DISTRICT ENERGY IN CITIES

Unlocking the Potential of Energy Efficiency and Renewable Energy

UNEP in collaboration with
Cities have a central role to play in the transition to sustainable energy: as managers of interdependent services and utilities, they are uniquely placed to enable the integrated solutions necessary to rapidly advance both energy efficiency and renewable energy. One such integrated solution is the development of modern district energy systems.

Moving to sustainable energy is critical if the world is to achieve its sustainable development goals: from eradicating poverty and social inequality, to combating climate change and ensuring a healthy environment. The United Nations Secretary-General’s Sustainable Energy for All initiative provides a framework for this transition through three complementary objectives: universal access to modern energy services, doubling the global rate of improvement in energy efficiency and doubling the share of renewables in the global energy mix. As cities represent more than 70 per cent of global energy demand, their energy policy responses are crucial to meeting these objectives.

Sustainable energy for cities could mean that socio-economic and environmental burdens such as blackouts, resource price shocks, energy poverty and air pollution are confined to the past. Huge opportunities to lift these burdens exist in cities’ heating and cooling sectors, which can account for up to half of cities’ energy consumption.

The UNEP report District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy identifies modern district energy as the most effective approach for many cities to transition to sustainable heating and cooling, by improving energy efficiency and enabling higher shares of renewables. Countries such as Denmark have made modern district energy the cornerstone of their energy policy to reach their goal of 100 per cent renewable energy, and, similarly, other countries, such as China, are exploring synergies between high levels of wind production and district heating.

Locally appropriate policies are required to harness the multiple benefits of district energy systems, lower upfront costs and reduce financial risk for investors. This publication is one of the first reports to provide concrete policy, finance and technology best-practice recommendations on addressing the heating and cooling sectors in cities through energy efficiency improvements and the integration of renewables, both of which are central to the energy transition. These recommendations have been developed in collaboration with 45 champion cities, all of which use district energy, with 11 of them using it to achieve 100 per cent renewables or carbon-neutral targets.

Port Louis, Mauritius, is developing the first seawater district cooling system in Africa. The state of Gujarat will develop a public district cooling system in India. Cities in West Asia are expanding their district cooling systems. Others in China and Eastern Europe, with high shares of district heating, are modernizing their systems to improve efficiency. Some cities with long-standing district energy systems in the European Union and United States are now integrating high shares of renewables in heating, cooling and power. This report establishes the framework to accelerate these efforts through an exchange of practice. For example, cities ranging from Port Louis to St. Paul or Kuwait City can learn from other cities, such as Hong Kong, Dubai or Paris, while also providing best-practice recommendations that will be relevant to other cities struggling with growing air-conditioning demand.

The barriers to district energy development exist at the local, regional and national levels. UNEP’s partnership with ICLEI – Local Governments for Sustainability, UN-Habitat and the Copenhagen Centre on Energy Efficiency (C2E2) enables this report to provide guidance at all levels of governance. This report is to be commended for its significant and cross-cutting contribution to how we can achieve sustainable energy for all.

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In 2013, UNEP initiated research on and surveyed low-carbon cities worldwide to identify the key factors underlying their success in scaling up energy efficiency and renewable energy, as well as in attaining targets for zero or low greenhouse gas emissions. District energy systems emerged as a best practice approach for providing a local, affordable and low-carbon energy supply. District energy represents a significant opportunity for cities to move towards climate-resilient, resource-efficient and low-carbon pathways.

Among the core components of the transition to a sustainable energy future are the integration of energy efficiency and renewable energy technologies, and the need to use "systems thinking" when addressing challenges in the energy, transport, buildings and industry sectors. Tackling the energy transition will require the intelligent use of synergies, flexibility in demand, and both short- and long-term energy storage solutions across different economic sectors, along with new approaches to governance. This publication, *District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy*, provides a glimpse into what integration and systems thinking look like in practice for heating and cooling networks, and showcases the central role of cities in the energy transition.

The development of modern (i.e., energy-efficient and climate-resilient) and affordable district energy systems in cities is one of the least-cost and most-efficient solutions for reducing greenhouse gas emissions and primary energy demand. A transition to such systems, combined with energy efficiency measures, could contribute as much as 58 per cent of the carbon dioxide (CO2) emission reductions required in the energy sector by 2050 to keep global temperature rise to within 2–3 degrees Celsius.

This publication is among the first to provide concrete policy, finance and technology best practice guidance on addressing the heating and cooling sectors in cities through energy efficiency improvements and the integration of renewables. The recommendations have been developed in collaboration with 45 “champion” cities, all of which use modern district energy, and 11 of which have set targets for either carbon neutrality or a 100 per cent renewable energy supply. This report is also the first to consolidate data on the multiple benefits that cities, countries and regions have achieved through the use of modern district energy, in an effort to support evidence-based policy recommendations and to raise awareness of the significance of the heating and cooling sectors, which have been insufficiently addressed in the climate and energy debate.

District energy is a proven energy solution that has been deployed for many years in a growing number of cities worldwide. In several European cities, such as Copenhagen (Denmark), Helsinki (Finland) and Vilnius (Lithuania), nearly all of the required heating and cooling is supplied via district networks. The largest district cooling capacity is in the United States, at 16 gigawatts-thermal (GWth), followed by the United Arab Emirates (10 GWth) and Japan (4 GWth).

Modern district energy systems supply heating and cooling services using technologies and approaches such as combined heat and power (CHP), thermal storage, heat pumps and decentralized energy. District energy creates synergies between the production and supply of heat, cooling, domestic hot water and electricity and can be integrated with municipal systems such as power, sanitation, sewage treatment, transport and waste. This report provides an overview of the various district energy technologies and their specific applications and costs, in order to help local governments and actors identify the most cost-competitive and appropriate options in their regions. It also highlights the need for dialogue between national and subnational governments and for the development of mutually reinforcing policies.
The ability of district energy systems to combine energy efficiency improvements with renewable energy integration has brought new relevance to these technologies. However, market barriers to greater deployment remain, including a lack of awareness about technology applications and their multiple benefits, a lack of integrated infrastructure and land-use planning, and the lack of an agreed methodology to recognize energy savings and environmental benefits, and the lack of agreed accounting methods to develop efficiency ratings, labels and standards for buildings. Additional barriers include interconnection regulations and grid access limitations, high upfront capital costs, and energy pricing regimes or market structures that disadvantage district energy systems relative to other technologies.

Despite these challenges, cities and countries worldwide have successfully developed targeted measures and policies to support district energy systems, fostering significant industry growth. The 45 champion cities collectively have installed more than 36 GW of district heating capacity (equivalent to some 3.6 million households), 6 GW of district cooling capacity (equivalent to some 680,000 households) and 12,000 km of district energy networks. Over the next 10 years, all 45 cities will increase their district energy capacity, with many of them finishing initial or planned projects, including Helsinki (Finland), Christchurch (New Zealand), GIFT City (India), Yerevan (Armenia), Hong Kong (China) and Port Louis (Mauritius).

Local governments are uniquely positioned to advance district energy systems in their various capacities as planners and regulators, as facilitators of finance, as role models and advocates, and as large consumers of energy and providers of infrastructure and services (e.g., energy, transport, housing, waste collection and wastewater treatment). The policy options available to cities often are influenced by national frameworks and the extent of devolved authority. This publication outlines the policy best practices that local governments can use within these four broad capacities, accounting for diverse national frameworks.
As providers of infrastructure and services, local governments can shape the low-carbon pathways of district energy systems, capture synergies across the different business segments and direct the district energy strategy towards broader social and economic objectives. Optimising district energy systems to ensure efficient resource use and to realise their diverse benefits requires working with actors outside of the standard heating/cooling utility and end-user model. Cities pursuing district energy have benefited from identifying synergies with non-energy utilities and incorporating these synergies into a mutually beneficial business case. In Bergen, Norway, the city’s urban densification policies promote district energy in coordination with the new light-rail network. Such collaboration can go further than just joint planning of infrastructure, and can mean investment in, or partnership with, other utilities.

Additional best practices include: waste-heat tariffs that reflect other utilities. Such collaboration can go further than just joint planning of user model. Cities pursuing district energy have benefited from resource use and to realize their diverse benefits requires working with neighboring municipalities for joint development or use of technical standards to integrate multiple networks; cooperation with neighboring municipalities for joint development or use of district energy networks; and a range of policies that encourage connection, such as zoning bylaws, density bonuses and building codes.

CITIES CAN CHOOSE FROM A VARIETY OF BUSINESS MODELS FOR DISTRICT ENERGY, DEPENDING ON THEIR SPECIFIC SITUATIONS

Cities worldwide are utilizing diverse business models for district energy, depending on the specific local context. The business model should ensure that all of the players involved – including investors, owners, operators, utilities/suppliers, end-consumers and municipalities – can achieve financial returns, in addition to any wider economic benefits that they seek. By evaluating the innovative business approaches being used elsewhere, planners can make better-informed decisions for developing and financially structuring systems in their own cities. The majority of business models for district energy involve the public sector; they range from fully publicly owned systems, to cooperative models and public-private partnerships, to privately owned and developed systems (see section 3 of the report). In 18 of the 45 champion cities, public ownership is the most dominant model, while in 22 of the cities, hybrid business models are the most dominant, ranging from a privately operated concession to a public-private joint venture.

Since 1927, the Paris Urban Heating Company (CPCU), a utility that is 53 per cent owned by the City of Paris, has developed district heating under a concession contract. The combination of city ownership and the use of a concession model has allowed Paris to maintain a high degree of control over district heating development, while also benefiting from the efficiency improvements and capital investment contributed by the private sector. The concession contract sets a maximum price for the heat delivered, indexed against the share of renewable heat generated. The City also can enforce a special low price for those in social housing. In addition to providing cheaper, more renewable heat, the CPCU provides Paris with an annual dividend of €2.6 million (US$2.6 million) and an annual concession fee of €7 million (US$8.1 million). The CPCU expects to achieve its 2030 target of 50 per cent renewable or recovered energy in the district heating network, which would lead to a net reduction in greenhouse gas emissions of some 50,000 tons of CO2-equivalent.

Incorporating national utilities into the business model – such as through full or partial ownership – is key to realizing the national benefits of district cooling. In Dubai, where air conditioning represents over 70 per cent of electricity consumption, the city aims to meet 40 per cent of its cooling needs through district cooling by 2050, using 50 per cent less electricity than standard air conditioning. By integrating the publicly owned electricity utility into the business model, Dubai’s district cooling is being developed with full recognition of the national benefits.

NATIONAL-LEVEL SUPPORT FOR DISTRICT ENERGY CAN SIGNIFICANTLY STRENGTHEN INITIATIVES AT THE SUBNATIONAL OR LOCAL LEVEL

Although many of the specific decisions and measures associated with a district energy system must be made at a local level, national policies are key to achieving optimal results. Based on the 45 champion cities, the four national policies with the greatest impact are: incentives for CHP and renewables, national regulation on tariffs, incorporation of district energy into building efficiency standards and labels, and tax regimes, alongside clear planning guidance and regulations that provide local governments with a mandate to act. For example, European Union legislation on energy efficiency requires that regional and local authorities develop plans for heating and cooling infrastructure that utilize all available renewable energy sources and CHP in their region. In Norway, the national licensing framework supports local implementation of district heat by requiring aspiring providers to develop detailed development plans that include evidence of the socio-economic and environmental benefits of district heating relative to other options.

The use of polluter taxes is a key best practice in Nordic countries such as Denmark, Finland and Sweden in achieving high levels of district energy. Taxes and other penalties also have played an important role in driving the modernization of district energy systems in China, where a national-level regulation empowers provincial authorities to fine cities for high levels of air pollutants. Amsterdam’s investment in a transmission line to integrate the city’s isolated boilers and to capture surplus waste heat is projected to have a payback period of only three years due to the avoided penalties on pollution and the reductions in coal purchases. Where taxes are not in place, national governments may offer grants and subsidies to indicate their support for district energy and to create a level playing field. Rotterdam, for example, received a €47 million (US$58.5 million) grant from the Dutch government to reflect the equivalent avoided social costs of CO2 and NOX emissions.

To encourage effective policy integration and implementation between the national and local levels, cities are increasingly involved in the design and development of “vertically integrated” state and national policies. Climate finance through Vertically Integrated Nationally Appropriate Mitigation Actions (V-NAMAs) represents a promising means of promoting low-carbon district energy systems. 

DECIDING NEXT STEPS TO ACCELERATE DISTRICT ENERGY

UNEP has developed a policy and investment road map comprising 10 key steps to accelerate the development, modernization and scale-up of district energy in cities. A decision tree, developed as an outcome of this publication and of the exchanges with the 45 champion cities, will guide cities through these various stages and highlight tools and best practices that could be available to local governments in their roles as planner and regulator, facilitator, provider and consumer, coordinator and advocate. Twinning between cities – matching champion ones with learning ones – will be a key component of UNEP’s new district energy initiative.

THE DECISION TREE IS SPLIT INTO FOUR BROAD AREAS:

WHY?

Why district energy, what is the energy demand and what are the near-available technology costs for district energy deployment?

WHEN?

When should district energy be developed, and what are the catalysts that take district energy from vision to reality?

WHAT?

What steps need to be taken to begin development of a district energy strategy in the city?

HOW?

How can the city foster and develop district energy? How can incentives, policy frameworks, business models and tariff structures best serve district energy in the city?

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Modern district energy systems (DES) will enable Frankfurt to achieve 100% renewable energy by 2050. Through DES, the city will improve energy efficiency, be able to switch from fossil fuels, use waste heat and provide balancing for variable renewable energy sources.

Accelerating the uptake of energy efficiency and renewable energy in the global energy mix is the single biggest contribution to keep global temperature rise below 2 degrees Celsius and the multiple benefits of an inclusive green economy. Cities account for more than 70 per cent of global energy use and for 40 to 50 per cent of greenhouse gas emissions worldwide (Seto et al., 2014). Systemic inefficiencies in the energy consumption of cities have economic and social costs for both cities and countries and are a major barrier to universal access to modern energy. Currently, space heating and cooling as well as hot water are estimated to account for roughly half of global energy consumption in buildings (IEA, 2011a). Any solutions for the climate and energy transition therefore must explicitly address urban heating and cooling, as well as their interaction with electricity consumption and production. Tackling the urban energy challenge will require the intelligent use of synergies, flexibility in demand, and short- and longer-term energy storage solutions across the different economic sectors.

One of the least-cost and most-efficient solutions in reducing emissions and primary energy demand is the development of modern (i.e., energy-efficient and climate-resilient) and affordable district energy systems in cities. District energy systems can supply steam, hot water or cold water around a city for use in buildings for heating or cooling, and can also produce electricity locally. A transition to such systems, combined with energy efficiency measures, could contribute as much as 58 per cent of the carbon dioxide (CO2) emission reductions required in the energy sector by 2050 to keep global temperature rise to within 2–3 degrees Celsius. To facilitate the transition to such systems, UNEP and a group of partners has launched a new initiative on District Energy in Cities, as the implementing mechanism for the Sustainable Energy for All (SE4ALL) District Energy Accelerator (see figure 1.1). Modern district energy systems combine district heating and cooling with elements such as combined heat and power (CHP), thermal storage, heat pumps and or decentralized energy. The centralized production of heat or cooling will enable the switch away from fossil fuels to be more economical in the future. District energy systems are increasingly climate-resilient, low-carbon and affordable, by allowing for:

- recovery and distribution to end users of surplus, low-grade heat and cooling (e.g., waste heat from industry or power stations, heat from groundwaters and sewage; and free cooling from lakes, rivers or seas);
- reduction in electricity consumption and primary energy use by switching heating and cooling production and aggregating heating and cooling demand for end-users – resulting in lower costs through efficiency and smoother load/peak shaving;
- integration and balancing of high shares of variable renewable power and renewable heating and cooling – particularly through relatively inexpensive thermal storage; and
- realization of economies of scale in renewable heating and cooling production.

In this publication, district energy describes energy solutions that seek synergies between the production and supply of heat, cooling, domestic hot water and electricity, with the goal of optimizing energy efficiency and local resource use. District energy is about local production matched to local use – not only at a building level, but also at the neighborhood and city level. It is about sharing energy among buildings to achieve optimum utilization of local heat sources. And it is about resource-efficient neighborhoods and resilient cities. There may be several ways to meet these goals, but this publication shows that district energy, given certain local conditions, can offer the best solutions.
This UNEP publication, District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy, prepared in collaboration with the Copenhagen Centre on Energy Efficiency (C2E),ICLEI – Local Governments for Sustainability and UN-Habitat, is the first of a series of guidance documents and tools within the new District Energy in Cities Initiative.

The publication offers an in-depth review of 45 cities around the world, providing a platform for further global expansion of district energy approaches across cities worldwide. It will serve as guidance for accelerated implementation and expansion of district energy systems through a “cities-for-cities” thematic twinning process. The publication highlights why and how cities are deploying district energy systems, including by demonstrating key policy best practices, new business models and emerging innovations.

METHODOLOGY

This publication is based on a broad range of information sources, including: 1) interviews on district energy use with local stakeholders, city officials, utilities and energy service providers in 65 cities, as well as industry and finance experts (see annex); 2) a comprehensive survey of 45 of these cities; 5) city planning documents; 4) consultations during two workshops and 5) a variety of other documents/publications. In 2013, UNEP initiated research on low-carbon cities worldwide to identify the key factors underpinning their success in scaling up energy efficiency and renewable energy, as well as in attaining targets for zero or low greenhouse gas emissions. District energy systems emerged as a best practice approach for providing a local, affordable and low-carbon energy supply, and represented a significant opportunity for other cities to move towards climate-resilient, resource-efficient and low-carbon pathways.

From late 2013 to early 2015, interviews, surveys and consultations were undertaken by the lead author with nearly 150 respondents from 65 cities around the world, gathering during two workshops: “Don’t Waste the Waste” at the World Urban Forum in Medellin, Colombia, in April 2014, and “Energy Efficiency Accelerators” at the Copenhagen Center on Energy Efficiency in Copenhagen, Denmark, in June 2014. Among the 65 cities researched, UNEP identified 45 cities with ambitious targets for greenhouse gas or carbon dioxide (CO2) reduction and/or renewable energy development, and that also had enacted a energy efficiency or renewable energy policy. This publication draws on case studies of these 45 champion cities to illustrate the various policy, finance and technology applications of district energy systems in different social and political contexts worldwide. It explores how local governments have overcome barriers in implementing such systems as well as the lessons learned for successful replication and scale-up.

Different demands and options exist for regulatory and policy support measures related to district heating and cooling, depending on the current market conditions. To strengthen replicability and knowledge transfer, the lessons can be presented and understood more effectively via the following three city groupings, adapted from the EcoheatEU report on Best Practice Support Schemes for district energy (Werner, 2011):

1. In consolidation cities, district heating and cooling systems have reached a very mature, almost saturated market share above 50-75 per cent.
2. In refurbishment cities, district heat also has high market shares, but the systems need some refurbishment in order to increase customer confidence, energy efficiency and profitability.
3. In expansion cities, district heating and cooling systems appear in some areas, but the total market share remains low (15-50 per cent). However, genuine interest in district heating and cooling is growing in these cities. By expanding existing systems and establishing new systems in other districts, the market shares can grow significantly.

In new cities, district heating and cooling has a very low market share (0-15 per cent). The city is in the process of identifying how to stimulate district heating and cooling, with small starter networks or demonstration projects envisioned. This publication concludes by presenting a best practice tool in the form of a decision tree based on findings from the 45 city case studies. The decision tree is designed to help local authorities and decision makers within cities accelerate their deployment of district energy from a variety of starting points and in a variety of policy settings. The full decision tree is available online as an interactive tool that cities can navigate through, it is supported by in-depth case studies for each of the 45 champion cities*

* For more information on how the champion cities are grouped, visit www.unep.org/energy/des

**For more information on how the champion cities are grouped, visit www.unep.org/energy/des**

**BACKGROUN**

**BOX 11**

**CITIES AROUND THE WORLD**

**THE 45 CHAMPION CITIES FOR DISTRICT ENERGY USE ARE:**

- **ABERDEEN**, U.K.
- **AMSTERDAM**, The Netherlands
- **ANSHAN**, China
- **ARINGTON COUNTY USA**
- **BERGEN**, Norway
- **BOTOSANI**, Romania
- **BREST**, France
- **CHRISTCHURCH**, New Zealand
- **COPENHAGEN**, Denmark
- **CYBERJAYA**, Malaysia
- **DOHA**, Qatar
- **DUBAI**, United Arab Emirates
- **FRANKFURT**, Germany
- **GENO**, Italy
- **GIFT CITY, India**
- **GOTHENBURG**, Sweden
- **GUELPH**, Canada
- **GÜSSING**, Austria
- **HELSINKI**, Finland
- **HONG KONG**, China
- **IZMIR**, Turkey
- **KUWAIT CITY, Kuwait**
- **LÓDŹ**, Poland
- **LONDON, UK**
- **MALMÖ**, Sweden
- **MILAN**, Italy
- **MUNICH**, Germany
- **OSLO**, Norway
- **PARIS, France**
- **PORT LOUIS**, Mauritius
- **RIYADH**, Saudi Arabia
- **ROTTERDAM**, The Netherlands
- **SEATTLE**, USA
- **SEOUL**, South Korea
- **SINGAPORE**, Singapore
- **SONDERBORG**, Denmark
- **ST. PAUL**, USA
- **TOKYO, Japan**
- **TORONTO**, Canada
- **VANCOUVER**, Canada
- **VÅXJÖ**, Sweden
- **VELENJE**, Slovenia
- **VILNIUS**, Lithuania
- **WARSAW, Poland**
- **YEREVAN**, Armenia

The 45 champion cities collectively have installed more than 36 gigawatts (GW) of district heating capacity (equivalent to approximately 5.6 million households), 6 GW of district cooling capacity (equivalent to approximately 600,000 households) and 12,000 kilometres of district energy network.*

* Household numbers based on connection capacity for a household of 10 kW. This average connection capacity will not be representative of all cities.
**KEY FINDINGS**

- **DISTRICT ENERGY** is being developed in the 45 champion cities because of its ability to dramatically reduce the carbon intensity of heating and cooling, lower energy costs, improve air quality, increase the share of renewables in the energy mix, reduce reliance on fossil fuels and energy imports, and increase the resilience of cities.

- **RENEWABLE ENERGY** can provide high levels of affordable heat and cooling when incorporated into district energy systems through economies of scale and diversity of supply. This is enabling 11 of the 45 champion cities to have 100 per cent renewable energy or carbon-neutral targets for all city sectors.

- **DISTRICT HEATING** is undergoing a resurgence as cities identify its ability to efficiently transform the municipal heating supply to be more cost-effective, cleaner and lower carbon, as well as more local, renewable and resilient. District heating can enable higher penetrations of variable renewable energy sources, such as wind and solar, in the electricity system, using large-scale heat pumps, combined heat and power (CHP), boilers and thermal storage. Such balancing is a cornerstone of energy policies in Denmark and Germany, and several provinces in China are examining the synergy between district heating and high levels of wind generation.

- **RETROFITTING AND MODERNIZING** historic district heating systems can lead to huge energy savings through capturing waste heat from sources such as CHP plants and industry, and by upgrading networks to reduce losses and inefficiencies. Anshan is investing in a heat transmission network that will connect 1 GW of previously wasted heat from a local steel plant.

- **DISTRICT COOLING** has huge potential to reduce soaring electricity demand from air conditioning and chillers, which can present problems at times of peak load and require expensive transmission system upgrades, electricity capacity additions and decentralized backup generators to deal with prolonged blackouts. In Dubai, 70 per cent of electricity demand is from air conditioners and the city has developed the world's largest district cooling network to reduce this demand. By 2030, the city will meet 40 per cent of its cooling needs through district cooling, using 10 per cent less electricity than standard air conditioning. And Cyberjaya is using district cooling to reduce and shift electricity demand by using highly efficient chillers with ice and cold water storage.

- **USING ENERGY SOURCES** such as fossil fuels or nuclear-powered electricity to provide space heating, hot water or cooling is inefficient and a waste of resources. District energy is the only way to utilize low-energy, low-grade waste heat or free cooling sources for these end-uses in buildings. Port Louis will pump water from 1,000 metres below sea level to provide cold water for a new district cooling system to replace decentralized air conditioning powered by fossil fuel-based electricity.

- **LOWER PRICES** for heat and cooling are possible through district energy, which can cost half as much as equivalent alternative technologies given certain market conditions and an appropriate density of demand.

- **COOLING DEMAND** in a city is difficult to quantify, as the data are often hidden within a building's total electricity bill and the cooling energy delivered is not measured. Similarly, quantifying heating demand can be difficult if a fuel is utilized that has other uses such as electricity (appliances) or gas (cooking).

- **LOCAL GOVERNMENTS AND STAKEHOLDERS** may identify district energy as a key solution for heating and cooling, but wait for the opportune time to act, such as when a clear champion has emerged and/or external events catalyze the urgency to act.
INTRODUCTION TO DISTRICT ENERGY

District energy is a proven energy solution that has been deployed for many years in a growing number of cities worldwide. It represents a diversity of technologies that seek to develop synergies between the production and supply of heat, cooling, domestic hot water and electricity. Cities are adopting district energy systems to achieve important benefits including: affordable energy provision; reduced reliance on energy imports and fossil fuels; community economic development and community control of energy supply; local air quality improvements; CO2 emission reductions; and an increased share of renewables in the energy mix. (See Table 1.1 for an overview of district heating and cooling technology options and their associated benefits.)

Contributions of district energy are significant and growing worldwide. District heating meets 12 per cent of heat demand in Europe* (Connolly et al., 2012) and 30 per cent in China (ADBI, 2014), with China doubling its network length between 2005 and 2011 (IEA, 2014a). In Russia, district heating supplies 50 per cent of the heat demand in buildings. In several European countries, nearly all of the required heating and cooling is supplied via district networks. The largest district cooling capacity is in the United States, at 16 gigawatts-thermal (GWth), followed by the UAE (10 GWth) and Japan (4 GWth) (Europower & Power, 2014). In South Korea, district cooling more than tripled between 2009 and 2011 (Europower & Power, 2014).

Yet the full potential of modern district energy systems remains largely untapped. Significant opportunities exist for growth, refurbishment and new development. For example, 60 per cent of the networks in Russia need repair or replacement (IEA, 2009). China’s largely coal-fired boilers are undergoing modernization, and, in the Gulf countries, district cooling could provide 50 per cent of forecasted cooling needs by 2050, adding 20 GW of new power capacity and 200,000 barrels of oil equivalent per day in fuel (Booz & Company, 2012). In the European Union (EU), less than half of the calorific value of waste incinerated in 414 waste-to-energy plants is currently recovered as electricity or heat, and almost 100 million tons of non-recycled waste is deposited in landfills (Connolly et al., 2012).

In India, cooling demand from air conditioners in major cities is putting strain on the power system, particularly at times of peak demand, and in some cities cooling is responsible for periodic blackouts. Such strain requires significant investment in additional power capacity to meet peak demand. With nearly 400 million people expected to move to India’s urban centres by 2050 (UN, 2014) and a projected 15 per cent reduction in the population without access to electricity by 2050, the strain on the country’s power system will only increase (IEA, 2015). In Mumbai, where an estimated 40 per cent of the city’s electricity demand is for cooling, only 16 per cent of commercial and residential buildings currently use air conditioning (Trebhuchar, 2009).

To address these gaps, several countries and regions have recently set targets and directives to tap the potential of modern district energy, including the EU, the United States, China and Japan (IEA, 2014b). District energy is experiencing a modernization that is helping to realize the full potential of this energy solution – not only economically and environmentally, but also in terms of its ability to integrate with numerous systems such as electricity, sanitation, sewage treatment, transport and waste.

11.1 DISRTICT COOLING

District cooling systems supply cold water through pipes in combination with cold storage. Cold water can be produced from waste heat (such as from power generation or industry) through the use of steam turbine- (or absorption chillers; from free cooling sources such as lakes, rivers or seas; and via electric chillers. District cooling can be more than twice as efficient as traditional decentralized chillers such as air-conditioning units and can reduce electricity use significantly during peak demand periods through reduced power consumption and the use of thermal storage. District cooling has important applications in many types of cities, from Helsinki to Port Louis. Cities in developing countries can benefit greatly from district cooling due to the high air-conditioning demand on often-strained power systems.

District cooling is becoming increasingly relevant as cooling demand surges worldwide. Energy consumption for space cooling increased 60 per cent globally from 2000 to 2010 (IEA, 2014b). Under the International Energy Agency’s (IEA) 2°C scenario, cooling is set to expand 625 per cent by 2050 in selected regions of Asia and Latin America (see figure 1.2) (IEA, 2014b). Cooling demand is growing as spending on energy services increases – particularly in developing countries – and as more of the population moves to cities.

District cooling reduces consumption of environmentally damaging refrigerants such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). HFCs deplete the ozone layer, while their replacement with HCFCs means that HFC emissions are growing at a rate of 8 per cent per year and are projected to rise to be the equivalent of 7 to 19 per cent of global CO2 emissions by 2050 (UNEP, 2014).

Some of the technologies used in district cooling are described in table 1.1. A comprehensive table of technologies is available online to accompany this report. And the European Commission’s Background Report on EU-27 District Heating and Cooling Potentials, Barriers, Best Practice and Measures of Promotion provides excellent technology and policy information (Andrews et al., 2012).

FIGURE 1.2 World final energy use for cooling in the IEA’s 2°C scenario, selected regions of Asia and Latin America, 2010–2050

Source: IEA, 2014b

* District heating accounts for approximately 12 per cent of the total residential and services heat demand in 2009 (Connolly et al., 2012).

laying a section of St. Paul’s district heating network in 1982. The network heats 80 per cent of downtown buildings, including the Minnesota State Capitol, seen in the background.
FIGURE 1.3 Historical development of district energy networks, to the modern day and into the future

TABLE 1.1 Selected district heating and cooling technology options

<table>
<thead>
<tr>
<th>TECHNOLOGY NAME</th>
<th>FUEL SOURCE AND CONDITION TECHNOLOGIES</th>
<th>APPLICABILITY CONSIDERATIONS</th>
<th>BENEFITS</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTRICT HEATING</td>
<td>Geological and geothermal</td>
<td>Suitable for isolated locations</td>
<td>Cost-effective and efficient</td>
<td>Paris is served by geothermal district heating networks.</td>
</tr>
<tr>
<td>DISTRICT HEATING</td>
<td>Waste-to-energy district heating plant</td>
<td>Suitable for locations with a high waste/hazardous waste fraction</td>
<td>Low environmental impact</td>
<td>Izmir uses geothermal to provide heat that is over 35 per cent cheaper than residential gas consumption.</td>
</tr>
<tr>
<td>DISTRICT HEATING</td>
<td>District heating boiler</td>
<td>Suitable for locations with a high energy demand</td>
<td>High reliability and efficiency</td>
<td>Rotterdams delivers heat to part of the city and will result in 375,000 tonnes of CO2 emission reductions by 2035.</td>
</tr>
<tr>
<td>WASTE HEAT RECOVERY</td>
<td>Waste heat from an industrial process or low-grade heat from sewage</td>
<td>Suitable for locations with a high energy demand</td>
<td>High energy recovery and efficiency</td>
<td>District heating systems in 45 champion cities use boilers as backup when baseload heat sources cannot meet peak demand.</td>
</tr>
<tr>
<td>COMBINED HEAT AND POWER (CHP)</td>
<td>Sources include gas, biomass, coal, biogas, etc.</td>
<td>Suitable for locations with a high energy demand</td>
<td>High efficiency and environmental benefits</td>
<td>Velenje’s 779 MW Slovenia Thermal Power Plant provides heat to the city and electricity for one third of Slovenia.</td>
</tr>
</tbody>
</table>

Source: Aalborg University and Danfoss District Energy, 2014

Installing a two-meter-diameter steam pipe for district heating in New York in the early 20th century (left).

Welding a modern, pre-insulated district heating pipe in Vancouver (right).


