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National District Cooling Potential Study for India

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DISTRICT ENERGY IN CITIES INITIATIVE

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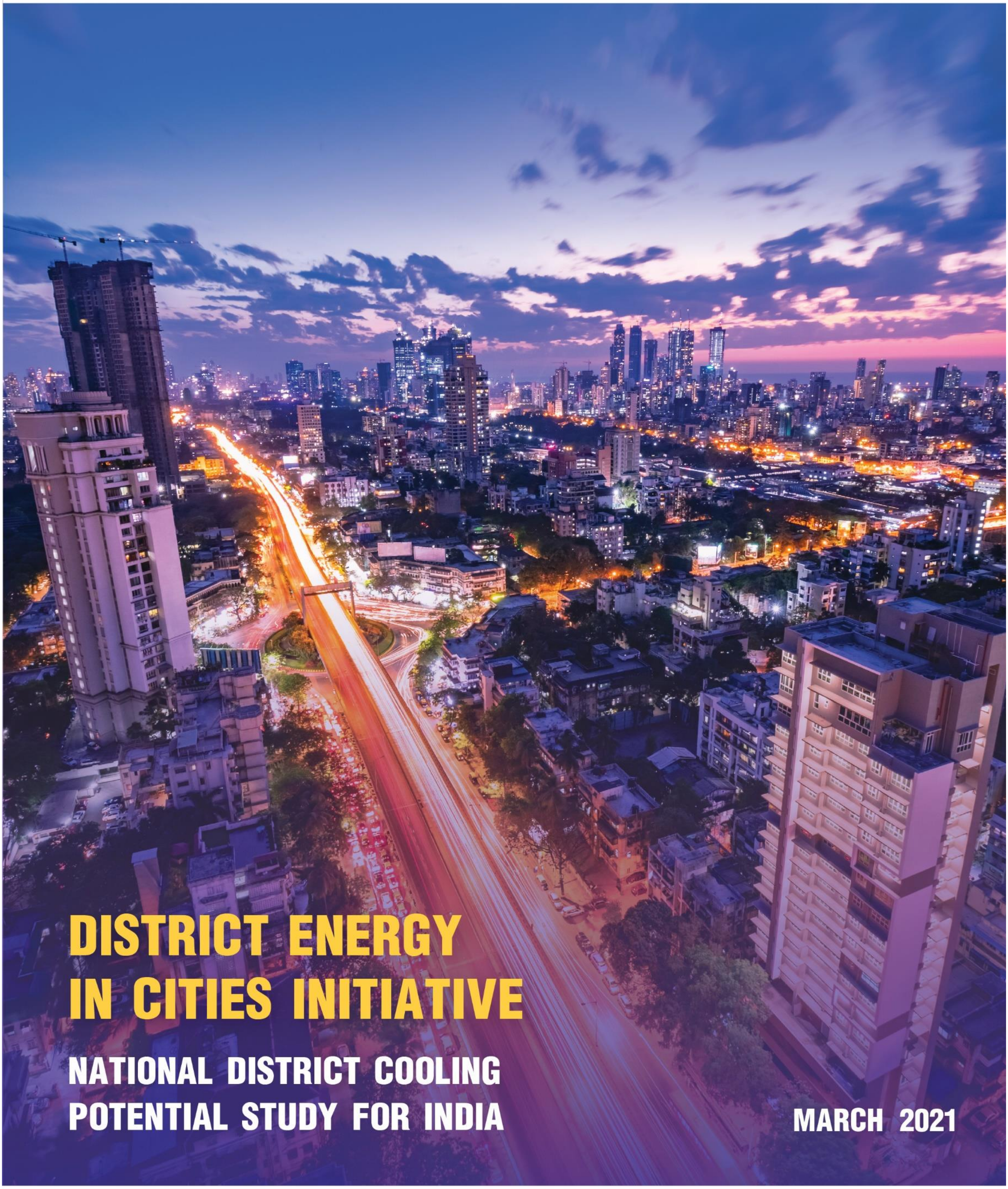

DISTRICT ENERGY IN CITIES INITIATIVE

NATIONAL DISTRICT COOLING POTENTIAL STUDY FOR INDIA

MARCH 2021

Prepared with support from Empower, EESL, UNEP and the Global Environment Facility

COPENHAGEN CENTRE ON ENERGY EFFICIENCY SEforALL EE HUB

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EMPOWER ENERGY SOLUTIONS

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United Nations Environment Programme (UNEP) and Energy Efficiency Services Limited (EESL) acknowledge valuable inputs and recommendations provided by key stakeholders including Ministry of Environment Forest and Climate Change (MoEFCC), Ministry of Housing and Urban Affairs (MoHUA), NITI Aayog and the Bureau of Energy Efficiency (BEE) proved invaluable in designing the District Energy in Cities Initiative's activities in India and the approach and methodology for undertaking district energy assessments in Indian cities. UNEP and EESL also acknowledge the support of the four pilot cities in India of Amaravati, Hyderabad Pharma City, Rajkot and Thane and the leadership of their city governments as well as the learning cities of Bhopal, Chennai, Coimbatore and Pune. Interactions and activities in all these cities have proved invaluable and help to justify many of the recommendations in the report.

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The District Energy in Cities Initiative

The District Energy in Cities Initiative is a multi-stakeholder partnership coordinated by UN Environment Programme. As one of six accelerators of the Sustainable Energy of All (SEforAll) Energy Efficiency Accelerator Platform, the Initiative is supporting market transformation efforts to shift the heating and cooling sector to energy efficient and renewable energy solutions. Over 60 organizations, including industry associations, manufacturers, utilities, financiers, non-government groups, as well as 45 champion cities across the world have partnered with the District Energy in Cities Initiative to support local and national governments implement district energy policies, programs and project pipelines that will accelerate investment in modern district energy systems. The Initiative is supporting 14 countries including India, where UNEP is working in partnership with Energy Efficiency Services Limited (EESL), the National Coordinator of the Initiative in India. The Initiative is supporting a variety of activities:

- Directly supporting pilot city projects, local policy development, local energy mapping and district energy master planning for district energy;
- National and state-level policy and regulatory recommendations and support to different Ministries deemed crucial for accelerating district cooling market;
- Supporting EESL to establish an investment programme on district cooling;
- Establishing knowledge products, tools, methodologies, MRV framework and best practices on district energy; and
- Awareness raising and capacity building, including to real estate and HVAC industry.

For more information, other knowledge products and contact details please visit:
www.districtenergyinitiative.org

सौरभ कुमार
कार्यपालक उपाध्यक्ष
ईईएसएल ग्रुप

SAURABH KUMAR
Executive Vice Chairperson
EESL Group

FOREWORD

The world has recently witnessed a global pandemic in the form of COVID-19 and have seen international and Indian economy undergoing a rigorous shift. The pandemic has affected lives and livelihoods of millions and created a paradigm shift on businesses in multiple sectors. This massive turmoil has also impacted the energy sector and under the conditions of strict lockdown, the power demand from hospitals, essential services and the residential sector was on the rise, while industrial demand and commercial activity showcased a substantial decline. Now, when the world is on the path of recovery, the energy sector is also recuperating through collective efforts with timely interventions, goals and timelines. But this journey is not easy and requires a balance between the soaring demand and maintaining the efficiency levels to maintain the sustainable energy supply without affecting the environment and society.

Energy Efficiency Services Limited (EESL) has always played pioneering role in promoting energy efficiency in India and has forever followed the philosophy of promoting a low carbon future, with significant economic and social impact. At EESL, we constantly promote innovation and actions that enable an ecosystem for responsible energy adoption that encourages energy efficiency and reduce emissions. With this vision, EESL works simultaneously on multiple progammes and projects on sustainable energy. This includes the Global Environment Facility (GEF) funded and UNEP supported project on conducting "National District Cooling Potential Study for India". The study aims to guide and transform the market towards well planned and quicker adoption of district cooling technology in India, by recommending short, medium- and long-term action items to different government and private sector stakeholders. The findings of the report would benefit policy makers, economists, planners, domain consultants and other relevant stakeholders.

EESL with such studies will continue to promote energy efficiency in the country, and support efforts and interventions towards providing sustainable energy and cooling for all.

Skumar

(Saurabh Kumar)

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Foreword – United Nations Environment Programme (UNEP)

Cooling has long been a blind spot in the global energy debate despite clear impacts being reported from countries with already high air conditioning demands for decades and the long ongoing effort on transitioning to refrigerants that protect the ozone layer and, more recently, that do not warm our planet. Shining light on this problem, the Ministry of Environment and Climate Change (MoEFCC) has shown clear foresight and leadership in preparing the Indian Cooling Action Plan (ICAP), a global first which links together climate, refrigerants and access to cooling in one comprehensive plan which is now triggering similar plans in countries worldwide. One learning from this Plan and other countries' experience is that even with strong building codes and standards, India will be left with a huge energy and refrigerant demand for space cooling, likely larger than any other country globally. This is one reason why the ICAP is advocating in the medium and long-term a shift to not-in-kind technologies such as district cooling, trigeneration and thermal storage.

Such technologies need to become the backbone of cities' transition to sustainable energy: increasing access to cooling; relieving stress on our power grids which and balancing higher shares of renewables; shifting to climate-friendly refrigerants faster, safer and cheaper; reducing potable water used for cooling; reducing urban heat island; and, crucially, unlocking highly-efficient and renewable technologies that transition cooling to net-zero emissions.

But starting India's market for district cooling is not simple – the pace of real estate in cities, the novelty of this technology and the diverse barriers that exist makes shifting the cities, industry and the country to district cooling all the harder. UNEP and EESL's work has shown that capital cost is not the issue for district cooling, but coordination, capacity and willingness to try a new technology. But all countries that have successfully developed district heating and district cooling have faced the same challenges. Through the UNEP-led District Energy in Cities Initiative we have a community of countries, cities and industry giving necessary support and guidance. What is needed now is a concerted, all-government effort to embrace this technology to deliver sustainable and affordable cooling. This report shows the full potential and pathway to this and UNEP looks forward to work with Government of India, state governments, cities and industry to bring about this vision.

I commend MoEFCC, Bureau of Energy Efficiency (BEE), EESL and Ministry of Housing and Urban Affairs (MoHUA) for their close engagement with UNEP and partners on this crucial topic.

Atul Bagai, Head, UNEP India Office

रजत कुमार सूद
प्रबंध निदेशक
RAJAT KUMAR SUD
Managing Director

150 YEARS OF CELEBRATING THE MAHATMA

EESL

एनर्जी एफिशिएंसी सर्विसेज़ लिमिटेड
विद्युत मंत्रालय के सार्वजनिक क्षेत्र के उपक्रमों की संयुक्त उद्यम कंपनी
ENERGY EFFICIENCY SERVICES LIMITED
A JV of PSUs under the Ministry of Power

PREFACE

The rapid urbanisation, population growth and rise in ambient temperatures have led to an increased demand for energy and cooling, especially in buildings. To meet this soaring demand, an evolution in terms of energy use, sources, business models and operations is required for the energy ecosystem. Energy Efficiency Services Limited (EESL), under the administration of Ministry of Power enables consumers, industries, and governments to effectively manage their energy demand through energy efficient technologies and is driving a large scale transformation of energy efficiency market. EESL aims to create market innovations with a solution driven approach through its Zero-Subsidy, Zero-Capex, and Pay-As-You-Save (PAYS) business model.

India is one of the first countries in the world to develop a comprehensive Cooling Action Plan which has a long term vision to address the cooling requirement across sectors and lists out actions which can help reduce the cooling demand. India Cooling Action Plan (ICAP) is one of the major driving forces for reducing the cooling demand and advancing energy efficiency in Indian cooling sector. The India Cooling Action Plan (ICAP) targets to reduce cooling demand across sectors by 20% to 25%, reduce refrigerant demand by 25% to 30% and reduce cooling energy requirements by 25% to 40% by the year 2037-38.

EESL is engaged in transforming the cooling sector and currently working to promote energy efficiency and reduce direct and indirect emissions due to cooling through Super-Efficient AC program (SEAC) and District Energy Systems (DES). Especially, with the help of UNEP, EESL has conducted rapid assessment studies in five cities for District Energy Systems.

Through the national district cooling potential study in India, EESL has made an earnest effort to speed up the pace for adoption of district cooling systems in India and increase the level of system level energy efficiency in space cooling in buildings. This study is expected to transform the market conditions for quicker adoption of the technology in India.

The report provides a comprehensive overview of trends in global market with respect to district cooling. It also covers the barriers and its mitigation measures in the uptake of district cooling systems in India.

New Delhi
March 2021

Rajat K Sud

(Rajat Kumar Sud)
Managing Director
EESL

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Increased urbanization is leading to rapid expansion of India's building sector, which results in increased cooling demand and subsequently the energy demand. Space cooling is no more luxury and has rather become a necessity for the occupants in the commercial as well as residential buildings. It has now become a necessity to gain the maximum efficiencies at the equipment and system levels to minimize the massive impact of energy consumption in buildings.

EESL has always been on forefront of taking such initiatives in India by implementing the world's largest non-subsidized energy efficiency portfolio across lighting, buildings, agriculture, etc., at a scale, which no other organization has been able to achieve. EESL along with UNEP led the district energy in cities initiatives as National Coordinating Agency in India. EESL with this initiative aimed to create such a market for district energy in India, that would support cities and developers in planning and developing new projects, devising innovative business models that account for the system-wide benefits of district energy. With this vision, EESL launched the study for "National District Cooling Potential Study for India" to promote and accelerate the adoption of district cooling systems in India. The study focusses on various benefits of district cooling system for end users, global advancements on technological and policy front and future potential in the country for coming decades. The report talks about the various business models adopted globally and relevant possible business models for Indian markets. It also portrays the short, medium- and long-term recommendations for various central and state level stakeholders to capture the potential of district cooling systems in India.

The study showcases the benefits of the district cooling systems for end users as well as developers, technology providers, system integrators etc. The study also offers a roadmap to all the policy makers, economists, design consultants, utilities etc. to scale up the deployment of district cooling systems in India.

The report benefited from valuable inputs from Clarke Energy, The Carbon Trust, Danfoss, GE, Tabreed, GIFT Gujarat, Broad Air Conditioning, Edina, GIZ, ICLE, AEEE, SSEF, IFC, ISHRAE, APUEA, NRDC, Adani, AAU, Ramboll and acknowledge their support in preparation of this report. I would also like to commend and congratulate the team members from UNEP, EESL and PwC India for carrying out such a comprehensive study and putting together this report. I look forward to the continued efforts towards achieving our future goals.

(S.P. Garnaik)

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List of abbreviations

AHU	Air handling units
AI	Artificial intelligence
BAU	Business as usual
BEE	Bureau of Energy Efficiency
BMS	Building management system
CFC	Chlorofluorocarbons
CHP	Combined heat and power
COGEN	Co-generation
COP	Coefficient of performance
CPWD	Central Public Works Department
DCICS	District cooling instrumentation and control system
DCP	District cooling plants
DCS	District cooling systems
DES	District energy systems
DISCOM	Distribution companies
ECBC	Energy conservation building code
EESL	Energy efficiency services limited
EIA	Environmental impact assessment
ERC ETS	Electricity Regulatory Commission Energy transfer station (ETS)
GCC	Gulf cooperation council
GHG	Greenhouse gas
GRIHA	Green Rating for Integrated Habitat Assessment
GWP	Global warming potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbons
HDPE	High-density polyethylene
HFC	Hydrofluorocarbons
HFO	Hydrofluoroolefins
HVAC	Heating ventilation and air conditioning

IBCP	Individual building chiller plants
ICAP	India Cooling Action Plan
IGBC	Indian Green Building Council
Kg	Kilogram
lbs.	Pounds
LEED	Leadership in energy and environmental design
Mn	Million
MOEF&CC	Ministry of Environment, Forest and Climate Change
MOP	Ministry of Power
MOUD	Ministry of Urban Development
MS pipe	Mild steel pipe
NBCC	National Buildings Construction Corporation Ltd
ODP	Ozone depletion potential
PPP	Public private partnership
RAC	Room air conditioning
RO	Reverse osmosis
SDA	State designated agency
sqft	Square feet
Sqft/Tr	Square feet per ton
sqm	Square metre
STP	Sewage treatment plant
TDS	Total dissolved solids
TES	Thermal energy storage
TR	Tonnes of refrigeration
TSE	Treated sewage effluent
TSS	Total suspended solids
ULB	Urban local body
UNEP	United Nations Environment Programme
VFD	Variable frequency drives
VPF	Variable primary flow
VRF	Variable refrigerant flow

Executive Summary

India is experiencing a rapid growth in space cooling demand driven by population growth, urbanisation, increasing incomes and rising urban heat. According to the India Cooling Action Plan (ICAP), urbanization and economic growth will increase commercial floor area by 2.5-3 times and the number of urban households will almost double over the next two decades (2018-2038) (MoEFCC, 2019). Altogether, demand for space cooling in India is expected to increase 11 times over the same period. Rapid increases in demand for cooling in cold chain, transportation and refrigeration are also projected. Building efficiency and design, passive cooling, nature-based solutions, fans and coolers from an environmental perspective should all be promoted before air conditioning. However, the reality of urban and building design in India and rising incomes and urban heat means air conditioning is becoming a necessity for many families and workers in Indian cities.

The Ministry of Power (MoP) through the Bureau of Energy Efficiency (BEE), has initiated a number of energy efficiency initiatives such as standards and labelling of appliances including cooling equipment/appliances, and minimum requirements for the energy-efficient design and construction of buildings (both commercial and residential). The Ministry of Environment, Forests and Climate change (MoEFCC) sets out in the ICAP that through these energy efficiency efforts, energy used for space cooling may be 30% lower in 2038 compared to business-as-usual. Such efforts would bring widespread socioeconomic and environmental benefits. However, approximately 700 TWh of energy and 80,000 Mt of refrigerants would still be required for space cooling (MoEFCC, 2019). Reducing this demand further and shifting to sustainable energy supply and refrigerants will be crucial to reducing greenhouse gas emissions, building a resilient energy system and improving access to cooling. To help achieve this, ICAP recommends the promotion of not-in-kind technologies including trigeneration, district cooling system (DCS) and thermal energy storage which should "significantly displace conventional air conditioning systems" in the long-term. This report sets out a pathway to achieving this from a technology, finance, policy and regulatory perspective.

At present, most air conditioning loads in India are met by on-site cooling technologies consisting of either window or room air conditioners or central air-cooled or water-cooled chillers powered by the electricity grid. The efficiency and refrigerant consumption of on-site cooling equipment varies significantly depending on the product, building and cooling system design, operation and maintenance, and even the building's ownership structure. In general, in dense urban areas, energy and refrigerant use for air conditioning is far lower if clusters of buildings and even whole townships are connected to a District Cooling System (DCS). Global experience and detailed analyses and existing projects in India show that these systems are also more reliable, cost-effective and would be highly beneficial to strengthening and supporting urban power grids, especially through cheap thermal storage and trigeneration.

DCS distributes (supplies and collects back) cooling energy in the form of chilled water from a central district cooling plant to multiple buildings through a distribution network of insulated, underground pipes for space and process cooling. Individual users purchase chilled water for their own building from the operator of the DCS and do not need to install their own chillers or cooling towers. Globally, DCS vary significantly in size from serving two buildings to serving an entire city. A DCS can serve a wide variety of loads inter alia commercial offices, hotels, residential, industry units, data centres, cold chain, sports arenas, malls, schools, institutional buildings and hospitals.

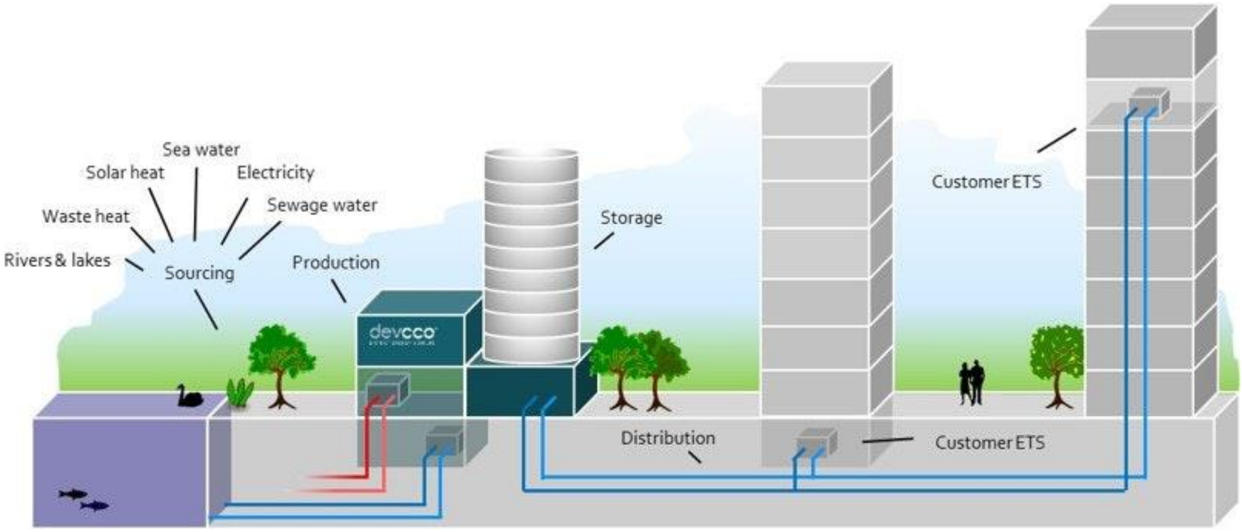


Figure 1: A schematic of a typical district cooling system
(Devcco District Energy Venture, 2018)

Much of the energy efficiency advantages of DCS result from combining many diverse load profiles, which allows the district cooling plant equipment to operate at high load factors with resulting higher levels of efficiency. This demand aggregation also provides the economies of scale that allows district cooling systems to cost-effectively utilise high-efficiency and sustainable technologies, such as trigeneration, that are less economically and technically feasible for an individual building. Aggregated cooling loads makes creative alternative technologies such as free cooling from lake, river or ocean water, grey water recovery and reuse, thermal energy storage, industrial waste heat capture etc., more feasible in application as they reduce cost and environmental impact associated with space cooling technologies. Additionally, district cooling offers huge benefit to building owners of not procuring, installing, operating, and maintaining air conditioning plants, which consumes large portions of annual budgets. This also offers them to have extra rooftop and basement space for commercial activities, savings in capital and operational cost and enjoy the luxury of having reliable, uninterrupted, and economical cooling as a service. Finally, the centralised approach of district cooling allows the safe and controlled use of environmentally friendly refrigerants that are not appropriate or available at the individual building level.

In brief, DCS offers several benefits which will vary dependent on the technology chosen to produce the chilled water. The below diagram shows the expected savings compared to an individual building operating a water-cooled chiller (as is common in many large commercial buildings in India). Compared to room air conditioners or air-cooled chillers, the energy savings would be even more significant.

Table 1: Estimated benefits of DCS in India compared to stand-alone water-cooled chillers
Source: UNEP & C2E2

	Reduction in primary energy	**Reduction in peak power demand**	**Reduction in water use**	**Reduction in CO2 emissions**	**Lifecycle refrigerant saving in 20 years**
DCS on electric chillers with 30% peak load thermal storage	25%-40%	25%-50%	15%-25%	25%-40%	55%-65%

Trigeneration DCS with 30% electric chillers	30%-50%	40%-60%	10%-20%	35%-55%	65%-75%
DCS with free cooling from rivers, seas or lakes	75%-85%	70%-75%	100%	100%	100%

The benefits of district cooling, trigeneration and thermal storage can be felt at the city level and help improve a city's climate resilience, reduce urban heat island, improve resource efficiency and circularity, retain wealth, provide alternative revenues for city governments and crucially reduce grid stress and blackouts. Globally, this model is generally termed 'district energy' and, besides district cooling, also includes district heating, domestic hot water provision, waste heat capture and production and balancing of local electricity. District energy systems have been adopted in Europe, the US, Canada, Gulf nations, Japan, Korea, Malaysia, China, Egypt, Colombia etc. for many years. A quick snapshot of different project examples globally is presented in figure below:

PARIS - FRANCE

District cooling practiced since 1991 in hotels, shops, offices. 60% of pipe network runs underground with sewage system.

CANADA - TORONTO

Enwave deep lake water cooling with 42,000TR, established in 2004.

MEDELLIN, COLOMBIA

EPM (Empresas Públicas de Medellín) district thermal energy plant with design capacity of 3600 TR established in 2016. This does not use HFC refrigerants.

INDIA

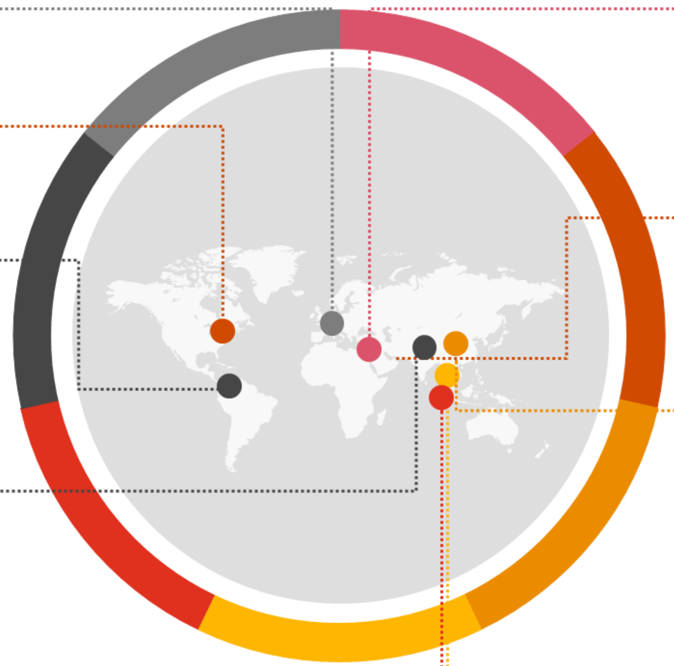
DLF Cybercity, Gurgaon – Trigeneration based operational 78,000 TR to serve 1.7 Mn Sqm commercial area

GIFT City, Ahmedabad - Installed 180,000 TR to serve planned 5.7 Mn Sqm commercial area

Amaravati Government Complex, Amaravati- Planned 20000 TR for serving space cooling demand of government offices

MALAYSIA

District cooling is practiced since 1999 in commercial buildings. One of the largest district cooling plant of capacity 14000 TR which serves 48 buildings.



EGYPT

A district cooling plant of 0.14 Mn TR (Smart Village) is to be completed in 2025.

DUBAI

In 20 years, over 75 DC plants, with refrigeration capacity of more than 3 MnTR are installed. New commercial and residential developments are addressed by DCS as part of master planning.

CHINA - SHENZEN

A district cooling plant with 0.4 Mn TR serving 19 Mn Sqm area (project to be completed in 2025).

