GOOD PRACTICE GUIDE

District Energy

C40 CITIES CLIMATE LEADERSHIP GROUP

UNEP

C40 Cities Climate Leadership Group

The C40 Cities Climate Leadership Group, now in its 10th year, connects more than 80 of the world's greatest cities, representing 600+ million people and one quarter of the global economy. Created and led by cities, C40 is focused on tackling climate change and driving urban action that reduces greenhouse gas emissions and climate risks, while increasing the health, well-being and economic opportunities of urban citizens. www.c40.org

The C40 Cities Climate Leadership Group has developed a series of Good Practice Guides in areas critical for reducing greenhouse gas emissions and climate risk. The Guides provide an overview of the key benefits of a particular climate action and outline successful approaches and strategies cities can employ to implement or effectively scale up these actions. These Guides are based on the experience and lessons learned from C40 cities and on the findings and recommendations of leading organisations and research institutions engaged in these areas. The good practice approaches are relevant for cities engaged in C40 Networks as well as for other cities around the world.

About the United Nations Environment Programme

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. Established in 1972, UNEP's mission is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

About UNEP Global District Energy in Cities Initiative

The Global District Energy in Cities Initiative (the DES Initiative) is supporting national and municipal governments in their efforts to develop, retrofit or scale up district energy systems (both district heating and district cooling systems). Although shares are expanding, there are still long-standing barriers to greater deployment of modern district energy, including awareness, local and institutional capacity, finance and a lack of appropriate policies. As such, the DES Initiative has brought together, 45 champion cities and 29 companies and organizations to support the transition to modern district energy.

It is the implementing mechanism of the Sustainable Energy for All District Energy Accelerator and will contribute to SDG7 on sustainable energy, and in particular its targets on renewable energy and energy efficiency.

DISTRICT ENERGY IN CITIES INITIATIVE

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EXECUTIVE SUMMARY

Cities worldwide account for over 70% of global energy use and 40-50% of GHG emissions.[i] In a number of cities, heating and cooling represent up to half of local energy consumption and with projected urban growth, there will be increasing pressure on these key infrastructures. Sustainable urban heating and cooling are thus central for cities' energy transition and for reaching their ambitious goals for tackling climate change. One of the least-costly and most efficient solutions in reducing GHG emissions and primary energy demand is the development of modern, efficient, climate-resilient and low-carbon district energy in cities.[ii]

This publication draws from the research and findings of the UNEP report, *District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy* published under the Global District Energy in Cities Initiative, of which C40 is a partner. This Good Practice Guide focuses on the key elements to successfully deliver district energy in cities, with a survey of best practices leading to better economic, social, and environmental outcomes for cities:

- **Set long-term targets for low-carbon energy and GHG emissions reduction**
- **Build public awareness and support**
- **Conduct energy mapping to identify appropriate opportunities for district energy**
- **Identify appropriate ownership models for implementing district energy systems**
- **Develop supportive policies and enabling tools**
- **Convert legacy district energy systems from fossil fuels to low-carbon sources**

The C40 District Energy Network was established to support cities in sharing experience to help mainstream policies and actions to reduce emissions by promoting low-carbon district heating, cooling and combined heat and power (CHP) systems.

The purpose of this Good Practice Guide is to summarise the key elements of district energy good practice for global dissemination, highlighting the success of C40 cities in planning and delivering low-carbon district energy systems.

1 BACKGROUND

1.1 Purpose

The C40 Cities Climate Leadership Group has developed a series of Good Practice Guides in areas critical for reducing GHG emissions and climate risk. The C40 Good Practice Guides provide an overview of the key benefits of a particular climate action and outline successful approaches and strategies cities can employ to effectively scale up these actions. These Guides are based on the experience and lessons learned from C40 cities and on the findings and recommendations of leading organisations and research institutions engaged in these areas.

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1.2 Introduction

Cities worldwide account for over 70% of global energy use and 40-50% of GHG emissions[iii]. In several cities, heating and cooling represent up to half of local energy consumption and, with projected urban growth, there will be increasing pressure on these key infrastructures. Any solution for the climate and energy transition in cities must integrate sustainable urban heating and cooling, as well as electricity. One of the least-cost and most efficient solutions in reducing GHG emissions and primary energy demand is the development of modern efficient, climate-resilient and low-carbon district energy in cities.[iv] The importance of district energy is increasingly being recognised globally, including in the European Union Heating and Cooling Strategy,[v] during LPAA events at COP21,[vi] and in the Sustainable Energy and Cities Energy Thematic meeting for Habitat III.[vii] Additionally, the 2015 New Climate Economy Report, *Better Growth, Better Climate,* by the Global Commission on the Economy and Climate also incorporates among its key recommendations to "develop low-carbon urban development strategies by 2020" and "invest at least US$1 trillion a year in clean energy", both of which provide further support to district energy.[viii]

2 DISTRICT ENERGY AND CLIMATE CHANGE

2.1 What is district energy?

District energy systems provide heating, cooling and potentially power from a central plant or a complex of distributed sources to many buildings – often in a neighbourhood, downtown district or campus – via a network of underground pipes. Without individual boilers or chillers, buildings connected to a district energy system benefit from increased energy efficiency, fuel flexibility brought on by economies of scale, and additional productive space in buildings. The improved efficiencies and potential for low-carbon fuel sources in district energy systems make them a key part of climate change and renewable energy strategies in many cities.

