.33	0.9	5.91	0.8	4.87	0.7
Recreational Space	3.79	0.55	10.53	1.53	11.33	1.6
Vacant lands, agriculture and other	559.26	81.8	459.74	66.9	369.62	55

Source: *(Rajkot Urban Development Authority, 2016)*

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

RMC uses micro level planning tool, in the form of a Town Planning Scheme (a micro level implementation of the larger development plan) which is prepared for smaller areas, to influence targeted development across the city by defining different land uses in different zones. Through its Town Planning Schemes, the RMC can promote district cooling by ensuring new developments are mixed-use and of high density. 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.

RMC could also ensure that public buildings 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, RMC could make space available where energy centers could be placed in public buildings or otherwise.

RMC can use its development authority to create high priority and medium priority 'zones' for district cooling, drawing on data from energy mapping (recommended in Box 3 and described further in Box 10) and using (e.g. cooling demand density) benchmarks for

district cooling viability, and attach specific condition to building permits within these zones. RMC could require large new developments entering the planning process, in a designated 'priority zone for district cooling', have to submit an 'energy efficiency plan' in order to obtain a building permit. This plan must outline the 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, RMC 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 DC ready for future connection, 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 RMC and international experts. In particular, ensuring high-quality of assessments given the lack of district cooling experience in India will be important[23].

Similarly, requests for re-zoning by building developers above a certain size could provide an opportunity for Rajkot to accelerate district cooling. RMC could permit re-zoning under the condition that the developer meets stricter operational/primary efficiency building standards[24] and/or evaluates the potential for district cooling and if techno-economically feasible, then establishes district cooling systems.

RMC can use the planning process to put in place specific connection policies (of different buildings types) in the high priority areas, such as for the proposed business park, banking and financial services and IT/ITeS buildings, retail and convention centres in Rajkot's greenfield Smart City site for instance.

Furthermore, RMC 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 franchise/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. Such a licensing system is more likely in the longer-term. Furthermore, RMC 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

[23] 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.

[24] 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.

then share the profits with consumers ensuring that they too benefit from the efficiency gains of DC.

In Rajkot, urban development is planned for a green-field site under the Smart City project and dense urban development is planned through transit oriented development zones (see Section 10.1), with application of higher sustainability standards for buildings. Such urban development projects 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, RMC 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.

Finally, as a provider of utility services such as water and sanitation, RMC has the authority over the installation of new utility lines such as district cooling pipes. During consultations, RMC has indicated that it can fast-track permissions needed for installation of piping and road works and can coordinate to ensure other utilities are installed in parallel. Undeveloped land parcels in the Smart City area and at potential high priority district cooling zones can be set aside for district cooling plants.

In addition, RMC has planned to implement waste-to-energy (WTE) plant in Rajkot, thus any opportunities for waste heat capture could be leveraged through RMC's planning authority. RMC could also promote building development relatively near the vicinity of the WTE[25] that could use the waste heat for a district cooling system.

6.2 Building Regulations and Certifications

Building development in Rajkot is controlled by the Draft General Development Control Regulations of the Draft Development Plan-2031, which regulates and lays out guidelines for land use zoning, density, floor space index (FSI), building heights and other development and building related guidelines. The permissible FSI for different land use zones in Rajkot is given in Table 7. The Draft General Development Control Regulations encourage development in underutilized areas and redevelopment within dense areas, with additional FSI availed on the payment of additional charges depending on the zone. The core city area has a permissible FSI of 2.25. The maximum permissible FSI for high-rise buildings in the residential zone is 2.25 while that for the commercial zone is 2.25. As indicated in section 1.1.3.2, the proposed TOZ and polycentric zones have much higher permissible FSI of 3.75 and 4.0 respectively in order to promote compact development and densification in these zones.

[25] While some WTE are place even 20km away from the district energy systems that will use their heat it is far better to be able to serve demand that is close to the WTE as transmission pipes are expensive and their construction difficult to coordinate.

Table 7: Zone wise Permissible FSI as per New Development Plan[26]

Use Zone	FSI Permissible[12] (Base)	FSI Chargeable	FSI Maximum Permissible[11]
City Area	2.25	Nil	2.25
Transit Oriented Zone[27]	1.8	1.95	3.75
Residential zone			
For low rise	1.5	0.35	1.875
For high rise	1.8	0.45	2.25
For others	1.2	0.3	1.5
Commercial zone	1.5	0.7	2.2
Industrial zone	1.2	0.3	1.5
Recreational zone	0.15	Nil	0.15
Residential affordable housing zone[28]	1.8	0.9	2.7
Knowledge and institutional zone	1.8	Nil	1.8
Public purpose zone	1	Nil	1
IT zone	1.8	Nil	1.8

Source: (Rajkot Urban Development Authority, 2016)

The RMC has undertaken strategic policy interventions in recent years to address building energy consumption. In 2004, the RMC mandated the use of solar water heating systems in new buildings through the local building bye-laws, which has led to more than 30 percent of the households using solar water heaters. In order to promote green buildings, Rajkot's General Development Control Regulations includes provisions to offer incentives of up to 5 percent in the chargeable FSI for green buildings that have a Green Rating for Integrated Habitat Assessment (GRIHA)[29] certificate and comply with the GRIHA rating system. However, there is scope for improvement with regards to the institutional arrangements and capacity to monitor and administer these incentives and to promote the uptake of the GRIHA or any other green building rating system the city. Hotels and hospitals are recommended to be designed as per the Energy Conservation Building Code (ECBC); however mandates or guidelines for the same are lacking in the local regulations. Rajkot is undertaking policy level interventions in this direction. The RMC will be developing a Green Building Policy and Green Building Guidebook under the ongoing Building Efficiency Accelerator project, which will focus on material use, energy efficient appliances, and maximizing use of renewable energy.

[26] Rajkot Draft Comprehensive Development Plan 2031 (second revised) part II: Planning proposals and recommendations
[27] Zone which provides opportunity for mixed use and high density development along the 2nd Ring Road
[28] This zone shall be considered as a condition for residential zone of specific category
[29] GRIHA is a rating tool that helps people assesses the performance of their building against certain nationally acceptable benchmarks. It evaluates the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'. It was adopted as the national rating system for green buildings by the Government of India in 2007

Box 5: Incentivizing district cooling through density bonuses

Rajkot could use the existing administrative structure of premium/ chargeable FSI payments to promote connection or development of district cooling, particularly for the proposed Transit Oriented Zones and Poly-centric Zones in Rajkot. Buildings under development that commit to connect to district cooling or develop a district cooling network could be granted additional FSI or have FSI payments reduced as an incentive. Coupled with this the city could highlight the floor space saved from connecting to district cooling. For many building developers, the prospect of additional rentable floor space would be a significant incentive and could help to establish initial networks and secure customers to a district cooling network. To ensure the long-term sustainability of such an incentive scheme, requirements to be given an FSI bonus could become increasingly difficult, could be linked more generally to building efficiency (for example through building certification schemes such as GRIHA or LEED). Several cities around the world are actively promoting district energy using this urban planning tool. Other cities in India, such as Rajkot, already provide FSI bonuses linked to sustainability criteria[30]. 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 (International Institute for Energy Conservation (IIEC), n.d.) **– likewise discussions can be undertaken with other banks to similarly develop incentives for green building certifications in Rajkot.**

Solar Water Heating

In order to promote adoption of solar water heating systems, the local development control regulation has been amended to include mandates for installation of solar water heating systems in buildings. The mandate has been linked to building usage approvals sought for new buildings, with provisions made for solar water heating system required to be shown as part of any plans submitted for building planning permission, including site verification, if required.

Box 6: District cooling ready buildings

Rajkot could adapt the DCR to ensure that developed buildings are district cooling ready in long-term, specifically requiring centralized cooling for specific building types, or for those over a certain size, or in a specific zone (e.g. high/medium priority zone). Such a mandate could be developed in a similar way to the Solar Water Heating mandate in DCR of Rajkot. A mandate requiring centralized cooling in hospitals above a specific FSI has already been developed in Rajkot, and can be expanded for application to multiple building types. In this way, even if buildings operate their own chillers, eventually they could be connected into a district cooling system. In some cities, buildings that already have their own chillers can still be connected into the district cooling network – the network operator can use their chiller to feed the building and the wider district cooling network – a more efficient and cost-effective use of the chiller. Building developers could also be given flexibility under the DCR if they develop district cooling.

[30] 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.

Mandates for connection to, or development of, district cooling systems in high priority zones, as discussed in Section 6.1, could be exercised through adaptation of the DCR. Such a policy would need to be accompanied by a support programme to the city and developers to ensure district cooling assessments and tendering do not slow down the development of real estate.

6.3 Legislation relating to space cooling

The existing General Development Control Regulations in Rajkot need to be strengthened to have 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 (see Annex 2.5 for more details). Existing provisions with regards to air conditioning are limited to a mandate for centralized HVAC systems in hospitals with high FSI (4 or more), and the use of non-CFC refrigerant based air conditioning systems suggested as an eco-friendly practice for hospitals. Specifications for air-conditioning of cinema halls and auditoriums in terms of comfort conditions are also indicated (see Table 8).

Table 8: Provisions in Rajkot's GDCR for energy efficiency and space cooling in buildings

For hospitals, where 4.0 or more FSI is granted, centralized HVAC systems have to be compulsorily implemented for ICU, operation theatres & other critical facilities Eco-friendly practices suggested for Hospitals: (a) Sewage Treatment Plant (b) rain water harvesting (c) waste management (d) pollution control method for air, water and light (e) introduction of non CFC equipment for refrigeration and air conditioning
Auditorium or cinema halls shall be air-conditioned as per following specifications: 1. Temperature Range- 22 to 26.5 degrees Celsius 2. Change of Air per hour- approximately 10 time`s 3. Relative Humidity- 50 to 60% 4. Fresh Air Requirement- 7.5 cubic feet per metre per person

The RMC has demonstrated its inclination to leverage its local policy regulation to address building energy use, as done previously through mandates on use of solar thermal systems in new buildings and incentives offered for green buildings. In discussions conducted during the rapid assessments and the inception workshop, the RMC has shown willingness to adapt its existing local building policies and use suitable policy instruments to promote district cooling and mitigate market risks. Rajkot's engagement in the Building Efficiency Accelerator Partnership further provides a platform for the city to undertake policy actions such as establishing or updating building regulations or putting in place incentives for use of new technologies, including district cooling.

The Energy Conservation Building Code (ECBC), formulated in 2007, is India's first building energy code and targets building energy efficiency. The ECBC addresses the design of new, large commercial buildings (having a connected load of 100kW or contract demand of 120 KVA and above) and aims at optimizing the energy demand in buildings, including that for space cooling. This includes minimum standards on building envelopes and HVAC system efficiencies (see the national analysis for more information on ECBC).

Box 7: Ensuring the ECBC promotes district cooling growth

Under the Building Efficiency Accelerator Programme, Rajkot is preparing city specific Green Building Guidelines, which seeks to adapt and promote ECBC guidelines to the local context and thus will be a major step for delivering sustainable buildings in Rajkot. Its adoption will involve incorporating the ECBC/Green building guideline norms into the DCR for Rajkot, will be enforced in the city. This will involve trainings to building assessors and developers as well as pilot implementation of buildings to demonstrate the new guidelines. These trainings could also serve to build capacity and awareness on district cooling, which can also be presented as an energy efficiency measure to the building industry.

The adoption of the new Green Building Guidelines in the DCR will provide an opportunity for Rajkot to ensure that efficiency improvements to buildings that connect to district cooling are acknowledged in its local building regulations. 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 local guidelines or the ECBC code for district cooling is too ambitious at such an early stage in the market, Rajkot could ensure that any benefits and incentives linked to the building sustainability are also made available to a district cooling demonstration project. Such incentives and benefits have not yet been defined, but some other states in India that have notified ECBC have developed rating systems and incentive schemes based on compliance with the standards within ECBC (e.g. the State of Andhra Pradesh (Pacific Northwest National Laboratory, 2016)**).**

6.4 Incentives and subsidies

As mentioned earlier, the RMC offers incentives in the form of a 5 percent discount in the chargeable FSI for buildings having a green rating certificate from GRIHA or any other Government recognized Institute. In order to avail this incentive, the owner or building developer shall have to apply to GRIHA prior to the commencement of the project for the rating certificate and registration.

To promote uptake of solar water heaters, the RMC previously offered a property tax waiver for new buildings that installed a solar water heating system through a provision in the General Development Control Regulations until the year 2013. A waiver of INR 2,500 (USD 38) in total over a five year period was offered for residential buildings while commercial buildings were offered a waiver of INR 5,000 (USD 77) in total over five years.

Recently, the District Collector, Rajkot (the foremost administrative official in charge of revenue collection and administration for the district) has issued a mandate for installation of solar rooftop photovoltaic systems in all upcoming new buildings. New buildings have to show that provisions for solar photovoltaic systems have been made in the building plans in order to obtain building use permission. As part of the ongoing Building Efficiency Accelerator project, RMC plans to introduce incentives and awards for property developers, architects, civil engineers to promote construction of green buildings.

During consultations conducted as part of the District Energy in Cities programme, RMC indicated its willingness to offer incentives to support and promote district cooling projects in the city. Development of such incentives will require detailed cost-benefit analyses.

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

Rajkot's power distribution company, PGVCL, has time of day tariffs in place to reduce peak demand or use in off peak times. The tariff during day[31] and night time[32] for non-residential, industrial and High Tension line consumers is different in order to reduce peak demand. For non-residential consumers, fixed charge is 50% of the fixed charge during day time. Energy tariff is INR 4.65 per kWh in the day time and INR 2.60 per kWh during the night time, dropping to almost half of the day time energy tariff. For commercial and industrial consumers with low tension service connections, fixed charge is 50% of fixed charge at day time. Energy tariff is INR 4.70 per kWh in day and INR 2.50 per kWh in the night, which is almost half. During night time, commercial and industrial consumers served by high tension connections, fixed charge is 1/3rd of the fixed charges during the day time. The night-time tariff for high tension commercial and industrial consumers is INR 2.4 per kWh, nearly half of the day-time tariff of INR 4.55 per kWh.

6.5 Demonstration Projects

The RMC has successfully implemented a number of initiatives to reduce energy consumption in municipal buildings and services to reduce energy consumption. The key projects implemented in recent years are as follows:

- **Energy Efficiency in lighting** – Around 300 existing High Pressure Sodium Vapour (HPSV) street lights were replaced with light emitting diode (LED) streetlights on a pilot basis. Following the successful implementation of this pilot, the RMC is now scaling up this initiative and undertaking LED retrofits for all 52,000 of its existing HPSV lights through an Energy Services Company (ESCO) PPP project. The streetlights will be operated and monitored using 500 smart controllers. The

implementation will result in annual electricity savings of 6.26 Million kWh and reduce GHG emission by about 5,146 tonnes of CO_2eq. Implementation of this project is underway at present and is expected to be completed by May, 2017.

- **Energy efficiency in water and drainage pumping stations** – The RMC is replacing its existing water and drainage pumping system with energy efficient pumps. The project is being implemented through the ESCO based PPP model and will result in annual electricity savings of 15.50 Million kWh.
- **Rooftop SPV system** –The RMC has installed 190 kW of rooftop solar photovoltaic systems in its office and school buildings, which has resulted in annual electricity savings of around 285,000 kWh. Installation of 125 kWp of rooftop solar photovoltaic systems is underway at present in RMC buildings, civic centres and swimming pools, with potential electricity savings of 187,500 kWh per year. Plans are in place to install additional rooftop solar systems of 210 kWp capacity in other buildings of the RMC.
- **Green Schools –** A budgetary allocation has been made in the RMC budget for the year 2017-18 to develop 10 existing municipal schools as green schools with help of the Indian Green Building Council (IGBC). These will serve as model green schools and help motivate other private schools in the city to adopt green practices.
- **Green Buildings for Affordable housing**– The RMC is incorporating green building concepts in terms of building design, orientation, and use of green building material in all of its affordable housing projects.

The RMC recognizes that such projects help in technology demonstration and have contributed to improving awareness across the community. It is however, difficult to assess the extent of impact that such projects have had in terms of adoption by Rajkot's citizens. It is envisaged that the engineering and planning students engaged under the Energy Lab to be developed as part of the on-going Building Efficiency Accelerator project can help the RMC to do periodic monitoring, verification and reporting of such energy efficiency and renewable energy initiatives. This will help to record benefits and further disseminate such information in the community.

Box 8: Rajkot as a demonstrator

RMC'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. It is also noticed through past experiences that Rajkot is replicating demonstration projects implemented under various international projects, as mentioned in section 1.4.5. Given how crucial city support and coordination is to deliver successful district cooling projects, investors and project developers will be reassured by the hands-on approach of RMC and its experience in coordinating relatively large sustainability programmes. Building on this leadership, RMC 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.

6.6 Project financing in Rajkot

The RMC has been willing to invest its own funds, to either complement other funding sources or to unilaterally fund renewable energy and energy efficiency projects as indicated in section 6.5. The RMC has availed financial assistance provided by MNRE to partly fund some of the solar photovoltaic installations in its buildings and facilities. The RMC has partnered with the IGBC to help transform ten of its municipal schools into green buildings and is investing its own funds in this initiative. The RMC has linked implementation of clean technology projects proposed as part of its voluntary engagement with international agencies to funding opportunities available under various government schemes and under its own budget.