**TABLE 1.1** Selected district heating and cooling technology options

<table>
<thead>
<tr>
<th>TECHNOLOGY NAME</th>
<th>FUEL SOURCE</th>
<th>CONVERSION TECHNOLOGIES</th>
<th>APPLICABILITY CONDITIONS/ CONSIDERATIONS</th>
<th>BENEFITS</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DISTRICT HEATING</strong></td>
<td>Fuel sources: (e.g., ambient air, water, waste heat from industrial processes)</td>
<td></td>
<td></td>
<td>May be used as baseline generation or as peak generation, depending on capital expenditure relative to electricity price.</td>
<td>Can convert electricity to heat at high efficiencies in times of surplus electricity generation.</td>
</tr>
<tr>
<td></td>
<td>Heat pumps can utilize heat from: underground (steady temperatures are not due to insulation from seasonal temperature variation rather than geothermal access), sewage and wastewater, and even from return water in district cooling.</td>
<td>Heat pumps are used to raise water to a suitable temperature for district heating.</td>
<td>Can use geothermal energy to provide energy to drive heat pumps.</td>
<td>Conversion: Heat pump</td>
<td></td>
</tr>
<tr>
<td><strong>SOLAR THERMAL</strong></td>
<td>Fuel source: Sun</td>
<td>Conversion: Solar collectors</td>
<td>Ground-mounted collectors can require significant land.</td>
<td><strong>ST. PAUL</strong> developed 2,140 m² of solar collectors with a thermal peak capacity of 1.2 MW to incorporate into the district heating network.</td>
<td>Renewable and CO₂ free-energy source.</td>
</tr>
<tr>
<td></td>
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<td>Backup: peak load source is required (e.g., boiler).</td>
<td>MALMÖ’s pioneering building-level solar thermal is net metered into a district heating network, creating the concept of “prosumers” – consumers of heat that can also provide heat into the system.</td>
<td>District heating enables larger solar thermal systems to be developed, as buildings do not need to store heat or consume all heat produced.</td>
</tr>
<tr>
<td><strong>ABSORPTION CHILLER DRIVEN FROM SUPLUS HEAT OR RENEWABLE SOURCE</strong></td>
<td>Fuel source: Surplus heat from waste incineration, industrial processes, power production</td>
<td></td>
<td></td>
<td>Absorption process often utilizes waste heat, enabling high levels of primary energy efficiency.</td>
<td>Integrating absorption chiller with heat source</td>
</tr>
<tr>
<td></td>
<td>Conversion: Absorption chiller with heat source</td>
<td></td>
<td></td>
<td>Can be combined with CHP to produce cooling as well as heat (tri-generation) in a combined cooling, heating, and power (CCHP) plant.</td>
<td>Integration chiller with heat source</td>
</tr>
<tr>
<td><strong>THERMAL STORAGE</strong></td>
<td>Fuel source: Cold or heat from district energy network or directly from district energy plant</td>
<td></td>
<td></td>
<td>Must consider storage capacity, discharge and charge ratios, efficiency of storage, and the storage period (IEA-ETSAP and IRENA, 2015).</td>
<td>Storage of hot water, cold water or ice.</td>
</tr>
<tr>
<td></td>
<td>Conversion: Storage of hot water, cold water or ice</td>
<td></td>
<td></td>
<td></td>
<td>As heating and cooling demand is typically seasonal, seasonal storage enables heat or cooling production to continue throughout the year, lowering the use of peak cooling or heating.</td>
</tr>
</tbody>
</table>

**ELECTRIC CHILLERS**

<table>
<thead>
<tr>
<th>TECHNOLOGY NAME</th>
<th>FUEL SOURCE</th>
<th>CONVERSION TECHNOLOGIES</th>
<th>APPLICABILITY CONDITIONS/ CONSIDERATIONS</th>
<th>BENEFITS</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DISTRICT COOLING</strong></td>
<td>Fuel source: Electricity</td>
<td>Conversion: Electric chillers</td>
<td>Any subsidies in any country (IEA-ETSAP and IRENA, 2013).</td>
<td><strong>OSLO</strong> is exploring the connection of St. Paul to the city’s wastewater, making it the largest heat pump station in the world.</td>
<td><strong>Still requires electricity for cooling, although a lot less.</strong></td>
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<td><strong>Helsinki</strong>’s Katri Vesa heat pump captures 105,000 GWh of heat from the city’s wastewater, making it the largest heat pump station in the world.</td>
<td>Electric chillers can convert electricity to heat at high efficiencies in times of surplus electricity generation.</td>
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<td></td>
<td><strong>ST. PAUL</strong> developed 2,140 m² of solar collectors with a thermal peak capacity of 1.2 MW to incorporate into the district heating network.</td>
<td><strong>Conversion:</strong> Electric chillers</td>
</tr>
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<td><strong>TRI-GENEVA</strong> is developing a deep ocean heat pump (see case study 3.12).</td>
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<td><strong>TORONTO</strong>’s district cooling system uses the city’s cold water pipeline to extract heat from deep in Lake Ontario, using pumps and heat exchangers and reducing the cost of cooling by 87 per cent (see case study 5.3).</td>
<td>Fuels: 90 per cent less CO₂ emissions; 55 per cent less electricity used; and a 50 per cent improvement in primary energy efficiency.</td>
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<td><strong>LONDON’S</strong> new Olympic Park development utilizes 4.4 MW absorption chillers in the tri-generation plant to produce cooling during summer when heat demand is lower (see case study 5.8).</td>
<td><strong>Use of renewables results in lower carbon emissions.</strong></td>
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<td><strong>VENEZUELA</strong>’s pilot project utilizing absorption chiller technology from waste heat has achieved significant electric savings relative to normal cooling technologies, at a production cost that is 70 per cent that of normal cooling technologies.</td>
<td><strong>Highly efficient electricity use reduces power consumption of the cooling system, particularly at peak, which can reduce the need for power infrastructure upgrades.</strong></td>
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<td><strong>LONDON’S</strong> Bankside district heating network utilizes 113 MW of hot water storage in combination with CHP to reduce the use of backup boilers to meet peak demand (see case study 3.2).</td>
<td><strong>Free cooling does not use environmentally damaging refrigerants for cooling unless supply water is not cold enough.</strong></td>
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<td><strong>CYBERJAYA utilizes both cold water storage (51,800 refrigeration ton-hours (RTHs); 125 MWh) and ice storage (59,000 RTHs; 157 MWh) (see case study 5.3).</strong></td>
<td><strong>Free cooling reduces energy demand for cooling in a city by shifting production to other periods of the day.</strong></td>
</tr>
</tbody>
</table>
1.2 WHY DISTRICT ENERGY?

Through development of district energy infrastructure, the 45 champion cities were achieving or pursuing the following benefits:

**GREENHOUSE GAS EMISSIONS REDUCTIONS**: Rapid, deep and cost-effective emissions reductions, due to fuel switching and to decreases in primary energy consumption of 90–50 per cent (e.g., the district cooling network in Paris uses 50 per cent less primary energy).

**AIR QUALITY IMPROVEMENTS**: Reduced indoor and outdoor air pollution and their associated health impacts, through reduced fossil fuel consumption.

**ENERGY EFFICIENCY IMPROVEMENTS**: Operational efficiency gains of up to 90 per cent through use of district energy infrastructure to link the heat and electricity sectors (e.g., Helsinki’s CHP plants often operate at 95 per cent primary energy efficiency).

**USE OF LOCAL AND RENEWABLE RESOURCES**: Harnessing of local energy sources, including from waste streams, reject heat, natural water bodies and renewable energy. Piloting of new technologies, such as thermal storage, to integrate variable renewables.

**RESILIENCE AND ENERGY ACCESS**: Reduced import dependency and fossil fuel price volatility. Management of electricity demand and reduced risk of blackouts.

**GREEN ECONOMY**: Cost savings from avoided or deferred investment in generation infrastructure and peak power capacity. Wealth creation through reduced fossil fuel bills and generation of local tax revenue. Employment from jobs created in system design, construction, equipment manufacturing, operation and maintenance.

These multiple benefits and the ability to integrate renewable energy and energy efficiency have led commentators ranging from the World Street Journal to the IEA to tout district energy systems as the fundamental solution and “backbone” of the sustainable energy transition (IEA, 2011b; Totty, 2011). Countries that are leaders in renewable energy or energy efficiency, or that have strong carbon targets – including China, the U.K., France, South Korea, New Zealand, the United States, Germany, Denmark, Sweden and the EU as a whole (see section 4) – are encouraging their cities to embrace district energy (Hausheer & Power, 2015; IEA, 2014b).

The benefits of district energy are realized most significantly at the city level (see table 1.2) and can be directed specifically to the end-users to encourage connection (see table 1.3). The benefits are also felt at the national level (see table 1.4), and national policy can enable district energy to capture these benefits (see section 4). Benefits of district energy can be accounted for through local policy design (see section 4) and through the business model used (see section 5). Tables 1.2 to 1.4 showcase some of these benefits and provide several examples from the 45 champion cities (for additional detail, see the case studies highlighted throughout this report).

**RESILIENCE-RELATED**

1. Increased energy security and reduced dependence on fuel imports due to more-efficient use of primary energy and local resources
2. Can be used in emergency situations where centralized generation fails or is not available, so that heat can still be provided during storms, and hospitals can remain operating
3. “Future-proofed” network allows for systems to be retrofitted easily with new and emerging technologies, without the need to install equipment in each building

**ECONOMIC**

1. Job creation through installation and operation and the increased reliance on local energy sources (local forest residues, landfill gas, renewables)
2. Additional income opportunities as interconnected systems allow for excess capacity and sharing with neighbouring systems
3. Local wealth retention from greater use of local resources, reduced fossil fuel imports and more-efficient primary energy consumption
4. Improvements in air quality that could reduce spending on health costs or environmental penalties
5. Possible relocation of businesses to the city due to increased energy security
6. Reduced consumption of fresh water in district cooling compared with conventional cooling systems
7. Significant dividends to the local government via the city-ownership model of district energy
8. Monetary savings from reduced landfill use
9. Attraction of compact urban planning that can lead to reduced spending on energy, utilities, etc.

**ENVIRONMENTAL**

1. Substantial contribution to meeting city-wide greenhouse gas reduction targets
2. Huge potential to improve city-wide air quality through reduced burning of fossil fuels that produce sulphur dioxide (SO2), nitrogen oxides (NOX) and particulates
3. Decreased heat loss into the atmosphere, minimizing the heat-island effect in cities
4. Alternative income stream from waste, which may create a business case to deal with waste appropriately, improving the local environment (e.g., development of improved waste collection to fuel landfill biogas systems)
5. Delivery of district heat alongside energy efficiency programmes through transition to fourth-generation systems, which in turn allow more waste heat and renewables in the energy system and enable the balancing of variable renewables such as solar and wind

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</table>

**ANSHAN**: avoidance of 1.2 million tons of coal per year (see case study 3.7)

**TOKYO**: increased resilience against earthquakes through more local generation of electricity

**TORONTO**: increased resilience against extreme weather events through local heat production

**GÜSSING**: isolation against oil price shocks from 1990 to today

**ANSHAN**: rapid (three-year) project payback time through capture of waste heat in the city

**MILAN**: avoided consumption of 30,000 tons of fossil fuels

**PARIS**: dividend for the city of €2 million (US$2.6 million) annually

**OSLO**: employment benefits estimated at 1,275 full-time jobs

**GÜSSING**: urban rejuvenation, creation of more than 1,100 indirect jobs and entry of 50 new businesses

**ST. PAUL**: US$12 million in energy expenses kept circulating in the local economy

**MILAN**: savings of 2.3 tons of particulate matter, 50,000 tons of CO2, 50 tons of NO and 25 tons of SO in 2011

**OSLO**: avoidance of 500,000 tons of waste going to landfill annually and pollution reduction equivalent to 150,000 cars driving 15,000 km a year in the city
1.3 ENERGY EFFICIENCY

1.3.1 TAKING ADVANTAGE OF LOW-EXERGY ENERGY SOURCES

The use of energy sources such as nuclear-powered electricity or fossil fuels to provide space heating, hot water or cooling services can be compared to “using a chainsaw to cut butter” – it is inefficient and an extreme waste of resources (Lovins, 1976). This is because these energy sources are both high temperature and high “energy,” meaning that they have high potential for useful mechanical work. Burning high-energy fuels such as coal or natural gas is not necessary to provide services, such as heating and cooling, that can be provided more efficiently using low-temperature, low-energy energy sources. The high-energy content could then be saved for processes that do not have an alternative (Gudmundsdottir and Thorsen, 2015).

Air conditioning is a clear example of using high-energy heat to obtain low-grade thermal energy. In some cities, such as Dubai, air conditioning can represent over 70 per cent of electricity consumption. For many developing countries, particularly in hot climates, this represents a huge drain of already-strained electricity networks and is impeding action on developing district energy alternatives (see case studies 5.12 on Porto Louis and 5.9 on Cebujaya).

District energy infrastructure is the only way to utilize low-exergy, low-grade waste heat or free cooling sources for end-users such as space heating, cooling and hot water services in buildings (see table 1.1). To the extent that it is technically and economically possible, cities should avoid the direct use of electricity and fossil fuels to generate low-energy heating and cooling, and should turn instead to district energy.

Cities should be taking advantage of the direct use of electricity and fossil fuels to provide space heating, hot water or cooling services. Thermal energy. In some cities, such as Pero Louis and Cebujaya), interconnecting networks (see case study 5.7 on Andalusia) and adapting modern approaches to billing (see case study 4.4 on Yerevan). The World Bank’s China Heat Reform and Building Energy Efficiency (☻HUBE SE) Global Environment Facility (GEF) Project, completed in October 2012, has demonstrated how consumption-based billing could result in energy savings of 10–15 per cent in China. As of December 2012, in the country’s north, such billing was used for only some 805 million square metres (m²) of heated area, out of a total heated building stock of 8 billion m². The World Bank has sought to boost implementation through replicable pilot studies, but municipal-level district heating companies remain resistant to billing reform due to the potential loss in revenues. Air pollution in cities is expected to be the key driver in ensuring broader implementation of consumption-based billing across China, in addition to efforts to enhance the role of provincial-level entities in district heating sector reform and to incentivize district heating companies to implement heat reforms more proactively (Py, 2014).

1.3.2 USING NETWORKS TO MAXIMIZE EFFICIENCY

District energy networks can maximize efficiency in a variety of ways. Through the use of thermal storage, heat or cooling demand can be shifted by hours, days or even months, smoothing the demand profile and enabling heat to be supplied in the most cost-effective way. Excess energy production is stored and used later during peak thermal demand periods. CHP plants, for example, can store excess heat, enabling them to operate only when it is most beneficial for the national or regional electricity market and to avoid having to react in response to small fluctuations in heat demand. This also allows for the integration of variable renewable energy into the power system. Thermal storage in combination with district energy is often more cost effective than power storage. Additionally, flexible infrastructure means that the network is able to grow over time and utilize different energy sources, as well as benefit from interconnection with other networks. Interconnecting of networks enables any excess energy that is produced to be shared with other district energy systems, reducing volatility in the overall network.

In refurbishment cities, significant energy efficiency gains can be achieved by upgrading networks (see case study 2.5 on Botosani), interconnecting networks (see case study 5.7 on Andalusia) and adopting modern approaches to billing (see case study 4.4 on Yerevan). The World Bank’s China Heat Reform and Building Energy Efficiency (HUBE SE) Global Environment Facility (GEF) Project, completed in October 2012, has demonstrated how consumption-based billing could result in energy savings of 10–15 per cent in China. As of December 2012, in the country’s north, such billing was used for only some 805 million square metres (m²) of heated area, out of a total heated building stock of 8 billion m². The World Bank has sought to boost implementation through replicable pilot studies, but municipal-level district heating companies remain resistant to billing reform due to the potential loss in revenues. Air pollution in cities is expected to be the key driver in ensuring broader implementation of consumption-based billing across China, in addition to efforts to enhance the role of provincial-level entities in district heating sector reform and to incentivize district heating companies to implement heat reforms more proactively (Py, 2014).

### TABLE 1.3 Benefits of district energy systems to end-users

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<tr>
<th>RESILIENCE-RELATED</th>
<th>ECONOMIC</th>
<th>ENVIRONMENTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ More-reliable energy source that can provide heat and cooling at times of disruption such as extreme weather events</td>
<td>▪ Transparent reduction of heating and cooling bills in the long term compared to alternative technologies</td>
<td>▪ Reduction of pollution produced in the home through heating and hot water production as a result of switching from coal and other fuels</td>
</tr>
<tr>
<td>▪ Isolation from energy price spikes and greater long-term certainty on heating and cooling bills because price is less reliant on fossil fuel prices</td>
<td>▪ Ability for local authorities to target end-users experiencing fuel poverty</td>
<td>▪ Health benefits from improved air quality</td>
</tr>
<tr>
<td>▪ Space savings from not having individual thermal energy production (e.g., freeing up office space)</td>
<td>▪ Ability to certify buildings to a high energy efficiency standard due to low primary energy factors, allowing users to benefit during leasing/sale of property</td>
<td>▪ Health benefits from greater utilization of the heating system by fuel-poor populations, due to more affordable provision of heat</td>
</tr>
<tr>
<td>▪ Ability to certify buildings to a high energy efficiency standard due to low primary energy factors, allowing users to benefit during leasing/sale of property</td>
<td>▪ Insulated improvement in building performance, reducing energy costs</td>
<td>▪ Improved safety as boilers, gas supply, etc. are kept out of the building</td>
</tr>
</tbody>
</table>

### TABLE 1.4 Benefits of district energy systems at the national level

<table>
<thead>
<tr>
<th>RESILIENCE-RELATED</th>
<th>ECONOMIC</th>
<th>ENVIRONMENTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Increased energy security and reduced dependence on fossil fuel imports</td>
<td>▪ Reduced greenhouse gas emissions from the carbon-intensive buildings sector</td>
<td>▪ Potential reduced energy imports due to lower primary energy consumption, improving balance of payments of the country</td>
</tr>
<tr>
<td>▪ Reduced stress on national or regional power grids through energy sharing and thermal storage (if alternative technology is electricity-based)</td>
<td>▪ Allowance of higher levels of variable renewable electricity on national or regional power grids, decreasing the carbon intensity of power production</td>
<td>▪ Ability to use variable power generated from renewable energy, reducing the need for curtailing and backup power plants</td>
</tr>
<tr>
<td>▪ Reduced electricity demand during peak periods, thus increasing reliability of power (if alternative technology is electricity-based)</td>
<td>▪ Deferred or reduced cost of upgrades in gas and electricity distribution networks as users switch to district energy</td>
<td>▪ Allows countries to meet national/international targets for carbon emissions, renewables, energy efficiency, energy intensity and air quality</td>
</tr>
<tr>
<td>▪ Reduced transmission losses as electricity is generated closer to where it is being used</td>
<td>▪ Reduces consumption of environmentally damaging refrigerants in the cooling sector</td>
<td>▪ Reduced transmission losses as electricity is generated closer to where it is being used</td>
</tr>
</tbody>
</table>

### RESILIENCE-RELATED

- Increased energy security and reduced dependence on fossil fuel imports
- Reduced stress on national or regional power grids through energy sharing and thermal storage (if alternative technology is electricity-based)
- Reduced electricity demand during peak periods, thus increasing reliability of power (if alternative technology is electricity-based)

### ECONOMIC

- Potential reduced energy imports due to lower primary energy consumption, improving balance of payments of the country
- Reduced greenhouse gas emissions from the carbon-intensive buildings sector
- Allowance of higher levels of variable renewable electricity on national or regional power grids, decreasing the carbon intensity of power production
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- Reduced transmission losses as electricity is generated closer to where it is being used

### ENVIRONMENTAL

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- Defers or reduced cost of upgrades in gas and electricity distribution networks as users switch to district energy
- Reduced transmission losses as electricity is generated closer to where it is being used

### DENMARK AND SWEDEN: development of district heat policy in response to 1970s oil crisis

- Japan: use of energy efficiency from cogeneration reduces high imports of natural gas relative to business as usual
- Botosan: reduction in breakdown of network of 45 per cent from 2010 (base) to 2013; expected to reach 94 per cent when modernization project is completed

### JAPAN: benefits of district energy systems

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- Reduced stress on national or regional power grids through energy sharing and thermal storage (if alternative technology is electricity-based)
- Reduced electricity demand during peak periods, thus increasing reliability of power (if alternative technology is electricity-based)
- Reduced transmission losses as electricity is generated closer to where it is being used

### DENMARK: 20 per cent reduction in national CO2 emissions since 1990 due to district heating

- Significant amount of heat captured from the carbon-intensive buildings sector, meaning that they have high potential for useful mechanical work. Burning high-energy fuels such as coal or natural gas is not necessary to provide services, such as heating and cooling, that can be provided more efficiently using low-temperature, low-energy energy sources. The high-energy content could then be saved for processes that do not have an alternative (Gudmundsdottir and Thorsen, 2015).

### BOTOSAN: following modernization, reconnection of 21 large-scale district heating consumers that previously had disconnected from the system but have now been reconnected due to more affordable heat

- Air conditioning is a clear example of using high-energy heat to obtain low-grade thermal energy. In some cities, such as Dubai, air conditioning can represent over 70 per cent of electricity consumption. For many developing countries, particularly in hot climates, this represents a huge drain of already-strained electricity networks and is impeding action on developing district energy alternatives (see case studies 5.12 on Porto Louis and 5.9 on Cebujaya).

- District energy infrastructure is the only way to utilize low-exergy, low-grade waste heat or free cooling sources for end-users such as space heating, cooling and hot water services in buildings (see table 1.1).

- To the extent that it is technically and economically possible, cities should avoid the direct use of electricity and fossil fuels to generate low-energy heating and cooling, and should turn instead to district energy.

- Cities should be taking advantage of the direct use of electricity and fossil fuels to provide space heating, hot water or cooling services. Thermal energy. In some cities, such as Pero Louis and Cebujaya), interconnecting networks (see case study 5.7 on Andalusia) and adapting modern approaches to billing (see case study 4.4 on Yerevan). The World Bank’s China Heat Reform and Building Energy Efficiency (HUBE SE) Global Environment Facility (GEF) Project, completed in October 2012, has demonstrated how consumption-based billing could result in energy savings of 10–15 per cent in China. As of December 2012, in the country’s north, such billing was used for only some 805 million square metres (m²) of heated area, out of a total heated building stock of 8 billion m². The World Bank has sought to boost implementation through replicable pilot studies, but municipal-level district heating companies remain resistant to billing reform due to the potential loss in revenues. Air pollution in cities is expected to be the key driver in ensuring broader implementation of consumption-based billing across China, in addition to efforts to enhance the role of provincial-level entities in district heating sector reform and to incentivize district heating companies to implement heat reforms more proactively (Py, 2014).
1.3.3 ENERGY EFFICIENCY IN BUILDINGS

In an effort to meet city, regional or national energy efficiency targets, local authorities are advancing district energy solutions to improve the thermal performance (operational efficiency) of their existing building stock and to utilize local energy sources – such as waste heat – that are not technically or economically viable at the scale of the single building. By harnessing economies of scale, district energy systems can improve the efficiency of homes and buildings in a cost-effective manner, complementing efforts to achieve energy efficiency standards or certification in buildings.

If buildings are very inefficient, they require basic efficiency measures at the building level, such as insulation, energy-efficient lighting and other retrofits. As a building’s efficiency improves, however, district energy can provide greater efficiency savings than full retrofits, as building’s efficiency improves, however, district energy can provide greater efficiency savings than full retrofits, as Frankfurt discovered when evaluating efficiency savings than full retrofits, as district energy can provide greater efficiency savings than full retrofits, as building’s efficiency improves, however, district energy can provide greater efficiency savings than full retrofits, as when progressing from the “C” level of certification for a building’s energy performance to the “E” level, building-level efficiency measures are more cost effective than district energy. But district energy becomes more cost effective when moving from the “E” level to the more-efficient “D” level, and from the “C” to the top-rated “A” level (although here, the cost of district energy may increase due to switching out of fossil fuels, such as converting natural gas CHP to biomass CHP).

Seattle’s privately owned district heat utility, Seattle Steam, has partnered with an energy service company (ESCO) to offer an energy saving programme directly to its own customers, helping them reduce energy consumption by 20 per cent. The programme assesses a building’s energy saving potential and provides access to grants and low-interest loans, which customers can pay back through their monthly utility bills. From a business development perspective, this lessens customers’ utility bills (typically after a payback of five to seven years), allowing Seattle Steam to retain customers. Furthermore, the efficiency improvements free up existing heat generation capacity to service new customers, allowing Seattle Steam to build its customer base without additional capital costs associated with increasing generation capacity.

District energy has proven beneficial in buildings that already are highly efficient. To qualify as low-emissions buildings, so-called passive houses often have to meet a very low energy-consumption standard of 25 kilowatt-hours (kWh)/m²/year or less, depending on the definition. In Helsinki, where even highly efficient houses can get too hot in summer, near-pasive buildings still benefit from hot water and cooling services.

Achieving efficiency standards or certification through district energy is not always possible, however, and many existing energy standards or certification schemes still benefit from hot water and cooling services. Achieving efficiency standards or certification through district energy is not always possible, however, and many existing energy standards or certification schemes still benefit from hot water and cooling services.

District energy has the potential to provide energy services that are resilient, affordable and accessible. Because of its efficiencies and economies of scale, it offers a tool for providing vulnerable sectors of society, such as populations in fuel poverty, with lower energy tariffs than for competitive technologies. District energy makes it possible to connect a city’s population to modern energy services (see case study 1.2 on Hohhot in China’s Inner Mongolia Autonomous Region), typically at lower prices (see case study 4.4 on Yerevan).

District energy also can provide affordable access to thermal energy by enabling communities to avoid many of the upstream investment costs associated with the power sector. In countries and cities with high demand for cooling, in particular, district cooling can reduce the high electricity demand for air conditioning and reduce peak demand. This in turn can reduce unnecessary excess capacity, freeing up infrastructure funds to better target energy efficiency in other sectors and/or to address the needs of rural populations.

FIGURE 1.4 Sankey diagram of business-as-usual heat/electricity/cooling system against modern district energy system

Note: The efficiencies shown in the Sankey diagram are illustrative only and will vary significantly based on equipment used in the production of heat, cooling and electricity.

Typically average global efficiency of coal power plants is 33 per cent, with the most efficient being approximately 41 per cent (World Coal Association, 2014). Gas CHP plants are typically 80–92 per cent efficient but can be as high as 97 per cent efficient.

FIGURE 1.5 Return on investment in Rotterdam from building-level efficiency improvements versus a district energy approach

Source: Jolman, 2014

1.3.4 ENERGY ACCESS

District energy has the potential to provide energy services that are resilient, affordable and accessible. Because of its efficiencies and economies of scale, it offers a tool for providing vulnerable sectors of society, such as populations in fuel poverty, with lower energy tariffs than for competitive technologies. District energy makes it possible to connect a city’s population to modern energy services (see case study 1.2 on Hohhot in China’s Inner Mongolia Autonomous Region), typically at lower prices (see case study 4.4 on Yerevan).

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District energy schemes are one of the most effective means for integrating renewable energy sources into heating and cooling sectors. Solar thermal, geothermal, bioenergy, waste heat and natural, free, cooling systems can benefit from the economies of scale that district energy provides.

Professor Ralph Sims, Massey University, New Zealand and member of the Scientific and Technical Advisory Panel of the GEF

1.4 RENEWABLE ENERGY

Section 1

1.4.1 USING ECONOMIES OF SCALE TO TAP INTO RENEWABLE AND LOCAL ENERGY SOURCES

By using district energy systems, it is possible to aggregate the heat needs of multiple and diverse consumers to a scale that optimizes the use of renewable energy sources that may not be economically viable at the household or building level (Chittum and Østergaard, 2014). This neighbourhood-scale approach enables the use of owner cooperation, aggregation of demand, and service models that otherwise would not be feasible. Currently, at least 20 per cent of EU-wide district heat is generated from renewable energy sources (REN21, 2014). In developing countries, readily available renewable sources, such as landfill gas, could be tapped for district energy purposes. Renewable heat or cooling can be directed into a district energy network using technologies described in table 1.1 and shown in figure 1.7.

1.4.2 FLEXIBILITY IN FUEL SUPPLY

As renewable technologies become more cost competitive, district energy schemes are ideally placed to phase in renewable energy through renewable fuels, untapped sources of waste heat, or technologies such as geothermal and solar thermal. Because district energy systems generally do not commit a city to a single fuel source, implementing such schemes can help protect local economies from the volatility of fossil fuel prices on the global market (see case study 1.1 on Gothenburg’s experience with fuel flexibility historically).

1.4.3 WIND-TO-HEAT

Several countries have begun using district heat systems to harness excess renewable electricity (particularly from wind and solar) during periods of oversupply. An example is the use of surplus wind power to heat water, either with heat pumps or directly using resistance heaters. In Denmark, combining variable renewable electricity with CHP and district heating is now a cornerstone of the country’s energy policy (REN21, 2014). When renewable power output is low, CHP plants can provide electricity even without enough heat demand, as the heat produced can be directed to thermal storage. China’s Inner Mongolia region is experimenting with wind-to-heat to reduce curtailment of wind power (see case study 1.2).

Middelfart wind farm, 3.5 km from Copenhagen, Denmark. When built in 2006, it was the largest offshore wind farm in the world, at 40 MW. Wind generation will provide 50 per cent of Denmark’s electricity by 2020. Such high shares of wind generation will be made possible, in part, by the country’s extensive district heat networks.

Gothenburg’s district heating system, initiated in 1953 with a CHP plant and later supplemented in 1972 with a waste incinerator, illustrates the flexibility in fuel supply that district energy offers. In response to the oil crisis of the 1970s and the city’s bad air quality, Gothenburg expanded the system significantly in the 1970s and 1980s. Today, the 1,500 km system supplies heat to some 60 per cent of the city’s residents, and 70 per cent of it comes from non-fossil fuel sources or waste heat from waste incineration, industry or sewage water. Göteborg Energi, the municipally owned utility, is a champion of renewable energy in district heating and is considering converting the 202 MW, Rya CHP plant to run on biogas.

Figure 1.6 shows how district heating production in Gothenburg doubled from 1973 to 2002, while emissions of CO₂, SO₂, and NOₓ simultaneously decreased. The heat profile shows the huge variety in renewable sources used throughout the year. Such flexibility has successfully insulated Gothenburg from international fossil fuel prices. Across Sweden, as the share of oil used in district heating networks has dropped from 90 per cent in 1980 to less than 10 per cent today, the country’s carbon intensity has similarly declined, from some 300 kg of CO₂ per MWh in 1980 to some 95 kg of CO₂ per MWh today.

Gothenburg also has developed district cooling, using free cooling from the Göta River supplemented by absorption cooling.

FIGURE 1.6: Gothenburg’s district heating production, 1973–2011, and the heating system’s fuel mix and profile.
FIGURE 1.7 Whole district energy system showing various end-users and the feeding in of heat and cooling sources (including renewables)

CONNECTING RENEWABLE ELECTRICITY GENERATION

Excess variable electricity production, such as wind generation, can be utilized and stored using district energy, providing valuable demand response for the power system. This electricity can power large-scale heat pumps, which capture low-grade heat (such as from underground) to produce hot water to be stored as heat in a district heating network. Similarly, high-efficiency electric chillers could provide demand response and store surplus cold water as cold to be used in district cooling. Through such means, district energy can enable higher shares of renewable energy in power systems.

The high density of heat and cooling demand from commercial consumers makes them ideal to connect to district energy.

CONNECTING COMMERCIAL DEMAND

Many cities have renewable sources of low-temperature water that can be used to provide district cooling. The cooling is extracted from sea, river, lake or aquifer water using a heat exchanger. District cooling networks can meet the demands of data centres, which normally require large amounts of electricity to cool.

WASTE INCINERATION

Instead of sending non-recyclable municipal solid waste to landfills, cities can incinerate it. The waste heats water into steam, and this heat is transferred into the district heating system. Some larger waste incinerators also have a steam turbine to produce electricity and heat. The exhaust fumes of the incinerator must be controlled so as not to contribute to local air pollution.

Solar thermal can be connected to district heating systems at a large scale (such as large ground-mounted installations) or at the building level. Buildings can be designed that allow building owners to provide heat to the district heating network in times of surplus, removing the need to store excess heat in the building.

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CAPTURING WASTE HEAT FROM SEWAGE AND WASTEWATER

Several cities capture the heat from wastewater and sewages. A heat exchanger in the pipes ensures no direct contact and removes the heat before the sewage is processed. An electric heat pump then uses the low-temperature waste heat to supply hot water for the district heating system.

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CAPTURING WASTE HEAT FROM INDUSTRIAL PROCESSES

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BUILDING CONNECTED TO DISTRICT ENERGY NETWORK

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Producing electricity from CHP is an important aspect of the district energy model. Electricity is more valuable than heat because of its higher exergy (see section 1.3.1), meaning that a 90 per cent efficient gas-fired CHP plant is more valuable to an energy system than a 90 per cent efficient gas boiler. CHP plants that provide heat to a district energy network typically rely on the heat demand profile of the network to determine when to produce electricity. Two unprofitable situations can arise for such plants (these examples apply to markets where there are fixed, regulated electricity prices):

- **Low (or Negative) Electricity Price, with High Heat Demand.** This could occur on a very windy, cold day. High amounts of wind generation can bring down the market price for electricity (even making it negative, which can lead to wind curtailment). In this situation, the CHP plant will have to run to meet heat demand even though it would not receive sufficient electricity revenues and would be unprofitable.