District energy is a proven energy solution, with its roots tracing back to heating greenhouses and thermal baths of ancient Rome. Since the launch of the first commercially successful district heating system in the US in the 19th century (steam heat system, temperatures below 200°C), many have been implemented in a growing number of cities around the world. They were first used as a response to energy shortages, fuelled by coal and oil-fired central heat generation (pressurized hot-water system, temperatures 100-200°C) but progressively converted to combined heat and power (CHP) [ix], biomass and renewable generation in search for greater efficiency and sustainability. Today, in some European and particularly Scandinavian cities, such as Copenhagen or Helsinki, almost all required heating is provided through low-carbon district energy networks. More recently, demand for district cooling is also rising, along increased urbanisation in hotter climates. District cooling works on a similar principle as district heating but delivers chilled water to buildings to substitute for less efficient traditional air-conditioning and chiller units.

2.2 What constitutes a modern district energy system?

Modern district energy systems supply heating and cooling services using modern technologies such as CHP, heat pumps, thermal storage, “waste” heat from industrial processes, geothermal, anaerobic digestion and decentralized renewable energy. Natural gas might be required to support district energy systems initially -- for instance in cases, where renewable energy is not yet competitive with gas -- but thanks to their flexible design and scale, district energy systems can be readily adapted for a switch to low-carbon sources, which is the final goal for many C40 cities. Overall, district energy systems are essential to support a transformational shift towards efficient, low-carbon, resilient and ultimately lower-cost energy in cities and can be integrated with other municipal systems, such as power, sewage treatment, sanitation, waste management and transport.

2.3 Transition to low-temperature networks

For a number of leading cities, the ultimate ambition for their district energy systems is a transition to low temperature networks, also referred to as "4th generation" systems[x], which operate at temperatures around or lower than 60°C. Many existing district energy systems fit into the "3rd generation" category; these systems operate at temperatures below 100°C, often have pre-insulated pipes, use traditional thermal plants as well as industry surplus heat, and rely on metering and monitoring to optimize heat delivery. The 4th generation systems integrate two-way district heating and cooling, use smart energy management (optimizing supply, distribution and consumption) and rely uniquely on renewable or secondary heat production.

4th generation district energy systems are being implemented in several cities around the world, including London[xi], UK (transition to low-grade waste heat sources in Bunhill Heat and Power network), Reykjavík[xii], Iceland (low-temperature geothermal district heating), Drammen[xiii], Norway (low-temperature district heating system fuelled by stable-temperature water from nearby fjord), Tokyo[xiv], Japan (using waste heat, heat pumps and solar), or Seoul[xv], South Korea (inter-municipality cooperation on transmission of waste heat for district energy).

2.4 Benefits of district energy

An increasing number of cities around the world (see case studies below) have developed, upgraded or are planning for a modern integrated district energy network to reap its multiple benefits, from economies of scale and flexibility, to greater energy efficiency, grid balancing and easier integration of renewable sources.

Recent research by the UNEP[xvi] in collaboration with ICLEI, UN Habitat and Copenhagen Centre on Energy Efficiency as part of the District Energy in Cities Initiative, examined global evidence and 45 in-depth case studies of district energy systems in Europe, Asia, North America and Africa. Their findings are supported by multiple case studies and examples emerging from across C40 cities, some of which are also referenced below. Based on those, a set of main district energy benefits was identified:

- Energy efficiency improvements
- Lower-cost integration of renewables and GHG emissions reductions
- Pollution reductions
- Resiliency and energy security
- Green growth

Energy efficiency improvements: District energy systems typically reduce primary energy demand in heating and cooling by 50% by by using low-grade energy sources, co-producing heat and electricity, and utilizing thermal storage, which helps to smooth the demand. District energy systems can also achieve operational efficiency of up to 90% through use of district energy infrastructure to link the heat and electricity sectors. In addition, the flexibility of district energy networks allows for their growth over time and switching to modern energy sources. For instance, cities such as Vancouver [xvii] or Cambridge, Massachusetts [xviii] are transitioning from traditional legacy steam heat systems to modern low-carbon district energy networks. In Dubai (United Arab Emirates), integrating cooling into the district energy system can generate an additional 50% reduction in electricity use. District energy systems can also greatly improve the operational efficiency of buildings, in particular those with that are relatively energy efficient, for which connection to a district energy system can be more cost-effective than a full retrofit (Frankfurt, Germany[xix]).

Lower-cost integration of renewables and GHG emissions reductions: District energy systems are among the most effective ways of integrating renewable energy into urban heating and cooling sectors. Economies of scale allow better balancing of peak demand and supply and the use of thermal storage can offset intermittency of renewable sources. District energy systems can directly use a range of renewable energy options for heating and cooling, including: geothermal; waste-to-energy; biomass; anaerobic digestion; waste heat recovered from sewage; co-generation (CHP); solar thermal; excess PV; wind or wave electricity powering heat pumps; industry surplus heat; and free cooling water from oceans and lakes. Higher efficiency and use of cleaner energy in modern district energy systems also lead to considerable and cost-effective GHG emissions reductions.[xx]

Pollution reductions: By switching to cleaner fuels and reducing energy consumption, cities can also reduce indoor and outdoor pollution (SO_2, NO_x, particulates). This is particularly important in emerging cities, such as in the Beijing-Tianjin-Hebei region of China, where air pollution is primarily linked to extensive coal use, including for power generation, heating, and heavy industry.[xxi] Another Chinese city, Anshan, aims to limit use of heavily polluting coal by a projected 1.2 million tons per year through connecting its district energy networks and capturing 1 GW of waste heat from a local steel plant.

Resiliency and energy security: District energy can increase energy security through reduced import dependency, lower vulnerability to fossil fuel price volatility (illustrated by Gothenburg's expansion of district heating after the 1970s oil crisis[xxii]) and availability of local district energy networks in emergency situations when central generation fails (such as the systems serving New York University and Co-Op City in New York that continued to function during Hurricane Sandy in 2012[xxiii]). With the right governance framework, district energy can also empower communities to take control of their local energy supply and demand, leading to greater ownership and efficiency. Introducing district cooling networks can also lead to lower consumption of fresh water in comparison with conventional cooling systems.