The RMC is also up scaling some pilot projects through various implementation modes such as PPP, Build-Operate-Transfer (BOT) and ESCO. The RMC has been effectively partnering with the private sector on a number of projects. Implementing a shared savings based ESCO model for replacement of existing street lights with LED lights will help achieve significant energy savings in the city's street lighting without any upfront investment. Plans are in place to set up a 4 MW waste to energy plant at its solid waste dumpsite at Nakrawadi under the BOT[33] model.

The RMC is implementing its affordable housing projects through the PPP mode as well. The private property developers will redevelop the slums into affordable housing projects and hand it over to low income home owners at no cost while utilizing the remaining land which was otherwise underutilized for real estate development. As mentioned previously, green building concepts are being integrated in to these affordable housing projects as well. Rajkot remains keen to work with a range of partners and to leverage technical and financial support to further its sustainability agenda as it has done previously.

Box 9: Financing district cooling

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

[33] BOT – Built Operate Transfer

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[34].

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
- Incorporation of utilities
- Incorporation of building developers
- International expertise
- International finance
- Smart City SPVs
- EESL / ESCO model

These are elaborated as follows

- RMC could either make a direct investment or have a partial stake based on the value of incentives they are willing to provide – such as land, access to energy sources, access to city-owned wastewater utilities and connections (e.g. London) - and this could create a revenue stream for the city (e.g. Paris/Toronto). As RMC has a tight city budget and no precedent of previously guaranteeing or providing loans the latter is more likely. RMC 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.

[34] 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.

- Tight utility budgets and a disincentive to invest in measures that reduce demand make their investment unlikely, however district cooling could provide an alternate revenue stream for them, they have power to scale up model across multiple cities and can internalize the benefits – including the investment in upstream infrastructure. Further, utilities can host an ESCO model where they have the assets to do so and 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 Rajkot, the Smart City green field 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 Rajkot

The key barriers towards implementation of district cooling projects in Rajkot 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 usage for space cooling, and decentralized chilled water systems installed across the city. Quantitative and spatial data on potential waste heat sources in the industrial sector, biogas sources along with documented information on existing installation and generation from renewable energy systems is also lacking. In order to structure a district cooling project, critical data on potential cooling demand and on patterns and usage of cooling systems is not readily available. There is no appliance level sub-metering to assess cooling loads. In addition, there is no quantitative and spatial data on potential waste heat sources in the industrial sector, biogas sources along with documented information on existing installation and generation from renewable energy systems.
- **Limited awareness on district cooling:** Lack of awareness with regard to district cooling concept, technology, benefits and subsequent perceived risk of cost escalation among property developers and buyers/leaser's is a key barrier to district cooling development in the city. This also inhibits sharing of confidential information by property developers. The limited awareness amongst all stakeholders in general restricts market demand for district cooling.
- **Lack of local technical expertise**: Lack of in-house experience within the RMC and a general lack of local technical expertise specific to implementation of district cooling systems would impact the pace of design and construction for any district cooling projects. However it is evident from past experiences that RMC is proactive in trailing new technology for demonstration and then scaling up the same while imbibing technical know-how and learnings.
- **Lack of enabling local regulations/policies and financial incentives to promote district cooling**: There are no regulations framed by the Central or State Government directly intended to promote district cooling systems. Also requisite provisions in the local building and development regulations and incentives to promote efficient space cooling in buildings are lacking.
- **Difficulty in retrofitting existing building developments:** Considering the highly dense and mixed use development in Rajkot city which has already taken place in prominent areas in the city, retrofitting in these areas is difficult as potential consumers will be reluctant to incur costs for any internal structural changes. It may prove difficult for building developers and managers have agreements with occupiers to make such changes. The networks for utilities and services have already been laid along with the transportation network. Limited information is available on buildings having centralized chilled water system in the city. Retrofitting existing brownfield development with district cooling systems is a challenging prospect.

- **Geological and Geographical conditions:** Rajkot's geology and soil contains hard rock, possibly resulting in escalated costs of laying the district cooling pipeline network (see section 1.1.2.3). Rajkot is located in a water scarce region and faces water shortage for most of the year, posing a challenge for district cooling systems to access the limited fresh water resource, and so Treated Sewage Effluent could be prioritised.
- **Lack of financing and project development experience**: The city and local stakeholders do not currently have the 'district cooling specific' experience to support a project from concept to construction, including feasibility studies, tendering, financing, business model design, procurement, negotiations, contracting and construction. Local financing institutions are unlikely to have the required experience to provide the complex finance required to district cooling projects which can have long returns and high initial investments.
- **Lack of local demonstration-scale district cooling projects:** A lack of pilot scale demonstration projects in the city leads to challenges in estimations of costs and future benefits. Given the lack of demonstration of the technology and its impacts at the local level, gaining confidence of stakeholders and real estate developers is difficult.
- **Rate of development in Rajkot:** The fast pace of the real-estate sector in many Indian cities provides some challenges in that a district cooling project would have to align with this pace. Furthermore, detailed building plans and HVAC system designs may only be made available later in the project at which point it may be too late to incorporate centralised cooling and/or ensure connection to district cooling.

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

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

9 Space cooling in Rajkot

Rajkot city experiences hot and humid weather conditions for about 8 months in the year and therefore the cooling demand to provide thermal comfort is expected to be significant across these months. Furthermore, building envelopes and building occupancy are major drivers of air-conditioning demand.

9.1 The extent of air-conditioning in Rajkot

As per Rajkot's solar city master plan, 17% of the city's households are using air conditioners. The average sale of air conditioners in the city is estimated to be around 10,000 units per year[35]. A load research survey conducted in 2009 by USAID and the Indian Institute of Management – Ahmedabad (IIM-A) under the Energy Conservation and Commercialization (ECO-III) project for 400 residential households and 200 commercial establishments in 22 cities in Gujarat, including Rajkot, indicates that air conditioners and ceiling fans are the primary appliances contributing to the total space cooling load for both the residential and commercial sector (USAID, 2010) (see section 1.7.1 for more details). The study indicates that the share of energy efficient BEE star rated air conditioners in the residential sector in the cities of Gujarat state was about 21 percent which included 1 star (0.7 percent), 2 star (6 percent), 3 star (7 percent), 4 star (0.7 percent) and 5 star (3 percent), with the remaining 79 percent representing non-star rated air conditioners. With regards to capacity, 77 percent of the air conditioners in the residential sector were of 1.5 tonne capacity, followed by 1 tonne (14 percent), 2 tonnes (8 percent) and 0.75 tonne (1 percent).

In Rajkot, a number of mid to large size commercial properties such as hotels and shopping malls that have come up of late are using air cooled (variable refrigerant flow, packaged rooftop systems) and water cooled central air-conditioning systems to meet their space cooling requirements. For instance, the Reliance Mega Mall and the Crystal Mall both use chilled water based air conditioning plants. The Hotel Bizz, Hotel Lords and the Eldorado are using air cooled central systems to provide cooling.

Section 1.7.3 details the impacts of space cooling on current power consumption in Rajkot. Such impacts are likely to intensify with increasing population, increasing wealth and new business developments. It is however difficult to truly assess the impacts of the increased air conditioning penetration on the energy demand and seasonal variations thereof, given the unavailability of comprehensive information available on the prevalence and type of air conditioning systems for different building types, technologies being used, and cooling demand across the year.

Box 10: Identifying opportunities for district cooling

In order to assess the scale of cooling in Rajkot, it is very important to effectively promote and plan for district cooling and identify potential district cooling projects. A GIS energy mapping of Rajkot is recommended (also described in Box 3). This would help to resolve

[35] Communication by local air-conditioner supplier.

some of the barriers linked to a lack of data described in the barriers section. Initially, major buildings could be incorporated under such mapping, particularly in zones deemed to have high potential. 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 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). RMC will need to play a crucial role in encouraging and supporting building owners to install meters and ensure these can be monitored.

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.

The combination of improved mapping, data and benchmarks will enable a full analysis on the current and longer-term impacts of space cooling in Rajkot, justifying new policies, technologies and investments. These impacts are likely to intensify with increasing population, increasing wealth and new business developments. Section 1.7.3 explores what can be deduced from the currently available data and it is recommended further, deeper analysis is undertaken.

No examples of residential buildings with centralized HVAC were identified in Rajkot, 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[36], 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.

[36] 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%.

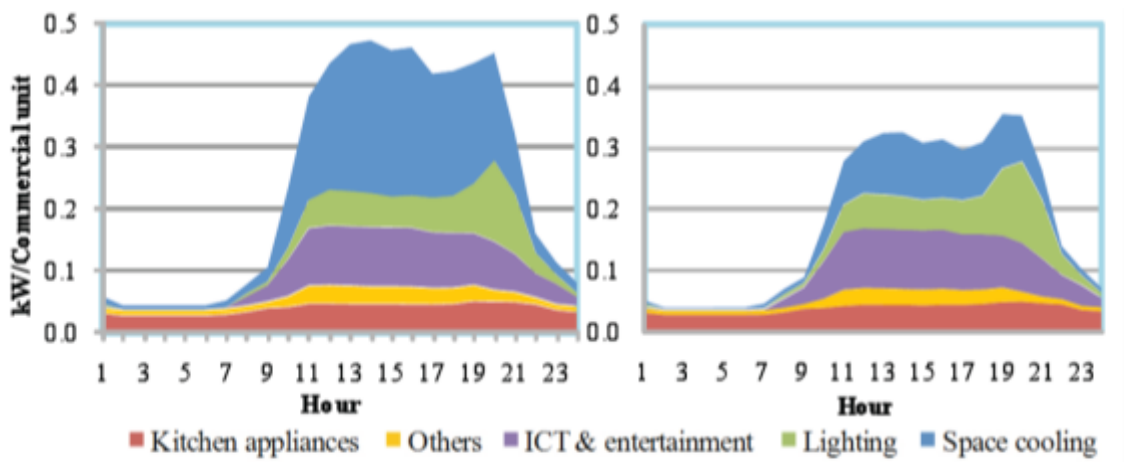
9.2 The operation of air-conditioning in Rajkot

The load research survey conducted by USAID and IIM-A provides insights on the seasonal variation in cooling demand for the commercial and residential sectors and the correlation between appliance ownership and use and income levels. Key findings of the study with regards to space cooling are summarized in the following sections. While the disaggregated survey data for Rajkot city is not available, it can be assumed that the findings are representative of the trends in Rajkot as well.

With regards to the commercial sector, space cooling accounted for 45 percent of the total connected load in the surveyed commercial establishments. Air-conditioners accounted for 83 percent of the total space cooling load, considerably higher than other space cooling appliances which included ceiling fans, table/wall fans, exhaust fans, and air-coolers. Overall, air-conditioners contributed to 37 percent of the total connected load in the commercial establishments, the highest share of any appliance across different end-uses of electricity.

Cooling demand is significantly higher during the summer season as compared to the winter season. On an average, about 52 percent of the total connected space cooling load is in operation in commercial establishments during the commercial peak hours (1000 to 2100 hours) in the summers and therefore electricity consumption is largely driven by space cooling. This proportion of the total connected space cooling load that is in operation in commercial establishments during peak hours drops down to an average of 22 percent in the winters.

Figure 13: Hourly electricity consumption by end-use category during summer and winter in Commercial Establishments in Gujarat cities



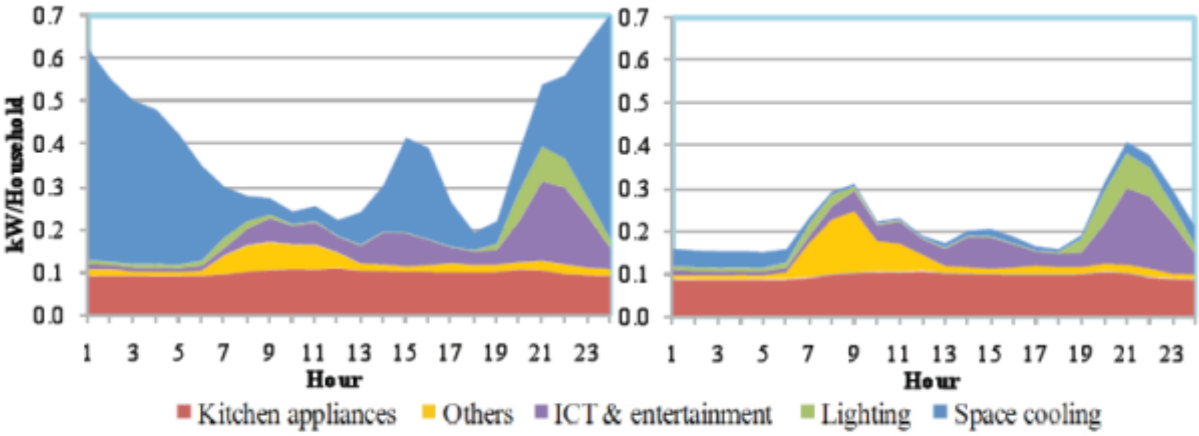
Source: (USAID, 2010)

For the residential sector, space cooling accounted for 22.6 percent of the total connected load in the surveyed households, with air-conditioners and ceiling fans contributing to 72 percent and 26 percent of the total space cooling load respectively. The correlation between income levels and appliance ownership is evident from the survey as well. The proportion of air-conditioning load was seen to increase with the income levels, with air-conditioners

contributing to 25.1 percent, 15.2 percent and 9.9 percent of the total connected load in high-income, medium-income, and low-income households surveyed respectively.

Cooling demand is considerably higher in the summers, with space cooling accounting for 47 percent of the total daily electricity consumption during summers as compared to a mere 10 percent in the winters. The share of space cooling in the electricity consumption is also seen to vary across income levels, with space cooling contributing to 58 percent, 49 percent, and 41 percent of the daily electricity consumption in the summers in high-income, medium-income, and low-income households respectively. Space cooling usage in households is found to differ widely in the summer and winters, with 33 percent of the total connected space cooling load in operation during summers in the residential peak hours (2000 to 0500 hours and 1400 to 1600 hours) as compared to a mere 3 percent in the winters.

Figure 14: Hourly electricity consumption of end use category during summer and winter in Households in Gujarat cities



Source: (USAID, 2010)

9.3 Impacts of cooling on electricity consumption

The Paschim Gujarat Vij Company Ltd. (PGVCL) is the distribution utility responsible for distribution of electricity in Rajkot city. Driven largely by the increased cooling demand and Rajkot's hot and humid weather, electricity consumption is observed to rise by 15 percent from the period between May up to October as compared to the yearly average. Rajkot consumed 1,508 Million kWh of electricity in the year 2015 (see Table 9). The electricity consumption is seen to be rising at an annual rate of 6.1 percent on an average since the year 2011.

The residential sector is the largest end-use consumer accounting for 38.1 percent of Rajkot's total electricity consumption. Electricity consumption by industrial consumers connected to low tension power distribution lines, large commercial and industrial consumers having high tension connections, and low tension commercial is significant as well, accounting for 22.9 percent, 22.8 percent, and 14 percent of the city's electricity consumption respectively.

Analyzing the impacts of cooling separately to electricity demand, including within GHG emission baselines and forecasts, is important to ensure space cooling is properly addressed and can help to justify future policies. Space cooling should be considered separately to other appliance electricity demand where possible. This could include estimating buildings' cooling demand based on real data from similar buildings or energy modelling and electricity bills.

Table 9: Total Electricity Consumption in Rajkot City, 2015

Consumer Category	Electricity Consumption (Million kWh)	Percentage Share (%)
Residential	574.8	38.1 %
Industrial (Low Tension)[37]	344.8	22.9 %
High Tension Consumers[38]	343.4	22.8 %
Commercial (Low Tension)[39]	211.3	14.0 %
Public Street Lighting	15.5	1.0 %
Institutional	13.5	0.9 %
Public Water Works	3.18	0.2 %
Agriculture	1.7	0.1 %
Others[40]	0.21	0.01%
Total	**1,508.4**	**100%**

Source: (PGVCL, 2016)

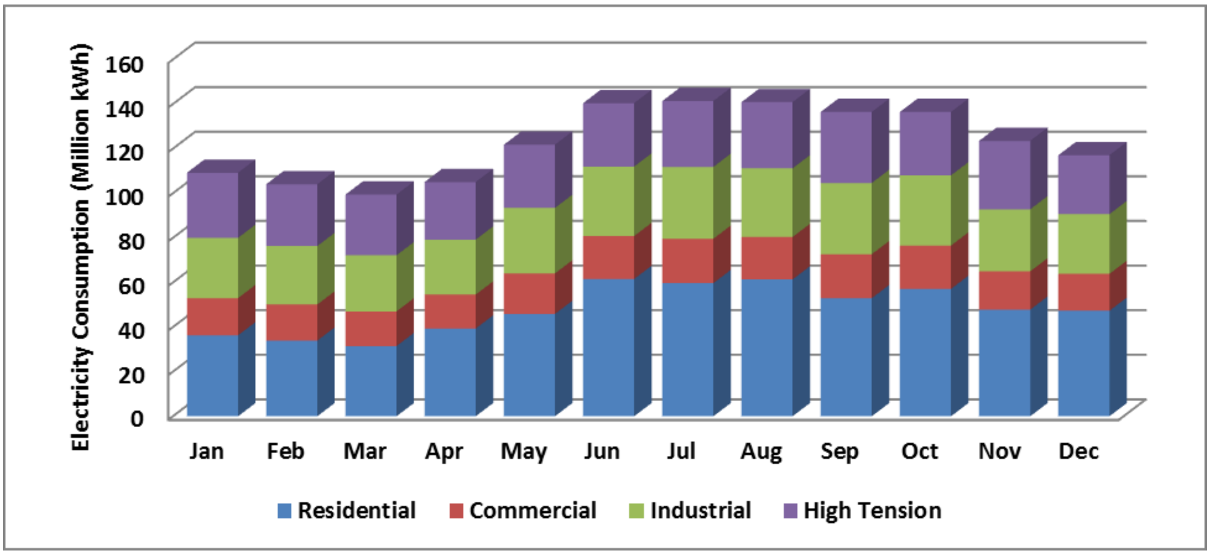
Monthly energy consumption can be helpful in understanding minimum and peak consumption in cities and the seasonal variations that exist. The monthly power consumption is seen to rise from May until October; months spanning the summer and monsoon seasons when Rajkot experiences hot and humid weather conditions in particular (see Figure 15). The electricity consumption peaks in the month of July, rising by 40 percent as compared to that in March. The residential and low tension consumers in particular are observed to consume much more electricity during the summer and monsoon months (April-October) as compared to the other months of the year.

