International Energy Agency Technology Collaboration Programme on
District Heating and Cooling including Combined Heat and Power

SUSTAINABLE DISTRICT COOLING GUIDELINES

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Abbreviations

4GDH	Fourth Generation District Heating
BAU	Business as usual
BOT	Build Operate Transfer
CAPEX	Capital expenditures
CCHP	Combined Cooling, Heating and Power
CDD	Cooling Degree Days
CEN/TC	European Committee for Standardization/Technical Committee
CFD	Computation Fluid Dynamic
CHP	Combined Heat and Power
COP	Coefficient of Performance
CSA	Customer supply agreements
DC	District Cooling
DH	District Heating
DHC	District Heating and Cooling
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EC	European Commission
EIA	Environmental Impact Assessment
EPC	Engineer Procure Construct

ETS	Energy transfer station
EU	European Union
FTZ	Free Trade Zone Trigeneration
GCC	Gulf cooperation council
GD&T	Geometric Dimensioning and Tolerancing
GHG	Greenhouse gases
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefins
HSE	Health, safety and environment
HVAC	Heating Ventilation and Air Conditioning
IEA	International Energy Agency
IT	Information Technology
LCA	Life Cycle Analysis
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact assessment
LNG	Liquified Natural Gas
MID	Measuring Instruments Design
OPEX	Operational expenditures
PCM	Phase change material

PED	Pressure equipment design
PFC	Perfluorocarbons
PPP	Public-Private Partnerships
PRC	People's Republic of China
PV	Photovoltaic
RES	Renewable Energy Sources
RMB	Renminbi (Chinese yuan)
ROM	Rough order of magnitude
SCADA	Supervisory control and data acquisition systems
SWAC	Sea water air conditioning
TPA	Third Party Access
TSO	Transmission System Operator
UNDP	United Nations Development Programme
VRF	Variable refrigerant flow
VRV	Variable refrigerant volume

Unit of measurement

dBA	Decibel Scale A
EJ	Exajoule
GW	Giga Watt
GWh	Giga Watt hour
J	Joule
kg	kilogram
kPa	Kilo Pascal
kWh	Kilo Watt hour
MW	Mega Watt
MWh	Mega Watt hour
Pa/m	Pascal per metre
RT	Refrigeration Tons
TWh	Terra Watt hour
Wh/m	Watt hour per metre

1 Introduction

'District Cooling has its roots in the early 1800s when plans were made to distribute clean, cold air to buildings through underground pipes. It is not known if these plans were actually carried out, and District Cooling was not introduced on a practical level until the Colorado Automatic Refrigerator Company was established in Denver in 1889. Many of the earlier systems used ammonia and saltwater to freeze meat and cool buildings used by the public such as restaurants, theatres etc. In the 1930s large cooling systems were built in the Rockefeller Centre in New York City and the United States Capitol buildings' [1].

A brief history of 'modern' District Cooling can be summarized using the following milestones:

1960s: first commercial District Cooling systems were installed in the USA in non-residential areas near cities.

1967: first district cooling system in Europe. Climadef began supplying District Heating and Cooling to the La Défense office complex in Paris.

1989: first District Cooling system in Scandinavia (Baerum, Oslo).

1992: Västerås Energi & Production initiated the production of District Cooling in Sweden.

1995: District Cooling was successfully established in Stockholm. In 2015, District Cooling in Sweden had an energy output of around 900 GWh [2].

Largest District Cooling systems today are operating in Asia (Singapore, Tokyo, Dubai, UAE, Qatar, Saudi Arabia), Central and Northern Europe (Stockholm, Paris, Helsinki, Vienna, Berlin, Copenhagen, Amsterdam and Barcelona) and North America (Chicago, Toronto). No information about the total number of District Cooling systems operating worldwide is available, while in Europe around 150 systems are in operation. Cold energy delivered by District Cooling systems can be estimated to some 83 TWh per year [3].

District Cooling is based on centralized production of cold water which is distributed to customers in a closed loop underground pipe network. Production can be based on various sources and technologies. Common renewable cold sources are seas, lakes, rivers and ground water. Where excess cold is available from industrial processes, it can be used directly in the District Cooling systems. Where excess heat is available, absorption chillers can be used to produce cooling. Storage of cold water or ice can help increase energy efficiency and lower operation and maintenance cost. At the customer end of the system, the cooling is transferred to buildings in energy transfer substations.

