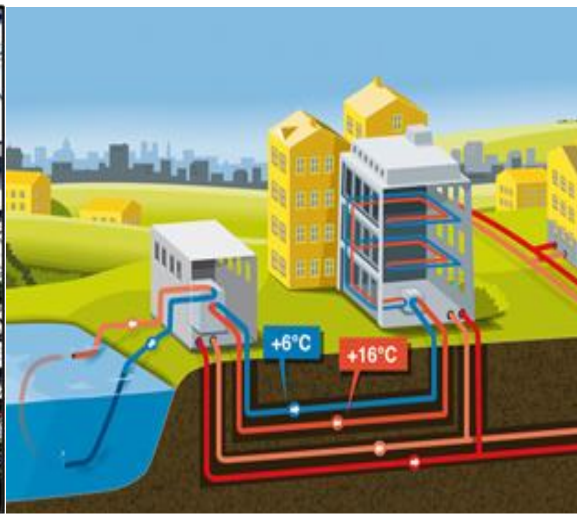

City Gas and District Cooling in India

Status and Development Potential

Prepared for
Asian Development Bank

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Abbreviations

ADB	Asian Development Bank
BAU	Business as usual
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CIC	Community Interest Company
CII	Confederation of Indian Industries
COP	Coefficient of Performance
DCS	District Cooling System
EER	Energy Efficiency Ratio
EESL	Energy Efficiency Services Limited
ESCO	Energy Saving Company
EWS	Economically Weaker Section
FDI	Foreign Direct Investment
FICCI	Federation of Indian Chambers of Commerce and Industry
GDP	Gross Domestic Product
GIFT-City	Gujarat International Finance Tec-City
HDV	Heavy Duty Vehicle
HVAC	Heating, Ventilation, and Air-Conditioning
ICAP	India Cooling Action Plan
IDA	International Development Agencies
IEA	International Energy Agency
IFSC	International Finance Service Centre
ISHRAE	Indian Society of Heating, Ventilation, and Air Conditioning
JV	Joint Venture
kWh	kilowatt hour
LDV	Light Duty Vehicle
LIG	Low-Income Group
LWAC	Lake Water Air-conditioning
MMSCMD	Million Metric Standard Cubic Meter per Day
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoP	Ministry of Power
MoPNG	Ministry of Petroleum and Natural Gas
MRV	Monitoring, Reporting and Verification
Mtoe	Millions of tonnes of oil equivalent
PFC	Power Finance Corporation
PSU	Public Sector Undertaking
R&D	Research & Development
ROI	Return on Investment
RoU	Right of Use Acquisition
SDA	State Designated Agency
SDG	Sustainable Development Goal
SEZ	Special Economic Zone

SI	System Integrator
SPV	Special Purpose Vehicle
SWAC	Seawater Air-conditioning
TP	Technology Provider
TR	Tonnes of Refrigeration
TWh	Terawatt Hour
ULB	Urban Local Bodies
UNEP	United Nations Environment Programme
USD	US Dollar
VRF	Variable Refrigerant Flow

Chapter 1: Rationale

1.1 Sectoral Demand Analysis of Cooling in India

India is a sub-tropical country and has very hot summers, humid rainy seasons and mild winters. India is developing at a rapid pace. This is evident in rapid urbanization and economic growth. An increase in purchasing power capacity and developments in the technological field have reduced the cost and have increased penetration of technology in the world. Urbanization and growth in the service sector have led to the construction of huge malls, many residential spaces, corporate offices, etc.

To ensure good health and wellbeing of people residing in these spaces and to combat hot summers, large air conditioners and chillers have been installed and are being used in these buildings. It has been observed that there is a direct correlation between cooling demands versus development. A huge amount of energy is consumed in the purview of cooling requirements.

Data has been collected from different countries in terms of per capita energy consumption in 2017-18. Per capita, energy consumption in India was observed to be 69kWh as compared to 272kWh of the world average. For the United States, it is 1878 KWh, which is 27 times higher than that of India. This also depicts the need for cooling requirements in India, which will grow tremendously with the increase in Indian economic development.

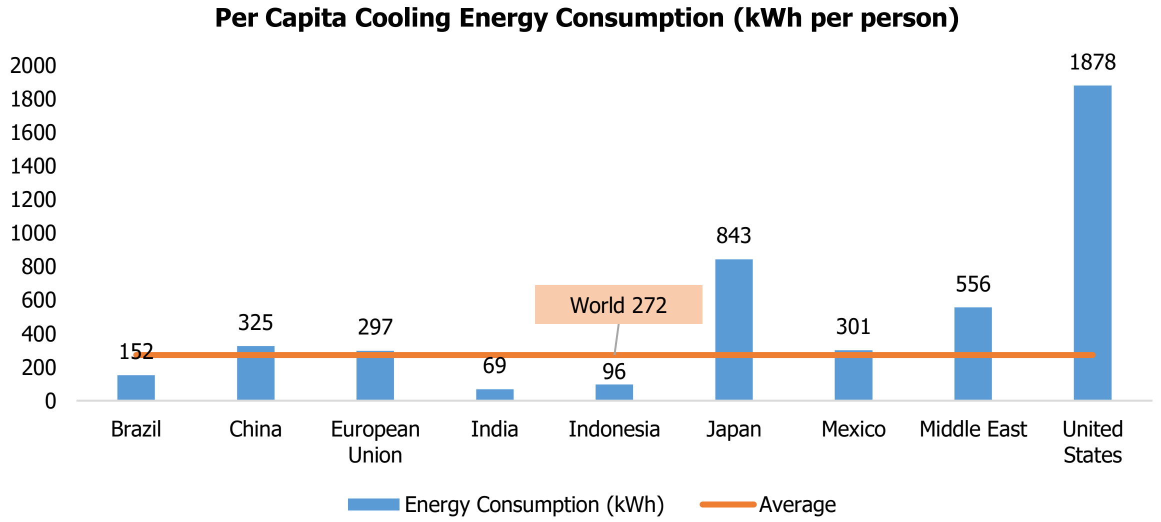


Figure 1: Per Capita Cooling Energy Consumption (kWh per person)[1]

There are five different sectors in general (also, identified by the Indo German Energy Forum – IGEF) that requires cooling energy for their daily functioning, which are:

1. Space cooling in buildings – Air conditioners, chiller systems, VRF (variable refrigerant flow) systems, Fan and air cooler
2. Mobile Air Conditioning – Passenger Light Duty Vehicle (LDV), Passenger Heavy Duty Vehicle (HDV) and railway
3. Refrigeration – Domestic type refrigerator, vending machine, water cooler, super/hypermarket system
4. Cold chain – Cold storage, packhouse, ripening chamber

[1] http://www.indiaenvironmentportal.org.in/files/file/DRAFT-India%20Cooling%20Action%20Plan.pdf

5. Industrial Process Cooling – Industrial air conditioning, process, and milk chiller

As per a recently published report, total cooling energy demand for India was found to be 59.8 Mtoe in 2017. Cooling energy demand is expected to grow by 3.1 times to 131.9 Mtoe in 2027. Please refer to the table shown below.

Annual Energy Consumption (Mtoe)				
Sectors	**2017 (Actual)**	**2027 (Estimated)**	**Increase in Consumption**	**% of Total Increase**
Space Cooling in Buildings	33.8	75.6	41.80	58%
Mobile Air Conditioning	3	5.5	2.50	3%
Refrigeration	17.8	32.5	14.70	20%
Cold Chain	1.2	3	1.80	2%
Industrial Process Cooling	4.1	15.3	11.20	16%
Total	**59.8**	**131.9**	**72.1**	**100%**

Table 1 Cooling requirement of different sectors

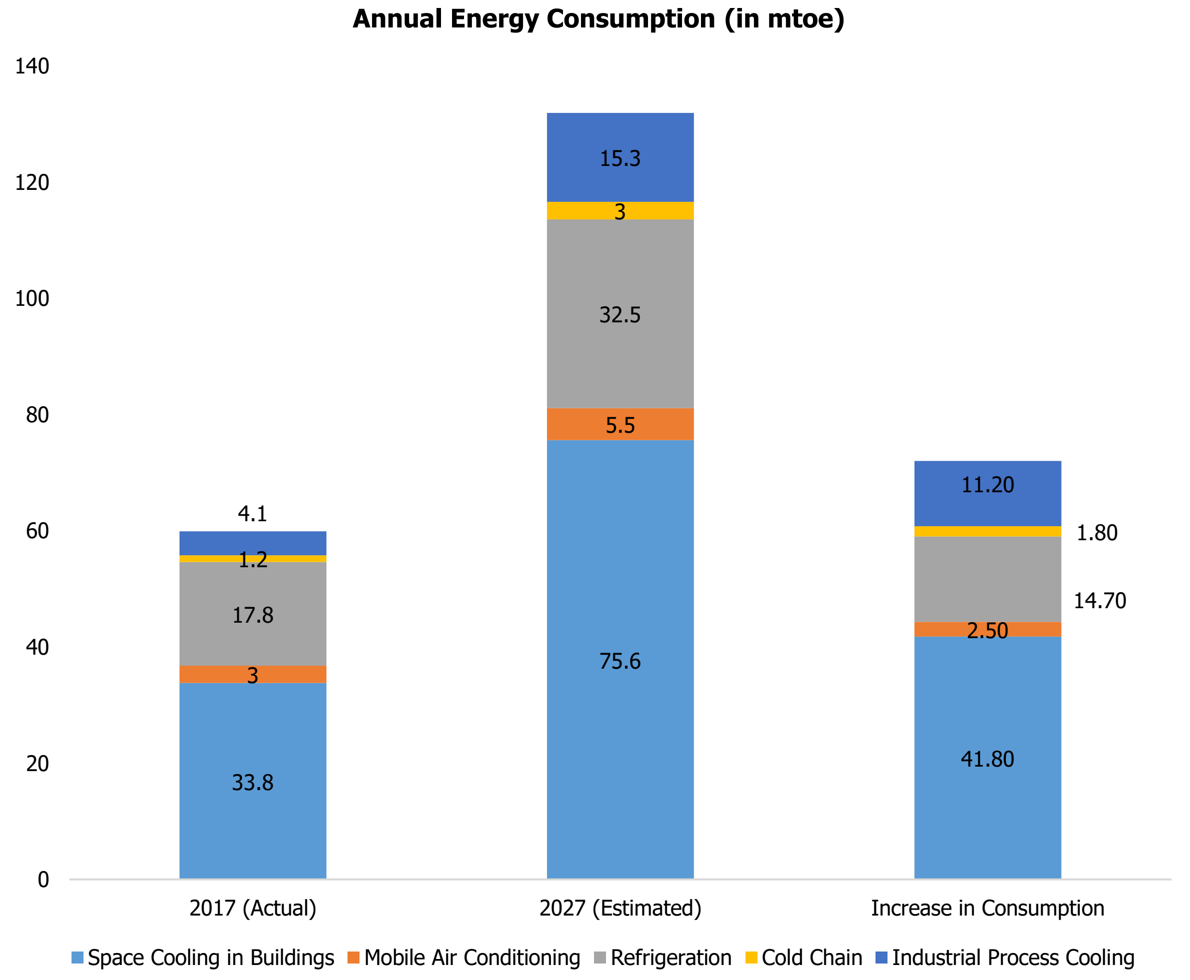


Figure 2: Cooling demand requirement for different sectors

Observation: Major cooling demand is by buildings, which is 56% of the total cooling energy requirement. 29% cooling requirement is from refrigeration sectors, such as refrigerators and water coolers. It has been estimated that of the total increase in the cooling requirement, space cooling plays a pivot role – contributing 58% of the total increase.

1.2 Context to New Technology Need/ Intervention

It has already been mentioned that India's expected cooling requirement will grow by 2.2 times to 3.1 times in 2027 and by 8 times in 2037-28. Building sector cooling demand will have a maximum growth of 11 times that of today. [2]

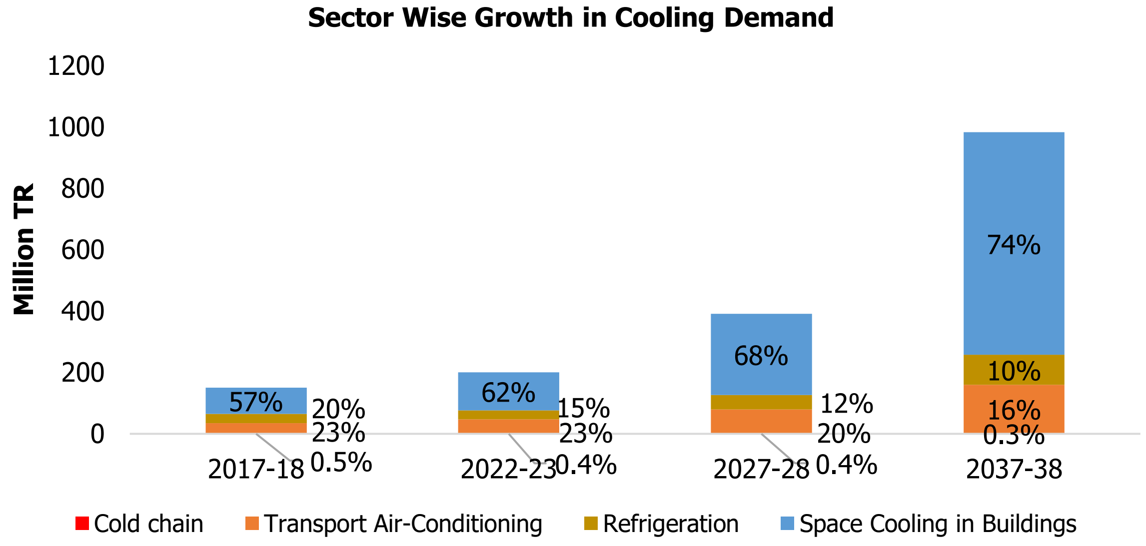


Figure 3: Sector-wise growth in Cooling Demand

The importance of cooling in space building and its linkage to good health and wellbeing and a decent working environment can be easily figured out by its linkage with **Sustainable Development Goal #3**. As urbanization is increasing and new businesses are coming up, so is the requirement of maintaining decent working conditions to facilitate people and increase their efficiency.

India is very much behind in terms of per capita cooling energy consumption. India is the second largest most populous country and it is developing very fast. Keeping the two things into consideration, it is almost obvious to say that cooling demand is going to increase unprecedentedly as compared to other countries. Also, because of India's location nearer to the equator, it faces mostly hot summers. This can be seen using the picture attached below.

[2] http://www.indiaenvironmentportal.org.in/files/file/DRAFT-India%20Cooling%20Action%20Plan.pdf

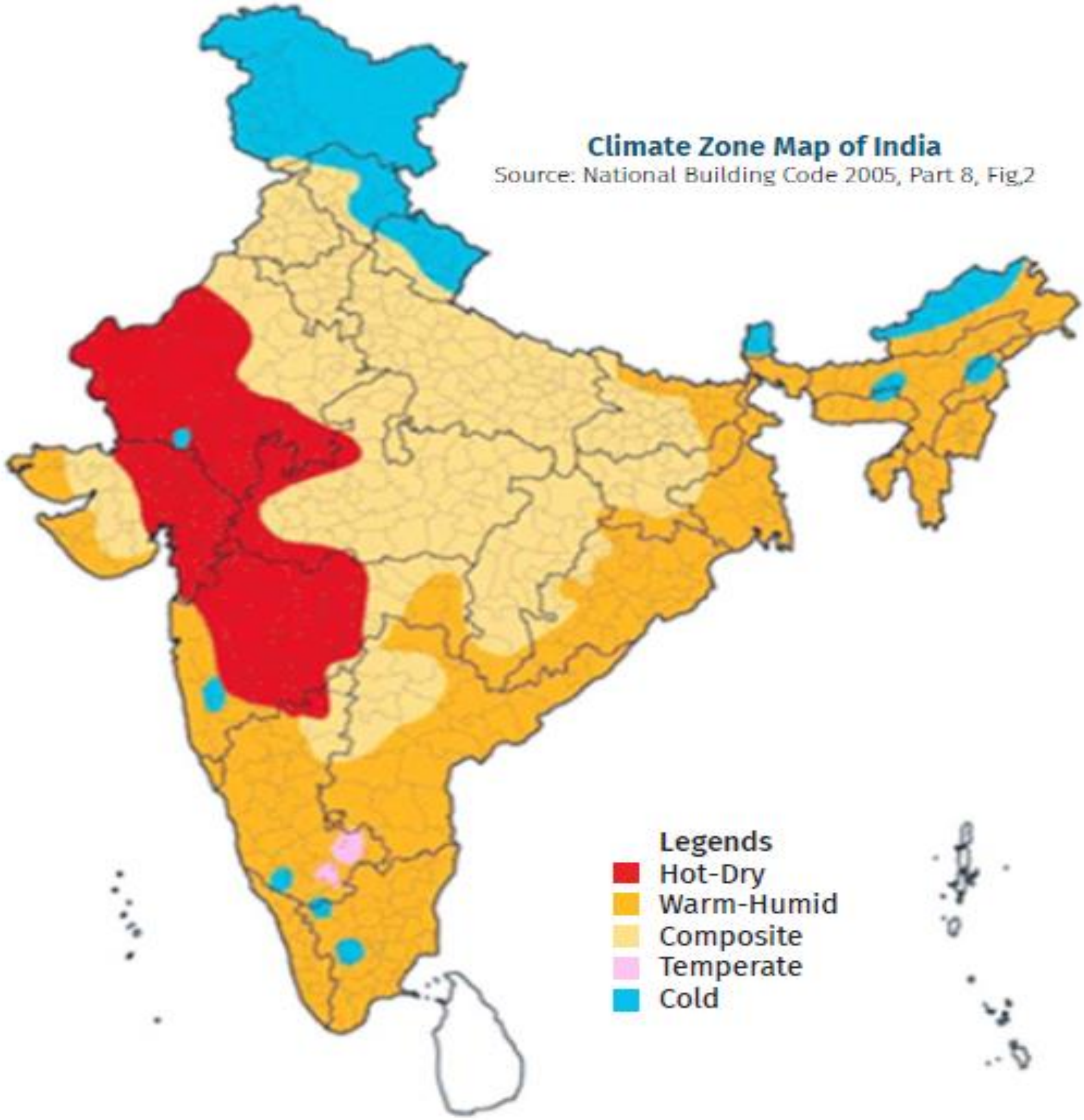


Figure 4: Climate Zone map of India[3]

Observation: We can observe here that west and southwest India faces are hotter than other parts of India. So, the cooling requirement in these regions will be higher as compared to other parts of India. To maintain an optimum working environment there are already some existing and most used cooling technologies present. These are:

Room air conditioner: This is mostly used in residential buildings. Effectiveness of one air conditioner is limited to only one room, hence the name room air conditioner.

Chiller System: This is mostly used in commercial buildings, where centralized cooling takes place using an effective heat exchanger process of water and air. The system comprises of chiller water pumps, cooling tower fans, air handling unit and heat exchanger.

Variable Refrigerant Flow (VRF) System: This system is used mostly in medium-sized commercial buildings and high-income group residential units, having varying exposure and

[3] http://www.indiaenvironmentportal.org.in/files/file/DRAFT-India%20Cooling%20Action%20Plan.pdf

cooling loads. Ease of operation and quick installation makes it a preferable choice. The variable cooling capacity of this system makes it preferable in terms of energy saving.
Packaged DX: These are large air compressors, mostly installed at the rooftop of buildings. These are effective for cooling small commercial buildings.

District Cooling: These systems require about 15% less capacity than conventional distributed cooling systems for the same cooling loads die to load diversity and flexibility in capacity design and installation. High initial investment, design and favorable financial supports are key challenges.

1.3 Potential of District Cooling and City Gas (distribution) in India[4]

District Cooling has two major requirements:

1. **Energy to run chiller plants and compressors** – which may be natural gas or electricity. For our study, we are restricting ourselves to city gas or natural gas.

2. **Water availability** – which will act as a medium of heat absorbent, during heat exchange process water will be via evaporation. Make-up water will be required to sustain the cooling process.

First, we need to go through the current gas distribution network available in India and what is the current supply and demand for natural gas.

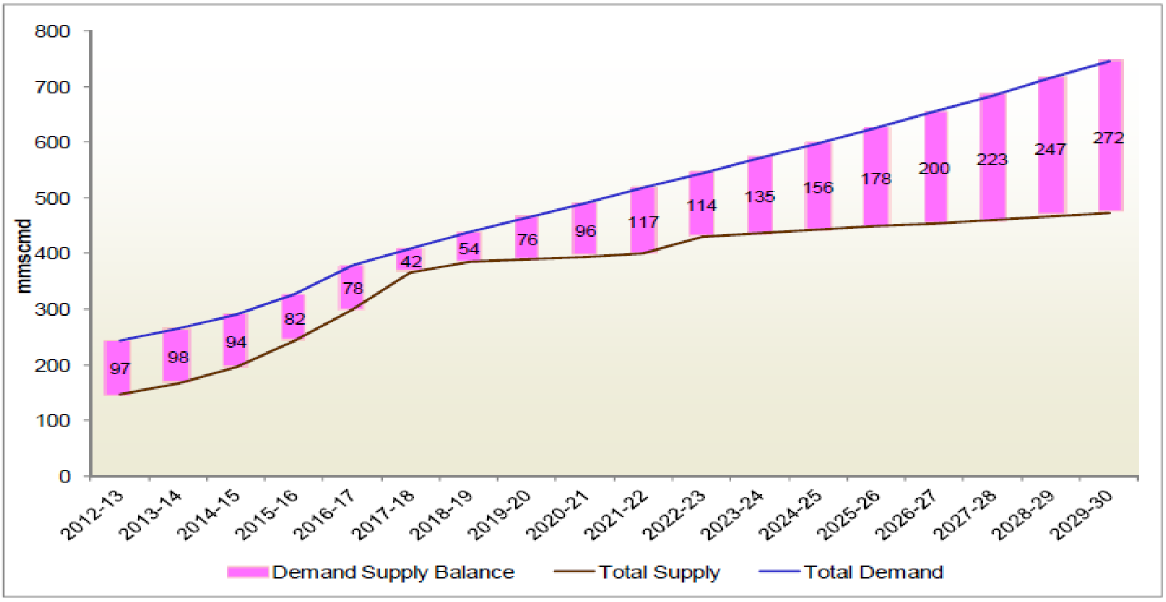


Figure 5: Demand-Supply balance of natural gas from 2012-12 to 2029-30

The gap between demand and supply of natural gas is increasing and is expected to rise from 42 MMSCMD (Million Metric Standard Cubic Meter per Day) to 272 MMSCMD in 2029-30.