The increasing trend in the monthly power consumption can be potentially linked to higher cooling demand. However, given that there is no data available on electricity consumed specifically for space cooling, it is difficult to evaluate the full impact that space cooling has based on the monthly electricity consumption. Other loads in a city can be seasonal such as lighting and refrigeration and monthly data cannot demonstrate the full impact of cooling on peak demand and thus on power infrastructure, as peaks due to cooling are averaged with period when cooling is used less. Given the urban setting of Rajkot city, there is little irrigation pumping – a fact substantiated by the low share of agriculture in the city's power

[37] Includes any seasonal or regularly operational industries having contracted load of up to 100 kW
[38] Includes consumers with contracted load of 100 kva and above including industries, commercial, public water works and sewerage pumping stations, agricultural irrigation.
[39] Includes any commercial consumer contracted load of up to 40 kW
[40] Includes hoarding and advertisement, crematorium/Burial Grounds, and Temporary Connections

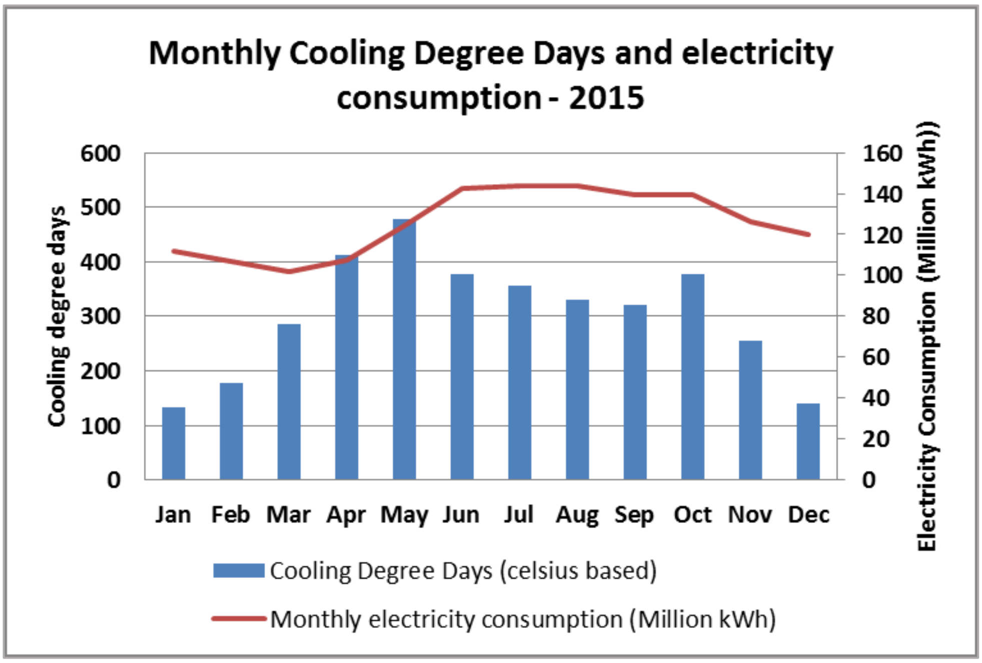
consumption. The seasonal variation in electricity consumption is likely to be predominantly caused by space cooling (including fans, desert water coolers, air conditioners and chillers). Demand for lighting may slightly increase during the monsoon season, when hours of daylight are diminished, however it is not expected to create a significant seasonal variation. The cooling degree days (CDD) for Rajkot are significantly higher during the summer months of April and May in particular (see Figure 16).

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



Source: Analysis based on data from PGVCL, 2016

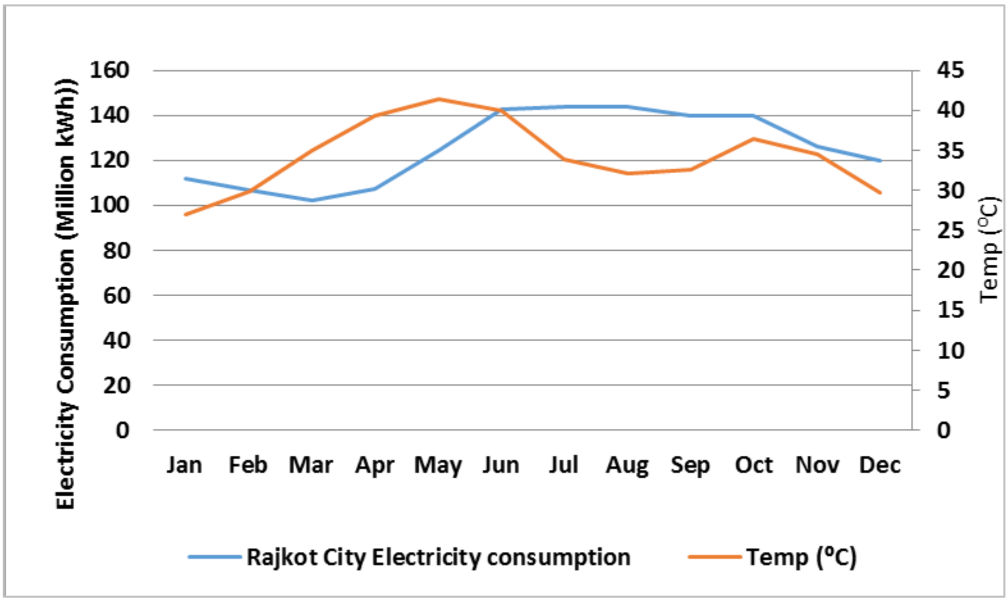
Figure 16: Relationship between Monthly Cooling Degree Days and Electricity Consumption for Rajkot City (2015)



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

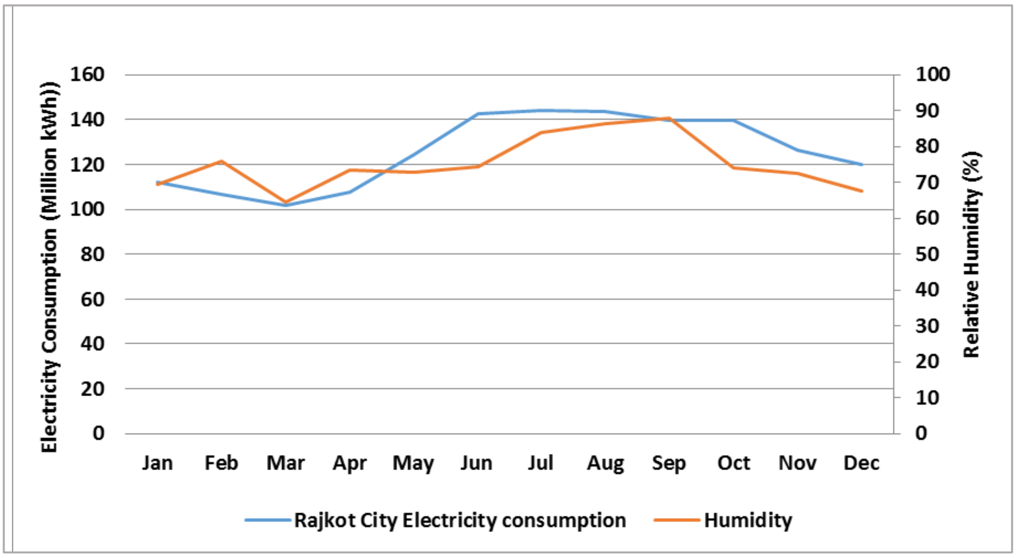
A positive correlation is observed between monthly electricity consumption and the relative humidity in particular (see Figure 17). The electricity consumption is also seen to peak when both temperature and relative humidity are relatively higher.

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



Source: Analysis based on data from PGVCL, 2016 and IMD, Rajkot Airport Station, 2015

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



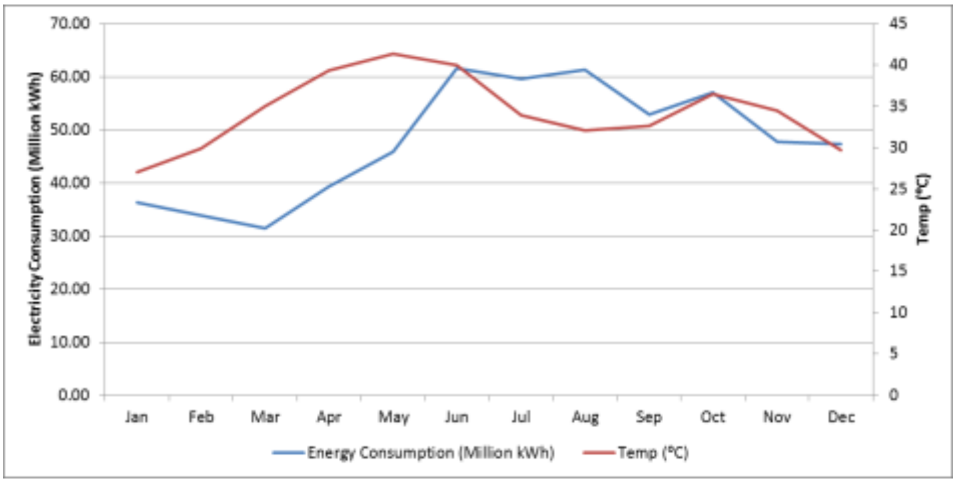
Source: Analysis based on data from PGVCL, 2016 and IMD, Rajkot Airport Station, 2015

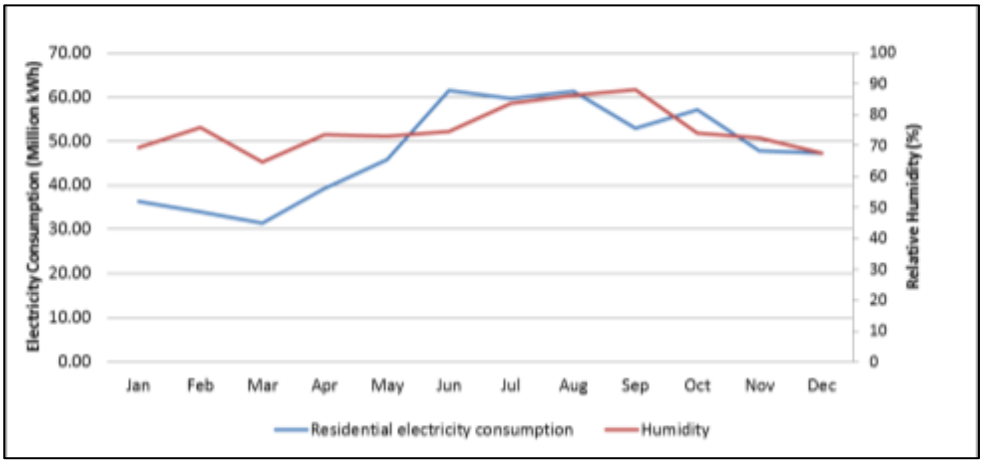
9.4 Sector-wise Analysis of Cooling Demand

9.4.1 Residential Sector

The electricity consumption in households is increasing by 15 percent from the month of May up to October as compared to the yearly average, with consumption nearly doubling in August as compared to that in March. Significant power is consumed in about 13 percent of residential households which have a sanctioned load of more than 2 kW. The seasonal load ratio for the residential sector is nearly 30 percent.

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



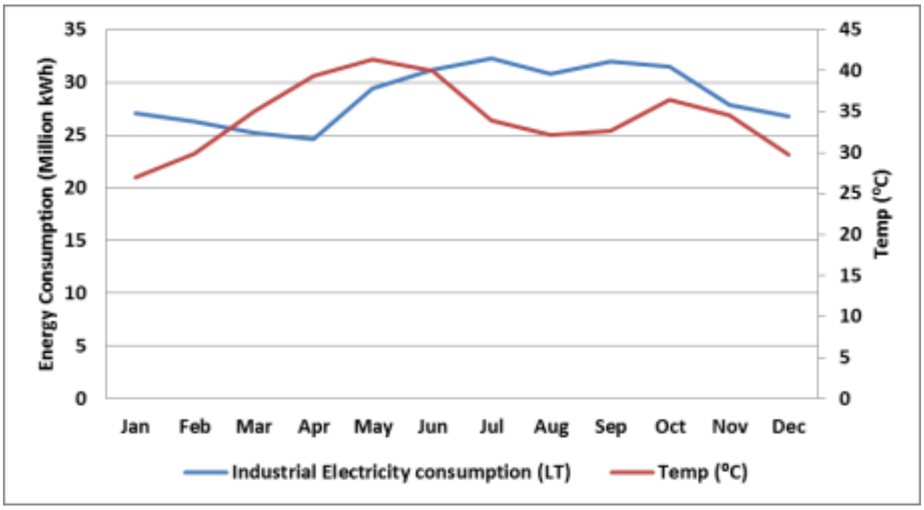


Source: Analysis based on data from PGVCL, 2016 and IMD, Rajkot Airport Station, 2015

9.4.2 Low Tension Consumers in the Industrial Sector

The electricity consumption by the low-tension consumers in the industrial sector rises from May onwards and remains comparatively similar during the months of June to October.

Figure 20: Relationship between Monthly Temperature/Relative Humidity and Electricity Consumption for Industrial Sector (LT) (2015)

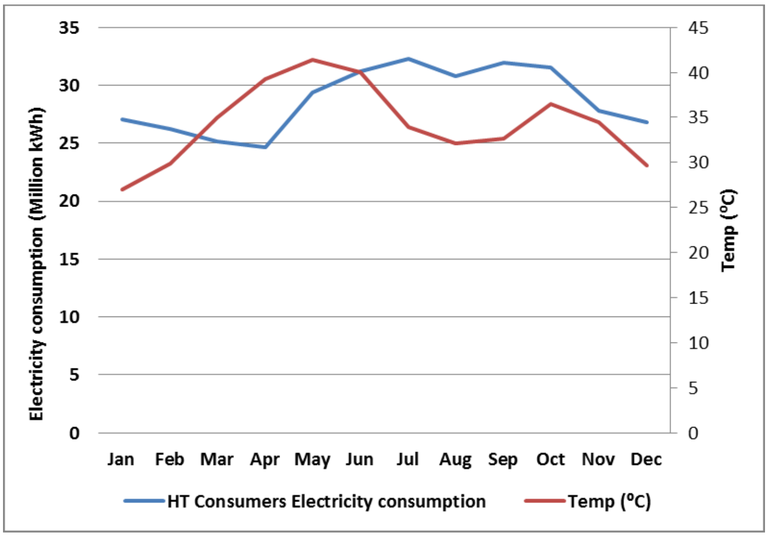


Source: Analysis based on data from PGVCL, 2016 and IMD, Rajkot Airport Station, 2015

9.4.3 High Tension Consumers in the Commercial and Industrial Sectors

Electricity consumption by high tension commercial and industrial consumers such as large shopping malls and industries (with a connected load of more than 100 kW) peaks in the month of September and is seen to slightly increase with the rise in temperature during the months of May to September.