Green growth: By making heat production highly efficient and connecting it to waste-to-heat and renewable energy use, district energy brings along cost savings from avoided investment in peak power capacity, individual generation infrastructure, fossil fuel imports and landfill expansion (if non-recyclable waste is not incinerated or not used in anaerobic digesters).

Furthermore, district energy can create additional income opportunities as interconnected networks allow for sharing excess energy capacity and a municipal ownership district energy model can bring additional dividends to the local government. Introducing district cooling networks can also lead to lower consumption of fresh water in comparison with conventional cooling systems. Finally, district energy sustains local jobs for design, construction and maintenance of the system. For example, the employment benefits from district energy in Oslo[xxiv], Norway are estimated at 1,375 full-time jobs.

2.5 Challenges to delivering successful district energy systems

There are a number of challenges that local governments might face when developing district energy systems, including:

Significant upfront costs: Developing new district energy systems has high upfront costs, which can be challenging for local authorities raising internal capital or seeking to attract private energy utility interest if the customer base has not been secured. The high upfront costs (CAPEX) stem from the significant infrastructure that needs to be built in case of new systems (distribution and connection pipes, thermal plants and storage, connection to electricity network in case of CHP plants), as well as associated development costs (permitting and feasibility studies).

Complex project development process: The presence of multiple and diverse stakeholders (customers, energy utilities, developers) that need to sign-up and commit to developing a strong district energy business case, a "champion" – often the local government - is required to help develop a customer base (likely critical for private utility investment), coordinate planning and oversee the permitting process. Given that many district energy systems are being established in areas with rapid development or re-development, this increases the time pressure on the generally slow district energy process (customer commitment/project development cycle). In addition, securing stakeholder cooperation might be difficult if the fuel mix is not green enough or if the risk is perceived as too high and/or incentives (such as density bonuses) as too low.

Regulatory and market barriers: On top of high-upfront costs and complex project planning, local governments might also be constrained by limited regulatory powers in the energy sector (e.g. being unable to mandate heat network connections or reform grid access and interconnection regulations to promote CHP) or by having limited or no stake in local utilities that would enable them to influence the business planning. District energy projects might also face challenges from existing market structures or pricing regimes that disadvantage district energy systems or their fuel sources relative to other technologies, such as a lack of supportive electric utility feed-in tariff schemes.

Limited capacity and public awareness: Developing new district energy systems or scaling-up the existing ones can also be challenging due to limited recognition of district energy's environmental, social, health and comfort co-benefits; insufficient local government capacity (including a lack of experience or resources for conducting feasibility studies); and lack of awareness or understanding of district energy amongst the public and potential customers.

Lack of integration with building policies, standards, ratings and certification frameworks: Many existing building policies and rating systems focus on individual building solutions, rewarding onsite production of heating/cooling rather than considering system efficiency. Furthermore, many of these frameworks do not account for or reward the near-term potential for district energy systems' complete conversion to low-carbon energy sources (i.e. fuel switching). For instance, many energy efficiency ratings (e.g. LEED) are based on energy consumption of individual buildings, without accounting for renewable or highly efficient energy production that complements any non-renewable sources in the district energy system. This creates a disincentive for district energy development and contradicts energy targets that encourage its deployment.

However, these challenges can often be overcome through inventive solutions, cooperation, coordination, and the planning and management best practices listed in Section 3 below.

3 GOOD PRACTICE APPROACHES FACILITATING DISTRICT ENERGY DEVELOPMENT

3.1 Categories of Good Practice

Within the C40 District Energy Network, at least six different but often complementary management approaches have been identified for developing sustainable district energy systems:

- Set long-term targets for low-carbon energy and GHG emissions reduction
- Build public awareness and support
- Conduct energy mapping to identify appropriate opportunities for district energy
- Identify appropriate ownership models for implementing district energy systems
- Develop supportive policies and enabling tools
- Convert legacy district energy systems from fossil fuels to low-carbon sources

3.2 Set long-term targets for low-carbon energy and GHG emissions reduction

By setting a clear vision and targets, local governments can build awareness and encourage support for the development of district energy systems. Articulating district energy, renewable energy, distributed generation and/or CO2 emissions reduction targets not only provides clear long-term guidance and focuses political attention, but can also help overcome conflicting interests in different city departments and prioritise policies, as shown not only in Paris' case study, but also others, particularly London (see Section 3.4.2), Oslo (see Section 3.6.1), Copenhagen (see Section 3.6.2), and Vancouver (see Section 3.7.1). This is why an energy strategy addressing the heating/cooling sector that links to broader energy or CO2 targets, identifies synergies with land-use and infrastructure planning, and communicates the benefits of district energy to customers/the public is critical.

Case study: *Paris - Climate and Energy Action Plan*

Summary: Paris developed district heating in 1927 to overcome air quality and fuel delivery issues. Today, large portions of the city are connected to district heating, including 50% of social housing, all hospitals and 50% of public buildings, delivering the heat-demand equivalent of 500,000 households. In early 1990s, Paris also developed the first district cooling network in Europe (Climespace), which uses from the Seine River and other sources for cooling and requires 50% less primary energy than traditional systems. At the same time, district energy is part of Paris' core strategy to help achieve the 75% reduction in CO2 emissions by 2050 defined in the Climate and Energy Action Plan (2012)[xxv]. To guide its district energy development and modernization, Paris set clear targets for district energy systems, providing longer-term vision and security for local planners, investors, developers and consumers.