[4] https://www.pngrb.gov.in/Hindi-Website/pdf/vision-NGPV-2030-06092013.pdf

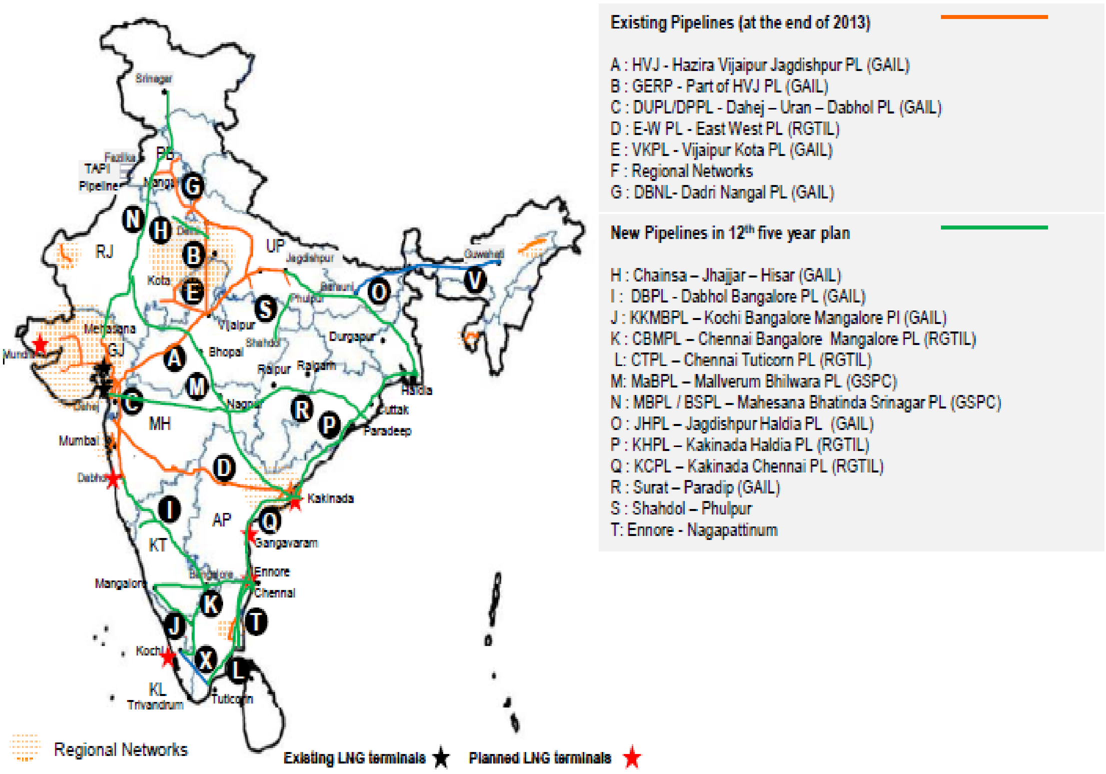
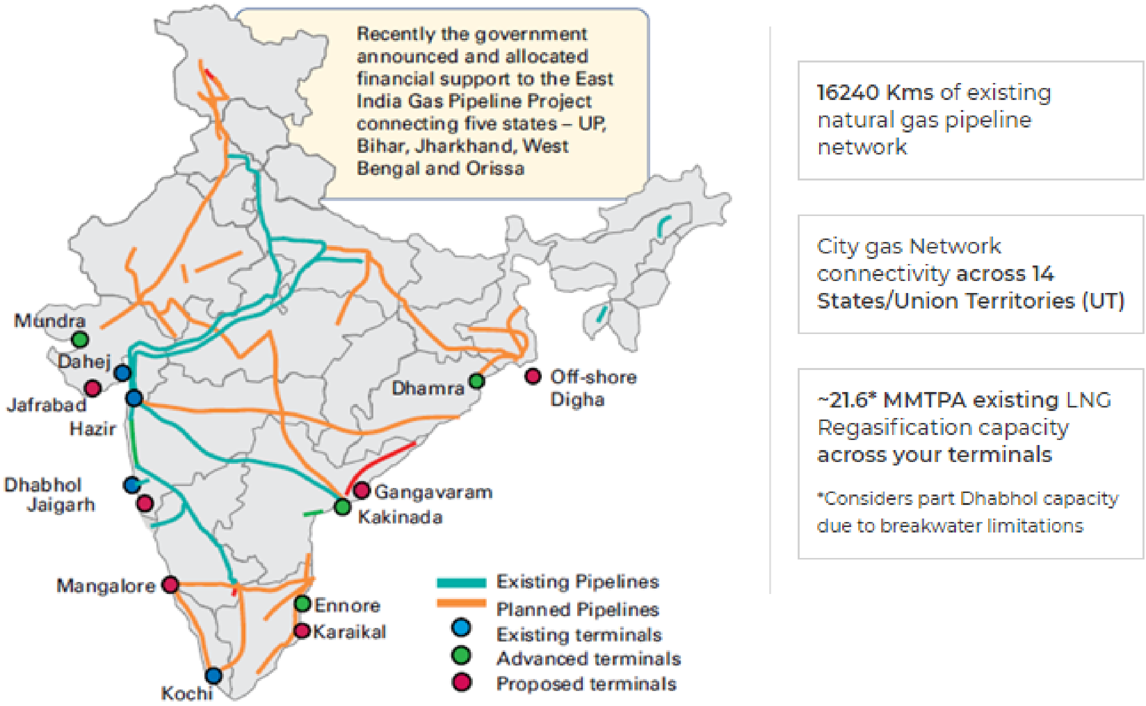


Figure 6: Gas transmission network in India at the end of the 12th five-year plan



Source: enincon research, PNGRB, PPAC, KPMG

Figure 7: City Gas Distribution Network in India, 2017[5]

[5] https://eninconperspectives.com/city-gas-distribution-market-in-india-analysing-current-status-and-infrastructure-requirement-for-strengthening-cgd-network-in-india/

Observation: The Gas network is mostly distributed across central and south India.

Observation: Using water tool, we can further trace the locations to find out which area, district cooling technology can be applied. In the South West and Northern area of India, near Punjab and Haryana – there is decent water availability.

Based on the three observations – heat map, gas network, and water availability, we can deduce that southwest India has the maximum potential to start with District Cooling projects.

India Water Tool[6]

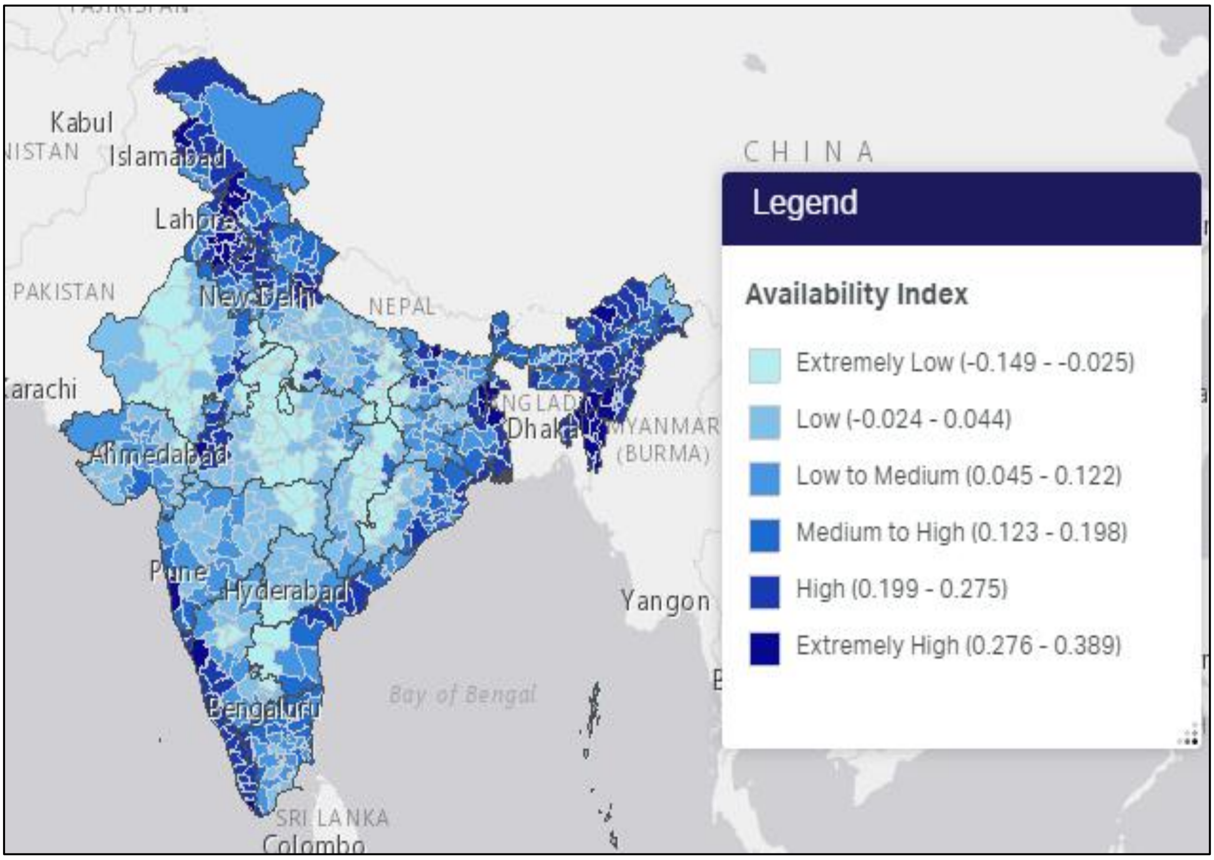


Figure 8: India Water Tool

[6] https://www.indiawatertool.in/

Chapter 2: Introduction to District Cooling

2.1 District Cooling: Definition, Benefits, and Requirements

District cooling refers to centralized production and distribution of cooling energy. Chilled water is delivered via underground insulated pipelines to different buildings, where heat exchangers are installed. These heat exchangers extract heat from the hot air of buildings, cooling it and then recirculate cold air inside the building. The heated water returns to the centralized chiller, where water is cooled again either using compressors or through cooling towers.[7]

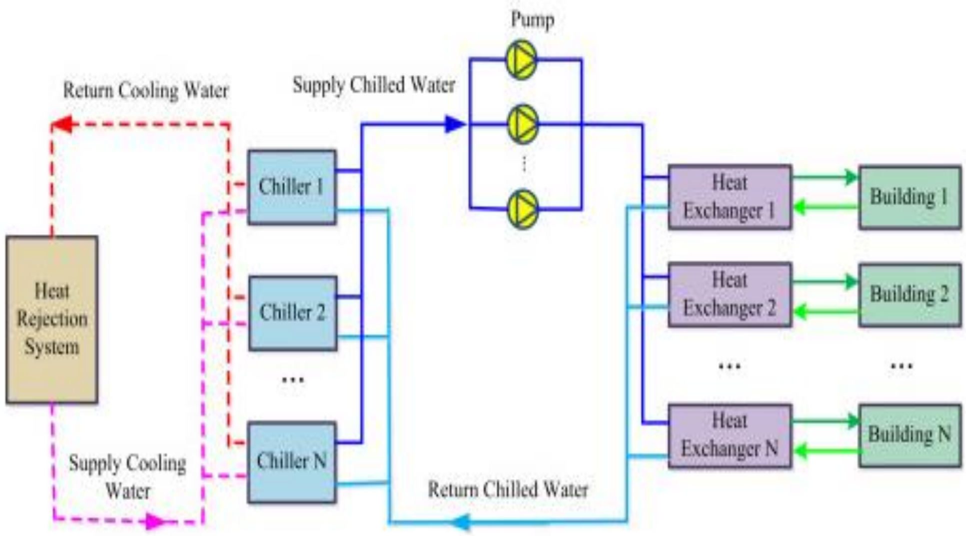


Figure 9: Typical design of a District Cooling System[8]

Benefits: [9]

- DC systems consume 40 to 50% less energy as compared to conventional cooling
- DC systems typically require 15% less capacity than conventional distributed cooling systems due to aggregation of cooling requirements in one place.
- Aggregation of cooling equipment at one place operation and maintenance cost.
- Using thermal storage capability in district cooling can smooth out power requirements in peak hours, helping in reducing strain on power networks during day time.
- District Cooling system can be easily integrated with renewable energies – such as solar energy during day time and the natural process of cooling water batteries – during the night.

Requirements: [10]

Space cooling has a direct linkage with good health and wellbeing (SDG 3), smart and sustainable cities (SDG 11) and economic development (SDG 8). Other than this, it is anticipated that the cooling requirement in buildings will grow by 11 times between 2018 and 2038. By 2050, International Energy Agency has forecasted that India will become the largest

[7] http://empower.ae/php/what-is-district-cooling.php?id=1
[8] https://www.sciencedirect.com/science/article/pii/S1364032115009144
[9] https://www.aeee.in/wp-content/uploads/2018/10/Demand-Analysis-for-Cooling-by-Sector-in-India-in-20271.pdf
[10] http://www.districtenergyinitiative.org/india

consumer of space cooling in the world and will be consuming 28% of total electricity and during peak loads cooling energy requirement will be 44%.

2.2 History and Present Market Situation

International Energy Agency has forecasted that India is likely to be the largest consumer of space cooling in the world by 2050. This demand for cooling will be concentrated in India's rapidly growing cities. Space cooling will be responsible for 28% of electricity demand and 44% of peak load. Electricity is still powered by thermal plants. An increase in electricity demand will result to increase in emissions and local air pollution. [11]

United Nations Environment Programme (UNEP) has launched District Energy in Cities Initiative to replicate and scale up best practices of District heating and cooling worldwide.[12] This Initiative has partnered with Energy Efficiency Service Limited (EESL) as the national coordinator of the Initiative in India.

The above-said Initiative has formed a National Project Steering Committee to guide the Initiative's work and ensure that District Cooling Projects are executed at a faster pace. In November 2017 five cities were assessed as market potentials for District Cooling – Bhopal, Coimbatore, Pune, Rajkot and Thane.

A feasibility study has already been carried out in Thane district. It is estimated that the estimated peak cooling demand is 10,180 TR and the annual cooling energy requirement is 18789 MWh. Partners involved in this project are EESL, ICLEI South Asia, the International Finance Corporation and the Carbon Trust.

In 2015, Rajkot signed-up to UN Environment's newly established District Energy in Cities Initiative. There is a plan of a 49-million-dollar district cooling project with 32,000TR capacity.

In Amaravati, there is a plan to develop a District Cooling project that can handle 20,000 TR of cooling load. In February 2019, the tender has been awarded to Tabreed. In Amaravati, a public-private partnership model is being developed that will cater to identification and connection of priority zones for district cooling – which includes mandatory connection of public buildings.

In GIFT City, Gandhinagar Gujarat, 10,000 TR District Cooling Project is coming up. It is being developed on 886 acres (359 hectares) of land comprising of a multi-service Special Economic Zone (SEZ) with IFSC (International Finance Service Centre) and a domestic finance center.

2.3 Introduction to Different Available District Cooling Systems

2.3.1 Heat exchange takes place using seawater

Seawater becomes a source of cold water. Hot water from the building flows directly into seawater. This type of cooling is feasible only at locations closer to sea or water bodies.

Real-life application: District Cooling in the city of Copenhagen uses a cooling supply from the sea.[13] The temperature of the water in Copenhagen Harbour is cold, temperature ranging

[11] http://www.districtenergyinitiative.org/india
[12] https://www.unenvironment.org/news-and-stories/story/district-energy-secret-weapon-climate-action-and-human-health
[13] https://www.forbes.com/sites/justingerdes/2012/10/24/copenhagens-seawater-cooling-delivers-energy-and-carbon-savings/#73434e774245

between 5.5 degree Celsius and 11.5 degree Celsius. It is estimated that every degree saved by pre-cooling with seawater saves 15% on electricity at the chiller.

Below is the water flow diagram of a similar kind of District Cooling System.

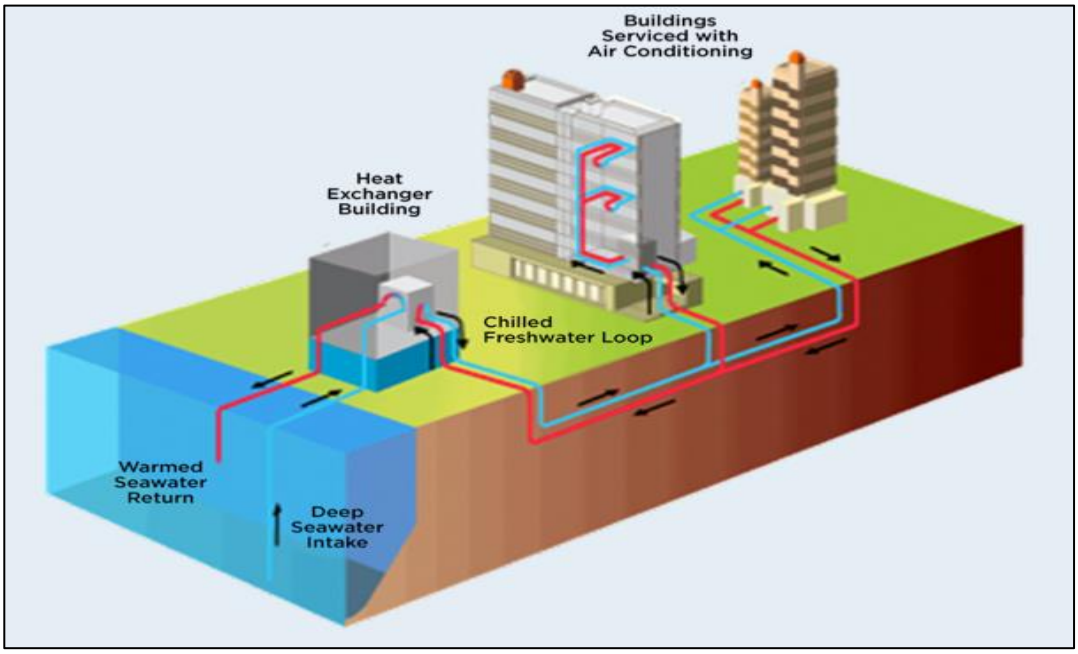


Figure 10: Use of Seawater or lake water for District Cooling[14]

Benefits of using seawater or lake water:

- Reduces emission by 80 to 90%
- Provides an endless supply of cool ocean water throughout the year
- Reduces reliance on fossil fuels, used in operating cooling towers for cooling heated water

2.3.2 Closed-loop system of a water circuit

Water circulates and recirculates along the pipelines. In this case, water is cooled using cooling towers.

[14] https://otecorporation.com/swac-2/

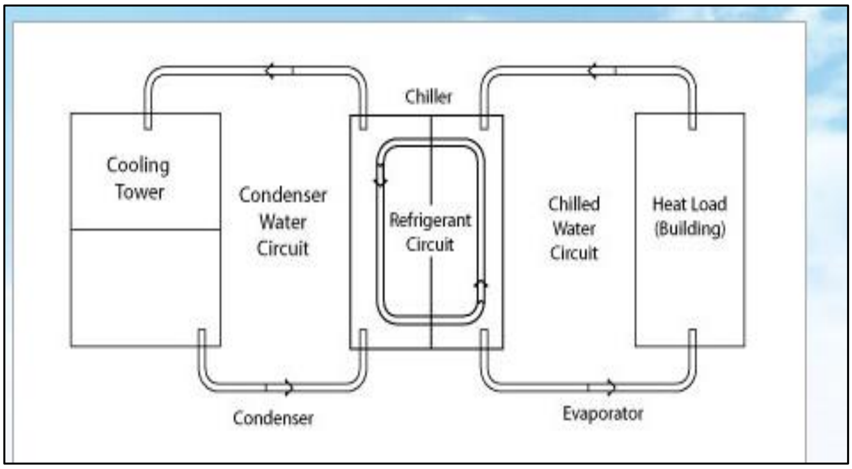


Figure 11: Chiller Loop with a Cooling Tower15

Water lost during evaporation needs to be added continuously. For 1 degree drop in temperature leads to evaporation of 0.2% of the total mass of water flowing through the cooling tower. [16]

<u>Real-life application</u>: District Cooling System at Gift City developed by the Government of Gujarat through a joint venture company named Gujarat International Finance Tec-City Company Limited. It has been developed on 886 acres of land. The central cooling plant consists of a chilled water plant, cooling towers with condensed water pump. The distribution network consists of insulated chilled water supply and returns pipes to prevent heat loss. [17]

2.3.3 Thermal Energy Storage system for District Cooling

To offset peak load during the daytime in summers, this storage concept has been developed. During off-peak times, for example at night, when the cooling requirement is low and the tariff rate is also low, the electricity can be used to cool the storage tank filled with water. This chilled water can be used in the daytime along with chiller cooled water to improve the overall efficiency of the chilled water circuit. Please refer to the image below for more details.