Figure 21: Relationship between Monthly Temperature and Electricity Consumption for High Tension Consumers (2015)

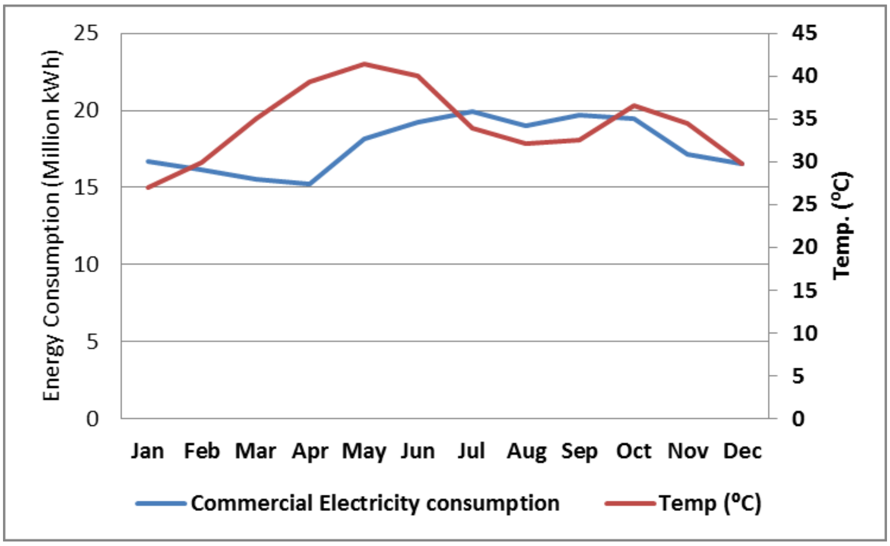


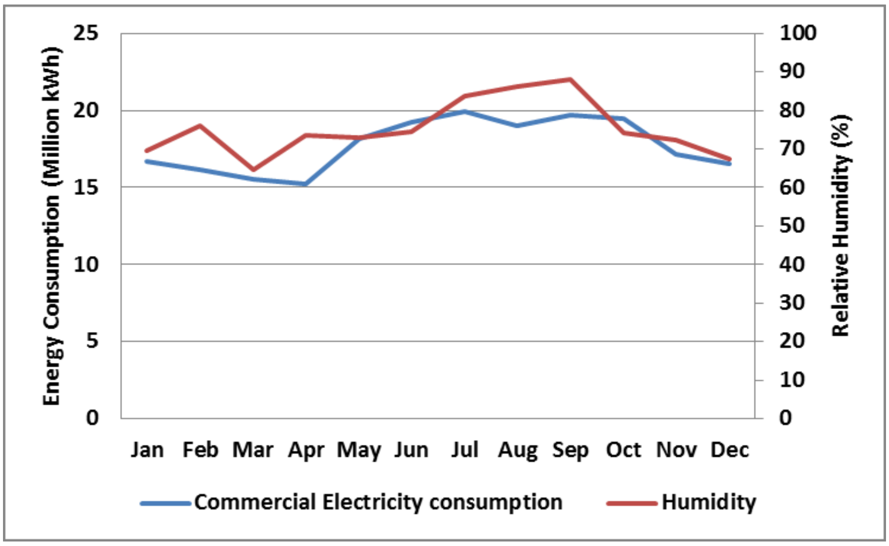
Source: Analysis based on data from PGVCL, 2016 and IMD, Rajkot Airport Station, 2015

9.4.4 Low Tension Consumers in the Commercial Sector

Electricity consumption in the commercial sector increases by about 30 percent from April onwards and has a consistently high trend over the months of June to October. The seasonal load ratio for the low tension commercial consumers is about 12 percent.

Figure 22: Relationship between Monthly Temperature/Relative Humidity and Electricity Consumption for Commercial Sector (2015)





Source: Analysis based on data from PGVCL, 2016 and IMD, Rajkot Airport Station, 2015

10 The Potential for District Cooling in Rajkot

10.1 Real estate development

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

With changing lifestyles as a result of rapid development, the city's power consumption is rising by 6 percent annually (see section 1.7.3). As indicated earlier, considerable seasonal variation exists in the cooling demand for the commercial and residential sector. Around 10,000 air-conditioners are sold in Rajkot every year. With the use and ownership of conditioners observed to be rising with increasing income levels, the sales of air-conditioners in the city are likely to increase as well in the coming years. Estimates based on findings of the load research survey undertaken by USAID and IIM-A for residential households and commercial establishments in Gujarat cities, indicate that the mid-income and high-income households[41] in Rajkot had a potential space cooling demand of 67,085 TR and 20,016 TR respectively in the year 2012-13[42]. It is projected that total number of households in Rajkot will rise to 342,675 in year 2020, with 173,736 mid-income households and 29,916 high-income households respectively – with an estimated space cooling demand of 78,167 TR for mid-income households and 23,321 TR high-income households. While the load research survey also includes commercial establishments, it is not possible to calculate similar estimates of cooling demand for the commercial sector due to limited data on the number of commercial establishments across the city. Targeting mixed-use zones having large commercial developments, which can act as anchor loads, will only aid the feasibility of district cooling systems.

Rajkot is now moving towards transit oriented development along the BRTS route to promote compact mixed-use development. High FSI has been allotted for a significantly large area covering the transit oriented zone, along the BRTS route, polycentric zone proposed around major highways, residential affordable housing zone proposed along 2nd ring road of city, and in the west zone of the city (see Table 10). As a result, a number of high rise residential developments are coming up in these areas, largely including apartments with more than 2 bedrooms. Thereby many similar upcoming developments in and around these areas are expected to house high income households, who in all likelihood will own at least one air-conditioner. A majority of the households in the recently developed areas in the west zone of Rajkot such as Kalawad road, Race course road, and Raiya road, have income levels

[41] Rajkot had 294,096 households in total in the year 2012-13, with the number of mid-income group and high-income group households estimated at 149,106 and 25,675 households respectively. Low Carbon Mobility Plan-Rajkot, 2011-2031

[42] As per the load research survey conducted in Gujarat cities by USAID and IIM-A, total 67 percent of high income households are using air conditioners. Of the high-income households owing air conditioners, 77 percent are using 1.5 TR size air-conditioners, 14 percent are using 1 TR air-conditioners, 8 percent are using 2 TR air-conditioners, and 1 percent are using 0.75 TR air-conditioners. Of 32 percent of mid-income households owing air conditioners, 77 percent are using 1.5 TR size air-conditioners, 14 percent are using 1 TR air-conditioners, 8 percent are using 2 TR air-conditioners, and 1 percent are using 0.75 TR air-conditioners. Further, connected space cooling load by income group is also available from the load research survey has been used to arrive at the estimated cooling demand.

ranging from INR 30,000 to INR 50,000 (USD 465 to USD 770) or more, relatively higher than the city's monthly average income of INR 22,000 (USD 340)[37].

Given the type of development and the higher purchasing power of the residents in these growth corridors, a number of commercial developments including hotels, shopping malls, leisure, and retail spaces have come up in these areas and are expected to come up in the future as well. Such mixed-use development which includes consumers having diversity of cooling demand offers opportunities for district cooling implementation. Furthermore, compact and mixed use development with a FSI of 4 is proposed at a prominently green field site at Raiya in ward number-1 under the Area based development component of Rajkot's Smart City Plan. Given the high density and diversity of the developments proposed, there exist promising opportunities to integrate district cooling at an early stage in this green field development (see section 1.9.5 for more details). However, areas that have low proportions of commercial buildings could make the profitability of district cooling more difficult.

Table 10: Proposed Area of Various Compact Development Zones

Compact Development	Area (sq. m)	Maximum permissible FSI
Transit oriented zone	34,490,000	3.75
Polycentric zone – existing highways	1,170	4
Residential Affordable Housing	26,700,000	2.7

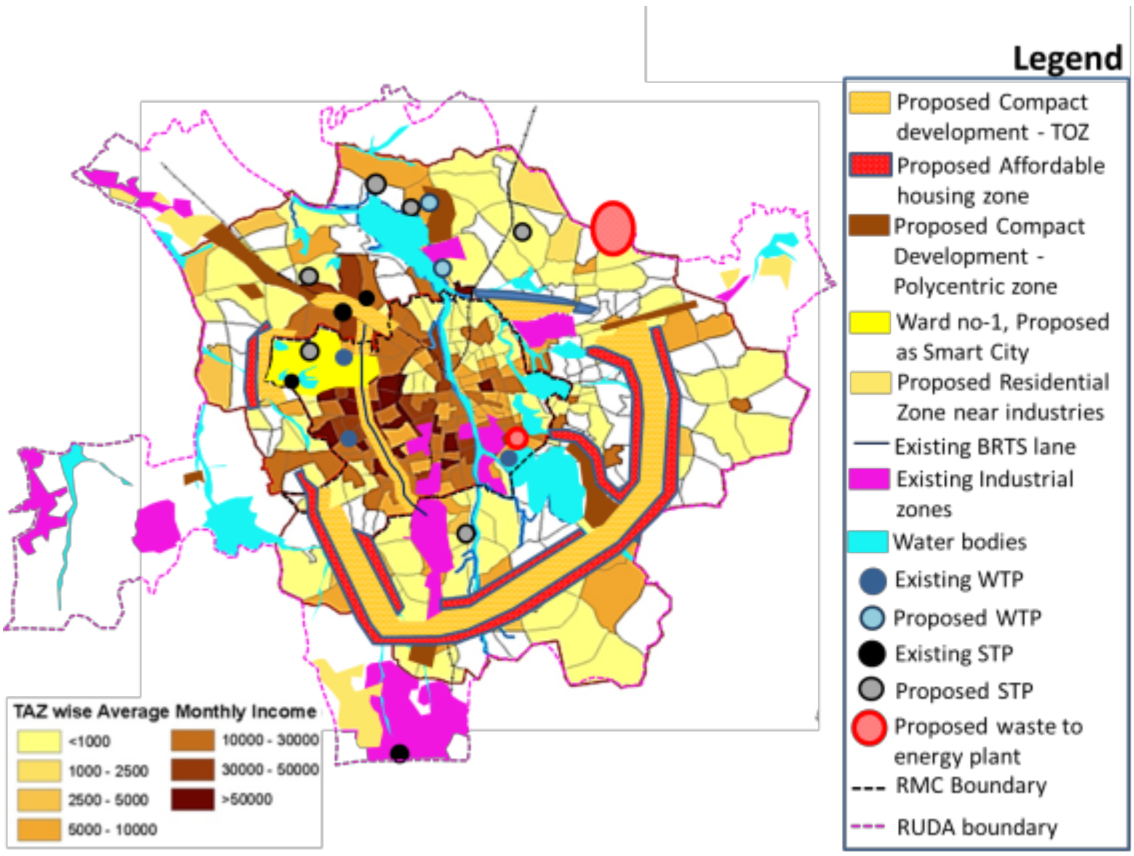
Source: (Rajkot Urban Development Authority, 2016)

Opportunities exist with regards to use of Rajkot's available local renewable and waste heat sources in the district cooling generation as well. A Waste to Energy plant of 130,000 metric tonnes (MT) capacity generating 4 Megawatt (MW) of power is proposed in the city along with a 5 MT per day waste to bio-methanation plant generating about 300m^3 of biogas. The numerous foundries and forging units located in industrial areas of Rajkot are sources of waste heat. As indicated in Figure 26, development is proposed in the vicinity of some of Rajkot's industrial areas. This might offers potential opportunities for integrating local waste heat from industries into the district cooling network. The industries with waste heat generation located in the Lodhika industrial estate are mapped in Annexure 2.7. With a wastewater treatment plant of 176 MLD has been proposed in the city, reuse of the treated wastewater that will be available in the chilled water network can be explored as well. Section 1.9.5 examines the feasibility of Rajkot's Smart city pilot area in ward no. 1 for district cooling.

Building developers in Rajkot 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.

Figure 23: Potential Development Zones and Infrastructure Linkages for District Cooling in Rajkot



Source: Adapted and prepared for this study based on RUDA Development Plan (Rajkot Urban Development Authority, 2016)

11 Techno-economic analyses of district cooling in Rajkot

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

11.1 Development of evaluation tool

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

- **Sub-model 1: Input**

The required input data includes:

1) built-up area of building types in the area planned for district cooling implementation
2) occupancy of building types
3) development timeline for different buildings
4) electricity and water tariffs charged to stand-alone buildings and a district cooling project
5) cooling demand per m^2
6) operational parameters including annual average COP and EFLHs[43]
7) capital and operating cost assumptions on stand-alone cooling systems, district cooling plants, land and network
8) CO_2 emission baseline.

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

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

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

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

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

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 Rajkot

Cooling demand

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

Annex 14.8 details the specific assumptions on building occupancy and building efficiencies used in establishing cooling demand for different building types. Cooling demand is also calculated based on expected appliance use leading to heat gain as well as climate. These are conservative estimates, for example, building efficiency assumptions are based on the ECBC standards which are not currently mandatory in any of the five cities.

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

Table 11: Assumptions of cooling demand

	Hotel	Office	Shopping mall	Hospital	Residential Apartment	Campus building
W/sqm	145	241	292	193	120	192

Equipment costs

In order to calculate the economic viability of a district cooling system and compare with standalone cooling systems inside buildings, several cost assumptions have been made. This cost data has been provided by local and international partners of the District Energy in Cities Initiative for rapid analysis and can be further verified in the future. The costs are conservative estimates. Table 12 summarizes these assumptions.

Table 12: Investment costs of district cooling system and standalone system per unit of installed capacity

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

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

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

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

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

Cooling system characteristics

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

Table 13: Annual efficiency (COP) of district cooling system and standalone system

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

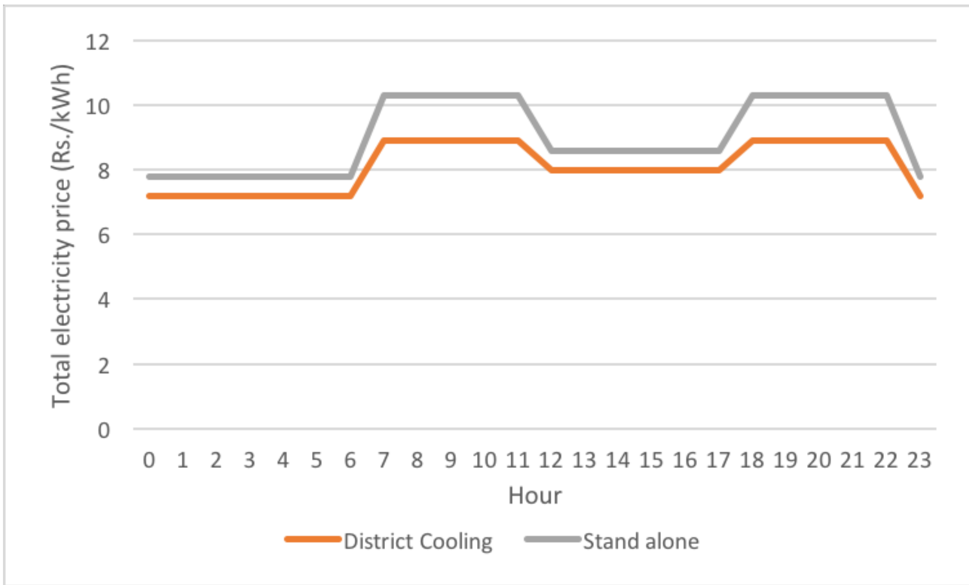
The operation of the district cooling and stand-alone systems for a given cooling load can, for high-level analyses, be characterized by the Equivalent Full Load Hours (EFLH). EFLH is the number of hours a cooling source has to operate at full capacity installed to produce the same amount of cooling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

Operation and Maintenance costs

Electricity tariffs are calculated from Gujarat State Electricity Distribution Company limited (PGVCL) tariffs and presented in Figure 24. District cooling plants are expected to access slightly lower overall electricity tariffs due to higher voltage connections (as they are able to centralize multiple cooling loads from different buildings) and they come under a different consumer type.

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

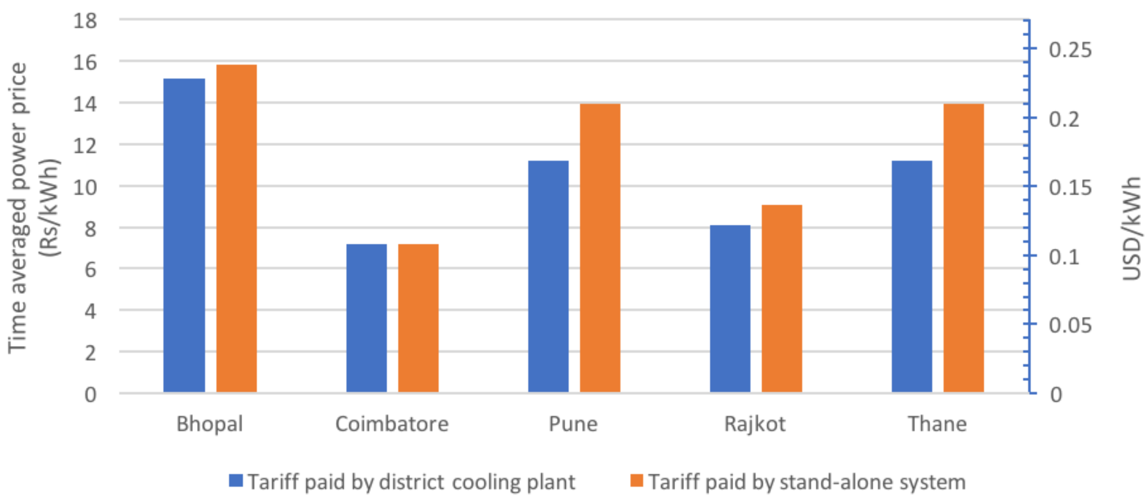
Figure 24: Electricity prices in Rajkot (Energy charge fee)



Source: Based on tariffs charged by orders from (PGVCL, 2015)

Compared to the other cities assessed in India, Rajkot has relatively low electricity prices, as can be seen in Figure 25. This can hinder the business model for district cooling as it makes being energy efficient in cooling slightly less profitable than in other cities.

Figure 25: Comparison of time-averaged electricity prices across all cities as paid by district cooling plants and stand-alone commercial cooling systems



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

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

Tariff structure of chilled water from district cooling system

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

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

The three charges are illustrated in Figure 26, the 20% buffer is shown by a red arrow and is 20% of the total district cooling payments.

Tax

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

As described above, VAT has not been applied and instead a buffer of 20% 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. A sensitivity analysis on VAT payments has been included for Rajkot on the analysis of Raiya Smart City Area.

Development timescales

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

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

This timescale will vary project to project and also on the contracting arrangements of when connection charges should be made. This timescale can be seen in the payments made in Figure 26.