- **High Electricity Price, with Low Heat Demand.** This could occur during a summer evening in a temperate climate. Expensive thermal power stations may be the marginal price in the electricity market, and thus the electricity price will be high. When heat demand is low, the CHP plant cannot run, as there is no off-take for its heat, and CHP plants generally do not have cooling towers. If the CHP plant could run, however, it would be very profitable due to the high electricity price. The CHP plant needs a demand for its heat (technically and to receive heat revenues) so that it can produce electricity (achieving high revenues).

Thermal storage and fossil fuel-based boilers (or electric boilers) could help in both of these situations. In the first situation, any heat in storage could be released instead of running the CHP plant, and if this were insufficient, gas boilers could run as well to produce hot water for the network. This running of fossil boilers would be beneficial and would avoid any wind curtailment that would occur if the CHP plant were forced to run (as has occurred in China’s IMAR, see case study 1.2), and electric boilers could also achieve this. In the second situation, the CHP plant could run if it could provide its heat to thermal storage, allowing the heat to be used in the district heating network at another time (perhaps seasonal storage could shift this heat to a higher demand period in autumn/winter). Other solutions, such as open networks with multiple demand users and heat sources, can also help to address the CHP situation. Germany’s Energiewende policy encourages the use of CHP because of its balancing synergies with solar (see case study 1.3). Furthermore, the demand-side response options available from the large-scale uptake of cold storage based on district cooling systems can also be used to help balance a power grid system that has high shares of variable renewable generation.

**Section 1.4.4 Balancing**

**Case Study 1.2**

**Wind-to-Heat in China’s Inner Mongolia Autonomous Region (IMAR)**

Inner Mongolia has the largest installed wind power capacity of any region in China—18 GW, or one quarter of the country’s total—and the regional government plans to increase this capacity to 50 GW by 2020. However, IMAR prioritizes the use of CHP, rather than electricity-only wind farms, to meet the region’s rising demand for electricity and heat. As a result, many wind farms are being forced to disconnect from the grid, particularly during winter nights when both CHP and wind generation are high but power demand is low. For this and other reasons, up to 45 per cent of wind power is curtailed in IMAR. The government is keen to pilot the use of curtailed wind power for district heating, including to help meet the rising heat demand in urban areas.

In Hohhot, the capital of IMAR, winter temperatures can drop to as low as −40°C, and sub-zero temperatures typically last for six months of the year. Thus, adequate heating is a basic human need and essential for socio-economic activities. Because Hohhot already has a high concentration of inhalable particulate matter during winter, coal-based heating can no longer be a solution to meet increasing heating demand. Through a decree issued in 2013, the Hohhot municipal government promoted the use of natural gas to meet the rising energy demand and address associated environmental and health concerns.

The Hohhot Chengfa Heating Company, a subsidiary of a municipally owned enterprise, plans to establish low-carbon, low-emission and highly efficient district heating systems in eastern Hohhot. It will install 50 MW of electric boilers to be powered by excess wind energy, 1,560 MW of natural gas boilers using low NOx boilers, 74 km of district heating pipeline, and heat exchangers covering nearly 50 million m² of space heating. Upon completion, the project will avoid the use of some 46,500 tons of coal equivalent annually as well as emissions of 1.3 million tons of CO2, 26,000 tons of particulate matter, 7,500 tons of NOx, and 9,000 tons of SOx (ADB, 2014).
15 Costs

District heating and cooling have been developed for many years without subsidies. District energy is cost-competitive in many climates and economies and is frequently a very cheap provider of heating and cooling. The ability to utilize waste heat/cold is an important driver in delivering low-cost thermal energy. However, there is no denying that, as with renewable electricity production, district energy typically has a high capital expenditure (CAPEX) and a relatively low operating expenditure (OPEX). This means that the avoided high CAPEX of decentralized solutions (such as single-building air-conditioning units or gas boilers), which collectively can be very high, needs to be captured in cost comparisons.

Other benefits outside the business case also may not be priced in, such as reductions in primary energy consumption, lower greenhouse gas emissions and improved air quality (see section 4.2). This is why cities and national governments are so important in the delivery of district energy, as they can help provide the business case with a more long-term vision and can account for socio-economic benefits in energy decision making. Figure 1.9 provides some reference levelized costs for district heating and cooling compared to decentralized production.

The components of the costs of heating/cooling from district energy to the end-consumer will depend on the revenues of the district energy system, as well as on the CAPEX and OPEX of the technologies, as described in the following sections.

15.1 District Energy CAPEX

Development Costs: These include the costs associated with prefeasibility studies, permitting applications, feasibility studies and planning applications.

Pipes and Network: A key issue is the density of buildings, as this will affect the length and diameter of pipes necessary to connect them. Designing pipe routes to ensure the most effective network will reduce costs. Consideration needs to be given to “future proofing” the network by allowing sufficient pipe size to connect future buildings in the future, along with the timing and sequence of construction. It may be necessary to pay the municipality for use of the street, or landowners to route the network across their land (although these fees may be reduced or waived if the landowner benefits from the project). Integration with other utilities/systems (e.g., sewage, transport) can reduce installation costs by installing at the same time as other development.

Figure 1.10 describes potential costs of district energy networks and connections for various linear heat/cool densities. Linear heat/cool density is a measure used in district energy to distinguish the annual demand expected per metre of network installed. The linear heat/cool density is reduced if the network is in an area with low heat density, such as the outskirts of a city. A reduced linear heat/cool density means a higher levelized cost of the network. Furthermore, houses and apartments must connect to the network, which represents a significant proportion of the cost of obtaining planning, construction and connection permits. Cost reductions are also necessary for operational system. An additional cost is connecting CHP plants to the local, regional or national electricity networks.

A glass accumulator tower at Pimlico District Heating Undertaking in London stores excess heat from the network.
1.5.2 DISTRICT ENERGY: OPEX AND FUEL COSTS

**FUEL**: The principal operating cost is for fuel. In the near term, projects may rely on fossil fuels until the connections and network are established. Low- or zero-cost heat sources can then be connected that could reduce the operating costs, including: locally available renewables such as biomass waste from sawmills, furniture factories or arboricultural management; solar or geothermal heat; and waste heat from industrial processes or other buildings such as data centers.

**OTHER**: Other operating costs include labour for operations; maintenance of local and state taxes; electricity, insurance, water; chemicals; service contracts for primary equipment; and management of projects.

1.5.3 DISTRICT ENERGY REVENUES

**HEATING/CoolING SALES**: The absolute demand and load profiles of buildings connected to the project ultimately determine the revenues that can be obtained. A diversified mix of consumers and thermal storage will mean a smoother aggregated load profile, allowing for cheaper and more efficient heat/cooling production. Prices received for heating and cooling may be regulated or be part of a more liberalized market. District energy providers often utilize a two-part rate design, with a capacity charge related to the peak demand of the customer building and a consumption charge reflecting the metered monthly volume of heating or cooling energy used in the building.

**POWER**: The majority of projects also derive revenues from power sales through CHP production. This power is usually delivered to a regional or national electricity grid, local distribution networks or specific local demand, depending on the capacity factor. The power price (and its variability) will depend on the regional or national market and typically follows these prices, discounted based on the terms of a power purchase agreement (PPA). If connected to a local distribution grid, the CHP plant may achieve retail prices for electricity, which, especially if based on time-of-day rates or congestion pricing, are of higher value and bring greater revenue. In Tokyo, CHP developers are approved as Specified Electricity Utilities and supply power to specified district energy zones at retail electricity prices. Revenues from electricity generation (as well as free heat sources) allow district energy systems to provide heat at prices below competitive technologies (such as gas boilers).

**ANCILLARY SERVICES AND CAPACITY PAYMENTS**: A capacity premium may be provided if the system is embedded in an area with a stressed power grid, and/or if it provides balancing services to the regional or national electricity grid. Such ancillary services and capacity payments could become more available to CHP plants if they are combined with boilers and thermal storage, as they then do not have to generate only according to the heat profile.

**PRICE CONSIDERATIONS**: Centralized plant costs and operational costs for district energy.

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**FIGURE 1.10** Network costs for district energy

**FIGURE 1.11** Centralized plant costs and operational costs for district energy
Cities have seen many different catalysts that have resulted in district energy systems. Unique business models or specific local conditions, such as the build-out or renewal of infrastructure, often have provided the impetus for district energy projects.

In DUBAI, the rapid pace of urban development as well as rising energy costs have encouraged building developers to incorporate district energy systems into new infrastructure projects as a means to provide a new service (cooling) to customers and to generate an additional income stream.

In VANCOUVER and LONDON, the Olympic Games of 2010 and 2012, respectively, were a key driver for new infrastructure development, and district energy provided a solution to meet a variety of goals, including reducing emissions and taking advantage of local fuel sources.

In CHRISTCHURCH, as part of the major rebuilding process under way following the 2011 earthquake, district energy has been included in city construction planning and development, helping to minimize costs and local impacts.

In ROTTERDAM, district energy was introduced into city planning during World War II. When the war ended, the Minister of Public Works and Reconstruction, Johan Ringers, oversaw the rebuilding of the city and the simultaneous placement of a district heating pipeline.

In 1949, Hotel Pax became the first building to be fully heated by the new system.

In ANSHAN has commenced significant renovation of its isolated, inefficient district heating networks into a modern system that captures waste heat from industry and new CHP plants. The catalyst was national regulation in China that required a solution to the city’s poor air quality, caused primarily by the use of coal to provide baseline heat to local heating networks.

PARIS developed district heating in 1927 to overcome local air quality issues and to address the challenge of delivering huge amounts of fuel to distributed users in the city centre. Today, large portions of the city are connected to district heating, including the Louvre museum, delivering the heat-demand equivalent of 460,000 households city-wide. Paris also developed the first district cooling network in Europe – Climespace – in 1991, part of which uses water from the Seine River for cooling.

In TORONTO, a unique business model served as the catalyst for finally implementing the city’s deep-lake water cooling system, conceptualized since the early 1980s. Too much silt in drinking water extracted from the lake meant that the city needed to develop a deeper, longer pipe to reduce filtering costs. This was exactly the pipe needed for the deep-water cooling system, creating the opportunity for the city to partner with the company Ensure to provide cooling to the city.

Access to energy resources was a catalyst for district heating in HELSINKI, where reliance on wood, oil and coal became a concern already in the 1940s. District energy helped to improve energy security as well as reduce local air pollution caused by the combustion and transport of imported fossil fuels. More recently, Helsinki has been implementing a district cooling system that relies on absorption chillers to use waste heat from cogeneration plants that was previously underutilized during the summer months.

In BOTOSANI, high levels of heat loss, network breakdowns, heat subsidies and electricity consumption meant that the city required finance to rehabilitate its aging district heating networks. The availability of finance from the International Finance Corporation and the EU Structural Funds provided the catalyst for modernization of Botosani’s district energy systems.

Such catalysts provide the impetus for a city to begin development of district energy. In the years to come, the types of catalysts will likely change, but planners and developers can still benefit from identifying potential catalysts in their cities. Section 2 of this report sets out a framework for tools that local authorities can use to develop district energy in their cities.
KEY FINDINGS

- **LOCAL GOVERNMENTS** are uniquely positioned to advance district energy systems in their various capacities: as planners and regulators, as facilitators of finance, as role models and advocates, and as large consumers of energy and providers of infrastructure and services.

- OF THE 45 CHAMPION CITIES for district energy, 43 are using their ability to influence planning policy and local regulations to promote and accelerate district energy deployment. Over half of the cities started with broad energy targets (e.g., energy efficiency, renewable energy, greenhouse gas emissions, etc.), which led to district energy-specific targets.

- WHEN LOCAL GOVERNMENTS do not have regulatory powers in the energy sector, a stake in a local utility, or the resources to undertake feasibility studies, they can incorporate energy supply or efficiency requirements into planning and land-use policies, as has been done in Amsterdam, London, Seoul and Tokyo.

- INTEGRATED ENERGY PLANNING AND MAPPING, supported by a designated coordination unit or a public-private partnership, is a best practice to identify synergies and opportunities for cost-effective district energy systems, and to apply tailored policies or financial incentives. Of the 45 champion cities, 55 per cent used spatial heat maps to bring together stakeholders for business development and to share opportunities, inform policy and optimize network design.

- ACROSS THE 45 CHAMPION CITIES, local governments were ranked as the “most important” actor in catalyzing investment in district energy systems. Several cities – including Dubai, Munich, Tokyo, Paris, and Warsaw – attracted more than US$150 million of investment in their respective district energy systems between 2009 and 2014.

- ALMOST ALL 45 CHAMPION CITIES have leveraged city assets, such as land and public buildings, for district energy installations or connections, including by providing anchor loads to alleviate load risk and facilitate investment. To reduce risk and project cost, smaller systems can be interconnected over time, as has occurred in Copenhagen and Dubai.

- FINANCIAL AND FISCAL INCENTIVES to support district energy include: debt provision and bond financing, loan guarantees and underwriting, access to senior-level grants and loans, revolving funds, city-level subsidies and development-based land-value capture strategies. All 45 champion cities use demonstration projects to raise awareness and technical understanding of district energy applications, and to showcase their commercial viability.

- OPTIMIZING DISTRICT ENERGY SYSTEMS to ensure efficient resource use and to realize the diverse benefits requires working with actors outside of the standard heating/cooling utility and end-user model. Cities pursuing district energy have benefited from identifying synergies with other utilities (water, waste management, transport) and incorporating these synergies into a mutually beneficial business case.

- MANY CITIES are looking to integrate publicly or privately owned waste heat through heat tariffs that reflect the cost of connection and the ability to guarantee supply. This is similar to the development of feed-in tariffs for renewable power.

- ADDITIONAL BEST PRACTICES INCLUDE: CHP access to the retail electricity market; net metering policies and incentives for feed-in of distributed generation; customer protection policies, including tariff regulation, technical standards to integrate multiple networks; and cooperation with neighbouring municipalities for joint development or use of networks.

- INTEGRATING ENERGY INTO URBAN PLANNING leads to the most efficient use of energy and to the optimization of local resources by encouraging mixed-use zoning and compact land use — two of the most important planning tools for encouraging district energy and reducing carbon emissions.

Section 2:

A FRAMEWORK FOR CITY-LEVEL POLICIES AND STRATEGIES FOR DISTRICT ENERGY
2.1 THE ROLE OF LOCAL GOVERNMENTS

Local governments worldwide are using a wide range of policies and activities to promote district energy, demonstrating the significant and diverse roles that cities can play in deploying such systems. These policies and activities can be grouped into four main categories, reflecting the varying roles of local governments as 1) planner and regulator, 2) facilitator, 3) provider and consumer and 4) coordinator and advocate, as described in sections 2.2 to 2.5.

The involvement of local government is important to ensure that district energy serves broader policy objectives, including energy security, economic development, community acceptability and higher environmental performance (e.g., low greenhouse gas emissions, good local air quality). Many successful private district energy systems have included some degree of local government involvement, whether in the form of passive policy frameworks or franchise agreements, more proactive vision, regulation and in-kind support; financial involvement such as grants, tax considerations or partial investment; or other support such as coordination of diverse stakeholder interests, awareness-building, public education and capacity-building.

2.2 LOCAL GOVERNMENT AS PLANNER AND REGULATOR

Local governments can effectively catalyze district energy deployment first and foremost in their role as planner and regulator. Local governments have an integral role in planning community-based energy solutions that can help meet specific targets and objectives. By adapting the local regulatory framework, governments can encourage the development of district energy through vision and target setting, integrated energy planning and mapping, policies that encourage connection, and waste-to-energy mandates. Table 2.1 summarizes the policy activities that local governments are undertaking in their role as planner and regulator.

- 2.2.1 ENERGY POLICY OBJECTIVES, STRATEGY AND TARGETS

“The role of target setting cannot be under-estimated. Next to the clear guidance for investors, an official target for renewable energy in a certain region can also help in overcoming conflicting interests of different departments – from environment, transport, economy, buildings, etc.”

Stefan Schurig, World Future Council, 2014

- BENEFITS OF A LONG-TERM ENERGY STRATEGY:

Given the many competing interests in a city, an energy strategy that explicitly addresses the heating/cooling sector and that outlines the potential role and benefits of district energy in the context of broader social, environmental and economic drivers is critical. An energy strategy provides validation and direction to a local government’s work in district energy. The time and resources spent delivering district energy projects can be justified against the potential benefits defined in the energy strategy and can improve the municipality’s long-term decision-making process.

Greater public understanding of district energy’s role in meeting a desired target can reduce opposition to projects and to any associated disturbance in development or operation. It can support efforts to coordinate actions among various stakeholders and to mobilize support from other levels of government (see case

<table>
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<tr>
<th>POLICY INTERVENTION AREA</th>
<th>DESCRIPTION OF POLICY ACTIVITY</th>
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| ENERGY POLICY OBJECTIVES, STRATEGY AND TARGETS (section 2.2.1) | - Energy strategy linking the benefits of district energy and broad policy targets, such as targets related to CO₂ and greenhouse gas emissions, energy intensity, fossil fuel consumption, energy efficiency and renewable energy
- District energy-related target or goals, whether for the future share of district heat/cooling power, the share of district energy in specific buildings (e.g., public buildings) or the share or absolute numbers of buildings connected |
| ENERGY MAPPING AND HOLISTIC ENERGY PLANNING (sections 2.2.2 and 2.2.3) | - Energy mapping, such as of a city’s local heat or cooling demand, in order to understand energy use, infrastructure, emissions and available resources
- Holistic energy planning that integrates district energy into land-use and infrastructure planning, provides guidelines for urban development plans to contain the energy vision, and requires energy assessments for new developments |
| CONNECTION POLICIES (section 2.2.4) | - Connection policies that encourage connection where it is economically and technically feasible and minimizes load risk
- Zoning bylaws that allow, encourage or require district energy developments |

Heizkraftwerk West CHP plant in Frankfurt, Germany.

Source: Adapted from Martinot, 2011, and Sims, 2009
studies 2.14 on Sonderborg and 2.5 on Beirut). An energy strategy’s long-term vision also can reassure investors, making possible longer-term infrastructure developments such as district energy. To plan for future network expansion, investors need to be confident of continued revenues. A strategy also can help mobilize champions, particularly when there is an absence of national policy to internalize the benefits that are accrued to different players (see case studies 2.1 on Amsterdam and 2.4 on London).

All 45 cities surveyed in this publication have some form of energy strategy that includes district energy. Although these strategies vary by city type, a consistent theme is the energy efficiency benefits of district energy (see table 2.2 on targets). Consolidated cities are looking to improve their energy efficiency by integrating new waste heat and renewable energy sources through district energy. In energy cities, energy efficiency improvements from district energy (relative to status quo heating and cooling technologies) are driving deployment. In small/medium cities, energy efficiency through district energy is a key driver in enabling energy independence and affordability.

### Developing an Energy Strategy: To develop an energy strategy, a city needs to undertake a holistic study of municipal energy use and needs, from which it can identify goals and pathways for realizing specific socio-economic benefits, both now and into the future. A key requirement of such a study is a local heat and cooling assessment that identifies potential energy technology pathways that can be pursued to achieve city goals.

In many cases, customers and political decision makers may underestimate or simply not know the energy demand for cooling from air conditioning and electric chillers, as these data may be hidden in a building’s total electricity bill and the cooling energy delivered is not measured (Persson et al., 2012). This leads policymakers to understate the potential role of cooling in achieving objectives such as energy access, affordability or reliability, and to overlook the need to regulate, research or support it. Additionally, because chiller plants in individual buildings often have 50–70 per cent more installed capacity than is required, this can result in overestimation of demand and potential over-stating of cooling revenue.

A heat and cooling assessment is key to understanding this demand, and can provide important data that can aid in strategy development at both the city and national levels (see section 4.1). For cities in hot climates, understanding local electricity consumption for cooling can enable governments to address issues of electricity demand locally rather than having to rely exclusively on improvement and development of the national electricity network. For cities in cool climates that have high heat demand, understanding the relative benefits of district heating versus energy efficiency measures in buildings can lead to greater impact or alleviate cost barriers. Retrofitting old or historical buildings to a passive-house standard can be expensive and may lead to efficiency improvements that could have been achieved more cheaply with a district energy connection, or that could be addressed with new financing tools through a combined approach with a district energy utility (see section 1.3.5, figure 1.5 and the case study online detailing Seattle’s energy efficiency ESCO model).

For many cities, a technology pathway that includes district energy will be the cheapest solution with the highest impact. As such, district energy can become a key component of a city’s energy strategy, as seen across the 45 champion cities. An important means of articulating the role of district energy in relation to energy consumption and its impact on wider policy objectives is through development of a district energy goal or target.

### Developing a Target or Goal for District Energy

Cities should develop their targets and goals for district energy alongside the tangible benefits and objectives to be achieved, which they can use to measure their actions and progress. Once these goals have been identified, they can then be followed by elaboration of specific policies and activities (see section 2.2.3).

Most cities that are active in district energy started with broader targets, such as targets for CO₂ and greenhouse gas emissions, energy intensity, fossil fuel consumption, energy efficiency (either for the city overall or for individual sectors, such as buildings) and renewable energy (see table 2.2). Over time and with learning, these broad targets can then lead to targets that are specific to district energy. An early demonstration project can provide concrete data and experience and ultimately legitimate a city-wide energy plan focused on scaling up district energy (see case studies 3.1 on Vancouver and 5.12 on Porto Louis). Nearly all of the 45 local governments surveyed have established some type of district energy goal, and the majority have developed a district energy-specific target that typically extends to the 2020–50 period and is based on a broader target (see figure 2.1).

France’s targets of, by 2020, 20 per cent renewable energy, 20 per cent energy efficiency improvement and 20 per cent reduction in CO₂ emissions (from a 2008 base) provided the incentive for Brest to develop a district heating system with a high share of renewables. These renewables provide cheaper heat than gas boilers and have benefited the city through a national grant and tax reductions on district heating.

### District Energy Targets Most Often are Seen in Consolidated or Refurbishment Cities and Can Include the Following:

- **Expansion of the District Energy System** for the total amount of homes (or unit equivalent) connected to the system, or by development type (e.g., Aarhus, Helsinki)
- **Target to Interconnect Segregated District Energy Networks** through transmission pipes (e.g., Frankfurt, Aachen)
- **Share of Total Greenhouse Gas Reduction Target** to be met by district energy (e.g., Vancouver)
- **Share of Electricity/Heating/Cooling Capacity or Consumption** provided by district energy systems (e.g., Dubai, Helsinki)
- **Share of Local Government’s Energy Usage** from buildings or operations that should come from district energy systems (e.g., Amsterdam)
- **Share of Renewable or Waste Heat to be Used** in a district energy system (e.g., Paris, Copenhagen)
- **Per Cent Increase in Energy Performance of Buildings** due to district energy (e.g., Hong Kong)
- **Sector Targets** for waste management or waste heat recovery (e.g., Bergen)
- **Targets for Replacing Existing Building Heating or Cooling Systems** (e.g., Copenhagen, Lodz)

A portion of Milan’s district heating network, connected to the Canovese CHP plant. Milan’s segregated networks are undergoing interconnection and expansion to form three large heat networks by 2016, which will then be interconnected via a ring around the city.

### FIGURE 2.1 Shares of the 45 champion cities that have targets for district energy and broader energy targets

<table>
<thead>
<tr>
<th>Number of cities</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
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<tbody>
<tr>
<td><strong>Greenhouse Gas Emissions Target</strong></td>
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<td><strong>Renewable Energy Target</strong></td>
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<td><strong>Energy Efficiency Target</strong></td>
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<td><strong>Building Efficiency Target</strong></td>
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<tr>
<td><strong>District Energy-Specific Target</strong></td>
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</tbody>
</table>
A residential equivalent unit (REU) is used to compare the heating consumption of homes and apartments to that of commercial or industrial buildings.

For more on local renewable energy targets, see the local policies section of REN21, 2014.

### TABLE 2.2  Targets and strategies for district energy that correspond to broader climate or energy targets, in selected champion cities

<table>
<thead>
<tr>
<th>CITY</th>
<th>CO2 EMISSION REDUCTION TARGET</th>
<th>RENEWABLE ENERGY AND/OR ENERGY EFFICIENCY TARGET</th>
<th>DISTRICT ENERGY-RELATED GOALS</th>
<th>FEATURES</th>
</tr>
</thead>
</table>
| AMSTERDAM  | 48% by 2025; 75% by 2040 (from 2000 base) | All new building development climate-neutral by 2025; 25% of power demand met locally by 2025; 50% of power demand met locally by 2040 | 100,000 residential equivalent unit* connections by 2020 (up from 55,000 today); 200,000 by 2040 | The city’s 90% ownership of land city-wide is being used to encourage district energy development; looking to capture waste heat from data centres.
|            |                               | Fuel switch from electricity and gas in heating and cooling to higher use of waste heat | Target to interconnect multiple systems using a ring transmission network | Network developed based on waste incinerator energy efficiency target. |
| BERGEN     | 50% by 2030 (from 2001 base) | 95% renewable energy supply | Use district heating in all new buildings and major renovations within the concession area for district heating | Carbon-neutral target; District heating systems/CHP as cornerstone of energy policy to integrate renewables; District heating currently meets 98% of city’s heat demand.
|            |                               | Replace oil-based heating (14% of greenhouse gas emissions) | Waste incinerators must utilize 80% of energy (higher than national target of 56%) | Use of treated sewage effluent water instead of fresh water; Reduced investment in power infrastructure. |
| COPENHAGEN | 20% by 2015 (from 2005 base) | By 2025: 100% renewable energy supply, 20% reduction in demand, 20% reduction in power consumption in commercial/service companies | By 2025: 100% share of renewable energy and waste incineration heat in the district heating system (up from 53% today) |
| DBAI       | 20% reduction from power plants by 2030 | Meet 40% of heating capacity through district cooling (up from 20% in 2011) by 2030 | By 2016, ban oil-fired installations in existing buildings where district heating (or gas) is available | Use of treated sewage effluent water instead of fresh water; Reduced investment in power infrastructure. |
|            | 50% reduction in energy demand by 2030; 5% renewable electricity by 2030 | Use district cooling in all new developments by 2010 | Incorporate thermal energy storage into all new district heating plants, representing at least 20% of the design capacity of the plant by 2010 |
| FRANKFURT  | 50% by 2020; 95% by 2050 (from 1990 base) | 100% renewable energy supply by 2050, while reducing demand | Connect waste heat from incinerator and industry; interconnect three district heat grids into a closed-loop system; integrate renewable energy such as biomass and biogas in CHP | 100% renewable energy target; Fuel switching using biomass, biogas and synthetic methane. |
| HELSINKI   | 30% by 2010 (from 1990 base) | 20% share of renewables in energy production in 2020 (up from 7% in 2015) | By 2015, cooling capacity of over 200 MW | Captures heat from district cooling return water, for zero-waste Tri-generation; Utility-set target.
|            |                               | By 2020, expand cooling to new residential areas | By 2020, expand cooling to new residential areas | Reduced consumption of fuel and power for cooling. |
| HONG KONG  | Reduce carbon intensity 50-60% by 2020 (from 2005 base) | Reduce carbon intensity 50-60% by 2020 (from 2005 base) | By 2020, reduce coal to less than 10% of the electricity generation mix | By 2020, phase out existing coal and reduce energy intensity by at least 25% (from 2005 base). |
|            |                               | Expand use of district cooling so that by 2020, up to 20% of commercial buildings will use up to 50% better in refrigeration performance compared with buildings using regular air conditioners | Reduced consumption of coal and power for cooling. | |

* For more on local renewable energy targets, see the local policies section of REN21, 2014.

** A residential equivalent unit (REU) is used to compare the heating consumption of homes and apartments to that of commercial or industrial buildings (offices and corporate buildings). One REU is equivalent to a single home or apartment, or 100 m² of commercial or industrial floor space. Amsterdam thus has 3,000,000 (18 million m²/100 = 450,000 REU).

To identify opportunities for targeting resources and policies to meet district energy goals, municipalities often need more detailed information on the current and future geographical distribution of energy use at the neighbourhood and building levels, as well as on local heat and energy assets and distribution structures. This can be achieved through an energy mapping process that analyses the local conditions, such as sources of excess heat, renewable heat assets (geothermal and solar), and concentrations of heat or cooling demand – often using GIS-based spatial information (Connolly et al., 2015; Persson et al., 2012). Further data and layers of analysis can be added over time, depending on the policy objectives and goals.

Energy maps for district energy can contain, among other variables, data on:

- Existing and projected energy consumption by sector, fuel source or type (residential, commercial, etc.)
- Sources of surplus or industrial heat supply
- Large energy consumers and buildings with potential excess heating or cooling capacity (e.g., buildings for events such as a stadium or arena)
- Current networks and potential network routes (see figure 2.5)
- Potential anchor loads and their energy consumption (see figure 2.4)
- Barriers and opportunities particular to the location related to local energy sources, distribution, transport, land use, development density and character
- Socio-economic indicators to identify fuel-poor areas that could benefit.

Energy mapping can help cities identify specific district energy projects that could be developed, how they can be best expanded and connected in the future, and how this expansion ties into other infrastructure development. Energy maps also can identify how a city can best apply its land-use authority (see section 2.2.5) to encourage district energy and to develop tailored incentives in different zones to reduce load risk (see section 2.2.4).

In addition, cities can use mapping to facilitate stakeholder engagement. Amsterdam, for example, uses mapping as a tool to build public-private partnerships, which helps the city share the task of data collection, scenario analysis and the development of new business models (see case study 2.1). Energy mapping also helps raise public awareness by creating an effective visualization tool for communication (Persson et al., 2012; Connolly et al., 2015). For some cities, a city-wide energy mapping exercise may not be initially realistic due to financial and other constraints. The idea of energy mapping is that the tool is constantly evolving. As such, a city should identify high-potential areas in the energy strategy and focus on a detailed mapping exercise of these areas (e.g., the Central Business District (CBD), airports, social housing, large retail areas). Obvious anchor loads and heat/cooling sources near these areas should still be accounted for.
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SECTION 2

AMSTERDAM: BUILDING THE BUSINESS CASE THROUGH ENERGY MAPPING

To create incentives for district energy projects, the City of Amsterdam is focusing on tools that facilitate the involvement of both end-users and private sector stakeholders in developing urban energy plans. According to the city, scaling up district energy is about finding the right combinations of stakeholders to create new, scalable business models, with potential clients being part of the development. The city, housing authorities or energy companies also need to encourage buy-in from residents and tenants, as these end-users are regularly involved in the decision to switch from natural gas to district heating. In Amsterdam, 70 per cent of occupants must agree to buy-in from residents and tenants, as companies also need to encourage being part of the development. The business models, with potential clients focusing on tools that facilitate the ping urban energy plans. According to the city, involving both end-users and private sector stakeholders in developing urban energy plans is about finding the right combinations of stakeholders to create new, scalable business models, with potential clients being part of the development. The city, housing authorities or energy companies also need to encourage buy-in from residents and tenants, as these end-users are regularly involved in the decision to switch from natural gas to district heating.

Amsterdam produced its Energy Atlas in collaboration with local stakeholders, including businesses and property owners, to ensure a bottom-up process. Currently, the interactive atlas shows:

- thermal and electricity production and consumption data in each district
- existing and proposed sustainable energy projects
- opportunities to connect to existing sources or networks
- data on building stock (size, construction date, density) in areas
- social indicators such as ownership of property, disposable incomes and consumption patterns, willingness to invest or launch initiatives, and modes of transport
- potential for energy saving and local/renewable energy generation
- an opportunity map for storage of heat and cooling in the city centre.

Amsterdam has used the Energy Atlas to provide a decision support tool for planning, to generate enthusiasm for district energy (and other energy technologies), and to encourage cooperation among various industrial partners on the exchange of energy and the use of excess waste heat from data centers. The energy atlas provides these stakeholders with insight into the thermal management in the area and allows them to identify different functions that could contribute to heat demand. Their calculations produced a balanced business case for the use of excess heat in Zuidoost and resulted in a new area plan on the use of waste heat. Mapping the energy flow and actively approaching potential partners would not have been possible without the use of current data visualization.

Amsterdam aims to use the Energy Atlas to replicate this end-user-driven urban development model in Zuidoost in order to advance district energy opportunities in other communities.

Over half of the cities surveyed had started to embark on an energy or heat mapping exercise in connection with their urban energy plans. London, for example, has developed an extensive heat map as part of the London Development Authority’s Decentralised Energy Master Planning programme, a partnership with Arup, the Greater London Authority, London Councils, Capital Ambitions and leading city boroughs. The London Heat Map showcases potential heat supply, demand and network opportunities for district energy across the city (see figures 2.2 and 2.3). To act on these opportunities, each of London’s 29 boroughs has developed an implementation plan that includes barriers and possibilities, actions to be taken by the council, key dates and personnel responsible. As a result of this programme, London envisions leveraging £8 billion (US$12.9 billion) of investment in district energy by 2030 (see case study 4.1 for more on the commercialization phase of the programme).