[15] http://www.baltimoreaircoil.com/english/products/closed-circuit-cooling-towers
[16] https://www.youtube.com/watch?v=0BBvt11r7Bw
[17] https://www.rehva.eu/rehva-journal/chapter/indias-first-district-cooling-system-at-gift-city

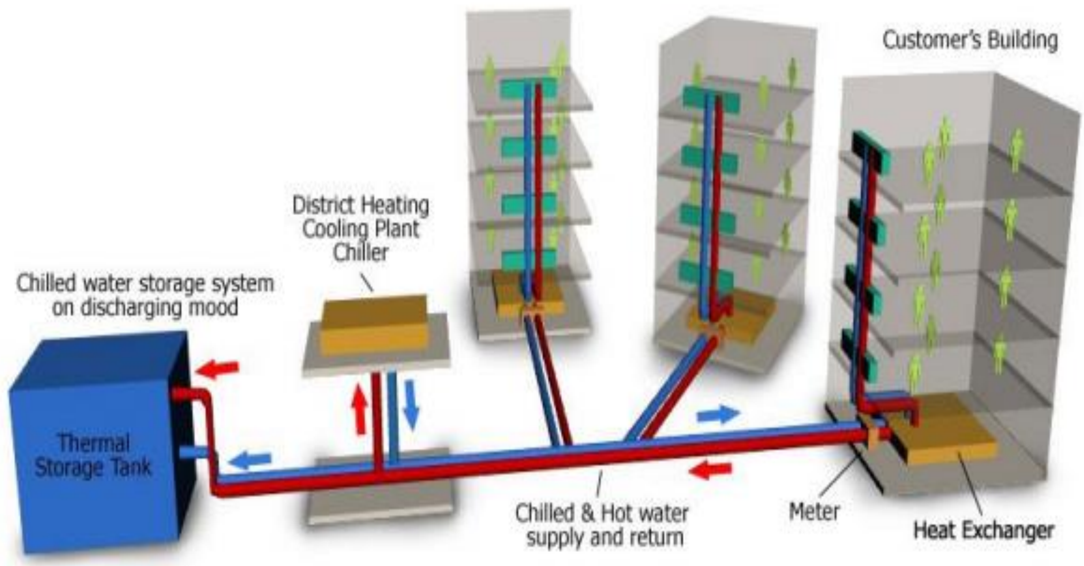


Figure 12: International Energy Administration (IEA) District Heating Cooling[18]

Real-life application: Ice storages being used in Chicago (District Energy Editorial, 2012), Paris (Schmid, 2007), and Yokohama (MM21DHC, 2013).

2.3.4 Hybrid System including thermally driven chillers:[19]

This is all about combining waste heat/renewable heat with cooling applications in the form of thermally driven chillers. Waste heat can be used to produce steam, and which can be used to run turbines. Similarly, renewable electricity can be used to run chiller pumps.

The working principle of the cooling system driven by solar thermal technology is that it converts solar radiation into heat energy. This heat energy is used to generate the required cooling by using it in thermally driven absorption chiller machines. [20]

[18] https://www.adb.org/sites/default/files/publication/222626/district-cooling-prc.pdf
[19] https://www.sciencedirect.com/topics/engineering/district-cooling-system
[20] https://reader.elsevier.com/reader/sd/pii/S1364032119301649?token=725BC8DA71EF62C29AECA084C8596FEEFFD36E4CC8963B013BB98C3C5C3126BFD54BE6924D79077F05E8F226682442BD

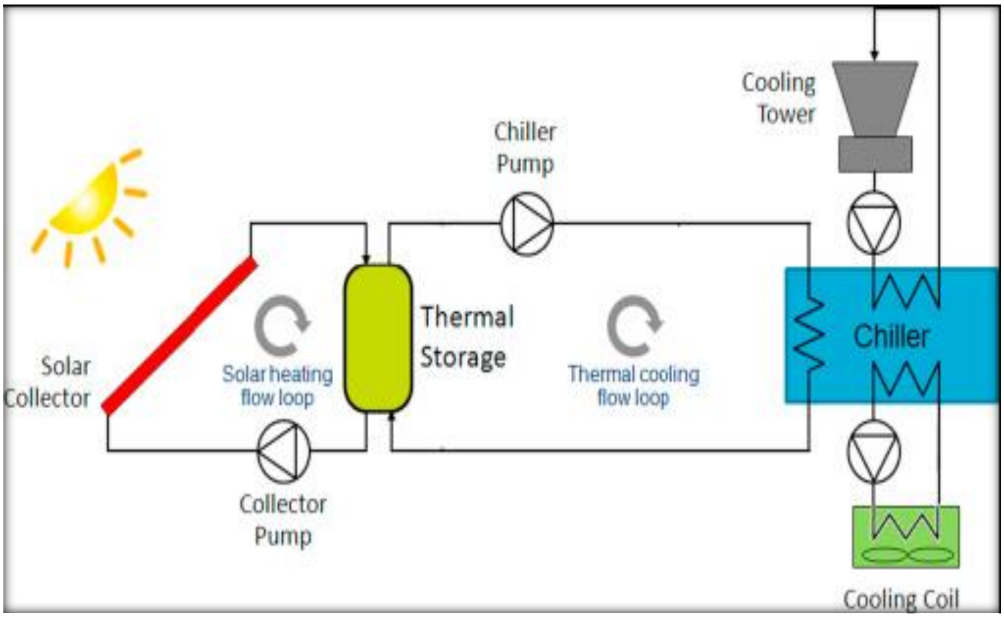


Figure 13: Thermally driven absorption chiller machines

This generic solar thermal cooling system consists of two flow loops separated by the hot thermal storage component. A solar heating flow loop conveys heat from solar thermal collectors to the thermal store. A thermal cooling flow loop conveys heat from the thermal store to the thermal cooling device. When the heat arriving from the collectors exceeds the heat being consumed by the thermal cooling device, then the thermal store is charged. Conversely, when the demand for heat to the thermal cooling device exceeds the supplied solar heat, the thermal store is discharged to match demand. [21]

There are some other locations in the world where District Cooling, in general, has already been implemented:

- Tabreed projects in Abu Dhabi. Tabreed has been supplying district cooling services to Sheikh Zayed Grand Mosque since 2007, Cleveland Clinic Abu Dhabi since 2013, Ferrari World Abu Dhabi since 2010, Burj Mohammed bin Rashid since 2014, ALDAR HQ since 2010 and many more.22
- Empower projects in Abu Dhabi: City of Arabia, Al Khail Gate, Dubai Health Care City, etc are some of the projects carried out by Empower.
- Nassau, Bahamas - Ocean Thermal Energy Corporation (OTE) designed a large Seawater Air-conditioning (SWAC)/Lake Water Air-conditioning (LWAC) system for the Baha Mar resort in The Bahamas.
- Bora Bora, French Polynesia - The InterContinental Resorts and Thalassa-Spa on the island of Bora Bora uses a SWAC/LWAC system in conjunction with a deepwater spa.
- Toronto, Canada – Enwave Energy Corporation developed a Lake Water Air Conditioning System in Lake Ontario in 2004. It has an integrated cooling tower. Capacity to cool is 3,200,000 sq m.
- Other locations are Halifax – Canada, Hong Kong – China, Amsterdam – Netherlands, Stockholm – Sweeden, Hamina – Finland, New York – United States.[23]

[21] https://www.sciencedirect.com/science/article/pii/S1364032114007485?via%3Dihub
[22] https://www.tabreed.ae/landmark-projects/
[23] https://otecorporation.com/swac-2/

Chapter 3: Policy and Regulatory Landscape for District Cooling and City Gas (distribution) in India

3.1 Overview of Central/State level Plans and Regulations

3.1.1 India Cooling Action Plan (ICAP) by Government of India

India Cooling Action Plan was released by the Union Minister of Environment, Forests and Climate Change, sometime back, to ensure that cooling requirements are efficiently met. The anticipated Indian cooling demand will grow three times by 2027 and eleven times by 2038. This could not only inhibit India's path to reducing carbon emission by 30% by 2030 as per Paris Agreement (2015) but also will have an adverse effect on energy availability for large energy-intensive sectors, especially manufacturing sectors. India Cooling Action Plan provides a 20-year perspective to address the cooling requirement across various sectors and recommends ways to provide access to sustainable cooling and thermal comfort for people.

The following goals have been taken up under this plan[24].

1. Recognition of "cooling and related areas" as a thrust area of research under national science and technology program to support the development of technological solutions and encourage innovation challenges.
2. Reduction of cooling demand across sectors by 20% to 25 % by the year 2037-38
3. Reduction of refrigerant demand by 25% to 30% by the year 2037-38
4. Reduction of cooling energy requirements by 25% to 40% by the year 2037-38
5. Training and certification of 100,000 servicing sector technicians by the year 2022-23, synergizing with Skill India Mission

Objectives under ICAP:

Under this action plan, some priority areas have been identified by ICAP, which can help in boosting district cooling projects in India:

1. Promote Research & Development (R&D) in the cooling sector through private-public-partnership
2. Implementation of building energy codes
3. Adoption of adaptive thermal comfort standards
4. Increasing energy efficiency of room air conditioners and fans
5. Enhancing consumer awareness through eco-labeling of cooling products
6. Allocate government funding and support towards targeted programs to enable cooling for the weaker segment
7. Public procurement of energy-efficient cooling equipment and trained and certified RAC (Refrigeration and Air Conditioning) service technicians for public building

3.1.2 District Energy in Cities Initiative by the UN Environment Programme (UNEP)

To identify major potential cities in the world under District Cooling projects – District Energy in Cities Initiative has been launched. The District Energy in Cities Initiative is a multi-stakeholder partnership coordinated by the UN Environment Programme (UNEP). The Initiative aims to double the rate of energy efficiency improvements for heating and cooling

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[24] http://www.indiaenvironmentportal.org.in/files/file/DRAFT-India%20Cooling%20Action%20Plan.pdf

in buildings by 2030. It currently provides technical support to cities in four pilot countries (Chile, China, India, and Serbia)

Partnership: In India, District Energy in Cities Initiative has partnered with Energy Efficiency Services Limited (EESL) – the national coordinator of this initiative.

National Project Steering Committee has been formed to guide the initiative's work of Smart Cities Mission, Energy Conservation Building Code, National Cooling Action Plan.

Its members are Bureau of Energy Efficiency, Ministry of Environment, Forests and Climate Change (co-chair); Ministry of New and Renewable Energy; the National Institution for Transforming India (NITI Aayog); the Energy and Resources Institute (TERI); ICLEI South Asia; Thane Municipal Corporation; International Finance Corporation; UN Environment and Energy Efficiency Services Limited (National Coordinator).

Expert Working Group consists of industry, financiers, manufacturers, city networks and operators from across the Initiative's partnerships. They perform technical studies and policy analyses.

Implementing Partners on the ground - Broad Group, Carbon Trust, Clarke Energy, Copenhagen Centre on Energy Efficiency (C2E2), Danfoss, Empower, Energy Efficiency Services Limited, General Electric, ICLEI - Local Governments for Sustainability, International District Energy Association (IDEA), International Finance Corporation (IFC), International Solar Alliance (ISA), ISHRAE, King & Spalding, PwC, Renew Power, Shell, Tabreed, Thermax [25]

Steps taken for Rapid Assessment of potential cities in District Cooling:

Under District Energy in Cities Initiative, a concept of Rapid Assessment has been developed which identifies suitable cities for district energy development. This assessment has led to the identification of the earlier said cities of Thane, Pune, Rajkot, Bhopal, and Coimbatore.

The following steps are followed under this assessment.[26]

1. Calculate present and estimate future cooling demand of the city.
2. Identify potential areas or buildings to be covered within cities and complete cost-benefit analysis
3. Analyze long term district cooling growth potential
4. Analyze long term benefits of district cooling to the city (cost, CO2, refrigerants, fossil fuel reduction, reduced peak load & electricity consumption, increase in local renewable energy)
5. Potential to connect or fuel district cooling with other sources, preferably renewable sources of energy.
6. How much the city is willing to cooperate in response to change in cooling philosophy, architectural change, cooperation from local government bodies.
7. Analyze barriers – financial, political, capacity, regulatory, planning, etc
8. Identify investors.

Data points measured under *Rapid Assessment*:

Based on the assessment, various data points are created related to [27]

[25] http://www.districtenergyinitiative.org/india
[26] http://www.districtenergyinitiative.org/sites/default/files/Indian%20Rapid%20Assessment%20Methodology_30April2019.pdf
[27] http://www.districtenergyinitiative.org/sites/default/files/Indian%20Rapid%20Assessment%20Methodology_30April2019.pdf

1. General information about the city (such as population, geographical area, employment level, energy market)
2. Cooling demand (such as historical cooling assessment, electricity consumption, temperature and weather conditions, cooling demand growth)
3. District cooling cost (such as availability and cost of land for energy centers, electricity or gas tariff, taxes, and duties)
4. District cooling design network (such as city plan detailing building location, cooling load of housing, commercial areas, hotels, municipal buildings, access to water)
5. Policy and regulations (such as local regulations around cooling – day/night-time temperature minimum temperature requirement, local/national policies related to subsidies on new cooling technologies, concession and acquisition laws, energy building standards)

3.1.3 Policies related to District Cooling:

District Cooling is a relatively new technology and there is no direct policy available for the same. However, there are policies related to the inputs which are required in District Cooling technology, i.e., Natural Gas and Water. In this section, we will be discussing policies related to Natural Gas and Water.

Natural Gas Pipelines Policy:[28]

Applicability

1. This policy will apply to natural gas pipelines and city or natural gas distribution networks.
2. The Petroleum & Natural Gas Regulatory Board established under the Petroleum & Natural Gas Regulatory Board Act, 2006 (hereinafter referred to as the Board) shall ensure selection of an entity to lay, build, operate or expand a natural gas pipeline or a city or local natural gas distribution network in a transparent and objective manner with a view to facilitating investments in the sector and protecting the interests of the consumers.

Grant of Authorization

1. No gas pipeline or the city or local gas distribution network will be laid, built, operated or expanded without the authorization by the Board.
2. Authorization for gas pipeline shall be granted to an entity only if the design pipeline capacity is at least 33% more than the capacity requirements of the concerned entity plus the firmed up contracted capacity (termed as total capacity) and this extra capacity is available for use on common carrier basis by any third party on open access and non-discriminatory basis at transportation rates laid down by the Board. The capacity available under "open access" common carrier basis will be allocated in a transparent and objective manner in line with the regulations to be drafted by the Board in this regard.
3. The entity authorized to lay, build, operate or expand a city or local natural gas distribution network will need to follow the marketing service obligations as may be prescribed by the Board in accordance with the provisions of the Act. The Board may decide on the period of exclusivity to lay, build, operate or expand a city or local natural gas distribution network in accordance with its regulations in a transparent manner while protecting the consumer interest.
4. Keeping in view the long term plan for the development of the natural gas sector and in public interest, the Central Government may, Suo motu, form an opinion about the need

[28] http://petroleum.nic.in/sites/default/files/Policy%20of%20Natural%20Gas%20pipelines%202006.pdf

for building a gas pipeline or a city or local distribution network on/in a particular route/ geographical area.

Bid Bond and Performance Bond

1. The entity proposing to lay, build, operate or expand a gas pipeline or city or local natural gas distribution network will be required to furnish to the Board a bid bond for an amount as may be decided by the Board with a view to ensuring that only serious bidders participate in the bidding process.
2. The successful bidder will have to furnish a performance bond for an amount as may be decided by the Board for ensuring timely construction as per the design/offer and for meeting performance undertakings during the operating phase.
3. The Board will review the progress of projects periodically with the authorized entities to satisfy itself that the conditions of authorization and milestones given in the project report are being fully complied with.

Conditions after Right of Use Acquisition

1. The ROU (Right of Use acquisition) for any transmission pipeline/city or local gas distribution project under the Petroleum Pipeline (Acquisition of Right of User in Land) Act, 1962 will only be considered by the Central Government after authorization for the same has been granted by the Board.
2. In case the route/alignment of the pipeline crosses another pipeline route/alignment, the points of the crossing would be decided by mutual agreement between the parties, failing which the matter will be referred to the Board whose decision will be final.
3. Unbundling of Operations
4. Any entity desirous of applying for building, operating or expanding common or contract carrier gas pipelines will have to give an undertaking that if such an entity has business interests in related areas of gas marketing or city or local gas distribution network or has a related entity (e.g., a parent company, group company, company under the same management, JV company, subsidiary or affiliated in any way to create a pecuniary interest) with business interests in such areas, it will ensure an arm's length relationship between gas pipeline activity and these activities or between itself and the related entity as the case may be.
5. The purpose of this policy is to ensure that pipeline ownership does not provide any competitive advantage to any gas seller and abuse of market power while establishing an efficient gas grid with open access for all the players on a non-discriminatory basis.

Gas Grid Connectivity

1. Gas Grid to be constructed on the basis of a comprehensive set of technical requirements and safety standards as well as a code for gas grid connectivity to be developed by the Board.

Transportation Tariff

1. Transportation tariffs will be fixed by the board.

FDI Policy

1. FDI is allowed to invest 100% in gas grid connection.

National Water Policy:[29]

Uses of Water

1. Safe water for drinking and sanitation should be considered as pre-emptive needs, followed by high priority allocation for other basic domestic needs (including needs of animals), achieving food security, supporting sustenance agriculture and minimum eco-system needs. Available water, after meeting the above needs, should be allocated in a manner to promote its conservation and efficient use.
2. River basin to be considered as a basic hydrological unit for planning.
3. A portion of river flows should be kept aside to meet ecological needs ensuring that the low and high flow releases are proportional to the natural flow regime, including base flow contribution in the low flow season through regulated groundwater use.

Enhancing Water Available for Use

1. Direct use of rainfall, desalination, and avoidance of inadvertent evapotranspiration are the new additional strategies for augmenting utilizable water resources.
2. Declining groundwater levels in over-exploited areas need to be arrested by introducing improved technologies of water use, incentivizing efficient water use and encouraging community-based management of aquifers.
3. Artificial recharging projects should be undertaken so that extraction is less than the recharge.

Demand Management and Water Use Efficiency

1. Benchmark, water footprints, and water auditing should be developed to promote and incentivize efficient use of water
2. Recycle and reuse of water, including return flows, should be the general norm.
3. A concurrent mechanism involving users for monitoring if the water use pattern is causing problems like unacceptable depletion or building up of groundwaters, salinity, alkalinity or similar quality problems, etc., with a view to planning appropriate interventions.

Pricing

- Pricing of water to be set up by each state after a wide-ranging consultation with all stakeholders.

[29] http://mowr.gov.in/sites/default/files/NWP2012Eng6495132651_1.pdf

3.1.4 Which Cities to Focus for District Cooling?

As discussed earlier, India being a sub-tropical country has a huge requirement for District Cooling. Based on India's geographical analysis and development pace of cities, we have designed a way to identify cities that can be targeted for the installation of District Cooling. The steps taken are:

1. Preparation of a list of 30+ fastest developing cities in India, across which the development and cooling requirements are closely related. [30]
2. Identification of whether in these cities, Natural Gas connectivity is available in the city or is under construction. [31]
3. In the last step, using the India Water Tool, we looked for water availability in these cities. [32]
4. We finally came out with a list of 15 potential cities that can be targetted for the District Cooling Project.

[30] http://www.walkthroughindia.com/offbeat/top-35-fastest-developing-and-emerging-cities-of-india/
[31] https://pngrb.gov.in/data-bank.html
[32] https://www.indiawatertool.in/

Draft Criteria for Selecting Cities for Future District Cooling Projects:

Table 2 Draft Criteria for Selecting Cities for Future District Cooling Projects

#	City	State	Feature, Special Characteristic (if any)	Natural Gas Availability		Water Availability	Selection Result
				Operational	Under Construction		
1	Bangalore	Karnataka	IT Hub	Yes	NA	Low to medium	No
2	Pune	Maharashtra	IT Hub	No	Yes	Low to medium	Yes
3	Hyderabad	Andhra Pradesh	IT Giants (Google HQ)	Yes	NA	Medium to High	Yes
4	Ghaziabad	UP	Delhi NCR	Yes	NA	High	Yes
5	Surat	Gujarat	Food, Textile, and Diamonds	Yes	NA	Low to medium	Yes
6	Faridabad	Haryana	Smart City Plan	No	Yes	Low to medium	Yes
7	Gurgaon	Haryana	Delhi NCR	No	Yes	Low to medium	Yes
8	Gandhinagar	Gujarat	Business City	Yes	NA	Low	No
9	Nasik	Maharashtra	River Godavari Bank	No	No	Rejected	No
10	Chandigarh	Chandigarh	Union Territory	No	Yes	Medium to High	Yes
11	Lucknow	UP	Capital City	Yes	NA	Low	No
12	Bhopal	MP	Smart City plan	No	Yes	Extremely Low	No
13	Vishakhapatnam	Andhra Pradesh	Smart City plan	No	Yes	High	Yes
14	Ahmedabad	Gujarat	Economic and Industrial hub	Yes	NA	Low to medium	Yes
15	Patna	Bihar	River Ganga	No	No	Rejected	No
16	Rajkot	Gujarat	Small scale manufacturing industries	Yes	NA	Low	No
17	Jaipur	Rajasthan	Textiles, Jewellery, Tourism	No	No	Rejected	No
18	Kochi	Kerala	Sea coast, Spices	No	No	Rejected	No
19	Gangtok	Sikkim	Tourism	No	No	Rejected	No
20	Mysore	Karnataka	Tourism	No	No	Rejected	No
21	Nagpur	Maharashtra	Smart City plan	No	No	Rejected	No

22	Vadodara	Gujarat	Vishwamitri River, Petrochemical and Chemical Industry	Yes	NA	Low	No
23	Raipur	Chhattisgarh	Market of Steel industry	No	No	Rejected	No
24	Thiruvananthapuram	Kerala	IT Hub	No	No	Rejected	No
25	Coimbatore	Tamil Nadu	Noyyal River	No	No	Rejected	No
26	Indore	MP	Smart City plan	Yes	NA	High	Yes
27	Guwahati	Assam	Brahmaputra River	No	Yes	Medium to High	Yes
28	Bhubaneshwar	Orissa	Capital City	No	No	Rejected	No
29	Kozhikode	Kerala	Small scale manufacturing and cyber parks	No	No	Rejected	No
30	Warangal	Telangana	Smart City plan	No	No	Rejected	No
31	Ludhiana	Punjab	Business City	No	No	Rejected	No
32	Jamshedpur	Jharkhand	Steel City, Kharkai River, and Subarnarekha River	No	No	Rejected	No
33	Aurangabad	Maharashtra	IT and manufacturing	No	No	Rejected	No
34	Vijayawada	Andhra Pradesh	Krishna River	Yes	NA	Medium to High	Yes
35	Tiruchirappalli	Tamil Nadu	Energy and fabrication capital	No	No	Rejected	No
36	Delhi	Delhi	Metro City	Yes	NA	Medium to High	Yes
37	Mumbai	Maharashtra	Metro City	Yes	NA	Medium to High	Yes
38	Kolkata	West Bengal	Metro City	Yes	NA	High	Yes

3.1.5 Comparative analysis of DCS with conventional cooling technology

Please refer to Annexure - DCS Energy Saving Calculator, for more detailed calculations.