SINGAPORE

Biggest project of 0.26 Mn TR (Marina Bay) commissioned in 2010 which is serving commercial buildings. Country has DC Act in place for district cooling in greenfield developments.

Figure 2: Global scenario of district cooling plants

These examples can act as learnings for India to promote **the technology and required policy and regulatory interventions.** Some of the key learnings from global experiences (specifically from the countries with hot climate and have significant cooling demand) are:

- Need for an **integrated policy framework** for promoting district cooling and strong government engagement.
- Need **involvements of municipalities and utilities** as key stakeholders
- **DCS pilot projects** are critical for starting the adoption of technology in market and public sector should take lead in establishing pilot projects. Prioritize dense industrial, commercial & mixed-use developments
- Mandate or strongly prioritize district cooling in **urban planning,** especially for dense greenfield developments having **8,000 to 10,000 TR/sqkm**
- **Residential district cooling** is viable in dense, mixed-use areas but will likely be confined to HIG without public investment
- Compulsory use of **treated water in cooling towers** can cut potable water consumption
- Should consider **special power tariffs** to promote thermal storage, DCS expansion and residential connection
- Support access to **low cost capital and project development costs**
- Establish and standardize project development process, **business models and contracting**

In India, large central cooling plants have already been in use for many years in the commercial building segment. Consumers like airports, IT campuses etc. do often provide space cooling by setting up large centralised air conditioning plants, which are **captive** systems by nature, i.e. will not expand beyond the development. However, adoption of **Merchant district cooling systems** (large central plants which provide chilled water as a utility service) is still at a very nascent stage in India and it requires concerted policymaker and industry attention.

Establishing the potential of such systems is critical for justifying the policy measures and action needed to bring them about. The report authors undertook a detailed exercise of estimating India's future (national) space cooling demand and how much of that space cooling demand can be tapped by district cooling systems in India's largest cities. **The national space cooling demand in new commercial buildings, which typically could be met by a district cooling service, lies in the range of 51 million ± 15% tons of refrigeration (TR) by year 2037-38.** This was estimated based on three different approaches and could be even higher if public policy shifted to reduce room air conditioning in favour of more centralised approaches to air conditioning in buildings and if brownfield projects are also included.

If this level of demand were served by district cooling, an estimated **25 GW of peak power demand could be reduced in the heart of cities, 27 million tonnes of CO_2 and 4,361 tonnes of refrigerant avoided and annual energy savings of 32 terawatt-hours (TWh).** If this demand were met by trigeneration DCS, peak reduction would increase to 32GW. These figures do not even include district cooling that could serve brownfield development, industrial and cold chain demand or MIG/HIG residential demand (which could be included if strong policy support existed).

Of course, in India and many other countries, numerous barriers to delivering such high levels of DCS up to 2038 exist that make it highly unlikely this level of DCS would transpire. Lack of foresight in planning, lack of public support and density of new developments are the key determiners that would prevent this level of DCS being delivered. But India should take inspiration from leading district energy cities and

countries such as Dubai where 40% of all buildings (residential and commercial) will be connected to DCS by 2030 and Denmark where almost all buildings in large cities are connected to district heating systems and customers enjoy some of the lowest heat prices in Europe showing it is definitely possible and affordable but requires strong government support to reach such levels. Although these countries are at a different stage of development India does have the benefit that most of its buildings have not been built so cost-effective and sustainable solutions like DCS could be incorporated early in urban design.

To evaluate less idealistic scenarios and considering district cooling as a “city-led initiative”, the projected commercial and residential development in 21 Tier 1 and Tier 2 cities of India was analysed. This assessment of 21 cities[1] reveals that approximately 30 million TR of new commercial demand will exist in these developed/developing cities by the year 2037-38 and an additional 48 mn TR of new residential demand. *Under an optimistic scenario, it is projected that around 9 Mn TR of space cooling in new commercial buildings can be tapped by district cooling systems in these 21 cities, which would need about 274 district cooling plants by 2037-38*[2]. With an assumption that a proportion of high-end residential apartments in developed cities will use district cooling systems as solution for space cooling in near future, the potential for DCS plants (for merchant district cooling) may go up to 300 by year 2037-38. It is also expected that a greater number of tier 1 and tier 2 cities will be developed by year 2035 and as a result the requirement for space cooling will increase, leading to increase in DCS potential. Overall, it is estimated that 12.57 million TR of district cooling could be developed in these cities under an Optimistic scenario.

This enormous potential of DCS offers huge opportunities for energy savings, resource efficiency and climate benefits to India:

~ $35 Bn

Investment potential (Billion dollars) to set up 300 District Cooling plants by 2037-38

~ 7850 GWh

Annual Energy Savings

~ 6100 MW

Energy Demand Savings

~ 6.6 Mn tonnes

Annual CO_2 emission reduction

~ 1068 tonnes

Refrigerant Savings

~ 78850 mn Ltr

Potable water savings

~ $10.5 Bn

Investment savings from infrastructure on power plant, city transformers, cables, water supply system etc.

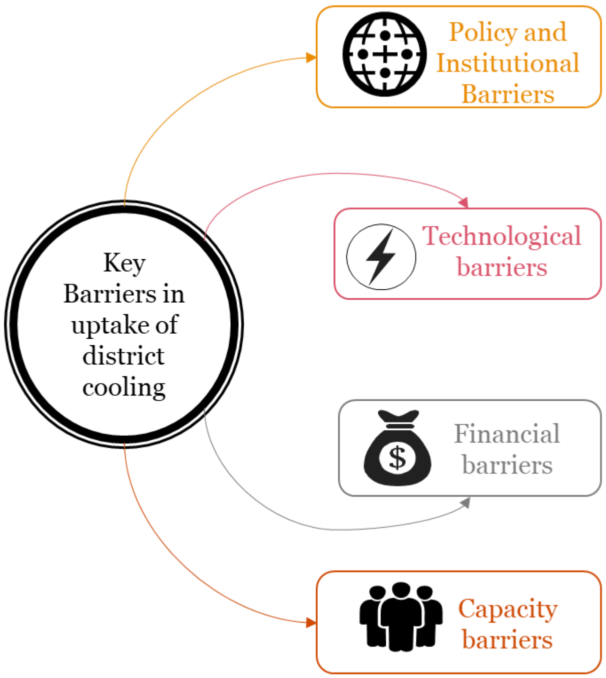
Figure 3: Potential saving opportunities from district cooling systems in India

The application of DCS is best scalable in the case of ‘captive’ as well as ‘merchant district cooling’. While ‘captive’ application is broadly being driven on its own, the uptake of **merchant district cooling system** in India is very limited. This can be attributed to the following barriers:

---

[1] 21 developed/developing tier 1&2 cities are selected based on population, availability of municipal corporations, availability of master planning data, having high population density areas and high FAR for future commercial and residential developments

[2] 1 district cooling plant = 20,000 TR, Diversity considered as 60% in sizing a district cooling plant



- Lack of promotion at national and state level urban development programs/schemes and lack of involvement of national and state energy departments and nodal agencies;
- Absence of contribution from municipal corporations and distribution companies (DISCOMs) for inclusion of district cooling at master planning stage
- Lack of policy drivers like Act, codes, electricity tariffs, fiscal instruments, contracting and leasing arrangements;
- Non-inclusion in national building regulations (ECBC 2017) and green building rating/certification systems

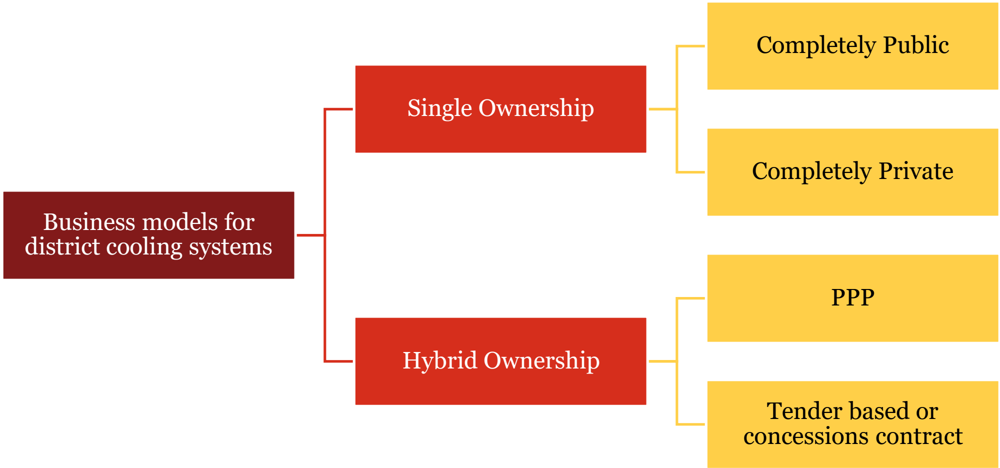
- Design risks like under or over projected loads, design temperatures and delta T, act as constraint for opting DCS as strategy for space cooling;
- Insufficient research and case studies to support the selection of technologies based on loads and applications

- Higher capital investment requirements discourage technology providers, owners, investors from pushing for DCSs.
- Phase wise developments leads to phase wise construction of distribution system & hence develops operational risks
- Revenue generation risks due to under or over projected loads

- Non availability of skilled professionals to design, operate and maintain district cooling plants
- Lack of awareness among the stakeholder about the benefits of district cooling
- Lack of capacity in government sector to develop master plans with integrating district cooling

Figure 4: Key barriers for uptake of merchant district cooling systems in India

Foreseeing enormous potential of district cooling systems in India, it is vital to establish trusted **business models, procurement models and contracting structures**, which can attract investors, developers and end-users for large scale expansion of DCS in the country. Globally, some of the trusted, adopted and generally practiced business models are: **Single ownership and hybrid ownership** as shown in figure below.



Some of the key attributes of both these ownership models is depicted in the figure below:

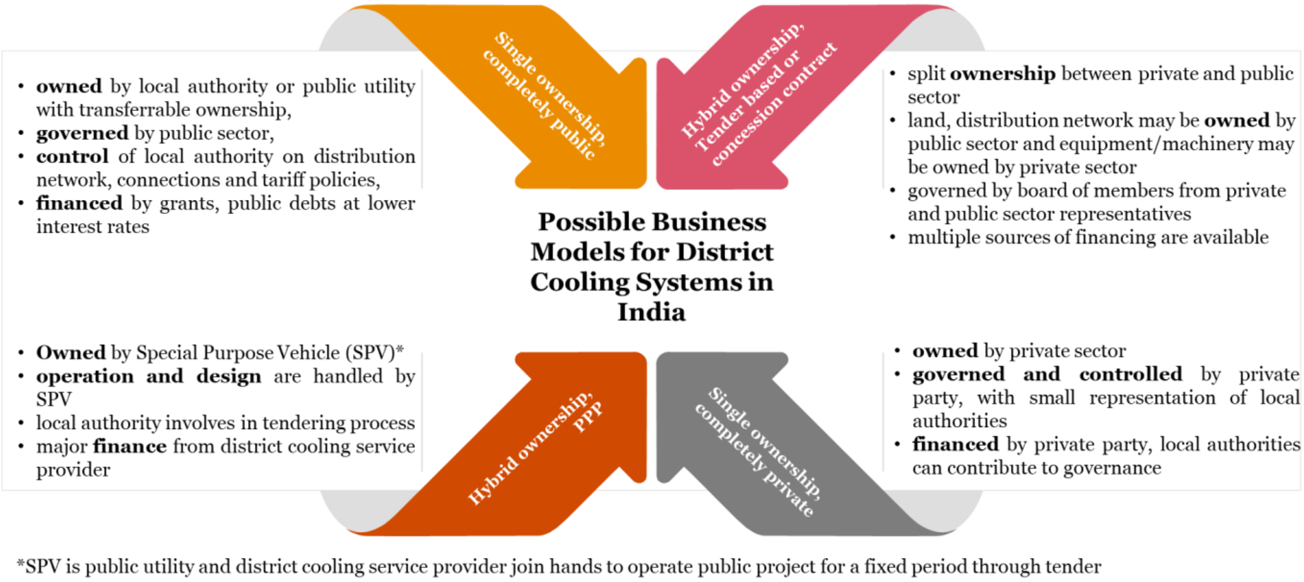


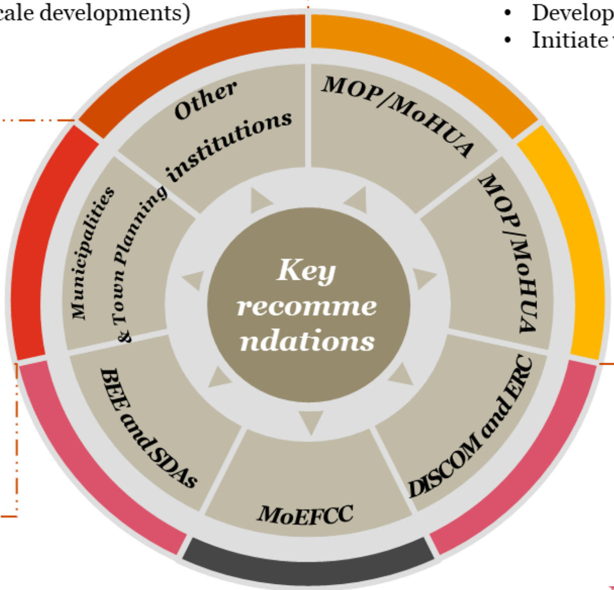
Figure 5: Possible business models for district cooling systems in India

Currently in India the large central plants are "**single ownership** (designed, installed, and operated by a single user for their own use)" in nature and completely private business models have been adopted for them. While the DCS with **Hybrid ownership** has the potential in addressing the technical, financial and capacity related barriers associated with the DCS implementation and can deliver better risk sharing between private and public sector, the adoption of this model is currently limited, partly owing to its more complex contractual arrangements between multi stakeholder groups (Government, City/ Municipality, Utility (Public / Private), DC service provider).

Hybrid business models with an emphasis on PPPs and joint ventures should be prioritised and tested in the Indian context and could benefit from **special power and water tariff**, financing options for district cooling service companies and should have involvement of expert contracting firms for various types of contracts and structuring. Going further in coming years the models of large neighbourhood or even city-level concession zones should also be explored.

Recommendations

A set of concrete policy, technology and financing intervention in terms of recommendations are developed in order to support and promote merchant type DCS in India. These recommendations are developed through review of best practice global examples and these are suggested for the short term (0-5 years), medium term (5 to 10 years) and long term (>10years) for various stakeholder categories. The key recommendations are:



Overall Recommendations for others

- Institutional support by National Buildings Construction Corporation Limited (NBCC) and Central Public Works Department (CPWD) to adopt DC in their large scale projects
- Adoption of technology in smart cities
- Inclusion in rating systems (GRIHA, LEED, IGBC for large scale developments)
- Financial support by providing soft loans, rebate in taxes etc
- Wavier in property taxes, corporate taxes and energy tariffs

Short Term (0-5 years)

- Inclusion of District Cooling at master planning stages
- Suggest changes in building bye laws

Medium Term (5-10 years)

- Inputs in formulation of District Cooling code
- Mandating District Cooling in high density mixed use developments, Land parcels to be sold with mandatory District Cooling connections
- Adoption of incentive schemes and training and capacity building

Long Term (>10 years)

- Mandatory adoption of DCS in all city level /urban local body level planning

Short Term (0-5 years)

- Clear recognition of District Cooling in ECBC and ENS
- Provision of readiness of buildings, to connect with DC network can be amended

Medium Term (5-10 years)

- Technical and financial support for demo projects
- Training and awareness programs at state level

Long Term (>10 years)

- Support in programme development and monitoring

Short Term (0-5 years)

- Development of roadmap for uptake of District cooling systems in India
- Formation of steering committee to lead with focused approach in India
- Training and capacity building, demonstration projects, demonstration of business models
  - Development of investment proposal and financing needs
  - Development of monitoring and verification frameworks
  - Initiate work on District Cooling Code

Medium Term (5-10 years)

- Development of policies to include DCS at master planning level, linking with MOHUA's LAP (local area plan) and TP (town planning) schemes
- Mandatory roles of ULBs/Utilities as key stakeholders
- Training and awareness, inclusion in building bye laws
- Development of DC code

Long Term (>10 years)

- Mandatory inclusion of DCS in future master planning

Short Term (0-5 Years)

- Support Ministry of Power in development of District Cooling Code
- Support in development of business models
- GST exemption on chilled water and lower electricity tariff for DC plants (as industry category)

Medium Term (5-10 years)

- Ensuring uninterrupted electricity for the land parcels sold with mandatory District Cooling connection
- Inputs in formulation of District Cooling code

Long Term (>10 years)

- Fee wavier on Transmission & Distribution losses, electricity duty and other surcharges

Short Term (0-5 years)

- Give suggestions for environmental clearances under MoEFCC, if any, for adoption of DCS.

Medium Term (5-10 years)

- Finalizing environmental guidelines/environment impact assessment for DCS in India

Figure 6: Key recommendations for all stakeholders

District cooling systems are a proven technology that has been deployed for many years in growing number of cities worldwide. DCS should be conceptualized in master planning stage of urban development for it to be a major driver of urban sustainability as it has been in numerous countries. Roles and responsibilities of municipalities and DISCOMs are utterly vital to promote DCS for large green field commercial developments in India. There is a need of a District Cooling Code for the country which prescribes legal, administrative, leasing and contracting guidelines for real estate developers, district cooling service providers, government departments and financial institutes. It is recommended to implement a few pilot projects (under merchant district cooling) to demonstrate the technology in Indian scenarios as a first step. In the long run, in order to reach higher shares of district cooling, fully mandate DCS in urban development and protect customers a full regulatory framework would likely be required.

1. Introduction to district cooling

1.1. Overview

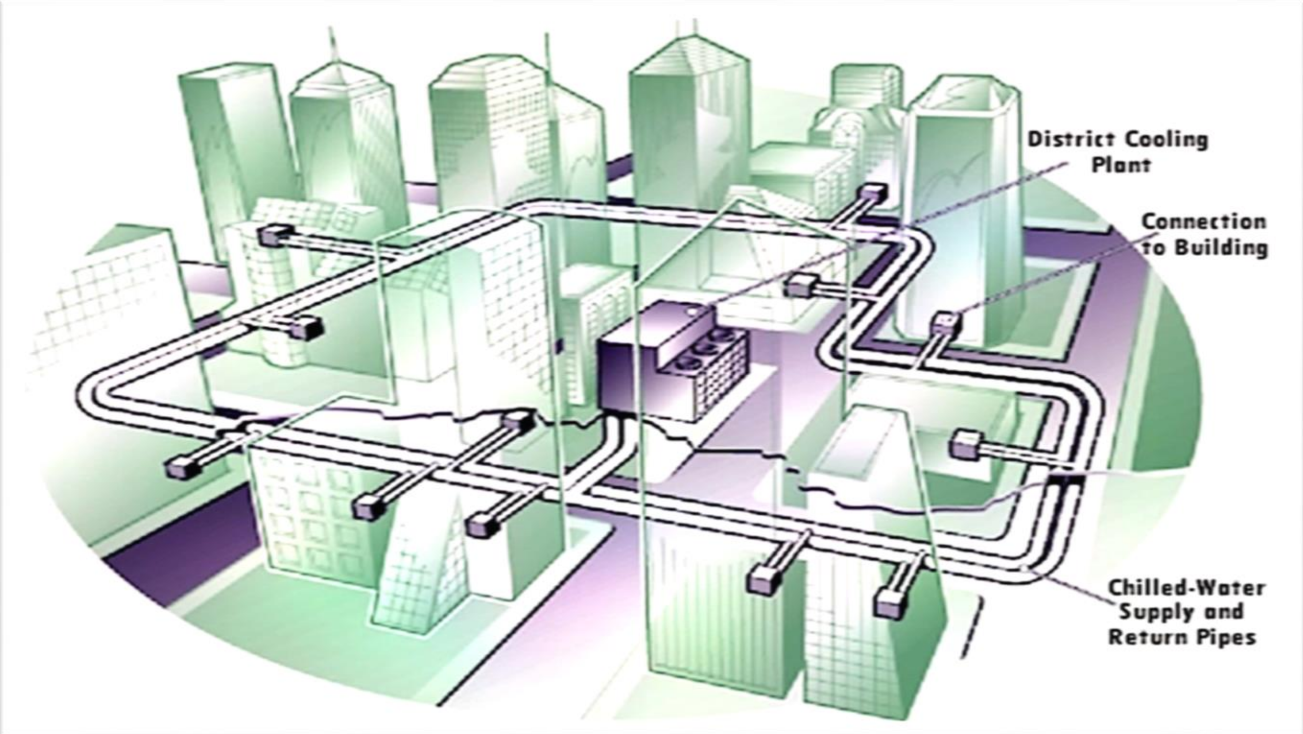


Figure 7: A schematic of typical district cooling systems (source: emsd.gov.hk)

A district cooling system (DCS) distributes (supplies and collects back) cooling energy in the form of chilled water from a central district cooling plant to multiple buildings through a distribution network of insulated, underground pipes for space and process cooling. Individual users purchase chilled water for their own building from the operator of the DCS and do not need to install their own chillers or cooling towers. A DCS varies significantly in size globally from serving multiple buildings to serving an entire city. They can be developed on private and public land or mix owner ship (details in business model section) and can serve a wide variety of customers including commercial, residential, public, industrial, and cold chain segments. The commercial viability of DCS is generally experienced in developments when there is a high density of air conditioning load such as hotels, offices, hospitals, and residential as well as industrial clusters.

DCSs have been a success globally as they deliver significant economic and environmental benefits, principally due to their high efficiency compared to stand-alone cooling systems. They can shift peak power demand using thermal storage and unlock large-scale renewable cooling that is not viable at an individual building level such as free cooling from rivers, seas, aquifers, and lakes. DCSs have the potential to integrate the sources of free cooling and waste heat. Therefore, this is one of the reasons why DCS has higher efficiency and brings more environmental benefit. (detailed benefits are mentioned in section 1.3).

All the subsequent sections for benefits, space cooling and investment potential, business models, barrier analysis, recommendation and next steps are applicable for district cooling systems.

Efficiency savings vary significantly dependent on the cooling systems that are being replaced and the technology the DCS uses to produce chilled water. In general, DCS projects deliver 30-70% primary energy savings compared to best-in-class stand-alone systems in dense urban areas. Due to higher efficiency and its ability to phase out HCFC and HFC refrigerants, DCS (together with trigeneration and thermal storage), is also prioritised in ICAP. An analysis of the attainable benefits of DCS in India is provided in section 1.3 and summarized here:

Table 2: Summarized benefits of district cooling system attainable in India

Reduced primary energy consumption for cooling system: 30% - 70%[3]	Benefits to local power grid including local generation, resilience, and balancing
Reduced peak power demand: 30%-35%	High reliability of cooling
Reduced potable water use: 15% -20%	Greater resilience to power and fossil fuel price volatility
Lifecycle refrigerant saving (20 years)[4] 10%-15%	Ability to use large scale renewable cooling (e.g. solar thermal, free cooling, geothermal, geo-exchange)
Reduced CO_2 emissions: 30%-35%	Alternative revenue stream for sources of waste heat or cool (e.g. incinerators, industry, LNG terminals)
Local jobs and alternative revenue to municipalities	High reliability power (when using trigeneration)
Role in mitigating global warming 0.5 -1°C (high efficiency and phasing out HFC refrigerants)[5]	

In some countries that have substantial heating demand or in industrial applications, the district cooling plant can also be designed to supply hot water or steam to buildings or industries to form a district heating and cooling system (DHCS). When cogeneration or trigeneration systems are used, the plant can also provide power for local buildings or for export to the power grid.

[3] The saving potential range is based on conventional to alternate technologies for DCS like trigeneration, free cooling, waste-to-energy plants, etc.
[4] Please refer to Figure 12 in Section 1.3.4
[5] in accordance to the Paris Agreement

1.2. Technological overview

A DCS can be broadly divided into three parts:

- An air conditioning plant – generates chilled water for cooling purposes
- Distribution network (DN) – distributes chilled water to end users
- Energy transfer station (ETS) - interface with buildings' own air-conditioning systems

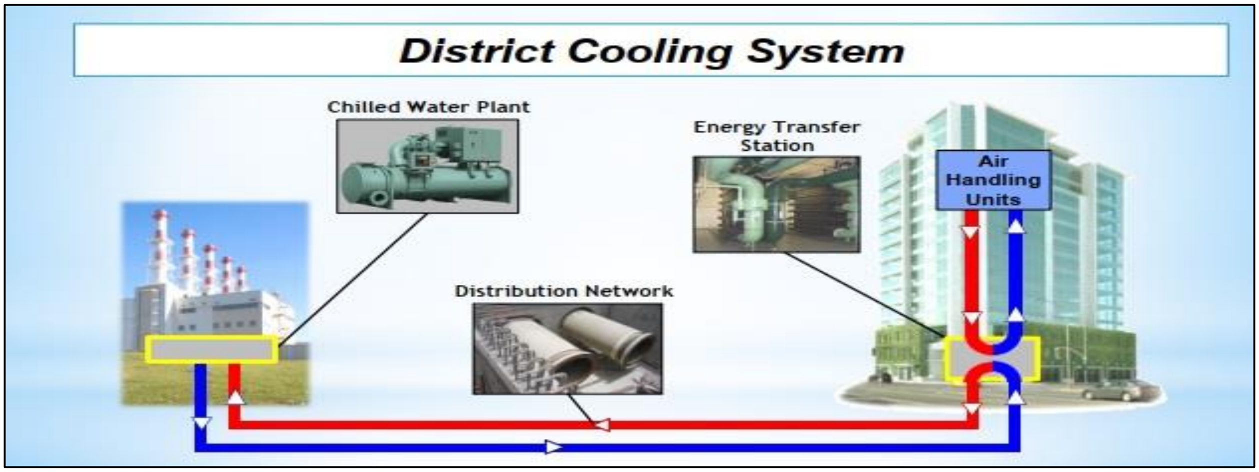


Figure 8: Key components of a typical district cooling system
(source: fujita-ec.com)

Various technological considerations are required for each of these parts, i.e. *chilled water generation*, *chilled water distribution* and *customer connection*. The air distribution is generally under the purview of building owner/customer.

Figure 9**9** captures the major components involved in each part. The details of these considerations are provided in Annexure 4 of the report.

