DISTRICT ENERGY IN CITIES INITIATIVE

E-TRAINING PROGRAM DISTRICT COOLING DEVELOPMENT

MODULE 1. INTRODUCTION TO DISTRICT COOLING

UN environment programme 50 1972-2022

COPENHAGEN CENTRE ON ENERGY EFFICIENCY SEforALL EE HUB

LEARNING OUTCOMES

Objective: share fundamental knowledge on district cooling systems (DCS)

By the end of this module, you will be able to:

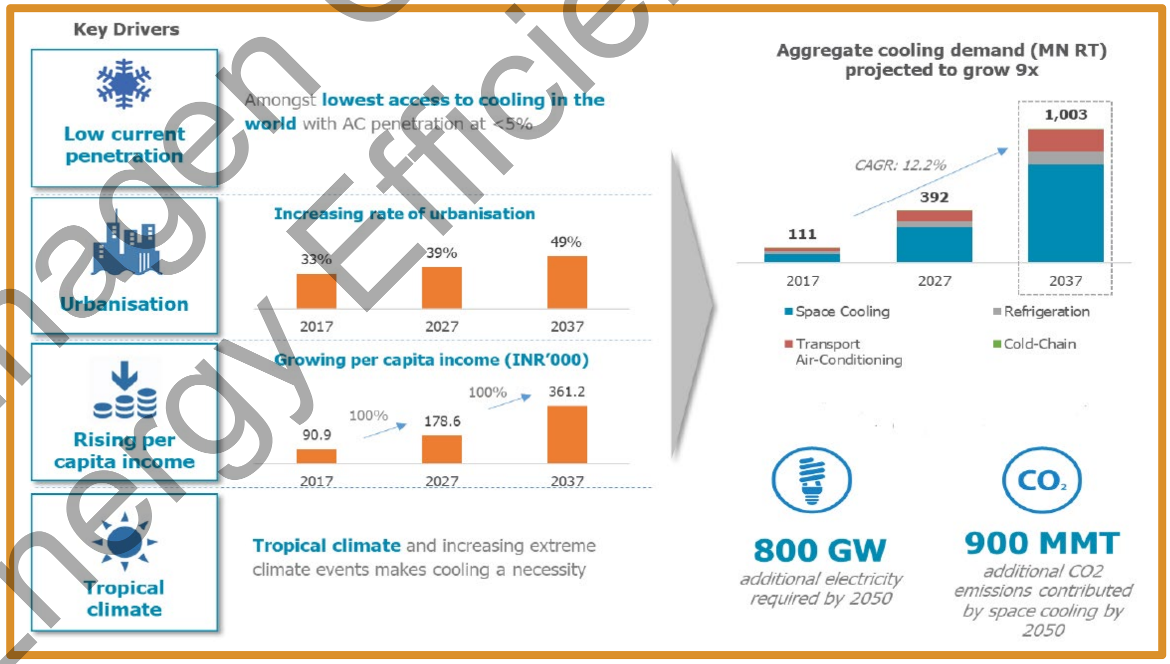
- Describe the role of district cooling (DC) in the decarbonisation of the building sector;
- Describe understand and discuss fundamentals of DCS including types of projects, networks and components;
- Identify and develop on the main benefits of DCS across various stakeholders;
- Recognise and apply key steps in the development of district cooling systems planning: phases, assessments, stakeholders, etc.;

THE ROLE OF COOLING

Tropical climate and increasing extreme climate events such as heat waves make **cooling a necessity in India**

- Aggregated cooling demand projected to grow **9x by 2038**
- Manifold increase in **energy demand (800GW)** and **emissions (900MMT CO2)** as a result of this growth by 2050

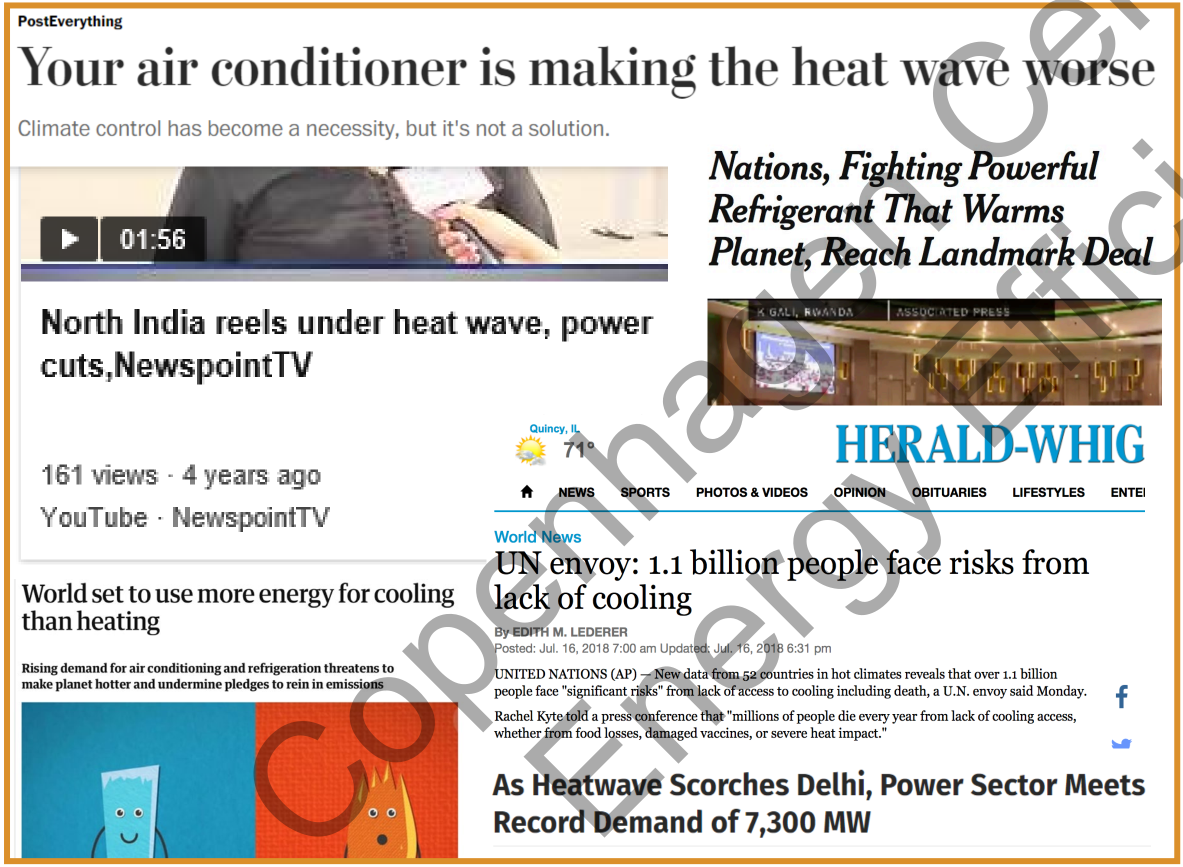
Drivers and cooling projections for 2037



Source: Climate centre for cities adapted from ICAP

BUSINESS-AS-USUAL VS TARGETS

Why business-as-usual is not an option?



India Cooling Action Plan targets for 2037:

- Reduction of cooling demand: **20-25%**
- Reduction of refrigerant demand: **20-30%**
- Reduction of energy requirements: **25-40%**

ALTERNATE SOLUTION: DISTRICT ENERGY

What is District Energy (DE)?

A **District Energy System** distributes thermal energy in the form of **chilled** (district cooling) or **hot water** (district heating) from a central source to multiple buildings spread over multiple locations through a network of underground pipes for use in space heating/cooling. The thermal energy is usually provided from a central plant, thus eliminating the need for individual systems.