Results: Paris' district energy targets are articulated in its updated Climate and Energy Action Plan (2012). The district heating network should use 60% renewable or recovered energy by 2020, sourced primarily from local energies (geothermal, solar thermal, solar PV, waste-to-energy and heat recovery from industry, drains, metro, etc.), with potential evaluated at 367 GWh in 2020. Additional local energy systems should also be built in new development districts, mainly by creating hot water loops fed by geothermal energy. Paris plans to draft a comprehensive heating master plan by 2022, in particular exploring options for connecting smaller district energy networks and allow for further integration of renewables. Already today, 50% of Paris is heated by three waste-to-energy plants, which alone avoid the emission of 800,000 tons of CO2 annually. The number of heat recovery installations should increase by 1,500 (37.3 GWh) by 2020.

Reasons for success: The drivers for Paris' target setting include the ambitious national and local climate change targets; strong regulatory experience that provides confidence in the targets and the local government's commitment to achieve them; and the rich endowments of local natural renewable resources, such as geothermal, which can be developed cost-effectively.

When/why a city might apply an approach like this: Cities without ambitious national targets can define local targets to help streamline district energy into urban planning and create a more stable policy environment to promote investor confidence. In cities with limited recent district energy experience, these targets can be particularly useful in focusing political attention and generating the necessary momentum for district energy development and conversion.

District energy or distributed generation targets can also be used to articulate the way forward for cities seeking to meet a citywide C02 emissions reduction target.

3.3 Build public awareness and support

Local city governments have an important role to play in raising awareness and understanding of district energy and its benefits, as well as in building confidence among stakeholders and investors. There is a broad range of tools a city can use to target broader public and residents, such as education campaigns through workshops, webinars, public media or dedicated websites; competitions and awards; reports, data gathering and publications; information centres; and demonstration projects. In addition, private-public partnerships and professional networks are essential to help mainstream district energy. Highlighting the resiliency benefits of district energy can be particularly useful for building public support in certain cities.

Case study: *Milan - Energy Help Desks*

Summary: In Milan[xxvi xxvii], developing and expanding the district heating network does not require as much a municipality-led infrastructure overhaul as it does cooperation from private building owners. This is because many buildings in Milan already have a building-wide central heating system, only requiring substitution of the existing boiler by a heat exchanger and connection to the network. This shift is directly cost-effective and has a short payback time (4–5 years) if replacing a diesel boiler. Previously, regional subsidies supported the switch from diesel oil to district heating, but thanks to decreasing prices of new technologies and stable or higher fuel prices, the switch is now cost-effective enough and is also generally offered by energy suppliers through energy service contracts. However, communication and awareness-raising of district energy and its benefits are key for building customer trust in these energy suppliers and obtaining the energy service agreements.

Results: Milan promotes the district energy and energy efficiency retrofits through its Energy Help Desks that are run by the municipality as an information service to current and potential customers. Energy experts are available in city districts' offices and help address any questions about potential energy service interventions, as well as available incentives and financing options for district heating, renewable energy and energy efficiency. In addition, a central office uses public information campaigns to counter the image of district heating as an inefficient and outdated technology and instead promotes it as a critical modern energy system for reducing carbon emissions and reaping other environmental benefits. To date, around 150,000 apartments in Milan are connected to the district heating network, with 150,000 expected to be connected in 2020[xxviii].

*Reasons for success***:** The success of Milan's awareness-raising approach is driven by a strong partnership with the energy utility and energy service providers, providing customers an "offer you cannot refuse". The help desks provide concrete information and responses to practical and technical questions, helping build trust in district heating and the retrofit/connection process.

When/why a city might apply an approach like this: Cities with limited experience with district energy – or with a legacy system that has a poor track record – should consider pro-actively educating stakeholders about district energy and its benefits before, during and after project development. By engaging developers and individual customers through information campaigns and awareness-raising efforts, the city and its utility partners can build their confidence in service providers and facilitate network connections.

3.4 Conduct energy mapping to identify appropriate opportunities for district energy

In order to identify the most cost-efficient, scalable or inter-connectable district energy project opportunities, leverage the city's land-use authority, facilitate public private partnerships, and raise public awareness, leading cities around the world develop comprehensive energy mapping tools. Energy mapping also helps identify current and future heat flows, supply and demand loads (high-density/high-demand areas) and potential for interconnections or adaptation of old heating systems.

Case study: *Amsterdam - Energy Atlas*

Summary: In Amsterdam, 70% of end-users must agree to a changeover to district heating, which drives the City of Amsterdam to focus on tools that facilitate the involvement of both end-users and private sector stakeholders (housing authorities, energy companies, developers) in developing urban energy plans. Amsterdam developed an open-source Energy Atlas to provide detailed information on the geographical distribution of energy demand and potential supply (thermal production, geothermal, industry and private buildings' waste heat) and a basis for local energy strategies; to enable implementation of the right combination of measures and technologies based on scenario modelling; and to help build the business case for district heating, cooling and power.

Results: Amsterdam launched its Energy Atlas[xxix] in April 2014, the result of collaboration with local stakeholders, including businesses and property owners. The Atlas is a multi-layered energy-GIS tool with a software decision-support system[xxx] that enables 'what-if' scenarios for improved urban planning. As a flexible modern mapping tool, it can be continuously updated or expanded. It also helps generate enthusiasm for district energy projects by providing detailed open information, and unveils collaboration and cooperation opportunities by bringing together different stakeholders interested in district energy development and providing them with concrete matchmaking opportunities.[xxxi]

Using the Energy Atlas has already enabled Amsterdam to transform Zuidoost, an existing 300-hectare mixed-use area, and to establish cooperation among various industrial partners on the exchange of energy and the use of excess waste heat from data centres. Amsterdam is currently replicating the positive experience from Zuidoost in order to advance district energy opportunities in other communities.