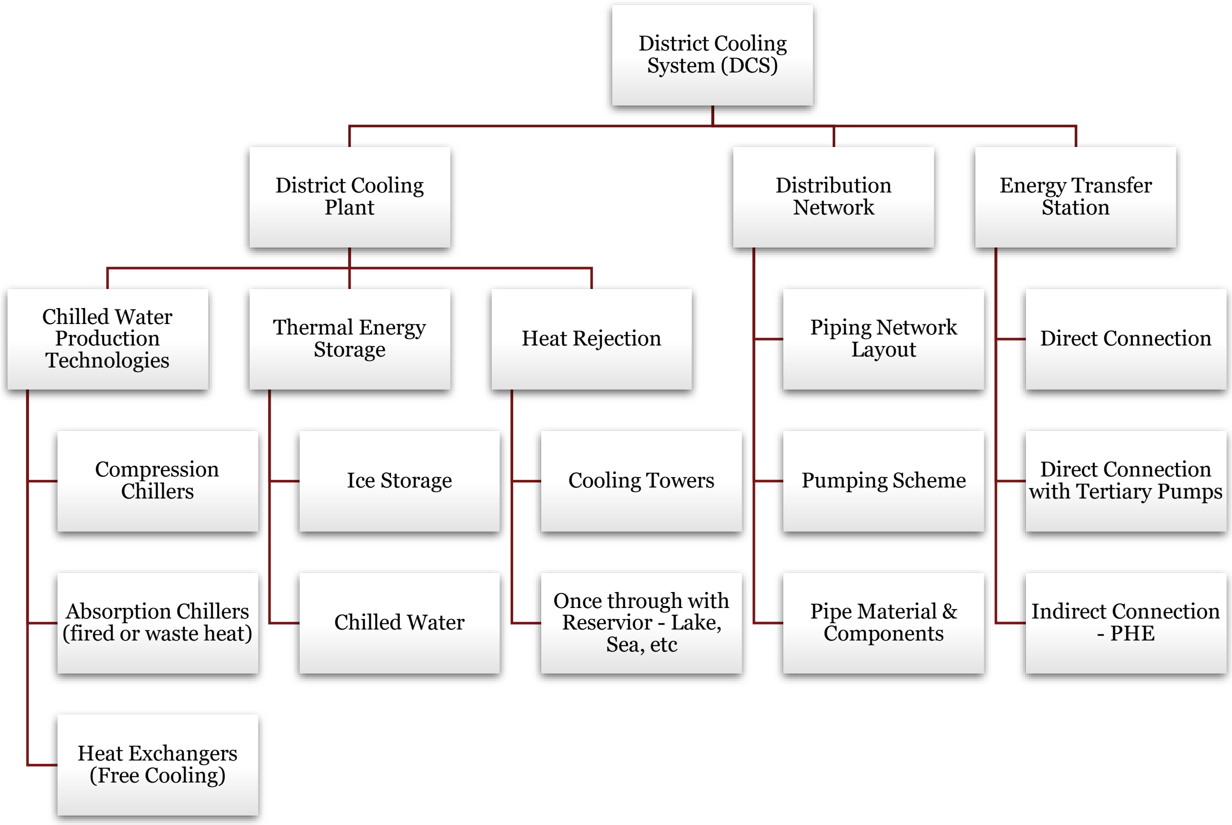


Figure 9: Technological overview of DCS

1.2.1. Examples of technologies used in global district energy systems

Globally, the DCS approach is expanded beyond cooling, whereby systems can also provide hot water and/or steam (for heating, hot water consumption or industry) dependent on local demands and electric power for captive consumers, local mini-grids, or the wider power grid. Generally, these systems are called district energy systems (DES)[6]. In India, as demand for cooling in buildings greatly exceeds that for heating, the term district cooling may be taken forward. Globally, such systems have also been integrated with municipal systems such as water, power, sanitation, sewage treatment, transport, and waste. Examples of such innovative integration are given below[7]. This enables integrated energy grids that fuel low-carbon, energy efficient heating and cooling, and maximize local renewable resources.[8]

- Waste heat capture from waste-to-energy plants for heating or cooling (e.g. Paris, Tokyo)
- Treated sewage effluent (TSE) used in cooling towers to reduce potable water use (e.g. Dubai)

[6] Other terms used include community energy, district heating, heat networks, etc. For all the basic principle is the same – central provision of heating or cooling.
[7] Numerous cities globally have undertaken each innovation and the cities named are just specific examples.
[8] District energy initiative by UNEP

- Wastewater system used to replace cooling towers in cooling season and as waste heat source in heating season (e.g. Zhengzhou, Paris)
- Waste heat extracted from metro system for district heating (e.g. London, Paris) and metro station served with district cooling (e.g. Dubai)
- Cogeneration/trigeneration directly powering city metros or electric transport (e.g. London)
- Integrated district heating and cooling networks, whereby heat pumps extract heat from return pipes of district cooling (e.g. Helsinki)
- Geothermal wells used as emergency water wells for city (e.g. Paris)
- Waste heat from local industries used for heating and cooling (e.g. Rotterdam, Gothenburg, Anshan)
- Waste cool from LNG regasification used in district cooling (e.g. Barcelona)
- Cogeneration used to provide emergency shelters and hospitals with back-up power and heat during disasters (e.g. Toronto, New York)
- Incentivized thermal storage used to reduce renewable power curtailment on the power grid (e.g. Guangzhou, Hohhot, Copenhagen)
- Free cooling extracted from potable water extraction from a nearby lake (e.g. Toronto)
- Multi-utility tunnels house piping and cabling of numerous municipal services (e.g. GIFT City)
- District heating pipelines used for district cooling service in cooling season (e.g. Zhengzhou)
- Biogas and landfill gas used in gas cogeneration (e.g. Paris)
- District heating or cooling plants placed underground and/or disguised as green parks (e.g. Paris, Shenzhen)
- Use of Open Cycle Gas Turbine Power Plant waste heat for desalination (e.g. Dubai)

1.3. Benefits of DCS

Why district cooling?

District cooling is being implemented worldwide by many kinds of organisations, including investor-owned power utilities, government-owned utilities, privately owned district energy companies, universities, airports, IT campuses, etc. District Cooling systems can serve a wide variety of buildings, viz. commercial offices, hotels, residential, sports arenas, malls, schools and hospitals, Food Processing Industries, as well as the cold chain.

District cooling is growing rapidly for many reasons (drivers and benefits):

- Increasing demand for comfort cooling and process cooling (data centres, cold chain etc.)
- Some cities and countries are beginning to view district cooling as a *public service* alongside water, gas, and electricity
- Outsourcing certain operations to specialist companies that can provide these services more cost effectively, at a higher quality, reliability, and more sustainably
- Economical/commercial benefits to the end users
- Reduction in peak electricity demand provided by district cooling
- Environmental policies to reduce emissions of CO_2 and refrigerants and use of potable water in cooling
- Customer value provided by district cooling service, i.e., potential lifecycle and upfront cost savings, superior comfort, convenience, flexibility, reliability, and space-saving in customers' roofs and basements

1.3.1. *End user benefits of district cooling*

1. **Comfort -** Comfort is the ultimate purpose of air conditioning. DCSs can keep people more comfortable because industrial-grade equipment is used to provide a consistent and high-quality source of cooling. In addition, expert operating teams can be focused on optimal operation and maintenance of cooling systems, thus increasing the reliability significantly. Buildings are quieter because there is no heavy equipment generating vibration and noise. Local urban heat island effects can be reduced significantly by centrally producing chilled water, using renewables that reduce dumping of heat in local atmosphere (e.g. free cooling with water bodies), and producing more chilled water at night with thermal storage. District cooling operators can also advise buildings on how to optimize and improve their internal HVAC systems for the good of the whole DCS network and increased comfort. Systems providing domestic hot water can allow households or businesses to do away with geysers and boilers and have high efficiency hot water whenever they require it.

2. **Convenience -** From the developer / building manager's standpoint, it is attractive to be able to provide reliable comfort without worrying about managing the equipment, labour, and material required for operating and maintaining chillers and cooling tower systems. This allows the manager to focus resources on more critical bottom-line tasks such as attracting and retaining tenants. For a hotel, the critical bottom-line tasks are managing guest experience. For a hospital, these are patient care and IEQ and the same in case of a mall include, managing its customer flow, lighting and ambience.

3. **Flexibility -** The pattern and timing of cooling requirements in a building vary depending on building use and weather. With building chiller systems, meeting air-conditioning requirements at night or on weekends can be difficult and costly, particularly when the load is less. With district cooling, these needs can be met easily and cost-effectively whenever necessary. Each building can use as much or as little cooling as needed, whenever required, without worrying about chiller cycling or efficiency.

4. **Reliability -** District cooling is more reliable than the conventional approach to cooling because DCSs use highly reliable industrial equipment and can provide equipment redundancy in cost effective manner. Staffed with professional operators around-the-clock, district cooling companies are specialist with expert operations and preventive maintenance programmes. Survey of existing DCS have shown reliability of > 99.9% as per International District Energy Association (IDEA).

5. **Sustainability -** Globally, building owners and tenants are demanding higher environmental standards in building design and services. District cooling in combination with building efficiency measures can significantly improve green building certifications, especially when the DCSs can access waste heat or renewable sources of energy that are unavailable at a single building level.

1.3.2. Cost benefits in district cooling installation

District cooling has numerous fundamental cost advantages that offer cost-savings to buildings. These include the following:

1. **Reduced installed capacity -** Not all buildings have their peak load at the same time. This "load diversity" means that when cooling loads are combined in a DCS, more buildings can be reliably

served at a lower installed capacity. DCS have achieved even > 50% (approx.) diversity when combining residential and commercial applications. This given an opportunity to design the infrastructure on lesser upfront investment (USD/MW). The illustrations are provided in figure below.

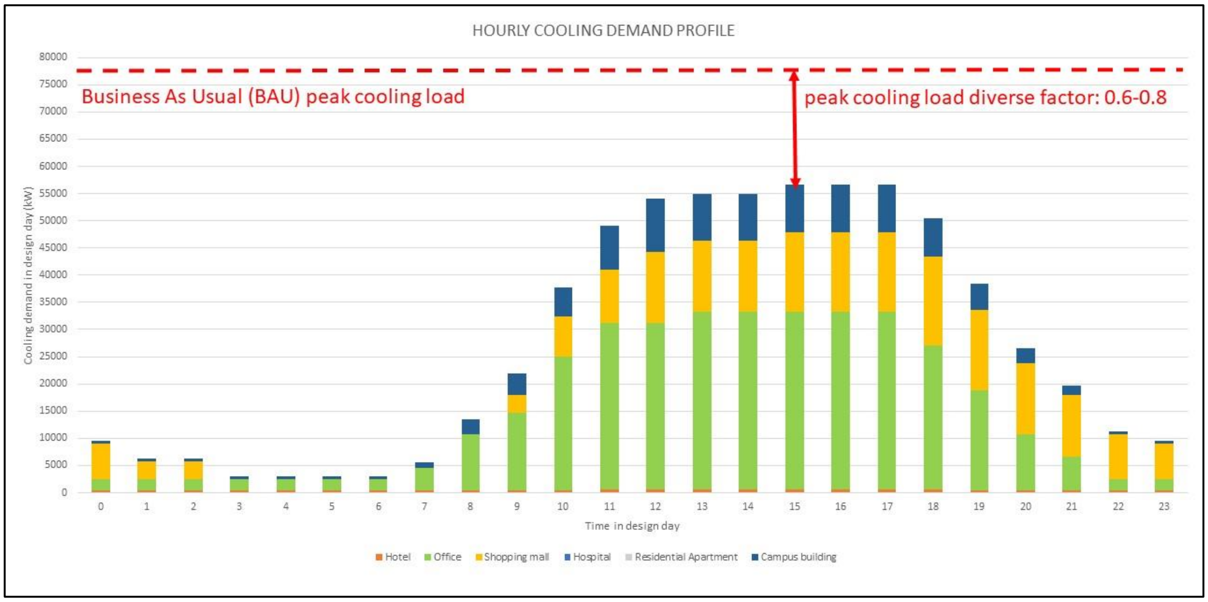


Figure 10: Cooling load diversity analysed in city of Thane Ghodbunder road area (source UNEP/C2E2)

2. **Optimised operations -** With district cooling, equipment can be operated at the most efficient levels, whereas with building cooling equipment, audits have shown that the units operate for most hours at less-than-optimal levels.

3. **Advanced technologies -** District cooling offers economies of scale to implement more efficient and advanced technologies such as the following:
    - Thermal energy storage (TES), which can further reduce peak power demand, save energy, enhance reliability, and reduce capital expenses for both utility and its customers
    - CHP – Combined cooling and power plant driven by natural gas/biomass/waste-to-energy/Renewable energy
    - Use of TSE water or even sea water for condenser cooling

According to the analysis in Thane city, the potential shift of peak electricity demands for cooling by different cooling technologies in district cooling is provided in the Figure below. These demands show the required capacity of electricity transformers from the electric grid to DC plants.

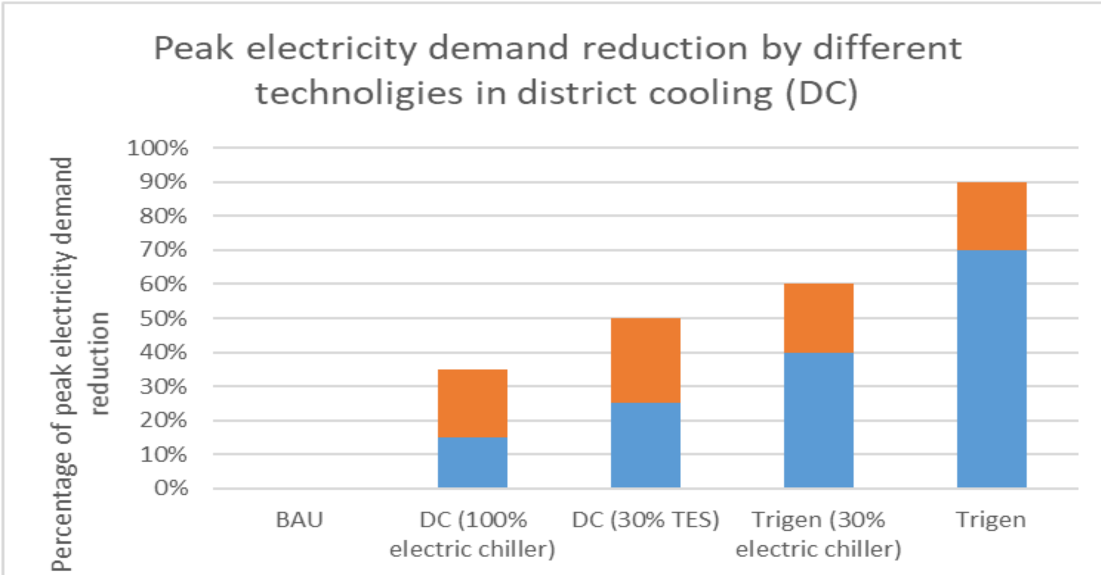


Figure 11: Peak demand reduction due to different district cooling technologies (source UNEP/C2E2)

4. **Competent manpower -** District cooling can cost-effectively use specialised expertise to operate and maintain the equipment required to reliably deliver building comfort. Improved maintenance ensures longer lifetime of equipment (e.g. DCS chillers can operate for 15+ years whereas a stand-alone building may replace chillers after only 10 years).

5. **Incentives -** District cooling systems can often access incentives in power regulations or from local authorities that individual buildings cannot – these incentives may have been developed to promote DCS. These can include:
    - Low off-peak tariffs to encourage TES
    - Low tariffs for high consumers of power – DCS plants will typically have greater than 5MW power demand. In India this means they can use open-access power or possibly industrial power tariffs, whereas individual buildings cannot
    - Some highly efficient technologies, like TES, free cooling from river and biomass trigeneration systems, may not be cost effective in the standalone building level but become economic viable in large scale as district energy system.

Benefits of DCS vs Individual Building Chiller Plants

The overall benefits of district cooling plant with the individual chiller plant for buildings, is given below:

Table 3: Overall benefits of DCS vs Individual Building Chiller Plant

Capital cost benefits	Operating cost benefits
By choosing district cooling service, a building avoids a large capital investment for the following: • Chillers and condenser cooling equipment • Power utility connection size deposit • Transformers, breakers, and cables • DG back-up cost and space • Water treatment plant • Water supply system for cooling towers and the electrical systems to support it • Construction cost for mechanic rooms for above systems (electric, cooling, water supply) • Construction and structure cost of cooling towers and their pipes to chillers	District cooling service allows the building owner to eliminate the annual cost of operating and maintaining for the following: • Scheduled annual maintenance • Periodic major maintenance • Unscheduled repairs • Refrigerant management • Spare parts and labour • Water treatment chemicals and monitoring system • Water and wastewater disposal costs • Management oversights • Predictable cost estimation

1.3.3. Infrastructure benefits

1. **Peak power demand reduction -** District cooling reduces peak power demand in new development by 40 - 80% depending on the type of district cooling technology used and proportion of TES. Gas based CCHP (combined cooling, heat and power) or trigeneration can reduce peak power substantially and provide local power close to demand.

2. **Reduction in cost to city governments and DISCOM –** For city governments, district cooling offers the benefits of utilisation of power/heat generated from WTE plant. This eventually enables city governments in achieving their sustainable development goals by reducing carbon emissions. For DISCOMS, district cooling reduces the capital investment required for additional power generation, transmission, and distribution infrastructure.

3. **Long-term grid balancing services -** District cooling and district heating plants globally have helped to support balancing of the power system and increased shares of renewable electricity, reducing curtailment (e.g. Denmark, Germany, China). The combination of responsive, local power production (CHP), demand (chillers/heat pumps), and storage enables this. For India, DCS should be a key infrastructure for balancing the power grid as the share of renewables increases.

1.3.4. Environmental benefits

1. **Energy efficiency -** District cooling with DCPs using electric chillers can typically reduce annual electricity consumption by ~25% over individual water-cooled central plant. In many cases, this reduction can be higher, reaching 30-40%. When technologies such as CHP and/or free cooling are used, electricity reductions can be up over 80%.

A substantial portion of energy savings results from 'optimised operations and maintenance' and efficient use of quality water for cooling tower. Individual buildings use conventional water treatment, which may not be suitable based on the available water quality. District cooling plants could be designed to use no municipal water and use a variety of technologies such as:

- Sea water / brackish water
- RO plants
- Treated sewage effluent (TSE)

Individual building systems use 'standard water treatment', i.e., water softener that may or may not be suitable. Improper water quality is one of the biggest reasons for derationing of chillers and cooling towers causing an impact of 30-35%, on equipment performance (in efficiency levels) in many cases.

2. **Climate change -** With growing national and international interest in strong action on climate change, climate change has become an increasingly important issue. District cooling can help extensively in mitigating the impact of new development on climate change through higher energy efficiency and this also leads to reduction in CO2 emissions by 30%-35%

3. **Water savings -** Cities are witnessing a looming water crisis. Buildings with central plants continue to use ground water or potable municipal water in cooling towers. Most buildings just have a softener for water treatment, which may not be enough.

   With water supplies becoming scarcer, DCSs can be designed based on TSE provided by municipal authorities. However, TSE quality may not be consistent or predictable but DCPs can design suitable water treatment systems for this issue. In the DCS design proper filtration and real time water treatment system is conceived for better water management and hence the DCP can operate at better CoC (cycles of concentration) minimizing the water loss.

   Although the make-up water requirements of DCS vs individual plants will not be drastically different, DCS can and should be designed with "STP recycled water", whereas individual building chiller plants end up using "Municipal Water / Borewell Water".

   In present scenario, it can very well be estimated that > 50% of the make-up water being used in individual building chiller plants is "fresh water" in India. With cities facing acute water shortages, such wastage of "fresh water" can and should be avoided.

   Based on 2,500 equivalent full load hours, a 20,000TR district cooling plant annual make-up water consumption will be approx. 500 million litres. Therefore, a single district cooling plant has the potential to save 250 million litres per annum of fresh water from being used incorrectly in cooling towers.

4. **Refrigerant savings -** Refrigerant management is a larger issue that has more-or-less been ignored in commercial buildings. Refrigerant leaks are not discovered timely and records of top-ups are not maintained properly. Most plant rooms do not have refrigerant leak detectors and almost none of them have a refrigerant storage and recovery unit.

In general, a chiller loses 2% of its refrigerant charge per annum[9]. With better maintenance, usage of refrigerant leak detectors & RSR units, a DCS Plant can reduce refrigerant loss to less than 0.5% per annum.

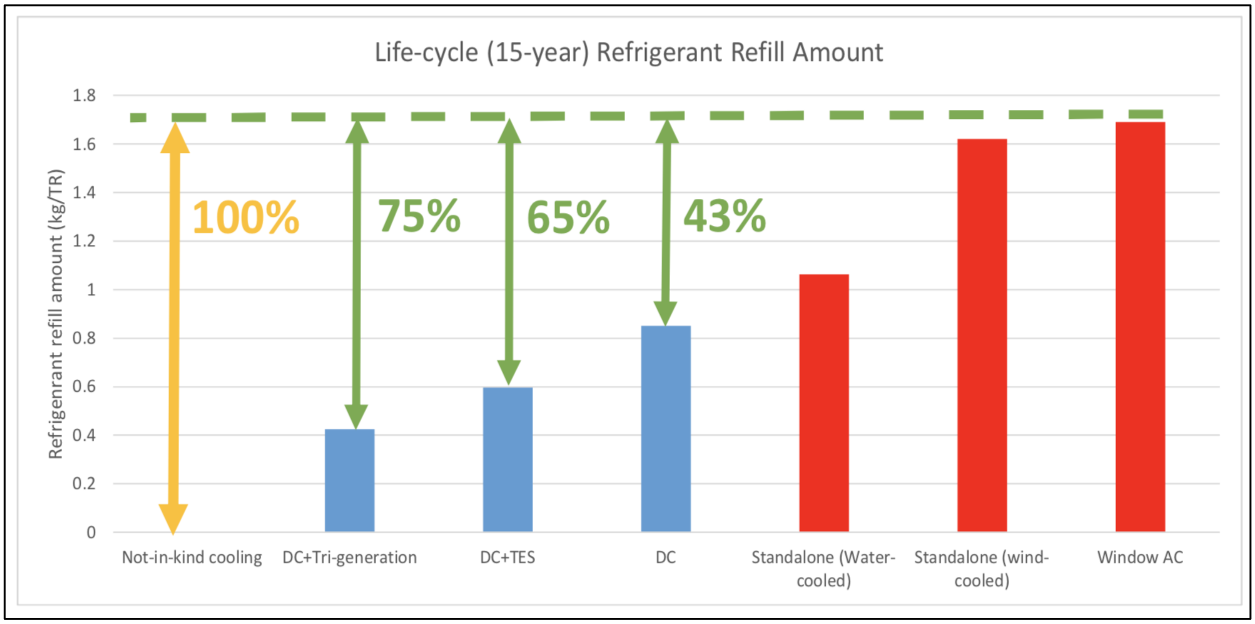


Figure 12: Refrigerant lifecycle
(Source : UNEP/C2E2)

A 20,000TR DCS plant would replace roughly 30,000TR of individual building-level chiller plants (due to diversity factor, stand-by, and TES Tank). Refrigerant top-up of 2% per annum is considered as a thumb rule for chillers installed in commercial buildings vs 0.5% per annum for DCS. Thus, annual savings in refrigerant top-up can be reduced by 1,250 lbs. This is equivalent to reducing direct CO2 emissions by ~750,000 kgs per annum per plant.

[9] LEED for new construction and major renovations V2.2, Credit EAc4 Enhanced Refrigerant Management, formula for refrigerant leakage (2% default)

2. Global district energy systems (DES) best practices

Although projects for district energy systems, have existed for over 100 years, DES is experiencing a global resurgence in **Europe, the US, Canada, Gulf nations, Japan, Korea, Malaysia, China and some projects are coming up in Latin America, North Africa, ASEAN, and island countries**. This resurgence can be attributed to the following:

- Cities and countries having reviewed strategies to improve energy consumption (more reliable, more sustainable, more cost-effective) and are increasingly engaged and active on heating and/or cooling as stand-alone energy-uses that require specific market interventions[10].
- Cities are increasingly empowered to act upon energy in general, which is also enabled by an increasingly decentralised energy system shifting from centralised fossil fuel power plants.
- Increased best practice sharing between countries and rise of global players on DES pushing the market in each continent.
- Increased focus on efficiency, renewables, air pollution, water use, and climate change, as well as a shift away from fossil fuels for reasons of energy security and environment, necessitates solutions such as DES to be considered.

Different[11] countries like Sweden**, UAE, Singapore, China, Colombia, France, Malaysia, and Egypt** all have started meeting their air conditioning demand with (DCS). As an approach to cooling, DES is not only applicable for hot countries or only developed countries. Indeed, the pace of real estate development in emerging economies and increasing cooling demand makes these markets ideal for district cooling investments.

For example, in the **UAE**, the first district-cooling scheme was commissioned in 1999 by Tabreed. By 2017, the total installed district cooling had reached 3 million TR, representing 10% of the UAE's total air-conditioning market. Currently, air conditioning accounts for up to 70% of the UAE's electricity demand. By 2030, the cooling demand is expected to increase to 20 million TR, of which 40%% is targeted to be provided via District Cooling Systems that will help in 30% reduction of carbon emissions.

Figure 13: Dubai Metro – The first mass transit network in the world to use district cooling

Additionally, the **Dubai Metro system**, is the first mass transit network in the world to use district cooling to lower temperature in

[10] Previously, cooling had been seen as an 'electricity sector problem' when in fact it needs separate attention by policymakers
11 (different based on climate zones and cooling/heating requirements)

stations. DCS has helped reduced total power demand for the Dubai Metro by 30-50%[12]. This clearly helps in understanding the potential of energy savings through DCSs in the country.

Malaysia is a regional leader in DCS with numerous successful projects developed over the last 20 years, such as in government-led projects of Cyberjaya and Putrajaya and numerous private sector projects. The country's electricity utility has been invested in DCS in Malaysia and abroad since 1997, reflecting the technology's cost-effectiveness and system-wide benefits, such as incentivizing projects to shift power demand away from peak periods by providing lower off-peak tariffs for thermal storage. The country's Low Carbon Cities Framework has also explicitly listed district cooling as an important low-carbon option for modern cities.

Similarly, other countries such as Singapore, Egypt, and China are also achieving energy efficiency through District Cooling Systems and contributing in the national missions of energy efficiency.

Global experience showcases the adoption of DCS for space conditioning. These examples can act as learnings for India to eventually drive the technology and required policy and regulation interventions.

2.1. City leadership on energy, heating, and cooling

Globally, cities are increasingly playing a greater role in the energy sector. Energy demand for heating/cooling requirements in buildings have made impact like air pollution, water scarcity, heat island effect, power grid stress, and blackouts in the past. In addition, local governments are often closest to those citizens experiencing energy poverty, at the risk of heat stress and inability to sufficiently heat or cool their houses. Local governments may even control construction and operation of social housing for such groups. Finally, the role of cities as leaders in pushing action on climate change and renewable energy is growing fast and globally many local governments are adopting targets and plans that are more ambitious than their national counterparts. When such targets and plans are comprehensively prepared, they explicitly include energy-use and prioritise heating and cooling demand as separate energy vectors to be tackled. Overall, cities are increasingly looking to promote technologies and approaches to energy, heating, and cooling that align with their priorities, integrate multiple sectors, improve urban resilience, target poverty reduction, provide local economic benefits, and are sustainable. District energy and building efficiency are two major approaches cities turn to. These approaches must be within their jurisdiction (particularly their role as planners). make use of local resources effectively (waste heat and renewables), integrate city systems (waste, water, buildings, sewage, power etc.), and contribute significantly to local economic development.