Financial structuring

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

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

11.2.1 Analysis of generic project archetype

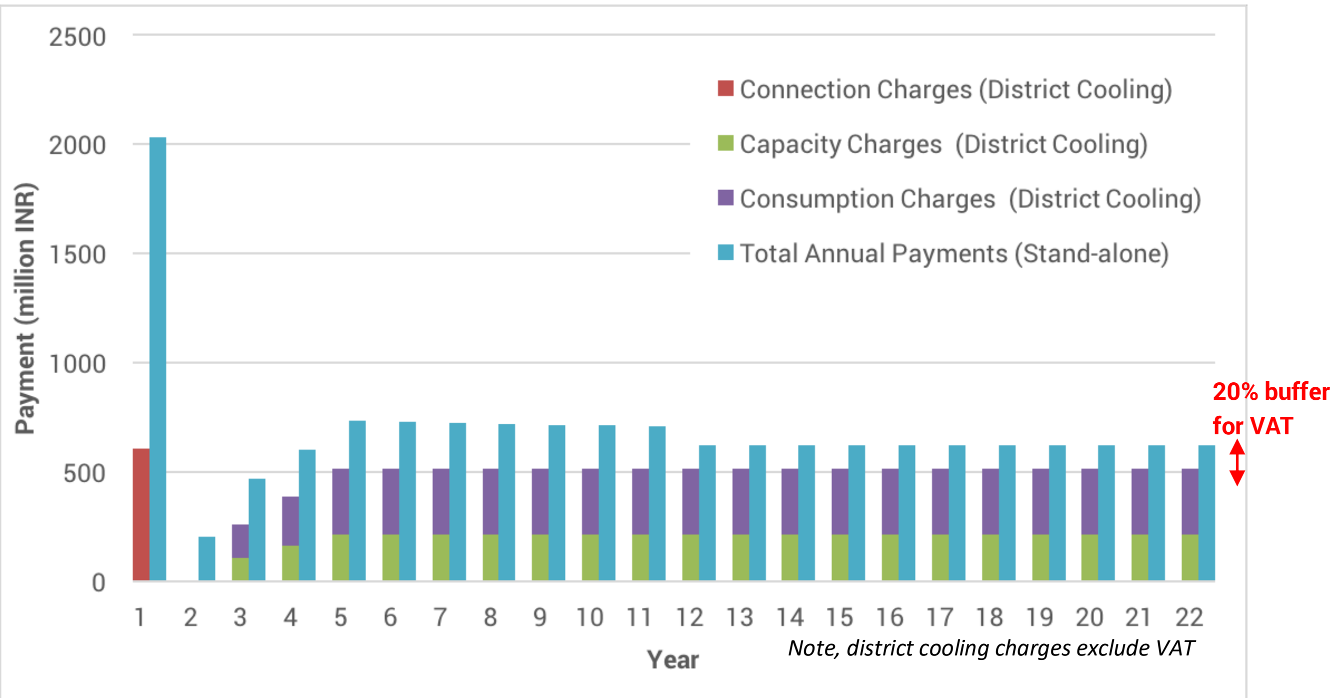
Through analysis of projects across all five cities, a development archetype was chosen that could be used as a typical development to enable comparison across all cities. The make-up of this archetype is shown in Table 14 below, it is mixed-use with multiple buildings with centralised cooling.

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

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 9% in Rajkot and the payback period is 16 years.

Figure 26: 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 this return on investment, this district cooling project would not be commercially viable in Rajkot without incentives. The IRR is lower than other cities assessed, predominantly due to relatively lower power prices which, as described previously, can make the business model for district cooling more difficult as energy efficiency is less financially attractive than a city with higher power prices. The sensitivity analysis undertaken in Section 11.4.2 on the Smart City Area shows that reducing the electricity price paid by the district cooling system (for example, providing low cost renewable power) or lowering the VAT paid on chilled water can have significant effects on the IRR. Other incentives such as free land and free water will make a much lower difference to the IRR.

In Rajkot, strong project design could help lower district cooling capital costs (mixed use and dense areas) and risks (such as risks of customers not connecting and/or not consuming cooling), improving the commercial viability of the technology. Rajkot may need to attract concessional finance for projects with a low IRR, incorporate investors that can control load risk (e.g. the city or building developers) and, as should be the case for most district cooling projects, attract investors with a long-term view on returns.

11.3 Selection of Probable Project Sites

This section presents the potential site that has been identified for the high-level feasibility assessment for deploying a district cooling system in Rajkot. The site is the Area Based Development of Rajkot's Smart City Plan and was identified based on discussions with the RMC. Sites were analysed for selection based on the criteria in Table 17 including having diverse mix-use development (existing and upcoming) with significant cooling demand and the presence of anchor loads.

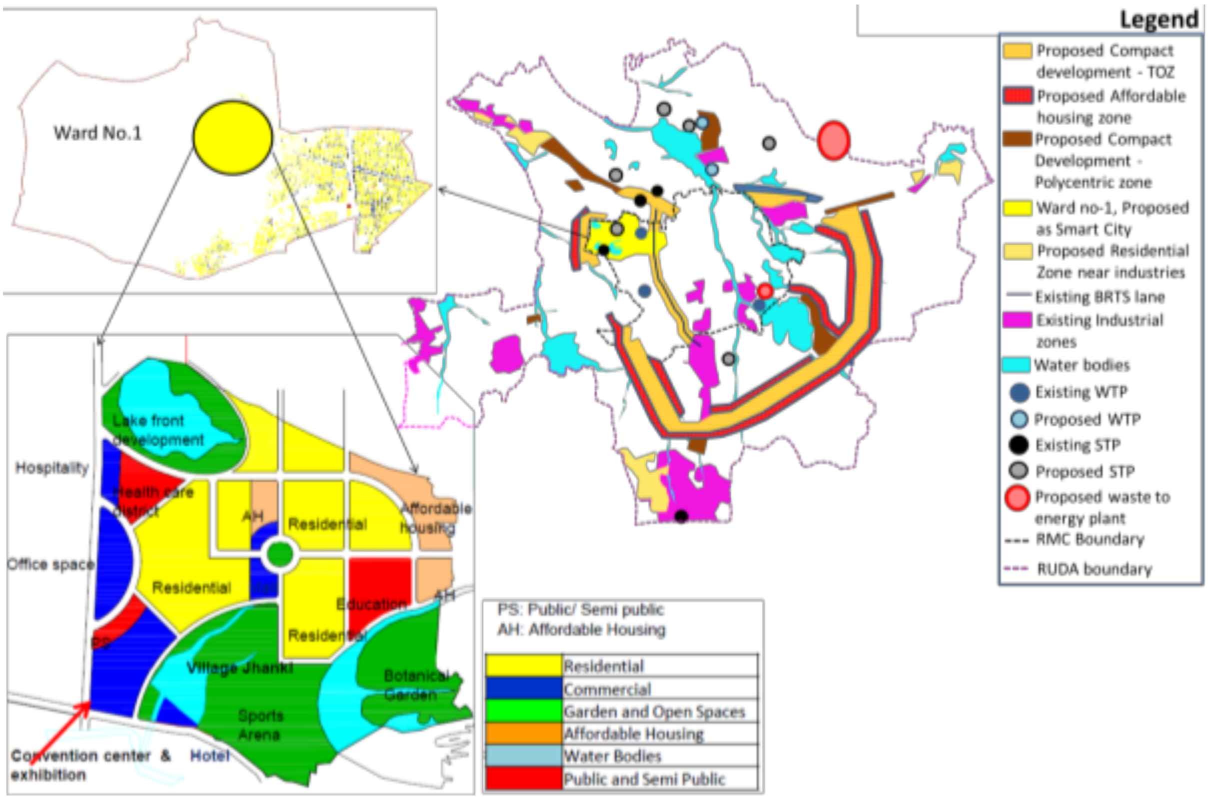
11.4 Smart City Raiya area in Ward No. 1

11.4.1 Collected data and site details

Under the Area-based Development proposal in its Smart City Plan, Rajkot will be going ahead with greenfield development at the Raiya site that spreads over an area of 2 sq. km. The Raiya area is situated in ward no. 1 and is located along the growth direction (west) of

the city. This smart city pilot area has large tracts of vacant land, with mixed-use development including residential, commercial, institutional, and recreational uses planned (see Figure 27 and Table 15).

Figure 27: Area Based Development Proposed in Ward Number -1 under Smart City Proposal



Source: (RMC, 2016)

Table 15: Area of different zones proposed under Area Based Development

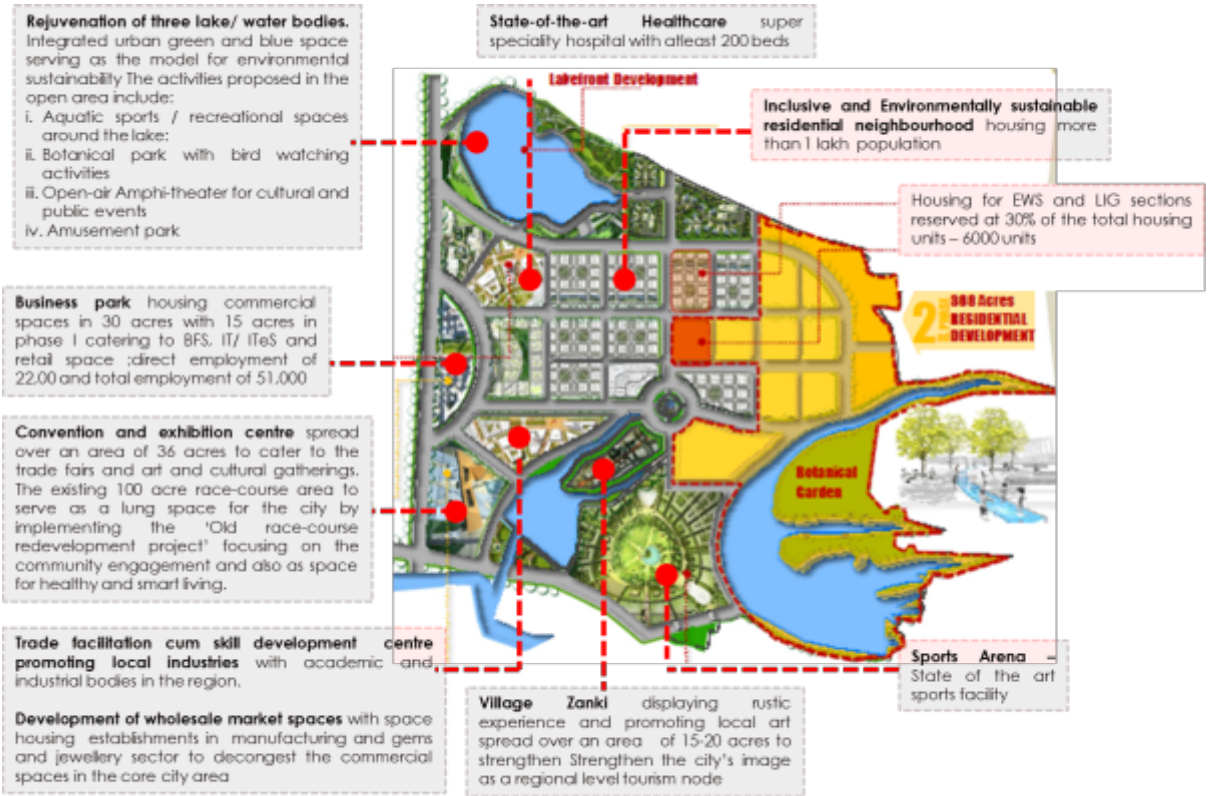
Zone	Area (sq.m.)	Share of total area
Residential	495,068	23%
Commercial - retail and wholesale	236,771	11%
Public- semi public	107,623	5%
Recreational, tourism and sports arena	774,889	36%
Transport	215,247	10%
Green, open spaces and water bodies	322,870	15%
Total	**2,152,472**	**100%**

Source: (RMC, 2016)

A business park spread over 30 acres, of which 15 acres cater to house banking and financial services, IT/ITeS, and retail space is proposed. A convention and exhibition centre spread

over 36 acres along with a complex that houses educational facilities and a super specialty hospital (with at least 200 beds) is planned as well. This area will also include high-density residential development housing around 100,000 persons, a trade facilitation cum skill development centre, market spaces housing gems and jewelry stores, and a state-of-the-art sports arena. The Raiya area will have dense development as well, given that it is located in ward no. 1, which is an identified polycentric corridor having a maximum permissible FSI of 4.0.

Figure 28: Details of Area Based Development Components



Source: (RMC, 2016)

Key objectives on renewable energy and building efficiency for the Raiya Smart City pilot area are outline in Section 5.1, as are the wider priorities of Rajkot's Pan-City proposal. The area targets having an 'assured energy supply' which can be interpreted as a smarter, more robust electricity grid with decentralized power. Indeed 20% of the pilot area's energy supply is targeted to come from renewable energy including a proposal to install 6.4 MW of solar photovoltaic systems that could approximately include:

- 4.4 MW capacity of grid connected solar panels with net metering across 18,000 households
- 2 MW of solar energy will be generated through utilization of vacant land for installation of solar panels

Furthermore, the Raiya area is targeted to have at least 80% buildings that are energy efficient and green buildings which will be mandated through the local development control regulations.

Therefore, potential opportunities to integrate renewables in the district cooling production and establish district cooling related mandates for this site exist. It is proposed to recycle and reuse of wastewater and storm water for non-potable purposes such as toilet flushing, gardening, and rejuvenation of three lakes in ward no. 1. Opportunities exist to explore reuse of the treated waste water from the Raiya wastewater plant and water from the lakes in the district cooling network as well.

Long-term expansion

A district cooling project serving just the Raiya area would be a significant undertaking given the size of planned development and the medium/long-term timescale. However, given the concentration of non-residential buildings in the west of Raiya Area, and the ability of district cooling systems to expand and interconnect in the long-term, it is pertinent to consider long-term expansion outside of the Raiya area.

Beyond the Raiya area, 70% of the surrounding land in ward no. 1 (where the pilot area is located) is vacant[46]. As such, this ward holds promising potential for longer-term expansion of the district cooling network outside of the Raiya area connecting both existing buildings and planned areas. Table 16 shows that approximately half of the currently developed area is non-residential. Underground utilities such as water and sewage pipelines are yet to be laid in more than 60 percent of the area in ward no. 1 (as seen from the network of water and drainage pipelines shown in the Annexure 2.2). Ward no. 1 is proposed to be developed as a polycentric corridor, with an emphasis on promoting compact high-rise and mixed-use development, and thereby there is potential for integrating district cooling into development plans for this area.

Table 16: Total area and proposed built-up area in ward no. 1

Total Area (sq. m)	**10,763,000**
Total Built up area (sq. m)	2,880,915
Vacant area (sq. m)	7,882,085
Total Built Up area = 2,880,915 sq. m	
Residential (sq. m)	1,573,453
Non-residential (sq. m)	1,307,462
Non-residential - 1,307,462 sq. m	
Commercial	1,216,133

[46] Vacant land is empty land available in the ward. Land use is finalized for such areas, with planning permissions given for some parcels of the land.

Educational	56,439
Financial	1,739
Micro scale cottage businesses	1,816
Health	6,741
Industry	576
Others	24,018

Source: (RMC, 2015)

Table 17: Site Selection Criteria for Ward Number 1

Technical requirements	Compact and mixed-use development is proposed for this site. The proposed development such as the business park, convention and exhibition centre, hospital, educational buildings, will have substantial demand for cooling. Vacant tracts of land are available in and around the site to potentially house the district cooling plant.
Availability of anchor loads with continuous load and diverse buildings can be connected	The proposed business park spread over an area of 30 acres (0.12 sq. km) housing banking and financial services, IT/ITeS, and retail spaces and the convention and exhibition centre spread over 36 acres (0.14 sq. km) can serve as anchor loads for the district cooling network. The site has a good mix of diverse buildings proposed such as commercial and corporate office spaces, educational facility, multi-speciality hospitals and a sports arena.
Potential for longer-term network expansion	The site is located in ward. No 1 which has about 70% of its area vacant at present. Compact and mixed-use development is planned for this ward and the maximum permissible FSI is 4.0. Therefore, ward. No .1 is expected to undergo high density development and there is potential for integrating district cooling into the development plans for this area.
Existing situation of buildings	The Raiya area is largely a greenfield area and 70% of its total area is vacant. Mixed land use plan is proposed for area based development for Smart city.
Influence from local government	The overall design and proposed initiatives for this site have been prepared by the RMC. Thus, the local government exerts a high degree of influence over the project and controls development in and around this site and can potentially intervene to help integrate district cooling.