Reasons for success: The success of Amsterdam's energy mapping was based on strong regulatory framework (i.e. district-connection targets and a connection mandate for all new developments); partnership with other utility providers (e.g. the water network), city monitoring departments and developers on sharing data (driven by partners' demand for the energy utility data once project finished); and public support driven by demand for open-source data that could facilitate cooperation between stakeholders on saving energy and financial resources.

Case study: *London - London Heat Map*

Summary: To facilitate achievement of its goal of having 25% of energy supplied by decentralized sources by 2025, the Greater London Authority developed the Decentralised Energy Master Planning (DEMaP) district energy programme, which ran from 2008-2010, with funding of €3.3 million (US$3.7 million). It focused on identifying opportunities for district heating networks through heat mapping and energy masterplanning as well as building capacity within local authorities to deliver district energy projects and develop planning policies that encourage, and where appropriate require, district energy in new developments. The main output of the programme was the London Heat Map[xxxii], which showcases potential heat supply, demand and network opportunities for district energy across the city.

Results: The London Heat Map is an interactive GIS tool that allows users to identify opportunities for decentralised energy projects in London. The Heat Map provides spatial intelligence on factors relevant to the identification and development of district energy opportunities, such as: location of major energy consumers, local and city-wide fuel consumption and CO_2 emissions, energy supply plants, community heating networks, and heat density. It is publicly accessible to anyone with an interest in district energy. Local authorities can use the map as a starting point to developing detailed Energy Master Plans to inform district energy policies in their Local Development Frameworks and climate change strategies. Developers can use the map to monitor compliance with the London Plan district energy policies (connection into an existing network or extending their own communal heating networks beyond their site boundaries). In addition, the periodically revised 'London Heat Network Manual' [xxxiii] provides practical guidance for local authorities, energy service companies, developers, network designers and planners on the development and delivery of heat networks in London.

Based on opportunities identified through the London Heat Map, London is already developing a number of district heating projects, such as the Lee Valley Heat Network, which aims to provide over 5,000 homes with required heating and hot water through harnessing waste heat sourced from a nearby EcoPark. On the city-level, London has continued with the Decentralised

Energy for London programme, providing assistance for commercialisation of large decentralised energy projects, primarily looking at district heating schemes supplied from CHP and waste heat.

Reasons for success: The success of London's energy mapping approach is based on the city's rich planning and monitoring experience, as well as availability of multiple communication platforms that facilitate reporting from building owners and public disclosure.

When/why a city might apply an approach like this: Comprehensive energy mapping, although often cost- and planning- intensive, is a crucial stepping-stone for city-wide development of district energy systems. It provides a critical overview of demand and supply to help guide district energy network prioritisation and maximise renewable energy – like waste heat and free cooling – sources. For cities that have recently started district energy planning, energy mapping provides multiple benefits, from comprehensive information to establishment of initial relationships with building owners during information gathering, which might facilitate later development of district systems. Cities that are hoping to support other local and regional authorities to pursue district energy systems will find energy mapping to be an important enabling tool.

3.5 Identify appropriate ownership models for implementing district energy systems

Public sector involvement – whether as local policymaker, urban planner, regulator or consumer, or more directly through partial or full ownership of projects – can be critical in coordinating and facilitating often complex district energy projects, even if there is a high degree of private sector control. Identifying appropriate business models and ownership structures based on a city's resources, capacity, regulatory authority, and external market conditions is key for delivering district energy projects. There are three main types of ownership models, distinguished by the relative involvement of public or private sectors. The choice of the model depends in principle on the return on investment for project investors and the degree of control and risk aversion of the public sector. Different public or private ownership structures might be appropriate for different district energy projects within the same city.

In the most common, "**wholly public**" business model, the local authority or public utility has full ownership and control of the system, which allows it to deliver broader environmental and social objectives, for example through renewables connection mandate, tariff control or preferential connection of social housing. The local authority also receives all the profits from the project, which can then be reinvested. In the case of district energy projects with attractive return on investment for the private sector, the "**hybrid public-private**" model might be appropriate. The local authority and private sector share a common vision and objectives and clearly defined parameters for risk allocation (agreed at project's conception), while the public sector keeps some control over the project and the private sector brings in expertise and private capital. If a district energy project has high return on investment (usually between 12 and 20%, or 9.5% for lower-risk projects), and the city is highly risk-averse and does not aim for high control, it may adopt the **wholly-privately owned Special Purpose Vehicle** business model.

Fitting the business model to the local situation is vital and the wide range of business models across cities worldwide is testament to this. As shares of district energy are accelerating, a shift in business model types is being realised, with more stakeholders involved, connecting ever more innovative heat and cool sources to the district energy infrastructure. Project developers and city authorities can develop or adapt business models to incorporate these new supplies, as has been seen in cities such as Helsinki, London, Oslo, Tokyo and Seattle.[xxxiv]

Case study: *Vancouver - South East False Creek Neighbourhood*

Summary: In 2010, Vancouver created the South East False Creek Neighbourhood Energy Utility (SEFC NEU),[xxxv] which represents the "wholly public" business model. It manages a district heating network largely based on renewable sources. The network is currently fuelled by waste heat from an expanded sewer pump station located within the NEU Energy Centre, but is designed to integrate future sources of renewable energy sources and waste heat. There were three main reasons that led the city to choose the "wholly public" business model. As the project had to be launched before the 2010 Winter Olympics, the development schedule was insufficient to secure a private utility and the related approvals. The public-led project was also an opportunity to demonstrate the commercial viability of modern district heating, as at the time of the initial project the private sector had not shown interest in or capacity to develop low-carbon district energy systems (a condition that has since changed). Additionally, the city had strong access to low-cost loans and was successful in securing grants.