2.2. International best practices and learnings India

Many cities and countries around the world have adopted/undertaken many initiatives to promote DES/DCS. Some international best practices for district cooling in various cities and countries with similar climatic conditions as India are presented below.

[12] https://www.desmi.com/cases/dubai-metro-district-cooling-uae.aspx

Table 4: International analysis on different parameters

Name of the country	Assessment Parameters			
	Scenario of DCS in the country	**Barriers for DCS in the country**	**Success drivers to the district cooling systems**	**Learnings for India**
UAE - Dubai	Multiple projects installed in the last 2 decades. Over 75 plants of DCS with refrigeration capacity of more than 3 MnTR. Most of the new commercial and residential development are addressed by DCS.	• Adoptability of technology among developers • Lack of concentrated loads/anchor loads in initial phases • Lack of centrally cooled buildings that can be converted into DCS	• Government policy for adoption and enforcement of technology • Upcoming dense development in city • Trusted business models • Replacement of air-cooled chillers with efficient water-cooled district cooling technology • Awareness among the end users by efforts of the government • Climatic conditions favour the need of DCSs in Dubai	• Policy framework supporting DCS adoption at city-level • Involvement of municipal corporation in master planning • Different kind of Business models and energy planning methods • Capturing market of air-cooled chiller as potential consumer for DCS • Careful sizing and commissioning of DCS plants and networks to avoid overinvestment before consumer demand • Will of utilities in district cooling as strategy • Development of awareness programmes
Shenzhen – China	China has one of the largest installations of DCS with the capacity of 0.4 million TR designed air conditioning capacity serving 19 million sqm area, mainly covering offices,	Awareness towards the technology	• Integration of energy planning to urban planning and incentive policy to ensure the connection of DC • High density areas that are	• Involvement of municipal corporation in integrating DCS in master planning • Prioritise DCS for commercial sector • Use of treated wastewater for cooling towers

	commercial, hotels, metro stations, etc. The phase wise development of this project started in 2011 and will end by 2025 (phase III).		preferable for DCS • Municipality required land to be set aside by real estate developers for DCP • High land price for the end-users to build their own systems inside their buildings • Climatic conditions	• Potential DCS consumer in high density area • Not feasible for only residential sector. It should be clubbed with load of commercial buildings • Use of ice storage in high density areas significantly lowers peak power demand but limits efficiency benefits of DCS (ice storage increases kW/TR
Singapore	Biggest project of Singapore for DCS, having 2,60,000 TR cooling capacity, serving Marina Bay. The development is mix use commercial development having hotels, offices, community centre, etc. Project started in 2006 and first phase was commissioned in year 2010.	The strong regulations for EE in buildings at design stages limits the requirement/scope of DCSs in country.	• Formation of Singapore district cooling Pte Ltd, by government in year 2000 • District cooling act and licensing provisions in the country • Targeting dense and greenfield development as potential consumer of DCS • Support from green building movement • Conducted awareness and training programmes for end users	• Policy development for supporting DCS in country • Formation of regulatory body to push DCS adoption in India • Feasibility in green field development • Not feasible for only residential sector. It should be clubbed with load of commercial buildings • Inclusion in green building guidelines • Awareness and training programmes
Paris - France	District cooling has been operated in Paris under a	• Cooling season for residential sector is 2 months, hence Paris DCS is	• Involvement of municipal corporation in	• Involvement of municipal corporation in

	concession since 1991, where Climespace constructed the first cooling network in Europe. This network replaces air conditioning and chillers for many offices, shops and hotels as well as some of the most famous buildings in Paris, such as the Louvre, by pumping cold water around the city. There are number of examples where district heating is being used in residential sector.	connected to non-residential sector where anchors had been predicted.	planning and routing • Formation of Paris Urban Heating Company (PUHC) • Underground connections are made to the River Seine • Possible low tariff for social housing • 60% of the DCS network in Paris is run through the city's sewage system.	integrating DCS in master planning • Formation of task force at city level to drive DCS • For constructing a DCS network, involvement of the city authorities plays an important role to coordinate with other utilities. • Special tariffs as per user segment • Not feasible for only residential sector. It should be clubbed with load of commercial buildings
Cyberjaya – Malaysia	There are numerous district cooling plants in Malaysia. The first plant was completed and became operational in 1999 and serves various commercial buildings. Malaysia now has several DCSs, including its largest one in Cyberjaya. This serves 48 buildings with 14,000 TR capacity in total. It has TES	• No specific body to regulate the development of district energy. • Lack of awareness about District Cooling Systems' benefits. • No specific acts or regulations applicable to district energy in Malaysia. • Lack of funding for early-stage assessments of projects • Lack of innovative business models.	• Interest of individuals have resulted in installation on around 15 plants in country • Cogeneration plants are more (may be due to gas availability and prices) • Capacity building on the benefits of DCS	• If gas is available, then COGEN plants can be option • Not feasible for only residential sector. The existing plants cover commercial spaces for space cooling. • Awareness among the developers and builders

	capacity of 95,000 RTH			
Smart Village – Egypt	One of the projects "smart village", adopted in May 2004, has1,44,000 TR air conditioning requirement, mainly covering IT buildings of the SEZ. First stage was inaugurated in July 2006 with 8000 TR. The project is expected to be completed by 2025.	• Spread out developments • Risk of early investments • Lack of awareness	• Smart village was designed from master planning phase. • Complete development is green field development and has not included residential in the potential consumers of DCS. • Heating requirement also catered by DCS • Project viability due to low power cost and cheap gas availability	• Spread out development (low density areas) leads to extra cost for piping • Not feasible for only residential sector. It should be clubbed with load of commercial buildings • DCS inclusion in master planning stage. 8000 to 10000 TR/sqkm as minimum requirement for viability of DCS in India

2.2.1. Key success driver of DCS adoption in Dubai - UAE

Figure 14 below shows the current overall cooling technology market share in Dubai. The city has diversified cooling technologies (by market share) adopted by various end users. The contribution of centralised cooling in stand-alone buildings from air-cooled chillers is significantly higher compared to the water-cooled systems. This is likely due to water scarcity and cost issues, given Dubai's water comes from desalination. The Government of Dubai has targeted to take district cooling share from 18% to 40% by 2030 as part of an overall strategy, including building efficiency measures, to reduce the city's air-conditioning power demand by 50%. This target for district cooling is achievable, in part, as the large, addressable market of 25% of buildings with centralized air-cooled systems will be highly cost-effective to connect. End Users will see a lot of cost savings with DCS if they are using air-cooled chillers as the kW/TR for Air Cooled is more than 1.4 kW/TR compared to 0.9 to 1.0 kW/TR for DCS.[13]

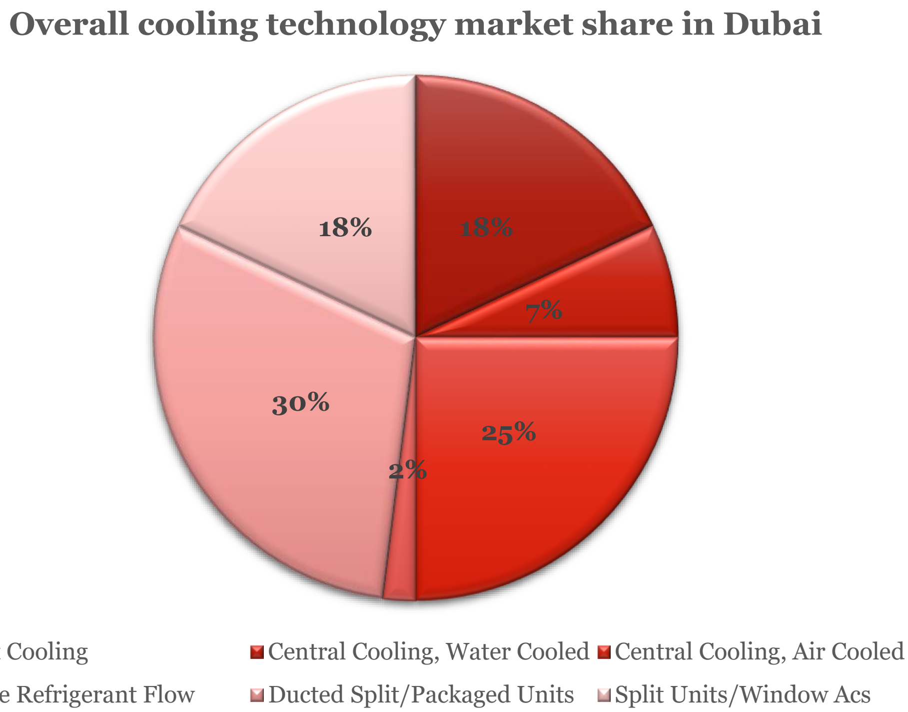


Figure 14: Overall cooling technology market share in Dubai (year 2015)
Source: RSB Dubai - Dubai Cooling Study

The target is to connect all new developments and all public sector building to the DCSs by 2030. This had also been recently accompanied by stronger regulation. The market is regulated by Regulatory & Supervisory Bureau for electricity and water in Dubai (RSB) in terms of licensing district cooling providers, billing, disputes, etc.[14]

[13] Dubai cooling study by RSB
[14] Utilities Middle East, District Cooling In Dubai To Be Regulated For Disputes, 2018 https://www.utilities-me.com/news/12193-district-cooling-in-dubai-to-be-regulated-for-disputes

3. District cooling systems in India

District cooling system is one of the not in-kind technology in India (as per ICAP). District cooling systems enable higher flexibility to incorporate multiple energy vectors (solar cooling, tri-generation, and waste cold energy) to meet cooling requirements and provide the ability to exploit thermal storage options or to adopt a system level management of cooling consumption.

Based on the currently installed and operational DCSs in India, there are broadly two types of systems:

1. These are designed, installed, and operated by a single user for their own use like airports, IT campuses, office complexes, malls, hospitals, etc. **These large central plants can be termed as "single ownership" executed through EPC route.**
2. These are large central plants that are not necessarily owned by the user, but they cater to mixed use areas such as special economic zones (SEZ), high density commercial developments, food parks, etc. and serve multiple types of buildings for cooling purpose. **These can be termed as "merchant type district cooling plants" where chilled water is served as utility to consumers/buildings.**

Some examples of DCS systems in India are given below:

1. GIFT City, Ahmedabad – 180,000 TR capacity (at full long-term capacity)
2. DLF cyber city (trigeneration based) – 78,000 TR capacity
3. Delhi Airport – Approx. 20,000 TR capacity
4. Mumbai Airport – Approx. 20,000 TR capacity
5. Chennai Airport – Approx. 12,000 TR capacity
6. Kolkata Airport – Approx. 12,000 TR capacity
7. Dhirubhai Ambani Knowledge City, Navi Mumbai- Approx. 12,000 TR capacity
8. Infosys (various campuses) – Approx. 50,000 TR (approx.)
9. Pragati Maidan, Delhi - Approx. 12,000 TR capacity (In Construction)
10. India International Convention Centre, Delhi – Approx. 10,000 TR capacity (In Construction)

For large and dense mix-use developments in India, district cooling makes techno-commercial sense over individual chiller plants. Existing district cooling plants and large central air conditioning plants are majorly single ownership type of plants. Merchant district cooling offers greater potential of DCS technology due to load diversity, flexibility in capital design, and installation. This needs to be planned and implemented to mitigate all the risks using policy intervention and support. Please refer to section 2.2 for international case studies of DCP. **Single ownership type of plants is being adopted by the end users/developers (like IT buildings, airports etc.) in business as usual scenarios.**

All the subsequent sections for estimating potential, investment potential, business models, barrier analysis and recommendations are applicable for merchant district cooling only.

Gujarat International Finance Tech-City or GIFT City is India's first merchant DCS developed by the Government of Gujarat. GIFT City has been developed on 886 acres of land with a planned total built up area of 5.76 Mn Sqm, and includes commercial buildings, residential buildings, social buildings such as hotel, club and malls, and a hospital. **With DCS, the total requirement of 270,000TR of air-conditioning shall be met with just 180,000TR of chillers**. Each plant has been designed with chilled water based stratified thermal energy storage tank, which can be charged during off-peak period and discharged during peak period, **thus reducing the electrical demand from 240MW to 135 MW only**.

Figure 15: GIFT one tower

GIFT City is a notable example of DCS that was properly planned with involvement of authorities and municipal corporation for planning and implementation of DCS in Gift city. **GIFT city has experienced challenges in terms of demand assessment**. Currently, only one plant of 10,000TR is operational feeding eight buildings. In DCS, capital costs are "front-loaded" because of the high costs of installing basic plant infrastructure and pipe mains in the early years.

Another successful example of district cooling for commercial buildings is **DLF Cyber city, Gurgaon**. DLF cyber city is India's Largest Integrated Business District and it has private captive power generation system. The project was developed in 2012, based on trigeneration. It serves 10 buildings, with conditioned area of more than 1.7 Mn Sqm. Cooling demand of 78,000 TR and power demand of 140 MW is served by trigeneration. This technology helped DLF to reduce 100 MW power demand and saves around 36,000 tonne CO2 per year. The plant is operating well and serving all the connected buildings. **As the Cogen plant is located in the basement of one of the buildings, there are some concerns regarding fire safety. Also, the increase in the price of gas over time has impacted the viability of self-generation of power.**

Figure 16: View of DLF cyber city

Amaravati Government Complex, Andhra Pradesh

Envisioned as a future sustainable city for the new capital for the State of Andhra Pradesh, the Amaravati master plan included several sustainability aspects including a city-wide network of district cooling plants wherever cooling load density was sufficient for life cycle cooling costs to be lower with DCS vs stand-alone cooling systems. The first amongst these DCS for **20,000 TR** was planned for the government complex area by Andhra Pradesh Capital Region Development Authority (APCRDA) to be implemented through a 33-year public-private partnership concession. APCRDA undertook a global tender (the first of its kind for a district cooling system in India) following which the concession was signed with Tabreed India in

February 2019. The firm offered to invest, develop and operate the DCS included a district cooling plant that would be expanded in a modular fashion in future, chilled water based stratified thermal energy storage tank, and networks designed to accommodate connecting future plant rooms to **serve up to 80,000 TR** whilst delivering a **20% life cycle cost savings** versus stand-alone cooling and a **35% peak power demand reduction.**

The construction of the DCS is now pending completion of the ongoing review by the new state government on changes to the planned capital city.

3.1. Initiatives in India for DCS

Foreseeing the growth in space cooling demand in India, in 2015 the **UNEP-led District Energy in Cities Initiative**[15] with EESL as its coordinator started supporting five Indian cities - **Bhopal, Coimbatore, Pune, Rajkot,** and **Thane** to explore district cooling projects. Rapid assessments were undertaken in five of these cities with ICLEI South Asia Secretariat where the feasibility of DCSs were assessed and confirmed and diverse local policy recommendations prepared[16]. In November 2017, these assessments were published alongside a high-level analysis on India's national and state-level policy framework for district cooling and potential measures and incentives at the state and national level that could be used to kick-start district cooling in the country. Out of these cities, **Rajkot** and **Thane** were selected as pilot cities. **Rajkot** has become the first Indian city to incorporate district cooling in the smart city plan. The team is supporting Rajkot city to finalize the DPR tendering for DC in their Smart City projects. Thane has a brownfield project under consideration by municipal corporation. In addition, the cities of Hyderabad Pharmacity and Amaravati (as described in earlier section) have also been supported as pilot cities.

City of Amaravati in Andhra Pradesh successfully tendered for a large DCS system in the government complex area. However, the development of the Amaravati city is currently on hold. The procurement documents and proposed business model can be used in other projects in India. The Initiative is also supporting Hyderabad Pharmacity in Telangana which could have 210,000 RT of DCS and also a district heating steam network. Technical support from the Initiative and other partners from the Initiative is being provided to the project owners and local authorities for preparing the full tendering documents.

The Initiative is supporting pilot cities following a methodology established by UNEP after analysing 45 champion cities for district energy in 2015. This methodology is presented in 'District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy'[17] and summarised below:

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[16] Available from: www.districtenergyinitiative.org/India

[17] Available from: www.districtenergyinitiative.org/publications

1.	**ASSESS** existing energy and climate policy objectives, strategies and targets, and identify catalysts
2.	**STRENGTHEN** or develop the institutional multi-stakeholder coordination framework
3.	**INTEGRATE** district energy into national and/or local energy strategy and planning
4.	**MAP** local energy demand and evaluate local energy resources
5.	**DETERMINE** relevant policy design considerations
6.	**CARRY OUT** project pre-feasibility and viability
7.	**DEVELOP** business plan
8.	**ANALYSE** procurement options
9.	**FACILITATE** finance
10.	**SET** measurable, reportable and verifiable project indicators

Figure 17: 10-step methodology for developing and promoting district energy in cities
Source: UNEP, 2015

3.1.1. Thane pilot city

Thane was selected as the Initiative's first pilot city in India and has been supported to follow the 10-step methodology in the above figure. Lead partners supporting the city are UNEP, ICLEI, EESL, IFC, C2E2 and the Carbon Trust.

A rapid assessment[18] was prepared and provided high-level technical and financial assessments of multiple upcoming or existing real estate projects in the city and identified barriers to their implementation. Two ideal sites for implementation of DCS were identified and taken to prefeasibility study[19], technology options were considered and both sites were found to be highly commercially viable either being a) entirely run on electric chillers b) hybrid project of trigeneration and electric chillers:

1) **Ghodbunder Road project**: a 8,800 TR brownfield project connecting 6 diverse existing buildings (malls, hospital, offices, etc.) with IRR[20] of 31% for a CAPEX of $22 million for trigeneration option; and

[18] Available from: http://www.districtenergyinitiative.org/sites/default/files/Thane%20Rapid%20Assessment%20Report%20Version%201.0-2.pdf
[19] Available from: http://www.districtenergyinitiative.org/sites/default/files/Thane%20District%20Cooling%20Pre-Feasibility%20Studies%20FINAL.pdf
[20] Pre-tax, over 20 years

2) **Hiranandani Estate project:** a 9,700 TR greenfield DCS project in the Hiranandani Estate in Thane connecting 6 large IT buildings and a hotel with IRR of 19% for a CAPEX of $27 million for trigeneration option.

After the pre-feasibility studies, a UNEP-led team conducted numerous stakeholders' discussions with the city of Thane and Hiranandani Group to go through business models and procurement options. The Ghodbunder road project is still under discussion with the city but has been setback several reasons including COVID-19. As it is a brownfield project, these delays are not a significant issue, but the project does need to be again championed by the city who has been crucial for bringing existing buildings on board with the scheme. The numerous offers of support to the city to cover project development and tendering costs need to be taken forward. Two likely business models and procurements being considered are a public tender for a private sector concession or EESL establishing a PPP to take forward the project with the city. The city has committed to making available land for the DCS plant and rights-of-way under municipal roads for DCS network and encouraging buildings to connect in the concession area.

The Hiranandani project construction timetable was extremely fast and early inclusion of DCS in the planning was not possible as the project was selected mid-construction. The time taken for awareness raising, bringing the real estate developer on board, feasibility analysis and identifying the business model meant that the project had moved from greenfield to brownfield before DCS could be confirmed. This shows that for Greenfield projects very early consideration of DCS is needed to match the very fast real estate pace in India or, if DCS is identified at midpoint of development, it is likely only a Business-to-Business arrangement that could move fast enough to meet the timetable. The DES Initiative is in discussions with Hiranandani Group to include DCS in the Panvel development in Mumbai where space is being left under roads for DCS network.

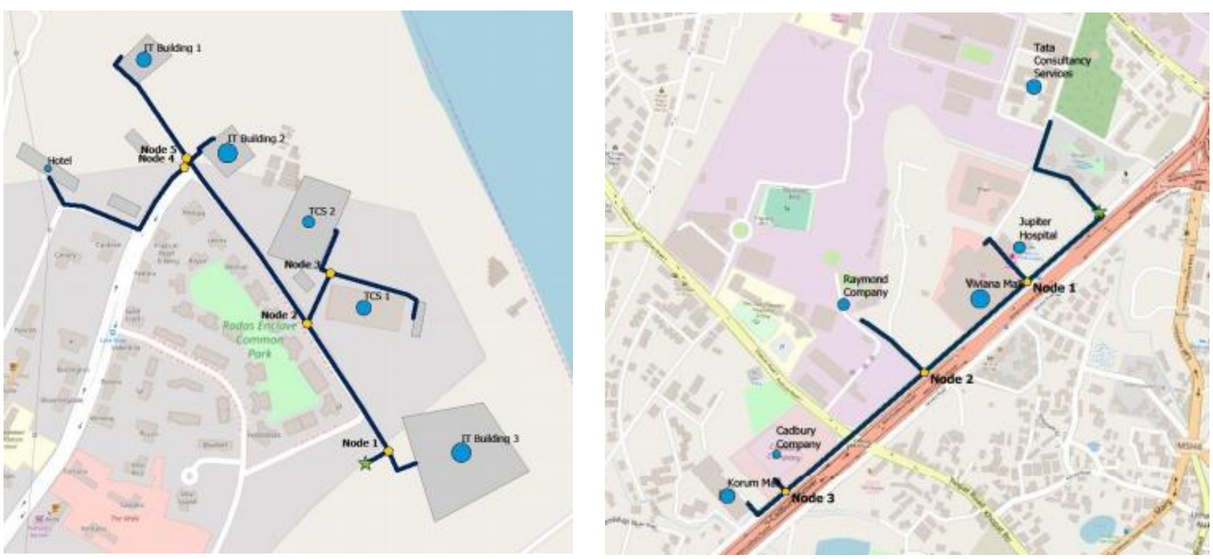

Figure 18: Hiranandani Estate project (left) overview and Ghodbunder Road project (right)
Source: UNEP, 2015

These were two of the first projects in India to go through a public prefeasibility process and the results and economic tool are being made available for other projects in Thane and India.

Beyond supporting the pilot projects, UNEP and partners have also taken significant other measures in the city:

- Developed energy and cooling GIS mapping that can be used in a city to understand the cooling demand in a city and to identify areas of high density (see figure below).
- Identified the viability of district cooling in one selected high cooling density cluster which is planned for future redevelopment and commented on next steps to determine feasibility of the system.
- Provided detailed policy recommendations to facilitate the use of district cooling in Thane
- Proposed a coordination structure for a District Cooling Cell in Thane
- Developed city-wide plan for DCS, defining a series of actions, policies and investments to deliver the full potential of district energy alongside a pipeline of projects to serve as a starting point.
- Building on the cooling demand mapping and deep assessment study, the Urban Revival Plan 12/ Wagle Estate area is indicated to support a viable district cooling network.
- Significant training and capacity building to the city and local stakeholders
- Designing a Monitoring, Reporting and Verification (MRV) framework for DCS in Thane and India

While these exercises have been applied to the city of Thane, the processes and methodologies are replicable and all documents, tools, methodologies and trainings are being prepared to be made available in an online Virtual Platform.

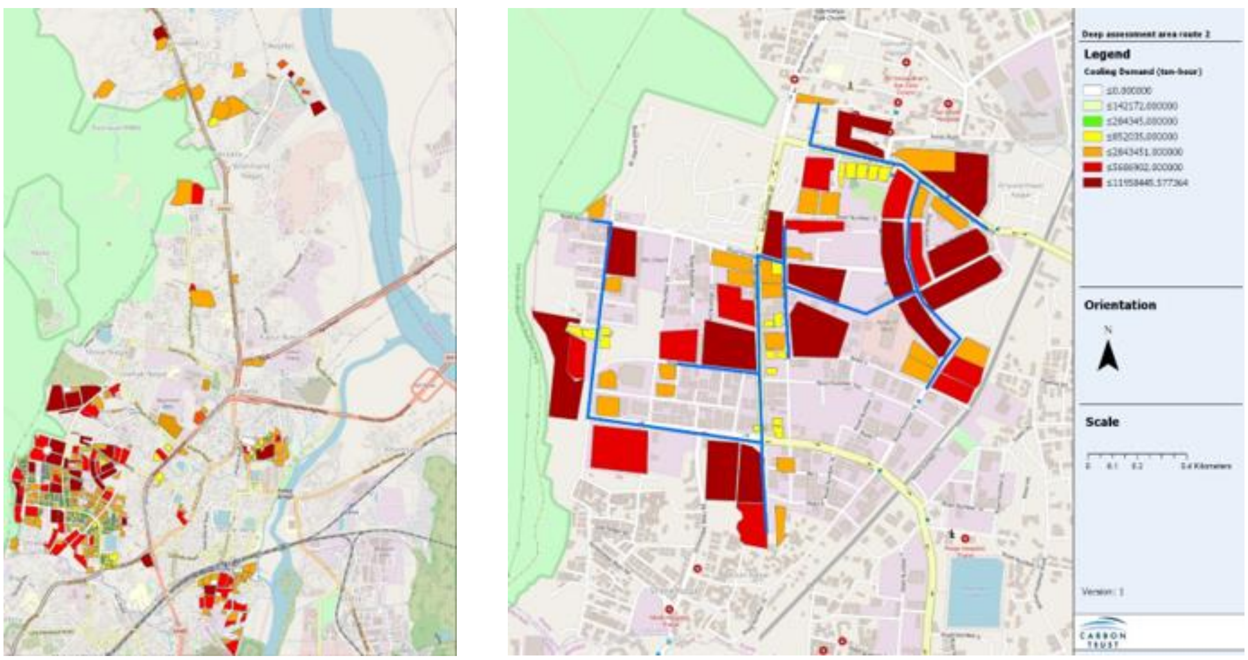

Figure 19: GIS Energy and Cool Mapping in Thane with Wagle Estate area detailed on right

3.1.2. Rajkot pilot city

The city of Rajkot was one of the first cities globally to sign up to the District Energy in Cities initiative under UNEP in 2015. Following this a rapid assessment of district energy potential was undertaken by UNEP, ICLEI, C2E2 and EESL covering amongst others the need, sustainability benefits and potential

impact from district cooling and the policy measures needed to take it forward. The assessment rightly concluded that district cooling is indeed commercially viable in Rajkot without the need for any separate viability gap funding or other policy measures from the state or the city. However the success for district cooling adoption would depend on projects being well designed right at the planning stage, robust implementation models being adopted either by the private sector or through PPP models and through active involvement of RMC considering this as a quasi-public utility to ensure benefits are captured and all stakeholders (consumers, real estate developers, city municipality, district cooling provider, electricity and other utilities) benefit in a fair manner.

Rajkot with support from the Initiative decided to develop more detailed evaluation of district cooling for the area-based development under its Smart City Plan as recommended in the rapid assessment. Rajkot Municipal Corporation (RMC) with their consultants INI Design Studio undertook a high-level techno-commercial analysis of district cooling versus other cooling options and analysed various scenarios for how much of this development if not 100% of proposed FSI should adopt district cooling.