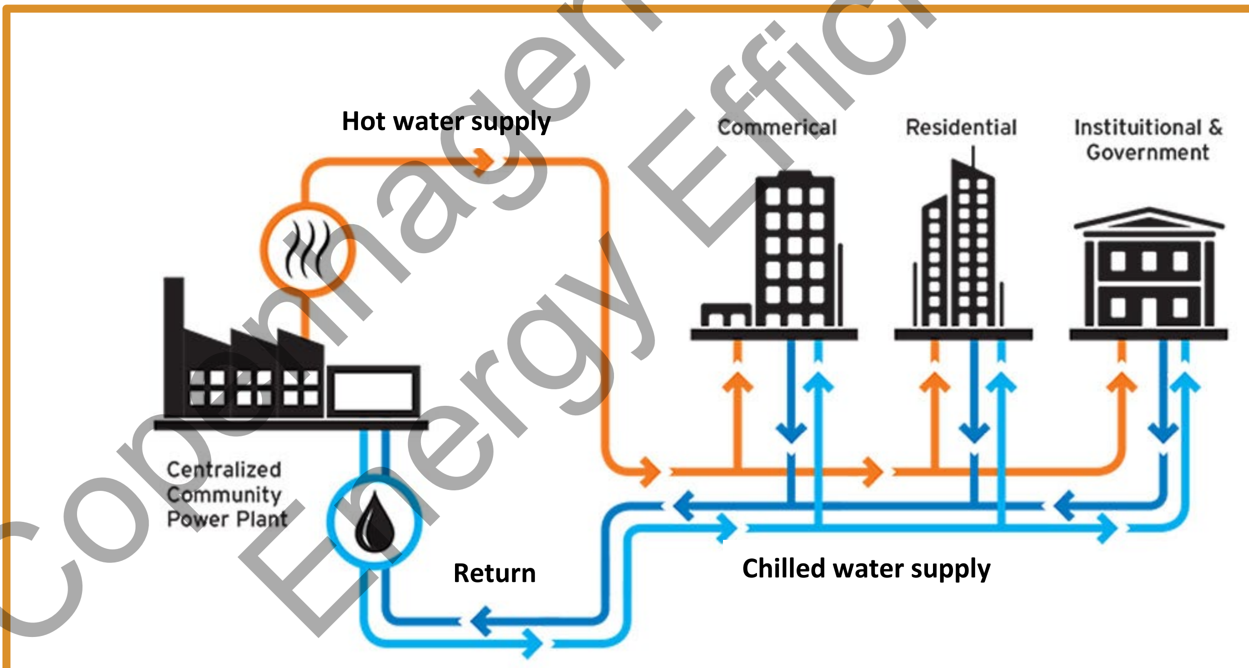


Image: Cleveland thermal

POTENTIAL OF DISTRICT ENERGY

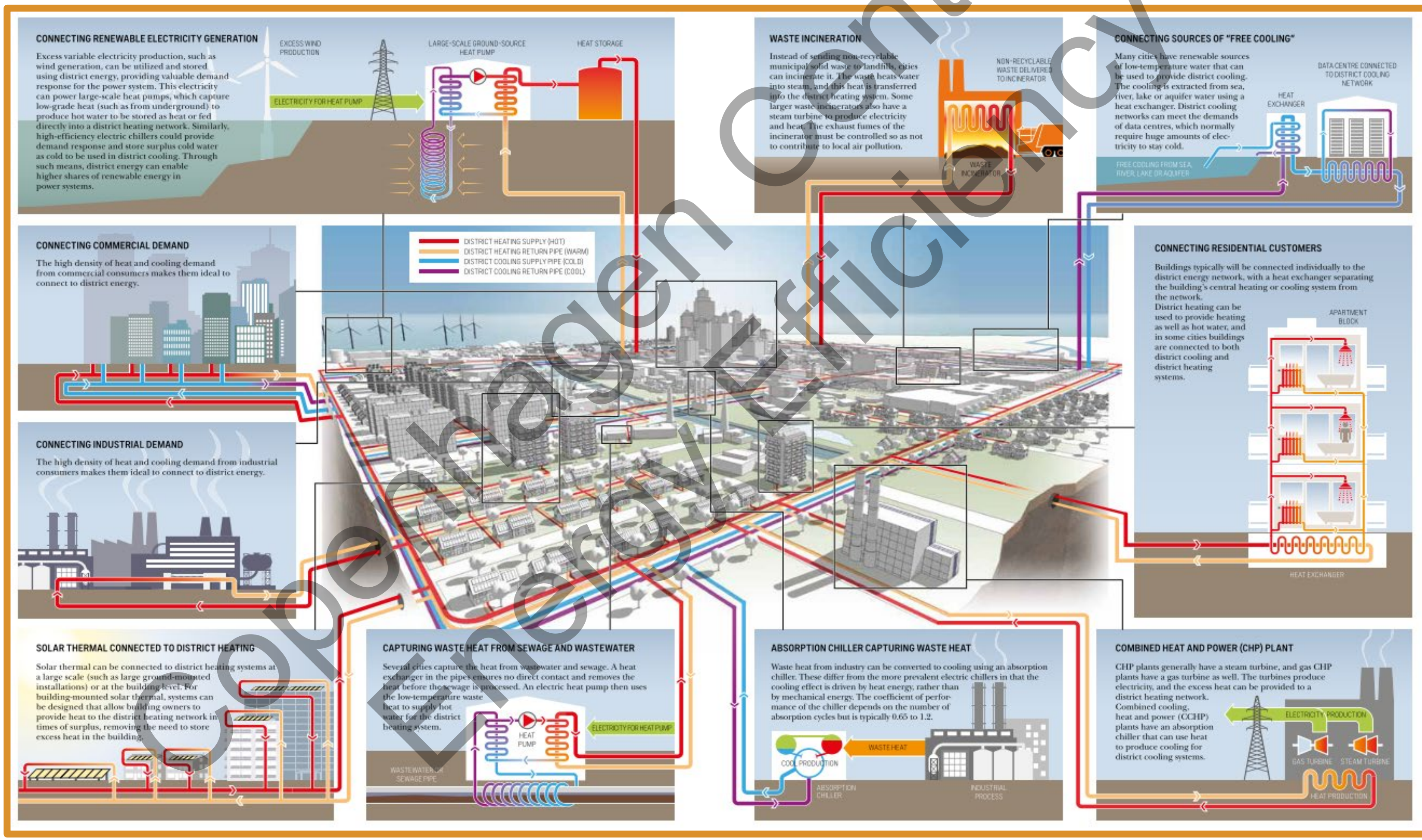


In a nutshell…

DE **uses local energy sources** that **otherwise would be wasted** or not used, in order to offer the local market a competitive and **high-energy-efficient** alternative to the traditional heating and/or cooling solutions

COMPONENTS OF THE SYSTEM

Components of District Energy Systems



Source: District Energy in Cities. Unlocking the Potential of Energy Efficiency and Renewable Energy

COMPONENTS OF THE SYSTEM

District Cooling (DC)

Local energy sources

Cooling can be extracted from free cooling sources such as lakes, seas or other waterways. Or it can be generated by a district cooling plant in the form of chilled water

Distribution

Network of underground insulated pipes that carry chilled water from the production site to the demand sites at a pre-determined temperature

Customer ETS (end-users)

Each building has an Energy Transfer Station (ETS) which is heat exchangers connecting to the secondary networks. They contain an interface to the buildings' own air conditioning circuits.