Results: When the system became operational in 2010, the municipality controlled 17% of the initial system load (25% of the floor area), but it was able to pass a service-area bylaw to guarantee connection of the additional loads. The network is publicly owned, which allows for transparent connection costs and energy tariffs, enabling the city to provide information on tariff cost and savings comparisons to building owners (e.g. savings from not having on-site boilers). This helped to build confidence and encouraged new connections from residents and private developers. The total cost of the project (CAD$32 million, i.e. US$31 million) was fully covered through utility customer rates and the utility was entirely financed by city-raised debt; however, the debt was structured as if the project was financed by 60% debt and 40% equity to demonstrate commercial viability to the private sector and give the city the option to divest in the future without impacts on customer tariffs. The SEFC system has grown its customer base by 260% since 2010. The SEFC's district heating network, conceived as a demonstration project, motivated the private development of an additional network, as well as plans for two legacy steam-heat systems' conversion from natural gas to renewable sources. Today, most of the new district energy investment in Vancouver is coming from the private sector, typically via a franchise agreement with the city to secure low carbon outcomes.

Reasons for success: Vancouver was able to adopt the "wholly public" model thanks to its strong access to low-cost finance and its ability to secure grants, which enabled it to implement the project without initial private investment and gave it the opportunity to carry out an innovative demonstration project that could be later replicated by private developers. The impending 2010 Winter Olympics also assured broader municipal backing for the project and its "wholly public" approach as the best way to guarantee successful delivery.

Case study: *Toronto - Enwave Energy Corporation*

Summary: In Toronto, the "hybrid public-private" business model served as the catalyst for implementing the city's deep-lake-water cooling system, planned since the early 1980s but challenged by lack of major private investment. The opportunity came when too much silt in drinking water extracted from Lake Ontario led the city to plan for a deeper, longer pipe to reduce filtering costs. Such a pipe, reaching the depths of the lake with stable low temperatures (4°C), could also serve for the deep-water cooling system. This created an incentive for the city to partner with the company Enwave through restructuring of the originally non-profit publicly owned Toronto District Heating Corporation that had restricted powers in securing long-term financing.

Results: Enwave's Deep Lake Water Cooling[xxxvi], integrated with the city's drinking water system, became operational in July 2004 and is the largest district cooling system from a renewable resource in North America, with 50 customers signed-on and 30 large commercial bank and data-centre buildings connected (3.2 million m^2, 75,000 tons of refrigeration equivalent). It also enhances the supply of potable water with a clean water source, decreases electrical demand and consumption, increases employment opportunities, and helps businesses and Toronto residents reduce greenhouse gas emissions and improve outdoor air quality. Enwave Energy Corporation originally had two shareholders − the City of Toronto and the Ontario Municipal Employees Retirement System (OMERS) – with a 43% and 57% share respectively. The City Council and OMERS have recently exited the project, selling Enwave for CAD$480 million (US$429 million), which resulted in a net profit of CAD$100 million (US$89 million) for the Toronto City Council.

Overall, the public-private partnership helped the long-planned project to reduce risk and secure financing. First, the partnership helped uncover the total benefits to the city, such as financial and environmental savings, which enabled the regulators to grant Enwave an exemption from water extraction fees (in particular as Enwave only extracts the cold from the water, not the resource itself), which was key for ensuring project's commercial viability. Second, the partnership helped develop a customer base, as the local government backing and awareness-raising about district cooling benefits contributed to increased confidence among potential customers and their signing of the required long-term contracts (some of nearly 20 years).

*Reasons for success***:** The success of the private-public partnership was driven by an early recognition of opportunity for partnership through connection of the drinking water and water for cooling supply. The involvement of the City of Toronto as investor and promoter helped create confidence in the project. The adaptation of local regulations (i.e. exemption from water extraction fees) also helped ensure the project's viability, while securing long-term benefits for the City of Toronto as well as revenues from the project's later privatization.

When/why a city might apply an approach like this: Based on the city characteristics, including regulatory powers, financing capacity, risk tolerance and the degree of access to low-cost finance, the city can choose the right ownership structure and business model. The wholly public model is particularly suitable for cities with strong financing capability, whereas the hybrid public-private and wholly private models enable cities to leverage private investments with lower risk to the municipal government, while keeping a certain degree of involvement in or oversight of the project.

3.6 Develop supportive policies and enabling tools

Supportive policies and enabling tools are key for district energy systems' development, especially to ensure a financially viable business model. Their impact is usually the highest if they can be integrated into an energy plan and urban planning frameworks. Moreover, district energy systems are most viable in high-density (compact) and mixed-use areas, containing many types of energy consumers (commercial, residential, public buildings) in close proximity, with varied demand profiles creating smoother and less-profiled energy demand than if buildings are zoned separately. More compact land use reduces the network costs significantly (e.g. cooling demand spread over a 100 km network has network costs over two times greater than a similar demand across 33 km of network[xxxvii].

In addition to mixed-use zoning policies, local authorities with stakes in municipal utility can directly mandate the use of recovered or renewable heat or prioritize socially optimal connections in order to achieve public policy objectives. Cities with strong regulatory powers can also introduce a range of policy interventions to support development of district heating or cooling, such as: mandate water-based heating or cooling systems for new developments; mainstream energy criteria in urban planning documents; plan for future energy infrastructure to meet growth and revitalization works; allocate exclusive franchise licences; and establish tailored connection policies. Different models exist which vary based on the targeted end-user, city area, connection criteria, policy intervention such as: mandatory connection enforced in service/franchise areas; for commercial or public buildings; for new developments; in all city areas; or 'connect unless' policies which require developers to connect to and use the district energy supply unless it is proven that this is not economically or technically feasible against specific "viability criteria."