The master plan study concluded that a district cooling system (DCS) would both be more economical and sustainable compared to decentralized water, air-cooled or DX systems within each building for air-conditioning. The master plan further proposed to adopt following strategy:

- All commercial, RMC, institutional, government and high-end residential buildings (3 or more-bedroom units) alone should be included under the district cooling scope with a total cooling load of **44,681 RT**
- Two plots be used within the master plan of size 80x40 meters for two district cooling plants of **14,000 RT each** and thermal storage tanks (TES) for up to 4 hours of storage for 3,500 RT be incorporated
- Infrastructure design to include sufficient corridors for a district cooling network (400 mm to 800mm chilled water supply and return lines) that can be buried or routed in the utility duct.
- The 66KV substation with dual sources/cabling be planned to ensure reliability of electricity supply for the total demand of **25MW** for the district cooling plant
- Peak make-up water demand for the proposed district cooling plants of **3.78 MLD** be met through tertiary treated water from the proposed sewage treatment plant (STP)

In addition to the high-level parameters proposed above in planning a district cooling system, the master plan rightly suggested suitable “mandated connection” be in place through bylaws that ensure a land parcel developer mandatorily designs their buildings with DCS in mind and connects to the DCS. This is a key policy for district cooling to be ‘de-risked’. The master plan study on DCS provided high level guidance for Rajkot Smart City in taking a Go/No-Go decision with regards to incorporating DCS into the development plan and demonstrated very generically possible options on how a DCS system could be planned along with some institutional planning aspects that RMC would need to keep in mind when implementing district cooling. RMC incorporated DCS into its Smart City Plan which has given the project a long-term support even through changing administration and COVID-19.

RMC has acted fast and with engineering support from UNEP prepared design for DCS pipeline network with a dedicated corridor for DCS pipelines. They also integrated DCS in their overall ‘integrated infrastructure tender’ for the smart city area, prepared for laying out pipes for the other utilities like waste water supply pipelines, drinking water pipelines, electrical ducts etc.

UNEP, ICLEI and RMC have decided to appoint a mix of local and international consultants to prepare a detail project report to take the full project (including DCS plant and operation) to tender and design appropriate policies. UNEP is supporting RMC to seek funding for this cost and is discussing with development banks and EESL.

The key lesson Rajkot has shown is that early-stage analysis of DCS, strong leadership from a city and inclusion of DCS in a city's long-term strategy and plan are crucial for DCS development led by a city.

4. Space cooling demand in commercial buildings in India

The space cooling demand in India is expected to rise by 11 times from the year 2018 to the year 2038 (ICAP). According to the International Energy Agency (IEA), by 2050 India is going to be the largest consumer of space cooling in the world with business-as-usual space cooling potentially responsible for 28% of electricity demand and 44% of the peak load[21].

This provides a huge opportunity to opt for DCS in India to reduce energy demand, balance the power grid, and gain the technological, socio economic, and sustainability benefits as have been described previously.

The following chapter details space cooling estimations enlisted in ICAP. Also, different scenarios have been derived through other approaches, to evaluate the potential district cooling market in India.

4.1. India Cooling Action Plan (ICAP)- Demand estimates

India Cooling Action Plan (ICAP), published by the Ministry of Environment, Forest & Climate Change, has been referred to as the basis for estimating the demand for space cooling in India.

ICAP[22] is the latest document referring specifically to India's cooling demand with appropriate approach to arrive at the conclusions for potential requirements of cooling across the sectors. Therefore, this document is referred as the basis for the estimation.

4.1.1. Cooling demand

India, a growing economy, is characterised by rising per capita income, rapid urbanisation, and a largely tropical climate. These factors will play a significant role in the rise of the cooling requirement in the country. As per ICAP, the cooling requirements can be divided into the following major sectors.

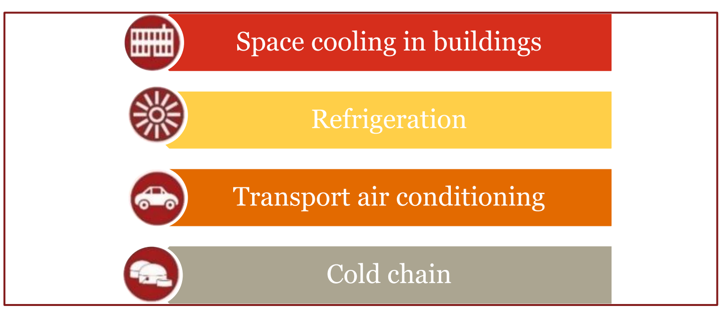

Figure 20: Various cooling sectors in India

According to the ICAP, the breakup of nationwide cooling requirement was 57% in space cooling in buildings (residential and commercial), followed by 23% in transport air conditioning, 20% in refrigeration and 0.5% in cold chain in 2017-18. By 2037-38, the nationwide cooling requirements is projected to grow

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[21] International Energy Agency, Future of Cooling
[22] ICAP 2019

by **8 times** compared to the 2017-18 baseline. The **space cooling in buildings** shows the most significant growth in demand (measured in tons of refrigeration), at nearly **11 times** compared to the current baseline in a 'reference' scenario.

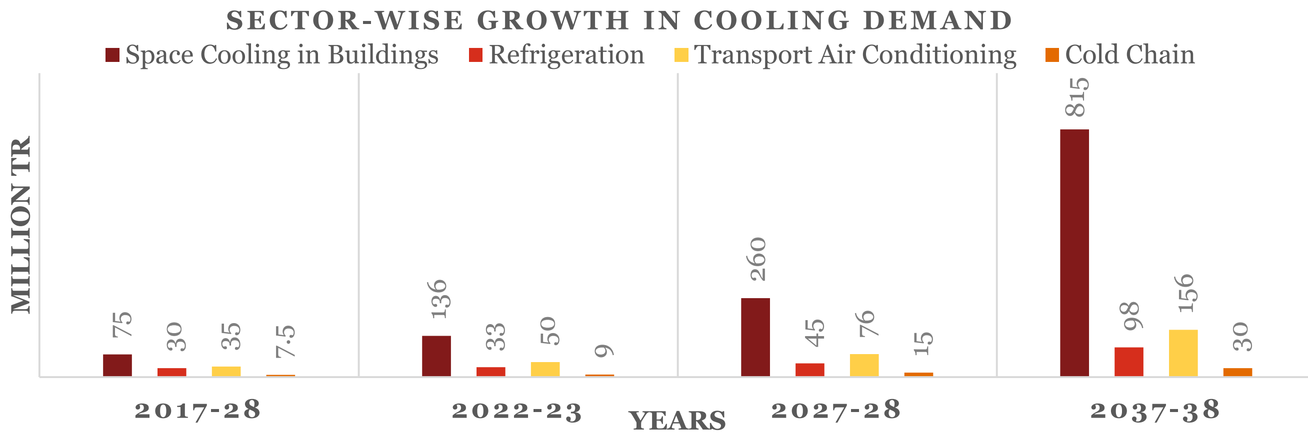


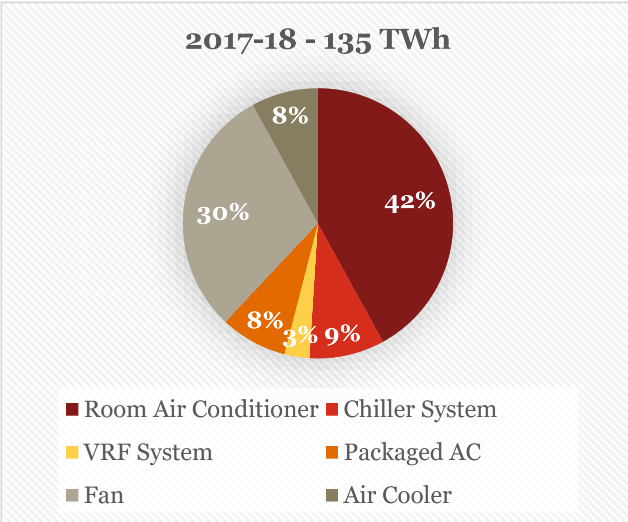
Figure 21: Cooling demand in various sectors
Source: ICAP 2019

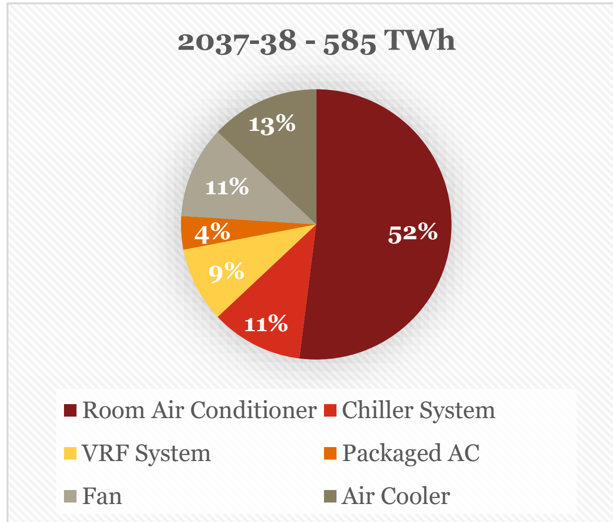
Since space cooling in buildings shows the maximum growth in demand by 2037-38, there is a need to address this growing demand in the most efficient and cost-effective manner by developing effective policies and supporting impactful technologies, district cooling being one of them. ICAP specifically recommends piloting and then scale-up of district cooling, trigeneration and thermal storage. Additionally, district cooling can also address the cold chain needs in urban and peri-urban areas, with considered variation of applications, and industrial cooling; however, this report focuses on district cooling application in space cooling requirements in buildings.

4.1.2. Energy consumption of space cooling in buildings[23]

Building sector is one of the biggest consumers of electricity in India. In energy terms, most of this demand is from air conditioning systems used for space cooling. **Figure 229** shows the breakdown of energy consumption by various air conditioning systems in buildings in the year 2017-18 and projected energy consumption in business as usual till the year 2037-38. While the space cooling demand will rise by 11 times, energy consumption will increase nearly 4 times. This can be presumed as the impact of energy efficiency improvements in upcoming buildings and relatively high share of cooling in residential buildings by 2037-38.

[23] ICAP 2019





Source: ICAP 2019

Figure 22: Space cooling energy consumption by equipment in the year 2017-18 and projections in 2037-38

As observed in the figure above, within space cooling, room air conditioners hold a dominant share of the sector's cooling energy consumption – at 42% in 2017-18 and which could grow to 52% by 2037-38. Currently, room air conditioners have a penetration of 7-9% in India, and most of the residences are cooled by fans and air coolers. Fans and air coolers will remain universal in 2037-38 and will consume nearly as much energy as systems such as chillers, DX, VRF and RAC. Energy efficiency in room air conditioner (RAC) segment is already targeted through the following initiatives:

- Standard and labelling programme of Bureau of Energy Efficiency (BEE) for fixed as well as variable speed air conditioners
- Energy Efficiency Services Limited (EESL's) programme for promoting super-efficient and climate friendly air conditioners

Therefore, this segment is already being covered by the government to improve energy efficiency.

The energy consumption for air conditioning not including RACs, i.e. chillers, VRF (already being used in high end residences also apart from commercial buildings) and packaged AC is currently at 27 TWh and is projected to grow by 433% to approx. 140 TWh in business as usual scenario by 2037-38. Such demand is predominantly concentrated in the commercial sector and needs to be addressed in a cost-effective and sustainable way.

4.2. Approaches adopted for assessment

ICAP provides assessment of cooling demand and the project team has expanded on this and examined different approaches to assess the national cooling demand in India that could be met by district cooling.

Approach 1: Cooling demand based on total electricity consumption in space cooling for select technologies	Referring to the current electricity consumption and projected electricity consumption by select air conditioning equipments (chillers, VRF and Package DX) as given in ICAP
	Estimating the consumption by space cooling equipments (chillers, VRF and package DX)
	Projecting electricity consumption to 2037-38 (in TWh) by these seleceted space cooling equipments
Approach 2: Cooling demand based on total commercial air-conditioned area and air conditioning requirements	Referring to the current and projected commercial built up area by 2037-38 data and current and projected air conditioning demand for the said commercial built up area by 2037-38.
	Estimating the additional space requirement by 2037-38
	Considered rigours implementation of ECBC and accounting energy efficiency while designing buildings
Approach 3: Cooling demand based on stock of refrigerant based equipments	Referring to the current stock and potential stock of refrigerant based equipment
	Considering equipment for commercial use (chiller, VRF and package DX) and its stock
	Excluding the RAC component as chillers, VRF and package DX are typically commercial equipments
	Discounting the standby stock (as we are estimating cooling load not the installed capacity)
	Calculating stock projected (in million TR) by 2037-38

4.3. Summary of national cooling demand, for new commercial buildings, from different approaches

A comprehensive analysis for estimating the cooling potential is performed with the above-mentioned approaches. The detailed analysis can be found in annexure 1 & 2.

It was observed that the national cooling demand for space cooling, in new commercial buildings that may typically be considered for DCS connection, by various approaches lies in the range of 51 million TR ± 15%, by year 2037-38. If this level of demand were served by district cooling an estimated **25 GW of peak power demand could be reduced in the heart of cities, 27 million tonnes of CO2 and 4,361 tonnes of refrigerant avoided and annual energy savings of 32 terawatt-hours (TWh).** If this demand were met by trigeneration DCS, peak reduction would increase to 32GW. These figures do not even include district cooling that could serve brownfield

development, industrial and cold chain demand or MIG/HIG residential demand (which could be included if strong policy support existed).

Of course, in India and many other countries, numerous barriers to delivering such high levels of DCS up to 2038 exist that make ***it highly unlikely this level of DCS would transpire***. Lack of foresight in planning, lack of public support and density of new developments are the key determiners that would prevent this level of DCS being delivered. But India should take inspiration from leading district energy cities and countries such as Dubai where 40% of all buildings (residential and commercial) will be connected to DCS by 2030 and Denmark where almost all buildings in large cities are connected to district heating systems and customers enjoy some of the lowest heat prices in Europe showing it is definitely possible and affordable but requires strong government support to reach such levels. Although these countries are at a different stage of development India does have the benefit that most of its buildings have not been built so cost-effective and sustainable solutions like DCS could be incorporated early in urban design.

The next section evaluates less idealistic scenarios and by considering district cooling as a “city-led initiative”, estimates how much cooling demand can be catered by district cooling in 21 Tier 1 and Tier 2 cities.

5. Estimation of potential of district cooling in India

The urban population of the country is expected to grow from 410 to 814 million from 2014 till 2050 (census of India 2011). It is an enormous task to handle this urban evolution and its associated implications in energy use and climate. India will likely be the largest consumer of space cooling in the world, with space cooling responsible for 28% of electricity demand, by 2050[24]. This demand for space cooling will be concentrated in India's rapidly growing cities raising the prospect for city-led approaches to space cooling (including district cooling).

5.1. Methodology of assessment

Global experience shows that demonstrating DCS, and certainly expanding DCS from isolated projects to large urban areas, is a **'city-led initiative'** requiring non-financial/financial (case-to-case variation) support from city governments, the most important being the incorporation of DCS into urban planning[25]. Certainly, individual private sector led projects will (and do) take-off with minimal intervention from public sector, but these will find it difficult to expand beyond private land without public support. For the high-level analysis, the following parameters were adopted for an initial **selection of Indian cities for assessment** that could cater significant shares of their space cooling demand by DCS[26]. After selection of cities, a detailed analysis is conducted:

[24] International Energy Agency, Future of Cooling.

[25] In India, large tracts of land are also planned at the state-government level (e.g. industrial areas) making the State Planning Departments also critical stakeholders for incorporating DCS into urban planning

[26] None of these parameters are absolute and DCS will be able to develop in cities and regions where the parameters are not met, but it will likely be more difficult.

Step 1: Assessment of developed Tier 1 and developing Tier 2 cities, for commercial buildings

- Considering cities having population atleast 2.5 million (Census 2011)
- Functional and forward looking municipal corporation
- Availability of master plans for 2030-31
- Cities with high population density for economic viability
- Considering Cities with high FAR for future Commercial development

Step 2: Assessment of Tier 2 cities, for commercial buildings

- Considering cities having population at least 1 million (Census 2011)
- Presence of municipal corporation/municipality
- Availability of master plans for 2030-31
- Cities with high population density for economic viability
- Considering Cities with high FAR for future Commercial development

Step 3: Assessment of Tier 1 and Tier 2 cities, for residential buildings

- Assessment for residential sector with potential of high rise premium apartments
- Considering all metro cities, developing cities of Tier 1 and Tier 2 (Census 2011)
- Cities with high population density for economic viability
- Considering Cities with high FAR for future residential development

Figure 23: Three-step analysis to access DCS potential in Indian cities

5.2. Summary of the detailed analysis to estimate potential of DCS in Indian cities

Indian cities are developing rapidly. Infrastructure requirements keep increasing due to rapid urbanisation and economic growth. All metro cities in India like Delhi NCR, Mumbai, Bangalore, Hyderabad, etc. are developing vertically. **Mixed-use development and high-rise premium residential buildings have become a trend in construction practice, and this is favourable for viability of DCS**. A detailed analysis of master plans of such cities shows a significant proportion of air conditioning demand of commercial and high-end residential buildings can be served by DCS.

For estimation of potential, master plans of 21 cities (including 12 cities of Tier 1 and 9 developing cities of tier 2) were assessed. ***It was observed in Chapter 4 that the national cooling demand for space cooling in new commercial buildings or similar, by various approaches, lies in the range of 51 million TR ± 15%, by year 2037-38 (section 4.3). This assessment of 21 cities shows that about 30 million TR will be required for commercial buildings in these developed/developing cities, by year 2037-38[27].*** Further, to estimate the potential of DCSs, out of this total space cooling demand, different scenarios like conservative, moderate, and optimistic are considered.

A summary of this analysis is presented in the table below. Please refer to annexure 3 for detailed analysis.

[27] Although methodologies do differ due to data availability at different scales it is compared as a point of interest that these 21 cities do represent the bulk of demand identified in Chapter 4.

Table 5: Total potential air-conditioned area catered by district cooling in Tier I and Tier II cities for new commercial buildings

Potential of DCS in new commercial buildings in India for year 2037-38						
	Potential in Tier 1, 12 developed cities			Potential in Tier 2, 9 developing cities		
Estimated new commercial Built up area (BUA) (mn sqm) by 2037-38	1080			252		
Derived air conditioned area based on growth rate on pro-rata comparison with ICAP (mn sqm)	689			161		
	Area, in mn sqm	**AC requirement, in mn TR**	**Number of DCS plants***	**Area, in mn sqm**	**AC requirement, in mn TR**	**Number of DCS plants***
Conservative scenario – Considering 10% as potential of DCS	69	2.47	**74**	16	0.58	**17**
Moderate scenario - Considering 15% as potential of DCS	103	3.71	**111**	24	0.87	**26**
Optimistic scenario - Considering 30% as potential of DCS	207	7.41	**222**	48	1.73	**52**

**Diversity considered as 60% in sizing a district cooling plant*

It is also to be considered that more tier 1 and tier 2 cities (apart from listed cities in table 9 & 10) will be coming up by year 2035 and hence the requirement for space cooling will increase, leading to increased DCS potential but these are not considered here.

Table 6: Total potential air-conditioned area catered by district cooling in Tier I and Tier II cities for residential buildings

Potential of DCS in residential buildings in India by year 2037-38			
Estimated new residential BUA (mn sqm) by 2037-38	4546		
Considering 30% as air-conditioned area, in mn sqm, by 2037-38	1364		
	Area, in mn sqm	**AC requirement, in mn TR**	**Number of district cooling plants***
Conservative scenario – Considering 3% as potential of DCS	41	1.5	18
Moderate scenario - Considering 5% as potential of DCS	68	2.4	29

Optimistic scenario - Considering 7% as potential of DCS	95	3.4	41

**Diversity considered as 80% in sizing a district cooling plant*

It is considered that 30% of the residential demand catered by DCS would be catered for by their own, dedicated district cooling plants. The majority, i.e. 70% of residential demand connecting to DCS need not have separate DCS plants as this demand can be catered for by a district cooling plant which will have been established for a commercial development. Since advantage of DCS is to benefit from load diversity, residential sector needs can be met, in-part, by DCS plants included in the commercial-sector analysis above.

Consideration of conservative, moderate and optimistic scenario is done based on policy push, involvement of municipal corporations/municipalities, pilot, and awareness programmes and many other factors. The scenarios are briefly described below:

Conservative Scenario	Moderate Scenario	Optimistic Scenario
• Business as usual scenario where big developers, campuses and individual building owners opt voluntarily for DCS through EPC route • Limited pilot projects for Merchant DCS • No policy push from government • Non inclusion at master planning level • Limited awareness / involvement of Utility	• Few pilot projects • Light policy push from government • Inclusion at master planning levels and local area planning in SEZs and leading area-based developments • Involvement of municipalities & utilities • Awareness programs in place for developers, municipal corporations, utilities, financial institutions etc • Incentive schemes in place	• Strong policy push from government for mandating DCS for large, dense developments • Inclusion at master planning levels • Pilot programmes supported by governments • District cooling code in place • Municipal corporation & DISCOM stake in DCS

Figure 24: Different scenarios for estimation of achievable potential of DC in India

This is the achievable potential of DCS for the targeted cities, which can be captured in next 10-18 years of time span. The above potential is based on application of space cooling only, and does not include DCS for food parks, industrial zones, etc.

5.3. Investment potential, energy saving, and energy demand reduction using district cooling systems

The following chart summarises the investment potential of district cooling along with savings in energy consumption and potential savings in energy demand in commercial developments in **selected** Tier 1 and Tier 2 cities of India up by year 2037-38:

Table 7: Energy saving, energy demand, and investment potential

Attributes	**By Year 2037-2038**		
	Conservative Scenario	Moderate Scenario	Optimistic Scenario

Total Commercial + Residential Air conditioning demand catered by DCS in (Mn Tr)	4.5	7.02	12.57
Number of District cooling plants*	109	167	315
Investment potential ($ Bn) **	12.9	20.1	35.9
Annual Energy Saving (GWh) ***	2822	4386	7855
Peak demand reduction (MW) *****	2201	3421	6127
Annual CO2 emission reduction (million tonnes of CO2)	2.4	3.7	6.6
Refrigerant savings in lifecycle (20 yr.) in tonnes	382.5	596.7	1068.5
Water savings in cooling tower (Mn liters)*******	27261	41626	78850
Investment savings from infrastructure on power plant, city transformers, cables, water supply systems etc. ($ Bn)	3.8	5.9	10.5

*Considered with 60% diversity factor for mix use development and 80% for DCP only for residential sector

**The calculation for investment potential is considered by taking USD 2500/TR, foreseeing future scenarios. The investment calculated does not consider cost of land (considered lease from municipality)

*** For energy saving, running period of 2500 hours have been considered in a year and saving of approximately 0.25 kW/TR is made using DCS instead of individual Chillers for buildings. Number of hours may vary by type of project and location. This is for electric chillers and could be higher if trigeneration or free cooling is used.

**** Presuming peak power demand reduction of 45% based on DCS using thermal storage.

***** More water can be saved through free cooling from rivers, utilizing waterless cooling equipment etc.

6. Business models, governance, and contracting for district energy systems

The first step toward building a business model for a district cooling project, is to understand the base requirements which form the foundation of the project. The ownership pattern of the base requirements determines, and ultimately shape up the applicable business model for the project. Before carrying out any further work or analysis on the project, the ownership pattern of these foundations must be clearly scoped. Any variation in the scoping of these essential requirements can:

- upset the overall project viability; and
- change the subsequent fundamentals and activities in the intricately linked developmental cycle of the project

The base requirements in a district cooling project are as follows -

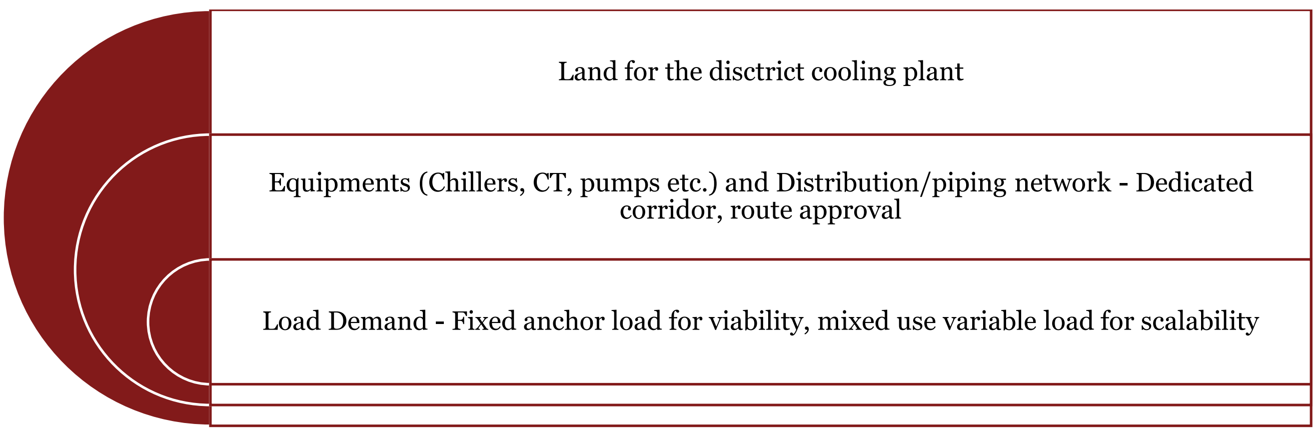


Figure 25: Base requirements for a district cooling project

Once the scoping of foundations is frozen, the degree of control (exercised by the public or private sector) is broadly established. Majority of district cooling projects around the world (especially the developing economies), involve a greater degree of control of public sector by acting as an investor, owner, operator or consumer. Typical stakeholders' groups and their roles in a district cooling project can be broadly summarized as follows –

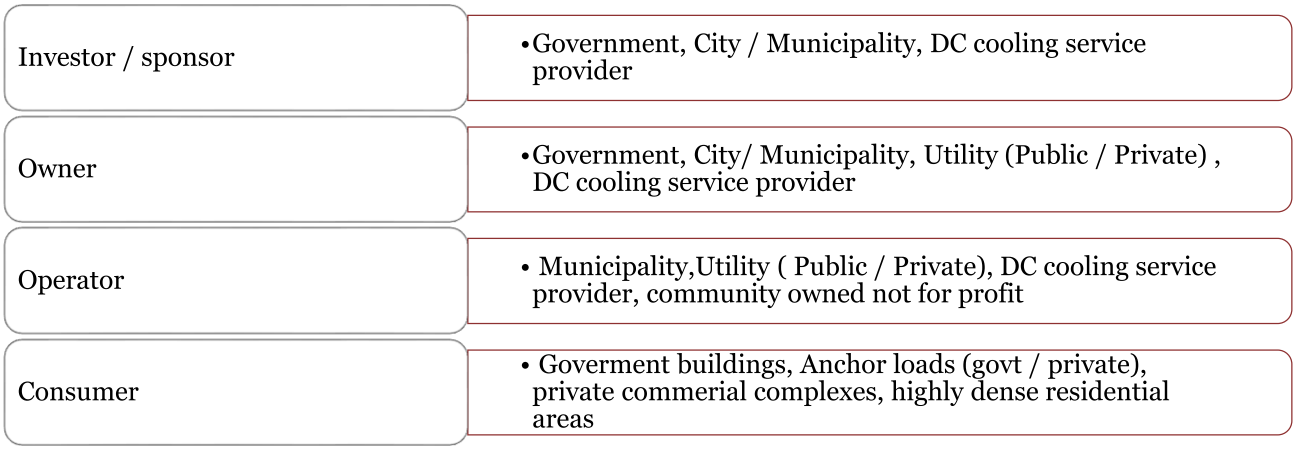


Figure 26: Different stakeholders in DC project

Even the projects with a high degree of private sector control and ownership are facilitated by the public sector through policy interventions and regulations.