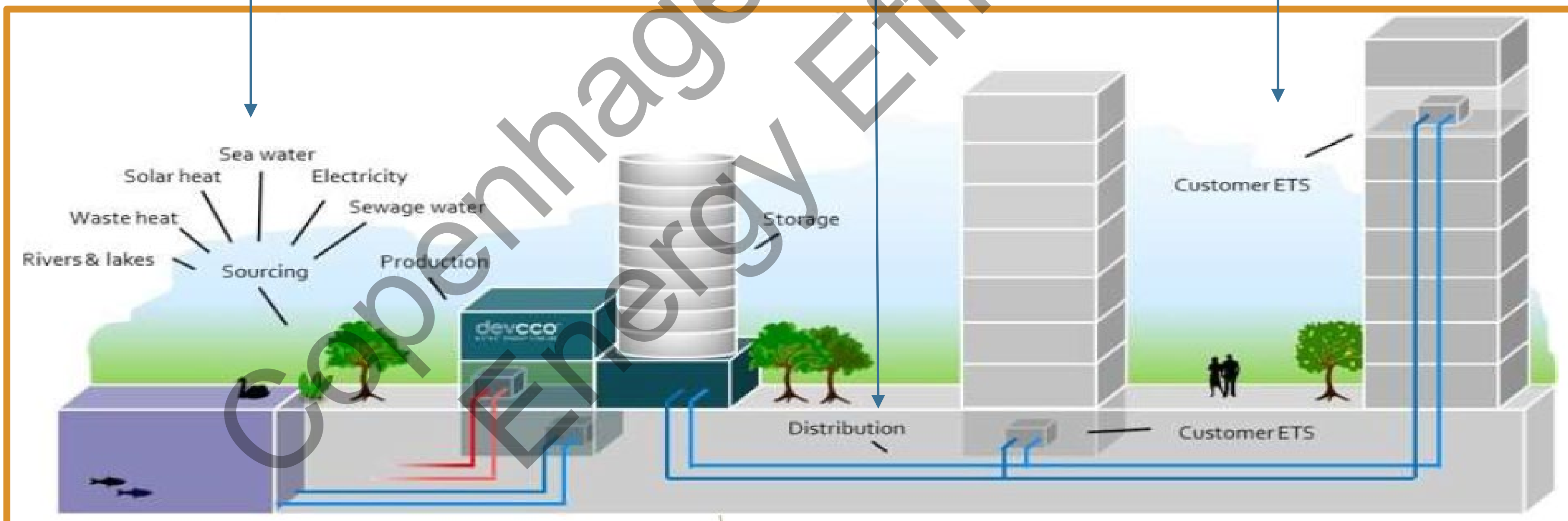


Image: Devcco

COMPONENTS OF THE SYSTEM

Chilled Water Production

- A district cooling system can have multiple **cooling generation plants and sources**
- Typical cooling generation sources include: **electric/absorptive chillers** or **free cooling** sources such as rivers, seas etc.
- Trigeneration or combined cooling, heating and power (CCHP) is method of generating cooling by utilising some of the heat from a power plant by linking it to an absorption chiller

- **Other accessories** needed for the generation unit are:
  - Circulation pumps: chilled/condensed water
  - Electricity transformers
  - Water supply and treatment systems
  - Cooling towers
  - Thermal storage systems: ice/chilled water storage
  - Central control systems

Absorptive chillers

Electric chillers

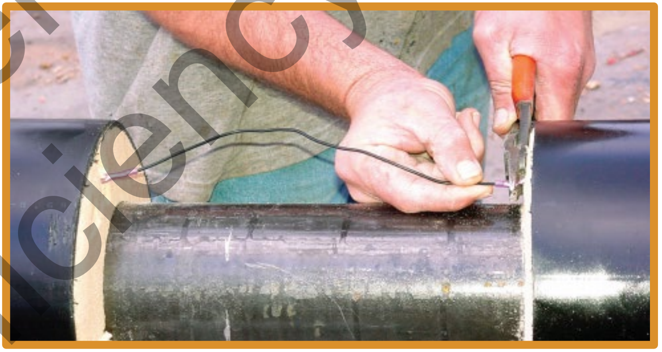
COMPONENTS OF THE SYSTEM

Distribution network

The **Distribution Network** contains:

- Pre insulated pipes buried underground
- Direct buried network or a utility corridor
- Leakage detective sensors and alarming system
- Booster pumps if needed

Leakage sensors & alarming system



Pre insulated chilled water pipe

Utility corridor

COMPONENTS OF THE SYSTEM

Energy transfer stations (ETS)

A typical ETS room has:

- Pipe connections or rough-in with knockout panels on exterior wall
- Heat exchangers for space conditioning
- Controls and meters

Normally it is regulated on **design and installation** as well as **maintained by district cooling suppliers**

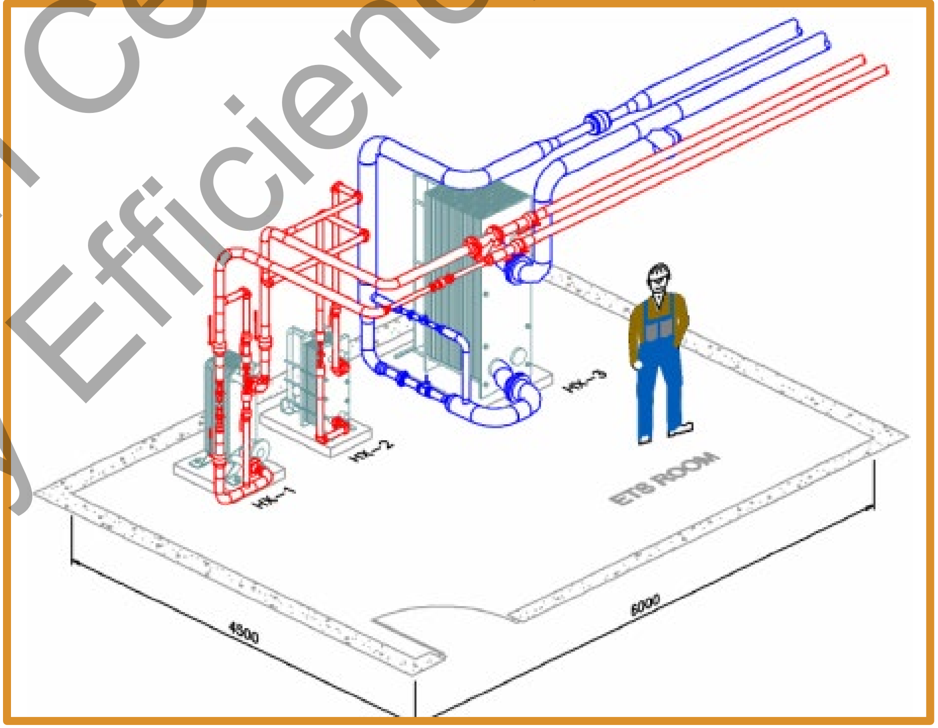
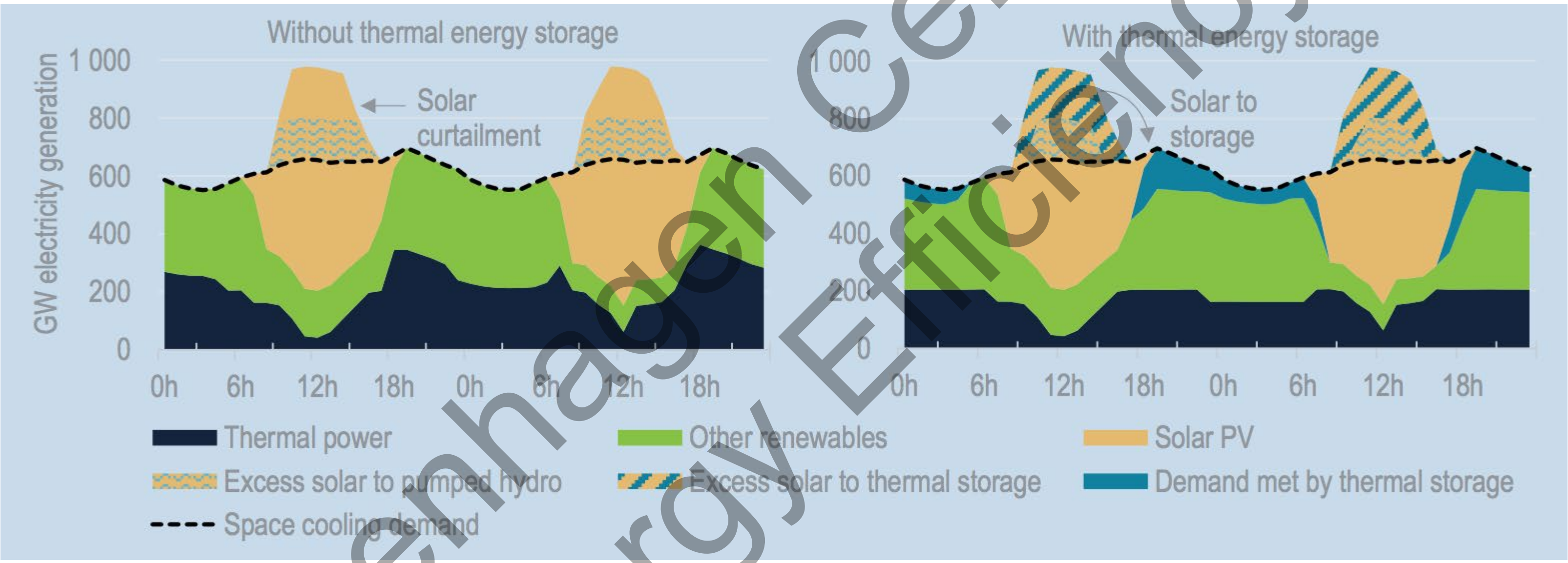


Image: DESIGN GUIDELINE FOR DISTRICT ENERGY, City of Toronto, 2016

COMPONENTS OF THE SYSTEM

Storage

Example: 2 days of cooling demand with and without storage



	No storage	Thermal storage
Peak residual demand	715	633
Curtailment	50	0.5
Cost savings (bil.USD/year)	-	9.7 (7.5 with battery)

Source: IEA

COMPONENTS OF THE SYSTEM

What happens to existing systems when connecting to DC?