11.4.2 How district cooling could be developed in the Raiya area in Ward No. 1

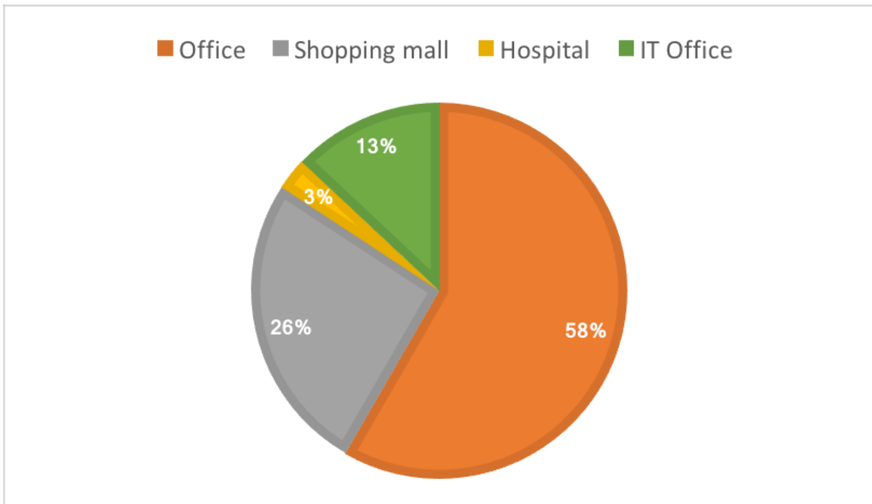
The potential for district cooling in the Raiya area has been analysed below. The western portion of the land-use plan shown in Figure 27 and Figure 28 has been assessed for district cooling viability. This section includes the 15 acres of business park that has been highlighted in the plan as a first phase of the development. In addition, the 200-bed specialty

hospital adjacent to the commercial zone has been considered. The 15 acres is described as land allocated for financial offices, IT/ITeS offices and retail, an ideal mix of different building types. No residential buildings have been considered in the analysis as it is highly unlikely that they could be connected. Hospitality buildings, exhibition centres, campus buildings, the sports arena etc. could all be considered although more detail would be needed even to do a high-level assessment.

Buildings served and cooling load

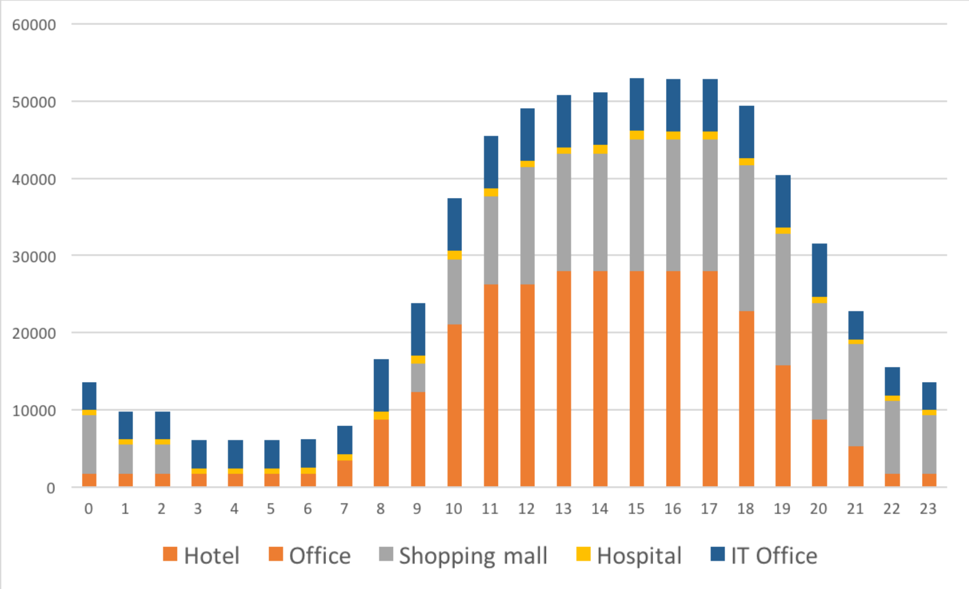
The total built-up area is estimated at 2,689,263 sq.ft (249,841 m^2) and the split by building type is shown in Figure 29. This is based on an assumption that the 15-acre first phase of the business park would comprise of 9 acres of standard office, 2 acres of IT Office and 4 acres of retail space and would use the maximum FSI of 4.0. The 200-bed hospital has been assumed to have a built-up area of 7,000 sq. m. The assumed occupancy of these building types is shown in Annex 14.9, IT/ITeS Offices are assumed to have longer operating hours than normal offices.

Figure 29: 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 30 below and would have an EFLH of 1930 hours.

Figure 30: 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 18: District cooling plant

Installed Cooling Capacity	52994	kW
	15068	RT
District cooling plant built-up area	3733	sq. m
Outdoor space for cooling towers	1195	sq. m
DC plant land requirement	2240	sq.m

The investment of district cooling system is calculated as below.

Table 19: District cooling system investment

DC system investment	Rs.	USD
DC plant	2,009,044,784	30,135,672
Land	76,377,638	1,145,665
Network	180,814,031	2,712,210
Sum	2,266,236,453	33,993,547
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 20: Annual cooling supply and operation fee

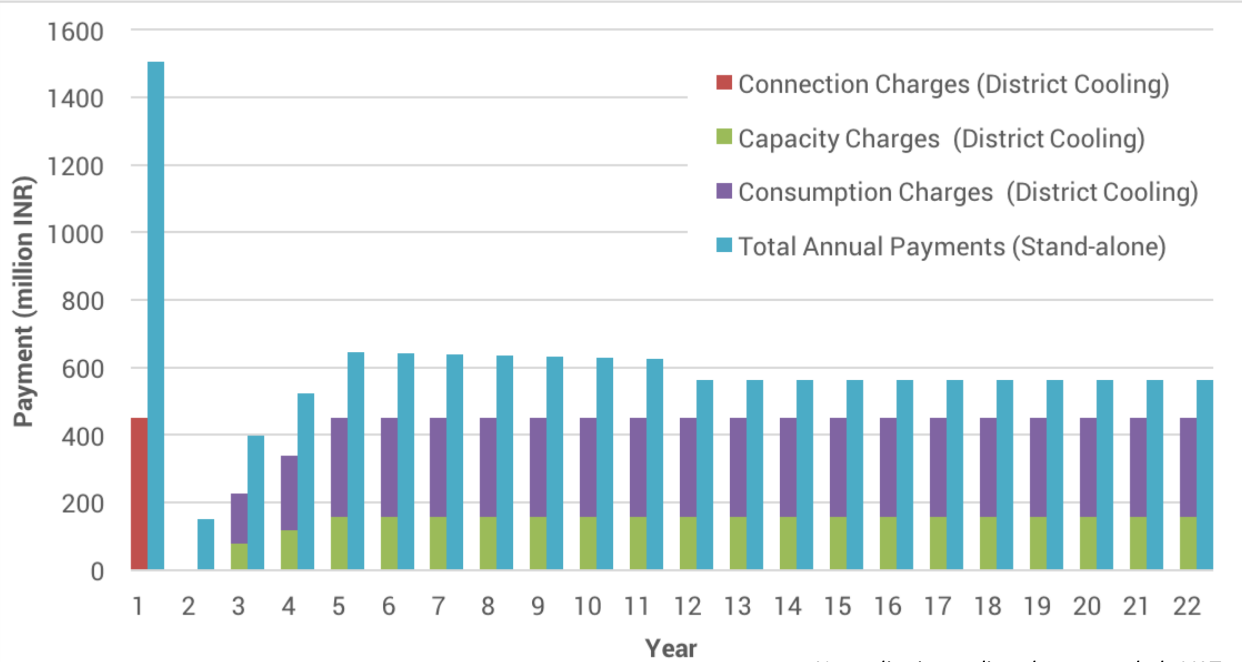
Annual cooling supply	kWh	54,018,696
Annual electricity consumption	kWh	15,359,311

Annual electricity fee	Rs.	170,212,161
	USD	2,553,182
Annual water consumption	m^3	442,348
Annual water fee	Rs.	90,681,371
	USD	1,360,221

Financial results

The economic analysis shows that when a metering charge equal to 0.152 USD/TR.h (10.1 INR/TR.h) is charged, the IRR of this project is 10%. This value is used as a baseline in this project for further economic analysis. As described in Section 11.2, this metering charge has been set to be 20% below the stand-alone costs for cooling. In reality, in order to attract and secure customer connections, the metering charge may be lower, lowering the IRR but ensuring load risk is minimised. Figure 31 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 31: Cost comparison for consumers in the Raiya Area for district cooling vs. stand-alone systems



Note, district cooling charges exclude VAT

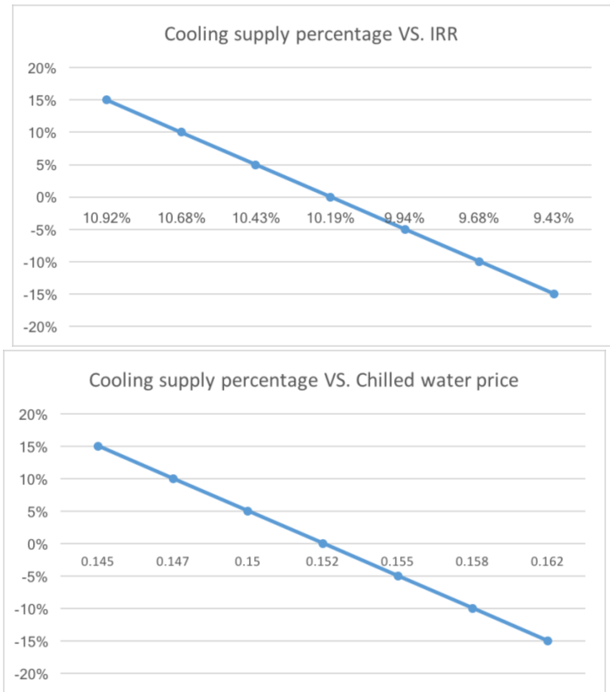
Sensitivity analysis

In this section, the results of a sensitivity analysis examining cooling demand, capital costs and electricity tariff are undertaken, changing these values from +15% to -15% so as to show the required change of chilled water price (metering charge) under fixed IRR and the changing IRR while keeping the chilled water price fixed at 0.152USD/TR.h (10.1 INR/TR.h). The 20% reduction below the stand-alone payment for VAT is maintained throughout.

- Sensitivity analysis on cooling demand

The sensitivity analysis results of cooling demand, from +15% to -15%, are shown in the Figure 32 below.

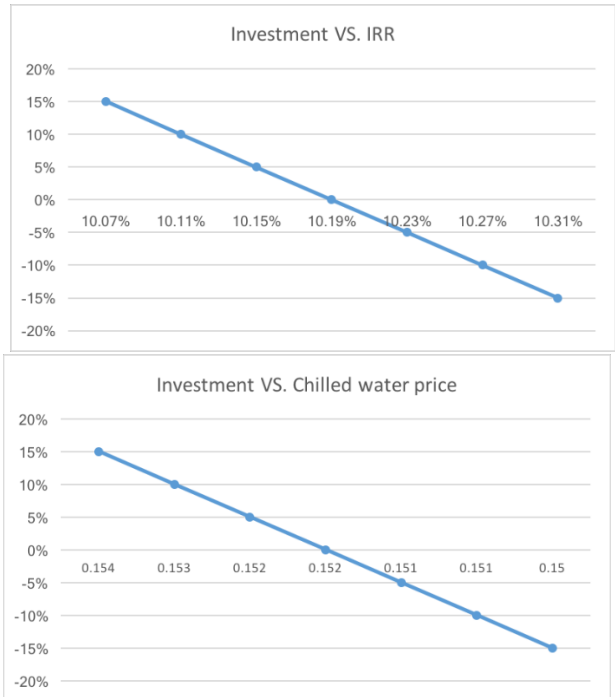
Figure 32: Sensitivity analysis results of changing cooling demand in Raiya Area



➢ Sensitivity analysis on capital costs

The sensitivity analysis results of investment, from +15% to -15%, are shown in the Figure 33 below.

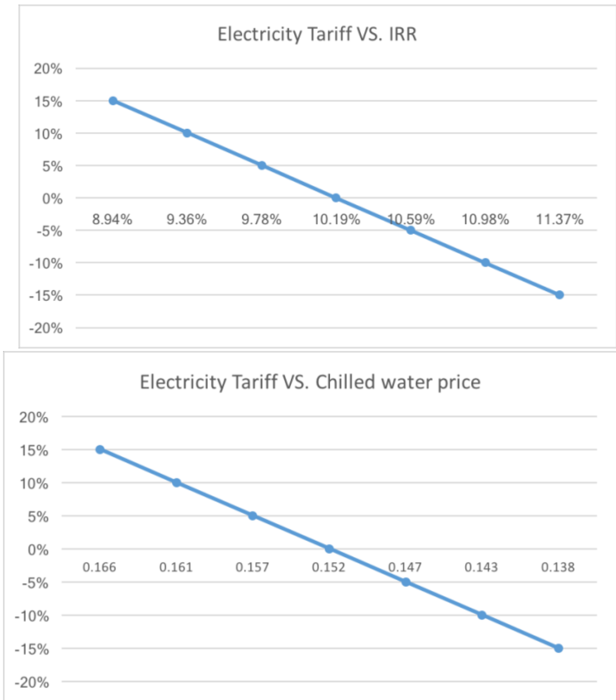
Figure 33: Sensitivity analysis results of changing capital costs in Raiya Area



➢ Sensitivity analysis on electricity tariff

The sensitivity analysis results on electricity tariff, changing the tariff paid by the district cooling system by +15% to -15%, are shown in the Figure 34 below. The tariff paid for by stand-alone systems was not changed.

Figure 34: Sensitivity analysis results of changing electricity prices in Raiya Area



➢ Sensitivity analysis on reduced VAT payments.

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

Given that the IRR in Rajkot is relatively low, the VAT (which could be set at state-level like for electricity) could be set at a relatively low value to encourage district cooling projects. The below analysis shows what happens to the IRR when the buffer zone of 20% is reduced[47] by adjusting the chilled water price:

Buffer between DC payment and stand-alone payment	Chilled water price (USD/TR.hr)	IRR	Payback period

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

20%	0.153	10.2%	15 years
10%	0.179	12.5%	13 years
0%	0.21	14.9%	11 years

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

The viability of connecting thermal energy storage to Raiya Area is presented in Section 11.5 below.

The specific benefits of connecting the Raiya Area to district cooling are presented in Section 11.6 below.

Box 11: Recommendations for Raiya Smart City Area

Given the commercial viability of district cooling assessed above, RMC could direct the Smart City SPV (RSDL) to incorporate district cooling into the design of the smart city area, particularly focusing on the planning of the business park and adjacent non-residential buildings likely to have centralised cooling. Furthermore, the placement of utilities, incorporation of existing buildings, identification of land for a district cooling plant should all be analysed. It may be that given the size of the whole Raiya area, multiple district cooling networks are established not focused on the business park that could later interconnect, these should also be examined.

If building layouts for the business park are already developed, a project pre-feasibility should be undertaken. If not, then an experienced international district cooling engineer can provide inputs to zonal design including FSI, building mix and utility tunnels that will benefit district cooling. It is highly recommended that the business park and adjacent major buildings are assessed for district cooling potential as soon as they are planned and district cooling concepts considered early on in their design. Given the relatively low power price in Rajkot, strong project planning is needed to reduce capital costs and increase the diversity of cooling demand.

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

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

should assess the use of Treated Sewage Effluent in district cooling systems. These benefits are directly in line with some of the goals outlined in the Smart City proposal.

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

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

11.5 The potential of thermal energy storage (TES)

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

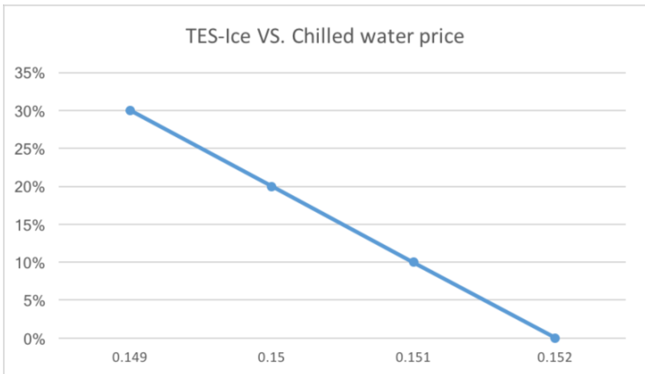
Based on the current electricity tariff in Rajkot and the situation of this project, ice storage is considered as a potential TES technology to use in a district cooling system because it has the highest cooling storage density amongst the TES technologies and as such requires far less land as compared to chilled water storage. Due to lack of information on similar projects in India, the cost of such a system are estimated based on applications in nearby countries, like China, Malaysia and Singapore. The extra costs of ice storage are listed below in Table 21. The COP of ice storage under off-peak period is set to be 1.76 KW/TR. For example, if a 10,000TR district cooling plant wanted to have 20% TES ice storage an additional investment of 3.2 million USD (1,631USD/TR x 20% x 10,000TR) would be required.

Table 21: Investment costs for various elements of an ice-storage system

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

The results for different coverage ratios of ice TES for peak load periods, ranging from 0% to 30%, are shown below in Figure 35 as tested on the Raiya Area. This shows that the application of TES results in a slightly lower chilled water price under a fixed IRR.

Figure 35: Sensitivity analysis results of coverage ratio of ice TES for peak period



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

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

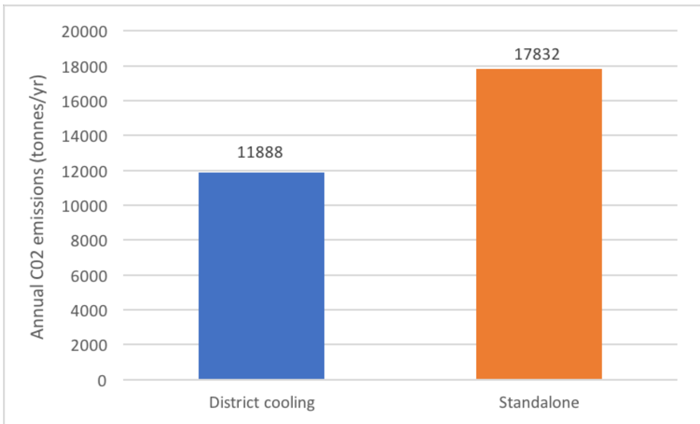
11.6 Benefits of district cooling

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 Raiya Area project are 5944

tons per year[48], as shown below in Figure 36. Due to a lack of data for CO_2 emissions for water supply, this contribution is not included.