Figure 2.2 shows London’s heat density in combination with current networks (yellow lines), current CHP plants (yellow diamonds) and potential networks (red lines). The existing network at the top of the image is the Olympic Park and Stratford City development project (discussed in detail in case study 3.8). Figure 2.3 highlights the city’s existing Westminster and Pimlico heat networks (yellow) and the proposed interconnection (red). The grey circles show potential central government anchor loads, and the red cross shows a potential anchor load of St Thomas’ Hospital, which consumes 59 GWh of fuel per year (see section 5.2).

Source: GLA, 2014

FIGURE 2.2 London Heat Map

Source: GLA, 2014

FIGURE 2.3 London Heat Map: Westminster and Pimlico networks

Source: GLA, 2014
Sadhu Johnston, City of Vancouver, 2014

**CASE STUDY 2.2**

**BERGEN and ST. PAUL**

**CAPTURING SYNERGIES THROUGH HOLISTIC PLANNING IN BERGEN AND ST. PAUL**

Bergen’s municipal master plan, which closely links energy, urban development and transport, has made it easier to identify expansion pathways for the city’s district energy network. For example, the city has identified a new light-rail project – which encourages compact urban design in developments along its route – as an area for a district heat network. Developing this network along the light-rail corridor will minimize disruption and direct network expansion towards the high-growth, dense areas that the light rail is encouraging.

A group of companies and agencies named the Digging Club – whose members include the district heating network owner, water and sewage departments, waste management company and local electricity distribution operator – is coordinating Bergen’s district energy planning efforts, in order to reduce the inconvenience for residents, businesses and road users when improving infrastructure works.

To encourage district energy, the energy plan can use policy interventions and adapt the planning framework to improve the business case of district heating or cooling. Such interventions can include:

- encouraging mixed-use zoning (see section 2.2.4)
- planning for compact land use in new developments (e.g., Frankfurt)
- requiring water-based heating or cooling systems in new developments (e.g., Dubai)
- developing local energy plans for new developments (e.g., Tokyo)
- using energy criteria in planning documents (e.g., London)
- identifying future sites for energy infrastructure to meet anticipated growth
- allocating franchise licences to give district energy operators exclusive delivery in set areas (e.g., Vancouver, Oslo; see also case study 4.2 on Norway)
- considering district energy in new infrastructure, waste management or public works (hospitals, leisure centres, etc.) projects (e.g., Hong Kong)
- establishing connection policies (see section 2.2.4)

Successful integrated planning requires collaboration among the diverse local government organizations that are affected by land-use planning – such as energy, waste, buildings, transport, etc. (see the discussion of coordination committees in section 2.5). Most of the 45 champion cities have established an administrative structure to coordinate these various bodies, for example through an interdepartmental committee, multi-stakeholder partnership or designated agency. Early collaboration helps to ensure that the energy plan is incorporated effectively into other planning documents and reduces the risks that can arise from permitting, rights of way, and lack of public awareness and support.

Denmark provides leading examples of the benefits of integrated heat planning. The presence of stable, integrated plans for heating has reduced the real and perceived risks to customers, heat suppliers, local authorities and owners of district energy systems – helping to develop long-term confidence in these systems. As a result, Denmark’s 400 district heating companies enjoy an average connection rate of 82 per cent (Chittum and Oestreng, 2014).
Section 2: Local government as planner and regulator

### 2.2. Local government as planner and regulator

#### 2.2.1. Mixed-use zoning and compact land use

District energy systems are most viable in high-density and mixed-use areas. This can be at any scale of development, from villages and small towns to large urban neighbourhoods or entire cities. In mixed-use areas, many types of energy consumers (commercial, residential, public buildings) are located in close proximity. When connected via a district energy network, areas that are zoned as mixed-use create smoother and less-profiled energy demand than if the buildings are zoned separately (see figure 2.4).

Targeting areas that have mixed use is important for district energy system development. Mixed-use zoning has huge potential for greenhouse gas emission reduction in cities (Seto et al., 2014), and encouragement of mixed-use zoning is one of the most important planning tools that local governments have for emissions reduction. The significant benefits that mixed-use zoning has on the economics of district energy should make this planning tool even more of a priority to local authorities.

**BOX 2.1**

**Mixed-use zoning and compact land use**

Having a smoother, less-profiled energy demand lowers the unit costs related to district energy infrastructure per square metre of building. A smoother profile reduces the need for less-desirable generation capacity, such as boilers and chillers, and allows for maximization of more-profitable and efficient capacity, such as CHP (which runs best as base load power, enabling it to recover its capital costs faster). With fossil fuel heat generation, a smoother load is more efficient because plants do not need to start up and shut down (i.e., cycle) as frequently.

The establishment of anchor loads (hospitals, data or leisure centres, hotels, government buildings, etc.) in a certain zone is extremely useful, as these can help to secure the initial build-up of a district energy system and are often controlled by public authorities who would be encouraging such build-up. Anchor loads generally have high energy demands that are not as profiled as other users.

For district energy development, compact land use is just as important as mixed-use zoning because the closer together that buildings (and hence energy demands) are, the less pipe is needed to connect them, greatly decreasing costs and losses (King and Parks, 2012). Figure 2.10 demonstrates the range of network costs that can occur as linear cool density increases: a 276 GWh cooling demand spread over a 100 km network (linear cool density: 10 GJ/metre/year) has network costs over two times greater than a similar demand across 55 km of network (linear cool density: 50 GJ/metre/year). Such a difference can determine whether district energy is competitive with decentralized, carbon-intensive technologies such as domestic air conditioning.

To maximize the potential of district energy, city planners must consider the benefits of compact land use on district energy potential, which in turn will enable dramatic reductions in carbon emissions.

**Figure 2.4** Energy demand profile in a mixed-use neighbourhood

Source: Data contribution from Bulbka

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#### 2.2.4. Connection policies

Because district energy projects require significant investment of capital prior to connecting customer buildings, one of the greatest risks in system deployment is load uncertainty. To aggregate, provide or guarantee a certain level of demand, local governments are promoting a variety of connection policies, with the aim of creating a minimum level of absolute load certainty through the use of anchor loads and consumer variety. Once load connection is made, additional risks may include customer retention (which can be managed by providing cost-competitive and reliable energy services) and ensuring that customers are actually using the district energy.

In theory, connecting existing buildings would be a good starting point for a district energy network because these structures have known heating/cooling load levels that are likely to continue, making them lower risk. However, it can be difficult for local governments to influence existing buildings, because often the only leverage that governments have is through planning control, meaning that there is no guarantee that existing buildings would connect to the network. In addition, connecting existing buildings can be more difficult if they are in a difficult area to develop.

As such, existing development is often not the best starting point for new district energy systems. Rather, new construction developments can act as a catalyst to establish a new network, which then can be extended to existing development. Alternatively, initial load certainty can be obtained by connecting large commercial buildings and local government assets (such as hospitals, social housing, etc.; see section 2.4.3).

Large buildings with intermittent heating and cooling loads, such as arenas, convention centres or studios, can be effective anchor loads and sources of capacity.

Local governments’ connection policies can include: mandatory connection, landlease models, density bonuses, credit towards green building requirements, and removing barriers to voluntary connection. These are described as follows.

#### 2.2.5. City-wide mandatory connection policies

Because district energy projects require significant investment of capital prior to connecting customer buildings, one of the greatest risks in system deployment is load uncertainty. To aggregate, provide or guarantee a certain level of demand, local governments are promoting a variety of connection policies, with the aim of creating a minimum level of absolute load certainty through the use of anchor loads and consumer variety. Once load connection is made, additional risks may include customer retention (which can be managed by providing cost-competitive and reliable energy services) and ensuring that customers are actually using the district energy system.

**City-wide mandatory connection policies** are often used to enable connection to district energy schemes. These policies typically target new commercial and public buildings. To ensure that end-users who are mandated to connect are not disadvantaged, profits to district energy companies are capped (as in Copenhagen), or tariffs are regulated to be lower than those for similar technologies (as in Singapore and Oslo), or both (as in Rotterdam). Cities can enforce mandatory connections in their capacity as an urban planner (if regulation allows) or, if they are large landowners, in their ability to lease land with conditions (land-lease models).

In Dubai, all public sector buildings and all new developments are required to connect to the district cooling system. In Oslo, all public buildings where possible must connect to the district heating network. In Lodz, a new building permit mandates that all new building developments connect to the district heating network. Not all cities are able to utilize a mandatory connection policy for all buildings, however, and may need to explore other policy options.

**Zonal mandatory connection policies** are similar to city-wide policies but focus only on specific areas or zones within a city. A city may use a “service-area bylaw” that effectively applies a mandatory connection policy to oblige buildings to connect to district energy schemes. These are described as follows.

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Olsø, Norway (top): Stade Francis le Blé in Brest (bottom). Connecting stadiums, leisure centres, hotels and other anchor loads diversifies the load, making the district energy system more efficient.
**THE GREATER LONDON AUTHORITY: ENCOURAGING CONNECTION THROUGH PLANNING**

The Greater London Authority's (GLA's) energy planning started with a focus on climate change, but it now also takes into account the city’s rapid growth and ageing infrastructure, including the electricity grid. London uses its land-use planning authority to promote district energy development. Current GLA planning policies require all new developments to include energy assessments that detail efforts to minimize the associated CO2 emissions. The supply of energy efficiently is part of these assessments, and, as such, major development proposals must develop along a heat hierarchy of:

1. connect to existing heating and cooling networks,
2. install a CHP network on the development site and
3. use communal heating and cooling.

Two thirds of the planning policies’ overall CO2 reductions since 2010 can be attributed to CHP development. Specialist advisors evaluate each energy assessment to ensure that the energy policies are met. Where they are not met, the developer makes a cash-musety contribution to account for the shortfall in CO2 emission reductions. In 2012, this planning policy resulted in significant commitments to new district heating systems, including:

- £120 million (US$192 million) of investment in a new, high-efficiency CHP plant able to produce 29 MW of electricity and a similar amount of heat. From 2000 to 2012, a total of 75 MW of CHP electrical capacity — roughly the amount required to supply 150,000 homes — was secured through the planning process.
- £135 million (US$213 million) of investment in heat network infrastructure for approximately 55,000 communally heated dwellings.
- Commitment to 10 very large (more than 1,000 dwellings each) mixed-use developments implementing site heat networks, each of which is key to the development of an area-wide network.

**Mandatory Connection (Unless) Policies**

Add flexibility to the planning process by requiring 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.” Or, cities may allow buildings to use alternative energy sources if this can be shown to be environmentally preferable to district energy (Bergen allows this in mandatory connection preferable to district energy (Bergen if this can be shown to be environmentally preferable to district energy (Bergen.

**Mandatory District Energy Development Through Zoning Policies**

Cities may require district energy systems in new development areas that are over a certain size and that cannot connect into other networks, and/or if district heating is the best available technology to provide sustainable heat services. In London, “major developments” must consider creating a CHP network if they cannot connect to a district energy network (see case study 2.5). Similarly, in Tokyo, if a new development area will be over 50,000 m², it has to develop a district energy system.

**Density bonuses,** whereby a city may grant extra development space (such as an extra story on a commercial office block) in return for the developer agreeing to connect to the district energy system.

**Access to rights-of-way,** whereby the city simplifies the development process by waiving or reducing some fees associated with obtaining right-of-way permits, soil displacement and other discretionary expenses consistent with treatment of infrastructure improvements.

**Take or pay,** whereby a local government could guarantee load or pay for any missing load if it is confident in customer connections based on the value proposition of the district energy system. This would apply to a concession model (see section 3.3.2) where the private utility may need guaranteed load.

**Banning undesirable alternatives,** such as the use of specific carbon- or energy-intensive technologies for heating. Starting in 2016, Copenhagen will not allow oil-fired installations to be installed in areas with district heating or natural gas networks. The city also has banned electric heating in all new buildings.

**Regulated and transparent tariffs** that are competitive with next-available technologies, which may make it more likely for building owners and developers to connect voluntarily to district energy. For example, Vancouver’s SEPC NEU has transparent heat tariffs and connection costs, which encourage connections (see case study 5.1).

**Streamlined reasoning or permitting processes** that, for example, give preference to developers that design buildings to be district energy-ready (as in Oslo).

**Building compatibility requirements,** whereby all new buildings must be compatible or district energy-ready across the city or certain areas.

**Provide financial assistance to new connections,** by partially paying the cost to connect (e.g., Brest) or paying the full cost (e.g., the private operator in Seattle paying for profitable connections).

**CASE STUDY 2.3**

**LONDON**

<table>
<thead>
<tr>
<th>MANDATORY CONNECTION (UNLESS) POLICIES</th>
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<tbody>
<tr>
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<tr>
<th>MANDATORY DISTRICT ENERGY DEVELOPMENT THROUGH ZONING POLICIES</th>
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<tbody>
<tr>
<td>For example, require district energy systems in new development areas that are over a certain size and that cannot connect into other networks, and/or if district heating is the best available technology to provide sustainable heat services. In London, “major developments” must consider creating a CHP network if they cannot connect to a district energy network (see case study 2.5). Similarly, in Tokyo, if a new development area will be over 50,000 m², it has to develop a district energy system.</td>
</tr>
</tbody>
</table>

**FIGURE 2.5** Connection policies by type in the 45 champion cities

- **Mandatory connection** enforced for service/franchise areas
- **Mandatory connection** enforced for commercial/public buildings
- **Mandatory connection** enforced for new developments
- **No mandatory connection**

<table>
<thead>
<tr>
<th>City Type</th>
<th>Mandatory Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancouver and Tokyo have this policy, but only for new developments over a certain size, and were not counted for this.</td>
<td>27%</td>
</tr>
<tr>
<td>Cities that are still developing their first district energy network are not included here because their connection policy is undecided.</td>
<td>23%</td>
</tr>
</tbody>
</table>

**SECTION 2**

2.2 Local government as planner and regulator | DISTRICT ENERGY
Under its District Energy Planning System for Effective Utilization, the city of Tokyo implemented several policies to promote district energy. For example, new developments above 50,000 m² of floor area are required to provide an Energy Plan for Effective Utilization in order to obtain a building permit. The Plan submission requires setting targets for energy-saving performance in newly constructed buildings, as well as studying the introduction of unused energy, renewable energy, and district heating and cooling.

For buildings that exceed 10,000 m² or residential developments that exceed 20,000 m² in total floor area, developers are also required to submit documentation evidencing an economic and technical assessment of district energy and consultation with district energy suppliers. Where the barrier is economic, the city will consider on a case-by-case basis if it can address this with remedial policies. A similar approach is taken in Seattle and Vancouver.

Municipal governments have played a central role in addressing the risks (actual and perceived) and costs associated with investing in district energy systems. Local governments are enabling and raising access to low-cost finance in order to stimulate private investment and industry activity. This relationship is supported by evidence from the 45 champion cities – including Dubai, London, Munich and Paris – with many cities attracting over US$150 million of investment in their respective district energy systems between 2009 and 2013. Local governments ranked the public sector as the “most important” actor to catalyze investment in district energy, particularly in new schemes. The private sector was ranked as “very important” in catalyzing investment, primarily through the provision of technical and operational support.

This section examines the role of local government as a facilitator of district energy through its ability to leverage finance. It focuses on three main policy intervention areas, as described in table 2.3.

- **2.3.1 Financing and Fiscal Incentives**
  City authorities have an important role to play in financially supporting the development of district energy, particularly in cities where it is a new technology or requires significant retrofitting. District energy is cost-competitive with other energy technologies. National policies may provide some financial (and fiscal) support, for example, sales, property taxes, permitting fees and carbon taxes. Municipal governments are enabling and easing investing in district energy systems. Local governments are providing some financial (and fiscal) support and technical expertise to overcome the risks associated with district energy systems.

The economic barriers to district energy systems result from the capital costs associated with the construction of plants, network and connections. As such, the cost of capital (or the required return) is a core driver of the cost competitiveness of any scheme and is determined by the risk of investing in the project. Economic barriers can be categorized as those that affect project risk (actual or perceived) and project cost.

**TABLE 2.3** Policy activities that local governments are undertaking in their role as facilitator

<table>
<thead>
<tr>
<th>POLICY INTERVENTION AREA</th>
<th>DESCRIPTION OF POLICY ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FINANCING AND FISCAL INCENTIVES</strong> (section 2.3.1)</td>
<td>- Debt provision and bond financing, loan guarantees and underwriting, city-financed revolving funds</td>
</tr>
<tr>
<td></td>
<td>- Grants, low-cost financing/loans, rebates, subsidies</td>
</tr>
<tr>
<td></td>
<td>- Tax credits and exemptions within tax systems; for example, sales, property taxes, permitting fees and carbon taxes</td>
</tr>
<tr>
<td><strong>CITY ASSETS</strong> (section 2.3.2)</td>
<td>- Use of local government land/property/buildings for district energy installations or connections, or for anchor loads (leasing/selling/permitting)</td>
</tr>
<tr>
<td><strong>DEMONSTRATION PROJECTS</strong> (section 2.3.3)</td>
<td>- Piloting and testing emerging (often hybrid) technologies, such as low-grade waste-heat recovery from sewage or metro, and renewable energy integration and storage</td>
</tr>
</tbody>
</table>

Source: Adapted from Martinot, 2011, and Sims, 2009

*The economic barriers to district energy systems result from the capital costs associated with the construction of plants, network and connections. As such, the cost of capital (or the required return) is a core driver of the cost competitiveness of any scheme and is determined by the risk of investing in the project. Economic barriers can be categorized as those that affect project risk (actual or perceived) and project cost.

**CASE STUDY 2.4**

"The Tokyo Metropolitan Government introduced its District Energy Planning System for Effective Utilization in 2009. The policy for this programme is based on the principle that 1) district-wide energy planning and 2) energy consideration in the early stages of planning are necessary to further promote the design of energy-efficient buildings and to introduce renewable energy." Yuko Nishida, City of Tokyo, 2014
taxes (such as polluter taxes and carbon pricing) and any revenue reductions among others (see section 4 for further discussion of the national government’s role).

Cities can accelerate district energy through a variety of financial and fiscal incentives (described below) that can significantly improve the viability of district energy projects, and that provide an alternative to direct public ownership of the project (a model that is discussed in section 3). Where cities have limited capacity to provide such incentives, they can still help efforts forward by creating favourable urban planning, energy regulations and local policies, as described in section 2.2.

II. DEBT PROVISION AND BOND FONDS: Cities can provide low-cost loans to projects by passing on their ability to raise low-cost recourse capital. Similarly, cities can issue general obligation bonds to provide debt to a project. Revenue bonds can also be issued to effectively provide this debt at a higher interest rate. Using non-recourse loans and revenue bonds in project financing will have a high due-diligence cost and is best suited to mature markets or in combination with connection guarantees.

In St. Paul, long-term revenue bonds were issued to develop both the heating and cooling networks, and the city was able to avoid having to guarantee debt repayments. This was made possible by the signing of long-term contracts with initial customers. Toronto, meanwhile, used revenue and general obligation bonds in tandem to raise the necessary capital for its deep-water lake cooling system. To secure the financing for the project, the city required future customers to sign contracts or letters of intent. A city’s issuance of bonds can be an important factor for decisions by federal, state and private investors, who look to municipal support as a key indicator of city priority and capacity for fostering district energy.

III. LOAN GUARANTEES AND UNDERWRITING: Loan guarantees from cities allow access to low-interest debt for projects, which can greatly reduce the total project cost. Creditors may require some form of loan guarantee from municipalities, obliging the city to repay the loan if the project defaults. In the U.K., the Aberdeen City Council underwrites (via a loan guarantee) the not-for-profit district heating company, allowing it to obtain commercial debt financing at attractive rates. In Denmark, district energy companies similarly may request that their municipality act as guarantee for the needed loans. This “kommune-garanti” reduces lenders’ risk and thus lowers interest rates. Kommunekredit, a credit union for Danish cities, lends out more than DKK1 billion ($US170 million) annually to district energy companies that hold the kommune-garanti. Since the early 1990s, there has been no instance of a municipal government being called upon to cover the losses of such loans (Chittum and Østergaard, 2014).

IV. GRANTS: Cities may provide capital grants or annual payments to specific projects to enable their initial development or to help direct them to social or environmental objectives. The City of London has provided development grants for early-stage feasibility assessments and investment-grade audits. The first phase of the Bunhill Heat and Power project in the city’s Islington borough, which aims to provide cheap heat to social housing, benefited from £4.2 million ($US5.7 million) in grants from the London Development Agency (now dissolved) and the Homes and Community Agency (see case study 5.2).

V. INTERNATIONAL OR NATIONAL GRANTS: Grant funding of district energy systems tends to come from higher levels of government than the city. This reflects the national importance of district energy (see section 4) as well as the city’s ability to better leverage its project money if it is engaged more fully in the business model (such as with equity or debt provision; see case study 2.7 on the Toronto Atmospheric Fund). Cities can help individual projects gain funding from national or international grants, as Vancouver did for the SEFC NEW project (see case study 5.1). Rotterdam was able to secure a €27 million ($US33.8 million) grant from the Dutch government to reflect the equivalent avoided social costs of CO₂ and NOₓ emissions. To fund the 1.1 MW River Center Solar Thermal project, St. Paul obtained a US$1 million grant from the U.S. Department of Energy, to match equivalent funding from the local public utility. Porto Louis was able to secure a US$1 million grant from the Sustainable Energy Fund for Africa, managed by the African Development Bank, for feasibility studies of its deep-sea water district cooling project. Project CELSUS, a grant programme provided by the EU, is financing innovative demonstration projects in London, Rotterdam, Gothenburg, Genoa and Gloucester (see section 5.5).

In the north-eastern Romanian town of Botosani (population 135,000), space heating and hot water services are provided by the municipally owned district heating utility, Modern Calor. The district heating system was built in the 1960s, following the typical socialist-era design concept of “low CAPEX, high OPEX”.

During the 1990s and early 2000s, Romania’s district heating sector experienced tremendous difficulties, as the lack of investments led to dramatic reductions in operational efficiency and reliability of heat supply. Combined with the rising cost of natural gas, this led to serious affordability constraints for end-users, resulting in disconnections from the network, which further reduced operational efficiencies. By the mid-2000s, Modern Calor’s annual heat losses topped 50 per cent. The poor financial state of the district heating sector resulted in a scarcity of long-term commercial financing needed to modernize these utilities.

EU Regional Operational Programs (part of EU Structural Funds) provided a greatly needed CAPEX incentive to upgrade dilapidated district heating systems throughout the country. However, several municipalities, including Botosani, experienced difficulties in securing their share of co-financing, as access to commercial financing was scarce. The International Finance Corporation’s (IFC’s) Subnational Finance Group assisted the project and provided a long-term debt to Botosani to help secure the municipality’s co-financing requirement.

CASE STUDY 2.5

As a result of the project, a state-of-the-art 8 MWth CHP plant and two 52 MWth heat-only boilers were installed, replacing an oversized and inefficient heat capacity of 560 MWth prior to the project; in addition, 6.5 km (dual-pipe) of transmission and 14.5 km of distribution in the district heating network were replaced. The second phase of the project financed replacement of an additional 3.7 km of distribution, as well as an energy efficiency improvement programme for residential buildings.

The total project cost was €157.5 million ($US177.1 million), with the IFC providing a loan of some €8 million ($US10 million). In addition to financial support, the IFC provided advisory services to Modern Calor to identify cost-reduction opportunities through technical measures (largely changes in operational modes) and cost-structure review. In total, the project is projected to abate 684,100 tons of CO₂-equivalent, and 21 large-scale district heating consumers who had formally disconnected from the system re-connected following project completion.

Source: Sharabaroff, 2014.
CASE STUDY 2.6

OSLO'S CLIMATE AND ENERGY FUND

The City of Oslo established a Climate and Energy Fund in 1992. While the fund was originally built up through a surcharge on electricity, activities are now paid for from the interest on the existing fund. The fund provides subsidies to projects that reduce greenhouse gas emissions and local air pollution from buildings and construction and that result in reduced and/or more effective use of energy. It has supported projects resulting in total energy savings of 1.5 terawatt-hours (TWh) per year, or about 10 per cent of what the city as a whole uses. In 2012, the fund supported 2,592 climate and energy efficiency projects, with half of the funding directed to new renewable energy, such as heat pumps, district heating, bioenergy and solar power.

CASE STUDY 2.7

TORONTO'S REVOLVING FUND MODEL

Toronto established the non-profit Toronto Atmospheric Fund (TAF) in 1999 with CAD$2 million (US$1.92 million) from the sale of a city-owned property. The fund’s mission is to accelerate reductions in local greenhouse gas emissions by testing and scaling up solutions in renewable energy, energy efficiency and reduced fossil fuel consumption. TAF originally provided only grants, but a key barrier to scaling was the availability of leverage capital. Today, TAF provides grants and loans, undertakes special projects and creates partnerships. TAF’s assets generate around CAD$1.5 million (US$1.15 million) in revenue annually for grants and special projects. Total project funding since inception has been about CAD$50 million (US$40.6 million). TAF provided CAD$280,000 (US$222,000) in 2002 for a feasibility study and subsequently loaned CAD$1 million (US$0.87 million) to help finance a tri-generation system that combines electricity generation, heating and cooling produced by a highly efficient system servicing three large buildings.

TAF also facilitated a partnership with the Federation of Canadian Municipalities, which then provided funding. (See also case study 3.5 on Toronto’s Enwave company.)

New city development in China (top). Pre-insulated district heat pipe in Botosani, Romania (bottom).

REVOLVING FUND: Some local governments are establishing investment funds or green funds to provide subsidies, grants and zero- or low-cost financing, particularly at early stages, for developments that are in the public interest. These endowments can stem from the sale of a city asset (such as city land, shares in a utility, etc.), a surcharge on utility energy bills or innovative sources such as avoided subsidy costs. The funds are designed to be self-sustaining and to grow through returns on investment, interest rates on debt and other revenues (see case study 2.6 on Oslo). A revolving fund allows for public support of strategic investments without necessitating direct city ownership, and it caps the city’s overall involvement in district energy. Often, the fund provides deferal on principal repayment for the first 5–5 years while the system is being constructed and customer revenue has not yet commenced. A revolving fund can support specific district energy starter schemes, designed both to illustrate the feasibility of installing a major heat network (see case study 2.7 on Toronto) and to provide the catalyst for the cost reductions and development of a local supply chain. Capital can be repaid and redeplored in other projects.

CITY-LEVEL SUBSIDIES: Although many countries provide national subsidies for low-carbon or energy-efficient heating or cooling, subsidies developed at a city level are less prominent. In Botosani, municipal heat networks historically were heavily subsidized by municipalities to account for inefficiencies in the network and to protect the population from high heat prices (Sharaharoff, 2014). Some cities exploring modern district energy systems have been advancing mechanisms – such as feed-in tariffs, net metering and heat incentives – that internalize the public benefits of these systems, in association with a public utility. Seoul has a city-level feed-in tariff for CHP, and Tokyo initiated a cogeneration subsidy to encourage increased electricity generation in response to the power outages from the 2011 earthquake (see section 2.4.1 for more on tariff setting).

DEVELOPMENT-BASED LAND-VALUE CAPTURE STRATEGIES: Converting rural to urban land can increase the land value by approximately 400 per cent in Latin America (Smolka, 2014), and this increase can be even higher for high-density urban land. Because such windfalls to the landowner can be captured for public use, land-value capture is described as a “no-brainer,” particularly as the value added to the land can be higher than the infrastructure cost needed to develop it. This concept has a long precedent in many countries, based on the “principle of unjustified enrichment” – or the idea that citizens should not accumulate wealth that does not result from their own efforts. Following the conclusions of the China Urbanization Study (World Bank and DRC, 2014), China’s State Council is shifting to a new strategy for development and will prioritize urban (re)development in transit station districts (1 km² in size). Within the next decade, China will have 6,000 new transit stations, 15 per cent of which (i.e., 900 districts) will have high development potential. These 1 km² districts around transit stations are very high-potential urban areas, where Development-Based Land-Value Capture (DB-LVC) strategies will be implemented to finance infrastructure investment and energy efficiency.

Rural land requisition allows for the development of new urban zones, increasing the value of the land. Future and continuing revenues from selling or leasing land in distinct zones, and capturing taxes from new landowners, provides the finance for infrastructure. This is an excellent demonstration of an integrated approach to district energy. By incorporating urban planning (mixed-use zoning, compact land use and high connectivity) with transport and district energy planning, financing of optimal and well-planned district energy projects can be achieved (World Bank and DRC, 2014).
Unless private property owners are willing to host generation within their buildings, cities will need to allot land for district energy generation. Publicly owned parcels can be used in-kind or can generate rents for the city, depending on the ownership model of the system (see case study 5.8 on London’s Olympic Park). As real estate is phased in, more generators can be added and connected within the network, and space should be allotted for future system growth. Since 2012, Seoul has supported the construction of fuel cell-CHP power plants – some on city-owned land – and the municipal government is targeting an additional total installed capacity of 250 MW (see section 2.4.4 on the city as a consumer for more examples).

Some cities may need to finance refinancments to modernize their district heating systems. Selling a portion of the district heating networks should be allotted for future system modernization and expansion of the district heating networks.

### 2.3.3 Demonstration Projects

Regulated district energy systems provide a stable, low-risk level of return to investors with long-time horizons. However, the private sector often has insufficient incentives to undertake more risky or unfamiliar initial investments. Once the pipes are in the ground, it is much easier to leverage private sector finance to expand the network. Local governments are supporting demonstration projects to illustrate the feasibility and commercial viability of modern district energy systems and showcase socio-economic benefits to citizens, private building owners, developers and investors (see case study 2.8 on Amsterdam).

#### Case Study 2.8

**AMSTERDAM**

The city of Amsterdam initiated the “Amsterdam Smart City” (ASC) initiative – together with the Amsterdam Economic Board, Liander, the grid operator and KPN – to bring together diverse stakeholders and to pilot local projects and policies focused on the energy transition. The designated areas are also tax-free zones to incentivize companies to pilot new technologies. The overall goal is to help the city achieve its CO2 emission targets and to support economic development in the Amsterdam Metropolitan Area, in order to improve residents’ quality of life.

The initiative involves more than 70 partners – including local companies, housing corporations and residents – in a variety of pilot projects focused on the energy transition, including district energy. The most effective initiatives are then implemented on a larger scale (see, for example, case study 2.1 on Amsterdam, which included cooperation among various industrial partners on the exchange of energy and the use of excess waste heat from data centers). All of the acquired knowledge and experience is shared via the ASC platform, helping to accelerate the city’s climate and energy programmes.

#### Case Study 2.9

**INDIA – GIFT CITY**

Gujarat International Finance Tec-City (GIFT City) is developing India’s first district cooling network as part of an effort to attract financial services companies to the country. This development is significant given the large potential for district cooling in India (see section 1.1). A demonstration project that is scalable not only showcases the technology, but provides local capacity building on how to develop a project, which could then be transferred nationally. It also builds investor confidence in district cooling technology and in the ability of local governments to deliver it.

The city has set up GIFT District Cooling Systems Limited, a Special Purpose Vehicle limited by shares, to define the proposed district cooling network through a public-private partnership model. The city opted to use district cooling due to its higher efficiency, lower operation and maintenance cost, and its ability to significantly cut carbon emissions. The system will reduce electricity consumption 65–80 per cent through the use of industrial-scale electric chillers, which have a far higher coefficient of performance and energy efficiency ratio.
"There was not one financial company that would say we are ready to invest in the transmission line, not until there is enough demand and supply connected. But in the beginning, it’s about risk taking. ‘We invested in the transmission line in order to get things done – we think it is workable and we have different rules about investment, and a different view on return on investment rates, as transmission delivers other benefits.’"