- For buildings with existing systems, the central chiller unit will be replaced, but the fan coil units or AHUs will remain the same
- Upon connecting to DC service, calculations are made to determine heat exchanger size that will replace the central unit and meters will be fit in to record temperatures to determine the cooling consumption and calibration is required to match internal system of the building to the DCS
- Additionally, within the service agreement contract there will be clear requirements on the DC provider to assure quality and reliability of chilled water service including provisions for providing sufficient notice and requirements for measures should the service not meet the standards.
- The service agreement contract will also define the term, duration and pricing scheme
- The existing system is usually dismantled

MULTIPLE BENEFITS TO CITIES

End users	Costing	Infrastructure	Environment
• Comfort • Convenience • Flexibility • Reliability • Sustainability	• Reduced installed capacity • Optimized operations • Advanced technologies • Competent manpower • Incentives	• Peak power demand reduction (30-35%) • Reduction in cost to city governments and DISCOMs • Long term grid balancing services	• Energy efficiency • Reduced CO2 emissions (30-35%) • Water savings (15-20%) • Refrigerant savings (10-15% over 20 years)

SUSTAINABLE DEVELOPMENT GOALS

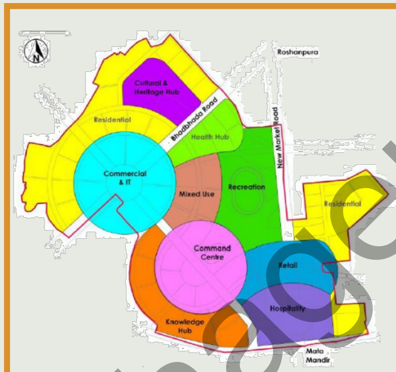
- 3 Health and wellbeing
- 7 Sustainable Energy for All
- 8 Sustainable Economic growth
- 9 Infrastructure, Industry, Innovation
- 11 Sustainable Cities
- 13 Climate Change

OPPORTUNITY FOR INDIA

India is commissioning **3 million sqft.** of commercial space per day

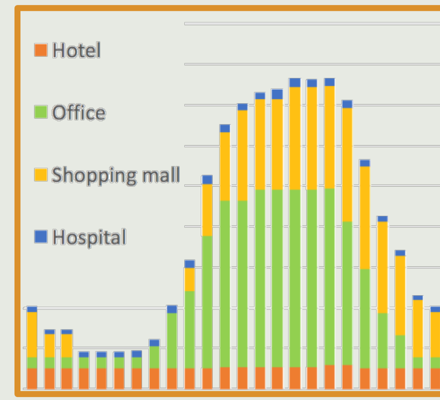
Target developments

- Smart City areas & CBDs
- Integrated townships, campus
- Industrial areas
- Dense brownfield sites
- Gas connections



Target Consumers

- Data centers, IT Offices
- Hospitals, hotels, malls, offices, conference centers
- Universities, public offices etc.
- HIG residential



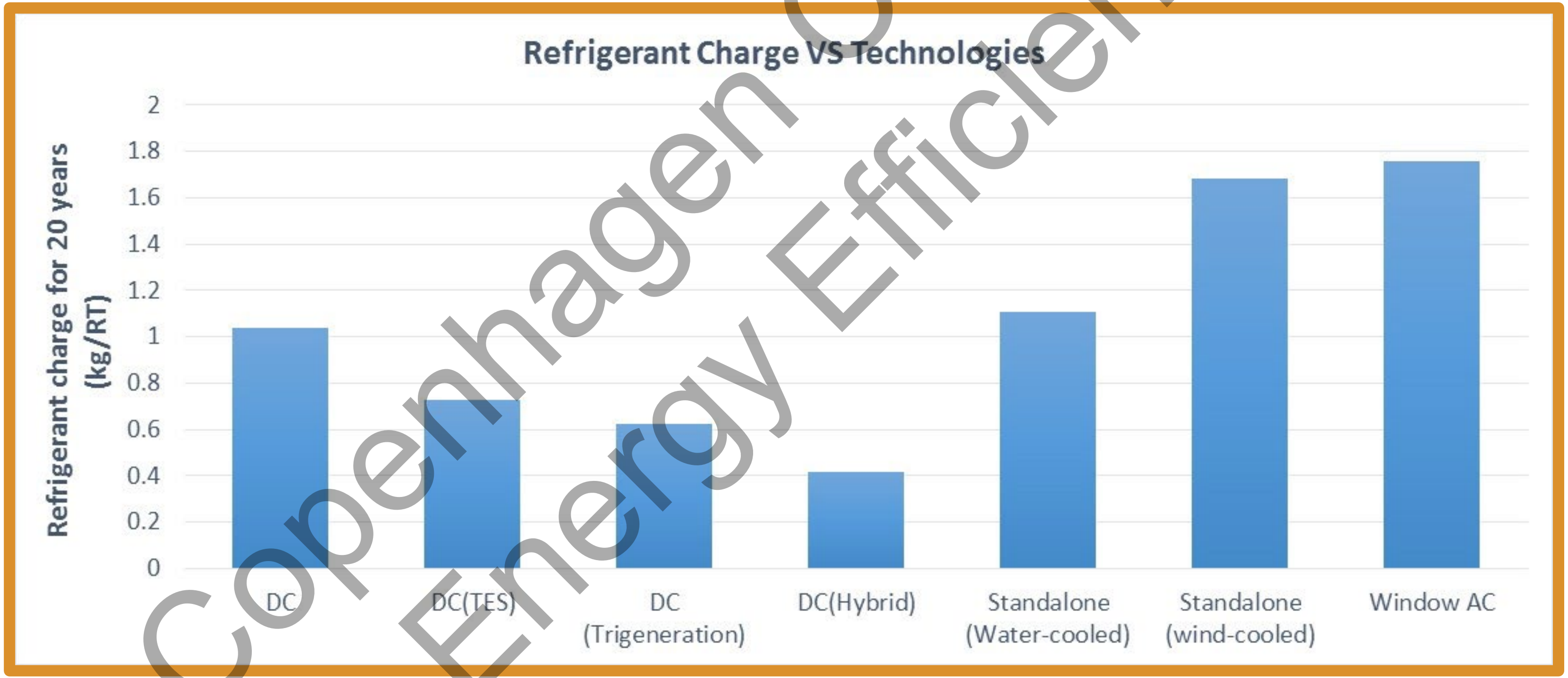
Control

- Municipal influence
- Real estate portfolio
- Large consumers

Source: AEEE,2017

OPPORTUNITY FOR INDIA

In 2021, India officially ratified the **Kigali Amendment** of the Montreal Protocol to **phase out hydrofluorocarbons (HFCs)** —used in refrigeration and air-conditioning that are known to accelerate global warming.



Source: C2E2

BARRIERS TO DISTRICT COOLING

Policy and Institutional Barriers

- Lack of promotion at national/state level urban development programs
- No contribution from municipal corporations & DISCOMs for inclusion at master planning stage
- Lack of policy drivers: Acts, Codes, Tariffs, fiscal instruments, contracting arrangements
- Non-inclusion in national building regulations (ECBC) & green building certification

Technological barriers

- 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

Financial barriers

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

Capacity barriers

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

Source: National district cooling potential study for India

BARRIERS TO DISTRICT COOLING

Interface Issues

Where will this Energy Transfer Station be, who will pay for it and who is responsible for it?