Other tools for encouraging connections include: a) density bonus (extra development space for developers in exchange for district energy connection) or collateral development fees reduction (right-of-way, soil displacement permits, etc.); b) guaranteed load or compensatory payments to a private district energy utility by local government; c) banning undesirable carbon- or energy-intensive technologies for heating (e.g. oil-fired boilers, electric heating); d) regulated, transparent and competitive tariffs to encourage voluntary connection; e) rezoning or permitting processes with preference for district energy-ready buildings; f) buildings' compatibility mandate for district-energy readiness; g) local green building standards that account for district energy; h) partial or full subsidy covering connection costs; and i) land-lease models.[xxxviii]

Case study: *Oslo – Broad set of supportive tools*

Summary: Oslo has set itself an ambitious target of 50% CO2-emissions reduction by 2030 and carbon neutrality by 2050. One of the main measures the city is pursuing is "phasing out fossil fuels for stationary heating", in parallel with the modernisation of the district energy system, which attracted extensive investments over 2006-2013. The district heating network currently covers 20% of the city's total heating demand (1.7 TWh), with almost 60% of heat production coming from waste incineration, heat pumps from sewage and biofuel plants. Oslo is also planning for low-temperature networks (receiving heat from ice arenas, data centres, stores, air-conditioning, solar heating, etc.) to be potentially integrated with the existing high-temperature network. To support the development and modernization of its district energy, Oslo has implemented a wide range of policies and enabling tools.

Results: Oslo's use of various policies to encourage connections is supporting the expansion of the district heating network.[xxxix] [xl] The city mandates that all municipal buildings that have the ability to connect to a district heating system do so, unless they can prove their current energy use has lower CO2 intensity than the district energy option (this is a "connect unless" policy, which is different than for example CPH mandatory connect policy). To ensure that end-users who are mandated to connect are not disadvantaged, tariffs are regulated to be lower than those for similar technologies. Oslo also encourages private building owners to connect to the network. Streamlined rezoning and permitting processes give preference to developers that design buildings to be district energy-ready. Similarly, the location specific sole-supplier franchise licences allocation, driven by the national policy and objective to expand district energy by 10TWh by 2020, helps de-risk private investment, and enables local authorities to mandate connections for the specific developments and protect consumers by establishing service standards and regulating tariffs. Oslo is also advocating for a national policy on zero fossil fuel consumption in buildings to support the city's forward-looking green agenda and expansion of the district energy network. Finally, Oslo is using its Climate and Energy Revolving Fund as an additional enabling tool, providing subsidies and low-cost financing for, among others, district energy projects. Established in 1982 and originally funded through a surcharge on electricity, project financing now comes from the interest on the existing fund. In 2012, the fund supported 2,592 climate and energy efficiency projects, with half of the funding directed to new renewable energy projects, such as heat pumps, district heating, bioenergy and solar power.

Reasons for success: The relatively strong regulatory powers of the local government enabled Oslo to adopt mandatory connections policy for public buildings. However, the success of other innovative policies and tools was based on recognition of opportunities for the local government to use crucial points of urban development planning to support the district energy business case (i.e. preferential permitting process, specific franchise license allocation, grants from the Revolving Fund, etc.).

Case study: *Copenhagen – Supportive policies*

Summary: In Copenhagen, the district heating system[xli] was intensively developed in the 1970s as a way to protect citizens and the economy from the dramatic rise in fossil fuel prices. Today, 98% of heating is supplied by modern district heating networks, which not only produce 40% less carbon emissions than individual gas boilers and 50% lower than oil boilers, but also save the city money. In 2009, Copenhagen Energy, which manages the city's district heating network, estimated that district heating costs for a typical home were around 45% of those for oil heating and 56% of natural gas for a typical home. The unprecedented coverage and effectiveness of the network is in large part due to enabling policies developed at the national and local level.

Results: The introduction of supportive policies dates back to 1979, when the national Heat Supply Act required local authorities to provide a regional heat plan. This spurred a wave of zoning and land-use planning, especially as the local authorities were newly enabled to mandate connections to the networks. The Copenhagen Heat Plan (1984) introduced new CHP units and, in 1980s, further policy measures were put in place: high levels of taxation of fossil fuels; requirement for utilities to provide at least 450MW of electricity via decentralised CHP (1986); and ban on electrical heating in new buildings (1988, extended to existing buildings in 1994) that led to expansion of consumer base for district energy utilities. As environmental concerns became more prominent in early 1990s, two CHP plants were converted from fossil fuels to biomass and the waste-to-energy share increased to the current 30%. A new planning system (1979) mandated local authorities to oversee conversion of all heat production to CHP. In 1992, subsidies for renewable electricity production were extended to CHP and gas, later replaced by an electricity transfer surcharge. Starting in 2016, Copenhagen will not allow new or old oil-fired installations in areas where district heating or natural gas networks are available. To provide a long-term vision for district energy networks, Copenhagen also integrated specific targets into its CPH 2025 Climate Plan, which sets down guidelines for achieving carbon neutrality by 2025. By 2025, Copenhagen should have a 100% share of renewable energy and waste-incineration heat in the district heating system (up from 35% today)[xlii].

Reasons for success: The success of enabling policies in Copenhagen (98% average connection to an increasingly low-carbon network) is driven by the integrated, consistent, coordinated and long-term heat-planning framework, which allows for exploring enabling policies' synergies and for reducing real and perceived risk for investors. General public support for CO2 emissions reduction also enabled the city to implement policy mandates (e.g. heat production conversion to CHP, ban on oil-fired installations).

When/why a city might apply an approach like this: Cities with strong regulatory powers can adopt this approach to ensure the commercial viability of their district heating projects. Those with the strongest authority, and potentially supportive national policies, could consider a mandatory connections policy to drive district energy development and expansion. Cities without that authority could still consider using their land use, zoning and other policies to facilitate district energy development. Adopting enabling policies and tools can also substitute for subsidies or other financial support to district energy utilities, in particular through helping to secure the costumer base for district energy projects.