BASIC INFORMATION			
Parameter	**Value**	**Units**	**Assumptions and Calculations**
No. of Households	100	number	
Area of one room	180.00	sqft	
No. of Split Air Conditioner (AC) installed per household	2	number	1 AC is installed in 1 room, therfore 2 AC per household
Total cooling area by split	36,000.00	square foot (sqft)	Area of one room * no. of household * no. of AC installed per household
TR of one AC	1.50	Tonne of Refrigeration (TR)	Assuming BEE 3 Star AC
Power Consumed per AC	1.70	kW	Assuming BEE 3 Star AC (as per the 3 star label)
District Cooling (DC) Capacity Installed	90.00	Tonne of Refrigeration (TR)	Assuming 1TR of chiller provides cooling to approximately 400sqft as per Indian Society for Heating, Refrigeration and Air Conditoning Engineers (ISHRAE) thumb rule
Operating hours	3,200.00	hours/year	Assuming the cooling is required for 200 days annually and each split unit is operated for 8 hrs a day (200*2)

ENERGY SAVING CALCULATIONS				
Parameters	**Individual AC Unit**	**Assumption and Calculations**	**District Cooling (DC)**	**Assumption and Calculations**
No. of Households	100		100	
No. of System Installed	200	No of AC * No of Households	1	(system here is considered as AC and DC both)
Operating hours / year	3,200		3,200	
Power Consumed (kW)	340.00	No of AC * No of Households * Power consumed per AC	316	1 TR = 3.51 kW
Energy Consumed (kWh)	1,088,000.00	Power Consumed * Operating hours	361,029	The Coefficient of Performance (CoP) assumed is 2.8 (referred from Energy Conservation Building Code - ECBC 017- CoP for air cooled chiller less than 260 TR). Total energy consumed = {(power consumed/CoP)* operating hours}
Energy Saved (kWh) annually	726,971.43			
CO_2 mitigated (tCO_2/MWh) annually	596.12	Based on Central Electricity Authority (CEA) Emission Factor		
Monetary Savings annually	4,361,828.57			Assuming average residential electricty cost is Rs 6/kWh

Chapter 4: Technical Feasibility of District Cooling Systems in India

4.1 The Indian Administrative Structure (3-tier)

4.1.1 The hierarchal structure in India

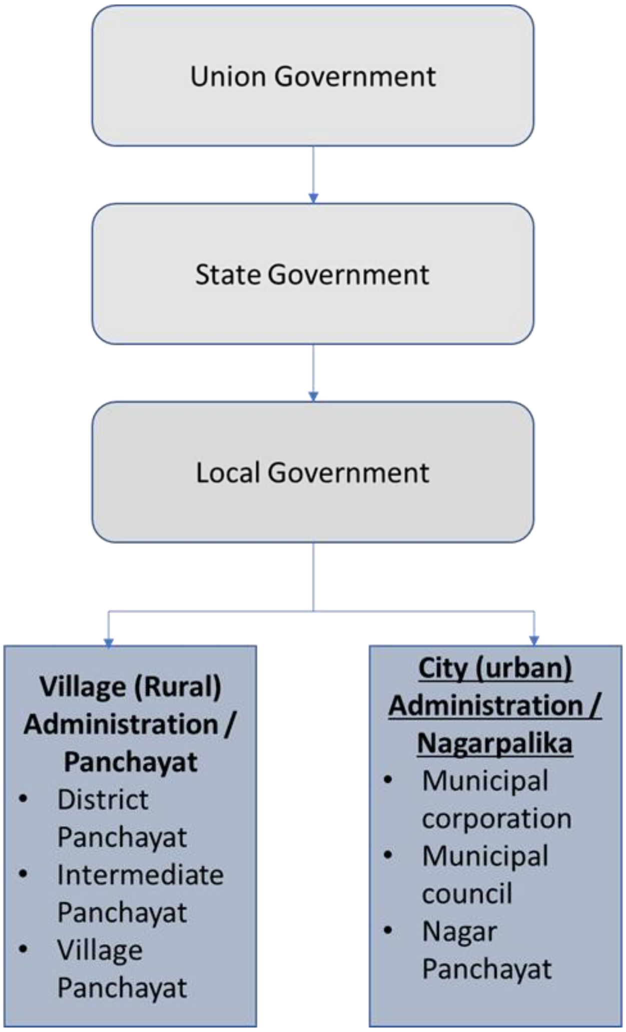

Figure 14: Three tier structure of Government of India

India has the distinction of being a unique federal country. Ordinarily, federalism involves a two-tier system – central/union government at the first level and the state/provincial government at the second level. But the Indian constitution provides for a three-tier[33] federal structure as below: -

1. Union Government at the top
2. State Government in the Middle
3. Local Government i.e. Panchayats and Municipalities at Grass Root

[33] https://www.civilserviceindia.com/subject/Political-Science/notes/grassroots-democracy.html

In the Indian **constitution,**[34] there is a dual polity with a vibrant division of powers between the Union and the States, each being supreme within the sphere allotted to it. The States in India are not the formation of the Centre nor do they draw their authority from the Union Government. Conversely, like the Union Government, they draw their authority directly from the Constitution and are free to operate in the field allotted to them by the Constitution.

The Union Government is dependent on the States to give effect to its programs. The scheme of distribution of administrative powers has some major objectives. It arms the Union Government with powers to have effective control over the administration of the states and espouses advice for intergovernmental cooperation and coordination.

The Local Government's jurisdiction is limited to a specific area and its functions relate to the provision of civic amenities to the population within that jurisdiction. A Local Government functions within the provisions of the statute which has created it. It is subordinate to the state or provincial government which exercises control and supervision over it. But the activities of the Local Government are not less numerous. Local Government has been undertaking new activities that either regulate the conduct of the citizens or are service such as the provision of mass transport, construction of houses for the poor, supply of electricity, health centers, parks, etc. In fact, Local Government is today much more important in the daily life of a citizen than the state or central government.

4.1.2 Functions at Union Level

Central executive body of the government, the cabinet performs an array of functions; there its role is critical and pivotal.

These functions can be mentioned as under[35]:

1. Formulation, execution, evaluation, and revision of the public policy in various spheres in which the party in power seeks to progress and practice.
2. Coordination among various ministries and other organs of the government which might indulge in conflicts, wastefulness, duplication of functions and empire building.
3. Preparation and monitoring of the legislative agenda which translated the policies of the government in action through statutory enactments.
4. Executive control over administration through appointments, rulemaking powers and handling of crises and disasters, natural as well as political.
5. Financial management through fiscal control and operation of funds like Consolidated Fund and Contingency Funds of India.
6. Review the work of planning and Planning Commission.

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[34] https://www.india.gov.in/sites/upload_files/npi/files/coi_part_full.pdf

[35] Article 245-255, Article 256-263, and Article 268-293 of the constitution of India.

4.1.3 Functions at State Level

The state government is defined as the government of a country's subdivisions and shares political power with the national government. In India, the state governments are the level of government below the central government. Each state of the country is governed by the state government.

Following are the roles and responsibilities of the state governments[36]:

1. State governments have separate departments for the efficient functioning of the state. States have jurisdiction over education, agriculture, public health, sanitation, hospitals and dispensaries, and many other departments.
2. Internal Security: The state governments have to maintain internal security, law, and order in the state. Internal security is managed through the state police.
3. Public order: States have jurisdiction over police and public order.
4. Education: Providing a public education system, maintaining school buildings and colleges, employment of teachers, providing help to underprivileged students all come under the education department of the state.
5. Agriculture: The state governments have to provide support for farmers, funds for best farming practices, disease prevention and aid during disasters such as floods or droughts.
6. Finances: State legislature handles the financial powers of the state, which include authorization of all expenditure, taxation, and borrowing by the state government. It has the power to originate money bills. It has control over taxes on entertainment and wealth and sales tax.
7. Reservation of bills: The state governor may reserve any Bill for the consideration of the President.
8. Transport: State government runs the trains, trams, bus and ferry services, and other public transportation in the cities and towns of the States.
9. Water supply: Water supply to cities and towns for drinking, including irrigation for farmers, is the responsibility of the State governments.
10. Budget: State governments make budget for state.

4.1.4 Functions of Local Government

The following are the responsibilities of Local Government: [37]

- Urban planning including town planning & Regulation of land-use and construction of buildings
- Planning for economic and social development
- Roads and bridges
- Water supply for domestic, industrial and commercial purposes
- Public health, sanitation conservancy, and solid waste management

[36] Article 245-255, Article 256-263, and Article 268-293 of the constitution of India.
[37] http://ncert.nic.in/ncerts/l/keps208.pdf

- Slum improvement and up-gradation
- Urban poverty alleviation
- Fire services
- Urban forestry, protection of the environment and promotion of ecological aspects
- Safeguarding the interests of weaker sections of society, including the handicapped and mentally retarded.
- Provision of urban amenities and facilities such as parks, gardens, playgrounds
- Promotion of cultural, educational and aesthetic aspects.
- Burials and burial grounds; cremations, cremation grounds, and electric crematoriums.
- Cattle pounds; prevention of cruelty to animals.
- Vital statistics including registration of births and deaths.
- Public amenities including street lighting, parking lots, bus stops and public conveniences.
- Regulation of slaughterhouses and tanneries.

4.2 Administration Landscape in India in the context of Energy, Environment, Climate Change

The responsibilities in the Energy Sector in India are shared between the Central Government and the States. Overall planning and decision-making powers in the Energy sector rest with various Central agencies - **The Ministry of Power (MoP)**, **The Ministry of Petroleum and Natural Gas (MoPNG)**, **The Ministry of Coal, The Ministry of New and Renewable Energy (MNRE)**, and the Department of Atomic Energy.

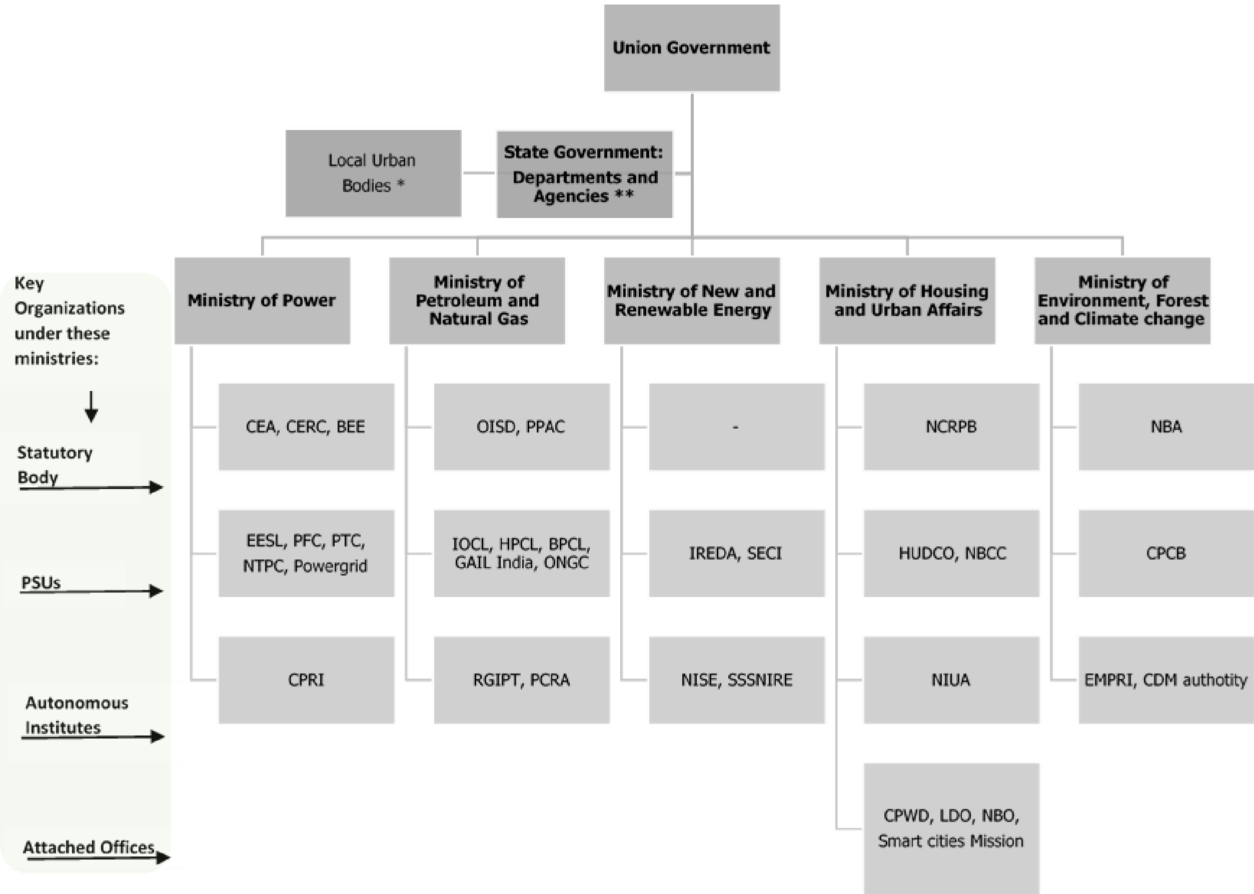
All these nodal agencies are guided by their own legal framework, in terms of acts and policies on the issue. The nodal ministries are supported in various aspects of their functioning and responsibilities by public sector undertakings, government agencies/institutions, and research institutes.

The responsibilities in the Environment and Climate Change sector in India are spearheaded by The **Ministry of Environment, Forest and Climate change (MoEFCC)**. It is responsible for planning, promoting, coordinating, and overseeing the implementation of environmental and forestry programs in the country. The main activities undertaken by the ministry include conservation and survey of the flora of India and fauna of India, forests and other wilderness areas; prevention and control of pollution; afforestation, and land degradation mitigation. It is responsible for the administration of the national parks of India.

The Ministry of Housing and Urban Affairs (MoHUA) coordinate the activities of various above-mentioned Central Ministries, State Governments and other nodal authorities and monitor the programs concerning all the issues of urban development in the country.

Together the Ministry of Housing and Urban Affairs, Ministry of Power, Ministry of Petroleum and Natural Gas, Ministry of Environment, Forest and Climate change and Ministry of New and Renewable Energy, these ministries coupled with the selected State Governments and Local urban Bodies in these States form the **stakeholders** on the policy, regulatory and planning side in the **context of City Gas and District cooling eco-system in India.**

4.2.1 Key Government Organizations



Abbreviations:

PSUs: Public Sector Undertakings, **CEA:** Central Electricity Authority, **CERC:** Central Electricity Regulatory Commission, **BEE:** Bureau of Energy Efficiency, **EESL:** Energy Efficiency Services Limited, **PFC:** Power Finance Corporation, **PTC:** Power Trading Corporation of India, **NTPC:** National Thermal Power Corporation, **CPRI:** Central Power Research Institute, **OISD:** Oil Industry Safety Directorate, **PPAC:** Petroleum Planning and Analysis cell, **IOCL:** Indian oil corporation Limited, **HPCL:** Hindustan Petroleum Corporation Limited, **BPCL:** Bharat Petroleum Corporation Limited, **ONGC:** Oil and Natural Gas Corporation Limited, **RGIPT:** Rajiv Gandhi Institute of Petroleum Technology, **PCRA:** Petroleum Conservation Research Association, **IREDA:** Indian Renewable Energy Development Agency, **SECI:** Solar Energy Corporation of India, **NISE:** National Institute of Solar Energy, **SSSNIRE:** Sardar Swaran Singh National Institute of Renewable Energy, **NCRPB:** National Capital Region Planning Board, **HUDCO:** Housing and Urban Development Corporation Limited, **NBCC:** National Building Construction Corporation Limited, **NIUA:** National Institute for Urban Affairs, **CPWD:** Central Public Works Department, **LDO:** Land and Development Office, **NBO:** National Building Organization, **NBA:** National Biodiversity Authority, **CPCB**: Central Pollution Control Board, **EMPRI:** Environment Management and Policy Research Institute, **GBPIHED:** Govind Ballabh Pant (G.B. Pant) Institute of Himalayan Environment and Development

* **Local Urban Bodies:** Municipal Corporation, City Development Authority, Town Planning Department

** **State Departments and Agencies:** State Designated Agencies (SDAs)/State Energy Departments, State Urban Development Department/Agency

Government Stakeholders for District Energy and Gas eco- system

Figure 15: Government stakeholders for district energy and gas eco-system

4.3 Why District Cooling for India?

4.3.1 Energy Use in Indian Cities

A research conducted by Oxford Economics stated that 17 among the top 20 fastest growing cities in the world are based in India. These cities include Surat, Agra, Bengaluru, Hyderabad, Nagpur, Tirupur, Rajkot, Tiruchirappalli, Chennai, and Vijayawada. As per the 2011 census, 31 percent of India is urbanized, and this figure is expected to touch 60 percent by 2050. India's urban population is expected to grow from 410 million in 2014 to 814 million by 2050. These people will be setting up their lives starting from a low base of development demanding modern fuels for lighting and cooking, appliances, heating and cooling, vehicles, etc. for an improved quality of life. There will be multiple commercial and residential hubs cropping up in all these expanding cities of India. As per India Energy Security Scenarios 2047, for a 'Determined Effort Scenario', India's energy demand in 2047 will be close to 1,500 million tonnes of oil equivalent.

Uninterrupted energy supply will be a key component in increasing the GDP of these Indian cities. India is yet to define its development pathways for rising and complex energy service demands and, hence, this sector provides the opportunity to better plan, for the future. The network of energy provision for residential and commercial buildings, mobility, public built spaces, and other urban arrangements are going to be long-lasting investments of the Indian economy. Currently, space heating and cooling and hot water supply itself are estimated to account for roughly half of global energy consumption in buildings.

For the ever-increasing area under the buildings and built spaces in India, cooling has become vitally important to many aspects of modern life. From providing thermal comfort in homes and offices to keeping the food, cars, medicines, industry and scientific instruments cool, the demand for cooling in all its forms is rapidly growing. There is much-needed recognition for cooling as a social imperative and as a developmental priority.

4.3.2 Cooling Demand in India

India, which currently has one of the lowest accesses to cooling across the world[38], is poised for rapid and significant growth in cooling demand. As the climate continues to change, **India's cooling energy consumption is expected to grow around 2.2 times in 2027 over the current baseline**[39]. Temperatures in the Indian states of Madhya Pradesh[40], Maharashtra and Rajasthan have seen daily highs of 42°C and are becoming the new normal. Combined with economic growth and urbanization, this brings a huge growth, thus the challenge of meeting the growing demand for cooling.

Cooling is a developmental need, according to the International Energy Agency (IEA), the **number of air conditioners in India is expected to rise from 15 million in 2011 to 240 million in 2030**. While this growth is in alignment with India's economic and social

[38] IEA. (2018). The Future of Cooling
[39] https://www.aeee.in/wp-content/uploads/2018/10/Demand-Analysis-for-Cooling-by-Sector-in-India-in-20271.pdf
[40] https://qz.com/india/1584261/indias-imd-warns-of-higher-temperatures-heatwaves-this-summer/

development, and the hot and humid climate conditions, it comes with adverse impacts in the form of significant additional power generation capacity, peak load impacts, and an enormous carbon footprint through both direct and indirect emissions.

4.3.3 Defining the demand sectors

The major cooling and air conditioning demanding sectors can be grouped under the following five categories:

Table 3: Major cooling and air conditioning demanding sectors

Demand Sector	Technology Type	End-use
Commercial space cooling	Refrigeration and Air Conditioning, chiller system, Variable refrigerant flow (VRF) systems, direct expansion air conditioning unit, Fan, and air cooler	Mainly office buildings/ complexes, retail sector, large commercial setups like airports, train stations and subways, the health sector (e.g. hospitals), leisure and hotel sector, and large campus areas in Universities, Exposition centers.
Domestic/Unitary air conditioning	Domestic-type AC units	Individual houses, Multifamily buildings, hostels, etc.
Mobile Air conditioning	Passenger Light Duty Vehicle, passenger Heavy-Duty Vehicle, and railway	Air-conditioning for comfort cooling of commuters in cars, buses, and railways
Cold Storages	Cold storage, packhouse and ripening chamber, reefer vehicle	Refrigeration of perishable food products during packaging, ripening, storage and transportation, storage warehouses
Industrial cooling	Industrial AC (non-ammonia), process and milk chiller (ammonia)	Air-conditioning or refrigeration requirements in pharmaceutical, textile, chemical, plastic, brewery, beverages, food processing, detergent industries

Out of these demand sectors, the commercial space cooling is the most critical sector as it is still ungoverned by stringent energy efficiency performance targets like in the industries.