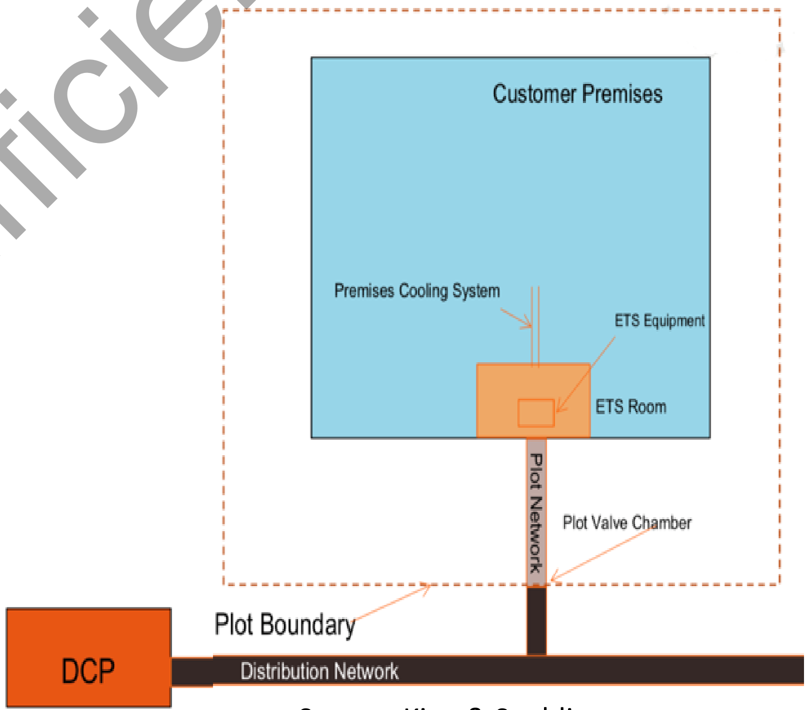
Cost of work: Who pays for:
- Constructing cooling plant
- Constructing network
- Constructing plot network
- Installing energy transfer station equipment

Timing of work: Who starts:
- Constructing network
- Constructing plot network

Ownership of each component
- During term?
- If early termination?
- After term ends?

Connection charge
- What does it cover?
- Does it determine plot network or energy transfer station equipment ownership?

Energy Transfer Station



Source: King & Spalding

HOW TO PLAN FOR DCS?

What is district cooling systems planning?

The process of developing long-range policies and actions to help guide the future of a local, national, regional or energy system to be able to introduce DCS in a long-term sustainable way.

Energy and emissions mapping & planning

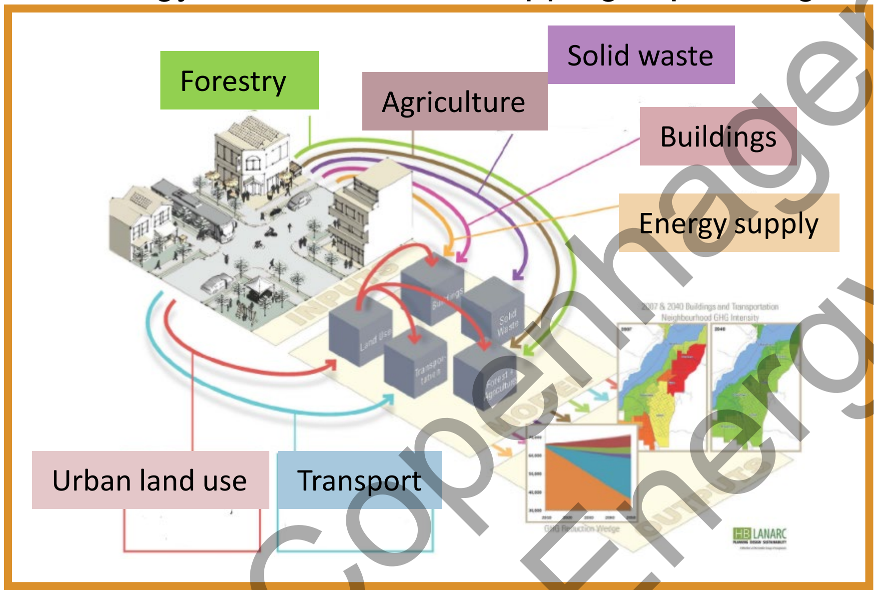


Image: Developing municipal policy and programs to accelerate market transformation in the building sector

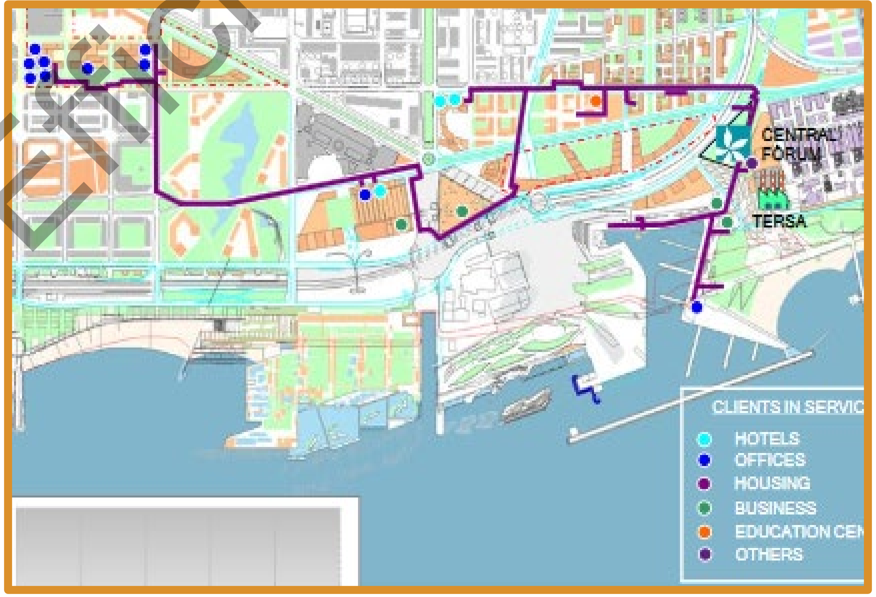


Image: Council, the City's Sustainability Office in City of Surrey

KEY CONCEPTS IN DC PLANNING

Types of projects

New	Consolidation	Refurbishment	Expansion
• District energy has a very low market share (0–15 per cent). • The city is in the process of stimulating district energy, with small starter networks or demonstration projects envisioned. • *E.g. India, Chile*	• Very mature market for district energy with above 50 per cent of the market share for heating or cooling of buildings. • *E.g. Denmark, Frankfurt, Gothenburg, Seoul*	• High market share of district energy. • However systems need some refurbishment in order to increase customer confidence, energy efficiency and profitability. • *E.g. Many cities in China, Russia, Mongolia, and Eastern and South-eastern Europe*	• District heating and cooling systems appear in some areas, but the total market share remains low (15–50 per cent). • Genuine interest in increasing the market share. • Geographical and in terms of energy system complexity. • *E.g. Rotterdam, Dubai, Vancouver, Paris, Tokyo, Toronto, Milan*

KEY CONCEPTS IN DC PLANNING

Greenfield and Brownfield for end user development status

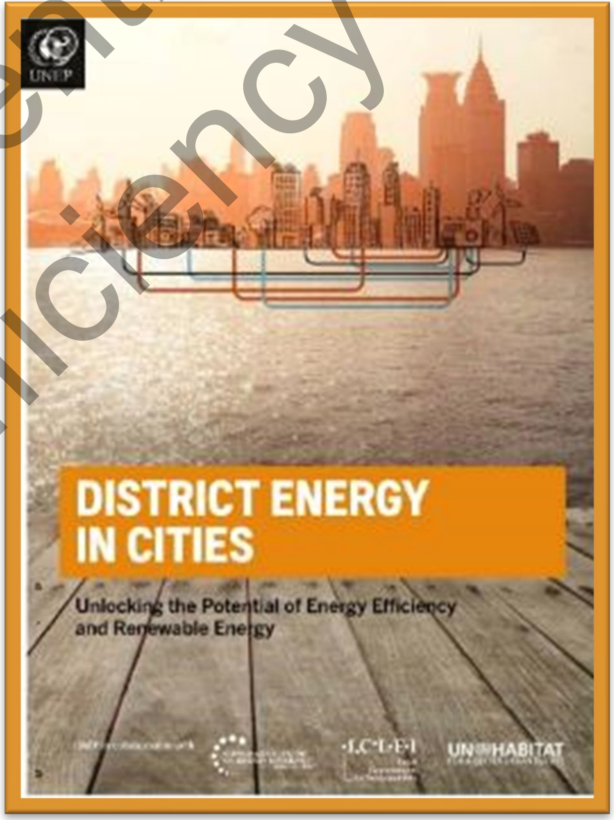
Greenfield	Brownfield
The process of developing new DCS over a region that has never been developed or partially under construction. **Pros:** larger pieces of real estate ideal for future expansion and zoning classification can be accessed, optimum pipe network and power plant location **Cons:** usually located outside city centres that might require additional infrastructure upgrades but those are offset by more accessible land costs	The process of developing a DCS over a region that was previously developed with existing buildings. There can even be existing DCS systems. **Pros:** located in the city centre and not in remote areas. **Cons:** require adjustments to already existing preliminary conditions (e.g. buildings, zones, etc.), limited space for power plants and setting up substations inside existing buildings