Figure 36: CO2 emission comparison for stand-alone and district cooling in Raiya Area

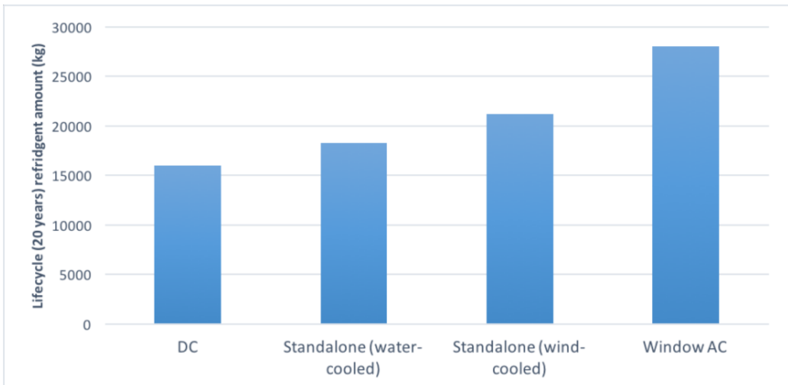


Electricity savings of 7.68GWh of electricity annually (33% reduction from stand-alone) are expected.

The CO_2 savings and electricity savings can be increased significantly by connecting renewable and waste heat resources. Furthermore, given the scale of Raiya Area and Ward no. 1, it is expected that future phases of the site will be connected to the district cooling system and even some existing buildings could be connected in the long-term – this will further increase the CO2 savings and electricity savings.

The district cooling system can also contribute to refrigerant phasing out, due to reduced cooling capacity in the whole district. Over the lifetime this is expected to be 2.2 tonnes, as compared to water-cooled chillers. The calculated results are shown below.

Figure 37: Lifecycle refrigerant comparison for district cooling vs. stand-alone solutions in Raiya Area



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

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

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, Rajkot can expect the following environmental benefits (these are also set out for the generic project in Section 11.2.1). 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 system in Raiya area, end-users can be charged less for cooling than they would if they were using stand-alone systems. As described in Box 10, the service and reliability of cooling will be improved, end-users do not have to maintain complex cooling systems, buildings can have improved environmental credentials or certifications, space can be made available on rooftops and in basements (as cooling system would now be outside the building) for solar power, roof terraces, basement leisure centres etc. and buildings would require a smaller power connection, saving money.

The district cooling operator can to an extent lower tariffs for different end-users to ensure their connection if their costs for stand-alone cooling are lower than those presented in Figure 31 above. The district cooling operator and end-user can typically have a dialogue to ensure both agree that district cooling is providing a more cost-effective service. As different building types may be subject to differing electricity tariffs (for example public buildings and residential buildings will pay lower electricity tariffs) such negotiation and flexibility in tariffs is crucial. If RMC has a stake in the district cooling project, or is providing specific incentives, it could influence expansion of the network to include socially and economically important buildings such as new hospitals, schools, campuses, public offices etc.

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

12 Summary and Conclusion

From the high-level analysis conducted in this assessment, it can be concluded that district cooling is commercially viable in Rajkot for well-designed projects and can deliver significant

benefits to the environment, consumers and the local economy. The climate, real estate growth, a high potential smart city area, clear existing impact of cooling demand and a local government willing to show leadership to accelerate district cooling, make Rajkot a high-priority city for demonstrating this technology.

Rajkot should ensure projects are well-designed with a diversity of building types and compact development to ensure the IRR is sufficiently high to attract investors, this is particularly important given the relatively low power prices in Rajkot

Rajkot 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 RMC 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 significant potential in Rajkot, this would be a missed opportunity.

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

13 Recommended Next Steps for RMC

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

Unlocking the Potential for Energy Efficiency and Renewable Energy' which is available online[49].

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

Raiya Area as a demonstration project

- RMC 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 of upcoming Business Park and surrounding area including assessment of renewables, waste heat, smart grid synergies and Treated Sewage Effluent.
- Stakeholder consultations to identify potential business models and develop a procurement plan
- Dependent on the chosen business model, attract funding for a feasibility study (e.g. multi-lateral development banks, state and national-level grants etc.)
- Independent analysis of RMC incentives and policies that can ensure project delivery including provision of low cost solar from Raiya Area PV installations and possibly reduced VAT from the state/national level on chilled water. This will be crucial given the currently analysed low IRR

City-wide actions (short-term)

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

City-wide action (medium-term)

- Establish a 'sustainable energy delivery unit' or include within the Smart City SPV
- Support piloting of innovative district cooling applications, e.g. Thermal Energy Storage (TES), waste heat connections, solar power and Treated Sewage Effluent to reduce water consumption
- Incorporation of district cooling into existing city strategies and targets. Set targets specifically for the district cooling sector (Box 3)
- Apply specific conditions on building permitting in zones through the DCR (Box 4 and Box 6)

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

- Consider developing density bonuses using FSI premium payments in DCR (Box 5)
- Mandate that specific building types are developed as ‘district cooling ready’ beyond existing mandate on hospitals to have centralised cooling (Box 5)
- Use public buildings to anchor new district cooling development (Box 4)
- If required, establish franchise zones or concession areas for district cooling (Box 4)

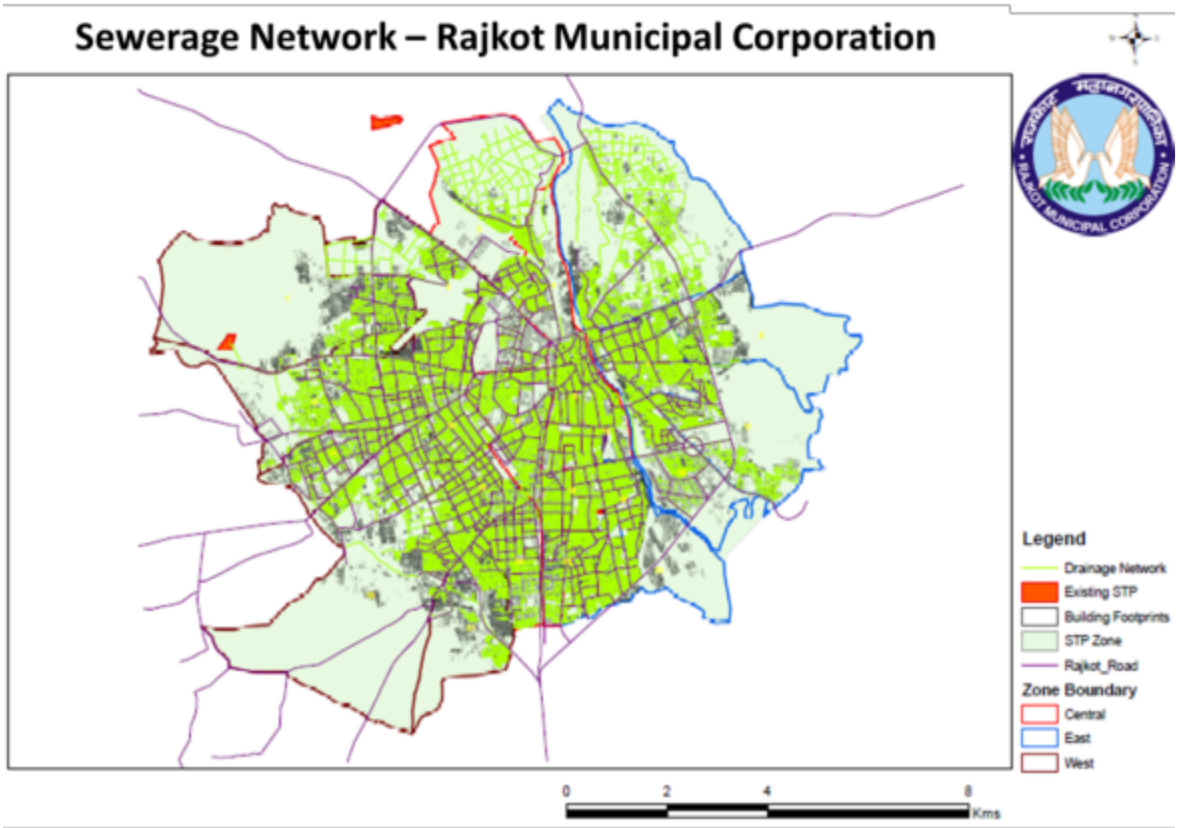
14 Annexures

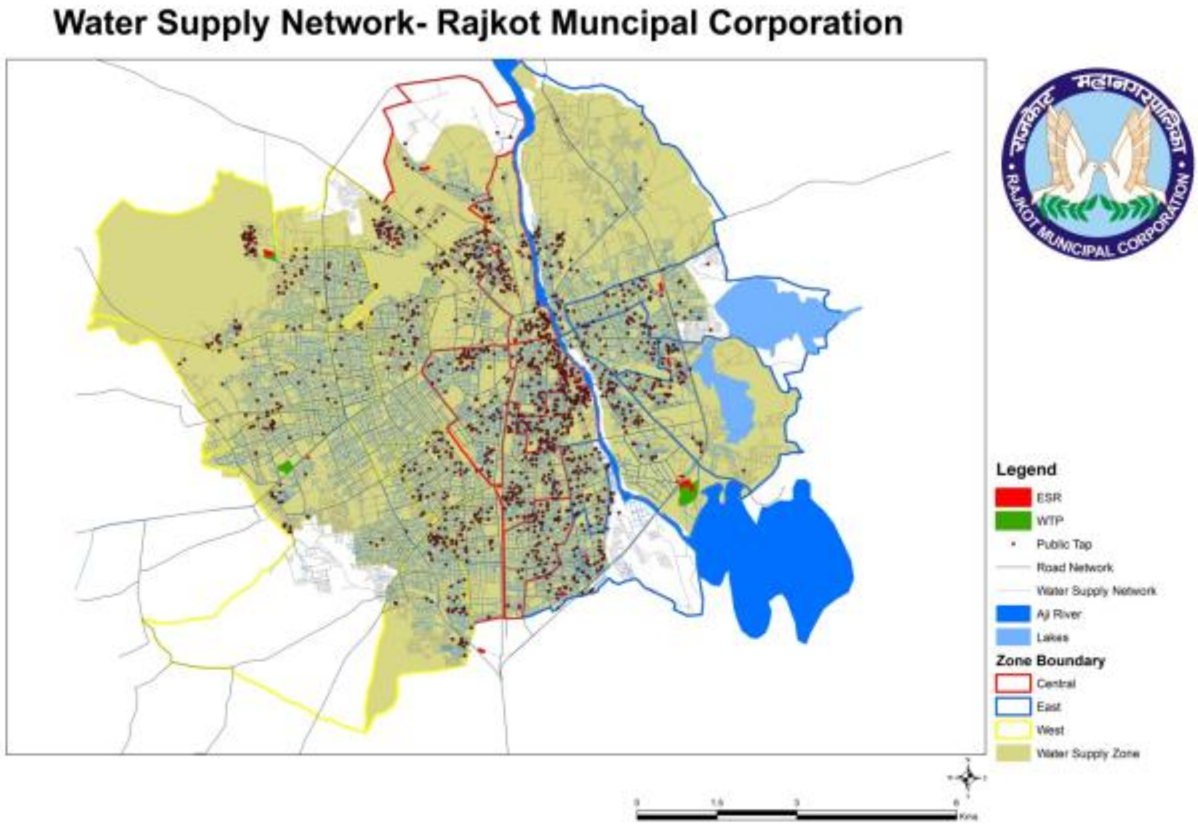
14.1 Ground water quality of Rajkot City

Constituents	Unit	Range
pH		7.09-8.19
EC	(µS/Cm) at 25°C	816-5890
Total Hardness	(mg/l)	110-1580
Total Dissolved Solids	(mg/l)	547-3946
HCO_3^-	(mg/l)	85-1183
Cl^-	(mg/l)	57-1631
SO_4^{--}	(mg/l)	1-453
NO_3^-	(mg/l)	0.8-152
Ca^{++}	(mg/l)	20-476
Mg^{++}	(mg/l)	14-180
Na^+	(mg/l)	45-826
K^+	(mg/l)	0.2-21.0
F^-	(mg/l)	0.0-2.26

Data Source: (Goverment of Gujarat, 2013)

14.2 Utility Mapping, Rajkot





14.3 Power tariff structure applicable in Rajkot

A - Tariff of supply of electricity at Low Tension				
Category	**Day/ Night**	**Charges**	**Tariff**	
Residential (RgPU)		Fixed Charges	Up to and including 2kW	INR 15/- Per month
			Above 2 to 4 kW	INR 25/- Per month
			Above 4 to 6 kW	INR 45/- Per month
			Above 6 kW	INR 70/- Per month
		Energy charges	1st 50 Units	INR 3.15 per Unit
			Next 50 Units	INR 3.60 per Unit
			Next 100 Units	INR 4.25 per Unit
			Next 50 Units	INR 4.35 per Unit
			Above 250 Units	INR 5.30 per Unit
General Lighting Purpose (GLP)		Fixed Charges	INR 70 per month	
		Energy charges	INR 3.90 per unit	
Non-residential (NRGP)	Day	Fixed Charges	1st 10 kW of connected load	INR 50 per kW
			Next 30 kW of connected load	INR 65 per kW

		Energy charges	up to 10 kW of connected : for entire consumption during the month load	INR 4.35 per unit
			Above 10 kW of connected : for entire consumption during the month load	INR 4.65 per unit
	Night	Fixed Charges	50% of fixed charges of NRGP	
		Energy charges	For entire monthly consumption	INR 2.60 per unit
Commercial and Industrial (Low Tension)	Day	Fixed Charges	1st 40 kW of billing demand	INR 90 per kW per month
			Next 20 kW of billing demand	INR 130 per kW per month
			Above 60 kW of billing demand	INR 195 per kW per month
			Billing demand in excess of contracted demand	INR 265 per kW per month
		Energy charges	For entire monthly consumption	INR 4.70 per unit
		Reactive charges	For entire monthly reactive energy drawn	INR 0.10 per KVARH
		Seasonal	Minimum Amount	INR 2970 per kW per annum
			energy charge during off season	INR 4.80 per unit
	Night	Fixed Charges	50% of fixed charges of LTMD	
		Energy charges	For entire monthly consumption	INR 2.50 per unit
		Reactive charges	For entire monthly reactive energy drawn	INR 0.10 per KVARH

B - Tariff of supply of electricity at High Tension				
High Tension (HT)	Day	Fixed Charges	1st 500 kVA of billing demand	INR 130 per kVA per month
			Next 500 kVA of billing demand	INR 240 per kVA per month
			for billing demand above 100 kVA	INR 425 per kVA per month

			for billing demand in excess of contracted demand	INR 505 per kVA per month
		Energy charges	Up to 500 kVA of billing demand	INR 4.35 per unit
			for billing demand above 500 kVA	INR 4.55 per unit
			for billing demand above 1000 kVA	INR 4.65 per unit
		Time of usage charges (peak)	Up to 500 kVA of billing demand	INR 0.45 per unit
			for billing demand above 500 kVA	INR 0.85 per unit
		Seasonal	Minimum amount	INR 4550 per kVA per Annum
			Energy charge during off season	INR 4.65 per unit
	Night	Fixed Charges	1/3rd of the fixed charges of HT	
		Energy charges	For entire consumption	INR 2.40 per unit

Source: (PGVCL, 2015)

14.4 Details of RMC's Funding Sources for Project Implementation

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

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

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

c) Projects on Public Private Partnerships (PPP)

14.5 Details of provision of Rajkot GDCR with regards to energy efficiency and space cooling in buildings

Provisions in Rajkot's GDCR with regards to energy efficiency and space cooling in buildings
For high rise building and for special building like assembly, institutional, industrial storage and hazardous occupancy the following additional information shall be furnished as per the GDCR. Details of building services, air-conditioning system with position or dampers, mechanical ventilation system, electrical services, boilers, gas pipes etc. where provided shall also be furnished.
Green buildings - The Competent Authority shall offer incentives in the rate of chargeable FSI for Green Buildings of up to 5% discount in the total payable amount to any owner or developer, who constructs an Energy Efficient Buildings and produce a certificate from GRIHA or any other Government recognized Institute, showing the green rating received for the building. The owner or developer shall have to apply prior to commencement of the project to GRIHA for the rating certificate and registration. Miscellaneous provisions for Hotels and Hospitals: The building shall preferably be designed as per Energy Conservation Building Code.
Permissible Uses in Basement - parking, safe deposit vault, A.C. Plant, storage other than inflammable material, Sewage Treatment Plan. Adequate opening for ventilation should be provided as directed by Competent Authority. The materials of the construction and fixtures of the cellar should be of fire resisting nature and in case; wood shall be used as structural part of the cellar or any fixtures thereof. The extent of ventilation shall be the same as required by the particular occupancy for which the basement is used. Any deficiency must be made good by resorting to a mechanical system, blowers, exhaust fans, air conditioning system, according to the standards in Part VII Building Services, section I lighting and Ventilation, National Building Code.
For hospitals, where 4.0 or more FSI is granted, centralized HVAC systems have to be compulsorily implemented for ICU, operation theatres & other critical facilities Eco-friendly practices suggested for Hospitals: (a) Sewage Treatment Plant (b) rain water harvesting (c) waste management (d) pollution control method for air, water and light (e) introduction of non CFC equipment for refrigeration and air conditioning
Heating and Air conditioning Any deficiency shall be compensated by use of mechanical system such as blowers, exhaust fans or air conditioning system according to the standards in Part VIII Building Services, Section-I Lighting and Ventilation, National Building Code, and to the satisfaction of the Competent Authority.
Auditorium or cinema halls shall be air-conditioned as per following specifications: 1. Temperature Range- 22 to 26.5 degrees Celsius 2. Change of Air per hour- approximately 10 time`s 3. Relative Humidity- 50 to 60% 4. Fresh Air Requirement- 7.5 cubic feet per metre per person