6.1. Cost components of district cooling

The major driver of the district cooling business model is the availability of finance (and its structure) for its various components. The major cost components of a district cooling project are –

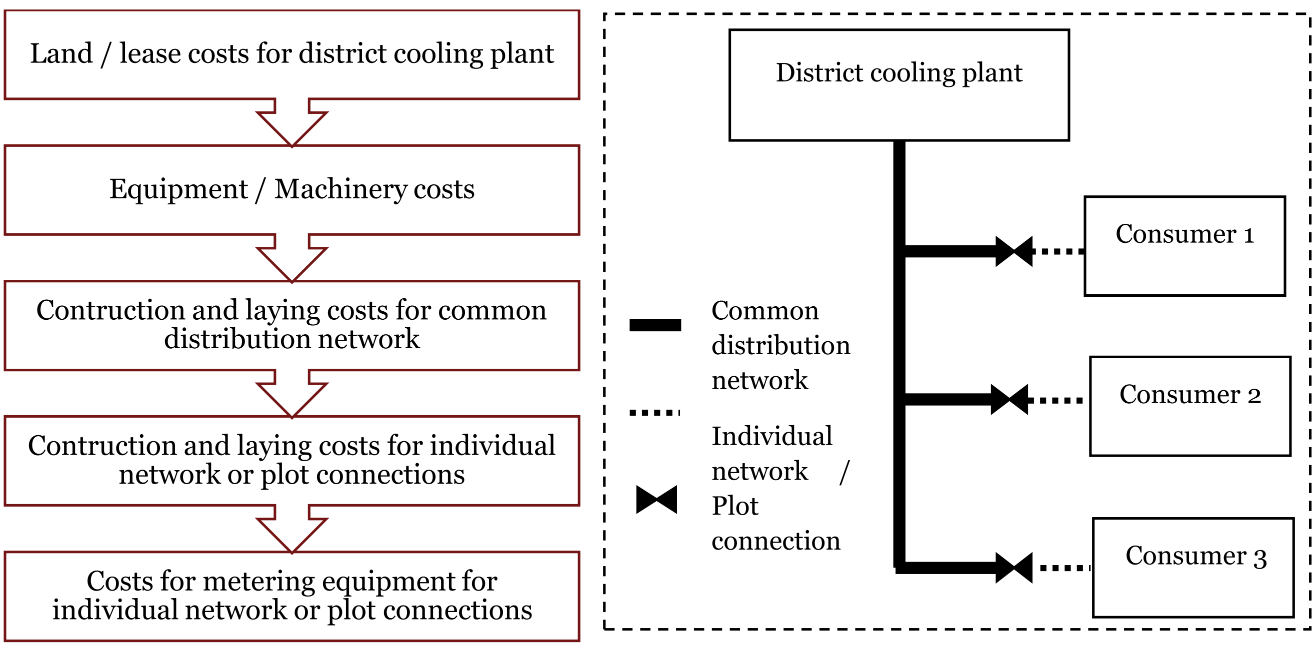


Figure 27: Various components of a district cooling

Like all the other business propositions, **ROI (Return on Investment)** determines the profile of stakeholders (private / public) investing in the project**.** The envisaged ROI of the project determines if the major source of funding for a project is from private or public sector. For example, private sector generally aims for higher ROI propositions because of its underlying motive of maximizing profit. The public sector

on the other hand prioritizes socio-economic benefits for community and therefore usually realizes a low to medium ROI. As mentioned earlier, most of the projects globally are public sector funded because of its ability to secure finance at lower interest rates. Even in private sector projects, public sector can facilitate private sector in securing finance at lower interest rates by acting as a guarantor or underwriter.
Some of the examples of public and private sources of finance are summarized in below -

Private finance	Public finance
• Private sector debt, equity • Financing from district cooling providers • Venture capital and business angels	• Grants • Public debt. at lower interest • Developmental bank loans at lower interest • City level subsidies • Energy revolving funds

Figure 28: Comparison between private and public finance

6.2. Business model classification

The ownership pattern determines the degree of control, ownership level (single/mixed) and level of investment, exercised by the stakeholders investing in it. The degree of control and level of investment, therefore, segregates the district energy business models into 2 main categories (with further subcategories) as depicted in the figure below[28] -

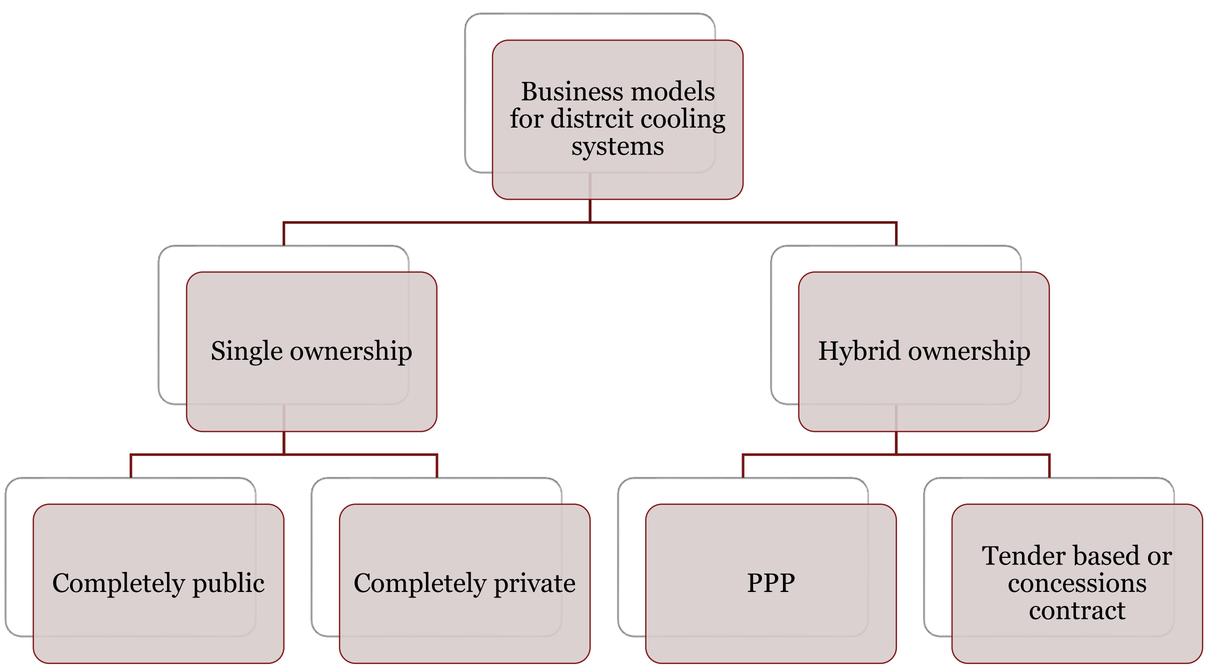


Figure 29: Business models of a district cooling project

[28] Business model classification / attributes have been inspired from stakeholder consultation with "King and Spalding'" and their inputs/work on district energy

The table below gives the important attributes and characteristics of each type of business model –

Table 8: Important attributes and characteristics of each type of business model

Business model	Ownership	Governance	Control	Source of finance
Single ownership Completely Public	Local authority or public utility has complete ownership of assets (100% equity) Ownership can be transferred to private sector in full or partial (through shares etc.)	Completely governed by the public sector. The authorities can outsource technical design, construction (EPC) and operation / Maintenance	Complete control of local authority on distribution network connections and tariff policies Utilities can easily cater to the anchor loads and encourage expansion / scalability by regulatory interventions (density bonus, tax exemptions)	Grants, public debt at lower interest, developmental bank loans at lower interest, city level subsidies or revolving funds
Single ownership Completely Private	Private sector has complete ownership of assets	The governance structure is determined by the private party as the ownership of assets lies with it.	Small representation of local authority / public sector except for regulatory aspects / project approvals	Financing is sought by private company's internal sources. Local authorities can contribute in form of grants for control in the governance structure
Hybrid ownership PPP	Ownership is split between the private (10%~49%) and public sector through a JV contract	Ownership and control of assets is distributed as per the skillset. e.g. Public sector can own land, common distribution network and facilitate regulatory barriers to project	Board representation as pet the ownership split of the hybrid model	Each entity is responsible for sourcing finance for the district energy functions they control.

		development and anchor loads. Private sector can own equipment / machinery and take on the design, construction and operations.		
Hybrid ownership Tender based / Concessions contract	In this model an SPV (generally constituting of District cooling provider company and a public utility) takes over the operation of the already existing public project for a fixed period through a tender process	Operations and design are completely in the hand of SPV during the lease period	The local authority has limited control during the tender period. The tariff policies of the ESCO are regulated to avoid monopolization by the presence of public utility in SPV	Major finance from district cooling service provider

6.3. Contracts for district cooling systems

This section gives an overview of the contractual structures in different business models among various stakeholders. The contracting structure in a single ownership model is much simpler as the complete ownership of assets (and revenue stream) lies with a single type of owner, but the trade-off is increased level of risk associated with the project. Whereas the hybrid ownership models transfer the risk away from a single party, but this comes at increased number and complexity of contracts between the stakeholders. A lot of restructuring is possible in the hybrid models subject to the legal and accounting advice from experts. Depending upon the ownership model, comprehensive contracts must be developed to cover the following issues:

- **Ownership** – To streamline who pays for which of the cost component of district cooling in case of PPP models. Lease agreements in case of tender based / concessions contract.
- **Power and water supply** – To reserve power in the grid (with its tariff structure) and provision of standby supply in case of outages. In case of CHP plants tariff structure for GAS or steam (with its tariff structure) must be in place. Similar contracts for water supply for cooling tower (with its tariff structure) and standby arrangement in case of outages.
- **Tariff structure for chilled water**
    - Connection charge - To cover the cost of connecting a consumer with the common distribution network
    - Capacity charge – To cover the operation and maintenance (routine/lifecycle) of the distribution network

- Consumption charge – The cover the rate at which chilled water will be distributed to consumers (INR/BTU) and captive issues

- Profit / revenue spread – to cover distribution of profit, reimbursement, royalties, etc. among the stakeholders of the PPP or JV
- Termination and end of term issues - To cover ownership and transfer of assets during or after the contract term

These contracts are drafted by a team of legal and accounting experts specialising in district energy systems. Unfortunately, there is a dearth of such experts in India at the moment. For some initial projects, help can be taken from international experts for drafting such contracts. Such experiences would also help in capacity building of experts in India and eventually develop standard templates that can be easily replicated.

The contracting structures[29] between stakeholders in different business models are represented in the figures below:

Single ownership (Completely private / Completely public)

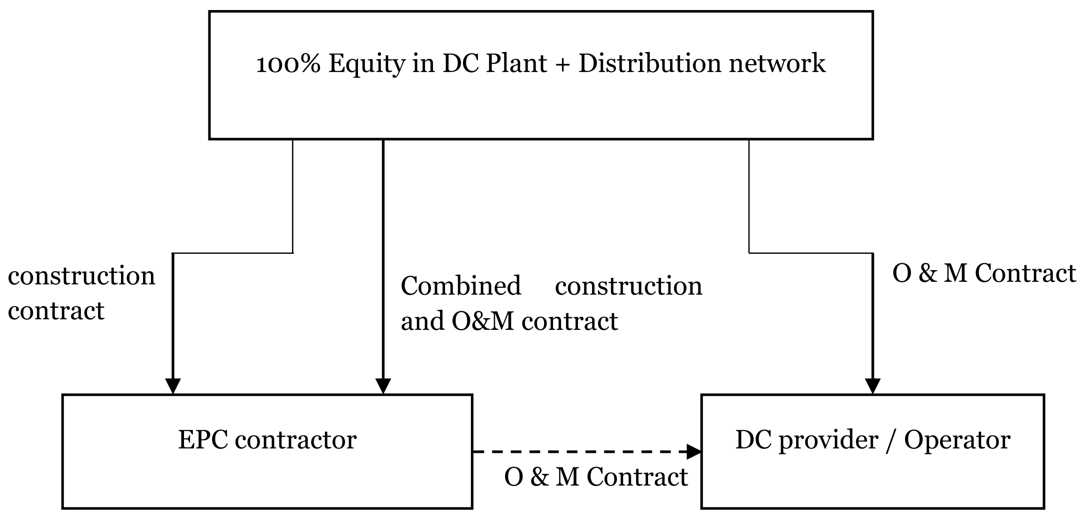


Figure 30: Flow in single ownership type business model

- The owner contracts out the construction of plant, distribution network and interface to an EPC contractor
- Short duration contracts for district cooling operation and maintenance can be given to EPC contractor or a 3rd party
- Minimum transfer of risk
- This model can be converted to hybrid ownership with suitable contracts in place

[29] This contracting structures have been inspired from stakeholder consultation with "King and Spalding'" and their inputs/work on district energy

PPP Contract

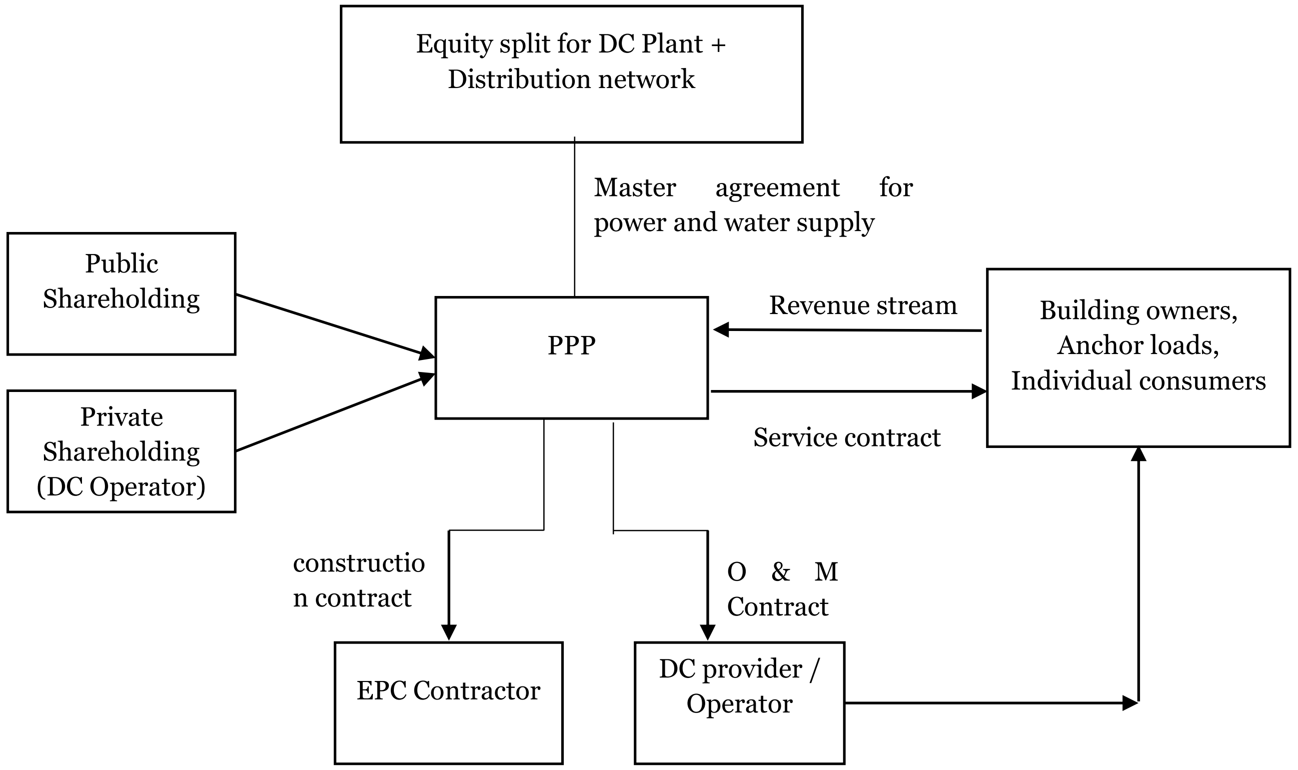


Figure 32: Flow in PPP type business model

- Cost is shared by equity partners as per their expertise
- Risk is also shared as per equity distribution Risk is efficiently transferred to the SPV
- Operation is run by District cooling provider

Tender based / Concession contract

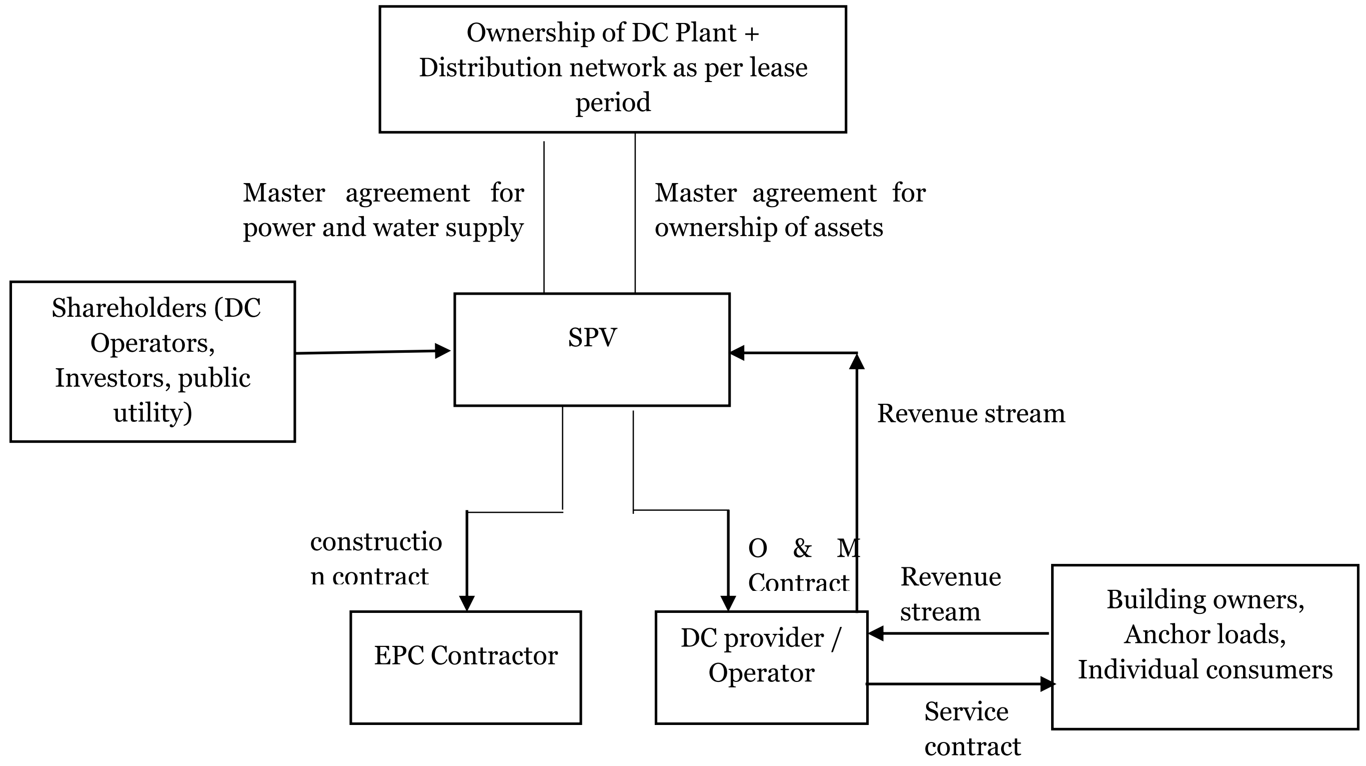


Figure 31: Flow in tender based business model

- The SPV acquires the ownership of assets during the lease period
- Tender process draws out the best results and costs
- Risk is efficiently transferred to the SPV

6.4. Business models recommendations for India

The major hurdle in district cooling projects is the complexity and risks associated with the project. These can be mitigated to an extent by the involvement of private sector players specializing in such projects. As discussed in the previous sections, the private sector involvement in such projects can be done through JV's, PPP, and tender based/ concession contracts with expert district cooling service companies. Private sector interest and participation in these projects can be increased by:

- **Special power and water tariff** – Tariff for power and water for such projects must be regulated in such a manner that the ROI becomes lucrative for the district cooling service companies.
- **Finance at low interest rates** – The public sector with its involvement can secure finance at lower rates of finance for the district cooling service companies. This can be done by public sector acting as a guarantor/underwriter for loans.
- **Contracting experts** – In India there is a dearth of lawyers' which expertise in drawing complex contracts for PPP and tender based business models for district cooling. Help can be taken from international contracting experts, for executing transparent structures for boosting stakeholder confidence and easy replication for future opportunities.
- **Availability of reliable power** – The paramount requirement for district cooling viability is the availability of reliable power source. If the power supply is not reliable the investors / sponsors have to provision for the standby arrangements such as DG sets etc. This substantially increases the finance and land requirements for the project and dampens the interest of stakeholders. Separate substations and transmission routes should be provided by the government in order to increase private sector interest for such projects.

7. Barrier analysis for district cooling systems in India

In India, DCS are having potential to serve a wide variety of buildings, viz. commercial offices, hotels, sports arenas, malls, schools & hospitals. However, a key point to note is that currently these large central plants are 'single ownership' and there are very few examples of 'merchant district cooling'.

The application of DCS is best scalable in case both "single ownership" as well as "merchant district cooling" are adopted. The possible barriers foreseen for adoption and implementation of this technology, in India, are categorized as below:

7.1. Policy and institutional barrier

7.1.1. Lack of promotion of district cooling at national and state level

- Lack of awareness about benefits of district cooling.
- No or limited engagement of national and state level stakeholders to address various mechanisms to promote district cooling.
- District cooling is not considered as the viable option for large dense green field development projects by municipalities and real estate developers. It is excluded while formulating roadmaps for smart cities, national mission, on sustainable habitat.
- An action plan to recognize DCS as viable option for space cooling under state and city level initiatives is not in place. At state level, energy departments and nodal agencies are not aware and not promoting DCS in their local programmes. Also, there is no recognition that this technology is a key tool for demand side management, balancing grid, and peak demand reduction. There is no cross checking/verification of considering DCS as option by developers while submitting project details for EIA clearances.
- Limited pilots and case studies in place to motivate different stakeholders.

7.1.2. Absence of involvement of DISCOMs and municipal corporations

- Currently, utilities are not involved due to lack awareness of potential benefits to them. Demand reduction for DISCOM and concentrated high loads are beneficial for DISCOM to consider DCS as strategy for urban development scenarios. Industrial associations and cold chain sector can also be benefitted by District Cooling Systems. Currently lack of awareness and willingness is restricting application of technology for industrial applications and cold sector (for pack houses).
- Municipal corporations will have to be 'forward looking' in working with district cooling service providers so that chilled water can be offered as a utility at an attractive price. Utilities can play vital role in steering district cooling in country.

7.1.3. Lack of policy drivers

Currently, India does not have a policy to promote DCS. Following are the key policy barriers:

- No legal framework (DCS Act) or policy to promote DCS

- No framework for defining roles of different stakeholders (supply and distribution network, utilities commitments, etc.)
- There is lack of tried and tested business model for district cooling application in India
- No standard contracts and leasing agreements
- DCS is not considered as a separate category for electricity tariffs
- No fiscal instruments/preferential treatment for DCS projects

7.1.4. Non-inclusion of DCS during development of master plans

- Urban planning departments have generally limited roles in planning and decision making in energy sector. Notably, urban planning plays vital role in energy consumption as buildings (commercial and residential) and infrastructure development consumes energy and resources. It has been observed that urban planning and land use planning does not generally address the issues related to energy and resource efficiency while doing the overall master planning. Also, there is lack of engagement between urban development and energy department at the national level.
- The opportunities to adopt and implement district cooling, were created by smart city missions. Due to absence of necessary roadmaps to include DCS in infrastructure development, these opportunities were not fetched by smart cities.

7.1.5. Non-inclusion in national building regulations and certifications

Energy Conservation Building Code (ECBC) -

- Currently in India, there is ECBC and ECBC-R in place to promote energy efficient design and operation in the commercial and residential buildings.
- ECBC 2017 promotes low energy comfort systems where trigeneration (waste to heat) is listed as one of the options as low energy comfort systems. Buildings having any of the low energy thermal comfort system installed for more than 50% and 90% of cooling/heating requirements of building, shall be deemed equivalent to ECBC+ and Super ECBC building standard respectively. However, there is no direct inclusion of district cooling in achieving compliances.
- For ECBC – R (Eco Niwas Samhita 2018), BEE has released its part 1 for building envelope. Part 1 covers energy efficient envelope for residential buildings. Part 2 is under development and it is expected that this will cover lighting and comfort systems in residential buildings. A general recommendation to include DCS as one strategy for thermal comfort applications, can be given to BEE.

Green building rating systems -

- Demand for energy efficient new construction has led to the emergence of Green Building Rating System worldwide. There are many rating systems that are recognised at the national level like GRIHA, LEED, and IGBC for large developments, townships, green campus, and cities. The rating systems consider energy, water, waste efficiency, use of renewable energy, refrigerant reduction, primarily. Adoptability of rating systems is increasing in India as this is directly linked with incentives offered by regulations. These rating systems offer specific incentives (vary state to state) like extra FAR, subsidized rates of loan, fast track EIA clearance, etc.
- **None of these rating systems mentions/includes a clause that promotes the adoption of DCSs in large developments where favourable conditions for district cooling are foreseen and don't offer any additional points for this technology.**
- Another international rating system Building Research Establishment's Environmental Assessment Method (BREEAM) was developed in the United Kingdom in 1990 and is one of the earliest building environmental assessment methods. **The Part L, regulation 25A document (standard for BREEAM) also consider district cooling/heating as high efficiency alternative system.**

7.2. Technological barriers

7.2.1. Design risks (or planned developments)

a. Load estimation:

Properly estimating cooling loads affects the design, operation, and cost-effectiveness of the DCSs in many ways. Overestimation of load may be appropriate for a building HVAC consulting engineer who wants to be sure that the customer has enough capacity. But for district cooling company, these estimates can lead to:

- over investment in district cooling infrastructure;
- over projection of revenues; and
- poor efficiencies in meeting low loads.