Source: National district cooling potential study for India

DISTRICT COOLING PLANNING

Key Steps in District Cooling planning

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. **Replicate**

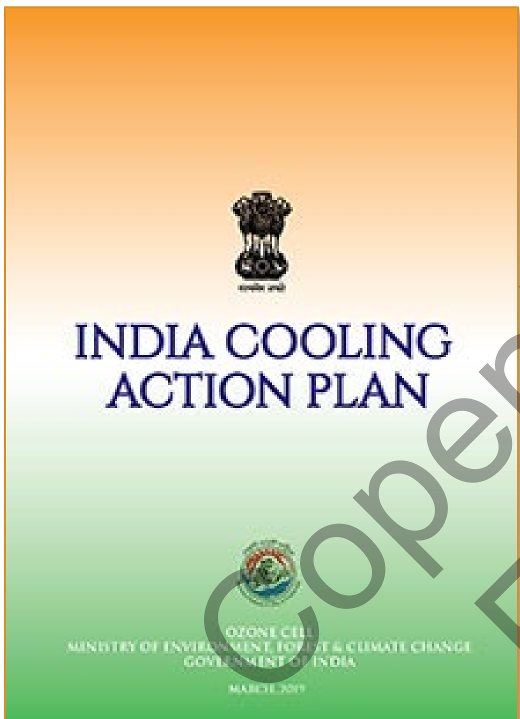


Source: District Energy in Cities. Unlocking the Potential of Energy Efficiency and Renewable Energy

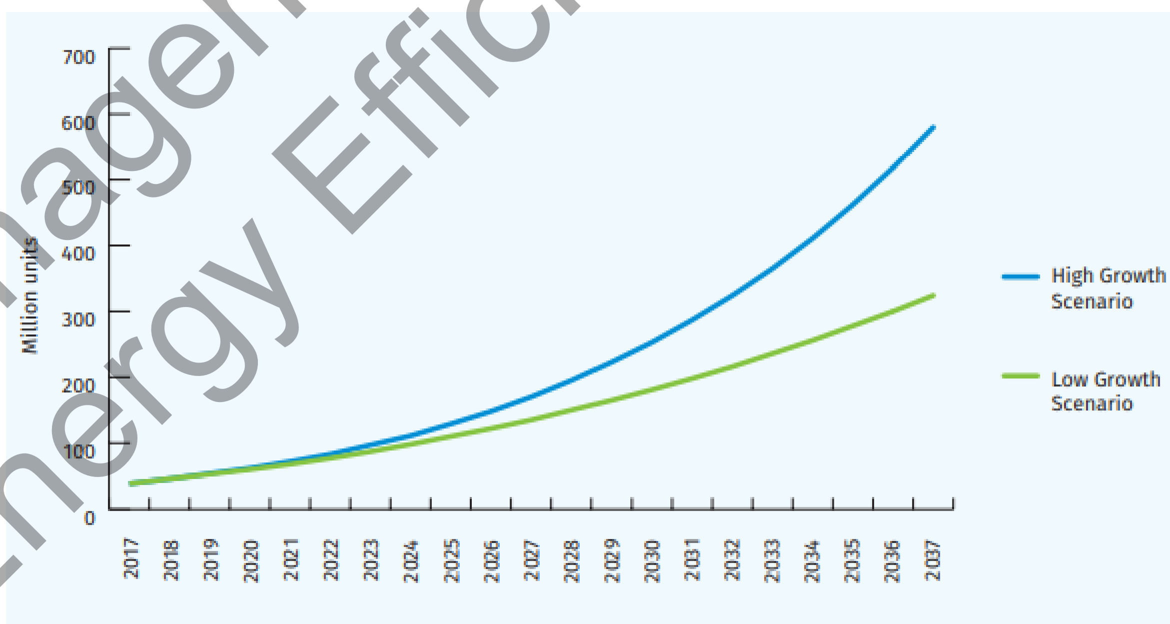
DISTRICT COOLING PLANNING

1. **ASSESS** existing energy and climate policy objectives, strategies and targets, and identify catalysts

ICAP analyses current and future cooling demand and sets targets for reduction



Room air conditioner stock projections



Source: ICAP

DISTRICT COOLING PLANNING

2. STRENGTHEN or develop the institutional multi-stakeholder coordination framework

Why is a multi-stakeholder coordination framework required?

- The benefits of a citywide, multi-stakeholder district cooling system are too widespread to motivate any single stakeholder to commit the resources required to drive this facilitation process.
- **Engagement from all stakeholders** in the development of district cooling ensures cost-effectiveness and reduces risk.
- Bringing the multiple stakeholders together under a '**coordination framework**' **formalises stakeholder engagement** and provides a platform and focal point for collaboration.
- Coordination framework can take many forms such as a dedicated unit in local government or an external public private partnership.

[Further details in Module 2!]

DISTRICT COOLING PLANNING

2. **STRENGTHEN** or develop the institutional multi-stakeholder coordination framework

Steps in establishing a multi-stakeholder coordination framework

1. Champion and catalyst to begin process
2. Identify relevant stakeholders
3. Map stakeholders to understand their motivations
4. Prioritize stakeholders based on interest and influence
5. Decide a structure of coordination
6. Engage with stakeholders to resolve barriers

[Further details in Module 2!]

DISTRICT COOLING PLANNING

3. **INTEGRATE** district energy into national and/or local energy strategy and planning

How can integrated energy planning further sustainable cool?

- To ensure cost-effective district cooling, cities need to analyse the interaction between energy, land use and infrastructure – including waste, water, buildings and transport.
- Cities can **require** energy planning to be integrated within all **new infrastructure development**, including planning for district cooling.
- Cities will have some control of local planning and can exert this authority to ensure optimal conditions for district cooling such as **mixed-use zoning** and the encouragement of high energy density areas (**compact** land use).
- Integrated energy planning can allow a city to **promote** and/or **designate areas** or zones that have favourable conditions for district cooling development or expansion, and to **apply tailored policies or financial incentives**.

[Further details in Module 4!]

DISTRICT COOLING PLANNING

4. MAP local energy demand and evaluate local energy resources

Steps in energy mapping process

1. Stakeholder engagement
2. Facilitate finance
3. Specify initial area
4. Data collection
5. Identify specific projects
6. Continuous updating and expansion

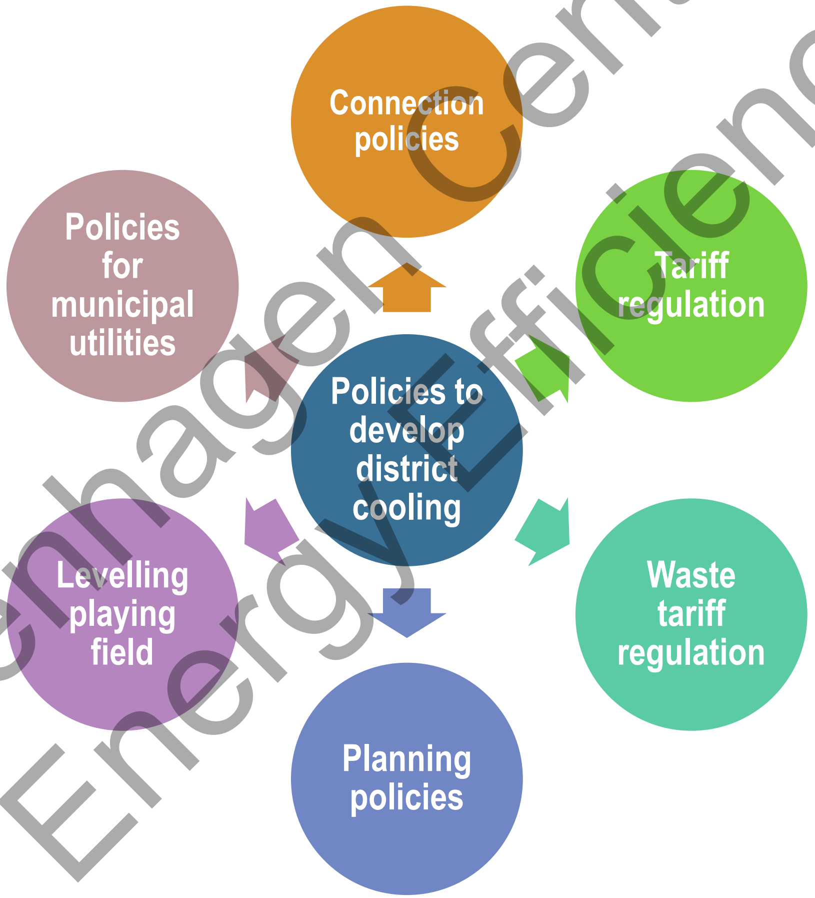
[Further details in Module 3!]