Source: (Rajkot Urban Development Authority, 2016)

14.6 Information Collected

Table 23: Monthly average Temperature and Relative Humidity, Rajkot 2015

Rajkot Weather Data - IMD , Rajkot Airport Station, 2015				
Month	**Max Temp (^{o}C)**	**Min Temp (^{o}C)**	**Relative Humidity @ 830 IST**	**Relative Humidity @ 1730 IST**
January	27.3	11.4	69.5	34.2
February	32.8	16.3	76	27
March	35	19.6	64.6	25
April	40.3	24.6	73.6	21.2
May	42.1	25.9	72.9	28.5
June	40.6	27.2	74.5	38.6
July	34.5	26.3	83.8	62.6
August	33.3	26.2	86.3	64
September	32.6	23.7	88	65.4
October	36.5	23	74.1	39.6
November	34.5	20.6	72.4	38.3
December	29.7	13.2	67.5	36.3

Data Source: (IMD, Rajkot Airport Station, 2015)

Table 24: Monthly electricity consumption, Rajkot - 2015

Urban Circle Month-wise Electricity Consumption (Million kWh) for year 2015												
er	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
al	36.32	33.93	31.48	39.35	45.89	61.57	59.70	61.37	52.96	57.11	47.81	47.33
na	1.02	0.77	0.79	0.87	1.11	1.09	1.17	1.45	1.44	1.48	1.24	1.04
cia	16.6	16.1	15.4	15.1	18.0	19.1	19.8	18.9	19.6	19.3	17.1	16.4
l	27.0	26.2	25.2	24.7	29.4	31.2	32.2	30.8	32.0	31.5	27.8	26.8
re	0.27	0.12	0.17	0.09	0.12	0.07	0.12	0.07	0.24	0.14	0.22	0.11
l	1.60	1.77	1.66	1.63	1.46	1.38	1.43	1.46	1.49	1.68	1.43	1.72
	29.21	27.71	27.20	25.82	28.34	28.43	29.54	29.70	31.83	28.42	30.71	26.43
	0.04	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.05	0.04	0.00	0.00
tal	112.05	106.62	101.94	107.54	124.34	142.83	143.97	143.75	139.56	139.67	126.29	119.84

Source: (PGVCL, 2016)

14.7 Potential of Lodhika Industrial Estate as Waste Heat Generation Source

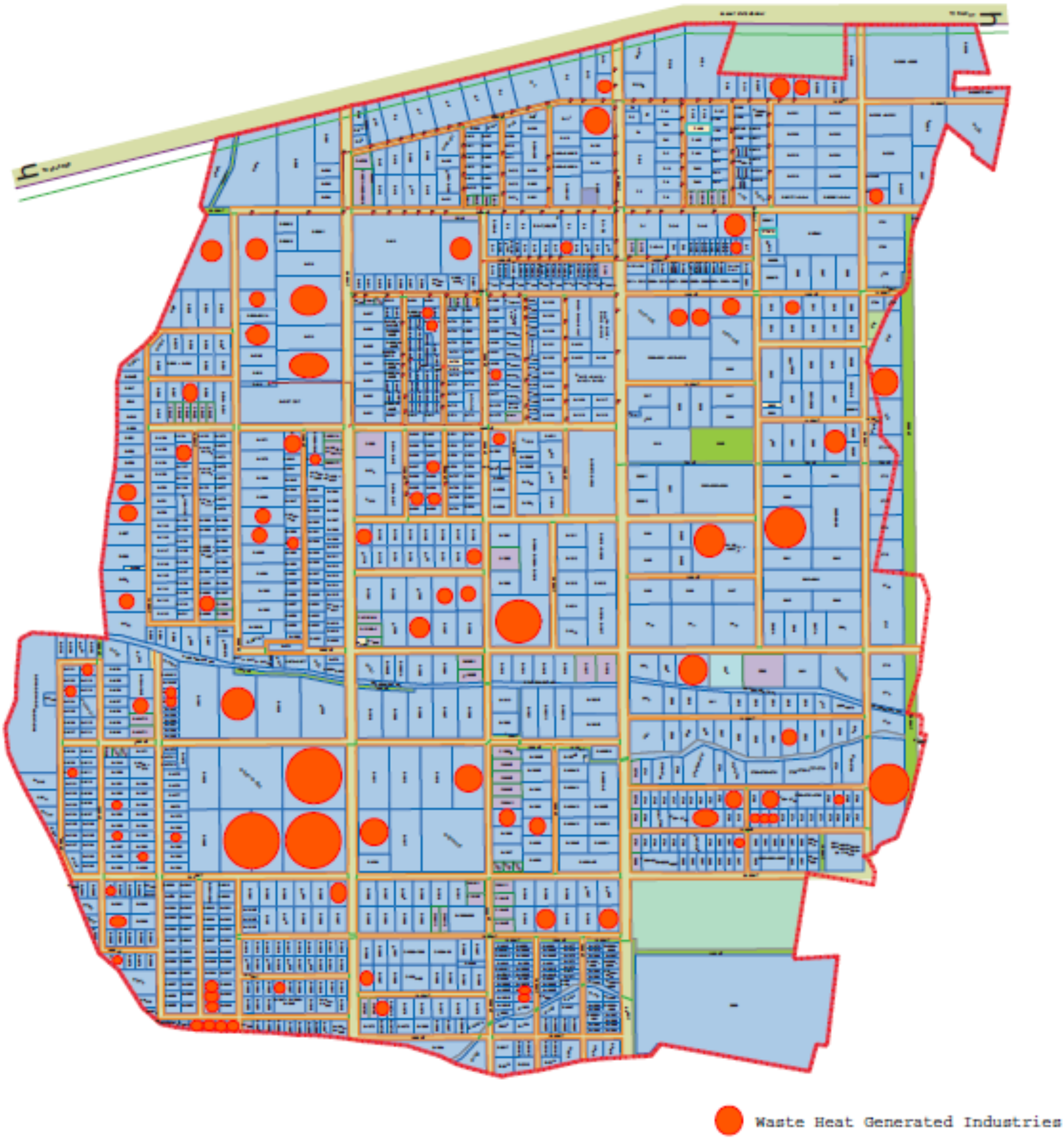
GIDC (Lodhika) Estate, setup by the Gujarat Industrial Development Corporation in 1990, is spread over an area of 424 hectares in close proximity to State Highway No. 23 and 12 kilo-metre from Rajkot city. The estate has 1,500 plots and is fully equipped with planned infrastructural facilities required for the industrial units. There are a total of 1,124 industries in the estate[50], including 56 foundry and 22 forging industries Lodhika Area and details of plots in Lodhika industrial estate is shown in Map-4 below. Lodhika Industrial Estate, and some industries located nearby have availability of waste heat which can be potentially utilized for cooling purposes.

Also, waste to energy plant for food waste generated from estate and sewage treatment plant are in the pipeline for this area, leading to potential opportunities of utilizing biogas and treated waste water for district cooling. Food waste generation from the estate is 1.5 MT per day, which will have biogas generation potential[51] of 82125m3. This biogas can be utilized for DES. Renewable energy can be used for cooling purpose. Also, there is proposal of 3MLD sewage treatment plant in estate, waste water or treated water can be utilized for this purpose.

[50] List of names, contact details, and type of industries is available. It cannot be attached as it is too big.

[51] Biogas yield from food waste is 80 to 200 meter cube per tonne

Figure 38: Plan of Lodhika Industrial Estate



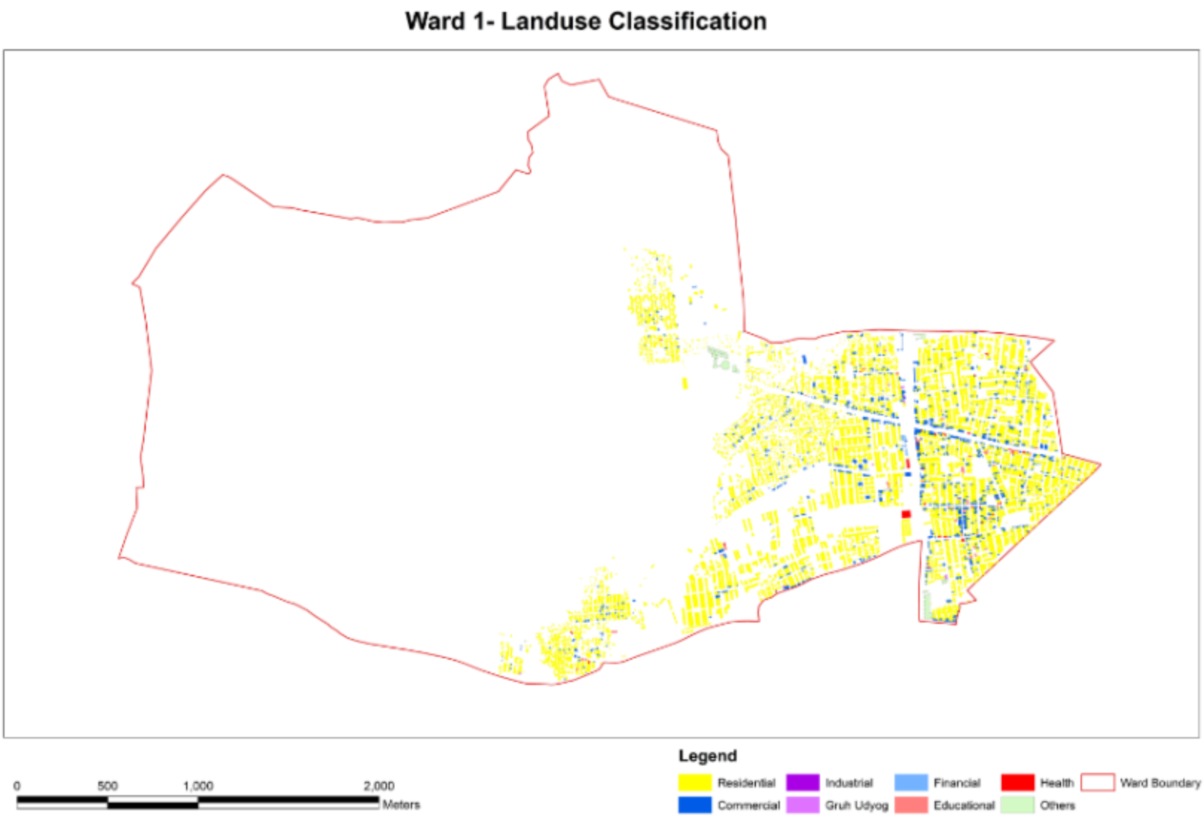
Source: (Gujarat Lodhika Industrial Association, 2015)

There are 56 foundry and 22 forging industries in the Lodhika industrial estate. Heat generated from foundry and forging industries can be utilized for DCS. Typical waste heat temperature from heat treating furnace is 425 to 650^{0}C[52].

[52] WASTE HEAT RECOVERY USING STIRLING ENGINE, 68 IJAET Vol III Issue I 2012

14.8 Further details of Ward 1 and Smart City Area

Figure 39: Land use classification of ward number 1



Source: (RMC, 2015)

14.9 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 25: 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 26: Assumptions of building design parameters

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

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

14.10 Summary of meetings

Rajkot CITY VISIT: November 26-27, 2015

Participants from the Project Team:

- Dr. Parimita Mohanty, CTCN, Coordinator-Asia Pacific, UNEP Regional Office for Asia and the Pacific
- Dr. Usha Rao, Senior Project Manager, KfW, New Delhi
- Mr. Moustapha Assayed, Technical Director, EMPOWER
- Mr. Sanjay Gupta, Sales Manager and DC, India, DANFOSS
- Mr. Ashish Verma, Manager, ICLEI South Asia
- Mr. Nikhil Kolsepatil, Sr. Engineer, ICLEI South Asia
- Ambrish Nasit, Project Associate, ICLEI South Asia

List of meetings conducted

- Meeting with Mr. Vijay Nehra, Municipal Commissioner,RMC
- Meeting with Mr. Sagathiya, Chief Town Planner & Mr. Dethariya, Executive Engineer (Lighting), RMC
- Meeting with Mr. J. J Gandhi, Paschim Gujarat Vij Company Limited (PGVCL)
- Visit to the 150 feet Ring Road, Rajkot
- Meeting with Mr. Nilesh Sheth & Mr. Sujit Udani, Builders Association
- Meeting with Mr.Vimal Monapara, Mr. Patel & Mr. Antala, Rajkot Engineering Association
- Visit De-briefing with Municipal Commissioner, RMC

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

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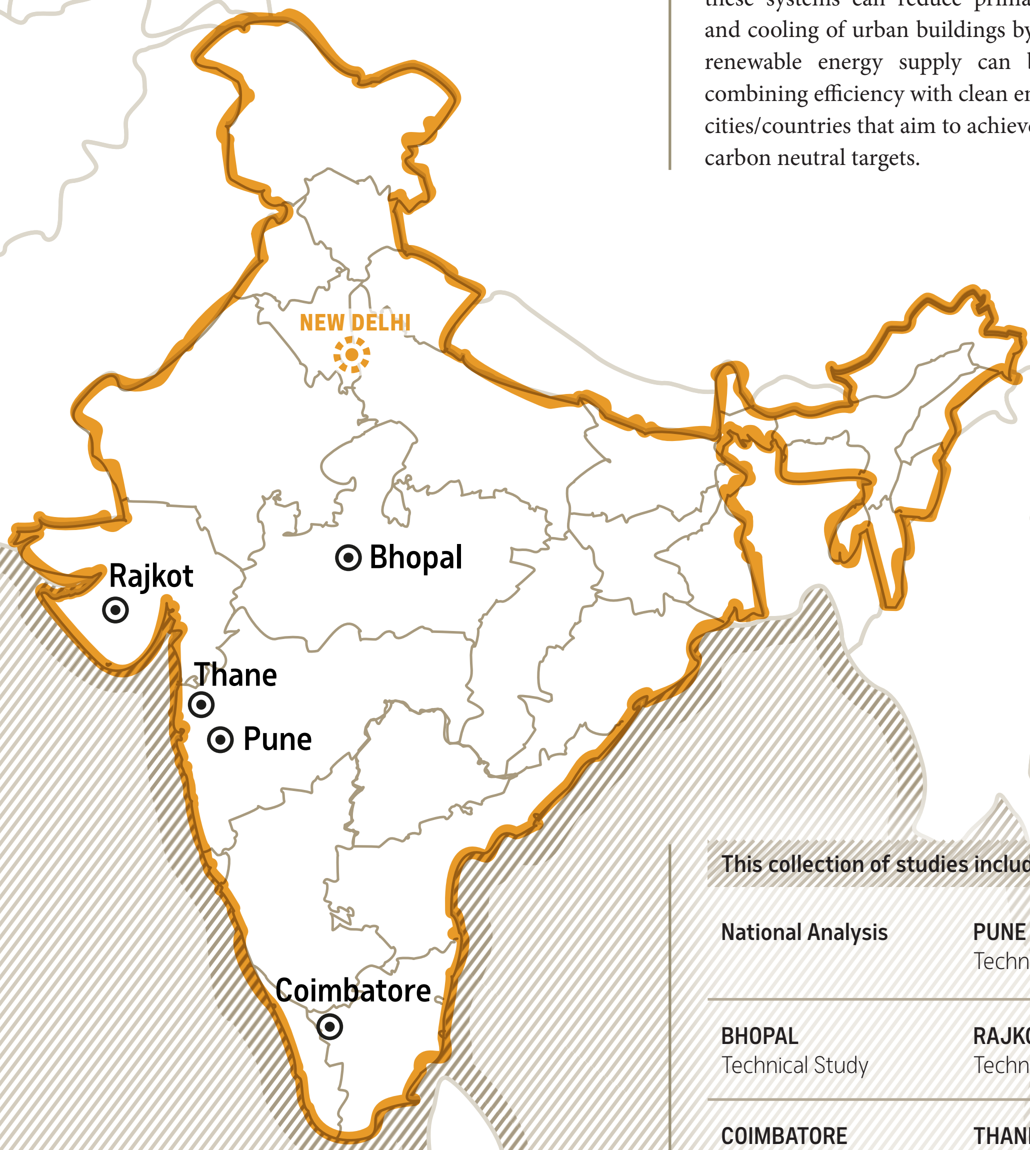
RAPID ASSESSMENTS OF FIVE INDIAN CITIES

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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