As elaborated in Section 2, the annual load profile enables calculation of the total annual energy, which is critical for rate structure development and revenue projections.

b. Design temperatures and Delta T:

Delta T is the designed difference between chilled water supply and return temperatures. Delta T is a key parameter in the design and operation of DCSs and is an excellent measure of total system performance at any load condition. With high delta T, less flow, lower pump energy, and smaller pipeline size is required to satisfy the cooling requirements. While it is very important to achieve high delta T, it should not come at the expense of customer comfort or control.

Supply-water temperature is limited by the district cooling plant and distribution system performance. Return water temperature is typically limited by cooling coil performance in customer building. These factors are also interrelated. Based on all above, DCSs are designed with a delta T of 7.5 to 10°C (e.g., 5.6/13.3 or 4.4/14.4).

The design risks can be mitigated to a large extent if the development is well planned & clients were to design their airside properly. This basically means that DCS is most viable in large & high-density new developments.

7.2.2. Insufficient research and case studies of district cooling in India

- There is lack in availability of research and case study of this technology in India. Since the technology is not completely implemented in India, there are less successful examples in this domain. "Cooling as service" is a very new concept in India. End users are not confident enough to get infrastructure for this service from the relevant authorities like municipality and DISCOMs.
- This is no supporting study/research that projects the potential of DCS and energy savings with it. UNEP is working on creating awareness/case studies for DCS. More work is required in this regard.

7.3. Financial barriers

7.3.1. Capital-intensiveness (or cost of capital)

- Development of DCSs can be a relatively capital-intensive undertaking if the load estimations and execution is not planned in phases. Further, capital costs are "front-loaded" because of the high costs of installing basic plant infrastructure and pipe mains in the early years. Therefore, a fundamental risk in development of a merchant DCS is lower-than-projected customer load or significantly delayed customer load. With the high capital investment, ROI can be for longer period.

- Since there are not enough pilots (district cooling plants) in India, the cost estimations and implications are still not very clear to any kind of stakeholder.
- No targeted/dedicated capital support to establish District Cooling Plants. Provisions like soft loans to support capital cost, are missing for DCS. Municipalities are also not able to take a step ahead due to unavailability of project development costs.
- Supplying chilled water from municipality will very likely come under any tax liability like GST/VAT for DCSs, whereas stand-alone systems will not have this tax liability. The tax exemption for chilled water supply can work as growth driver for adoption and penetration of DCS in India.

7.3.2. Distribution system construction & operation risks

- Underground congestion: A significant risk is higher-than-anticipated costs in piping due to unforeseen congestion in underground services already in the streets. In India, we may have multiple agencies that have laid out their piping, sewer or cabling infrastructure underground and clarity of layout may not be there. ***Underground congestion is one of the barriers in incorporating DCS for brownfield projects with existing buildings.***

- Soil conditions can also present surprises and soil samples must be studied in advance. Distribution system construction is a specialised area and the cost of rectifying problems is high.

7.3.3. Revenue generation risks

- **Metering cost:** Risks related to inaccurate metering include low revenues leading to diminished profits OR overbilling leading to spoiling customer relationship. Meters need to be high-quality with a regular calibration programme and cross-checks.
- **Lesser than projected billing**: This depends on district cooling rate structure. Normally, the district cooling company will have a two-part rate structure - contracted capacity rate and consumption rate. Connection charge (Plot Network + ETS + Metering) may be a separate head or built-in the contracted capacity rate
- **Delta T penalty:** The district cooling company would have a “delta T penalty” to protect themselves from “excess flow and inefficiency issues”.

7.4. Capacity and human resource

- Since there are limited installations of district cooling in India, the experiences of administrative and technical challenges are yet to be faced by the experts.
- There is lack of domestic consultancy experience in DCS: There are building services consultant but the expertise for designing and execution of DCSs is lacking.
- There is lack of awareness of technology, costs, energy savings, performance and benefits of district cooling: The stakeholders are still not certain about the tangible and intangible benefits of technology. The main reason behind this is lack of awareness.
- There is lack of capacity and human resources to develop, integrate, and implement district cooling projects among the stakeholders and within urban planning departments.

8. Recommendations and actions items

Although, district energy (cooling) system has been recognised as a cross-cutting technology in the "National Cooling Action Plan", there is need to have a long-term vision/action plan for adoption of DCS at the national level. Based on the findings of this study and linking to the barrier analysis in the previous section, recommendations/action plan is developed and divided into three process steps, i.e. **short term (0 – 5 years), medium (5-10 years) and long-term actions (> 10 years)**

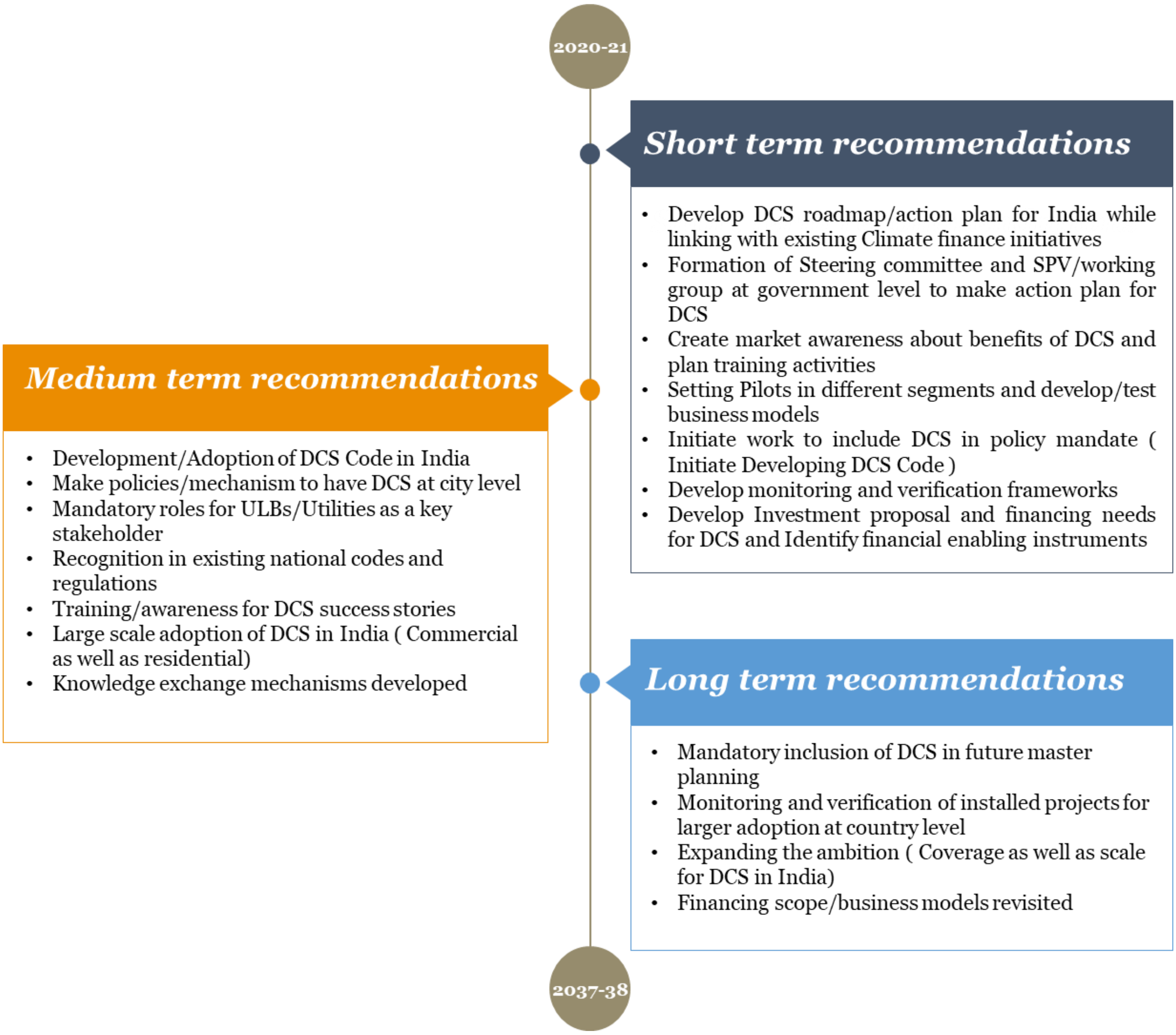


Figure 33: Recommendations for stakeholders in nutshell

The proposed recommendations are further divided as per specific stakeholder, which are presented under section 8.1.

8.1. General recommendations

Table 9: Stakeholder specific general recommendations

<table>
<tr><th rowspan="2">Concerned stakeholder</th><th colspan="3">Key Recommendations</th></tr>
<tr><th>Short term (0-5 years)</th><th>Medium term (5-10 Years)</th><th>Long term (>10 Years)</th></tr>
<tr><td>Ministry of Power (MOP)/Ministry of Housing and Urban Affairs (MoHUA)

(Any of the Ministries or both can take the lead in policy development)</td><td>• Development of DCS roadmap/action plan for India
• Steering committee formulation and special working group with the focused approach of development of DCS in India
• Leading DCS awareness and trainings in India
• Promote Pilots in different segments (Merchant as well as single ownership systems)
• Develop Investment proposal and financing needs for DCS and Identify financial enabling instruments
• Develop monitoring and verification frameworks
• Develop/test business models for DCS which also includes standard contracting procedures, standard leasing agreements and roles of different stakeholders
• Initiate work to include DCS in policy mandate (Initiate Developing DCS Code)*
• Identify barriers in adoption of DCS and suggest/adopt mitigation measures
• Linkage with Climate finance initiatives
• Considering large real estate and industrial projects to assess district cooling as part of environmental clearances at EIA stage</td><td>• Development/Adoption of DCS Code in India*
• Engage key stakeholders (national as well as city level) to contribute developing policies.
• Make policies/mechanism to have DCS at city level
• Mandatory roles for ULBs/utilities as a key stakeholder
• Engaging ULBs and energy departments to ensure incorporation of DCS at master planning stages
• Linking with MoHUA's existing programs like Local Area Plan (LAP) & Town Planning Scheme (TPS)
• Integration of DCS in smart cities (initiative by MoHUA)
• Recognition in existing national codes and regulations
• Adopt sustainable financing mechanisms
• Training/awareness for DCS success stories**
• Large scale adoption of DCS in India (Commercial as well as residential)
• Technical and financial support to large mix use developments in these smart cities
• Testing different business models and contracting procedures and develop case studies
• Knowledge exchange mechanisms developed</td><td>• Mandatory inclusion of DCS in future master planning
• Monitoring and verification of installed projects for larger adoption at country level
• Expanding the ambition Coverage as well as scale for DCS in India)
• Financing scope/business models revisited</td></tr>
<tr><td>Municipality/ Town planning</td><td>• Propose officials and other stakeholders for awareness and training on DCS benefits and models.</td><td>• Inputs for finalisation for DCS Code in India.
• Mandating municipalities to evaluate district cooling feasibility for high density development</td><td>• Mandatory adoption of DCS in all city level /ULB level planning.
• Mandatory requirements for providing utilities for DCS projects</td></tr>
</table>

departments at city/state level	• Involvement of town planning department, at master planning stage, to suggest modification in planned infrastructure projects where prerequisites of DCS (dense variable load with anchor loads) can be identified. • Working with stakeholders to uptake few pilot programmes to showcase technology adoption. This will boost the penetration of DCS among developers. • Contributing in exploring treated sewage effluent TSE water usage in cooling tower (for makeup water) in order to maximize water savings in DCS projects. • Suggest changes in building byelaws for inclusion of DCS	• Land parcels to be sold with the mandatory requirement of taking DCS connection. • Ensuring utilities supply and piping design network for pilot projects • Amending building byelaws based on stakeholder consultation inputs. • Adoption of incentive mechanisms like soft loans, extra FAR, etc. for DCS adoption (although area utilized by plant should not be considered in extra FAR allowed) • Enforcing treated sewage effluent TSE water usage in cooling tower (for makeup water) in order to maximize water savings	• Reporting on success factors of DCS projects • Suggestions to pace adoption of DCS in all future planning
Distribution companies (DISCOMs)	• Support MoP in developing guidelines for access to DCS projects • Support development of business models	• Ensuring uninterrupted electricity (to operate plants) for land parcels sold with mandatory requirement of taking DCS connection • Inputs to MoHUA and MOP, for formation of DC code	• Ensuring uninterrupted electricity (to operate plants) for land parcels sold with mandatory requirement of taking DCS connection
Electricity Regulation Commissions	• Proposing mechanism for putting district cooling under "industry" category, with liaison with Ministry of industry. Once DCS is covered under industry category, the electricity tariffs will be lowered as compared to commercial category. • GST on chilled water supply shall be exempted or concessioned	• Adoption of DCS under the industry category • Any other support to promote DCS in India • Preferential power tariffs for residential sector which should not be higher than cost of Supply or Residential category tariff in the state of consumption after considering subsidy amount passed on to customers through DBT	• Support in improvement and active development of the DCS programme • To promote DCS and tri generation exemptions like cross subsidy surcharge wavier, additional surcharge wavier, Waiver of 100% banking, transmission & wheeling charges for drawl of banked power or power through open access, Waiver of T&D losses, Unutilized banked power shall be purchased by State Discoms at their Average Power Purchase Price, Waiver of Electricity Duty / GST as and when applicable, Grid connectivity and infrastructure to be provided by Govt. at its own cost, GST /Tax (Central and State

			Taxes) waivers on Capital items shall be offered
MOEFCC	• Give suggestions for environmental clearances under MoEFCC, if any, for adoption of DCS.	• Finalizing environmental guidelines/environment impact assessment for DCS in India	• Inputs to MoHUA and MOP, for formation of DC code
Bureau of Energy Efficiency and State designated agencies (SDAs)	• ECBC 2017 promotes to adopt for low energy comfort systems where trigeneration (waste to heat) is recognized as one of the low energy comfort systems. However, the advantages if multiple buildings opt for DCS, can be included. Since states are free to amend ECBC as per state conditions, they may include district cooling technology. • As per EC ACT, section 13, enables BEE to provide technical administration of DC market and ensuring EE gain. BEE can consider including provisions of including DCS in ECBC and ENS, by some means. • Additionally, provision of readiness of buildings, to connect with DC network can be amended. These provisions could be space requirements, façade readiness, monitoring equipment etc.	• Technical and financial support programs for pilot projects • Training and awareness programs to SDAs and energy departments • Any other role as defined by MoP for evolution of DC Code and its larger adoption in India.	• Support in DCS programme development and monitoring as per their role.
Institutional support	Large government development organizations like NBCC and CPWD should consider district cooling as a strategy in their projects. The potential developments under NBCC and CPWD can support smart city initiatives of MoHUA. Systematic approach during planning stage, with focused technical expertise is needed in green field developments in smart cities.		
Green building rating system	GRIHA, LEED, IGBC etc. can work in integrating DCS in design for campus and large developments, as energy saving strategy. State and city level governments can offer incentives linked to green development with district cooling for thermal comfort in buildings (commercial and residential)		
Financial enabling mechanisms	Consideration of incentives linked with extra FAR, property taxes, land approvals, fast track environmental clearances, and load guarantees. Provision of soft loans and other incentives promote DCS Consideration of district cooling under industrial category to avail benefits of lower electricity tariffs. Clarity on tax liability when serving chilled water as utility for operation of DCSs. Corporate Tax waivers for DCS developer can also be considered. Assessment of impact if chilled water is covered under tax liability. The business model will be amended accordingly. In the initial		

	stages of development of policy framework, government can consider providing tax rebates/relaxations.
Capacity building through training and awareness**	• Benefits of DCS in comparison to conventional cooling (workshops, webinars, other outreach activities) from prospective of end user • Comparison between standalone DCS and merchant DCS and different business models and its successes/challenges • Organise national as well international study tours to witness standalone as well as merchant DCS operation • Develop case studies of demonstration projects such as Gift City, Cyber City, and other future projects • At city level, explore strategic partnerships with international private sector in city-promoted projects and create knowledge exchange forums.

*A DC Code should be formulated, which defines DCS definitions, administrative requirements, service areas for district cooling services, licensing of district cooling services, control of licenses, matters related to licenses, offenses and role of key government departments, for successful implementation of DCS pan India. Similar codes/acts/regulations have been formulated in other countries for district cooling such as Egypt, Singapore and UAE and have existed for decades on district heating in numerous countries.

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10. Annexures

10.1. Annexure 1: Assumption in calculation for space cooling demand in India by 2037-38

The following assumptions were taken from ICAP in the analysis to derive at the national cooling demand by 2037-38.

- Equivalent full load hours (EFLH) of operation of 2500 hours in a year, for a typical commercial building (refer to Demand Analysis for Cooling by Sector in India in 2027, page 31)
- Considering 1 kW/TR for chiller plant (including auxiliary equipment), note this is the more efficient end of the expected range
- All new commercial buildings will follow minimum ECBC standard as it is assumed that ECBC will be notified by 2020-21 in India.
- Before ECBC/green building movement the general design practice for central plant design for typical commercial building was 200-225 sqft/TR.
- It is assumed that due to impact of ECBC and green building movement the design practice shall be 300-350 sqft/TR, for a typical commercial building
- With high energy efficiency measures, the design of 400 sqft/TR can also be achieved
- In residential sector VRF demand could be replaced by DCS, but not RAC[30]
- An average district cooling plant can be considered as 20,000 TR (although far smaller and far larger DCPs are common globally, this is a good average)
- A rule of thumb viability of DCS is when AC load density is greater than 10,000TR/sqkm although this is very approximate and depends on many factors

10.2. Annexure 2: Estimation of space cooling demand by various approaches

10.2.1. Estimation of cooling demand (in mn TR) as per Approach 1[31]

Table 10: Estimation of cooling demand as per approach 1

Year of assessment	**2017-18**	**2037-38**
Total Electricity consumption (in TWh)	135	585
Electricity consumption (by percentage) by space cooling equipment		
Chiller	9%	11%
VRF	3%	9%
Package DX	8%	4%
Subtotal of electricity consumption by selected space cooling equipment	20%	24%

[30] This is a conservative assumption and reflects the fact that residential with VRF is most likely in HIG buildings. Dense residential developments that would otherwise have RACs could alternatively be designed with district cooling (especially in mixed-use developments). However, this is more complicated than connecting commercial buildings to DCS and is unlikely to materialise without strong public support for DCS.

[31] Data from ICAP

Electricity consumption by selected space cooling equipment (in TWh)	27	140
Projection of electricity consumption in new commercial construction by 2037-38 (in TWh)	113	
Estimated Demand (in mn TR) served by chillers, VRF, Package DX and RAC in new commercial buildings by 2037-38	***45.2***	

10.2.2. Estimation of cooling demand (in mn TR) as per Approach 2[32]

Table 11: Estimation of cooling demand as per approach 2

Year of assessment	**2017-18**	**2037-38**
Commercial air-conditioned area (in mn sqm)	300	1600
Sqft/Tr to calculate estimated demand (for 2037-28, 23% improvement is considered due to rigours implementation of ECBC)	225	290
Deriving mn TR from above estimation of design applied to commercial air-conditioned area.	14.34	59.36
Estimated Demand (in mn TR) in new commercial sector by 2037-38	***45***	

10.2.3. Estimation of cooling demand (in mn TR) as per Approach 3[33]

Table 12: Estimation of cooling demand as per approach 3

Year wise stock	**2017-18**	**2037-38**
Total refrigerant based equipment stock (in mn TR) as per ICAP	70	720
Chillers	8%	5%
VRF	4%	5%
Package DX	7%	2%
Room air conditioners	81%	88%
Non-RAC equipment as per ICAP in mn TR as a proxy for commercial equipment relevant for DCS	13.3	86.4
New addition in non-RAC (in mn TR) by 2037-38 as a proxy for new commercial equipment relevant for DCS	73.1	
Discounting the 20% as this includes back up/stand by system	20%	
Demand in new commercial construction (in mn TR) by 2037-38	***58.48***	

[32] ICAP 2019
[33] ICAP 2019

10.3. Annexure 3: Analysis to estimate potential of DCS in Indian cities

10.3.1. Analysis 1: Potential of DCS in commercial development in tier 1 and tier 2 cities (based on master plan availability)

District cooling is a viable solution in cities with high-density developments. Therefore, the first approach is analysing the potential of DCS in high-density commercial developments of Tier I and Tier II cities of India, with a minimum population of 2.5 million. The data for proposed commercial developments in these cities is obtained from the City Master Plan 2031 for selected cities. 12 Tier 1 and Tier 2 cities are analysed below (based on the information available in city master plans).

Table 13: Analysis of commercial built up area in Tier I cities

Name of the city	Commercial plot area (in hectares)**	FAR
Mumbai	757.2	5
Delhi	348.7	3.5-4
Chennai	3277.8	4.8
Bangalore	1484.2	3.25
Hyderabad	26.4	5
Ahmedabad (Green field - Dholera)	5518.8	4
Pune	11.652	3.5
Surat	2306.4	2.25
Nagpur	4201.8	2
Naya Raipur (Green field)	1430.4	2
Lucknow	2203.2	2
Guwahati	264.6	2.25
Total area in hectares	21381	3.3 (Wt. Avg)
Total commercial built up area (in mn sqm) ***		**720**

**Source: City Master Plan 2031
*** Commercial plot area is the net area for which building construction is allowed, in a land parcel

A total of 720 mn sqm of commercial built-up area is proposed to be built in 12 identified cities by 2030-31. This is extrapolated to 1080 mn sqm of built-up area by 2037-38 (considering growth rate same as ICAP).

From this it is projected that **689 mn sqm** of **new commercial air-conditioned area** will be constructed by 2037-38 Out of which 10%, 15%, 30% are considered as potential air-conditioned area which can be tapped by DCS.

India can opt for conservative, moderate or optimistic approach. By going with different approaches, the new commercial air conditioning demand that can be catered by DCS, varies from 2.47 mn TR (74 DCP) to 7.41 mn TR (222 DCP) by 2037-38.

10.3.2. Analysis 2: Potential of DCS in commercial development in tier 2 cities having population more than 1 mn

In the second phase of analysis, upcoming commercial developments in Tier II cities with a population of more than 1 mn were analysed[34].

Table 14: Analysis of commercial built up area in Tier 2 cities

Name of the city	Commercial plot area (in hectares)**	FAR
Indore	93.2	2.5
Gurgaon-NCR Region	1038	2.5
Bhopal	573.1	2.5
Thane	13.8	2.5
Patna	2018.4	3
Vishakhapatnam	670.8	3
Faridabad new city	1241.4	2.5
Rajkot	505.2	3
Bhubaneshwar	72.54	2.75
Total area in hectares	6226	2.7 (Avg)
Total commercial built up area (in mn sqm) ***		**168.11**

**Source: City Master Plan 2031
*** Commercial plot area is the net area for which building construction is allowed, in a land parcel

By 2030-31, a total of 168 mn sqm commercial built-up area is projected in these Tier II cities.

The commercial built up area until 2037-38 is calculated at 252 mn sqm of which 161 mn sqm is considered as air-conditioned area and of this 10%, 15% and 30% is considered as potential area which can be tapped by DCS.

The commercial air conditioning demand which can be catered by DCS in 9 tier II cities range from 0.58 mn TR (17 DCP) to 1.73 mn TR (52 DCP) by 2037-38.

10.3.3. Analysis 3: Potential of DCS in residential sector for Tier I and Tier II cities

The third phase of the analysis assesses the potential of DCS in residential sector. Tier 1 and Tier 2 cities with upcoming high-density residential developments were identified. As per the City Master Plan 2031, data for the following cities were analysed:

Table 15: Analysis of residential built up area in Tier I and Tier II cities

Name of the city	Residential plot area (in Hectares)**	FAR
Mumbai	13145.4	3
Noida -NCR region	3433.2	2.75
Chennai	9557.4	2
Bangalore	25486.2	2

[34] Out of 43 Tier II cities, commercial development data till 2031 in nine cities was available in the City Master Plan.

Ahmedabad (Green field - Dholera)	5868	1.8
Surat	1764	1.8
Nagpur	22860	1.25
Naya Raipur (Green field)	1268.0	1.3
Lucknow	20037	1.5
Guwahati	6229.8	1.75
Indore	116.7	1.75
Gurgaon- NCR Region	9612.6	1.5
Bhopal	5527.6	1.75
Patna	18928.2	1.8
Vishakhapatnam	8066.4	1.75
Faridabad new city	8596.8	1.5
Rajkot	7845	1.8
Bhubaneshwar	28.08	2
Total Residential area	**168370**	**Avg- 1.8**
Total Residential built up area in mn sq. m		**3030**

**Source: City Master Plan 2031

The upcoming residential area in the cities is projected at 3,030 mn sqm area by year 2031. The average permissible Floor to Area Ratio (FAR) for residential buildings of these cities is 1.8. Extrapolating to 2037-38 it can be expected that 4546 mn sqm of built up residential area will be developed. Considering 30% as air conditioning area in residential buildings, the estimated new conditioned area until **2037-38** is calculated at 1364 mn sqm and **3%, 5%, 7%** as potential area which can be tapped by DCS.

With policy intervention from central and local governments, the air conditioning requirement in residential sector that can be tapped by DCS varies from 1.5 mn TR to 3.4 mn TR, by 2037-28.

It is experienced from the learnings derived from various other countries that DCS in residential sector is not easily implementable due to various techno-commercial reasons and it is recommended to look at residential sector as add-on / mixed use development.

10.4. Annexure 4: Technological overview

10.4.1. District Cooling Plants

This section will provide an overview of various aspects of District Cooling Plants.

(i) Chilled-water production technologies
There are basically two major categories of commercial chilling technologies: compression and absorption

(a) Compression Chillers

District Cooling Plants (DCP) are large in capacity and would mostly use centrifugal compressors. In Individual Building Chiller Plants (IBCP) up to 1200TR, screw compressors are more commonly used.

In IBCP, there are few chillers and no thermal storage, so the focus is on chiller performance at part load conditions. ***In case of DCP, the chiller loading tends to be higher due to a greater number of chillers and usage of thermal energy storage tank***.