City of Rotterdam representative, 2014

As a provider of infrastructure and services (energy, transport, housing, wastewater treatment, etc.), a city can shape the low-carbon pathways of these services, capture synergies across the different business segments, and direct the local district energy strategy towards social and economic objectives. As a consumer of heating and cooling (in public buildings, social housing, hospitals, leisure centres, etc.), the city is ideally placed to demand the energy services that it deems optimal and has the ability to facilitate a project’s conception through the provision of anchor load and connection certainty. Table 2.4 summarizes the roles and leverage that a city has as both a provider and consumer of services.

| 2.4 LOCAL GOVERNMENT AS PROVIDER AND CONSUMER |

The Forum des Halles (left) and Louvre Museum (right) in Paris are both heated by CPCU as well as being cooled by Climespace, with the Paris district heating network producing 5.5 TWh of heat and 1 TWh of electricity per year. The network started by delivering heat to a factory in Paris while also pre-heating passenger trains prior to departure, and quickly expanded as neighbouring buildings wished to benefit from heating that was cheap, safe and reliable. Today, the network continues to flourish using the underground tunnels and pipelines that already serve the Paris metro system. CPCU’s 475 km network connects the equivalent of all social housing units, and half of all public buildings (see section 2.2.1 on targets). The network started by delivering heat to a factory in Paris while also pre-heating passenger trains prior to departure, and quickly expanded as neighbouring buildings wished to benefit from heating that was cheap, safe and reliable. Today, the network continues to flourish using the underground tunnels and pipelines that already serve the Paris metro system. CPCU’s 475 km network connects the equivalent of all social housing units, and half of all public buildings (see section 2.2.1 on targets). Local authorities can also direct municipal utilities to focus on specific demand groups, such as social housing (see case study 2.10 on Paris).

| 2.4.1 MUNICIPAL UTILITY TARGETS AND PROMOTION POLICIES |

Local governments that have stakes in a municipal utility can prescribe the use of recovered or renewable heat in district energy networks in order to achieve public policy objectives. Anderh, Copenhagen, Frankfurt, Oslo, Paris and Växjö are just a few examples of cities that have mandated the use of waste or renewable heat or cooling (see section 2.2.1 on targets). Local authorities can also direct municipal utilities to focus on specific demand groups, such as social housing (see case study 2.10 on Paris).

| TABLE 2.4 | Policy activities that local governments are undertaking in their role as provider and consumer |

<table>
<thead>
<tr>
<th>POLICY INTERVENTION AREA</th>
<th>DESCRIPTION OF POLICY ACTIVITY</th>
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<tbody>
<tr>
<td>CITY-OWNED OR OPERATED UTILITIES AND WASTE-HEAT TARIFF REGULATION including local utilities, distribution companies, energy service companies (ESCOs) (sections 2.4.1–2.4.3)</td>
<td>■ Utility mandates and incentives ■ Interconnection policies and incentives ■ Waste-heat tariff regulation and customer protection policies ■ Investment in, or partnership with, other utilities</td>
</tr>
<tr>
<td>PROCUREMENT, PURCHASING, INVESTMENT (sections 2.4.4)</td>
<td>■ Investment in district energy for government buildings, schools, public transport; purchase or joint purchase of district heating/cooling or power ( cogeneration) with other cities; green public procurement</td>
</tr>
</tbody>
</table>

Source: Adapted from Martinot, 2011, and Sins, 2009

Historically, district energy has played an important role in Paris and has been developed mostly on its financial credentials and ability to provide security of supply. In 1927, the city created a concession for developing a network to deliver steam for heating national and public buildings. The goal was (to follow): 1) to reduce the city’s coal and wood use in order to minimize fire risk and improve air quality, and 2) to reduce the need for thousands of people to deliver coal or wood to the streets of Paris (see section 1.6 on catalysis for district energy). After World War II, the city of Paris became a 55 per cent shareholder in the Paris Urban Heating Company (CPCU), which, 30 years later, still operates (under concession) the Paris district heating network.

The network started by delivering heat to a factory in Paris while also pre-heating passenger trains prior to departure, and quickly expanded as neighbouring buildings wished to benefit from heating that was cheap, safe and reliable. Today, the network continues to flourish using the underground tunnels and pipelines that already serve the Paris metro system. CPCU’s 475 km network connects the equivalent of all social housing units, and half of all public buildings (see section 2.2.1 on targets). Heat is produced at eight facilities— including two cogeneration facilities and three waste-to-energy plants – that have a combined total of 1.4 GW of generating capacity and produce 5.5 TWh of heat and 1 TWh of electricity per year. The waste-to-energy plants avoid the emission of 800,000 tons of CO₂ annually.

Because the city has a large stake in CPCU, it is able to control the production mix of heat and to influence the company’s policy objectives. As the network’s role has developed, it now aims not only to provide affordable, reliable heat, but also to reduce the city’s carbon emissions by lowering primary energy use and enabling a greater share of renewable heat. CPCU’s target is to achieve 50 per cent renewable or recovered energy in heat production by 2015, and 60 per cent by 2020, in line with the Paris Climate Action Plan. This transition will include developing biomass and geothermal; heat recovery from sewers; and co-firing coal and wood. If the 50 per cent target is met, a national value-added tax (VAT) incentive will save CPCU customers some €35 million (US$43.7 million) a year by reducing the VAT on heat to 5.5 per cent. Once CPCU reaches a 50 per cent renewable share, the city will investigate the establishment of mandatory connection zones to encourage connection (see section 2.2.4).

Paris has a relatively large amount of social housing, with 1 in 5 people living in social housing units and a higher proportion in some suburbs. Through the city’s stake in CPCU, the district heating network is being developed to incorporate new social housing. The concession contract sets a maximum price for the heat delivered, indexed against the share of renewable heat generated. The city of Paris also can enforce a special low price for those in social housing.
In Copenhagen, local municipalities own many of the local heat distribution networks. Over time, transmission infrastructure spanning individual networks was developed to share energy and access larger supply sources. In many cases, the transmission systems evolved as partnerships among municipal distribution companies. Such systems have been crucial in enabling Copenhagen to meet over 98 per cent of its heat demand with district heating. Figure 2.7 shows the city’s current heat networks and highlights the importance of transmission lines in connecting the networks.

Cities worldwide are emulating Copenhagen’s model of nodal development leading to the interconnection of municipal utility transmission because of its demonstrable efficiencies and its ability to connect large heat sources to the network. The key role of municipal ownership in developing transmission lines to connect nodal networks is a recommended best practice to help cities expand their systems into fully interconnected city-wide networks.

Anshan, with the help of Danish companies, is doing just this (see figure 2.8). The local authority’s ownership of a district heating company made it possible to invest directly in a transmission network that will connect the city’s 42 district heating companies, pooling demand and generation capacity and enabling the connection of 1 GW of waste heat from a steel plant (see case study 5.7).

The ZERO Carbon Roadmap was developed by ProjectZero, a public-private partnership that is enabling Sonderborg to realize its zero carbon visions – including the city’s plans for district energy (see case study 2.14). London has identified city-wide district energy as crucial to meeting its target of 25 per cent decentralised energy by 2025. It is not clear, however, whether such a network would be municipally owned, due in part to the highly liberalized and privatized nature of the U.K. energy system. It is possible that the municipality’s role could be in establishing concession contracts or tenders for the build-out of transmission pipes. Development of the network will be made easier by interconnection standards currently under consideration.

In some cities, the development of transmission lines is key to connecting heat sources that are located far from demand. Bergen (see case study 3.5) and Oslo both have long transmission lines leading to waste incinerators. Rotterdam has developed a 27 km transmission system to connect waste heat in the harbour (see case study 2.11). And in Velenje, waste heat from the 779 MW Šoštanj Thermal Power Plant supplies most of the heat to the city’s extensive district energy network (97 per cent of residential demand), helping to keep the city’s heat price extremely low. The plant, located in a neighbouring municipality, is connected by a transmission line that was only possible because of the 85 per cent share that Velenje has in the public utility that owns the plant.
In Rotterdam, the city partially owns the two utilities, Warmtebedrijf Rotterdam and Eneco. Warmtebedrijf Rotterdam transports waste heat from the harbour area to the city, and Eneco distributes heat in the city’s north. Rotterdam has one of the largest industrial harbours in Europe, with significant potential for waste heat recovery. Initially, the city solicited private sector actors to invest in developing a heat transmission connection between the harbour and the city’s district heat networks, but these actors were not ready to invest in the line until sufficient demand and supply was connected (Hoevel and Webb, 2012). In 2010, the city decided to invest €58 million (US$50.9 million) to establish a municipal district heating company (Warmtebedrijf Rotterdam) to develop a 26 km heat transmission connection. The line would initially connect Rotterdam’s Rozenburg (AVR) waste incinerator, located in the harbour, to the Nuon heat network in Rotterdam-South and the Eneco network in Rotterdam-North.

To create sufficient economies of scale on the demand side for the two distribution companies (Eneco and Nuon) to develop the heat transmission connection, the line would initially connect and support future expansion. Among the public sector objectives achieved from the network connection project are reduced carbon intensity, improved local air quality, greater cost efficiency and the utilisation of waste heat. The city’s stake in Warmtebedrijf and in the Nuon and Eneco concessions was a key factor in the network’s success and makes it possible for the city to also support waste heat sources, such as from a steel plant, to the city, and Eneco distributes heat in the city’s north. In its capacity as a shareholder of Warmtebedrijf Rotterdam, the city of Rotterdam provided equity that enabled the utility to fund its investment in the heat transmission system. This municipal contribution was critical because of the severe disruption to financial markets during the development period. By providing equity to Warmtebedrijf Rotterdam, the City emphasised the utility’s role as a public utility. The city’s stake in Warmtebedrijf and in the Nuon and Eneco concessions was a key factor in the network’s success and makes it possible for the city to also support future expansion. Among the public sector objectives achieved from the network connection project are reduced carbon intensity, improved local air quality, greater cost efficiency and the utilisation of waste heat.

In 2015, Warmtebedrijf Rotterdam finalized the connection between the Rozenburg incinerator and the city of Rotterdam, and in 2014 Eneco finalized the connection between the incinerator and the city’s north. The network enables the transmission of significant amounts of waste heat from the harbour. With both utilities connected, Rotterdam now has its own “heat roundabout,” which ensures a reliable heat supply to the city (boosting resilience), makes possible the transition to more sustainable energy sources and supports growth of the district energy network in both the city and the region.

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The development of new waste-to-energy facilities, sewage treatment plants and landfills can drive the creation of a district energy system, particularly when the local government wants to leverage this opportunity and not let a resource be wasted. District energy networks also can utilize waste heat from industry and data centres, and waste cooling from liquefied natural gas (LNG) terminals (see table 1.1 for examples of these technology users and their benefits). Waste heat sources, which tend to be more plentiful than heating sources, can be combined with an absorption chiller to provide cooling. Yet numerous cities have faced difficulties in pricing waste energy accurately.

Policy recommendations for tariff setting will differ depending on the city’s heat mix, the maturity of the market and who is deciding on the tariffs. Generally, having a public utility can enable a city to set a framework for pricing heat that can encourage more sources to connect. The tariff for heat should account for:

1. The cost of connection to waste energy and any running costs (e.g., electricity running a heat pump; the cost of avoided electricity generation).
2. The cost to the utility of required redundancy in the network (e.g., gas boilers or electric chillers) to reflect the fact that waste heat may not be able to guarantee supply, and
3. Any incentives needed to encourage the waste heat provider to connect to the network (and shift away from its core business practice).

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3. Any incentives needed to encourage the waste heat provider to connect to the network (and shift away from its core business practice).
**Next-Cost Technology:** Although waste heat sources are flexible in providing heat up to a maximum level of supply, they frequently will be producing heat at the maximum rate possible so as to provide as much baseload heat into a system as possible. This is due to the high-CAPEX, low-OPEX nature of capturing waste heat and its avoidance of using additional fossil fuels. This provision at baseload will normally mean that there is a slightly more expensive technology not producing at full capacity. The heat price of this more expensive technology can provide a good metric against which to base a waste heat price; however, considerations on reboundancy should still be made (see case study 2.12 on Gothenburg).

**District Energy Networks often are designed to ensure that baseload heat can be running as often as possible. To meet system demand peaks, they will use a more flexible plant that is often more carbon-and fossil fuel-intensive, in combination with thermal storage.**

For example, the SEFC NEU energy centre in Vancouver utilizes waste heat from the wastewater system using a 5.2 MW heat pump that is designed to meet 50 per cent of peak heat capacity, but that over the whole year supplies 70 per cent of the system’s heat demand (see case study 2.1). The waste heat is provided for free, although connection and running costs are paid for by SEFC NEU. The heat is free, as Metro Vancouver (a public entity) decided that this would maximize utility of the resource.

**Integrating with Other Utilities:** Optimizing district energy systems to ensure efficient resource use and to realize their diverse benefits requires working with actors outside of the standard heating/cooling utility and end-user model. Cities pursuing district energy have benefited from identifying synergies with non-energy utilities – such as providers of water, waste management or transport – and incorporating these synergies into a mutually beneficial business case (see case study 2.13 on the EU’s Project CELSIUS). Bergen’s urban densification policies, for example, promote district energy in coordination with the city’s new light-rail network (see section 2.1).

Such collaboration can go further than just joint planning of infrastructure, and can mean the participation of multiple utilities in developing the business case. Rotterdam, which historically has enjoyed plentiful natural gas supplies and has an extensive gas network, is expanding district energy as a means to reduce domestic gas production, meet carbon-reduction targets and improve air quality. The city hopes to develop a business model that can identify synergies between district energy systems and gas distribution networks, and that incorporates the value of offsetting investments in gas piping. Although it is not clear how this will work in practice, it is an innovative step towards trying to capture the external benefits of district energy.

Toronto’s district energy company, Enwave, was able to develop its deep-water cooling system because the project was mutually beneficial for the local water utility, Toronto Water, which needed new pipes to extract water from Lake Ontario. Enwave pays to co-locate its network with Toronto Water’s drinking water systems and pays for pumping costs, allowing the company to pump heat into the drinking water system (see case study 5.5).

Historically, waste incineration was solely a means to reduce the flow of waste to landfills. But today, as a result of municipal waste management plans (as in Tokyo or national laws as in Norway), many incinerators are required to utilize waste heat, making these facilities critical to district heating systems. Incorporating waste incineration into the business model involves providing sufficient revenues to cover connection costs and any other deviation from the core business model in air pollution control. Connected heat and heating/cooling utilities can result in cost savings for both parties, reducing the costs of waste management and energy provision in a city.

Wastewater utilities are increasingly involved in district energy as well, because of the thermal energy contained in sewage. Metro Vancouver, which operates the city’s sewage system, is looking to work with district energy companies to utilize this resource, and is even willing to do so for free as long as it does not affect the core business (Carmichael, 2014). Oslo, Seattle and Tokyo are also installing sewage-capture systems.

Local electricity utilities can benefit from the distributed cogeneration that district energy often provides. In Bergen, electricity companies, facing capacity concerns and network strains, supported the development of district heating because it reduced reinforcement costs and provided additional revenues. The local district heating industry association was created mostly by electricity suppliers. London, Seattle and Tokyo also are investigating the incorporation of electricity suppliers into district energy networks, utilizing waste heat from substations and transit lines. Seattle is working to overcome electricity suppliers’ concerns about locating pressurized water close to electricity lines. London is looking to overcome the challenge of not receiving retail rates for CHP-produced power by using this electricity to run more of the city’s low-voltage meter system (see case study 4.4 on London’s Licence Lite). In Tokyo, if CHP developers are approved as “Specified Electricity Utilities” under the Electricity Business Act, they can provide power to a specified area, such as the district heating and cooling area they supply, and can sell the electricity at retail prices. Both Tokyo and London also are investigating the use of waste heat from their metro systems in district heating.

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**CASE STUDY 2.12**

**Gothenburg’s Waste Heat: Indexing Against Tomato Prices**

In the 1970s, there were discussions about how to value the excess heat from refineries in Gothenburg. The parties had a hard time agreeing on a price for this waste heat, as they had very different perspectives on its value. From the city’s perspective, the heat would not be utilized otherwise and so should be priced at a low level. From the refinery’s perspective, the heat could be used to grow tomatoes and therefore should be valued at the world market price for tomatoes. After tough negotiations, the national government stepped in and supported the parties financially so that they could conclude a deal.

In Gothenburg today, the price for waste heat is set via individual heat purchase agreements, linked to the marginal alternative price. The city uses two main principles to set the price for waste heat: 1) The heat should be valued in relation to the alternative for district heat production (so if the alternative is cogeneration from natural gas, then the waste heat should be valued in relation to this production heat price, whereas if the alternative is a heat pump or a natural gas boiler, it should be valued in relation to that), and 2) the excess heat should be valued in relation to how much it costs for Göteborg Energi to produce its own heat (i.e., using next-cost technology pricing).

Waste heat prices can thus fluctuate to a large extent, which is why there can be a minimum and a maximum price. In summertime, when the company’s own production is not running at all, the prices are fixed at a lower rate. Although this method of setting the price was developed by Göteborg Energi and the Gothenburg refineries, it is now used in many other cities in Sweden as well.
SECTION 2

**2.4.4 CITY AS CONSUMER**

Perhaps the most important factor in developing financially viable district energy projects is the ability to find an initial consumer base with a large and steady demand load. Consequently, new district energy schemes often involve the use of public buildings such as schools, hospitals, leisure centres and municipal housing buildings. Many publicly owned or regulated buildings are used 24 hours a day and/or have fairly large and steady loads (also referred to as anchor loads). Often these buildings also have space available where energy centres could be placed, making them ideal cornerstones for developing heat networks.

The city, as a consumer of energy, can set district energy targets for its buildings and operations (see table 2.2 for examples). Also important are formal and informal networks and contacts between, for example, municipal employees or officials and municipal housing companies and cooperative housing associations (Summerton, 1992).

In Christchurch, where there is no pre-existing district energy network, public facilities will be the anchor customers of the city’s new district energy system, as part of the earthquake rebuild. Public sector organizations have been key to identifying this development opportunity, undertaking feasibility studies and procuring preferred partner companies to develop the new system.

The Greater London Authority’s district energy strategy assumes a strong public sector role in preparing the district energy market for eventual private sector takeover. The city targets the London borough authorities to lead and coordinate district schemes based on two key factors: 1) although most of the land in London is privatized, the boroughs have access to more housing land, estates and office buildings, all of which can act as anchor loads delivering a base-heat demand and revenue; and 2) the boroughs can take cheaper loans and take a longer-term risk for public benefit than the private sector.

The focus on borough and public sector buildings provides the most-secure and lowest-risk opportunities for long-term heat contracts and network expansion. In the United States, some private entities have used long-term customer service contracts from a municipality (20-year off-take agreements) as security collateral on debt. This demonstrates the importance of load uncertainty, as highlighted in section 2.2.4.

**CASE STUDY 2.13**

Through its Project CELSIUS grant programme, the EU is pioneering innovative business models and technologies accessible across Europe in cities such as Gothenburg (lead partner), Cologne, Genoa, London and Rotterdam. The programme’s overall aim is to save energy by utilizing more waste heat in Europe. Business models incorporate a range of actors for whom district energy is not a core part of their business. Cities at the forefront of these efforts include Gothenburg, which is basing 60 per cent of its district heating on waste/recycled heat including from industries, waste incineration and waste water treatment; even ships are connected to district heating networks. Rotterdam is taking advantage of free cooling from river water and has also created a “heat hub”, incorporating smart storage into the heat network rather than at the source of waste heat. And in London, waste heat from an electricity substation and the subway are connected into the city’s Rush Hill energy centre.

In Velenje, Slovenia has established an energy agency, KSSENA, to facilitate the implementation of its energy concept, including modern district energy.

**EU PROJECT CELSIUS: THE ROLE OF GRANTS IN BUILDING CAPACITY FOR NEW BUSINESS MODELS**

**Table 2.5** provides an overview of the city’s role as an advocate. Capacity-building is crucial to raising public and investor awareness, thereby lowering perceived risk, improving the bankability of projects and facilitating effective policy implementation.

**2.5 LOCAL GOVERNMENT AS A COORDINATOR AND ADVOCATE**

As shown in sections 2.1 to 2.3, implementing district energy demands a new level of planning and coordination capacity as well as significant time, expertise and resources from local governments. Developing a district energy system requires a strong champion or series of advocates committed to coordinating agencies and processes; developing a customer base; securing permits, approvals, and regulatory requirements; and driving the overall process. In some cities, the local public utility may be instrumental in steering district energy systems towards city objectives (as seen in section 2.3). In others, the driver may be an institutional structure created to help develop and implement the district energy vision. Regardless of the form, local governments have a vital role to play in advocacy and coordination.

“A key question when it comes to energy planning and the municipal approach to energy is, where does it start? It doesn’t start with energy, it starts with the community.”

Fernando Caruso, City of Toronto, 2014

**Table 2.5** Policy activities that local governments are undertaking in their role as coordinator and advocate

<table>
<thead>
<tr>
<th>POLICY INTERVENTION AREA</th>
<th>DESCRIPTION OF POLICY ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARKET FACILITATION AND CAPACITY-BUILDING (section 2.5.1)</td>
<td>• Dedicated city unit or coordination mechanism to facilitate the development of bankable projects through capacity-building, trainings, project structuring, multi-stakeholder engagement</td>
</tr>
<tr>
<td>AWARENESS-RAISING AND OUTREACH (section 2.5.2)</td>
<td>• Outreach through public media and education campaigns; awards, community events; website, publications, geospatial energy, infrastructure and emissions mapping; information centres</td>
</tr>
<tr>
<td>ADVOCATING FOR DISTRICT ENERGY AT OTHER LEVELS OF GOVERNMENT (section 2.5.3)</td>
<td>• Promotion of district energy systems in state- and federal-level policy and regulatory processes, including in utility operations in the city • Lobbying of higher levels of government for supporting policies and funding commitments, including grants and taxation policies</td>
</tr>
</tbody>
</table>

Source: Adapted from Marsini, 2011, and Sims, 2009

![Image](7978.png)
2.5.1 MARKET FACILITATION AND CAPACITY-BUILDING

Coordination and capacity-building is required at different stages in the development of district energy, from planning to implementation. Planners often serve many different property owners, and unless there is one large developer of the system, the economic benefits of a city-wide, multi-stakeholder district energy system are too widespread to motivate any single stakeholder to commit the resources required to drive this facilitation process. Having a dedicated city unit or coordination mechanism to facilitate the development of bankable projects through capacity-building, training, project structuring and multi-stakeholder engagement is a key best practice in developing and implementing a district energy strategy.

A dedicated district energy champion is essential to coordinate within the city council and across stakeholders, and to scan the horizon for project and financing opportunities. Several cities have a champion in the form of a public utility, government agency or specific councilors. Such champions may have a regulatory function, or they may be “market facilitators” that provide information, training, finance, stakeholder convening, etc. Often, government departments or agencies tasked with promoting district energy take on both these roles. The key contribution of such agencies is outlined below.

• STAKEHOLDER COORDINATION AND COMMITMENT FOR VISION SETTING AND IMPLEMENTATION: Stakeholder acceptance of the vision, target, process and shared responsibility is crucial. It is important to involve stakeholders in setting goals and identifying activities in the energy plan, and to create ownership in the plan’s implementation. An independent body or designated agency can provide representation for stakeholders in developing a district energy vision and build commitment to its implementation. This also provides the space for the city to understand stakeholders’ positions and interests in order to negotiate common goals and activities, and can help build commitment from partners when they see the benefits that they can gain from cooperation.

Dedicated municipal staff and council members also need to coordinate across city units to develop community-based energy systems and to provide consistent advocacy through their varying initiatives to help disseminate this vision to a wider audience. These coordinating efforts are essential to ensure that work is not duplicated, that (from a technical standpoint) the system continues to operate smoothly, and that (from a financial standpoint) inefficiencies in the planning and development process do not increase costs (e.g., Dubai and Bergen). Planning and consenting risk alone can represent 20–25 per cent of a project’s costs (as seen, for example, in London).

• DATA COLLECTION FOR POLICY, OUTREACH AND AWARENESS-RAISING: Cities have to provide evidence to companies and consumers of the concrete benefits of district energy systems and of different policy and business models. This requires data on existing and future energy demand in buildings and on current and potential heat and cooling sources (see section 2.1), as well as scenario and feasibility analyses. Setting up a designated unit or independent body can help to coordinate the stakeholders necessary for data collection and to support analysis. In Amsterdam, involving different actors in mapping and scenario building (see case study 2.1) was a key success factor in both assessing the data on waste heat resources from diverse stakeholders and creating cooperation to translate the analysis into a district heat project for the city. Such evidence-based policy setting is also important to overcome political changes in the future (see case study 2.15 on Frankfurt).

• AWARENESS-RAISING AND OUTREACH

Within the current energy dialogue, there is a multi-disciplinary need to involve professional stakeholders as well as citizens, in order to promote sustainable urban development and alternative energy generation. Yet such discussions need to go beyond the energy sector. A broader understanding of district energy systems can be fostered by making use of tools such as public media and education campaigns; awards; community events; websites; publications; spatial, energy infrastructure and emissions mapping; heat mapping; and information centers. Making the process of developing and executing a district energy project as transparent as possible can result in greater acceptance by potential heat customers as well as broad political consensus for project implementation.

Raising awareness of the working principles and benefits of district energy is often a largely “invisible” solution among society at large, and is especially important in countries where the district heating market is underdeveloped and where knowledge and experience can be limited. Civic partnerships, professional networks and community organizations are essential groups with whom to cooperate to catalyze discussions of district energy systems and to advocate for their incorporation into city strategies. Milan, for example, has created municipality-run Energy Help Desks that provide technical and financial information on energy efficiency and renewables, and strongly promote district heating to consumers (see case study 2.16). Continued communication and dialogue with a wide range of stakeholders – including consumers, the wider public, national, regional and local policymakers; investors; universities; architects and builders; and others – is a vital element for the successful expansion and implementation of district energy strategies. The aim is to mainstream actions to foster the transition to such systems and to sustainable urban development.

2.5.2 AWARENESS-RAISING AND OUTREACH

To transition Sonderborg to a zero-carbon community by 2029, local stakeholders established ProjectZero as a public-private partnership in 2007. For the city, this was a means to secure a strong partnership among key stakeholders, with contributions from the regional utility company, SonEnergi; the Danish national energy company, DONG Energy; the Danfoss fund; the Nordica Fund and Sonderborg Municipality. The ProjectZero Company supports the city in coordinating, developing and implementing the energy strategy together with multiple stakeholders. It initiates energy efficiency improvement programmes, supports the transformation of current energy infrastructure to green renewable sources and monitors progress based on energy consumption and production data. In 2009, ProjectZero and the city launched a joint master plan for achieving the city’s ambitious goal.

The plan shows how energy-efficient solutions and community engagement will reduce energy consumption to some 40 per cent by 2029, in part by switching to carbon-neutral district heating sources.

One of the first steps in the initiative has been to “green” the existing district-heating system by replacing natural gas with renewable energy sources, combined with energy retrofitting of existing buildings. To achieve this goal, the ProjectZero Company has developed several successful programmes to encourage stakeholder participation. It offers training programmes and also allows companies to promote themselves as ZERO companies if they adopt strategies to reduce their emissions by a minimum of 10 per cent within the first year.

SOLAR THERMAL PLANT (LEFT) AND CHP PLANT (RIGHT) IN SONDERBORG
“We set up a new structure in 1990 to deliver these policy targets. Municipal energy policy was a new concept. We made it happen.”


Frankfurt has created an Energy Agency that acts as an arm’s-length, independent consultancy service able to: carry out a systematic search on potential customers and suitable sites for CHP and district energy; promote regular exchange with the local utilities and other key stakeholders; develop case studies on energy supply alternatives for new urban development schemes; offer free consulting services; and provide after “sales” customer service. Together, these activities are seen to have led to the success of the district energy component of the city’s climate protection policy (Fox, 2012).

For example, the feasibility studies often have resulted in new CHP plants or in connections to existing district heating areas. The city of Frankfurt recognized that, due to the efficiency of CHP, this approach holds enormous potential for reducing greenhouse gas emissions. Because there was political consensus on the matter, there has been no change in policy related to district energy, despite changes in government over the past three decades.

2.5.3 ADVOCATING FOR DISTRICT ENERGY AT OTHER LEVELS OF GOVERNMENT

Cities can become involved in broader policies to push forward district energy, whether at higher levels of government, with other municipalities, or with utilities or various regulatory agencies. Although national policies and regulations can help foster a market for district energy (see section 4), the city’s role in lobbying for, demonstrating and providing input on policies is very important. Such policies can include:

- benchmarking and disclosure requirements of building energy performance
- interconnection measures/standards that enable district energy
- incentives for the electricity produced in district energy systems (e.g., CHP) to reflect the benefits of local, decentralized power generation
- clear, consistent rules for connecting CHP to the electricity network
- guaranteed purchase of CHP electricity (i.e., priority in exporting to the grid)
- licensing exemption (operators can generate without a generator licence, which helps to keep costs down)
- enabling of decentralized generators such as allowing net metering of heating/cooling
- feed-in tariffs (or equivalent) for heating/cooling

In both Amsterdam and Rotterdam, the liberalization and enlargement of energy companies has reduced the influence of local authorities over energy issues. As a result, lobbying on a national level and cooperating with energy providers and network companies in the city itself has become necessary to influence national policy changes that can facilitate the energy transition. By doing so, Amsterdam successfully advanced a net metering policy that allows decentralized generators to provide heat to the district energy network. Oulu is currently advocating for a national policy on zero fossil fuel consumption in buildings to move forward the city’s progressive green agenda and support expansion of the district energy network.

In Milan, many existing buildings already have a centralized heating system. In these cases, besides substituting the existing boiler with a heat exchanger and connecting to the network, no other significant infrastructure work is needed in the shift to district heating. When the existing system has a diesel oil boiler, this shift is cost-effective and has a short payback time (4–5 years). The region previously provided subsidies to promote the switch from diesel oil, but today it is cost-effective enough not to need any financial support. Energy suppliers offer reconditioning through energy service contracts. However, communication is key to obtaining these agreements, and building owners need to be educated on the benefits of being a customer of a district energy system. The municipality strongly promotes this awareness-raising through its Energy Help Desks, as switching away from diesel oil boilers in order to improve local air quality is a municipal priority.

Energy Help Desks are run by the municipality and provide an information service on energy issues to end-users and residents. Energy experts are available according to a fixed schedule in the institutional offices of the city’s districts, to address any questions and to provide information on potential interventions, available incentives and financing instruments for district heating, energy efficiency and renewable energy. A new central office, opened in September 2014, promotes district heating through information campaigns that elaborate its environmental benefits.
Section 3:
BUSINESS MODELS FOR DISTRICT ENERGY:
A CONTINUUM FROM PUBLIC TO PRIVATE

The City of Vancouver, for the 2010 Winter Olympics, developed a publicly owned district heating utility that captures waste heat from sewage. The financial structuring of the project proved the commercial viability of district heating in Vancouver and has encouraged private sector development of district heating elsewhere in the city.

KEY FINDINGS

- **THE MAJORITY OF BUSINESS MODELS** for district energy involve the public sector to some degree, and in many cases the public sector has partial or full ownership of the project. The degree to which the public sector is involved is determined in part by how much it may wish to steer a district energy project towards a variety of local objectives.

- **BUSINESS MODELS THAT ARE REPLICAble AND SCALABLE** both technically and financially at the neighbourhood, city and national levels are key to the acceleration of district energy.

- **THE “WHOLLY PUBLIC” BUSINESS MODEL** is the most common globally. The public sector, in its role as local authority or public utility, has full ownership of the system, which allows it to have complete control of the project and makes it possible to deliver broader social objectives, such as environmental outcomes and the alleviation of fuel poverty through tariff control. Of the 45 champion cities, 18 have or are developing “wholly public” models as the majority district energy model.

- **“HYBRID PUBLIC AND PRIVATE” BUSINESS MODELS** have a rate of return that will attract the private sector, but the public sector is still willing to invest in the project and retain some control. Of the 45 champion cities, 22 have or are developing “hybrid public and private” models as the majority district energy model. These business models can include:
  - a public and private joint venture where investment is provided by both parties that are creating a district energy company, or where the public and private sector finance different assets in the district energy system (e.g., production of heat/cooling versus transmission and distribution);
  - a concession contract where the public sector is involved in the design and development of a project, which is then developed, financed and operated by the private sector, and the city usually has the option to buy back the project in the future; and
  - a community-owned not-for-profit or cooperative business model where a municipality can establish a district energy system as a mutual, community-owned not-for-profit or cooperative. In this model, the local authority takes on a lot of risk initially in development and if it underwrites any finance to the project.

- **“PRIVATE” BUSINESS MODELS** are pursued where there is a high rate of return for the private sector, and require limited public sector support. They are developed as wholly privately owned Special Purpose Vehicles, but may benefit from guaranteed demand from the public sector or a subsidy or local incentives. Of the 45 champion cities, 5 have or are developing “private” models as the majority district energy model. However, many cities also had small private sector projects.

- **BUSINESS MODELS FOR DEVELOPING COUNTRIES** that are beginning to develop district energy typically have strong public sector ownership, as energy markets often are not liberalized and market mechanisms for reflecting the municipal, regional and national benefits are not present. For example, the benefits of reduced peak and total electricity consumption due to district cooling may mean that the publicly owned electricity utility should have a strong presence in the business model.

THIS SECTION LOOKS AT

3.1 Introduction
3.2 The “wholly public” business model
3.3 The “hybrid public and private” business model
3.4 The “private” business model
3.5 Expanding the business model via additional innovative practices
3.1 INTRODUCTION

The business model for a district energy system is very project-specific. It needs to ensure that all of the players involved – including investors, owners, operators, utilities/suppliers, end-consumers and municipalities – can achieve financial returns, in addition to any wider economic benefits that they seek.