DISTRICT COOLING PLANNING

5. DETERMINE relevant policy design considerations

- Mandates for renewables and waste heat
- Social housing focus
- Interconnection and transmission

- CHP FiT
- Municipal subsidies or fiscal benefits
- Pass through of national energy subsidies
- Other policies may come from national level



- Protect consumers
- Limit profits and pass on costs
- Next available technology
- Other policies may come from national level

- Encourage waste heat connection
- Cost of connection and cost of redundancy
- Ability to guarantee supply

[Further details in Module 5!]

DISTRICT COOLING PLANNING

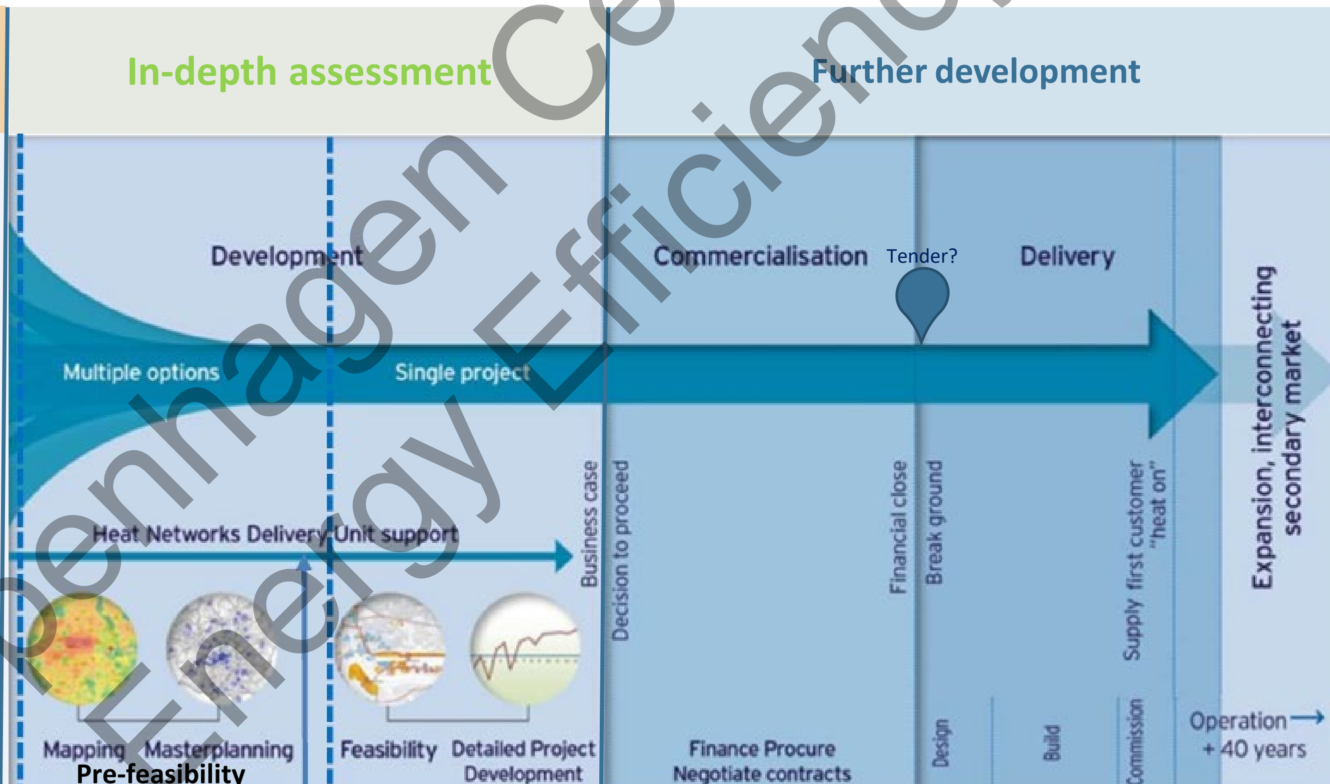
6. CARRY OUT project pre-feasibility and viability

Initial assessment

Light touch
requires prior knowledge of the viability of DES in different cities within a country and an understanding of cities

▼

Rapid assessment
technical, economic and environmental potential. policy gaps and energy and GHG saving potential



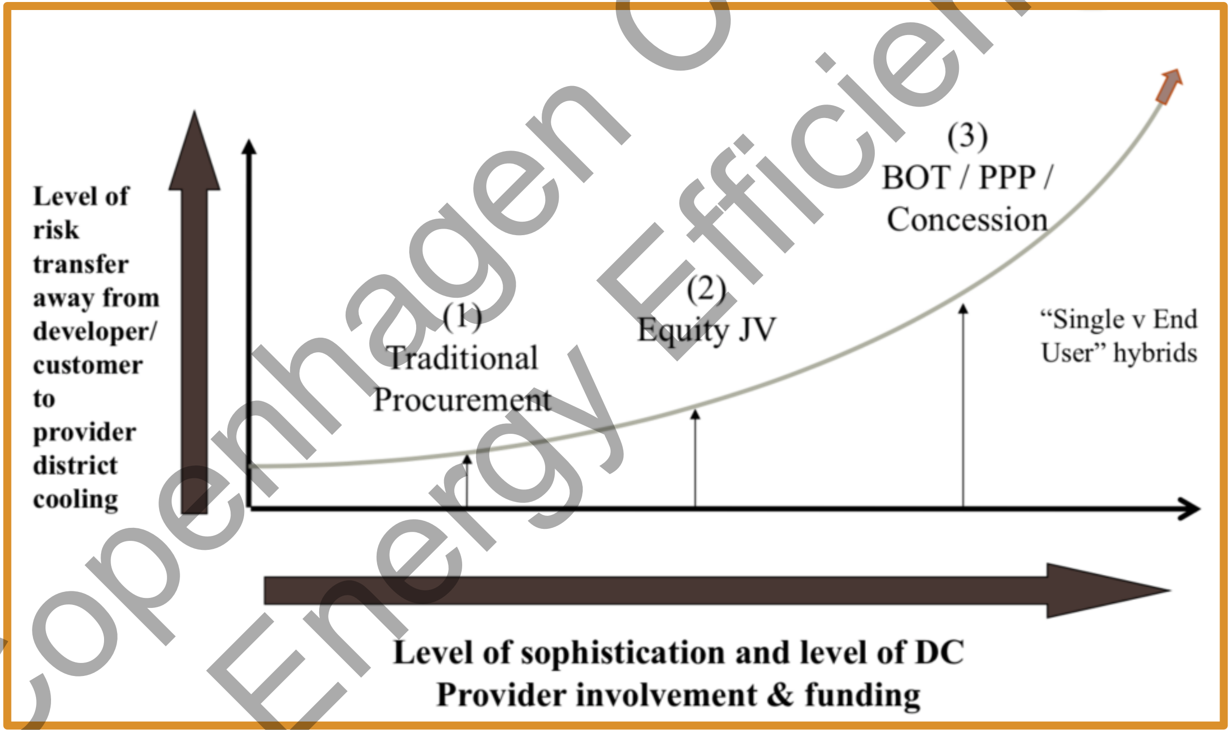
Source: Adapted from Carbon Trust

[Further details in Module 6!]

DISTRICT COOLING PLANNING

7. DEVELOP business plan

Business models in DES based on ownership type



Source: King & Spalding

[Further details in Module 6!]

DISTRICT COOLING PLANNING

8. ANALYSE procurement options

- Procurement options will depend on **the business plan** and degree of **private sector involvement.**
- Designing a **procurement package** that will attract **strong bids from the private sector** can require experience in local authorities or municipal utilities and capacity building is key to ensuring procurement is high quality and competitive.
- **International and national support** in capacity building for cities, as well as **city-twinning and inter-city support** can ensure that cities have appropriate experience in designing procurement packages and contracts with the private sector.
- If district cooling is to be developed under a **concession contract,** the procurement package is an opportunity for the local authority to control and direct private sector investment.
- Many cities procure the private sector on short-term design and build contracts.

[Further details in Module 6!]