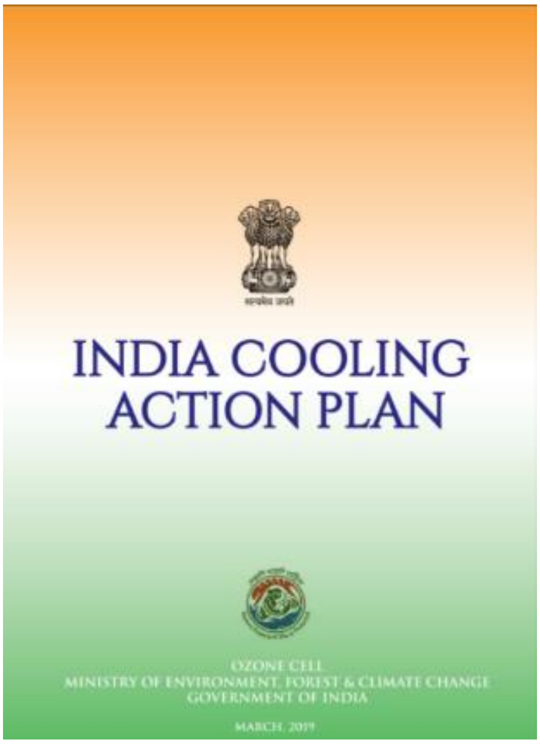
The average energy consumption of this sector and future consumption at the current growth rate can be found in the table below:

	2017	**2027 (BAU[41])**
Annual energy consumption[42] (Terawatt Hour - TWh)	126	281
Total emissions (Metric tons of carbon dioxide equivalent or MTCO2e)	124	284

[41] BAU – Business as usual
[42] https://www.aeee.in/wp-content/uploads/2018/10/Demand-Analysis-for-Cooling-by-Sector-in-India-in-20271.pdf

4.3.4 India’s Cooling Action Plan (ICAP)

India’s recent comprehensive Cooling Action Plan targets an increase in sustainable cooling while helping to fight climate change, towards achieving this, one of the most efficient and promising solution is ‘District cooling systems’ and India is rapidly adopting it and a number of examples and pilots are coming up in the country. India is the first country in the world to develop such a document, which addresses cooling requirement across sectors and lists out actions which can help reduce the cooling demand. The overarching goal is to provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits for the society.



The goals emerging from the suggested interventions stated in ICAP are:

1. Reduction of cooling demand across sectors by 20% to 25 % by the year 2037-38.
2. Reduction of refrigerant demand by 25% to 30% by the year 2037-38.
3. Reduction of cooling energy requirements by 25% to 40% by the year 2037-38.
4. Training and certification of 100,000 servicing sector technicians by the year 2022-23, in synergy with Skill India Mission.
5. Recognize “cooling and related areas” as a thrust area of research under the National Science & Technology Program.

The broad objectives of the India Cooling Action Plan include:

- Assessment of cooling requirements across sectors in the next 20 years and the associated refrigerant demand and energy use.
- Map the technologies available to cater to the cooling requirement including passive interventions, refrigerant-based technologies and alternative technologies such as not-in-kind technologies.
- Suggest interventions in each sector to provide for sustainable cooling and thermal comfort for all.
- Focus on skilling of Refrigeration and Air Conditioning RAC service technicians.
- Develop an R&D innovation ecosystem for the indigenous development of alternative technologies.

The following benefits would accrue to society over and above the environmental benefits:

- Thermal comfort for all – provision for cooling for Economically Weaker Section (EWS) and Low-Income Group (LIG) housing.
- Sustainable cooling – low GHG emissions related to cooling.

- Doubling Farmers Income – better cold chain infrastructure – better value of products to farmers, less wastage of produce.
- Skilled workforce for better livelihoods and environmental protection.
- Make in India – domestic manufacturing of air-conditioning and related cooling equipment.
- Robust R&D on alternative cooling technologies – to provide the push to innovation in a cooling sector.

India Cooling Action Plan can be accessed at
http://www.ozonecell.com/viewsection.jsp?lang=0&id=0,256,815

4.3.5 Current Momentum in India

The central government has already considered District cooling system as a cross-cutting technology in the "National Cooling Action Plan" — a vision document to meet the country's rapidly growing cooling needs in a climate-friendly manner prepared by MoEFCC. Also, district cooling may complement the Smart Cities Initiative of India as well, by – improving efficiency and the quality of infrastructure, and thus delivering a more sustainable, liveable urban environment.

In order to kick-start the District Cooling Initiative in India, **UNEP has signed an agreement with Energy Efficiency Services Limited** (A Joint Venture of Public Sector Undertakings under the Ministry of Power) to lead and coordinate the DES-related activities as the National Coordinating Agency till 2020 (More details can be accessed at http://www.districtenergyinitiative.org/india). At present**, assessments have been carried** out across **five cities: Bhopal, Rajkot, Thane, Pune, and Coimbatore**, which confirm that cooling large buildings through district cooling networks is more cost-effective and significantly better environmentally. Electricity and CO_2 reductions of at least 35% are forecasted as there are significant water and refrigerant reductions.

Energy Efficiency Services Limited (EESL) (www.eeslindia.org) is the **Initiative's National Coordinator**[43] for India and has been building momentum within the relevant national ministries in India to develop a national support programme for district cooling and bring district cooling

[43] http://www.districtenergyinitiative.org/sites/default/files/publications/des-progress-report-110120191042.pdf

under the upcoming National Cooling Action Plan. In May 2018, EESL coordinated the first National Project Steering Committee in India, co-chaired by the Ministry of Environment, Forests and Climate Change (MoEFCC) and the Bureau of Energy Efficiency (BEE), showcasing the parallel effort of the national government and District Energy in Cities. Rapid progress has called for a dedicated team member on the ground in our Delhi office, who will keep our broad activities organized and effective from July 2018.

Key updates in District Cooling from India:

- A workshop on 'Cooling Smart Cities - The Arrival of District Energy in India' in Rajkot was organized by UN Environment along with ICLEI South Asia, Energy Efficiency Services Limited (EESL), the International Solar Alliance as partners and hosted by the Rajkot Municipal Corporation in the state of Gujarat. Links to key excerpts from the workshop:
  1. http://www.districtenergyinitiative.org/cooling-smart-cities-rajkot-leads-way
  2. http://southasia.iclei.org/newsdetails/article/rajkot-to-be-one-of-the-first-indian-cities-to-develop-district-cooling-system.html

  Link to Press Release:
  http://isolaralliance.org/docs/Rajkot%20DES%20Press%20Release%20v07FEB18%201800hrs.pdf

- UN Environment report on high-level national analysis was undertaken alongside five district energy rapid assessments of the Indian cities of Bhopal, Coimbatore, Pune, Rajkot, and Thane. More details can be accessed at http://www.districtenergyinitiative.org/city-country-tools

Public and Private Partnership for District Cooling in India

In association with Smart City Sweden – In India, Sweco is preparing proposals for a district cooling system to serve the city of Pimpri, India. The assignment is part of an Indian initiative to develop 100 smart and sustainable cities. Sweden is one of six countries that India has chosen to collaborate with in this initiative, which has also given rise to the formation of the Smart City Sweden – in India platform, which Sweco is part of.

In the spring of 2018, Sweden carried out a feasibility study to explore the opportunities to transform Pimpri, where some 20 Swedish companies are already established, into a smart and sustainable city. Based on the results of the feasibility study, India wants to move forward with plans for a district cooling system covering the city's 95-hectare exhibition and convention centre. District cooling is used for applications such as refrigeration rooms and air conditioning.

Sweco's assignment includes the proposal of a district cooling system for the Pune International Exhibition and Convention Centre. By using coolants and energy sources with low emissions, the ambition is to make the exhibition and convention centre fully carbon neutral.

https://www.sweco.se/en/our-offer/project/district-cooling-in-india/

- A 20,000 TR (tonnes of refrigeration) district cooling system to be set up in Amravati, India by UAE company Tabreed, will commence from early 2021. More details can be accessed at:
    1. https://www.business-standard.com/article/economy-policy/amaravati-to-adopt-district-cooling-in-govt-bldgs-signs-deal-with-uae-firm-119021300789_1.html
    2. https://economictimes.indiatimes.com/industry/indl-goods/svs/engineering/uaes-tabreed-to-build-indias-first-district-cooling-system-in-amaravati/articleshow/67992274.cms?from=mdr

- The district cooling system is being implemented in India at Gujarat International Finance Tec-City (GIFT City) – India's 1st Smart City. The first phase of this District cooling system with a capacity of 10,000 TR is in operation since April 2015. More details can be accessed at https://www.rehva.eu/rehva-journal/chapter/indias-first-district-cooling-system-at-gift-city

4.4 Mapping of Stakeholders

The mapping of relevant national and state-level entities for district cooling development is presented below in order to understand their roles and their level of engagement.

Table 4: Stakeholder Mapping with respect to District Cooling

S. No.	Stakeholder	Role with respect to district cooling
1	Ministry of New and Renewable Energy (MNRE) https://mnre.gov.in/	• MNRE is the nodal ministry to promote the development and deployment of new and renewable energy. • It also administers the Solar Cities Program, with an intent to empower cities to undertake planning and

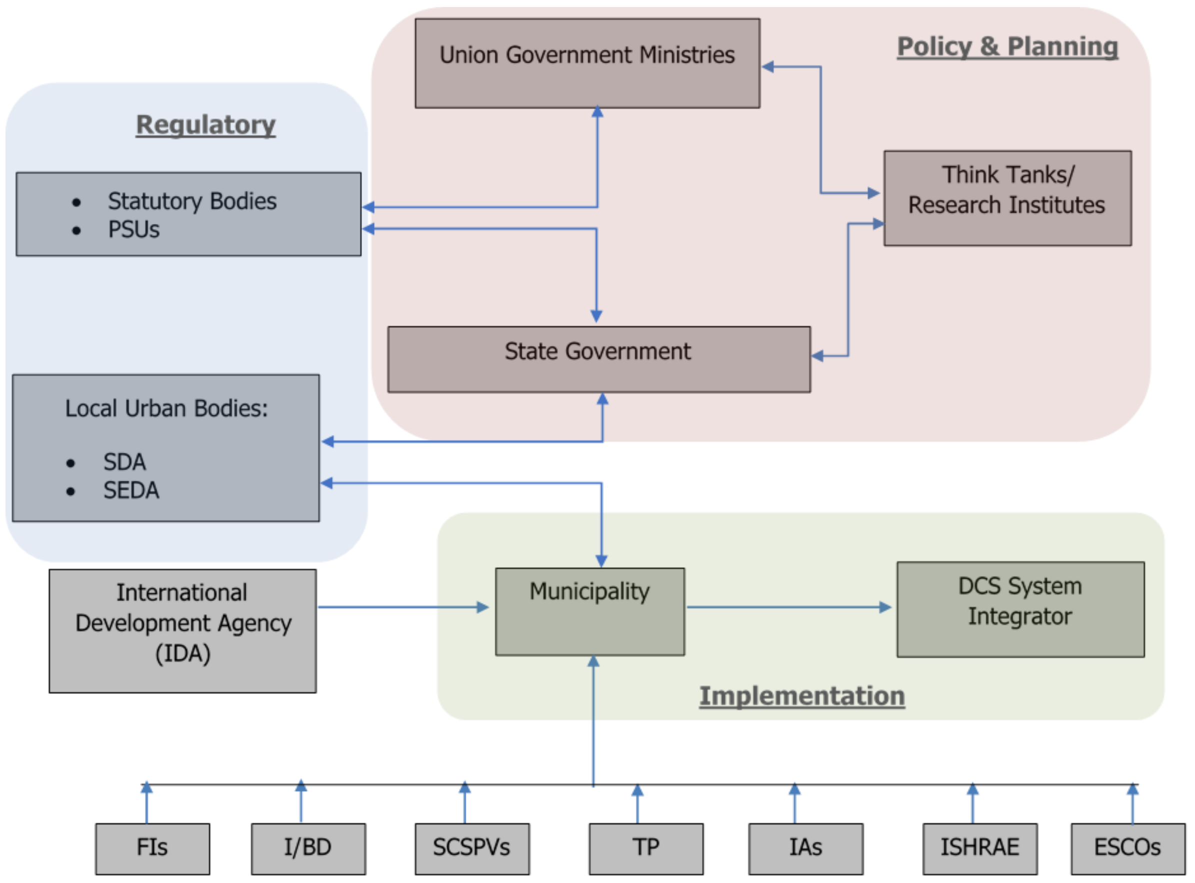
		integration of renewable energy and energy efficiency in the urban energy mix. • MNRE’s agenda of exploring the use of geothermal heat pumps/geo-exchange systems for space cooling etc. will play a major role in the context of District Cooling Systems.
2	Ministry of Housing and Urban Affairs (MoHUA) http://mohua.gov.in/	MoHUA is the apex ministry for formulation and administration of the rules, regulations and laws and large-scale programs relating to urban development and housing in India, and thereby is a key actor to promote and integrate District Cooling in cities.
3	Ministry of Power (MoP) https://powermin.nic.in/	MoP being the central nodal ministry for electrical energy in India will ultimately serve as the central authority and play a key role in formulating program and policy regulations to promote District Cooling in Cities.
4	Ministry of Environment, Forests and Climate Change (MoEFCC) http://moef.gov.in/	• MoEFCC is the nodal agency for the planning, promotion, co-ordination and overseeing the implementation of India's environmental, forestry and climate change policies and program. • It can play a major role in integrating district cooling into India’s climate and environmental strategy and devise program initiatives to support it. • It is the Global Environment Facility (GEF) focal point in India and can liaise with other multilateral/bilateral institutions to access support for promoting district cooling.
5	State Urban Development Department/Agency mohua.gov.in/cms/states-uts-list.php	The State Urban Development Department/Agency is the nodal agency at the State level, in charge of ensuring proper and planned growth of cities and towns in the respective states with adequate infrastructure, amenities, and services provided to the citizens through the Urban Local Bodies and parastatal agencies. These serve as the nodal department for co-ordination, monitoring and implementation of various National and State schemes for development, infrastructure creation, civic amenities, and thereby a key state-level actor.
6	State Designated Agencies (SDAs)/State Energy Departments https://www.beeindia.gov.in/content/sdas	The SDA’s/State Energy Departments are responsible for the implementation of energy conservation and energy efficiency programs in the respective states. The SDA’s can play a major role in ensuring appropriate design and implementation of program and policy regulations to promote district cooling at the State level. Further, they can provide information on existing and planned renewable energy generation in the city for integration with District Cooling Systems.

7	Bureau of Energy Efficiency (BEE) https://www.beeindia.gov.in/	BEE is responsible for spearheading the market transformation in the economy towards energy efficiency through various regulatory and promotional instruments. BEE guides any policy and institutional changes regarding energy efficiency. In the context of Cooling/District Cooling, BEE can play a significant role in terms of aligning it with energy efficiency along with helping in the development of the required policy/institutional landscape.
8	Central Electricity Regulatory Commission (CERC) www.cercind.gov.in/ State Electricity Regulatory Commissions (SERCs) http://www.cercind.gov.in/serc.html	CERC and SERCs being regulatory bodies at the National and State level, respectively, can promote District Cooling by framing and implementing appropriate tariff-based mechanisms and guidelines.
9	Bureau of Indian Standards (BIS) https://bis.gov.in/?lang=en	BIS, the National Standards Body of India, is the agency in all matters concerning standardization, certification, and quality, and will serve as a source for assisting in this regard for District Cooling Systems.
10	Indian Society of Heating, Ventilation, and Air Conditioning (ISHRAE) https://www.ishrae.in/	ISHRAE is an associate of ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers). ASHRAE and ISHRAE standards and guidelines are adopted for Heating, Ventilation, Air-Conditioning and Refrigeration (HVAC) design and integrated into energy-efficient policy instruments such as the Energy Conservation Building Code (ECBC) as well. ISHRAE is expected to play a key role in promoting the use of Energy Efficient Cooling Systems (including District Cooling) in India.
11	Municipal Corporation & Town Planners	Responsible for: • Integration of district cooling development as a focus area in the city's long-term vision and strategy. • Share data on local government buildings and utilities, offering connections to local government buildings such as large hospitals, office buildings. • Identification of strategic high-density mixed-use zones and building clusters (existing and planned), key economic sectors with opportunities for district cooling network development. • Facilitation of planning and implementation of district cooling infrastructure. • Maintenance of the District Cooling Systems
12	Smart City Special Purpose Vehicles (SPVs)	The SPVs established to deliver the Smart City Plans could provide a useful conduit for district cooling investment. The SPVs will be attracting investment

	http://smartcities.gov.in/content/innerpage/spvs.php	from external parties and would manage building development and utility development in an area, helping to lower risk for the District Cooling project. This could be in parallel to SPVs incorporating district cooling into their Smart City Plans as a priority.
13	Power Utilities (State-owned and private)	State Electric utilities or private companies involved in the generation, transmission, and distribution of electricity are key resources to help in the assessment of baseline and future power demand, identify and implement requisite mechanisms, incentives, undertake infrastructure augmentation to support the deployment of District Cooling Systems.
14	Central Electricity Authority (CEA) www.cea.nic.in	CEA prescribes the standards on matters such as the construction of electrical plants, electric lines and connectivity to the grid, installation and operation of meters and safety and grid standards.
15	Financial Institutions / Public Sector Banks / Private Sector Banks	Financing institutions along with public and private sector banks can provide financial support and develop appropriate financing schemes for district cooling projects. Some of the active institutions in this landscape are: • Indian Renewable Energy Development Agency (IREDA) • Small Industries Development Bank of India (SIDBI) • State Bank of India • Punjab National Bank • ICICI Bank • Yes Bank
16	International Development Agencies (IDA) / Development Aid Agencies	IDA's like Asian Development Bank (ADB), French Development Agency (AfD), Kreditanstalt für Wiederaufbau (KfW), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Japan International Cooperation Agency (JICA), Swiss Agency for Development and Cooperation (SDC), can open the gates for initial funding for bringing the appropriate technologies to India.
17	Industry Associations Confederation of Indian Industries (CII) www.cii.in Federation of Indian Chambers of Commerce & Industry (FICCI) www.ficci.in	The Industry Associations (including CII, FICCI, and many other sectoral associations) work closely with the government on policy issues, enhancing efficiency, competitiveness, etc. They can play a key role in awareness generation, market and supply-chain creation, adoption of standards, and technical expertise with regards to district cooling.
19	Infrastructure/ Building developers	• 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 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
20	Energy Service Companies (ESCOs)	ESCOs will play a significant role in developing the market for improved cooling through district cooling in the built environment. ESCOs can assist in conducting building energy audits and play an integral role in establishing a framework for measuring space cooling and Heating, Ventilation, and Air-Conditioning (HVAC) performance.
21	Technology Providers (TP)	• Provide inputs on energy audit of the buildings, practical issues and associated risks with regards to district cooling integration and market acceptance. • Provide support/guidance for conceptualization, planning and implementation projects • Provide first-hand experience on technical aspects and local regulations towards HVAC and consequently district cooling. • Provide equipment/appliance/material across the value chain of the District Cooling implementation
22	System Integrators (SI)	To provide complete turnkey solution for setting up of the District cooling system/plant, in coordination and to the requirements of the municipal corporations.
23	Energy Efficiency Services Limited (EESL)	EESL will play a major role in the development of district cooling in India. A Public-Sector Company under the Ministry of Power, it has one of the largest energy efficiency project portfolios in the world (approx. $2 billion of projects ongoing). EESL's expertise in district cooling could be boosted through a partnership with the international private sector to operate the system through a joint venture and/or with a local utility to internalize the benefits to the power system.

4.4.1 Understanding the Stakeholder Landscape



PSUs: Public Sector Undertakings, **SDA:** State Development Agency, **SEDA:** State Energy Development Agency, **DCS:** District Cooling System, **FIs:** Financial Institutions, **I/BD:** Infrastructure/Building Developers, **SCSPVS:** Smart Cities Special Purpose Vehicles, **TP:** Technology Providers, **IAs:** Industry Associations, **ISHRAE:** Indian Society of Heating, Ventilation and Air Conditioning, **ESCOs:** Energy Service Companies

DCS ecosystem for India

Figure 16: DCS eco-system for India

As per the till-date activity, the municipal corporations (municipalities/urban local bodies) will be the implementation nodal agencies for District Cooling in India and will also be at the forefront for receiving the funds from the International Funding Agencies through the channel of the financial institutions in India.

Alongside, town planners and urban developers will play a critical role in establishing the DCS in India. They will be taking over the operations and maintenance of these systems. The municipalities will be guided by the union and state governments and the research institutions (both public and private). Government of India's own think tank and the apex policy-making body 'NITI Aayog' (formerly 'The Planning Commission of India) will have a crucial role in the policy and planning framework front. Also guiding the municipalities would be the statutory bodies (illustrated in the section above) under the central ministries and state development agencies and state energy agencies on the regulatory front.

On the implementation front, the municipalities will hire system integrators (and in turn, they collaborate with different technology providers) to provide a turnkey solution for the selected project. On this front, the building developer associations, manufacturer/ Industry associations, ISHRAE, ESCOs, Technology providers and even the smart cities special purpose vehicles will be acting as the empanelled partners sharing knowledge and providing their expertise to the system integrator.

4.4.2 Stakeholder Responsibility matrix

Table 5: Stakeholder responsibility matrix

	Union Government	State Government	Local Government/ Municipality/ Municipal Corporation	Financial Institutions	International Development Agency	System Integrator (SI)/ Technology Provider (TP)
Policy Framework	✔	✔				
Regulatory Framework	✔	✔				
Project Implementation & Maintenance		✔	✔			✔
Mobilization of Finance	✔	✔		✔	✔	
Monitoring, Reporting, and Verification (MRV)			✔			✔

Chapter 5: Economic Feasibility of District Cooling Systems and city gas (distribution) in India

5.1 Analysis of possible investment opportunities and business models

United Nations Environment Initiative is promoting a city-led approach to space cooling and the Initiative has been formed which is led by EESL, which is exploring into the potential of District Cooling in 5 different cities in India. In these five cities, Bhopal, Coimbatore, Pune, Rajkot and Thane – 600 million dollars of commercially viable district cooling projects have been identified.

Details of costs assumed can be found below:

Table 6 Costs assumed

Items	Bhopal	Coimbatore	Pune	Rajkot	Thane
Population	1,798,218	1,610,000	3,115,431	1,346,000	1,841,488
Area (square km)	285.9	275	243.8	129	128.23

Average Temperature (degree Celsius)	25.3	28.9	24.1	28.2	28
District Cooling Demand (in TR)	38,924	109,889	14,113	15,068	16,103
Estimated Project Cost (in dollars)	87,812,767	247,912,753	31,840,139	33,993,547	36,328,387

The total identified costs across these cities are expected to be 437.88 million US dollars.

Other than this, in the last chapter, we already had identified 12 different cities, which are Hyderabad, Ghaziabad, Surat, Faridabad, Gurgaon, Chandigarh, Vishakhapatnam, Ahmedabad, Indore, Guwahati, Vijayawada, Mumbai, and Kolkata. From the above data, we can assume these cities have a minimum potential of 30 to 80 million US dollars each.