This section provides insight into potential business models and financial structures for project developers in a variety of investment environments. Showcasing innovative approaches from cities around the world can help planners make better-informed decisions on how to develop and financially structure a district energy system. Categorization of such approaches can help planners identify similarities that may apply to their own cities and specific circumstances. This section outlines the business models used in individual projects as well as some city-wide business models (for discussion of the business models of each of the 45 champion cities, see the full case studies available online).

The section builds on the revenues and costs described in section 1.5 and on the role of the city as a provider of energy services, as described in section 2.4.1.

### 3.1.1 CATEGORIZING BUSINESS MODELS

When designing a business model for a new district energy system, it is important to consider site-specific circumstances, including the type of project finance that is available. The majority of business models for district energy involve the public sector to some degree, whether as a local policymaker, planner, regulator or consumer, or more directly through partial or full ownership of projects (see section 2). Public sector involvement can be critical in coordinating multiple, diverse projects around a broader city-wide vision. Even projects with a high degree of private sector control are often still facilitated or supported in some way by the public sector.

Although the business models and ownership structures described here vary significantly, they can be grouped along a continuum from public to private. The relative involvement of the public or private sector depends broadly on two factors: 1) the return on investment for project investors, and 2) the degree of control and risk appetite of the public sector.

#### RETURN ON INVESTMENT (ROI) FOR PROJECT INVESTORS

The ROI is a financial metric that is dependent on both a project’s Internal Rate of Return (IRR) and its Weighted Average Cost of Capital (WACC). The IRR is extremely site-specific and is developed initially by the project sponsor, which could be a private district energy company or private utility, or a public body such as a local authority or public utility. The IRR will depend on the costs and incomes of the project. The WACC depends on the project’s risk profile and its current and future sponsors, as well as on the debt-to-equity ratio of its financial structuring. Typically, while private sector investors will focus primarily on the financial IRR of a given project, the public sector, either as a local authority or a public utility, will also account for additional socio-economic costs and benefits that are external to standard project finance.

#### DEGREE OF CONTROL AND RISK APPETITE OF THE PUBLIC SECTOR

The public sector may wish to steer a district energy project towards a variety of local objectives (see section 2.2), including cheaper local energy for public, private and/or residential customers (e.g., the alleviation of fuel poverty); local job creation; local wealth retention; low-carbon power generation; and/or local air pollution reduction. By quantifying these objectives through economic modelling, it is possible to realize additional ROI outside of the standard financial modelling.

The degree of public sector control over a project can vary widely, ranging from full development, ownership and operation (see section 2.4) to a role focused mainly on project coordination, local planning and policy (see section 2.2). The public sector may also wish to showcase the business case for district energy projects in the city by developing demonstration projects (see section 2.5). Some cities and countries are more inclined to have energy services provided by public utilities, while others are more open to private sector participation. The degree to which private sector involvement in energy provision influences the business model.

The public sector is extremely important in project development because of:
- its ability to leverage finance for projects, such as through access to senior levels of grant funding and better access to capital (see section 2.3),
- its ability to be a large, stable consumer and to provide off-take agreements (see section 2.4), and
- its longer-term planning focus, greater interest in meeting social and environmental objectives and ability to coordinate the multiple stakeholders involved in district energy.

### TABLE 3.1 Categorization of business models for district energy systems

<table>
<thead>
<tr>
<th>FINANCIAL RETURN ON INVESTMENT</th>
<th>DEGREE OF CONTROL AND RISK APPETITE OF PUBLIC SECTOR</th>
<th>TYPE OF BUSINESS MODEL</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>High or Medium / Low</td>
<td>Wholly public</td>
<td>District energy to meet social objectives related to housing or fuel poverty</td>
</tr>
<tr>
<td>MEDIUM / LOW</td>
<td>High or Medium / Low</td>
<td>Public/private hybrid</td>
<td>Public sector demonstrating the business case of district energy systems</td>
</tr>
<tr>
<td>MEDIUM / HIGH</td>
<td>Medium</td>
<td>Public/private joint venture</td>
<td>Public sector lowering the IRR by allowing cheaper energy tariffs than the private sector would</td>
</tr>
<tr>
<td>HIGH</td>
<td>Medium / Low</td>
<td>Private (with public facilitation)</td>
<td>Community-owned not-for-profit or cooperative</td>
</tr>
</tbody>
</table>

[Image: Laying district cooling pipes in Dubai, UAE]
Section 3

3.2 The "Wholly Public" Business Model

Of the various ownership models for district energy systems, the "wholly public" business model is the most common globally. Here, the public sector, in its role as local authority or public utility, has full ownership of the system, which gives it complete control of the project and makes it possible to deliver broader social objectives, such as environmental outcomes and the alleviation of fuel poverty through tariff control. The public sector can achieve these objectives by assessing a potential project based on its economic returns.

"Wholly public" projects typically are developed either by a subsidiary of the local authority (such as a pre-existing or newly created public utility), or within a department of the local authority, where they are funded using the authority’s balance sheet. Existing, city-wide public utilities can play an important role in developing district energy and are often kept as separate utilities to identify a difference in their core business practice. In Oslo and Bergen (see case study 3.3), the waste incinerators are publicly owned but are separated from the district energy company, and in Vancouver (see case study 3.1), the wastewater utility is separate from the district energy company. Such separation is important if the system is to be later sold to the private sector. "Wholly public" projects are common in both consolidated and subnational cities, and their existence reflects the city’s desired degree of control over the provision of thermal energy.

This section focuses on the project-level investments that these existing utilities make, as well as on the creation of new public utilities in expansion cities (15–50 per cent market share of district energy) or new cities (0–25 per cent market share of district energy). The "wholly public" ownership model also can be used to demonstrate the business case for district energy systems within a city (see case study 3.1 on Vancouver).

Risk and Governance: In the "wholly public" business model, the city takes on most of the risk associated with the investment. In expansion or new cities, if a project has a low IRR, typically in the range of 2–6 per cent, an internal department of the local authority can develop and operate the project to reduce administrative costs (see case study 5.2 on London). Consolidated cities develop such projects via the public utility, and the low return is spread across other projects that have higher IRRs. Projects with a higher IRR in expansion or new cities are being developed by creating a "Special Purpose Vehicle" (SPV) or subsidiary (such as a new public utility) to reduce the administrative burden on the local authority, with governance typically overseen by a board of directors that represents the local authority. Shifting to a subsidiary can provide additional benefits, including limiting the city’s financial liability in the event of project failure; increasing the flexibility and speed of decisions, and offering greater transparency and a more commercial operation. The local authority can outsource the technical design and construction (and sometimes operation) of the project to reduce risk related to the delivery cost and time frame.

In some cities, such as Bergen (see case study 5.3), multiple neighboring municipalities have ownership over the utilities that provide district heating. This reflects the ability of district energy to supply multiple cities through interconnections.

Sources of Finance: A district energy project with a low IRR will compete for financing with other projects that the local authority is considering. To the extent that a district energy system contributes to a city’s strategic objectives — such as reducing carbon, improving resilience or energy security, or providing affordable heat supply — projects often leverage the city’s cash reserves and/or public debt raised based on the balance sheet of the local authority. The lower interest rate of public debt is why many proponents of district energy systems argue that cities can (and should) be investing in this way (see section 2.5), and why several district energy models are locally led.

For example, the $3.5 million (US$5.6 million) connection between London’s publicly owned Westminster and Pimlico heat networks (see figure 2.4)
Involvement.

demonstrate the commercial viability of a

development (an IRR of 9.24 per cent), even

even though the anticipated cash flow revenues are

Public projects with higher IRRs that have

been funded in cash by the Council (£2.7 million, or

Council in cash within a discretionary budget, as it was

Council in cash within a discretionary budget, as it was

been funded in cash by the Council (£2.7 million, or

BKK Varme AS will invest NOK200 million (US$32 million)

BKK Varme AS was created to own and

in district heating and cooling up until 2025 (Hawkey and

Municipalities directed BIR AS to use energy from the

In 2003, an SPV, BKK Varme AS, was created to own and

BKK Varme AS was created to own and

lie to the network to meet demand. The incinerator burns waste

of the project can shift (to varying degrees) to the private sector.

Such a move could free up funds at the local authority for other projects and is the

principle behind a revolving fund (see section 2.5.1). Allowing private actors to

partially own the project (i.e., becoming a

public-private partnership) also may result in higher returns, as private
actors bring different experiences and may help the company to expand (see case study 3.9 on Cyberjaya). In 2011, War saw sold at 85 per cent share of its

publicly owned district heating utility to provide funds for essential upgrades to

the network (see section 2.5.2).

If the project was not initially set up as an

SPV, then the local authority could establish a company limited by shares and then transfer ownership of the assets to that company, which can then be fully or partially sold to the private sector.

Finally, there might be a desire for the

company to be owned by the community, in which case the shares can be transferred to community organizations. Alternatively, the company may be established as a

not-for-profit company limited by guarantee, with members instead of shares.

The first phase of the project was fully funded by the

Council in cash within a discretionary budget, as it was felt that any debt on the project could raise heat tariffs

outside the affordable warmth objectives. The first phase also benefited from £1.2 million (US$1.6 million) in grants from the London Development

Agency and the Homes and Community Agency. The second phase has been

funded in cash by the Council (£2.7 million, or

US$4.5 million), as well as from an EU Project CELSUM grant (£1 million or US$1.6 million) (Islington Council, 2014). These grants were critical to delivering the project at the tariffs required for affordable warmth objectives.

After undertaking a series of heat-mapping exercises of

London’s Islington Borough, the local Council prioritized

the design, construction and operation of the network (over 10 years) to an external contractor.

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3.3 THE “HYBRID PUBLIC AND PRIVATE” BUSINESS MODEL

If a district heating system’s technical feasibility study and financial modelling indicate that the project has a return on investment that will attract the private sector, it may be desirable to adopt a “hybrid public and private” model. Here, the local authority is willing to carry some risk and has a desire to exercise expertise in operating the district energy system and also to benefit from advice on future extensions from an experienced business partner.

The original section of the network was financed by Brest Métropole, as the previous contract between Dalkia and the city did not permit a return on any additional financial commitment by Dalkia.

The network and all production sites are owned by Brest Métropole, which sets the tariffs to promote district heating and connect social housing. The whole system is operated by SAS Dalkia Nord Finistère (DNF), a company that is 49 per cent owned by Sotraial, a subsidiary company of Brest Métropole, and 51 per cent owned by Dalkia, a multi-national energy service company. Dalkia provides the technical expertise in operating the district energy system and also advises Brest Métropole on future investments that the city could make to the system. In this way, the city maintains ownership of the system and controls its future development while benefiting from advice on future extensions from an experienced business partner.

3.3.2 CONCESSION CONTRACT

Under the concession contract model for the private sector, the public authority typically develops a feasibility study of the district energy project and then tenders it to the private sector (usually an energy service company, or ESCO) as a concession that runs for a specified term (see case study 3.6 on Yerevan). The concession contract model for the public-private sector is very similar but usually involves the creation of a utility that is a mixture of public and private ownership (although it can just be public) (see case study 3.9 on Cybejyara). For example, Empower in Dubai was created through a Royal Decree issued by the Ruler of Dubai and has a concession of 25 years, which allows the city to buy the 30 per cent stake that is private (see case study 3.6). This utility is then given the concession for the district energy development for a specified time period.

A concession model is particularly applicable for retrofit projects in towns and cities where public streets are used for network routes and where residential, institutional and commercial buildings are connected. The concession provides the option of the city buying back a project after the concession period.

RISK AND GOVERNANCE: In this model, the ESCO can affect the delivery of district energy services by having exclusive rights to install, operate and maintain district energy systems. The presence of the local authority as designer of the concession contract is likely to mitigate many of the risks associated with gaining project approvals. The ESCO may be limited in the terms it can charge due to local competition or contractual levels set to avoid monopolization of energy distribution.

3.3.3 PUBLIC AND PRIVATE JOINT VENTURE

The joint-venture model typically involves the creation of an MPV, with ownership split between the public and private sector.

3.3.3.1 JOINT VENTURE

The city of Brest and adjacent small cities, collectively known as Brest Métropole, developed a district heat network around the central basin of a waste-water treatment plant in 1988 that produces 150 GWh of heat (equivalent to 20,000 households) and 20 GWh of electricity per year. The waste-to-energy plant serves 85 per cent of the heat demand in Brest Métropole’s 25 km heat network, and, through substitution of fossil fuels, the plant saves 20,000 tons of CO2 per year. Because over 50 per cent of the district heat is from renewable energy, the system benefits from a reduced VAT rate of 5.5 per cent (normally VAT would be 20 per cent). This is the same VAT reduction that the Paris Urban Heating Company (CPCU) is trying to achieve (see case study 2.10).

The network has plans to double in size by 2017 to 45 km, with additional renewable heat capacity such as geothermal heat pumps and biomass boilers added as well as 5 MW of heat storage delivering 2.4 GWh of heat per year during peak demand. This increase in size represents €29 million (US$36 million) of investment in the network, €20 million (US$25 million) from the city of Brest to be amortized over 25 years and €9 million (US$11 million) from a grant (see section 2.3.1).

RENEWABLE HEAT IN BREST: A “WHOLLY PUBLIC” MODEL

The presence of the public sector can mean that other sources of finance become available, such as grants, local authority debt and development bank loans. The city also can offer land as an equity contribution to joint ventures, which can help provide collateral in raising financing. Further, the city can provide specific tax incentives that in effect could act as a source of finance. In a split asset model, each entity will be responsible for sourcing finance for the district energy functions they control.

CONTROL: In a pooled asset model, governance is typically via a board of directors appointed by each project partner, with board representation reflecting the ownership split and the public/private hybrid model. The exit strategy is either to continue with the status quo, team up with the partner or other private sector interests (see case study 3.5 on Toronto) or, conversely, to buy out the partner so that the district energy project becomes wholly municipal.

The fact that the local authority ultimately may own the system, as well as the contracting/financing complexities associated with a concession model, means that the local authority still takes on significant risk. Additionally, the ESCO may transfer risk to the local authority by requiring guaranteed revenues (via a connection policy). For example, the new development of district energy in Christchurch is expected to be designed, delivered and funded by the private sector, although public facilities will serve as the anchor loads. The local authority is developing feasibility studies and procuring private sector partners to deliver the project.

SOURCES OF FINANCE: ESCOs can vary greatly in size, and this will affect how they finance the district energy system. Large ESCOs have large amounts of capital, allowing them to finance projects internally rather than having to borrow on a project-by-project basis. Large ESCOs evaluate projects individually and will treat each system as a profit center; however, they rely on their overall corporate balance sheet to raise the capital for system development (Sternhell and Pierson, 2013). As with public-private partnerships, the city can provide land to the ESCO, which may then be used to accelerate development and potentially reduce energy tariffs.

CONTROL: The local authority may have limited control of the concession during the concession period. At the end of the term, the assets can be returned to the local authority through a sale. The local authority then has the choice of placing the assets in municipal or community ownership or issuing a fresh concession.
**CASE STUDY 3.6**

Dubai has developed the world’s biggest district cooling network, meeting a demand equivalent to 1 million tons of refrigeration annually (550 MW). The network requires just half the energy of the air-conditioning units it replaces, and thermal storage makes it possible to return electricity use during peak hours. This has enabled Dubai to limit growth in its electricity transmission network—a key objective of the district energy system.

The network was created through a public-private partnership between TECOM Investments, a real estate developer and the operator of Dubai’s leading business parks, and the public utility Dubai Energy and Water (DEWA). The resulting SPV, called Empower (Emirates Central Cooling Systems Corporation), represents 70 per cent ownership by DEWA and 30 per cent ownership by TECOM. Empower designs, builds, and operates Dubai’s district cooling network under a 25-year concession contract, with an anticipated ROI of 10–12 per cent over the contract period.

The majority ownership by DEWA means that the city’s objectives can be fulfilled: the network is built to be expandable and flexible; it uses innovative technology to replace potable water with recycled water such as treated sewage effluent (TSE); it uses energy efficiency measures to reduce cooling demand; and there is a significant focus on research and development. Both DEWA and TECOM provide anchor loads, including significant loads from government buildings. In addition, the presence of the public sector has been combined with regulations requiring new developments to connect to the district cooling system. Although the use of TSE is very beneficial, it poses potential challenges because the effluent is also used for agriculture in the region (particularly during the summer months when cooling demand is also higher). Housing developers in Dubai sparked the initial demand for district cooling, as they can benefit from the service and maintenance charges associated with supplying their developments with cooling. Through use of an innovative energy efficiency policy, Empower has developed a cooling network that is profitable whether user demand increases or remains the same. Empower actively encourages efficiency measures for cooling—a business model that would not be possible without DEWA’s presence in the partnership, since energy efficiency is seen as beneficial to the city. Empower runs campaigns to encourage end-users to be more energy-efficient and will lower the contract price of cooling if a user consumes less than the anticipated amount over three years.

**CASE STUDY 3.5**

The Toronto District Heating Corporation (TDHC) was originally a non-profit, publicly owned entity that combined the heat networks of five hospital and university campuses. However, legislation limited the power of TDHC in the area of long-term financing, impairing its ability to implement innovative solutions. As a result, TDHC was restructured into the for-profit Enwave Energy Corporation, with 45 per cent city ownership and 55 per cent ownership by BPC Penso Corporation (a subsidiary of the Ontario Municipal Employees Retirement System pension fund).

The creation of Enwave has allowed for innovative solutions in cooling, as well as for longer-term financing. Since 1981, it had been known that lake water could be used for cooling in Toronto, yet no significant financial backing was available for such a project. Starting in 2004, Enwave enabled the development of a deep-water cooling system that is integrated with the city’s drinking water system, providing the equivalent of 75,000 tons of refrigeration (205 MW) to large banks and data centres, which require high levels of reliability and stability. The system was financed by public and private bonds, with customers required to sign contracts or letters of intent in order for the company to secure financing.

The City Council and Penso have since exited the project, selling Enwave to Brookfield Asset Management for CAD$180 million (US$149 million). This netted the City Council CAD$168 million (US$135 million), or CAD$180 million (US$149 million) more than it had invested.

**CASE STUDY 3.7**

Currently, district heating in Anshan is dominated by a few large district heating companies, some of which are owned by the city and some of which are privately owned. These networks are separate and typically are fuelled by inefficient coal boilers that are not optimized for the load on the network. To modernize its district energy system, Anshan plans to utilize some 1 GW of surplus heat produced by the local Angang Steel plant to heat 50 million m², or some 70 per cent of the city’s total heating area. Angang Steel would become the largest heat source for the city.

The local government has been working with Danfoss, a Danish district energy company, and CDOW, a Danish district energy consultancy, to develop additional sustainable and integrated heating solutions for the city. The local government is catalyzing this use of waste heat through the development of a new transmission line to capture excess heat, initially from the Angang Steel plant. This transmission line will be owned 60 per cent by the municipally owned Qianfeng district heating company and 40 per cent by FUAN, a private company.

The transmission system will enable future development options such as the connection of geothermal resources as well as two planned CHP plants in the city’s north and south. Local heat networks will then tap into the new transmission line, using the waste heat produced from the boilers used as peaking boilers on local networks. Many of the existing boilers will be improved and replaced with larger, more-efficient models. The current separated networks suffer from high demand volatility due to the smaller numbers of users, and pooling the networks will reduce the ratio of peak load to base load.

Currently, domestic hot water is typically prepared using electric or gas boilers at the individual household level, the revamped district heating will replace some of this production.

The new heat-capture project represents a US$64 million investment in a more efficient system that aims to lower carbon intensity and improve local air quality. The local government is providing the finance for the project. A short payback period of three years highlights the significant financial benefits that the project will bring as Anshan closes the loop on waste heat and simultaneously reduces the city’s coal consumption by a projected 1.2 million tons.

The project will be connected in stages, with 6.7 million m² connected in phase one and 10 million m² in phase two. Angang Steel will receive a set heat tariff for the waste heat of CNY0.11 (1.8 U.S. cents) per kWh. The capital cost of extracting the waste heat from the company’s steam turbine will be CNY10 million (US$1.64 million), only 2.6 per cent of the project’s total cost.

In Anshan, the local government’s role in ownership of the transmission system has been critical to capturing Angang Steel’s waste heat and allowing the optimization of the district energy system in the city. The split-ownership model of private sector production and distribution allows the local government to focus efforts on the transmission line. The provincial government in Liaoning Province, where Anshan is located, has supported the actions of the Anshan government and attaches great importance to the use of industrial surplus heat. Since early 2014, the provincial government has cooperated with Baoing Steel, the city government of Benxi and Danfoss on the province’s first replication project, with a scope of 360 MW of surplus heat.
CASE STUDY 3.8
LONDON'S OLYMPIC PARK: A PRIVATE CONCESSION CONTRACT MODEL

When London's Olympic Development Authority (ODA) assessed the available options for procuring energy for the 2012 Olympic Games, it determined that a long-term concession would result in more cost savings than procuring infrastructure from incumbent utility companies, or engaging in competitive procurement for short-term design-and-build contracts. During the feasibility stage, ODA decided to develop a district heating system, with a limited district cooling network, by installing two co-generation woodchip boilers providing baseload power, adding a renewable heat source, and no such tenders were received. A 3.5 MW woodchip boiler was deemed too risky for these renewable waste-to-gas heat resources, and the scale of demand of the energy centres was assessed as being too high for a single, 40-year concession contract to finance, design, build and operate the heating and cooling network and associated energy centres. Applications had to be based on the design developed by ODA during the feasibility process, although additional applications could be made with a different design. Although biomass gasification and waste-to-gas were considered initially, the scale of demand of the energy centres was deemed too risky for these renewable sources, and no such tenders were received. A 3.5 MW wood chip boiler provides baseload power, adding a renewable element to the investment.

The contract was awarded to the energy service company Cofely, with the resulting concession agreement between Cofely, Stratford City Development Ltd and ODA. Cofely was granted exclusivity to supply heat and cooling for all buildings within the Olympic Park, in combination with large thermal storage. Two public authorities – ODA and Stratford City Development – engaged in a competitive procurement process for a single, 40-year concession contract to finance, design, build and operate the heating and cooling network and associated energy centres. Applications had to be based on the designs developed by ODA during the feasibility process, although additional applications could be made with a different design. Although biomass gasification and waste-to-gas were considered initially, the scale of demand of the energy centres was deemed too risky for these renewable sources, and no such tenders were received. A 3.5 MW wood chip boiler provides baseload power, adding a renewable element to the investment.

CASE STUDY 3.9
PENDINGINAN MEGAJANA SDN BHD IN CYBERJAYA: A PUBLIC-PRIVATE CONCESSION CONTRACT MODEL

Malaysia is pioneering district cooling systems to tackle rising electricity demand from air conditioning, which accounts for 50–50.5 per cent of energy demand from buildings nationwide. Over the past 20 years, the country has installed 11 district cooling systems with a capacity of 290,000 tons of refrigeration (667 MW). The city of Cyberjaya, located about 50 km south of Kuala Lumpur, implemented district cooling in 1998. It commissioned a local energy service company, Pendinginan Megajana Sdn Bhd (a wholly owned subsidiary of Cyberview Sdn Bhd), under a build-operate-concession, where ownership of the equipment remains with the company. The primary goals were to reduce the capital costs of separately installed individual chillers, to lower operating costs and to demonstrate viability.

The system comprises two district cooling plants with a total chiller capacity of 18,500 refrigerant tons (64.2 MW), built in two stages between 1998 and 2012 and complemented by ice storage (55,500 refrigeration ton-hours; 125 MWh), cold water storage (139,000 refrigeration ton-hours; 157 MWh) and 15 km of pipeline. The system serves 38 large customer buildings in Cyberjaya. Total project investment between 1998 and 2012 was around US$50 million, and the project had an IRR of 11.7 per cent over a project duration of 50 years, with a payback period of 8.2 years.

As a result of the project, chiller peak electricity demand has been reduced by 3 MW, and the capital cost for the installed chillers is 18 per cent lower than for using individual chillers. Thermal storage for demand-side management enabled the production of chilled water and ice at reduced costs during the evening, taking advantage of the night-time tariff (which is less than half of the peak-time tariff). It is estimated that 60 per cent of a regular office’s utility bill goes to air conditioning alone, and for data centers, this can reach 80 per cent. Annual cost savings through district cooling are 30 per cent compared to stand-alone systems (ADB, 2013).

Demand for district cooling in Cyberjaya is anticipated to grow by another 10,000–15,000 refrigerant tons over the next three years, which means more plants in the pipeline. The energy service company Cofely recently acquired a 49 per cent stake in Pendinginan Megajana Sdn Bhd. Cofely is anticipated to help develop larger district cooling systems in Cyberjaya (Cofely, 2013).

3.3.3 COMMUNITY-OWNED NOT-FOR-PROFIT OR COOPERATIVE

As another option, a municipality may wish to establish a district energy system as a mutual, community-owned not-for-profit or cooperative. In Copenhagen, all retailers of heat are required to be not-for-profit mutuals, cooperatives, or municipally owned (see case study 3.10).

RISK AND GOVERNANCE: In the not-for-profit or cooperative model, the local authority initially takes on a large share of the risk. Once the mutual is well established, risks to the local authority decrease. Some risks can be passed through to contractors for design and construction.

SOURCES OF FINANCE: In this model, the municipality may need to underwrite the risk, as start-up entities will not have the same covenant strength as the municipality to secure low-cost finance. Once the mutual has paid off this lower-rate finance, the risk on the local authority is lowered significantly. The presence of the local authority can leverage low-cost funds for the project, as occurred in Aberdeen (see case study 3.11).
CASE STUDY 3.10

Høje Taastrup Fjernvarme, one of Copenhagen’s largest heat companies, was formed in 1992 by the merger of a cooperative district heating company and a municipal one. Høje Taastrup Fjernvarme purchases heat from the municipally owned transmission company, which itself buys heat from privately owned power stations in the surrounding areas. Høje Taastrup Fjernvarme then distributes the heat to its 5,260 customers, including residential, commercial and industrial buildings. Customers connect via an agreement under which they become a member-owner of the cooperative. The governing board is made up of seven members elected by customers and two members nominated by the local authority. The municipality provides the mutual with a guarantee that underwrites the risk. This allows it to obtain low-cost financing at 1.5 per cent from a mortgage company (a mutual bank); without the guarantee, it would have to pay 2.5 per cent. In 2012, Høje Taastrup Fjernvarme made a profit of £18.25 million (US$29.2 million). The low profit margin is because a benefit is passed to the owner-members in the form of low heating rates. The company also provides grants for demand-side energy efficiency projects.

District heating in Denmark has strong legislative backing under a series of Heat Laws. Municipalities are required to undertake heat mapping, using the results to determine the appropriate energy distribution infrastructure. Building owners, including householders, are obliged to connect. This removes a significant risk to the development and financing of district heating projects. To counter the potential for monopoly abuse, all retailers of heat are legally obliged to be not-for-profit and are therefore either cooperative, mutual or municipal companies. The municipal companies own and operate the transmission and/or distribution systems, while the cooperatives and mutuals undertake the retailing of heat directly to customers. Although heat retailers do not compete for customers, they do compete with each other to deliver the lowest heat prices. This is overseen by the Danish Energy Regulatory Authority, which publishes annual lists of the heat prices offered by retailers.

If a local authority has a proposed district energy project with a high return on investment (usually between 12 and 20 per cent, although it can be 9.5 per cent for lower-risk projects), but the local authority has a low risk tolerance and a relatively low desire for control, it may be able to attract interest from private sector companies. This does not mean that the local authority is removed from the project; many successful privately owned district energy systems still have arms-length local authority involvement. For example, the local authority may have been the original project proponent and/or it could still attract financing and grants for the project. The local authority may help with any connections deemed socially optimal that are too high risk for the private sector. It could also develop initiatives that encourage social or environmental objectives, such as mechanisms that support low-carbon generation.

This section discusses some examples of wholly privately owned SPVs for district energy.

3.4.1 WHOLLY PRIVATELY OWNED SPV

When designing a business model for a new district energy system, it is important to consider site-specific circumstances, including the type of project finance that is available. The majority of business models for district energy involve the public sector to some degree, whether as a local policedmarker, planner, regulator, or consumer, or more directly through partial or full ownership of projects (see section 2). Public sector involvement can be critical in coordinating multiple, diverse projects around a broader city-wide vision. Even projects with a high degree of private sector control are often still facilitated or supported in some way by the public sector.

Although the business models and ownership structures described here vary significantly, they can be grouped along a continuum from public to private ownership. The relative involvement of the public or private sector depends broadly on two factors: 1) the return on investment for project investors, and 2) the degree of control and risk appetite of the public sector.

PORT LOUIS, MAURITIUS

RISK AND GOVERNANCE: In this model, risk is carried by the private company, although the company could enter into a Joint Cooperation Agreement (JCA) with the local authority to mitigate risks in planning or expansion, or to encourage connection of demand through planning policies. This is often called a Strategic Partnership Model. In return, the local authority may benefit from reduced tariffs, profit sharing, connection of customers with higher credit risk (who are more likely to be in fuel poverty), and other social or environmental objectives.

SOURCES OF FINANCE: Financing is provided by the private sector company, through either inter-company debt or external commercial debt. The private sector company may require a capital contribution in the form of a connection charge for any public buildings connected to the network. Local or national authorities may be able to attract international loans or grants for the project (see case study 3.12 on Port Louis).

CONTROL: The private sector company determines the governance structure, since the project is wholly owned by the company. The governance structure may include offering the local authority a minor representation on the board of an SPV or on a local project board if the company has entered into a JCA with the local authority.
Countries can pursue district heating and cooling through a variety of business models, and the choice of model will depend on the economic and financial returns on investment as well as on the degree to which the public sector wishes to control the district energy project.

In developing countries, there is huge potential for district energy in both cooling and heating, depending on the local climate and requirements. Energy markets in many of these countries are less liberalized and significantly less privatized than in developed countries. As has been highlighted throughout this report, district energy requires strong public sector involvement in project development and operation, and the model of publicly owned energy services in many developing countries may provide a strong platform for project development. In some countries, problems such as access to capital, expertise and institutional inefficiencies may need to be addressed.

District cooling has huge potential in both developed and developing countries. In Kowloon City, for example, air-conditioning demand accounts for 70 per cent of peak power demand and over 50 per cent of annual energy consumption. District cooling could reduce peak power demand by 46 per cent and annual electricity consumption by 44 per cent compared to a conventional air-cooled system (Ben-Nakhi, 2011).

Developing a technology that is slowly building traction in some developing country cities because of its ability to alleviate stressors on power systems caused by air conditioning (see case studies 3.9 on Cyberjaya and 3.12 on Port Louis). The benefits of district cooling are felt by various stakeholders. Consumers benefit from lower and/or more stable cooling costs (if the system is well placed) and from not having to house and maintain individual cooling solutions. Meanwhile, municipal, regional or national energy utilities are able to provide less electricity at peak demand and overall, reducing the need for transmission system upgrades and capacity additions. Finally, the local economy could potentially benefit greatly from fewer blackouts, reduced need for backup generation in individual buildings, lower electricity prices, and cheaper and easier reduction of refrigerants such as HFCs and HFOs in traditional air-conditioning units (UNEP, 2014), as described in section 1.1.1.

In many developing countries, utilities are publicly owned and may be responsible for producing, transmitting and distributing electricity. An important way to account for the wider benefits of district cooling is to include such a local/national electricity utility in the business model for district energy. This can be done directly (as Dubai has done; see case study 5.6) or indirectly through local, regional or national government ownership, with this ownership providing strong connections to publicly owned electricity utilities. This is particularly important in a non-liberalized market structure where electricity prices may be regulated. In such markets, without strong electricity price signals, a privately owned district cooling system may not be incentivized or have the permission to develop cold storage (which can help shift electricity demand from peak load); connect particular user groups; develop combined power and cooling; innovatively use heat sources for absorption cooling; access sources of free cooling; or lower electricity consumption as much as possible during certain periods of the day. For example, in many countries, independent power producers cannot develop projects to sell electricity to the regional/national grid and thus may lack the incentive to develop combined power and cooling plants.

The presence of a publicly owned utility in the business model would enable a district cooling project to develop such plants. The publicly owned nature of power utilities or government subsidiaries is also beneficial to the business model, as described in sections 5.2 and 5.3. Such benefits could include access to anchor loads, easier planning, better data, integration with other utilities and cheaper electricity.

A publicly owned district cooling utility in a hot developing country city would be well placed to provide services and to develop in line with national and regional interests. However, the presence of the private sector in a business model is beneficial as a provider of capital, demand load, experience and technology. International ESCOs will be important in developing district cooling in some hot developing country cities, and their importance should be weighed against having a strong public sector role in projects. As such, models such as public and private joint ventures can enable district cooling projects to access the benefits of both the public and private sectors, as described in section 5.3.1.