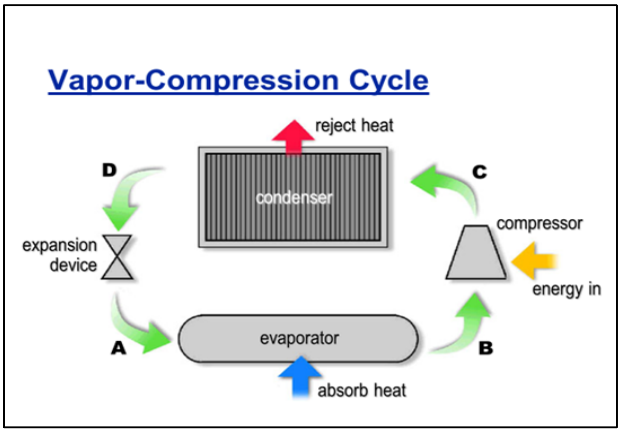

Figure 34: Schematic of Vapor compression cycle

Capacity control of compressors can be done with the use of inlet guide vanes or variable speed or both. Variable Frequency Drives (VFD) on compressors can dramatically improve part-load efficiency when the lift is lower than design. Low-voltage VFDs are economical but medium-voltage and high-voltage VFDs are very expensive. Normally, chillers are not selected for low voltage beyond 1200 TR capacity. ***Hence, while VFD Centrifugal Chillers have almost become the norm in IBCP, DCS may not use VFD due to cost, chiller loading and TES operating philosophy.***

It is not uncommon that a large DCP is envisioned, but in the early years it must supply only a fraction of the ultimate load. It can also be such that the loads are less in off-peak season. VFD chiller can be very beneficial to maintain plant efficiency even in low load conditions. The other technology that can be used is TES which shall be discussed separately.

(b) Absorption Chillers

The absorption cycle uses heat to generate cooling using two media: a refrigerant and an absorbent. Water/Lithium Bromide is the most common refrigerant/absorbent media pair. The absorption process uses an absorber, generator, pump and recuperative heat exchangers to replace the compressor in the vapor-compression cycle. Heat source may be Natural Gas, Steam or Hot Water.

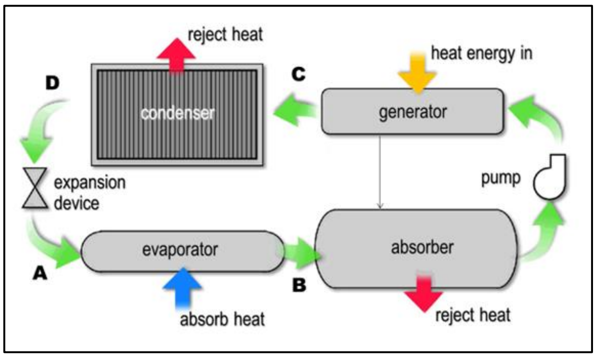

Figure 35: Schematic of Vapor absorption cycle

Table 16: Pros and cons of absorption chillers

Pros of absorption chiller	Cons of absorption chillers
• Significantly lower electrical requirement for chiller operation • Minimal sound and vibration • Ability to utilize recovered waste heat from diverse sources (e.g. power stations, industry, solar etc.) • Use of natural refrigerants with no threat of environmental degradation	• Substantial capacity and performance degradation at high condenser water entering temperatures and fouling • Higher heat rejection and make-up water requirements • Larger space requirements • Higher installed cost per TR • Limitations in producing lower chilled water supply temperatures • Limitations of variable flow • Threat of crystallization and corrosion

Coefficient of performance (COP) achievable is 0.65 to 0.7 for single-effect and 1.2 to 1.3 for double-effect. However, a low COP may still yield a lower operating cost depending on cost of heat source.

Capacity deration in absorption chillers for typical district cooling operating conditions can be as high as 40%. Also, absorption chillers are not well-suited for low supply-temperature production. ***In case of DCP, it makes sense to develop a series plant configuration with absorption chillers as the upstream chiller***.

(c) CHP or Cogeneration (COGEN) – Electricity & Cooling

Technologies for indirectly producing cooling with natural gas include:

- Engine / Turbine power generators, feeding electric chillers
- Exhaust from engine or turbine may be used to generate steam, which can then be used to drive compressor or be fed to a steam absorption chiller
- Exhaust and hot water from engine / turbine that can be directly fed to an absorption chiller.

These are integrated technology systems and can have many possible combinations depending on cost effectiveness, energy efficiency, space requirements, regulation and flexibility. These approaches have the potential to increase energy efficiency, promote operational flexibility and enhance the ability to deal with uncertain future costs of natural gas and electric energy.

Depending on the relative price of electricity and gas, CHP can improve cost-effectiveness. For example, one configuration is a central electrical combined CHP consisting of reciprocating gas engines, producing electricity, with heat recovery of jacket water and exhaust. The electrical power generated would be used to supply large electric motor driven centrifugal chillers. Jacket water heat would be used in single effect absorption chiller and exhaust gases would be used in a double effect absorption chiller.

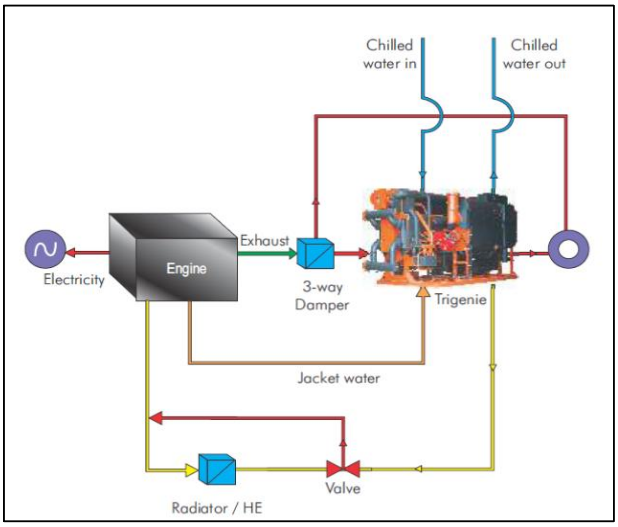

Figure 36: Schematic of Trigeneration (source – Thermax Trigenie Catalogue)

If the power prices are low (e.g. due to coal-based power) and natural gas is priced higher (natural gas is a clean fuel and is in high demand for Fertilizer, Transportation, Residential, Steel and other sectors), CHP may not be economical. The selection of the optimum configuration is dependent on the assumptions for electrical utility price, natural gas fuel price, cost of capital, space availability and safety regulations.

In India, there are COGEN installations with Absorption Chillers. A case in point is DLF Cybercity, Gurgaon that has 2 x 40 MW COGEN plants. Each plant has exhaust / exhaust + hot water driven absorption chillers totalling ~17,500 TR.

(ii) Thermal energy storage

Storage of chilled water or ice is normally an integral part of many District Cooling Systems. Thermal energy storage (TES) allows cooling energy to be generated at night for use during peak loads. This process helps manage the electrical demand and reduce the need to build electrical infrastructure for generation, transmission & distribution of electricity. TES also allows a reduction in installed chiller plant capacity, often reducing net capital cost.

Load-levelling thermal energy storage can typically achieve a 20% reduction in peak chiller plant TR load for District Cooling Systems.

TES types can be as below:
(a) Chilled Water Stratification Tank
Chilled water is the most common and simplest form of TES, using concrete or steel tanks to store chilled water at 4 to 5.5°C.

Due to the difference in densities of water at different temperatures, a stable stratification of layers of water can be obtained.

(b) Ice thermal storage allows storage in a more compact space. However, it requires lower evaporating temperature and hence, higher kW/TR. Ice thermal storage makes sense if there is a large differential tariff between peak and off-peak electricity tariffs and/or limited space for chilled water tanks.

Benefits of TES are as below:

- **Peak load management** – This is especially important in dense urban areas where the electrical distribution grid is capacity constrained. For CHP, implementing chilled water TES ensures a large economic benefit by reducing the amount of installed power generation required and leads to better loading of power generating sets, which results into higher waste heat recovery.
- **Energy efficiency** – Chilled water TES leads to higher loading, and hence, avoids higher kW/TR on auxiliary equipment of the system
- **Capital cost avoidance** – TES used for load levelling can reduce the necessary installed chiller plant capacity and provide redundancy. Chilled water storage can even double as fire protection water storage.
- **Operational flexibility** – TES can help in avoiding frequent chiller cycling for night-time low load operation or off-season cooling needs. TES can also facilitate chiller maintenance.

In India, IBCP is mostly designed without considering TES due to space, cost and simplicity parameters. DCP does integrate thermal storage in its design and this aspect leads to huge impact on peak electrical demand of cities apart from enhancing efficiencies at partial loads.

(iii) District cooling plant configuration

Figure 37: District Cooling Plant at Business Bay – Empower (Dubai)

(a) Chiller sizing and configuration

The type, number and arrangement of chillers for a district cooling plant are dependent on the cooling load profile for the system and delta T due to sequencing challenges. (Delta T is the difference of chilled water return & supply temperatures)

(b) Series counterflow configuration

The series counterflow puts pairs of chillers in series with one another, with flow through evaporator and condenser in opposite directions. This reduces the 'compressor lift' and hence improves the chiller kW/TR.

Series counterflow arrangement can be quite beneficial for CHP where the absorption chiller can be the downstream chiller.

(c) Voltage option for compressor motor

For electric chillers > 1200 TR, it is common to use medium voltage motors (3.3KV/6.6KV/11KV). The advantages of high voltage are:

- DOL starter can be used
- Step-down transformer may not be required
- Space for electrical eqpt is reduced
- Cable size is reduced
- I^2R losses are reduced
- Plant efficiency is increased

(d) Heat exchanger design

Chillers come with enhanced copper tubes for both evaporator and condenser. However, depending on water quality, it may be necessary to consider alternate materials. For e.g., CuNi 90/10, CuNi 70/30, SS, Titanium, etc.

With Titanium, one can even use sea water in condensers and even avoid using cooling towers.

In IBCP, capex considerations drive purchases, and chillers being installed are with standard metallurgy. However, DCP will tend to focus on life-cycle cost and go for customization if beneficial. A case in point is DCP in Bahrain Bay that was designed with Titanium Tubes in Condenser and directly used sea water for cooling.

(iv) Refrigerants

For chillers, CFCs were the most common refrigerants in the world. R11 was the refrigerant with the highest cycle efficiency. However, due to concerns of ozone depletion, there was a transition from CFC to HCFC and HCFC to HFC brought about world over by the Montreal Protocol. HFCs are refrigerants with zero ozone depletion potential (ODP).

Climate change is the greatest environmental challenge facing the earth and HFC refrigerants have significant global warming potential (GWP). As part of Kigali Amendment to the Montreal Protocol, there is a phase-down timetable for HFCs, and newer refrigerants are coming up that have zero ODP & very low GWP.

Low GWP alternates like R-513A & R-514A (HFO Blends) are being offered as refrigerants in place of R-134a & R-123 (HFC). A refrigerant of note is R-1233zd (HFO) that has zero ODP & near zero GWP. Many manufacturers are now offering centrifugal chillers with this new HFO refrigerant.

Refrigerant management is a larger issue that has more-or-less been ignored in Commercial Buildings. Refrigerant leaks are not discovered timely and records of top-ups are not maintained properly. Most plant rooms do not have Refrigerant Leak detectors and almost none of them has a Refrigerant Storage and Recovery unit. This is one of the strongest reasons in favour of district cooling for sustainability.

While IBCP continues to use R-134a refrigerant, DCP can be mandated to use Low GWP alternates.

(v) Heat rejection

Heat absorbed from the chilled-water production process along with compressor power must be rejected from the chiller condenser to the outside environment. The proper selection and control of the heat rejection equipment are significant components of district cooling plant operating costs. Heat rejection systems can be based on one of the following:

- Cooling towers with potable water for make-up
- Cooling towers with recycled wastewater for make-up
- Once through use of fresh water, sea water or wastewater

Variable speed drives can be very beneficial for cooling tower fans. Also, cooling towers should be designed to operate well at lower water flow rates.

IBCP continues to use Municipal / Borewell Water in cooling towers due to lack of proper water treatment plant in its design. DCP can and should be designed on recycled wastewater or once thru' wherever feasible.

(vi) Water treatment

As water quality varies from region to region, there is no recommended water treatment program. The objectives of a successful water treatment program are to

- Minimize deposition (scale or sediments)
- Minimize corrosion (ion concentration in circulating cooling water)
- Control microbiological activity

Achieving these goals will lead to maximized plant life, enhanced efficiency of system, eliminating risk of failure of components and ensuring safe operating waterside conditions.

Sources of make-up water for cooling towers can be:

- Municipal water
- Ground water (may be brackish or have high Total Dissolved Solids or TDS)
- Treated sewage effluent (TSE or recycled water from sewage treatment plants)
- Sea water or brackish water treated using reverse osmosis (RO) or other technologies

Sea water or lake water may also be used in "once through" arrangement, in which case there are no cooling towers or make-up water requirements.

With water supplies becoming scarcer, DCSs can be designed based on TSE. Singapore and Middle East regions are conscientiously using recycled water for chiller plants. However, TSE quality may not be consistent or predictable and can create problems in the tower and condenser systems.

In DCP, it is possible to circulate sea water straight through the chiller condensers so that no cooling towers are required. However, there are formidable challenges in using this strategy:

- Sea water piping and pumping (distance)
- Allowable temperature increase and discharge point (environmental clearances)
- Pipe and heat exchanger Material of Construction (MOC)
- Pre-treatment requirements (filtration, chlorination, etc)

District Cooling Plants have automatic dosing and control for both chilled water and condenser water circuits. In addition, blowdown is automated. These aspects are ignored to a large extent in individual plants, thus leading to deration in capacity, reduced efficiency, increased make-up water and chemicals consumption.

(vii) Miscellaneous items

District cooling operators rely on high efficiency and expert operation and maintenance to ensure a profit and often use various other technologies that a stand-alone building's chiller plant may not incorporate.

Total suspended solids (TSS) is also a concern as condenser water circuit is open. ***Side stream filters and cooling tower basin sweepers are being used in DCP.***

Proper equipment access for better & faster maintenance (for example - use of overhead cranes, hoisting points, proper lighting, tools & tackles, space for carrying out repairs, etc) are other seemingly minor points in DCP design but these go a long way in ensuring reliable and efficient operations.

Similarly, electrical systems design and maintenance is very important for District Cooling Plants.

(viii) District cooling instrumentation and control system (DCICS)

District cooling instrumentation and control system is required to perform the following functions:

- Control and monitor process conditions for sequencing of equipment
- Automatically gather and archive accurate energy metering data at Plant and energy transfer station (ETS) level
- Automatically gather and archive data for predictive maintenance and energy efficiency optimization
- Provide alarms for detecting performance drifts as well as failures
- Improved data gathering ensures strong Monitoring, Reporting and Verification frameworks for GHG emission reductions and other benefits

DCICS is a "key tool & differentiator" that makes District Cooling Plants perform better than individual building chiller plants.

Table 17: Comparison of instrument and control in typical commercial building & district cooling plant

Instrumentation and control for	Common Issues/Advantages
Typical Commercial Building	• Use of minimum efficiency equipment (capital cost considerations dominate) • Improperly applied equipment (load estimation and Bill of Quantity based on thumb rules) • No system level commissioning (Building Management System is not installed / bypassed in most Plant Rooms) • Reactive maintenance (breakdown maintenance) • No optimization (no consciousness about system efficiency) • No tracking of data or reporting (manual data recording which is never analysed)
District Cooling Plant	• High efficiency equipment (life-cycle cost considerations) • Best-in-class equipment application (well-designed in terms of sizing, specs, load profile, etc) • Data recording & analytics (proper metering, data archiving, data analysis) • Predictive maintenance (condition-based maintenance which leads to higher realized efficiency)

	• Perpetual optimization (system level efficiency measurements & advanced tools like AI) • Real-time measurement & dashboard reporting; fault analysis (ensures reliability, efficiency & uptime)

District Cooling Plants are designed, commissioned and operated at a much higher efficiency levels compared to 'typical building chiller plants. It is not uncommon to see chiller plants in commercial buildings running at '1.20 kW/TR' whereas well designed, commissioned and operated DCS can consistently run at lower than '0.95 kW/TR' averaged over the year (~25% lower energy consumption).

10.4.2. Chilled water distribution

A chilled-water distribution system is one of the largest capital expenses in any District Cooling Systems (30%-40%) of the total District Cooling Systems cost. It is imperative for DCS designers to carefully assess the load, diversity, flow rate and pressure requirements as well as heat gain to ensure available capacity and eliminate unnecessary waste or excess load estimation in the design. Unlike IBCP, the distribution system should be designed to accommodate future expansion and designed to last as it is very expensive to replace or resize buried pipe once it is installed.

(i) Hydraulic design

A hydraulic model is a critical tool for optimizing the design and operation of a District Cooling Systems. The model should consider the below:

- Customer loads and system diversity
- Start-up and growth
- Piping layout
- ***Delta T (increasing Delta T reduces pipeline size and chilled water pump energy consumption. However, Delta T has to be provided by the load and it is essential that Air Side is designed accordingly. Delta T of 9-10°C is common in DCS vs 5-6°C, being used mostly in centrally conditioned buildings)***
- Pipe sizing based on life-cycle cost analysis
- Pressure loss due to fittings

(ii) Pumping schemes

In general, variable primary flow (VPF) is the growing trend and is considered to have modest energy and first-cost savings advantages, a smaller footprint but some added control complexity. Primary-secondary system design is considered reliable, conservative and easy to operate.

VPF should only be used if the following applies:

- Chillers are compatible with variable flow
- Modest variations in chilled water supply temperatures are acceptable
- Flow and temperature measurement instruments are accurate
- System design incorporates and operators are trained to maintain minimum evaporator flow rates

One can even design all variable-speed primary-secondary systems with primary pump as headered so that chillers can be over-pumped if delta T is low.

One can also design "distributed secondary pumps" (secondary pumps located at individual customer buildings) system but should be considered only if chilled water system loads and extents are clearly defined.

For very large distribution systems, and for interconnection of multiple sub-systems, to have booster pumps at a strategic point seems to be necessary in the distribution system. Also, booster pumps can allow chilled-water

transmission further away from a central plant as an alternative to increasing distribution pipe size. Booster pumps may even be an attractive option for existing systems with constrained capacity, where replacing existing pipeline main is impractical or cost-prohibitive, but delta T improvement opportunities should generally be investigated first.

Chilled water pumping system in IBCP is mostly Primary Constant – Secondary Variable. In DCS, with enhanced automation and skilled operators, pumping scheme is chosen as per application and is fully optimized.

<u>(iii) Distribution system: materials and components</u>

Steel pipe may be a good choice if

- a tough and leak-tight piping system with high reliability is valued
- insulation is required
- clean water can be maintained in the chilled-water distribution
- the ability to operate at higher velocities is desired

Cons with steel pipe are the low speed of installation & high first cost.

In IBCP, MS pipe is most used. For DCS, HDPE (high-density polyethylene) may be a good choice if

- Trench conditions are aggressive
- System is low-pressure
- System has routings with small directional changes
- Pipe sizes are smaller

In DCS, there is a growing trend towards pre-insulated piping along with sensor-wire leak-detection system. The system uses electric resistance to detect moisture in the insulation. Another option is to use acoustic leak-detection sounding equipment.

A distribution system should have isolation valves at all major branch points. Valves could be “in-chamber” or “direct-buried”.

Piping System	Carrier Pipe Joint Integrity	Joint Inspection	Insulated Joints Possible*	Corrosion Resistance	Installation Skill Level	Installation Time	Strength under Burial Conditions
Welded steel	Excellent	NDT (x-ray, etc.), pressure testing	Yes	Low, requires protection	High	High	Excellent
Soldered copper	Medium	Pressure testing	Yes	Good	Medium	Medium	Good
Ductile iron	Low	Pressure testing	No	Low, requires protection	Low/medium	Low	Very good
Cement pipe	Low	Pressure testing	No	Excellent	Low/medium	Low	Good
FRP	Low/medium	Pressure testing	Yes	Excellent	Medium	Low/medium	Low
PVC	Low	Pressure testing	No	Excellent	Low/medium	Low	Low
HDPE	High	Pressure testing	Yes	Excellent	Medium	Small D = Low	
Large D = Medium	Excellent	Small D = Low					
Large D = Medium/high							

*Insulated joints are not recommended for piping systems that have allowable leakage rates for joints.

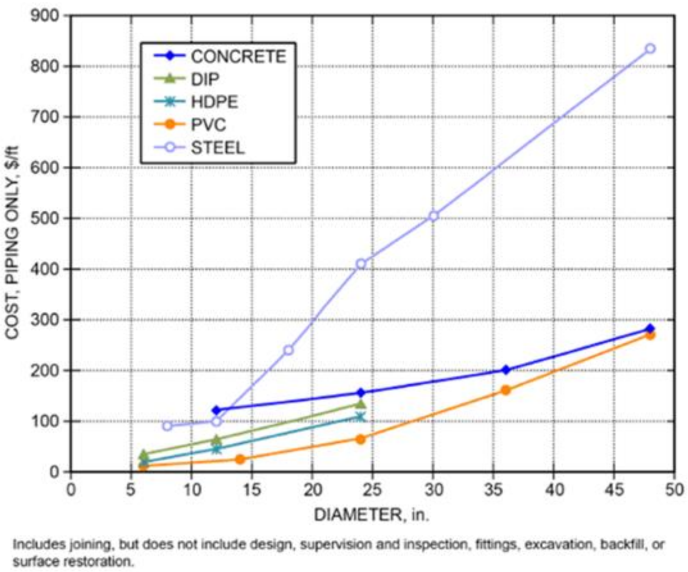

Figure 38: Cost of piping vs its diameter
(source – ASHRAE Handbook 2016 HVAC Systems and Equipment's Chapter 12)

Pipe installation types:

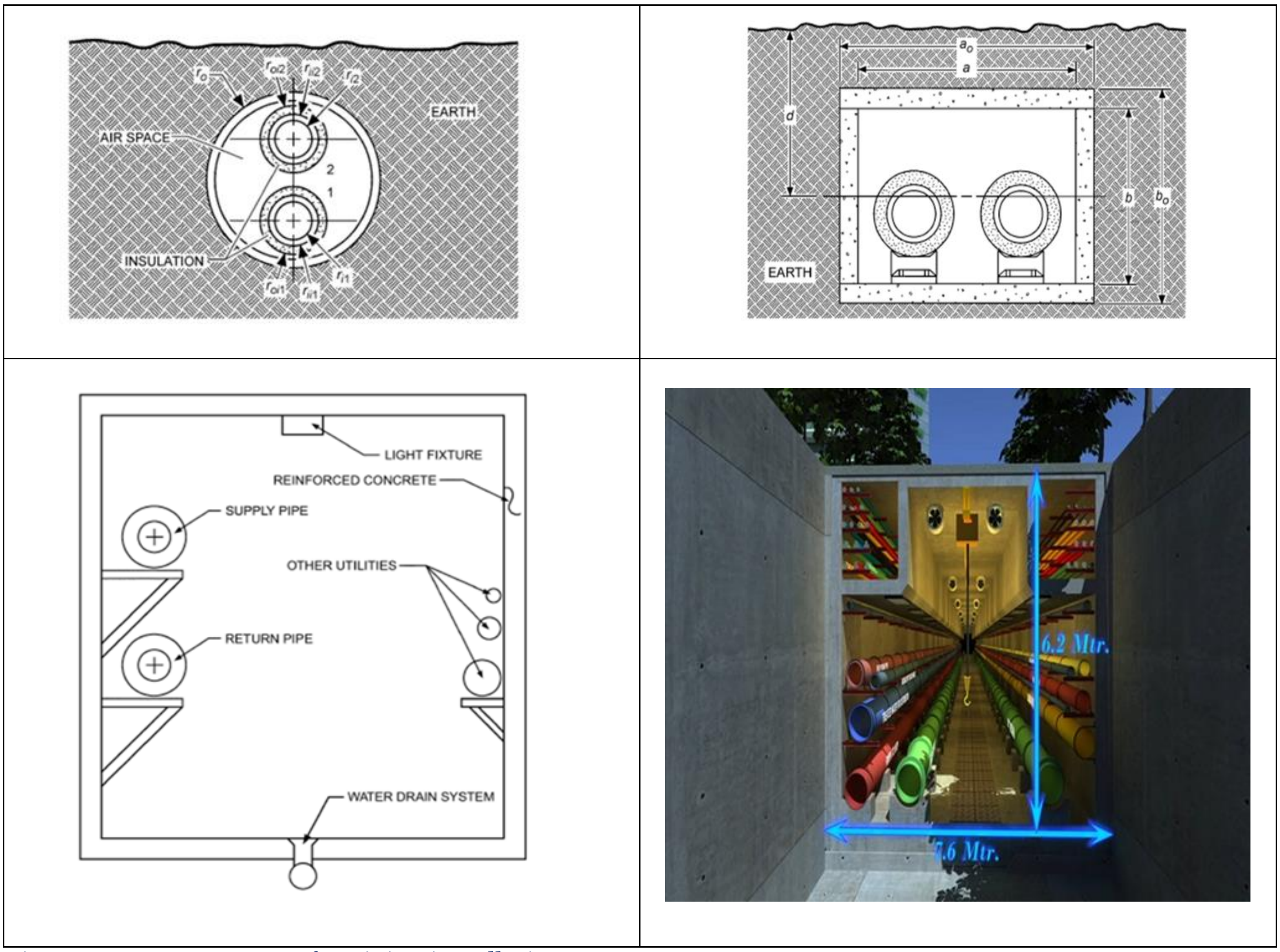

Figure 39: Arrangements for piping installation
(source – ASHRAE Handbook 2016 HVAC Systems and Equipment's Chapter 12)

10.4.3. Customer connection

An energy transfer station (ETS) serves as the thermal energy transfer point between the district cooling company and each customer's HVAC (heating ventilation and air conditioning) system. It also demarcates the physical boundary for ownership, responsibility and maintenance of equipment. At the ETS, a revenue-grade flow meter and temperature sensors are used to calculate cooling energy consumption and demand for customer billing.

There are both direct and indirect ETS connections, and there are optimal circumstances for the use of each in DCS. In comparison, IBCP will always use direct connection.

Direct Connection

- Recommended for low rise with total capacity below 15,000 TR
- Precautions should be taken for monitoring buildings highest point pressure with motorized valve to isolate buildings with potential leakage
- Is the most energy efficient method and simplest to control low ΔT syndrome

Direct Connection with Tertiary Customer Pumps

- Recommended for low rise with large customer buildings
- De-coupler between secondary & tertiary circuit and control secondary pumping to achieve minimal pressure of 5 psig at the suction of tertiary pump
- Difficult to control and manage, require careful design details

•Indirect Connection with Plate Heat Exchanger

- Recommended for high rise with large commercial buildings
- Separate secondary and tertiary circuit increases reliability

With or without an indirect connection, it is essential for the district cooling company to maintain proper chilled water supply temperature control in customer buildings. It is equally important for customer building to deliver high return water temperature to the plant.

This study includes analysis and best practices on:

TECHNOLOGY OVERVIEW, BENEFITS, DISTRICT COOLING POTENTIAL, BUSINESS MODELS, POLICY AND REGULATORY FRAMEWORKS, RECOMMENDATIONS

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