There are small projects also coming up, such as

1. Amravati Project, Andhra Pradesh - Tabreed, UAE based company has signed a concession with Andhra Pradesh government to build a 20000 TR project, costing around 21 million USD in Amravati. Cooling services are expected to commence in 2021.
2. Gift City, Gandhinagar Gujarat – The first phase of District Cooling of 10000 TR is in operation since 2015 and further it is planning to build on this capacity to 18000 TR.

5.2 Prevailing Business Models[44]

The business model has been divided into a framework based on the degree of control and return on investment. The role of government increases with low ROI as private players will be reluctant to invest in it and with its risk-taking ability. Also, if the government entirely wants to control the project and can handle the risk involved with the District Energy project, then the government will have a major say in this business model. This has been explained below.

Table 7: Prevailing business models

Type	Financial Return on Investment	Degree of control and risk appetite of the public sector	Types of Business Model
Type 1	Low	High	Wholly Public
Type 1	Medium/Low	High	Wholly Public
Type 2	Medium/High	Medium	Public/Private hybrid
Type 3	High	Medium/Low	Private (with public facilitation)

5.2.1 Prevailing business model for Type 1:

Public Owned Model:

City of Vancouver:

The city of Vancouver owns the South East False Greek Neighbourhood Energy Utility (SEFC NEU). It developed, completely owns and operates a district heating network based on various renewable sources. The network captures waste heat from a sewer pump station.

Reason for development under Type 1:

[44] http://www.districtenergyinitiative.org/sites/default/files/report_pdf/03%20District%20Energy%20Chapter%203_print.pdf

a) Lack of time, to be developed before the 2010 Winter Olympics.
b) The city wanted to showcase this project as a commercially viable example

Time required for implementation:
5 years

Salient features of this project:
a) 90% of the area's heating floor space is residential, catering to 16,000 people heating load.
b) Because of being publicly owned, connection cost and energy tariffs are transparent.
c) The total cost of the project was 32 million dollars.
d) The entire project was 100% financed by debt.
e) As it is publicly owned, the rate of interest charged on debt was very low.

London Islington Borough:

Buildings covered:
Five council-owned housing estates and two council-owned leisure centers which had existing communal heating systems.

Reason for development:
Existing heat networks had costly tariff rates. So, it was decided to build own heating sources.

Mode of funding:
No debt. As it was felt that debt will increase the cost of the tariff.

Investment incurred:
12.6 million dollars approximately.

5.2.2 Prevailing business model for Type 2:

a) Pooled Asset Model: Different actors combine skillsets through a single company or utility.

Toronto District Heating Corporation

Area Covered:
Five hospital and university campuses

Ownership:
Originally, 43% owned by the city and 53% owned by BPC Penco Corporation (a subsidiary of Municipal Retirement Pension Fund)

Mode of funding:
Using private and public bonds

Empower in Dubai

Area covered
Meets demand of 1 million tons of refrigeration annually.

Ownership:
70% by Dubai Energy and Water and 30% by TECOM

Anticipated ROI:
10 to 12% yearly

b) Split Asset Model: Skillsets are separated and are individually managed. For example, the public sector managing waste incineration and heat transmission whereas the private sector managing CHP heat production.

District heating in Anshan:

Area covered:
50 million m^2, or 70% of the total city's heating area

Ownership:
60% transmission line by municipal and 40% by private FUAN company. Production and distribution of heat are handled by the private sector.

Source of heat:
Angang Steel plant and two CHP plants in city's North and South

c) Public-Private Concession Contract Model: Under the concession contract model for the private sector, the public authority typically develops a feasibility study of the district energy project and then tenders it to the private sector (usually an energy service company, or ESCO) as a concession that runs for a specified term.

London's Olympic Park:

Olympic Development Authority carried out the feasibility study. The contract was awarded to the energy service company Cofely. Cofely was granted exclusivity to supply heat and cooling for all buildings within Athletes Village, Olympic Park, and Stratford City.

Investment incurred:
160 million dollars

d) Community-owned Not-for-profit or Cooperative model

Hoje Taarstrup Fjernvarme in Copenhagen

The company was formed in 1992 by the merger of a cooperative district heating company and a municipal one.

Area covered:
5,260 customers, including residential, commercial and industrial buildings.

Mode of Operation:
Høje Taarstrup Fjernvarme purchases heat from the municipality-owned transmission company, which itself buys heat from privately owned power stations in the surrounding areas. Customers connect via an agreement under which they become a member-owner of the cooperative. The governing board is made up of seven members elected by customers and two members nominated by the local authority.

The municipal companies own and operate the transmission and/or distribution systems, while the cooperatives and mutual undertake the retailing of heat directly to customers.

Investment:
The municipality provides low-cost financing at 1.5% and the low-profit margin allows to pass on the benefits of low heating rates to the owner-members.

5.2.3 Prevailing business model for Type 3:

a) Private business model: The public sector acts as a facilitator, while the entire operation is controlled by the private sector.

Port Louis Sea Water Air Conditioning:

Area Covered:
60 high-density buildings (both public and private) in Mauritius by 2016.

Operation:
The first-of-its-kind SWAC project on the island (and in Africa) will pump water at 5°C from 1,000 meters below sea level to cool buildings in the heart of the capital city. The SWAC is being developed by a local company Sotravic Ltd.

Mode of funding:
Local banks, international financial institutions

Investment incurred:
130 million dollars

Role of Government is limited to promote the scheme to attract concessional finance from development banks

5.2.4 Summary of Prevailing Business Models

Table 8 Summary of Prevailing Business Models

Type	Model	Risk and Governance	Source of Funding	Control
Type 1	Wholly Public	The city undertakes most of the risk of investment. The project is characterized by low IRR. Design and construction are sometimes outsourced to reduce risk and time frame of project development.	Major sources of funding are the city's cash reserves or public debt	Governance is controlled by the local government, whereas the tariff rates are controlled by the public sector. The company goes for equitable billing and can have differential tariffs for commercial vs domestic users.
Type 2 a	Pooled Asset Model:	Risk is shared by both public and private partners. The public sector (i.e., local authority) can underwrite the sales risk, guaranteeing to commit to long-term heat/cool off-take	Both private and public sector raise equity. Debt is based on future cash flows and can be underwritten by either party. The land is provided by a municipal	Governance is controlled by directors appointed by each project partner. The exit strategy is through selling out their portions to their partners.

		contracts, and can deal with regulatory barriers to project development. Private sector parties, meanwhile, can take on the design, construction and operation risk, transferring this risk away from city taxpayers and on to private sector equity holders.	corporation. The presence of the public sector attracts a low cost of funds. Tax rebates are also provided in this model.	
Type 2 b	Split Asset Model:	-do-	-do-	-do-
Type 2 c	Public-Private Concession Contract Model:	The company (usually private sector Energy Saving Company) which designs, builds and operates the district energy system bears the entire risk. The presence of local authority minimizes risk to some extent.	Energy Saving Company (ESCO) is normally large and major funding is internal. Land for the project is provided by the local authority, which in turn can reduce tariffs.	The local authority has limited control. At the end of the term, a local authority can issue a fresh contract that can either be provided to municipal, community or to a private company.
Type 2 d	Community -owned Not-for-profit or Cooperative model	A major risk is born by the local authority. Once mutual amongst retailers is established, the risk born by local authority decreases.	Municipality underwrites for initial funding. The presence of local authority attracts low-cost funds.	The governance structure is decided by representatives elected by the members of the mutual.
Type 3	Private business model	Risk is born by a private company. The local authority may help in establishing infrastructure and availing low-interest loans. The local authority, in turn, is benefitted by reduced tariff and profit-sharing.	Financing is done self, either in the form of equity or loans. The local authorities may support in getting international loans or grants for the project.	The private sector company determines the governance structure, tariff, and distribution of energy.

5.3 Possible ownership models for District Cooling in India

Table 9 Possible ownership models for District Cooling in India

S. No.	Model	Description
1	100% municipal ownership and operation directly	The municipality is ultimately responsible for each element of the district cooling network´s delivery, but a third party may be contracted out to deliver services such as the design, build, where the municipality is responsible for the operation, and/or maintenance of the system.
2	100% municipal ownership and	The establishment of a Special Purpose Vehicle (SPV) means that the district cooling network would have its own business plan and budget,

	operation, through a subsidiary corporation	which is separate from the public body's business plan, and which focuses exclusively on the district cooling network. The SPV would be responsible for securing funding, and owning and operating the district cooling network, but would be able to contract third parties for different roles (the design, build, operate and/or maintain), in the same way, that a full public model could. Additional important advantages of this approach include the insulation against risk and alignment with the Municipality's aims
3	Community Interest Company ownership[45]	**A Community Interest Company (CIC)** is a type of limited company with an asset lock that restricts the distribution of profits and capital, and ownership includes either one or a mixture of the following: the municipality, building associations and/or cooperatives. **A private limited company with a community benefit would be created and district cooling network funding can be acquired through shares bought by the respective shareholders.** Community Interest Companies tend to be more commonly used where there is a high proportion of residential connections.
4	Joint Venture between a municipality and a private sector company (the private sector company may provide operating expertise)	A hybrid public/private partnership business model merges different advantages and disadvantages from the fully public and private models. A Hybrid model creates a partnership between the public and private sector in the form of a Joint Venture (JV) or SPV (note that this SPV is not a publicly owned SPV) wherein **the district cooling network will be owned, funded, and delivered jointly by a private company and a public body. Bringing in a private partner opens additional sources of funding and expertise for the project whilst at the same time diluting the Municipality's control over the network.**
5	Split ownership and operation, the municipality owning and operating the distribution systems with private sector owning and operating Energy Centre	The private company will likely possess the specialist skills required to design, build, operate, and maintain the network which means that the Municipality will not need to contract out a third party for these activities. An additional benefit of this model is that the private partner is incentivized by their interest in the project and their involvement as an operator/maintainer to optimize and maintain the system to the highest standards.
6	100% private ownership and operation	A wholly private governance model is where **a private company secures funding for the district cooling network and owns and operates the network**. In comparison with the fully public, hybrid public/private, and stakeholder owned governance models, **this model is perceived as the highest cost approach with the highest customer prices**.

5.4 Electricity / Gas Tariff Analysis

Gas Tariff Analysis:
Gail owns and operates about 11,400 km of Natural Gas pipeline network in India and has around 75% market share in Natural Gas Transmission within the country. The detailed network for City Gas Distribution has been shown below. [46]

[45] UNEP Pre-feasibility study for DCS in Thane
[46] https://gailebank.gail.co.in/goga/NewApplication/images/Map%20-%204jun18%20-%20V1.6%20JPG%20format.jpg

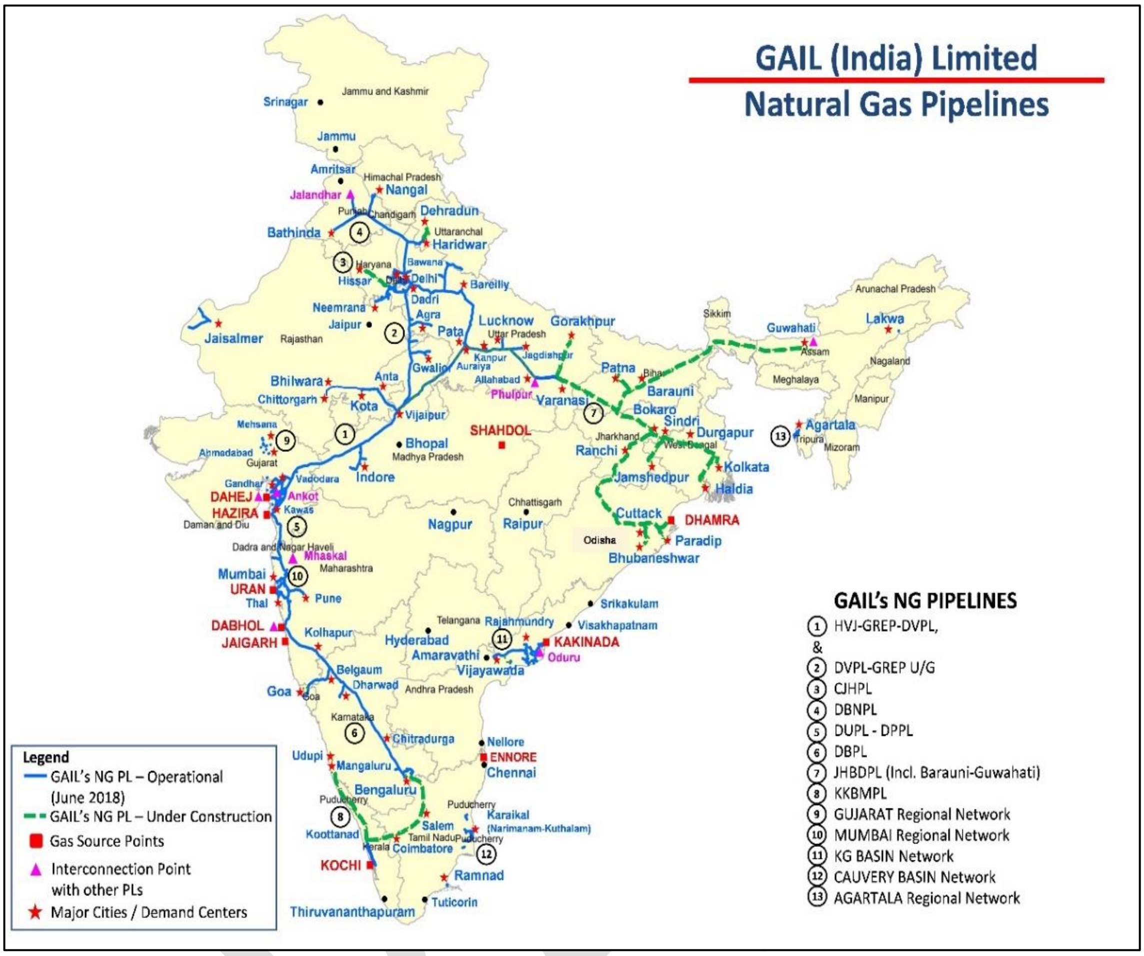


Figure 17: City Gas Distribution in India

In India, there is a system of Zonal transmission tariff, where the pipeline network is divided into zones of 300 km each. The consumers located near to the source and within 300 km range pay less tariff than the consumers away from the source.
Presently, the tariffs for the three declared zones are:

Tariff	Zone 1	Zone 2	Zone 3
Rs/MMBTU	45.37	45.41	45.44

The tariffs are to be levied from 1st September 2019. [47]

Electricity Tariff Analysis:[48]
Commercial users have been divided based on maximum power demand. For each type of consumer, bills are charged differently. It is observed that for South and South-West Indian states the tariff rate is on the higher side as compared to others.

Table 10 State-wise average rates of Electricity with effect from 1st April 2016

State/Utility-wise Estimated Average Rates of Electricity in India - Part I
(As on 01.04.2017)
(Rate in Paisa/kWh)

[47] https://pngrb.gov.in/pdf/orders/Excel_19082019.xlsx
[48] https://www.indiastat.com/table/power/26/utility-wise-average-rates-of-electricity-supply-and-electricity-duty-tax-1998-2015/728055/1188004/data.aspx

States/UTs/Utilities	Commercial			
	2KW (300 KWh/Month)	10KW (1500 KWh/Month)	30KW (4500 KWh/Month)	50KW (7500 KWh/Month)
Andhra Pradesh	856.91	980.78	1007.42	1012.75
Arunachal Pradesh	500.00	500.00	500.00	500.00
Assam	814.33	833.53	853.60	854.24
	-	-	-	-
Bihar	644.83U	788.99	794.18	795.21
	296.80R	-	-	-
Chhattisgarh	701.87	866.13	903.47	910.93
Goa	468.33	523.00	534.33	536.60
Gujarat	585.42	585.42	642.36	655.56
Haryana	615.00	685.00	738.33	738.33
Himachal Pradesh	581.40	552.60	554.56	554.56
Jammu and Kashmir	401.50	627.73	627.73	627.73
Jharkhand	716.67U	720.67	721.33	721.47
	215.00R	-	-	-
Karnataka	881.57D	895.7D	898.06D	898.53D
	821.50F	835.63F	837.99F	838.46F
Kerala	854.00	1063.00	1103.00	1103.00
Madhya Pradesh	739.10U	744.29U	879.24U	879.44U
	716.30R	721.33R	860.08R	860.28R
Maharashtra	1019.93	1227.62	1360.67	1360.65
Manipur	556.67	626.00	-	-
Meghalaya	699.33	738.00	744.44	745.73
Mizoram	500.00	574.67	587.11	589.60
Nagaland	758.00	847.60	862.53	865.52
Odisha	627.47	707.89	721.30	723.98
Punjab	754.46	761.09	762.20	762.42
Rajasthan	953.33	985.67	1078.19	1081.21
Sikkim	533.50	611.97	627.32	630.39
Tamil Nadu	836.50	932.58	939.69	941.12
Telangana	891.00	975.00	995.67	999.80
Tripura	691.50	768.33	768.33	768.33
Uttar Pradesh	827.50U	1004.83U	1027.72U	1032.30U
	400.83R	400.83R	400.83R	400.83R
Uttarakhand	561.67	561.67	646.37	646.37
West Bengal	880.79U	1027.09U	1044.80U	1048.34U
	880.06R	1026.94R	1044.75R	1048.31R
Andaman and Nicobar Islands	678.33	840.33	880.11	888.07
Chandigarh	587.67	614.00	619.78	620.93
Dadra and Nagar Haveli	308.33	329.67	333.22	333.93
Daman and Diu	331.67	358.33	362.78	363.67
Delhi (BYPL/BRPL/NDPL)	994.00	994.00	1081.11	1081.11
Delhi (NDMC)	850.50	850.50	1068.53	1068.53
Lakshadweep	668.33	749.67	763.22	765.93
Puducherry	601.21	645.24	652.58	654.05

Capital Cost Estimates [49]

The data has been obtained from the feasibility analysis conducted on Thane, Pune, Rajkot, Coimbatore, and Bhopal. [50]

Based on the data few assumptions have been made and accordingly, an excel sheet calculator has been prepared.

Assumptions:

1. Equipment cost, which includes construction cost too of District Cooling is assumed to be 2000 USD/TR
2. Land cost of District Cooling plant is assumed to be 512 USD/m2
3. Network cost of piping, metering, insulation, and installation is assumed to be 180 USD/TR
4. District Cooling plant land requirement per TR is assumed to be 0.1486 m2/TR

Table 11 District Cooling Cost Calculator

Tonne of Refrigeration (TR)	100,000
Distribution Network Cost (USD/TR)	180
Land Cost Assumptions (USD/m2)	512
Equipment Cost of Cooling plant per TR (USD/TR)	2,000
District Cooling Plant Built-up Area (m^2/TR)	0.25
Outdoor space for cooling towers (m^2/TR)	0.08
DC Plant land requirement (m^2/TR)	0.15
Energy Transfer Station - District Cooling plant (USD/TR)	2,000
District Cooling Equipment Investment (USD)	200,000,000
District Cooling Plant Land Investment (USD)	7,608,320
Network Cost (USD)	18,000,000
Total Cost (USD)	2256,08,320

Please refer to the annexure on 'District Cooling Cost Calculator', for more calculations.

5.5 Overview of technology options and Energy source for the above technology

Grid electricity is the most used source of energy for District Cooling. However, there are other sources too which either are used in conjunction with electricity or are standalone to lower down the fuel requirement and improve the efficiency of District Cooling.