District cooling is a technology that will need to be demonstrated in a city before city-wide deployment could be investigated. A lack of data on cooling demand and a lack of funds to fully understand the effects of this demand at a city and national level (see section 2.2.1) mean that initial projects should be developed that target localized, high-consuming sectors.

Aberdeen City Council: A Not-For-Profit Model

In 1999, Aberdeen City Council adopted an Affordable Warmth Strategy to tackle fuel poverty in the city. The Council commissioned a study to identify the technical solution best able to deliver low-cost heating to residents. This identified seawater air-conditioning systems connected to CHP. Although the Council could afford to install this technology in one cluster of blocks, it could do so only at the rate of one project every 12 years due to capital constraints. Commercial energy service companies could access third-party investment to accelerate deployment, but the returns required would result in high heating charges to residents, undermining the objective of reducing fuel poverty. The Council therefore established an arms-length not-for-profit company, limited by guarantee based on membership. Members were drawn from the local community, including residents, who nominated board directors, with two seats reserved on the board for the Council.

For the first project, serving 289 apartments in four blocks at Stockethill, the Council entered into a contract with the company to deliver the project based on an annual payment of £219,088 (US$350,000) over a 10-year term. Based on the security provided by this contract, the company was able to take out a capital loan of £1.1 million (US$1.6 million) to deliver the project at a rate of return similar to that available to the City Council. At that point, a government-funded capital grant programme unexpectedly became available, and the company was able to spread the loan finance over two more projects. Blending it with grants and the funds otherwise intended for refurbishing the heating systems under the Council’s capital investment programme for upgrading the stock.

Aberdeen

Port Louis

Port Louis’s Sea Water Air Conditioning (SWAC) Project: A “Private” Business Model

The SWAC system is being developed by a local company, Sotracis Ltd., at an estimated cost of MUR1 billion (US$150 million) and will be financed mainly through private funding from local banks and international financial institutions. The role of the government of Mauritius is to promote the scheme to attract concessionary finance from development banks. Already, the African Development Bank’s Sustainable Energy Fund for Africa (SEFA) has given a project preparation grant of US$1 million to finance the initial development stage of the SWAC system in Port Louis (AH Sac, 2014; Capital, 2014; ADB, 2014). The project is expected to be extended to a second city, Enewe, to replace the conventional air-conditioning systems of data centres.

As part of the road map to develop its “ocean economy”, Mauritius is initiating a district cooling system that would use sea water for air-conditioning purposes. The first-of-its-kind SWAC project on the island (and in Africa) will pump water at 5°C from 1,000 metres below sea level to cool buildings in the heart of the capital city, Port Louis. The system is expected to provide cooling, through 3.5 km of pipes, to some 60 high-density buildings (both public and private) in the city by 2016. The project will allow Mauritius to reduce its power supply, provided mostly through fossil-fuel-based plants, by about 26 MW. This represents 6 per cent of the country’s forecast peak electricity demand in 2014 of 404 MW (National Assembly, 2011). It will also enable the City of Port Louis to reduce its carbon footprint by 40,000 tons of CO2 annually. It will also enable the City of Port Louis to reduce its carbon footprint by 40,000 tons of CO2 annually.

CASE STUDY 3.11

CASE STUDY 3.12

3.5 Expanding the business model

Via Additional Innovative Practices

Aberdeen City Council: A Not-For-Profit Model

Port Louis’s Sea Water Air Conditioning (SWAC) Project: A “Private” Business Model

Section 3
Section 4: REALIZING NATIONAL OBJECTIVES AND FULL BENEFITS OF DISTRICT ENERGY

KEY FINDINGS

- **NATIONAL POLICIES** are key to achieving optimal results for district energy. Policies at the national level allow for the appropriate devolution of authority, national support for local coordination and capacity to deliver projects, and the accounting for district energy in national standards. Such policies are key to realizing the national benefits that arise from development of district energy such as decreased imports of fossil fuels, reduced strain on national power infrastructure and the integration of renewable energy (see table 1.3 for more national benefits).

- **EFFICIENCY RATINGS, LABELS AND STANDARDS** are developed based on accounting methods often set out in national policies. Such methods were a key barrier to district energy deployment across the 45 champion cities, as they may prioritize building-level efficiencies over full energy-system efficiencies. To help address this challenge, cities can advocate for change in national policy. As a best practice, energy efficiency in buildings should be optimized to account for efficiency in energy supply and to target the reduction of fossil primary energy consumption.

- **DEVOLVING AUTHORITY** from the national level to local authorities allows district energy systems to benefit from local expertise and the influence and action of local authorities. Such devolution can include setting a regulatory framework that explicitly grants authority in areas such as mandatory connection policies, energy master planning and mapping, energy service provision and building codes. For example, national governments may encourage or mandate local authorities to create cost-effective energy or heat plans that require district energy to be considered in a city. This starts the process of a city developing an energy strategy, a key best practice in developing district energy and optimizing the heating/cooling sectors.

- **FINANCIAL AND CAPACITY SUPPORT** should be provided to local authorities to match any devolved responsibility. This can be financial and capacity support for energy mapping, project planning, related organizational development, appropriate commercial arrangements and technical quality control. Such support can be in the form of grants or providing access to funds for the early stages of projects.

- **LEVELLING THE PLAYING FIELD** for district energy must start with national governments acknowledging the multiple benefits of district energy and putting in place financial and regulatory measures to address pricing regimes that either do not account for the benefits of district energy systems or disadvantage them due to direct or indirect subsidies. This can be through national adjustments to tax regimes and direct subsidies for electricity, heat or cooling generation.

- **TARIFF REGULATION** is key to optimizing the planning, coordination and monitoring of district energy developments between different levels of government. One approach to simultaneously provide specific finance for local authorities and support multi-level governance is to incorporate local authority action into national mitigation strategies through Vertically Integrated Nationally Appropriate Mitigation Actions (V-NAMAs). V-NAMAs would support developing country governments in their efforts to mobilize local and provincial actors for achieving national mitigation targets through cost-effective incentive packages and measurable, reportable, and verifiable (MRV) actions and results.

- **A VERTICALLY INTEGRATED GOVERNANCE STRUCTURE** is key to optimizing the planning, coordination and monitoring of district energy developments between different levels of government. One approach to simultaneously provide specific finance for local authorities and support multi-level governance is to incorporate local authority action into national mitigation strategies through Vertically Integrated Nationally Appropriate Mitigation Actions (V-NAMAs). V-NAMAs would support developing country governments in their efforts to mobilize local and provincial actors for achieving national mitigation targets through cost-effective incentive packages and measurable, reportable, and verifiable (MRV) actions and results.
4.1 INTRODUCTION

“Cities will play a critical role in achieving multiple energy policy targets for an efficient, sustainable future. Analysis under the IEA CHP and DHC Collaborative has shown that by aligning local initiatives and national policy frameworks, it is possible to improve market structures in support of flexible, integrated and sustainable energy systems.”

John Draper, IEA, 2014

Multilevel governance can interrupt effective policy integration and implementation between the national and local levels. For example, strategic, policy and administrative arrangements can be misaligned with the provision of funding, capacity or information (Hammer et al., 2011). Cities are increasingly helping to design and develop “vertically integrated” state and national policies to help overcome these barriers. Section 4.5 explores how some cities are accessing new climate financing mechanisms for emerging economies and developing countries, such as Nationally Appropriate Mitigation Actions (NAMAs).

Multi-level governance can interrupt effective policy integration and implementation between the national and local levels. For example, strategic, policy and administrative arrangements can be misaligned with the provision of funding, capacity or information (Hammer et al., 2011). Cities are increasingly helping to design and develop “vertically integrated” state and national policies to help overcome these barriers. Section 4.5 explores how some cities are accessing new climate financing mechanisms for emerging economies and developing countries, such as Nationally Appropriate Mitigation Actions (NAMAs).

As with other aspects of the energy transition, a key factor in the successful development and scale-up of modern district energy is establishing an appropriate policy framework. Although many of the decisions and measures associated with a given system can and must be made at a local level, national policies are key to achieving optimal results. Policies at the national level allow for the appropriate devolution of authority, national support for local coordination and capacity to deliver projects, and the accounting for district energy in national standards (see section 4.1). Although the benefits associated with district energy are felt at the national as well as the local level (see tables 1.3 and 1.4), the national benefits are not easily captured or valued in the local business case for these systems. District energy is already cost-competitive (see figure 1.8), but national policy measures are necessary to bring it on to a level playing field with other technologies to reflect its national benefits (see section 4.2).

Investing in district energy requires a long-term commitment. A national climate or energy vision that explicitly addresses the heating or cooling sector is a first step in building investor confidence in the long-term priorities of governments. Reducing policy uncertainty is best achieved when national energy visions for district energy contain medium- and long-term objectives with clear milestones and reviews (IEA, 2014b; Euroheat & Power, 2013).

4.2 DE-RISKING INVESTMENT

Because district energy interacts with other areas of energy production, supply and consumption (i.e., end-use) that are regulated, it is particularly vulnerable to legislative inconsistencies among these areas, which can hamper the business case significantly.

Across the 45 champion cities, a key barrier to district energy deployment was the accounting methods used to develop efficiency ratings, labels and standards for buildings, such as the Leadership in Energy and Environmental Design (LEED) certificate system (see box 4.1). Methods that rely on energy consumption at delivery to the building do not account for the ways that electricity and heat are produced, or for the use of non-renewable energy, creating a disincentive to use district energy and contradicting energy targets for its deployment. In the Netherlands, installing an electric heat pump in an individual house results in an impressive improvement in the efficiency label, whereas connecting a house to district heating often has no effect on labelling.

Cities themselves cannot remedy this challenge, although they can advocate for changes in standards (as shown in section 2). A recent study by Euroheat & Power (2015) concludes that energy efficiency in buildings should not be considered in isolation, but rather should be optimized by taking into account efficiency in energy supply, and by targeting the reduction of fossil primary energy rather than final energy.
Experience indicates that local governments develop local mapping and planning. Cities are the ideal leaders in resolution that can be achieved only in a city, and cities are the ideal leaders in service provision, and building codes (see section 2). Such devolution has occurred to give preference to on-site solutions (by virtue of a focus on energy efficiency, principally through energy systems that connect to new systems relying on natural gas as a transitional strategy (to larger, more cost-effective reductions once overall development achieves a critical threshold) are currently penalized and receive no credit for future upgrades (which often provide more-significant energy and greenhouse gas reductions). So developers must invest not only in connecting but also in installing other near-term (and potentially redundant or less cost-effective) systems and measures to achieve necessary credits for certification. The U.S. Green Building Council has released an updated guideline on district energy that enables buildings connecting to district energy to new systems, and the delivery of this potential.

**LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED) CERTIFICATION**

The development cost at the individual project level can be up to 10 per cent of CAPEX for projects over £20 million (US$32 million) and 15 per cent for projects over £5 million (US$8 million). Developing projects is time consuming for energy and heat plans. The Danish national government mandates this and provides a high degree of autonomy and flexibility to cities in this planning. Sometimes, the national vision can become a driver for local governments to act on district energy (as in London). In cases where cities have not given much consideration to the heating or cooling sector, or traditionally have not been involved in energy provision, national governments that develop district energy strategies can accelerate local implementation by requiring local energy visions and maps (see box 4.2 on the EU).

**EU LEGISLATION ON HEAT PLANNING**

Rating policies and certificate systems such as Leadership in Energy and Environmental Design (LEED), while sometimes offering small credit value for implementing district energy systems, often do not acknowledge the full benefits or contributions of district energy and tend to give preference to on-site solutions (by virtue of a focus on green buildings), regardless of overall cost and benefit. An important issue is the calculation of energy efficiency for new buildings and the energy labels for existing buildings.

Sometimes the business model for district energy dictates a slow build-out that requires a temporary strategy and/or use of transitional technologies. Under LEED, buildings that connect to new systems relying on natural gas as a transitional strategy (to larger, more cost-effective reductions once overall development achieves a critical threshold) are currently penalized and receive no credit for future upgrades (which often provide more-significant energy and greenhouse gas reductions). So developers must invest not only in connecting but also in installing other near-term (and potentially redundant or less cost-effective) systems and measures to achieve necessary credits for certification. The U.S. Green Building Council has released an updated guideline on district energy that enables buildings connecting to district energy to new energy credits for efficiency improvements, renewable energy supplies and refrigerators (in the case of district cooling) as a result of district energy, as well as to possibly earn an innovation point related to “green heat” supply to buildings.

**BOX 4.1**

**BOX 4.2**

EU legislation on energy efficiency requires that regional and local authorities plan and design an urban heating and cooling infrastructure that utilizes all available renewable energy sources and CHP in their region. The overall objective is to encourage the identification of cost-effective potential for delivering energy efficiency, principally through the use of cogeneration, efficient district heating and cooling, and the recovery of industrial waste heat – when these are not cost effective, through other efficient heating and cooling supply options, and the delivery of this potential.

EU Member States are required to identify the potential for high-efficiency cogeneration and efficient district heating and cooling and to analyse the costs and benefits of the opportunities that exist in their country. They are required to take adequate measures to ensure that these opportunities are developed if there is cost-effective potential. Italy implemented this legislation on July 4, 2014, and in turn, the continued development of district heating and cooling in Milan is being planned in coherence with the reference legislation.

Source: EU, 2012

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* In EU Energy Efficiency Directive 2012/27/EU, “efficient district heating and cooling” refers to a district heating or cooling system that uses at least 50 per cent renewable energy, 50 per cent waste heat, 75 per cent cogenerated heat or 50 per cent of a combination of such energy and heat. District heating is dealt with in Article 2 (where the definition of “efficient district heating and cooling” is provided), and in Article 14 of the EU Directive (Article 10 of the Italian Decree).
4.3 Economic competitiveness: a level playing field and multiple benefits

National governments are slowly recognizing the multiple benefits of district energy and are putting in place financial and regulatory measures to address pricing regimes that either do not account for the benefits of district energy systems, or that disadvantage them due to direct or indirect subsidies. This section reviews some of the common national measures that have helped create success in the 45 champion cities, recognizing that the measure required will depend on the specific national priorities, the technologies involved, their maturity, and on sector experience and history (IEA, 2012; Werner, 2011; Pöyry and AECOM, 2009). Government intervention to improve the competitiveness of district energy systems can be justified when it compensates for issues not recognized in the usual pricing structure (IEA, 2014b).

4.3.1 National taxes

Taxes on fossil fuel emissions (e.g., carbon taxes) have been used in Denmark, Sweden and Finland to even the playing field for district energy. A carbon tax demonstrates a preference for a long-term market solution rather than specific project support, reflecting the maturity of these markets (Forrester, 1999; Werner, 2011). This is through the benefits of energy efficiency. In Sweden, a CO2 tax was critical to the country’s energy transition strategy. The City of Vaxjo noted that the CO2 tax, which raises the cost of oil consumption in plants and in private homes, was key to district energy development, as consumers seek cheaper alternatives. Similarly, Gothenburg identified the CO2 tax as the most important national policy for district energy in the city (see case study 4.1). Penalties have played a key role in driving the development of district energy systems in Anshan. Air pollution emissions are penalized at the national level in China because of their detrimental effect on health: the central government discloses the 10 best and worst cities every month, and issues a performance evaluation of provinces. In 2013, Anshan was fined CNY1.8 million (US$283,000), and the fines will reportedly fund the “blue sky” project, an anti-pollution project launched in 2012. The regulation empowers provincial authorities to fine 14 cities for excessive concentrations of particulate matter (PM10), SO2 and CO2 (Xinmei, 2015). To prevent such penalties, Anshan is opting to develop and improve district energy systems, which are seen as a better value for the money than paying fines.

France, under the National Housing Commitment Act, has a policy stating that if a city can reach 50 per cent renewable or recovered heat in its district heat network, it will benefit from a 5.5 per cent reduction in the value-added tax (VAT). The purpose of this is to allow district heating to have a similar VAT level to other competitive heat solutions, such as gas and electricity (see case study 2.10).

Brest’s district heating system currently benefits from this VAT reduction (from a normal VAT of 20 per cent), as 85 per cent of the heat demand is provided by a waste-to-energy plant. A tax on waste heat that is not recycled is a potential national policy measure that could improve the use of this heat. Cities have noted that industries often have little incentive to put waste heat into a district energy system, as it is not in their core business. Where taxes are not in place, national governments may offer grants and subsidies to indicate their recognition of the socio-economic benefits of district energy and/or to create a level playing field (see case study 2.11).
Historic façades in Frankfurt, Germany (bottom).

CHP plant in Łódź, Poland (top).

SECTION 4

1.3). Under the CHP Act, transmission the electricity system (see case study incorporate high levels of solar PV onto in Germany, particularly its potential to realize the benefits of district heating (see chapter 4.3) (IEA, 2014b). Offering better rates for the electricity produced in CHP plants can enhance revenue and reduce public funding requirements for district energy networks, as well as provide sufficient RIO to engage the private sector in delivery. Cities such as Velenje, Lodz and Frankfurt have been able to accelerate modern district energy as a result of national CHP policies. In their role as facilitators, local authorities can help suppliers of distributed energy avoid the centralized electricity market, as has occurred in London (see case study 4.3).

For some CHP plants, the opportunity cost of heat production (reduced electricity production) can set a tariff that is sufficient to ensure that the CHP is profitable. For example, a reduction in heat efficiency of a combined-cycle gas turbine CHP plant from 50 per cent to 45 per cent in order to produce more heat (a 14 per cent decrease) would set the tariff for heat at 14 per cent of the wholesale electricity price (very low) (Goalmundson and Thorsen, 2015). For other CHP plants, which may have must-suns enforced due to lack of backup capacity or for which running electricity alone would not pay off the CAPEX, higher heat tariffs may be required. If such tariffs are too high, CHP price support may be required.

Some countries have implemented CHP feed-in tariffs that are designed to encourage CHP development, given that its multiple benefits often are not priced into the business model. Yemen has implemented a feed-in tariff for CHP to realize the benefits of district heating (see case study 4.4), and Germany’s Combined Heat and Power Act targets 25 per cent of electricity to come from CHP by 2020. Such support is important given CHP’s benefits in Germany, particularly its potential to incorporate high levels of solar PV onto the electricity system (see case study 1.3). Under the CHP Act, transmission operators must prioritize production from CHP plants, which also receive a top-up on the electricity price that they receive to a level dependent on their size. For new large plants, this will be US$20 per MWh, which is paid for by a “CHP surcharge” on electricity bills.

4.3.3 TARIFF REGULATION

Tarif regulation is an important aspect of district energy that can ensure consumer protection in a naturally monopolistic market. Tarif regulation is particularly important in ensuring consumer protection if mandatory connection policies are enacted (see section 2.2.4). Tariffs can be regulated in numerous ways: some are regulated so that district energy is priced at the alternative technology costs, and some are effectively indirectly regulated by controlling the profits of district energy companies or the costs that they can pass on to consumers. Often, where connection is voluntary, countries will rely on competition from other sources of heat or cooling to ensure fair prices. Furthermore, tariffs can be applied at the same rate to groups of consumers (e.g., all residential customers pay the same tariff), or costs can be levied at specific customers relating to the cost of network expansion to connect them. Levyng specific costs at individual consumers can be important to insulate unmoved consumers from costs, in order to serve a particular geographical region or consumer type; however, it could leave individual consumers with unfairly high heat tariffs.

4.3.3.1 TARIFF REGULATED AT ALTERNATIVE TECHNOLOGY COST. Some countries control tariffs through national policies requiring that heat or cooling be priced at the cost of the next-alternative technology. The main benefit is that consumers will always get a better deal than if the district energy network were not there. For mandatory connection policies, this is important, as consumers may not have a choice in whether they connect. However, this pricing model will not necessarily mean cheaper and less volatile prices for consumers, often a key benefit of district energy. Countries where the next-alternative technology (such as domestic gas boilers) has high or volatile prices may consider a tariff regulated at the next-alternative cost to not be passing on the significant benefits of district energy.

In May 2009, the U.K. regulator Ofgem introduced electricity-supply licence changes to allow generators of distributed energy to enter into arrangements with third-party licensed suppliers. As a result, distributed generators can be granted supply licences of their own without having to become a direct party to industry codes that govern the central trading arrangements. Under Licence Lite, in order to sell the electricity, the “junior supplier” has to enter into a contract with a third-party “senior” supplier for electricity convenience services; the senior supplier is then responsible for transporting the electricity over the public wires using the relevant distribution network operator. The third party undertakes the installation of meters and any administration tasks, including the “change of supplier” process. The small supplier retains title to the electricity and “owns” the customer.

As of October 2014, no such permits had been issued. Barriers include uncertainty over what kind of terms should appear in the contract between a small supplier or district energy system and a third-party licensed supplier for electricity convenience services, as well as a lack of interest from existing industry suppliers. Likewise, there is no real obligation on existing larger suppliers to offer such services to a small supplier or district energy system, nor are there any provisions or restrictions on the terms they can offer. Finally, the existence of the scheme is not well known.

The Greater London Authority wants to take the leading role in piloting Licence Lite by working with the boroughs (who become generators and suppliers) and purchasing their excess power at a higher rate. This is foreseen to help attract more than £8 billion (US$12.8 billion) of investment in electricity infrastructure in the city up to 2025.

Already, the excess power from several CHP plants in the GLA boroughs is going into the network, but because they are not being paid sufficiently for it, many CHP plants have been shut down. One borough, Haringey Council, carried out feasibility studies for two district heating networks, with the support of the GLA, and found that, assuming wholesale rates for CHP power, there was a funding gap in both cases that would require grant funding. If the CHP plants were given access to the retail market, however, this could provide enough RIO to remove the need for “grant funding” and instead engage the private sector. In other words, with changes in the market structure, it is possible to better engage the private sector to deliver schemes (Davidson, 2013).

LONDON’S “LICENSE LITE”: FACILITATING PEER-TO-PEER ENERGY SALES BASED ON NOMINAL “WHEELING” CHARGES FOR USE OF LOCAL WIRES

CASE STUDY 4.3
Heat supply in Yerevan, and throughout Armenia, has changed dramatically over the last 20–30 years. The country has no domestic fossil fuel resources, and up until the 1990s, when Armenia faced an economic and energy crisis, there was no natural gas to fuel district heating networks that supplied 90 per cent of residential and public buildings. By 1992, however, municipal district heating had virtually disappeared.

During the early 1990s, irregular intervals of gas imports forced the population to rely on individual heating solutions such as wood, kerosene and costly electricity. From 1996, gas supply improved and primary energy prices were liberalized, but district heating remained unused due to low reliability, poor maintenance and significant heat losses (up to 50 per cent in Yerevan’s Avan district), which were related to extremely low payment collection rates in the first place (consumers opted instead for individual gas boilers and electric heaters). A 2006 assessment found that centralized heat production (using the existing district heat networks) was approximately 60 per cent more expensive than individual gas-fired heaters. The assessment was carried out during development of the United Nations Development Programme (UNDP)–GEF project, Armenia – Improving the Energy Efficiency of Municipal Heating and Hot Water Supply (2012).

This important project has the potential to restore vast amounts of Yerevan’s – and Armenia’s – district heat networks to provide heat that is safer, cheaper and more reliable than individual gas-fired heaters. The assessment was carried out during development of the United Nations Development Programme (UNDP)–GEF project, Armenia – Improving the Energy Efficiency of Municipal Heating and Hot Water Supply (2012).

This project has the potential to restore vast amounts of Yerevan’s – and Armenia’s – district heat networks to provide heat that is safer, cheaper and more reliable than individual gas-fired heaters. The assessment was carried out during development of the United Nations Development Programme (UNDP)–GEF project, Armenia – Improving the Energy Efficiency of Municipal Heating and Hot Water Supply (2012).

The team recommended that a public-private partnership was the best model for reducing environmental risk and reduce heat tariffs. The public sector role would have to be some ownership but also to reduce institutional barriers and offer favourable conditions to investment. This led to the Yerevan municipality creating the heat supply company. An important factor in the development was the restoration and construction of internal networks in the apartments being connected. Such development was considered as a soft loan and would be paid off by a separate tariff rate. In addition, public awareness campaigns for local residents were seen as crucial for the project, as residents were skeptical of district heating given its poor performance historically. They also had to be persuaded that the low heat tariffs could remain in place in the future.

The initial phase of connecting 10,000 residents is set to reduce energy consumption by 50-2 GW h annually and save 10–20,000 tons of CO2-equivalent. In 2006, the heat supply company AranGasConGeneration CJSC was founded, with the majority of shares owned by foreign investors and a minority held by the municipality of Yerevan.

Furthermore, district energy operators may need to pass on costs, which could mean unviable business models. One potential issue with such regulation is that it does not necessarily require district energy companies to innovate and reduce costs, particularly if the fuel for the next-available technology is the same fuel used for the incumbent one. If a district heating company loses money, it is mostly gas CHP producing the heat. Or, pricing district cooling against the next-available technology pricing may mean that electric chillers make the most sense, potentially ruling out other, lower-carbon technologies, such as absorption chillers. Such issues will be very country dependent, and each country must weigh the benefits of a regulated price based on alternative technologies against the negatives of such a price structure.

In Norway, tariffs for district energy are regulated to be below the next-available technology, which is electric heating. In return for such regulation, district energy companies may lose a profit from the cost of a licence area, which helps to ensure that costs are low enough for the regulated tariff (see case study 4.1). In Singapore, under the 2011 District Cooling Act, all commercial buildings in the Marina Bay district cooling zone are mandated to connect, and tariff controls prevent tariffs from exceeding the equivalent costs of chilled water produced by building-scale plants. The district cooling operator in Singapore is allowed to earn a baseline return based on its invested assets; however, once start-up losses have been recovered and the system achieves a critical mass of load for economic efficiency, any financial gain above the baseline return must be shared equally between the operator and its customers. Therefore, customers are assured of long-term savings, while the start-up demand risks associated with a greenfield project are mitigated. Yerevan is successfully attracting consumers back to district heating by implementing multi-tariff structures that are priced to be similar to individual natural gas boilers and that also encourage energy conservation by having a significant variable charge (see case study 4.4).

TARIFF REGULATED INDIRECTLY THROUGH CAPPED PROFITS AND PASS-THROUGH COSTS. One benefit of this model of tariff regulation is that, when district energy is cheaper than the alternative technology customers experience savings in their energy expenditure. However, if in certain years district energy is more expensive (for example, due to falling gas prices) the consumer could potentially pay more than the next-available technology.

In Denmark, the national government determines which price for district heating and district cooling prices, and this can then be levied on consumers. If a price is significantly lower than the cost of heat, the consumer pays a cost, such as the cost to connect a new home, the district heating company must ensure that this consumer pays the fixed cost. Although this is perhaps a fair model for connection, it can increase the proportion of fixed costs versus variable costs in the tariff, which can reduce the incentive for energy conservation (Chittum and Østergaard, 2014). For off-peak tariffs, a price cap provides oversight ensures that district heating companies charge fair tariffs and do not pass on costs that should not be incurred by the consumers. Furthermore, consumers are able to evaluate their tariff against other tariffs nationally, as district heating companies must publicly report tariffs. Japan has broken down of fixed and variable costs each year (Chittum and Østergaard, 2014). The tariff regulation of pass-through costs in Denmark has ensured that consumers in Denmark have enjoyed low prices for heat relative to other technologies, with 94.4 per cent of the heat sold by Danish district heating companies being cheaper to customers than an alternative individual heating solution (Chittum and Østergaard, 2014).

In the Canadian province of British Columbia, energy utilities are regulated by the British Columbia Utilities Commission, which enforces a rate structure and allowable return on equity, essentially limiting the profits of the utilities. This translates explicitly to the charging of an allowable average cost, or the district heating cooling operators, or subsidies some how should be redirected to storage at the district cooling level, stimulating more efficient and timely electricity use.

District Heating Manual for London (GLA and Arup, 2013). After all, district energy could be set slightly cheaper than individual heating/cooling solutions, but consumers will never own the connection to their property, whereas they would only have a boiler or air conditioner after 10 years, and such ownership should be accounted for in pricing formulas. Industry standards of contracts to consumers should be developed, as well as services that can advise consumers on the best heating option.

The District Heating Manual for London (GLA and Arup, 2013). After all, district energy could be set slightly cheaper than individual heating/cooling solutions, but consumers will never own the connection to their property, whereas they would only have a boiler or air conditioner after 10 years, and such ownership should be accounted for in pricing formulas. Industry standards of contracts to consumers should be developed, as well as services that can advise consumers on the best heating option. For countries where energy is subsidized at the consumer level (for example, for electricity or natural gas), such subsidies should be removed and the utility also allowed to pass through district heating prices. For example, in a country with district cooling, if electricity prices to residential customers are subsidized to be flat throughout the day and low, then the success of district heating could mean that district heating prices to keep district cooling competitive, and 2) flat-priced district heating could be more competitive to the district cooling operators, or subsidies some how should be redirected to storage at the district cooling level, stimulating more efficient and timely electricity use.

TARIFF NOT REGULATED. In the absence of regulatory authorities from the national level, local authorities can still influence tariffs through active participation in and ownership of district energy in their municipalities. This could be through concessions given out with requirements on tariff levels, or public ownership and controlling costs and eliminating profits to reduce tariffs (see case study 3.2 on Bunhill Heat and Power). For some to some extent, competition between heat sources will be deemed sufficient to keep prices low. However, consumers will need to be protected due to the effect of long-term contracts, which could be five years (GLA and Arup, 2013). All district energy could be set slightly cheaper than individual heating/cooling solutions, but consumers will never own the connection to their property, whereas they would only have a boiler or air conditioner after 10 years, and such ownership should be accounted for in pricing formulas. Industry standards of contracts to consumers should be developed, as well as services that can advise consumers on the best heating option.
4.4 VERTICAL INTEGRATION

Also referred to as subnational integration or multi-governance approaches, effective vertical integration is needed to optimize planning, coordination and monitoring of developments between different levels of government, from national/federal to state/provincial and local. Considering that each level of government has its specific mandate and responsibilities, effective vertical integration between different levels of government is increasingly important, especially in the context of addressing climate change (mitigation and adaptation), sustainable development and energy security.

New multi-level governance models are needed to ensure the timely engagement of all government levels involved in low-emission development, and to mutually reinforce each other’s roles and activities. Vertical integration also directly relates to improved measurable, reportable, and verifiable (MRV) actions and results. The MRV aspect aims to increase confidence in data, the process and the results – and can help ensure transparency. District energy offers an effective level of engagement, with a wide range of action instruments available to local governments to lead, guide and drive developments in this area – aligning with national policies and plans. These include strategy, bylaws, policies, urban and spatial planning, using financial incentives and disincentives, supporting market development, and coordinating stakeholder engagement, among others.

Local government actions often complement and, in many cases go beyond, state and national policies. In turn, national governments often consider using successful subnational programmes as blueprints for national policies (REN21, 2014; Leslau et al., 2015; NREL, 2018). Christchurch’s district energy technology and policy demonstration project is a test bed for potential scale-up and replication across New Zealand. China is experimenting with carbon trading at the local level before potentially launching such trading nationwide (Song and Lei, 2014; Climate Institute, 2013). In turn, many national and regional authorities across Europe are advancing incentives for district energy projects to reach their targets, as outlined in sections 4.1 and 4.2.

As cities become increasingly important for achieving national goals, they are playing a growing role in the design and development of “vertically integrated” state and national policies. Asia Pacific Economic Co-operation (APEC) has advanced its “Low Carbon Model Town” project using Yujia, China; Samui Island, Thailand; and Da Nang, Vietnam as the first three case studies. And in 2015, eight “model cities” in Brazil, India, South Africa and Indonesia began formulating low-emissions development strategies using a common methodology developed by ICLEI for local governments. Through such means, cities are exploring ways to tap into new climate financing mechanisms for emerging economies and developing countries, including Nationally Appropriate Mitigation Actions (NAMAs).

4.4.1 LEVERAGING NATIONALLY APPROPRIATE MITIGATION ACTIONS (NAMAS) FOR LOCAL EFFORTS

At the 2010 United Nations Climate Change Conference in Cancún, Mexico, Parties agreed that developing countries will implement Nationally Appropriate Mitigation Actions (NAMAs) that must be measurable, reportable and verifiable. A NAMA is any action that ultimately contributes to greenhouse gas emission reductions while addressing the development needs of a country. While a NAMA may encompass a specific project or measure to reduce emissions in the short term, it also may encompass policies, strategies and research programmes that lead to longer-term reductions.

Although the role of local and provincial actors in climate mitigation is undisputed, there is a lack of replicable experience with successful multi-level governance approaches in NAMAs. This includes strategies for how cities can leverage climate finance to support local authorities in undertaking actions, such as energy policies, that can provide strong national mitigation benefits that are not monetized but that can generate significant value and/or resources from local authorities. As seen in the case of district energy, national governments have started to develop incentives that can correspond to such public benefits (see sections 4.1 and 4.2).