3.7 Convert legacy district energy systems from fossil fuels to low-carbon sources

Converting legacy steam systems to low-carbon energy sources offers a district energy "quick-win" because it enables fuel switching across a large number of buildings and requires lower levels of investment since most network infrastructure is already in place. Similarly, interconnecting new systems with legacy district energy systems might bring additional benefits, such as better heat and cooling demand balancing, enabling easier integration of renewable sources.

Case study: *Vancouver - Neighbourhood Energy Strategy*

Summary: District energy is today a major part of Vancouver's effort to reduce its carbon emissions by 33% by 2020 from a 2007 baseline. The city aims to achieve a district energy target reduction of 120,000 tonnes of CO2 emissions per year by 2020 as outlined in its Greenest City Action Plan. Driven by these targets, Vancouver has developed a Neighbourhood Energy Strategy (NES) and supporting Energy Centre Guidelines to help the city convert legacy steam heat systems to lower carbon fuel sources (delivering an estimated 95,000 tonnes CO2 emissions reduction) and promote development of new low-carbon systems in high-density areas of the city (delivering an estimated 25,000 tonnes C02 emissions reduction).

Results: Target areas viable for NES implementation were identified in an energy mapping exercise based on the location of existing and proposed heat systems, existing and projected development density and major development projects, as well as the potential for existing buildings heated by natural gas to be connected to NES. The three key target areas identified in the energy study were Downtown (with a large steam heat system built in 1960s serving more than 210 buildings), the Cambie Corridor (with the opportunity to convert the steam heat systems of two hospital campuses), and Central Broadway (with a high number of potentially convertible natural-gas heated buildings). In addition, five site-scale energy projects as well as two new NES (Southeast False Creek – see section 3.5.1 and Northeast False Creek) are already being implemented in areas with potential large developments.

Reasons for success: Vancouver benefits from having prior steam heat district energy systems in place, which lowers the amount of investment necessary for achieving a modern and low-carbon district heating. The conversion is also greatly facilitated by a clear CO2 reduction target from district energy (120,000 tonnes of CO2 emissions per year by 2020), to which converting the legacy steam system alone will contribute an estimated 80%.

Case study: *Warsaw - Sustainable Energy Action Plan for Warsaw in the perspective of 2020*

Summary: Warsaw's district heating system[xliii] dates back to early 1950s when the 1720km-long network (the largest of its kind in Europe), covering close to 80% of Warsaw's heat demand, was built. Connecting Warsaw's main public buildings (e.g. Parliament, presidential palace) and the city's high-rise blocks of flats, the district heating network has been providing an affordable and more comfortable alternative to the low-tech coal-based and often filterless home stoves still widespread in Poland. Thanks to continuous improvements, in 2009, 90% of the energy produced in the system was from cogeneration, providing up to 30% fuel consumption and CO2 emissions reduction. However, in 2013, the main source of greenhouse gas emissions in Warsaw was still the energy sector (78% of total emissions). The already developed district heating system thus offered a great potential for additional emissions reduction through fuel switching.

Results: Spurred by joining the Covenant of Mayors in 2009 and publishing its "Sustainable Energy Action Plan for Warsaw in the perspective of 2020"[xliv] in 2011, Warsaw started to diversify the fuel sources of its district heating system to include low-carbon sources, retrofit and modernize the system, and support electricity and heat consumption reduction (e.g. by installing individual household meters, refurbishing buildings and creating innovative private-public partnerships). It plans to supply about 50% of the heat from gas, biomass and waste-to-heat sources. Partnership with the private sector and privatization of the network in 2012 (sold to Dalkia, then in 2014 to Veolia) allowed Warsaw to guarantee future investments, while keeping the district heating prices low and attractive to customers (with the lowest prices in Poland). In 2013, Warsaw opened its Czajka Waste Water Treatment Plant[xlv], which now ensures treatment of 100% of the wastewater of Warsaw and produces heat from biogas and sludge and generates electricity for half of street lighting in the City. Warsaw also continues to expand the district heating network, for instance through district heating connections of new revitalization projects (e.g. 2015-2022 revitalization programme of the Praga district with total investment of 130 mln euro).

Reasons for success: Driven by international commitments, Warsaw managed to exploit the potential of the existing district heating network infrastructure, driving down the costs of conversion to low-carbon energies. Privatising the network, while keeping a degree of oversight, also helped the City of Warsaw expand the network in a cost-effective manner and guarantee investments for continuing the conversion to low-carbon energy sources.

When/why a city might apply an approach like this: A city with a legacy steam heating system might adopt this approach to leverage past infrastructure investments and help achieve CO2 reductions more quickly, efficiently and at a lower cost. If the city has a number of smaller legacy steam networks, their interconnections can be exploited to allow for greater integration of low-carbon sources.

4 FURTHER READING

For more detailed information and additional case studies, refer to:

- UNEP (2015) - *District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy*. Available at: www.districtenergyinitiative.org (http://districtenergyinitiative.org//report/DistrictEnergyReportBook.pdf)

For further information on planning, development and delivery of district energy systems, as well as their contribution to green growth and climate change mitigation, refer to:

- USDN (2015). *Multi-User Microgrids & District Energy – USDN Final Report*. Available at: http://www.bostonredevelopmentauthority.org/getattachment/fa993b9a-d3ab-43a2-8981-94a7a49b8a33
- King, M., Bradford, B. (2013) - *Community Energy: Planning, Development & Delivery – Strategies for Thermal Networks*. Available at: http://www.districtenergy.org/assets/pdfs/Community-Energy-Dev-Guide-US-version/USCommunityEnergyGuidehi.pdf
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