A comparative study of the location, energy sources and benefits have been summed up in the table below.[51]

Location	Energy Sources	Cooling/Energy Storage Technology and Capacities	Energy Savings and Environmental Benefits	Economic Benefits

[49] http://www.districtenergyinitiative.org/sites/default/files/Bhopal%20Rapid%20Assessment%20Report%20Version%201.0.pdf
[50] http://www.districtenergyinitiative.org/sites/default/files/Bhopal%20Rapid%20Assessment%20Report%20Version%201.0.pdf
[51]https://res.mdpi.com/energies/energies-12-00235/article_deploy/energies-12-00235 v2.pdf?filename=&attachment=1

Chan et al (2006) Hong Kong	Grid Electricity	Cooling: Seawater-cooled Storage: Ice tanks or series chiller-led arrangements with chillers	Energy Savings: DCS with ice storage and chiller priority control consumes less electricity	Electricity cost for ice storage with chiller priority control is very less.
Norrkoping, Sweden (2004)	Waste, biofuel, rubber, and oil-fired CHP plant electricity and heat	Cooling: Nearby river cooling water	Environmental benefits: Global CO2 reduced up to 80% using absorption cooling as compared to compression cooling.	The production cost of cooling reduced by 170% using absorption cooling. 30% reduction in system cost due to electricity savings
Soderman (2007), Finland	Grid Electricity	Cooling: Electrical vapor compression chillers (COP, 3) Storage: Coldwater in above-ground steel tanks or underground basins	Not reported	Annual DC investment and operating costs minimized to identify optimum cooling plants locations/capacities, storage media/capacities and distribution pipeline routing
Turkey (2015)	Steam extracted from inlet stage of LP turbine in coal-fired power plants	Cooling: single and two-stage absorption chillers.	Energy efficiency: Efficiency cooling improved by 3 to 5.5%.	Not reported
Södertälje Sweeden (2007)	The heat from waste-fired, peat/biomass-fired, oil-fired, and electric boilers and Coal-, oil- and waste-fired CHP plant electricity and heat	Cooling: Absorption chillers (COP, 0.7) Electrical vapor compression chillers (COP, 2–5) Free lake cooling water	Electricity consumption reduced by ~40% using absorption chillers instead of electrical chillers and increased lake water cooling Electricity/heat production-induced CO_2 emissions reduced through investments in condensing power	Investments in new absorption chillers to replace electrical chillers and increased lake water cooling optimized through minimization of system costs
Bangkok Thailand (2009)	Waste heat and electricity from MSW-fired power plants	Electrical vapor compression chillers Single and double effect compression thermal chiller	Energy savings: Cooling energy consumption reduced by 1 MWfuel/MWcooling compared with electrical chillers-based cooling Environmental benefits: Emissions	Total investment and annual O&M costs of MSW co-generation with 14 × 10 MW-absorption chillers: M$149.49 and M$28.6, respectively; 4.7 years payback period

			reduced by 0.13 kgCO2/kWh of cooling (i.e., by 60%) using MSW co-generation coupled with absorption cooling compared with electrical chillers-based cooling	Total investment and annual O&M costs of MSW co-generation and 14 × 10 MW-electrical chillers: M$139.44 and M$32.04, respectively; 4.9 years payback period
Kuwait (2014)	Waste heat from NG-fired SOFC-GT power plant Electricity from NG-fired SOFC-GT power plant	Double-effect H_2O/LiBr absorption chillers (2620 RT; COP, 1.3) Electrical vapor compression chillers (20,680 RT; rated efficiency, 0.61 kW/RT)	Fuel energy consumption reduced by 54%, peak electrical power consumption reduced by 57%, and fuel-to-cooling efficiency improved by 346%, all relative to PACUs	Cost of per ton-hour of cooling reduced by 53%
Abu Dhabi, UAE (2015)	Heat from CC (i.e., steam extracted from ST LP turbine) fed to absorption chillers Heat from solar PTC fed to CC HRSG Electricity from Combined Cycle	Steam-driven double-effect H2O/LiBr absorption chillers (4 × 20.7 MW; COP, 1.31) Electrical vapor compression chillers (COP, 2.2–4.0)	Fossil-fuel savings of 26% and 33% in winter and summer days, relative to fossil-fuelled electricity compression cooling only Peak electricity demand reduced by ~8 MW (20%) and ~25 MW (31%) in winter and summer days, respectively, relative to fossil-fuelled electricity compression cooling only	Energy savings not quantified yet.
Riyadh, Saudi Arabia (2018)	Thermal energy from either North-south or East-west oriented PTCs or CRS heliostats Electricity and heat from PTC/CRS solar field driven SRC, with steam extracted from SRC LP turbine to drive thermal chillers	Double-effect H2O/LiBr absorption chillers (4 × 20.7 MW; COP, 1.31) Electrical vapor compression chillers (50 MW; COP, 2.5–5.0)	Energy savings of the three solar field configurations, the CRS system requires the lowest amount of solar energy and produces the least excess heat	Investment cost of solar and storage systems minimized through optimization of solar field aperture area and storage tank volume Of the three solar field configurations, the Central Receiver System leads to the lowest investment cost

Energy sources can be divided into grid electricity, natural gas, waste heat. Renewable energy can support fuel intake for District cooling. Central chiller plant, based on fuel used, can be subdivided into vapour compression chiller and thermally activated chiller. The thermally activated chiller can be further divided into a single-effect absorption chiller and a double-effect absorption chiller. The coefficient of performance (COP) varies between 0.5 to 0.8 for a single effect and 1.1 to 1.51 for double effect. For natural gas, COP is around 1.42 and for electricity-driven chiller, which is the most used chiller system, COP is 6.6. As per the paper "School of Energy and Environment" the seasonal energy efficiency ratio of the cooling source system (EER) was found to be 3.85. We will be using this EER for our comparative calculations.

Cooling sources can be divided into natural water bodies – rivers and lakes and cooling towers. In the liquid regasification process, liquid natural gas at -162 degree Celsius is converted back to natural gas at room temperature. In this process, it absorbs heat and functions as a heat exchanger.

A comparative study on the coefficient of performance (COP) for different types of energy inputs have been summed below:[52]

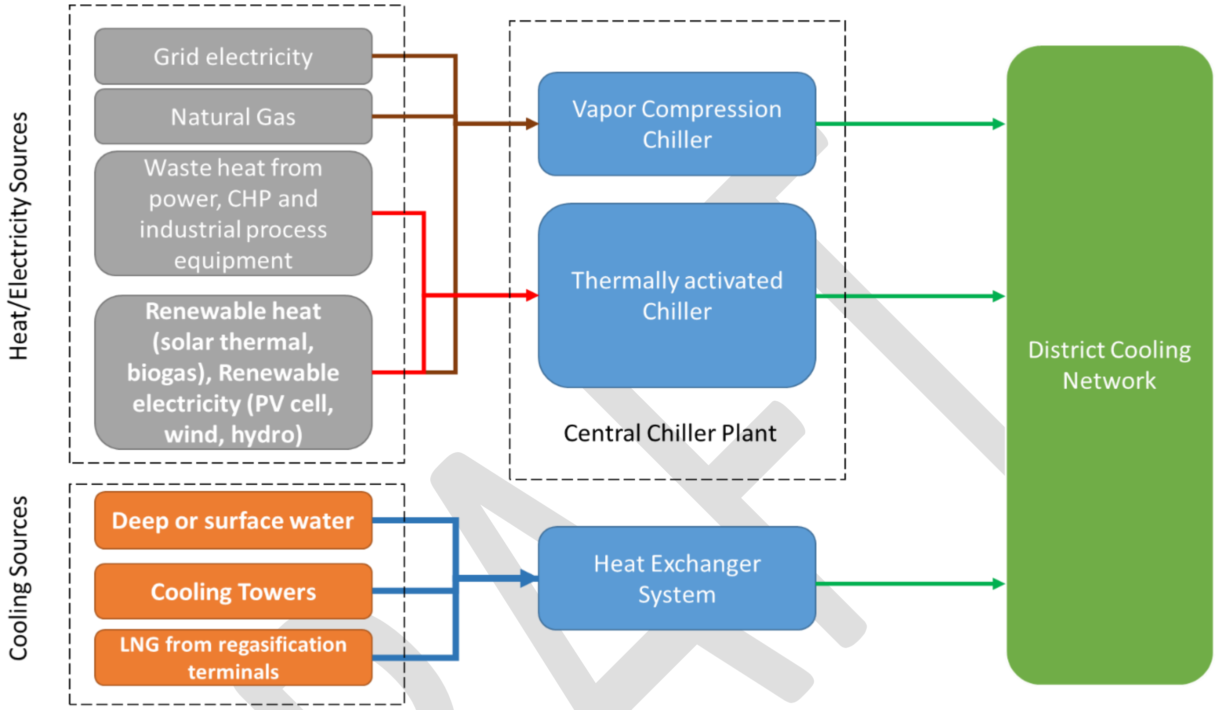
Table 12 Coefficient of Performance (COP) comparative study

Chiller	**Type of Energy Input**	**Cooling Power Required (kW)**	**COP**
Steam adsorption (double effect)	8 bar steam	2000	1.39
Hot water absorption (single effect)	98-degree Celsius hot water	2000	0.79
Gas absorption (DFAC)	Natural Gas	282 to 2462	1.42
Compressor Chiller	Electricity	2000	6.6
Engine-driven compressor chiller (ICE)	Fossil Fuels	140	2.7

[52] https://pdfs.semanticscholar.org/3697/ebc0c3d3fceb9e3aa835547d047e5767887f.pdf

Figure 18: District Cooling energy sources, cooling sources and technologies

The process diagram highlights different energy sources, cooling sources and available technologies in District Cooling.



5.6 Correlation between electrical power demand and cooling demand

Scenario 1: Individual Air Conditioning units

Scenario 2: Central District Cooling System

Assumptions:	
No. of households	100
Area of one room	180 SqFt
No. of Split AC installed per household	2
TR of one 1 AC	1.5
Area enough for 1 TR of Cooling	400 SqFt

Total Cooling Area under one split AC for 100 households = 180 SqFt/house X 100 house=18,000 SqFt

Total Cooling Area under two split AC for 100 households = 18,000 SqFt X 2 =36,000sqft

1 TR produced by a District Cooling system can cool 400 SqFt (ISHRAE thumb rule)

Number of TRs to be produced under District Cooling for 36,000 SqFt = 36,000 SqFt / 400 SqFt/TR = 90 TRs

Energy savings in ACs if they are used for 3,200 hours in one year.

Table 13 Energy Savings in ACs

	Spilt AC	**DCS**	**Comments**
Numbers installed for 100 houses	200	1	Assumption stated above
Operating hours	3,200	3,200	Assumption stated above
Power consumed (kW)	346	82.22	1.5 TR of cooling = 3.517 kW*[53] EER for a three-star AC = 3.1**[54] Power Consumed by one split AC = 1.5X3.517/3.1 kW Power Consumed by DCS = 90X3.517/3.85***[55]
Energy Consumed	1,107,200	263,089.87	number of hours X power consumption
Energy Saved (kWh)		844,110.13	Difference between the two
CO2 mitigated (kgCO2/kWh)		801,904.62	0.95 kg CO2 per kWh is generated[56]
Monetary Savings (assuming Rs 6/kWh)		5,064,660.78	

In one year, we expect to save 8.44 lakh of kWh, mitigate 800 tonnes of CO2 and save Rs 50 crores in a 90 TR system.

Please refer to the annexure for a detailed calculation tool.

5.7 Impact on the power infrastructure

Cooling demand in each city is assumed to be 15,000 TR in sync with those estimated in cities Pune, Rajkot, and Thane. For 90 TR of cooling load, 263 MWh of electrical energy is required. By the unitary method, for 150,000 TR, 438,483 MWh energy will be consumed. We assume that a 60% cooling infrastructure is already present in these cities. This means for the demand of 15,000 TR, 60% of TR is already present, and is fulfilled via split ACs. This 60% of TR is met by 1107200 MWh of electrical energy which is less as compared to 438,483 MWh. Using the District Cooling System, we will be saving energy equivalent to 668,716 MWh in one year. Thus, we will be releasing stress on power infrastructure.

[53] https://electricalbaba.com/calculate-power-consumption-ac/
[54] https://www.researchgate.net/post/How_to_calculate_the_energy_consumption_by_Air_Conditioner_AC_load
[55] https://www.sciencedirect.com/science/article/pii/S1877705817350026
[56] https://www3.epa.gov/ttnchie1/conference/ei20/session5/mmittal.pdf

Chapter 6: Recommendations and Way Forward

Considering the current baseline, it is suggested to go forward via the following options:

Short-term
- Municipal ownership and operation directly
- Municipal ownership and operation, through a subsidiary/SPV (special purpose vehicle) corporation set up for 102 Smart Cities

Medium-term
- Community Interest Company ownership
- Joint Venture between a municipality and a private sector company

Long-term
- Split ownership and operation, the municipality owning and operating the distribution systems with private sector owning and operating Energy Centre
- 100% private ownership and operation

There are hardly any success stories in the context of district cooling business models. So, it is difficult to strongly recommend any of the above. However, a likely and workable possibility is to go forward with the SPV model, backed by the Ministry of Housing and Urban Affairs (MoHUA) for the 102 Smart Cities in India. Any future investments planned by ADB and the technical assistance provided by consultants, the rationale for the same can be summarised as under:

Benefits of involvement of Municipalities /Government:
1. The involvement of the government will mitigate political risks (paperwork, ease of doing business, licenses, policies, etc.).
2. Land availability is a major concern for the project, which can be handled by the municipality and the local government.
3. Attract cheaper modes of finance – a large number of investors, low-interest rates and tax rebates.
4. Local people will support and will have faith in the project as it is backed by the government.
5. Since the project is backed by the government, so it is expected to have many off-takers.

Benefits of Involvement of private partners:
1. Technical proven expertise from national and international private players
2. Backed by similar other project implementation, there are increased chances of success of the project
3. Increased effectiveness and efficiency of the project

This gets very well aligned with the ongoing national project, Smart Cities Mission, implementation of which is being planned through a Special Purpose Vehicle (SPV) created for the purpose, at each city level. The SPV will plan, appraise, approve, release funds, implement, manage, operate, monitor and evaluate the Smart City development projects. Each smart city will have a SPV which will be headed by a full-time CEO and have nominees of Central Government, State Government and ULB on its Board. The States/ULBs shall ensure that, (a) a dedicated and substantial revenue stream is made available to the SPV so as to make it self-sustainable and could evolve its own creditworthiness for raising additional resources from the market and (b) Government contribution for Smart City is used only to create infrastructure that has public benefit outcomes. The execution of projects may be done through joint ventures, subsidiaries, public-private partnership (PPP), turnkey contracts, etc suitably dovetailed with revenue streams.

> *Smart Cities Mission, sometimes referred to as Smart City Mission, is an urban renewal and retrofitting program by the Government of India with the mission to develop 100 smart cities across the country making them citizen-friendly and sustainable. The Union Ministry of Housing and Urban Affairs (MoHUA) is responsible for implementing the mission in collaboration with the state governments of the respective cities.*

This mission is expected to take a leapfrog jump, with the Union government planning to expand the Smart Cities Mission to all 4,000 cities in the country, in 2020.

We do take into consideration, the recently launched India Cooling Action Plan, which aims to assess the cooling requirements and the associated refrigerant demand and energy use across sectors in the next 20 years. The plan includes developing a research and development innovation ecosystem for the indigenous development of alternative technologies.

It is suggested not to reinvent the wheel again, however, the following addons can further benefit the acceleration of adoption of District Cooling in India:

1. An overall implementation framework, which prescribes the institutional and governance framework for implementing the recommendations, at both national and state levels. The mandates of different institutions, agencies, and departments, at both Central and state levels, the vertical and horizontal coordination necessary, and the resources needed to staff, train and fund the interventions must be further added to the draft action plan. The ICAP must provide some guidance to states and articulate the role of non-state actors such as builders, manufacturers, consumer groups, industry associations in supporting the recommendations. In the context of District Cooling, which is placed in the midterm solution in the Plan, IIEC and ADB can work together to further strengthen this aspect.

2. Defining and mapping heat stress in India's different climate zones: ICAP's assumption that cooling needs and approaches in all climate zones of India are the same needs to be corrected. Heat thresholds vary in India across states and people's ways to deal with heat also differ. For example, heat in humid Chennai differs from the dry heat Delhi or Jaipur experiences during peak summers. While the ICAP admits that heat is increasing, it does not present a mapping of heat stress in India. There is a need to support the recommendations with an analysis of trends in temperature and heat stress and therefore projected cooling demand in India's different climate zones. The plan can adopt a few pilot cases (cities or states) to project future heat under different climate scenarios to ensure that the plan adequately prepares India for future needs. The proposed recommendation on heat action plans is much needed and it can be strengthened further by calling for a mapping exercise by local jurisdictions of vulnerable populations and their cooling needs. In the context of District Cooling, this becomes an important aspect to be considered, going forward.

The following measures are suggested for the further promotion of district cooling in the Indian context

- Formation of an entity, taking a role of National Coordinator role in District Cooling (at the moment, EESL is the National Coordinating Agency for UN Environment-led District Energy in Cities Initiative), similar to the role taken on by the International District Energy

Association and the Swedish District Heating Association in both district heating and cooling.

- On a parallel front, to further accelerate the movement of District Cooling, it is suggested to have state-level coordination entity, which can act as one-stop solution / nodal point, for all projects under the ambit of District Energy
- Develop a screening tool with benchmark values for identifying feasible district cooling projects, including ranking/selection of states and cities
- For the identified cities (can include Smart Cities as well), the following short-term and medium-term actions are recommended:
    a. Establish a multi-stakeholder coordination group (short-term)
    b. GIS energy mapping and development of district cooling benchmarks including metering of cooling demand
    c. 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
    d. Identify opportunities and establish 'high priority' and 'medium priority' zones to promote district cooling
    e. Establish a 'sustainable energy delivery unit' or include within the Smart City SPV
    f. 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
    g. Incorporation of district cooling into existing city strategies and targets. Set targets specifically for the district cooling sector
- Produce a best-practice handbook for district cooling in India, covering the entire project value chain.
- Identify a district cooling pilot project to serve as a demonstration project for international district cooling best practice (cue can be taken from till-date assessments done for 5 cities (Thane, Rajkot, Pune, Bhopal, and Coimbatore) in India, from the UN Environment project)

Technical assistance would facilitate the implementation of some of the foregoing items. Technical assistance would be needed to support the International Institute for Energy Conservation (IIEC) and Asia Pacific Urban Energy Association (APUEA) to institutionalize district cooling in its present operation.

The following work, for example, could be done under technical assistance:

- Upgrade the existing magazine published by the association to include a chapter specifically on district cooling landscape and technologies in the Indian context
- Upgrade the existing website of the association to include a district cooling section for India
- Identify district cooling operators in India
- Upgrade the existing statistical database of the association to include district cooling or establish a new database.
- Publish the best-practice handbook for district cooling in India.

Annexures

Annexure A: Stakeholder Consultation – summary of meetings done during May – Dec 2019

Entity	Status
Energy Efficiency Services Limited (EESL)	✔ meeting completed with the stakeholder; inputs incorporated in this report
Ministry of New and Renewable Energy (MNRE)	✔ meeting completed with the stakeholder; inputs incorporated in this report
Danfoss India	✔ meeting completed with the stakeholder; inputs incorporated in this report
Carrier Air-conditioning & Refrigeration Ltd.	✔ meeting completed with the stakeholder; inputs incorporated in this report
Daikin Airconditioning India Pvt. Ltd.	✔ meeting completed with the stakeholder; inputs incorporated in this report
Ministry of Housing and Urban Development (MoHUA)	✔ meeting completed with the stakeholder; inputs incorporated in this report
Ministry of Environment Forest and Climate Change (MoEFCC)	✔ meeting completed with the stakeholder; inputs incorporated in this report
Thane Municipal Corporation, Maharashtra	Tentatively planned for the calendar year 2020
Rajkot Municipal Corporation, Gujarat	Tentatively planned for the calendar year 2020
Broad India	Tentatively planned for the calendar year 2020
Empower Solutions	Tentatively planned for the calendar year 2020
UN Environment (India Office)	✔ meeting completed with the stakeholder; inputs incorporated in this report
National Central Cooling Company PJSC (Tabreed)	Tentatively planned for the calendar year 2020
RAMA – Refrigeration and Airconditioning Manufacturers Association	Tentatively planned for the calendar year 2020
ISHRAE – Indian Society of Heating, Refrigerating and Air Conditioning Engineers	Tentatively planned for the calendar year 2020
Delhi Mumbai Industrial Corridor Development Corporation (DMICDC)	✔ meeting completed with the stakeholder; inputs incorporated in this report
National Capital Region Transport Corporation (NCRTC)	✔ meeting completed with the stakeholder; inputs incorporated in this report
NITI Aayog	✔ meeting completed with the stakeholder; inputs incorporated in this report

Annexure A1: Excerpts from some of the key meetings:

Meeting #1 | Ministry of Housing and Urban Affairs (MoHUA), Government of India | 4th September 2019

Attendees:

- Mr. Kunal Kumar, Joint Secretary, MHUA
- Mr. Keerthi Kumar Challa, Analyst Projects, ADB
- Mr. Sanjay Dube, CEO, IIEC
- Ms. Disha Sharma, Project Manager, IIEC
- Mr. Kartik Dube, Assistant Project Manager, IIEC

Discussions:

- Mr. Sanjay Dube briefed about the project objectives and activities.
- Mr. Kunal Kumar requested a two-pager document from the project team- detailing the concept and benefits of shifting to District cooling (in terms of energy savings, GHG mitigation, etc.)
- Mr. Kunal agreed to share this note with the city MDs and seek their responses and interest in the concept.
- It was agreed to organize a small round table conference in November with city SPVs to discuss the potential of a pilot.

Deliverables

- Note on District Cooling (Annexure L)

Meeting #2 | NITI Aayog | 4th September 2019

Attendees:

- Mr. RK Pradhan, Chief Deputy Advisor (Energy, Climate Change and Overseas Engagement), NITI Aayog
- Mr. Sanjay Dube, CEO, IIEC
- Ms. Disha Sharma, Project Manager, IIEC
- Mr. Kartik Dube, Assistant Project Manager, IIEC

Discussions:

- Mr. Sanjay Dube briefed about the project objectives and activities.
- Mr. RK Pradhan informed that currently, NITI Aayog is working on developing a policy framework related to mainstreaming EE and developing a national portal for data management for primary and secondary energy production and consumption in a different sector. The data bank will include sector-specific energy consumption detail bifurcated by fuel type, state, and city.
- He also informed that currently NITI Aayog is not specifically focusing on cooling, although they realize the potential in the sector as with energy efficiency measures being adopted in different sectors, cooling will be forming the major chunk of energy demand in the coming decade. He proposed to support IIEC on the concept as and when IIEC develops a model where NITI Aayog can fit in.

Meeting #3 | National Capital Region Transport Corporation (NCRTC) | 5th September 2019

Attendees:

- Mr. Rajiv Datt, Sr. Advisor, NCRTC

- Mr. Sudhir Kumar Sharma, IRSS, NCRTC
- Mr. Saurabh Srivastava, Sr.Executive/Coordinator, NCRTC
- Ms. Disha Sharma, Project Manager, IIEC
- Mr. Kartik Dube, Assistant Project Manager, IIEC

Discussions:

- NCRTC is a joint venture between the central government and four states (Delhi, Haryana, Uttar Pradesh, and Rajasthan) government. The reporting is to Join Secretary of Urban Development.
- Mr. Sudhir Srivastava informed the project team about the high-speed rail corridor being developed between Delhi-Meerut, Delhi-Alwar, and Delhi- Panipat. The corridors are being developed in a phased manner.
- The first phase is being constructed between Delhi-Meerut. All DPRs for this phase have been made and the construction activity has commenced. The second phase will be developed between Delhi-Alwar. The DPRs for this phase have also been developed.
- Along the corridors there are provisions for developing stations, these stations will be connected to local metro (Delhi metro and upcoming Meerut metro), bus depots and railway tracks (Nizamuddin Train Station and Sarai Kale Khan, New Delhi). Along the Delhi-Meerut corridor, there are provisions for establishing operation and maintenance depots, multi-modal rail stations (underground and above ground), warehouses and cold storages for aiding the supply chain of perishable food items (storage capacity of 600-700 tones), that feeds into Delhi.
- Apart from this corporate office of NCRTC is also being planned in Jangpura. About 700-800 professionals will be housed in the buildings. There will also be other facilities (control rooms, stacking lines) developed along with the corporate office.
- NCRTC is also planning to develop commercial spaces along the station line (Malls, food courts, etc.).
- It was informed that all the development is being implemented with the help of grant support from ADB. Mr. Keerthi Kumar Challa is the project manager looking after this contract.
- From the discussions, it was identified that there is potential for probable implementation of District Cooling system along the underground railway stations lines, corporate office, etc., and the commercial hubs and cold storage around the proposed depots

Next Steps

- NCRTC to share the DPRs with the project team - already shared and attached separately
- IIEC to share District Cooling Concept Note with NCRTC team – already shared (Annexure L)
- A meeting to be organized between NCRTC, IIEC, and ADB to discuss the next steps.