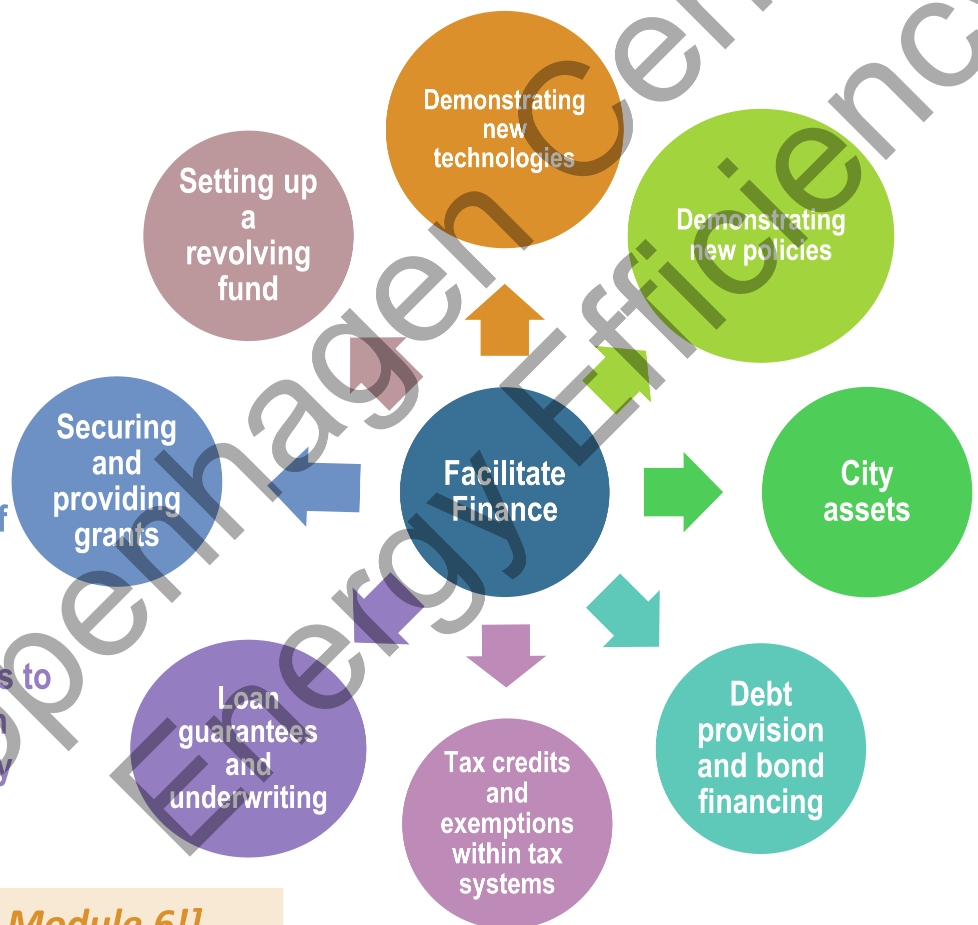
DISTRICT COOLING PLANNING

9. FACILITATE finance

'New' cities can set up a revolving fund designed to create multiple starter networks

Cities can provide grants to projects but also attract national and international grants on the projects behalf

Cities can guarantee projects to lower the cost of debt, which may be important for socially important projects



Demonstration of policies and technologies can leverage private sector investment in other networks

City assets such as land, public-rights-of-way and access to publicly owned anchor loads can reduce risk of projects

Many cities use their access to cheaper debt to lower the financial cost of a project and use their influence to ensure the project's success

[Further details in Module 6!]

DISTRICT
ENERGY
IN CITIES

CASE STUDIES

Paris, source: District Energy in Cities. Unlocking the Potential of Energy Efficiency and Renewable Energy

CASE STUDIES: DISTRICT HEATING

GIFT City, India

- Large compression chillers with planned **180,000 TR capacity**
- **Thermal storage** being implemented to reduce peak demand
- Electricity demand reduction by nearly **44%**
- DC pipes placed in multi-utility tunnels alongside other utilities

Gulf JP, Thailand

- Greenfield industrial zones with power and utilities supply
- 8 MW Siemens Gas Turbine, powers absorption chillers
- Chilled water is supplied to nearby industries (e.g. Michelin tyre plant)

CASE STUDIES: DISTRICT COOLING

PORT LOUIS, MAURITIUS

Image: Sotravic Ltd.

- Developing district cooling to serve the business district and save **40,000 tons of CO_2** per year
- Pump seawater from 1000m deep at 5°C
- Received **$1 million grant** from African Development Bank for development costs
- Could reduce country's peak power by 6%

CAIRO, EGYPT

Image: Unsplash

- Fast growing **district cooling market**
- Developing **National District Cooling Code** to overcome barriers, accelerate growth
- Supports city planners, creates an Energy Authority, and establishes legislation

CASE STUDIES: DISTRICT COOLING

Some examples of DCS in India are:

- GIFT City, Ahmedabad – 180,000 TR capacity (at full long-term capacity)
- DLF cyber city (trigeneration based) – 78,000 TR capacity
- Delhi Airport – Approx. 20,000 TR capacity
- Mumbai Airport – Approx. 20,000 TR capacity
- Chennai Airport – Approx. 12,000 TR capacity
- Kolkata Airport – Approx. 12,000 TR capacity
- Dhirubhai Ambani Knowledge City, Navi Mumbai- Approx. 12,000 TR capacity
- Infosys (various campuses) – Approx. 50,000 TR (approx.)
- Pragati Maidan, Delhi - Approx. 12,000 TR capacity (In Construction)
- 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

Source: National DC potential study for India

KEY TAKEAWAYS (I/II)

Some of the main aspects we have seen in this module are:

- DE aims to use **local energy sources** that otherwise would be wasted or not used, in order to offer for the local market a **competitive and high-energy-efficient alternative** to the traditional heating and/or cooling solutions;
- It has been established as a key technology in **decarbonising building cooling sector** by utilizing local, renewable sources of cold;
- DC helps **cities align themselves with SDGs** while providing multiple technical benefits such as HCFC reduction, CO_2 emission reduction, reduction in peak power demand, reduced cost of cooling etc. while also providing **benefits to the stakeholders** involved**;**
- DCS projects can be divided into various types based on **market share** (new, consolidation, refurbishment & expansion) and **end user development** status (greenfield & brownfield)

KEY TAKEAWAYS (II/II)

Some of the main aspects we have seen in this module are:

- District cooling planning is the **process of developing long-range policies and actions** to help guide the future of a local, national, regional or energy system to be able to introduce DCS in a **long-term sustainable way**.

- It can be divided into **ten key steps**:
  (1) Assess existing energy and climate policy objectives, strategies;
  (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) Replicate.

THANK YOU FOR COMPLETING THIS E-MODULE!

For more information about the initiative or this Training, please visit the following websites or contact:

www.districtenergyinitiative.org

unep.org

c2e2.unepdtu.org

E-TRAINING PROGRAM

DISTRICT COOLING DEVELOPMENT

In the upcoming modules, you will learn about ...

Module 2
- Stakeholder coordination for district cooling development

Module 3
- Energy mapping and data collection to identify long-term opportunities for district cooling systems

Module 4
- Strategy development: Incorporating district cooling into local energy and low carbon systems

Module 5
- Carbon heating and cooling strategies

Module 6
- Business models for sound sustainable district cooling systems

INTERFACE RESPONSIBILITIES

Component	Design, construction & installation	Ownership	testing	Interface risk	Operation & management
DC plant (DCP)	Provider	Provider will be granted leasehold rights over the DC plot	Provider	Provider- interface with DN	Provider
Plot network	Provider	Provider, until payment in full by customer of connection charge under a CSA, then title transfers to customer	Provider at plot boundary valve chamber	See distribution network	Provider
ETS equipment	Provider	Provider, until payment in full by the customer of the connection charge under a CSA, then title transfers to customer	Provider	Provider- interface with plot network	Provider
Distribution network (DN)	Design: Initially master developer (MD) then novated to provider on signing master agreement Construction: Initially MD then novation/direct engagement by provider if timing works	Provider will be granted easement/lease rights over the DN	Provider	Provider- interface between plot network and DN and between DN and DCP	Provider
Meters (bulk)	Provider	Provider	Provider	NA	Provider
Meters (end-user)	Location, design & installation: MD/Customer Specification & procurement: Provider	Provider	Provider	NA	Provider

Source: King & Spalding