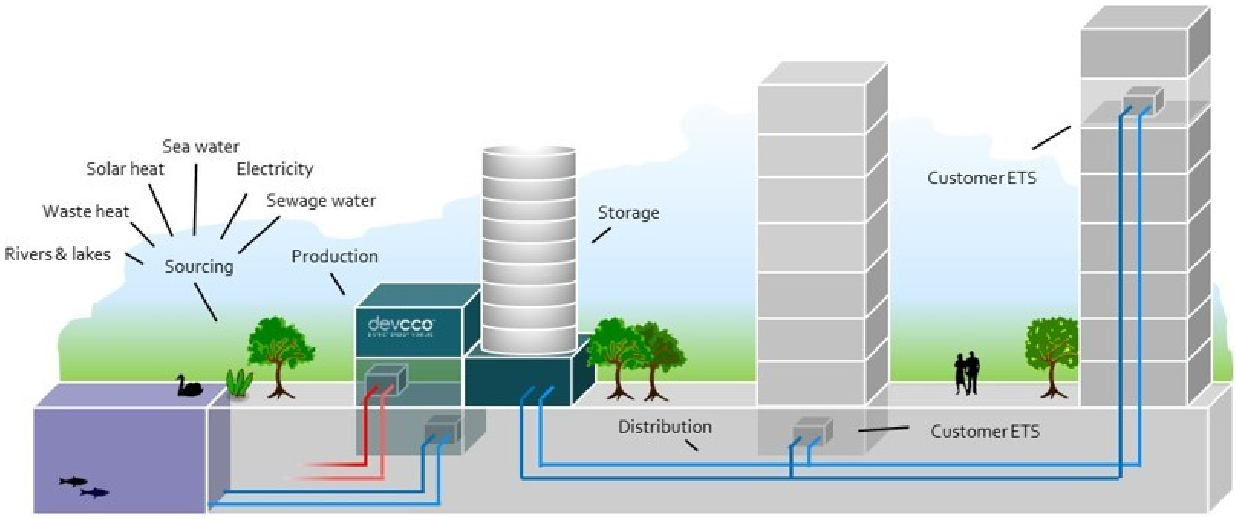

Figure 1: general scheme of a District Cooling system [4]

District Cooling systems can exploit renewable energy sources and excess energy from anthropic processes, significantly contributing to decarbonization of the heating and cooling sector. Furthermore, as they usually make use of thermal energy storage in order to meet peak cooling demand during warm summer days, they will in the future offer increasingly valuable flexibility to the electricity grid, which makes them economically appealing and attractive from the perspective of national and regional energy planning. Given the current energetic framework, which calls for greenhouse gas emission reduction [5] and for innovative approaches to face the issue of intermittent renewable energy sources, District Cooling is therefore increasingly raising interest among policy makers and municipalities.

Attention in this report is put on cooling sources and on cooling production technologies, with the intent of guiding readers through the many available options for implementing or expanding sustainable District Cooling systems that can meet sustainability requirements set at national, European and international levels.

The current guideline report first explains what District Cooling is, and why it can be beneficial for society and investors Chapter 2. Chapter 3 provides an overview of District Cooling development, followed by a detailed description of energy sources and cold generation technologies Chapter 4 and by a comprehensive list of best practices as case studies Chapter 5. Chapter 6 extensively considers design aspects of a DC system, from feasibility evaluation to maintenance. Chapter 7 is about basic and advanced control logics and concludes the technical section. Chapter 8 provides a methodology for estimating the cooling demand of a district, which is the first action to be undertaken by project developers in order to assess whether District Cooling can be economically feasible. Chapter 9 shows a list of innovative District Energy concepts, whereas Chapter 10 is an overview of potential business models for District Cooling systems. Finally, Chapter 11 explains the role of public authorities in the development of District Cooling projects.

Further information is reported in the Appendixes:

- Appendix 1 shows a flowchart of the implementation process of District Cooling projects;
- Appendix 2 provides a checklist for designers and project developers;
- Appendix 3 lists relevant standards at European, American, Chinese and international levels;
- Appendix 4 provides information about heat losses in District Cooling piping.

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