Annexure B: Technology Providers (Illustrative)

Company	Website
Broad Group	www.broad.com
Clarke Energy	www.clarke-energy.com
Danfoss	www.danfoss.com
Renew Power	renewpower.in
Thermax	www.thermaxglobal.com/
Shell	www.shell.us
Voltas	www.voltas.com
WSP	www.wsp.com
Siemens	www.siemens.com
Kirloskar Chillers	kcpl.kirloskar.com/
BHEL	www.bhel.com
Carrier Airconditioning & Refrigeration Ltd.	www.carrier.com
Daikin India	www.daikinindia.com
Blue Star India	www.bluestarindia.com
Godrej Group	www.godrej.com
Swegon Blue Box Pvt Ltd	www.blueboxcooling.com
Johnson Controls	www.johnsoncontrols.com
General Electric	www.ge.com/in/

Annexure C: System Integrators (Illustrative)

Company	Website
Tabreed	www.tabreed.ae/
ETA Engineering	www.eta-engg.com
Empower	www.empowerfoundation.org/
Engie	engie.com/en
Emicool	www.emicool.net/
Qatar District cooling company	https://www.qatarcool.com/
Fortum	www.fortum.com
Veolia	www.veolia.com
Ramboll Group	ramboll.com
Pal Group	www.palgroup.com/

Annexure D: Financial Institutions (Illustrative)

Entity	Website
Indian Renewable Energy Development Agency (IREDA)	https://www.ireda.in/
Small Industries Development Bank of India (SIDBI)	https://www.sidbi.in/
State Bank of India	sbi.co.in
Punjab National Bank	pnbindia.in
Yes Bank	www.yesbank.in
Power Finance Corporation	pfcindia.com

Annexure E: Industry/ Manufacturer Associations (Illustrative)

Entity	Website
ISHRAE – Indian Society of Heating, Refrigerating and Air Conditioning Engineers	www.ishrae.in
AIACRA – All India Air conditioning & Refrigeration Association	www.aiacra.com
RAMA – Refrigeration and Airconditioning Manufacturers Association	https://in.kompass.com/c/refrigeration-and-air-conditioning-manufacturers-association/in765194/
Confederation of Indian Industry (CII)	https://www.cii.in/
Refrigeration & Air-conditioning Servicing Sector Society (RASSS)	http://www.rasss.org/
Federation of Indian Chambers of Commerce & Industry (FICCI)	www.ficci.in

Annexure F: Infrastructure / Building developers (Illustrative)

Entity	Type	Website
Larsen & Toubro	Engineering, Power, and Equipment	www.larsentoubro.com
GMR Infrastructure	Construction	https://www.gmrgroup.in/home/
Punj Lloyd	Plumbing and pipeline	www.punjlloyd.com
Hindustan Construction Company	Construction	www.hccindia.com
NCC Limited	Construction	www.ncclimited.com
Gammon India	Construction	www.gammonindia.com
Simplex Infrastructures Limited	Construction	www.simplexinfra.com/
GVK Power & Infrastructure Limited	Power and energy	GVK.com
IRB Infrastructure	Construction	www.irb.co.in
Afcons Infrastructure Ltd	Power and energy	
Madhucon Projects		www.madhucon.com
MARG Group	Plumbing	www.marggroup.com
EMMAR Group	construction	www.emaar.com
JMC Projects (India)	Power and Energy	https://www.jmcprojects.com/
SPML Infra	Plumbing and Pipeline	www.spml.co.in/
Ahluwalia Contracts (India)	Construction, Plumbing, and Pipeline	www.acilnet.com
Shriram EPC	Construction	www.shriram.com/

Annexure G: Energy Service Companies (ESCO's)

Entity	Website
List of 141 (ESCOs) empanelled with the Bureau of Energy Efficiency (BEE)	https://beeindia.gov.in/sites/default/files/list%20of%20ESCOs_combined%20v1.2%20%281%29.pdf

Annexure H: Case Studies

Case Study: 1	
Title: India's First District Cooling System at GIFT City	
Description:	GIFT City is India's first globally benchmarked International finance service centre (IFSC), developed by the Government of Gujarat through a joint venture company named Gujarat International Finance Tec-City Company Limited. GIFT City has been developed on 886 acres of land with a total built-up area of 62 million square feet, the estimated air conditioning load requirement for these developments will be about 270,000 TR, which requires electrical power demand of 240 MW. More details about the GIFT city can be accessed here: http://www.giftgujarat.in/business-structure Based on the above, GIFT City is proposed to be served with three DCS plants of equal capacity (60,000 TR each), Total: 180,000TR. Each plant has been designed to accommodate are centrifugal chillers with 2500 TR capacity each and use a chilled water-based stratified thermal energy storage tank with electrical demand 135 MW only.
Highlights of the project:	• Built Area: 62 million square feet • Three DCS plants (60,000 TR each) • Electrical demand 135 MW
Source: Air Conditioning and Refrigeration Journal	

Case Study: 2	
Title: Graz, Austria: solar district heating at different scales	
Description:	District heat generation in Graz is mostly based on the combustion of fossil fuels in three large cogeneration plants with a capacity of 230-250 MWth. To shift from fossil fuels, a diverse set of newly added district heating capacity is planned, predominantly sourced from renewable and especially solar heat. This has been motivated primarily by the predictability of costs using this approach. Local district heating networks in newly connected neighborhoods operate at lower temperatures to facilitate the future integration of renewable energy (Energie Graz GmbH, 2016a). Between 2002 and 2016, large-scale rooftop thermal solar collector systems were installed on several buildings and connected to the district heating network. These systems have a combined collector area of over 15 000 m2 and meet 0.6% of annual district heating demand. Since their peak output in summer is around half the baseload, there is no need for a storage tank.
Highlights of the project:	• Network length: 780 km • District heating share: 40% (61 000 apartments) • District heating produced: 950 GWh • Peak load: 423 MWth

Network temperatures: Winter 120°C/ summer 75°C return 60°C
Source: IRENA

Case Study: 3	
Title: Ball State University case study	
Description:	This district energy system serves a campus of 47 buildings and 5.6 million ft.2 (520, 250 m2) for 19,000 students and is the largest ground source/geothermal heat pump system at a higher education institution in the USA. The bore field uses the earth's ability to store heat in the ground, depending on the time of the year. The field acts as a heat source in heating mode and a heat sink in cooling mode. The bore field comprised of 3383 boreholes 4–5 in. (10 to 13 cm) in diameter which was drilled 400–500 ft. (122 to 152 meters) deep, encompassing approximately 700 miles (1126 km) of loop-field piping. At the heart of the system are four 2500-ton electric centrifugal chillers that generate 42 °F (5.5 °C) chilled water and create 150–170 °F (66–77 °C) hot water to serve the campus district cooling and district heating water loops.
Highlights of the project:	• Location: Muncie, Indiana, USA • Owner: Ball State University, • Startup Date: Spring 2012, • Cost: US$85,000,000, • Capacity: 10,000-ton cooling and 150,000,000 Btu/h (43960 kWth) heating • Piping: 1¼-in. (3.2 cm) diameter geothermal loops, • Savings: $2.2 million per year
Source: Mike Luster, Senior Mechanical Engineer, MEP Associates, LLC.	

Annexure I: Gujarat International Finance Tec-City (GIFT) District Cooling Project Case Study

Background
The City, in the Ahmedabad-Gandhinagar region in the state of Gujarat, is planned on **886 acres** of land with **62 million sq. ft. of Built-Up Area** which includes Office spaces, Residential apartments, Schools, Hospitals, Hotels, Clubs, Retail and various recreational facilities and has been named as the **'Gujarat International Finance Tec-City (GIFT)'**.

The estimated cost of the entire project is Rs. 70,000 crores (700 billion Rs). Its main purpose is to provide high-quality physical infrastructure (electricity, water, gas, district cooling, roads, telecoms, and broadband) so that finance and tech firms can relocate their operations there from Mumbai, Bangalore, Gurgaon, etc. It will have a special economic zone (SEZ), international education zone, integrated townships, an entertainment zone, hotels, a convention center, an international techno park, Software Technology Parks of India (STPI) units, shopping malls, stock exchanges, and service units.

District Cooling Plant at GIFT City

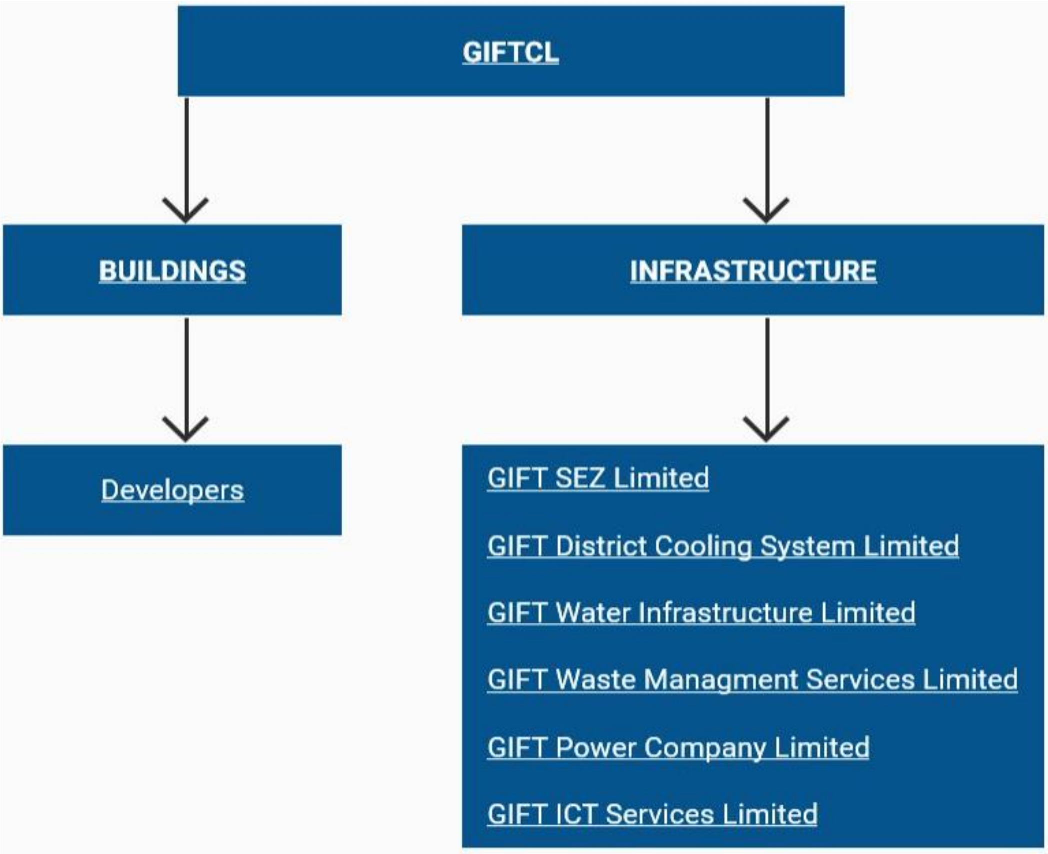
Institutional Structure of GIFT City

Gujarat Urban Development Company Limited (GUDCL)
GUDCL facilitates urban development by assisting the state government in the formulation of policy, institutional capacity building, project implementation, and in raising funds from multilateral agencies for urban projects. For more details of GUDCL, please refer to the following URL: www.gudcltd.com
Infrastructure Leasing & Financial Services Ltd (IL&FS)

Incorporated in 1987, the business architecture of IL&FS focuses on providing services in the development of Core Infrastructure Areas suitably complemented with an array of Financial Services. The various businesses are conducted through subsidiaries with IL&FS being a principal shareholder in each.

IL&FS has catalysed over USD 8 Billion of infrastructure projects and is currently working on several innovative projects mostly based on Public-Private Partnership format. For more details of IL&FS, please refer to the following URL: www.ilfsindia.com

GIFT project is being implemented by **Gujarat International Finance Tec-City Company Ltd. (GIFTCL)**. GIFTCL has been set up as a Joint Venture (JV) Company between the Government of Gujarat (GoG) represented by Gujarat Urban Development Company Limited (GUDC) and Infrastructure Leasing & Financial Services Limited (IL&FS).



Role of GIFT CL

District Cooling System (DCS) Project Highlights

- **Engineering, Procurement and Development Contractor:** ETA Engineering Pvt. Ltd.
- **Client:** GIFT City (Gujarat International Finance Tech City)
- **Design Review Consultant:** Tata Consulting Engineers
- **Scope of Work:** Design, Supply, Construction, Erection, Testing and Commissioning and Operation and Maintenance of Chilled water system of 10000 ton of refrigeration (TR), in the modular format of 5000 TR in series counter flow arrangement for stage-1 and 5000 TR for stage-2 and 10000 Tons of refrigeration hours (TRH) Thermal Energy Storage (TES) Tank.
- Total three DCS plants of equal capacity (60,000 TR each), Total: 180,000TR
- The plant will use Centrifugal chillers with 2500 TR capacity each
- **Electrical demand**: 135 MW
- **Cost of Project:** Approx. 100 Crores.

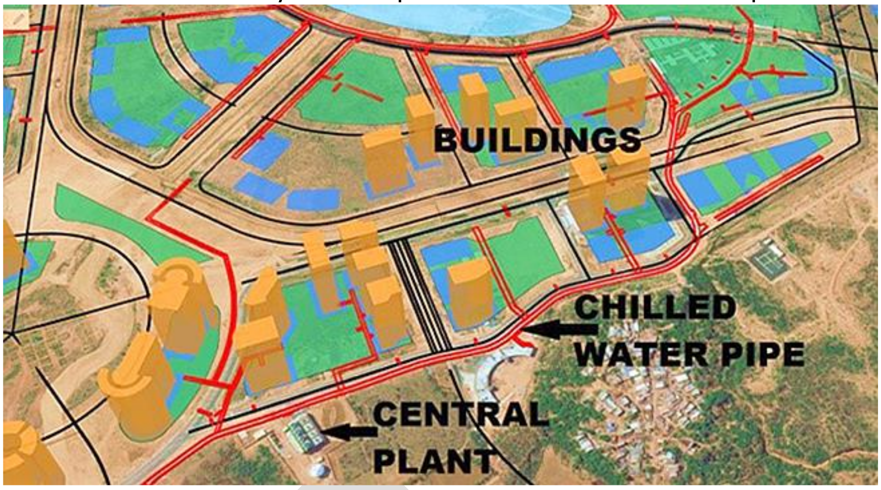
The Technology deployed for DCS

DCS Phase 1, currently installed in GIFT is an electricity-based[57] cooling plant with the above-mentioned specifications. It consists of three primary components:

1. A central cooling plant
2. The chilled distribution network
3. The consumer system or energy transfer station

[57] This has been confirmed by GIFTCL.

The central plant generates chilled water with electrically run compressor drive chillers or absorption chillers. Large size centrifugal chillers with higher efficiency are used to take advantage of the economies of scale. Apart from energy-efficient chillers, the central plant consists of:



- Chilled water pumps
- Cooling towers with condenser water pumps
- Thermal energy storage tank
- Electrical power distribution system and control system
- Centralized automation and control of equipment

Water Supply & Sewerage System
- Water Sources:
  - Narmada Main canal
  - Recycling and Reuse of Wastewater
  - Rainwater Harvesting
- 24 x 7 Water Supply
- Concept of Zero Discharge City
- Perennial waterfront ensured through the construction of three barrages on river Sabarmati
- Proposed landscaped promenade at the riverbank along GIFT City

Infrastructure Development - Progress
For this section please refer to the 'PROJECT STATUS' report attached to the same email.
Or use the following link: http://www.giftgujarat.in/documents/Project-Update-August-2015.pdf

GUJARAT INTERNATIONAL FINANCE TEC-CITY COMPANY LIMITED

GUJARAT INTERNATIONAL FINANCE TEC-CITY COMPANY LIMITED
GIFTCL, Zonal Facility Centre, Block-12, Road 1-D, Zone-I, GIFT City, Gandhinagar, Gujarat, Pin-382355, India Website : www.giftgujarat.in

• Eligibility For Submission Of Bids

1. The Bidder may be a company, partnership firm, Proprietary firm, limited liability partnership (LLP), or any other legal entity validly incorporated and/or existing under the Laws of India and is competent to Contract.
2. A bidder (including any proposed subcontractor of a bidder) if affiliated with an entity which has provided consulting services during the preparatory stages of the Works or who has been hired (or is proposed to be hired) as Engineer's Representative for the Contract shall not be eligible to participate in the bidding process.
3. Bidders shall provide evidence of their eligibility to the satisfaction of the Employer.
4. Consortium is not allowed.

• Minimum Qualification of the Bidder

1. The Bidder must be a well established Engineering Contractor having experience in similar scope of works. The bidder should possess and be able to deploy all the machinery/ equipment necessary for the timely completion of the Works and shall augment the same if considered necessary by the Engineer to achieve the targeted progress of the works at no additional cost to the Employer.
2. To get qualified for being considered for award of the Contract, bidders shall provide evidence, satisfactory to the Employer, of their capability and adequacy of resources to carry out and execute the Contract effectively. All bidders shall include the following information and documents with their bids

(a) Bidders should meet the following minimum qualification cum eligibility criteria on a pass or fail basis:

Financial Eligibility Criteria

Bidder should have

i. Achieved in preceding 3 (three) consecutive financial years ending on 31st March 2015, average annual financial turnover of (of all classes of engineering works only) not less than (Refer Format 10 in Section 5 of the bidding document). **Rs. 2.5 Crores**
ii. liquid assets and/ or credit facilities of not less than **Rs.25 Lakhs** (credit lines/ letter of credit support from bank to be enclosed) (Refer Format 2 in Section 5 of the bidding document)
iii. Profitability before tax in preceding 3 (three) consecutive financial years should be positive.
iv. Net worth (NW) for each of the 3 (three) consecutive financial years ending on 31st March 2015 should be more than **Rs. 10 Lakhs.** Net worth (NW) = Share Capital + Reserves and Surplus – Miscellaneous Expenditure – Revaluation Reserves, if any (Refer Format 2 in Section 5 of the bidding document)
v. Minimum Bid Capacity of **Rs.1.25 Crore** (Refer Format 4 in Section 5 of the bidding document)

Office Address: GIFTCL, Zonal Facility Centre, Block-12, Road 1-D, Zone-I, GIFT City, Gandhinagar, Gujarat, Pin-382355, India
Tel.: +91 79 30018300/27912511 Fax.: +91 79 30018321 Website:www.giftgujarat.in

Technical Eligibility Criteria

The bidder should have executed & successfully completed and commissioned following minimum quantities of work in last three consecutive years as on date of inviting tender in single completed project:

a)Electrification of 2 (two) buildings of government or semi government or commercial buildings of area of minimum 1000 sq. Mt. including installation of luminaries, all other electrical equipments, etc. in any one of the last three years and their satisfactory working for the last one working year.

b)The Bidder should have Govt. of Gujarat Electrical License.

•General Information Regarding E-tendering

1. The website address for E-Tender ishttps://gift.nprocure.com.
2. Bid document may be downloaded online from website at https://gift.nprocure.com. By interested bidders during the dates of online downloading of bidding documents and Bids will be submitted on or before the last date and time for submission of bids as mentioned in the Abstract of the bid document
3. Bidders have to submit Financial Bid [Volume-2 (Section 11)] in electronic format only on https://gift.nprocure.com website on or before the last date & time for online submission. Offers in physical form shall not be accepted in any case.
4. The Bidder should submit the Technical Bid including Tender Fee, Bid Security, Bid & related documents etc. [Volume-1 (Section 1 to 10)] in physical form at the office of GIFTCL, GIFT City, Gandhinagar, so as to reach on or before last date and time of physical submission of technical bids, as mentioned in the Abstract of the bid document. GIFTCL shall not be responsible for any kind of postal delay.
5. Bids shall not be received, entertained, accepted after the stipulated date and time.
6. The interested bidders, who wish to participate in E-tendering, will have to be registered on https://gift.nprocure.com and will have a valid Digital Certificate as per Information Technology Act, 2000, using which they can sign, submit their bids electronically. The Bidders who already have a valid Digital Certificate need not to procure a new Digital Certificate. However, the bidders who are not having a valid Digital Certificate can procure the same from M/s. (n) Code Solution, GNFC, Ahmedabad, who is a licensed certifying authority by Government of India.
7. In case bidder needs any clarification or if any training is required for participating in E-tendering or if there any problem regarding downloading, viewing or online submission of bid/ tender, the bidders can contact M/s. (n) Code Solution on following addressed, before last date of online submission of bid:-

M/s. (n) Code Solution, A division of G.N.F.C. Ltd.,
301, G.N.F.C. Infor Tower, Bodakdev, S.G. Road,
Ahmedabad, Gujarat – 380 054 (India),
Phone No.079-40007501, 40007512, 40007516, 40007517,18004194632
9898540855, 9898589652
Fax 079-26857321 Email: nprocure@ncode.in
Website:- https://www.nprocure.com

Annexure J: District Cooling Cost Calculator*(attached)*
Annexure K: DCS Energy Saving Calculator *(attached)*
Annexure L: Note on District Cooling *(attached)*

References

India Cooling Action Plan, September 2018, Ministry of Environment, Forest and Climate Change, Government of India

India's First District Cooling Systems at GIFT City, February 2018, REHVA Journal

Development of District Cooling System for Amaravati Government Complex in Amaravati, Andhra Pradesh on PPP Basis, Request for Proposal (RFP), May 2018, Andhra Pradesh Capital Region Development Authority

Rapid Assessments of Five Indian Cities, November 2017, UN Environment District Energy in Cities Initiative