However, local, provincial and national governments continue to face barriers in coordinating efforts to optimize synergies and achieve policy objectives. Two pilot approaches are under way in South Africa (see case study 4.5) and Indonesia, funded by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). They provide some initial experiences to address this gap. This BMUB–IKI project on “Involving sub-national actors into national mitigation strategies through vertically integrated NAMAs” or “V-NAMAs” supports developing country governments in their efforts to coordinate local and provincial policies for achieving national mitigation targets through cost-effective incentive packages and MRV systems.

Initial experiences emerging from the two pilot V-NAMAs in Indonesia and South Africa under the BMUB/GIZ programme include:

- **Ownership for V-NAMAs Starts at the National Level**: While the principal focus of V-NAMAs is to engage and motivate subnationals in the NAMA process, the initial step was still to place the V-NAMAs within the national-level institutional and climate strategy context.

- **V-NAMA as an Approach Operationalizing the National Climate Strategy at the Subnational Level**: In Indonesia, V-NAMA is seen as part of the national action plan for reducing greenhouse gas emissions (RAN-GRK), which is broken down at the provincial level (RADD-GK). V-NAMA is testing modalities for engaging municipalities in a systematic way, for example through establishing local V-NAMA coordination bodies, which regularly engage with the national and provincial level but also exchange experiences among themselves. In South Africa, V-NAMA is seen as part of the energy efficiency climate flagship programme of the national Climate Change Response Strategy. The V-NAMA gave the DEA a first opportunity to explore in practical terms how to design MRV mechanisms, which involves bottom-up reporting of climate actions at the local level—a valuable experience for replication in future NAMAs involving subnational actors.

4.4.2 SOME INITIAL EXPERIENCES WITH V-NAMAS

- **Selection of Subnationals to Participate in V-NAMA Pilots Has Been Top-Down, but Does Not Have to Be So**: Once they had agreed upon a workable institutional arrangement, the national-level ministries picked the subnational actors to participate, using a mix of technical and political criteria. For future V-NAMAs, a more competitive and transparent process could be considered, whereby subnational actors are selected based on their motivation, demonstrated willingness to commit own efforts, and greenhouse gas reduction potential. Good practice on how to design a competitive selection process is available in other international programmes.

V-NAMA as an Approach Operationalizing the National Climate Strategy at the Subnational Level

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V-NAMA as a Funding Mechanism: Designing a Climate Finance Mechanism for Subnationals

Government struggles to roll out their national climate programmes, including NAMAs, because often the climate finance mechanisms to accompany the programmes still need to be developed. Participating provinces and municipalities generally have the expectation that through the V-NAMAs they will gain access to additional funding to realize their local priority programmes. At the local level, the line between what is climate finance or “regular” budget, and what comes from national or international sources, is often blurred and of limited relevance, as long as there is a tangible incentive and the access to it is not too burdensome.
In South Africa, as part of the V-NAMA development, an improved energy efficiency funding mechanism has been designed for municipalities, and in Indonesia a discussion has been initiated with the Indonesia Climate Change Trust Fund on how to give cities access to climate finance for improving their waste management (and thereby reduce greenhouse gas emissions). In both countries, the Ministry of Finance or National Treasury has emerged as a key V-NAMA stakeholder regarding questions of national climate finance, how to blend national with international and local funding, and how to effectively channel climate finance to subnational entities.

V-NAMA as a framework for initiating a trust-building, “vertical dialogue” on local climate action between the subnational and national level. The relationship between national and subnational government is often characterized by a deep-rooted mutual distrust (e.g., “local government diverts climate finance to other use”, “national government is erratic in shifting funding priorities and wants to micro-manage without having the technical capacity”, etc.). This leads to suboptimal implementation arrangements (e.g., management of local actions out of national ministries). Furthermore, there is often a lack of understanding (and respect) for the realities and priorities of local governments, leading to poorly designed national support programmes that fail to achieve lasting local results, such as for infrastructure investments that local governments are incapable of operating sustainably.

In South Africa, a new and so-far untested opportunity to apply the V-NAMA approach. As demonstrated earlier, district energy holds substantial potential for greenhouse gas mitigation, which can be unlocked only via a co-active local government in its roles as building owner, regulator and matchmaker between the supply and demand of waste energy. At the same time, the national government (and, depending on the country, provincial governments) plays a critical role in establishing transparent standards for regulating grid access, tariff setting and valuing ancillary services such as reserve capacity. Hence, a vertical integration of regulation and incentives will be a prerequisite for creating the environment for attracting public or private investments into the district energy sector.

In a developing country, one of the incentives might be to mobilize climate finance for district energy investments under a V-NAMA regime. To that effect, a group of motivated cities could approach the national government’s lead agency for NAMA development to agree on a broad framework for a district energy V-NAMA, stipulating the key stakeholders at the national and local level (which are likely to include the ministries responsible for energy, buildings, and waste, as well as concerned city-level agencies and representatives from the energy company and private sector). A feasibility study would need to examine in detail the greenhouse gas reduction potential, the financial viability of various business models, and the optimal design given the specific circumstances of the city area. Based on the results, a NAMA proposal could be developed describing a national mitigation programme combining strategic policy reforms, capacity-building, and blending of domestic, private, and, where needed, international climate finance sources.
Section 5:
THE WAY FORWARD: DECIDING NEXT STEPS TO ACCELERATE DISTRICT ENERGY

KEY FINDINGS

The decision tree developed as an outcome of this publication will guide cities through the various stages in district energy development and highlight tools and best practices that could be considered based on their local conditions. This section provides an outline of the decision tree and key areas of intervention and action that will be available in the online tool accompanying this publication. This section also outlines a policy and investment road map that comprises 10 key steps to accelerate the development, modernization and scale-up of district energy in cities.

THE DECISION TREE IS SPLIT INTO FOUR BROAD AREAS:

WHY?
Why district energy: what is the energy demand and what are the next-available technology costs for district energy deployment?

WHEN?
When should district energy be developed, and what are the catalysts that take district energy from vision to reality?

WHAT?
What steps need to be taken to begin development of a district energy strategy in the city?

HOW?
How can incentives, policy frameworks, business models and tariff structures best serve district energy in the city?

An estimated 400 million people are expected to move to India’s urban centres by 2050, increasing cooling demand and putting strain on the power system. In Mumbai, an estimated 40% of the city’s electricity demand is for cooling. India is developing district cooling in Gujarat International Finance Tec-City (GIFT City) as a replicable demonstration project.

Section 5: THE WAY FORWARD: DECIDING NEXT STEPS TO ACCELERATE DISTRICT ENERGY

05

THIS SECTION LOOKS AT
5.1 Why?
5.2 When?
5.3 What?
5.4 How?
5.5 Concluding remarks
5.6 Further areas of research
Diverse cities are exploring district energy as a solution for achieving numerous policy objectives. This section explores the two primary variables for why a city would consider turning to district energy: heating and cooling demand, and costs. Section 5.2 then discusses when a city may take the decision to act on district energy, based on a number of policy drivers.

### 5.1 WHY?

#### 5.1.1 HEATING AND COOLING DEMAND

Increasing demand for heating and cooling increases the infrastructure and capital budgeting requirements at the city level and nationally. All cities have several pockets of free and local energy sources for heat and cooling that district energy can utilize. District energy has the ability to connect waste energy and to utilize primary energy as efficiently as possible.

If the city has high levels of heat and/or cooling demand, and this demand is distributed such that some areas have significantly high density of demand, then this demand may be best served with district energy. If demand is not high or very few areas of high demand exist in the city, then ambitions for district energy may be smaller.

#### 5.1.2 COSTS OF ALTERNATIVE FUELS AND TECHNOLOGIES FOR HEATING AND COOLING

The current technologies used to produce heat and/or cooling in a city will affect the cost-competitiveness of district energy. For example, natural gas imports from a volatile international market can make electricity and gas bills expensive and uncertain. Rather than a combination of individual gas boilers and gas-fired power stations, gas CHP in combination with district energy (and any waste sources of heat that this district energy can also connect) can reduce a city’s gas imports, insulating it to an extent from volatile gas prices. Furthermore, centralized gas production of heat is far easier to fuel switch than individual gas boilers.

If the city is using a high proportion of (cheap or valuable) electricity to meet heating or cooling demand, then district energy is an opportunity to avoid power infrastructure investment (such as power stations and transmission grid) and can alleviate grid demand, particularly at times of stress on the grid. For example, district cooling can significantly reduce the peak electricity load of a city. At peak load, the most expensive power plants will be running, and district cooling can reduce the need for such plants. This is a significant problem in extremely hot cities that have high levels of electricity consumption from air conditioning.

Alternatively, not using electricity for cooling and heating can reduce electricity’s cost to users and allow it to be used for more valuable activities such as improving access to electricity in rural areas, exporting to other countries at a higher price or powering industry. In Oslo, despite large local hydro resources, the city decided that it would prefer to use the hydropower to create aluminium rather than heat and cool using electricity.

District energy can allow the production of heat outside of individual homes and in a cleaner, more efficient way, improving local air quality and emissions.

As seen in this publication, the drivers of district energy have evolved over time based on the status of the technology in a city and on the economic development of the city as a whole. In consolidated cities, these drivers often have evolved, from air quality and energy independence to renewable energy integration and primary energy efficiency. In redeveloped cities, the historical drivers (affordability and access of cheap heat to the population) remain, but energy independence and efficiency are also driving modernization. For emerging cities, the drivers relate to the energy efficiency improvements and energy independence that district energy can provide relative to status quo heating and cooling technologies, as well as the environmental and economic benefits that this provides.

Interviews with local governments and stakeholders suggest that cities have often identified district energy as a key solution for these drivers, but have waited for the opportunity time to act. This has usually been when a clear champion has emerged and/or when external events have catalyzed the urgency to act. In most cases, an external catalyst has mobilized the support required for district energy build-up or modernization or has led to district energy systems emerging as the response to the event.

When the intent to develop district energy has been established, cities will need to identify what actions and steps need to be taken to respond to these catalysts. The following sections of the decision tree - “What?” and “How?” - outline how the decision tree will guide local authorities to take the necessary actions considering their resources, context and jurisdiction to act.
5.3 WHAT?

5.3.1 DEVELOP AN ENERGY STRATEGY AND DISTRICT ENERGY-RELATED GOALS OR TARGETS

As discussed in section 2.2.1, an energy strategy with a clear articulation of the benefits of district energy is critical to providing a coherent vision around which to mobilize diverse stakeholders. Cities first need to develop a holistic study of their energy use and energy needs in order to understand how best to realize socio-economic or environmental objectives. Such a holistic study must include a heat and cooling assessment to answer questions such as: How much electricity is used for cooling, and when is it used? How much gas, oil and wood is used for heating (and not cooking)? (see section 2.2.1).

This assessment can identify potential energy technology pathways to achieve city objectives by identifying a technology’s impact on air quality and CO2, electricity grid constraints; fossil fuel dependency; and energy affordability. For many cities, a technology pathway that includes district energy will be the cheapest solution with highest impact.

Such assessment also will allow a city to develop an energy strategy that explicitly speaks to the role of district energy in addressing policy objectives such as: How much can gas imports be reduced by 2020? How can a city’s peak electricity demand be reduced? How much can heating’s contribution to CO2 emissions be reduced by 2020? Based on this energy strategy, district energy-related goals or targets can be set that are associated with the benefits. This target can evolve as the city progresses in district energy.

In a new market, the step between a broad energy strategy, such as emission reductions, to a city-wide district energy-related goal or target is often achieved over time and with learning by the city. As targets and strategies evolve over time, experiences from, for example, demonstration projects, can provide lessons and showcase benefits that can be incorporated into the energy strategy (see energy mapping below).

To develop an energy strategy and district energy-related goal or target, a city needs to have the capacity to complete a heat and cooling assessment – i.e., to collect and analyse data on its heat/cooling demands, density, resources, etc. This requires some coordination of stakeholders but is not as intensive as energy mapping (see below). Such an assessment could benefit from international/national funding and assistance, particularly for developing country cities. It could lead to better understanding of basic energy metrics in the city (annual gas consumption per capita; approximate numbers of air conditioners; heating degree days, etc.).

Through a city-twinning programme, a city with similar metrics can be identified, lessons on energy strategy development in that city (such as methodologies, generalizations etc.) can be shared, and development best practices can be identified. Twinning between cities – matching champion ones with learning ones – will be a key component of the new district energy initiative.

5.3.2 ENGAGE IN ENERGY MAPPING

A key best practice is to build on the city’s heat/cooling assessment and on the stakeholder engagement and institutional coordination developed in this process to develop a detailed heat/cooling mapping of the city. As discussed in section 2.2.2, the first step is to collect spatial data on areas of dense heat or cool demand, local energy assets such as excess waste heat, renewable heat, free cooling and distribution infrastructure. This will enable the identification of individual projects, future interconnection potential, future growth in the city and required policy interventions. Where a city is unable to develop city-wide energy mapping due to a lack of funds, mapping can focus on high-potential areas such as the Central Business District (CBD) or zones/areas of new development.

Best practice is to begin to develop an institutional structure for multi-stakeholder coordination (see section 2.5) and to use data input from stakeholders, such as the distribution utility, public buildings, housing associations, etc. Where the institutional capacity or funding does not exist to carry out a thorough energy mapping, a city can explore the following options:

- Develop a public-private partnership in planning, coordination and project development. Mobilize private partners on the basis of the potential benefits and the objective to scale up district energy to help with strategy development and capacity-building (see section 2.4 on Sonderborg’s ProjectZero).
- Identify the most economically viable areas in the city that have high heat or cooling demand, such as commercial districts or new developments. Develop an energy map for these specific areas in collaboration with any private sector actors, and assess potential benefits from district energy deployment in those specific areas. Such potential benefits can legitimize – and facilitate funding for – the demonstration project (see case study 5.12 on Port Louis).
- Use the experience from a demonstration project, and the benefits showcased, to leverage further finance for full energy mapping in the city.
- Use demonstration projects to develop the institutional frameworks and capacity-building that are vital for the development of energy mapping. The city can then scale up capacity and institutional frameworks in a step-wise manner, using lessons from the demonstration project (see case study 3.1 on Vancouver).

FIGURE 5.1 Assessing pathways to energy mapping in expansion cities

- Does the city have the institutional capacity and funds to do city-wide energy mapping?
  - NO, city lacks institutional capacity
  - YES, city lacks funds for assessment

- Use the experience from a demonstration project, and the benefits showcased, to leverage further finance for full energy mapping in the city.
- Use demonstration projects to develop the institutional frameworks and capacity-building that are vital for the development of energy mapping. The city can then scale up capacity and institutional frameworks in a step-wise manner, using lessons from the demonstration project (see case study 3.1 on Vancouver).

- Use lessons learned, capacity-building and institutional framework developed during demonstration project to proceed to full mapping

- Based on energy mapping, identify projects, stakeholders and policy interventions needed to realize district energy strategy

- Ensure that the mapping is detailed enough to mobilizing public and private stakeholders to provide key data for energy mapping

- Develop energy mapping for a specific area or zone to showcase potential benefits, perhaps with international/national financial support

- Develop energy mapping for a specific area or zone to build institutional capacity, perhaps with international/national support

- Develop a DEMONSTRATION PROJECT in this specific area or zone
5.4 HOW?

This section provides insight into how the online decision tree will guide a local authority through the different options for developing district energy, utilizing the policy tools available to the city as planner and regulator, facilitator, provider and consumer, coordinator and advocate. Some of these policy options are made available through the national regulatory and policy framework and are influenced by the extent to which responsibility is devolved to the local authority.

From the 45 champion cities surveyed, a clear recommended first step was to assess what incentives exist at the national level to internalize the benefits of district energy and level the playing field. From the cities surveyed, the four national policies with the greatest impact are: incentives for CHP and renewables (see section 4.2); national regulation on tariffs (see section 4.2.3); incorporation of district energy into building efficiency standards (see section 4.1); and polluter taxes (see section 4.2). The decision tree in figure 5.2 explores the potential variations of such polluter taxes (for example, taxes on CO₂, fossil fuels or pollutants such as SO₂, NOₓ or particulates) and how they can enable district energy. The use of polluter taxes has been a key best practice in Nordic countries such as Denmark, Finland and Sweden in achieving high levels of district energy.

Polluter taxes may not be as strong in other national frameworks, where such taxes are not stable enough or at a sufficient level to internalize the socio-economic and environmental benefits of district energy. As such, local authorities will need to explore other national policies and incentives. This could include assessing projects on a case-by-case basis and working with the different stakeholders who stand to benefit from district energy systems (such as other, non-energy utilities) in order to internalize the benefits in the business model and create a level playing field. Such an approach may not accelerate district energy to the same level as in the Nordic countries, or not as quickly, but will provide proof of concept. For example, the lack of polluter taxes on industry in the harbour in Rotterdam means (in combination with high guarantee on supply) that the business case is not strong enough without local authority development.

A mapping exercise in the city can enable a local authority to demonstrate benefits that are not realized because of insufficient polluter tax. Such benefits are critical to the leveraging of finance from national or international funds. With regard to the benefit associated with CO₂ reduction, V-NAMAs may be an appropriate tool for a city’s request for financing district energy. As V-NAMAs need to be linked to demonstrable benefits (see case study 4.5 on V-NAMAs in South Africa, and section 4.3). In parallel to looking at the national framework, a city will have to assess whether integrating district energy into land-use and infrastructure planning, as identified as a best practice, is a viable option going forward. Heating and cooling infrastructure, unlike electricity and gas which are based on national or regional infrastructure, are best placed to be handled at the local level. There is often a grey area regarding how cities can intervene in its planning and permitting. Cities will often need to collaborate with national or regional utilities that are indirectly responsible for heating and cooling (such as those providing electricity for air conditioning). This collaboration will be dependent on how heating and cooling currently affects their business model, such as leading to grid constraints and blackouts on a national network for air conditioning. In several cases, identifying how district energy can relieve constraints on the electricity grid or the burden of replacing/installing new gas infrastructure has led to fruitful collaboration (e.g., Vancouver’s collaboration with BC Hydro; see also case studies 3.12 on Port Louis and 2.11 on Rotterdam.)

If the city’s role as planner of energy infrastructure is clearer, then the city can consider developing district energy as a utility or encouraging it through its various roles. One of these key roles, as shown in the decision tree, is through connection policies to reduce load risk for a district energy project. One such connection policy could be mandatory connections. If a city decides to create a mandatory connection policy, it is important to guarantee that it is the most cost-effective choice for the consumer, either through transparency on prices and profits of utilities (e.g., the non-profit heat utility model in Denmark); through tariff regulation to be cheaper than the next-available fuel; or by putting the onus on the developer to prove that it is not cost-effective through city planning tools (e.g., London, Tokyo) or through national licensing schemes (e.g., case study 4.2 on Norsoy). It is important to consider the criteria against which these cost assessments are made. In the EU, these assessments must account for a full economic cost-benefit analysis of modern district energy systems.

The full decision tree is available online along with the case studies of the 45 champion cities.

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**FIGURE 5.2** Assessing options in expansion cities to develop district energy based on the national and local regulatory framework.

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**POLICY FRAMEWORK**

- **LOCAL** (devolved authority)
  - Taxes
  - District energy in energy efficiency building standards
  - CHP and renewable heat incentives
  - Tariff regulation

- **NATIONAL**
  - National or local utilities indirectly providing heating and cooling (e.g., gas/electricity utilities)
  - Land-use planning: city has authority to develop, plan or provide permits for heating/cooling infrastructure
  - Targets and strategy
  - Building codes

- **MAYBE**
  - Provider of heat/cooling without constraints or difficulties on gas/electricity network
  - Constraints or difficulties on gas/electricity network

- **YES**
  - Demonstration of pilot projects that prove benefits of district energy even in unconstrained system
  - Coordination between energy utility and gas/electricity utility

- **BUILD**
  - Coordinate with gas/electricity utilities
  - Build the business case around public private partnership or public-private partnership

- **YES**
  - Connection policies
  - City as citizen
  - Facilitate finance

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- **National funds/programmes (V-NAMAs)**
  - Grants (V-NAMAs)
  - Case-by-case business models
  - Mapping

- **Regional** (grey area) make case

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- **Consortium**: working with the different stakeholders who stand to benefit from district energy systems (such as other, non-energy utilities) in order to internalize the benefits in the business model and create a level playing field. Such an approach may not accelerate district energy to the same level as in the Nordic countries, or not as quickly, but will provide proof of concept. For example, the lack of polluter taxes on industry in the harbour in Rotterdam means (in combination with high guarantee on supply) that the business case is not strong enough without local authority development.

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- **Coordination**: a mapping exercise in the city can enable a local authority to demonstrate benefits that are not realized because of insufficient polluter tax. Such benefits are critical to the leveraging of finance from national or international funds. With regard to the benefit associated with CO₂ reduction, V-NAMAs may be an appropriate tool for a city’s request for financing district energy. As V-NAMAs need to be linked to demonstrable benefits (see case study 4.5 on V-NAMAs in South Africa, and section 4.3). In parallel to looking at the national framework, a city will have to assess whether integrating district energy into land-use and infrastructure planning, as identified as a best practice, is a viable option going forward.

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- **Connection**: heating and cooling infrastructure, unlike electricity and gas which are based on national or regional infrastructure, are best placed to be handled at the local level. There is often a grey area regarding how cities can intervene in its planning and permitting. Cities will often need to collaborate with national or regional utilities that are indirectly responsible for heating and cooling (such as those providing electricity for air conditioning). This collaboration will be dependent on how heating and cooling currently affects their business model, such as leading to grid constraints and blackouts on a national network for air conditioning. In several cases, identifying how district energy can relieve constraints on the electricity grid or the burden of replacing/installing new gas infrastructure has led to fruitful collaboration (e.g., Vancouver’s collaboration with BC Hydro; see also case studies 3.12 on Port Louis and 2.11 on Rotterdam.)

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- **Connection policy**: if a city decides to create a mandatory connection policy, it is important to guarantee that it is the most cost-effective choice for the consumer, either through transparency on prices and profits of utilities (e.g., the non-profit heat utility model in Denmark); through tariff regulation to be cheaper than the next-available fuel; or by putting the onus on the developer to prove that it is not cost-effective through city planning tools (e.g., London, Tokyo) or through national licensing schemes (e.g., case study 4.2 on Norsoy). It is important to consider the criteria against which these cost assessments are made. In the EU, these assessments must account for a full economic cost-benefit analysis of modern district energy systems.
5.5 KEY STEPS IN DEVELOPING A DISTRICT ENERGY SYSTEM

The decision tree will highlight the decision-making considerations under 10 key steps to support the development of a policy and investment road map for district energy systems (see figure 5.5). These steps can be taken individually or packaged to meet specific city conditions and needs. The existing policy actions in a city and the degree of experience in developing district energy systems will inform which steps are applicable in a city. The decision tree will help a city navigate the options and tools that are available, based on their local conditions, to address each area of action. In this context, development of a district energy system connects new systems or systems in need of upgrade or retrofit.

Capacity-building is a cross-cutting area of action that is implicit within each step. Through the public-private partnership model of the District Energy in Cities Initiative, tailored support using the 10 key steps is intended to be provided to the cities/counties. Twisting between cities—matching mentor ones with learning ones—will be one of the key components of the new district energy initiative to transfer and scale up lessons learned and best practices.

5.6 CONCLUDING REMARKS: OVERCOMING KEY CHALLENGES AND CAPTURING OPPORTUNITIES

Cities need to address diverse barriers and challenges to enable the deployment of modern district energy systems. The best strategic policy responses will depend on local conditions, including a city’s social and economic and environmental objectives; market structure; population density and size; availability of capital; credit rating; local expertise; existing infrastructure; and energy mix. The following is a summary of some of the main barriers common to cities, and the lessons learned from their experiences.

- Inadequate municipal control over the energy sector: When local governments do not have regulatory power over the energy sector, or do not have a stake in a local utility, they can incorporate energy-supply or efficiency requirements into planning, land-use and procurement policies. In some cities, such as in Amsterdam, the Greater London Authority, Seoul, and Tokyo.

- Inadequate capacity and public acceptance: Raising awareness and technical understanding of district energy applications and their multiple benefits is critical in order for city authorities to engage with the market as an “intelligent client” – managing feasibility analyses, developing appropriate policies, engaging with stakeholders, developing business models and garnering public acceptance – all of which are critical to build the trust of potential users. Examples include Milan’s designated “help desks” and Frankfurt’s Energy Agency; partnering with the private sector to leverage their expertise (e.g., Anishan); and developing demonstration projects (e.g., Vancouver).

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- Coordination and cooperation between multiple stakeholders and interests: A strong – often public – champion is required to develop a case for district energy and to ensure a rules-based permitting process. Local governments can establish a coordination structure to ensure integrated, holistic planning and/or develop energy maps to visually communicate opportunities, bring together the different partners for business development and inform the planning process. Amsterdam used energy mapping to establish cooperation among various industrial partners on the exchange of energy and use of excess waste heat from data centers.

- High cost of feasibility studies: A local authority has enough funds if it raises internal money for a scheme that may not proceed and that it may not have the capacity to undertake. Cities such as Tokyo and the Greater London Authority have used their planning authority to place the onus on property developers to undertake feasibility studies. An alternative is an external development grant to finance initial feasibility studies, such as the US$1 million project preparation grant from the African Development Bank for the Sea Water Air Conditioning (SWAC) Project in Port Louis.

- De-risking capital investment: For district energy projects, capital is typically invested prior to the connection of customer buildings, thus, the greatest risk in system deployment is load uncertainty. To provide investor security and alleviate financial risks, local governments can use land-use and connection policies (e.g., Lodi; Yelene) or designate district energy high-priority and opportunity zones (e.g., Vancouver’s Neighborhood Energy Strategy, Hong Kong’s district cooling zones, Singapore’s district cooling zones) in the city. To reduce risk and project cost, smaller systems can be interconnected over time as a city-wide system, as exemplified in Copenhagen. This allows the system to be built out as load is connected (as has occurred in Dubai with district cooling), reducing the risk of not being able to connect new demand. Local governments can also provide loan guarantees, as in Aberdeen; leverage international financing, as in Bontan; or develop a revolving fund to reduce the costs of finance, particularly for projects that have high public benefit, as in Tokyo.

- Putting a price on waste heat: The integration of publicly or privately owned waste heat can be achieved through heat tariffs that reflect the cost to connect and the ability to guarantee supply. This is similar to the development of feed-in tariffs for renewable electricity generation – a variable waste heat supply should have its consumption maximized but may be able to only predict and not guarantee heat.

- Regulating tariffs to ensure customer protection: Tariff regulation is an important aspect of district energy that can ensure consumer protection in a naturally monopolistic market. In some cases, the local governments may control over tariffs set by the private sector through concession agreements. Tariffs can be 1) regulated so that district energy is priced at the alternative technology costs, or 2) effectively indirectly regulated by controlling the profits of district energy companies or the costs that they can pass on to consumers.

- Existing market structure and distortions: Modern district energy systems are negatively affected by market distortions (e.g., fossil fuel subsidies). Local governments can reform subsidies or provide financial and fiscal incentives to create a level playing field, or develop a revolving fund to provide low-cost financing of those developments that are in the public interest, with the capital then repaid and redeployed in other projects (e.g., the Toronto Atmospheric Fund, the Oslo Climate and Energy Fund).

- Multi-level governance and national regulations: As with other aspects of the energy transition, a key factor in the successful development of district energy networks is the establishment of an appropriate policy framework. Although many models exist in mature or nascent markets, and policies associated with the establishment of a green system can and must be made at a local level, coherent and coordinated multilevel governance is key to achieving optimal results. City-level action can help translate principles established at a supra-national, national or regional level into practice on the ground. Insufficient multi-stakeholder involvement and coordination is another challenge to address. Devolution as part of broad national strategies can encourage difficulties in developing countries due to 1) the delay in building up local capacity and 2) the delay in devolving financial resources (e.g., fiscal revenue). This can limit the speed and efficiency of development under devolution.

- Energy market influence on design of business models: The energy market in a country and the degree of liberalization, privatization and regulation shape the business model for district energy. In many developing countries, utilities are publicly owned and may be responsible for producing, transmitting and distributing electricity. Incorporating national utilities into the business model – such as through full or partial ownership – is key to realizing the macro-economic benefits of district energy.

The economic, social and environmental benefits of district energy systems have not always been fully accounted for in technology comparisons. In addition, the long-term nature of district energy investment can mean that it is ignored over simpler, short-term energy solutions that can, in the long term, be less beneficial overall. District energy systems do not necessarily need subsidies, but they do need financial, fiscal or policy support to bring them on to an even playing field with other technologies.
As a stand-alone report, this publication is intended to accelerate district energy and to launch the Global District Energy in Cities Initiative. Significant areas of research still need to be addressed, however, particularly with regard to district cooling and how it relates to energy efficiency, energy access and renewable energy. The following areas of research would be particularly beneficial to district energy going forward:

- Exploring the impact of cooling demand at the city and national level and the comparative benefits of district cooling against national power system upgrades and developments.
- Understanding the extent to which district cooling could allow a greater focus on access to electricity in a country by reducing strain on the national power system.
- Improving data collection and analysis methodologies for countries and cities looking to understand cooling demand, and developing best practice guidelines.
- Elaborating national energy policies and market structures that enable the national benefits of district cooling to be captured in the business model.
- Developing cost data and guidelines to enable cities to compare district energy against competitive technologies.
- Designing replicable national policies that can attract finance and expertise for refurbishment of district heating systems to become modern and efficient.
- Evaluating the ability of district energy, in particular CHP and CCHP technologies, to provide balancing for power systems and to enable higher levels of variable renewable generation.
- Demonstrating the importance for district energy development of vertically integrated structures between city, regional and national authorities.
- Quantifying the multiple benefits of district energy in the context of various nexus dimensions such as resource use, water, land use, and health.
AALBORG UNIVERSITY AND DANFOSS DISTRICT ENERGY (2014). Diagram provided by Henrik Lund, Aalborg University, and Jan Eric Thorsen, Danfoss District Energy. Aalborg and Nordborg, Denmark.


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“DISTRICT ENERGY: OPTIONS, IMPLEMENTATION ISSUES, AND THE WAY FORWARD”

SE4ALL ENERGY EFFICIENCY HUB WORKSHOP ON DOUBLING THE GLOBAL RATE OF IMPROVEMENT IN ENERGY EFFICIENCY BY 2030, U nited Nations Conference on Trade and Development, New York, 17 J une 2014

INTERVIEWS

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INTERVIEWEES AND SURVEY RESPONDENTS

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“DISTRICT ENERGY: OPTIONS, IMPLEMENTATION ISSUES, AND THE WAY FORWARD”

SE4ALL ENERGY EFFICIENCY HUB WORKSHOP ON DOUBLING THE GLOBAL RATE OF IMPROVEMENT IN ENERGY EFFICIENCY BY 2030, UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT, NEW YORK, 17 JUNE 2014

INTERVIEWS
ANCHOR LOAD. A heat or cooling demand that is significant for an external process such as district heating or district cooling. Absorption chillers do not use HCFCs. “Indirect-fired” chillers use waste heat, fuel to produce heat, which then produces water. “Direct-fired” absorption chillers use the emission of an equivalent mass of CO2. Efficiency exercises. Economic and technical viability of a building energy certificate system. LEVELIZED COST. The price per unit of energy produced that is required to ensure that the investment and future payments break even given a set discount rate and lifetime. MIXED-USE ZONING. An urban planning tool that encourages different building-use types to be developed in proximity. Such zoning is used in districts because the land is more variegated, and hence smoother.

NATIONAL APPROPRIATE MITIGATION ACTIONS (NAMAS). An action that contributes to greenhouse gas emission reductions, while addressing the development needs of a country. A NAMA may encompass a specific project or measure to reduce emissions in the short term. It may encompass policies, strategies and research programmes that lead to longer-term reductions.

NET PRESENT VALUE (NPV). The difference between present values of cash inflows and the present value of cash outflows. Present value is calculated using a discount rate.

NEW CITIES. Cities where district heating and cooling has a very low market share (0–15 per cent). ‘New cities’ are in the process of identifying how to stimulate district heating and cooling, with small networks or demonstration projects envisioned.

NODAL DEVELOPMENT. The initial development of district energy in segregated “nodes” within a city, which consist of small network or separate company to own the project, bearing risk and liability from the project sponsor(s).

STORAGE. Technology used to store thermal energy. Storage is connected into the district energy network to allow surplus production from thermal or electric power plants to be exported to the district energy network for future use.

WASTE-TO-ENERGY OR WASTE INCINERATION. Burning of municipal solid waste to recover heat and to subsidize a technology. The electricity price paid by consumers, which includes generation, transmission and distribution costs.

WATTAGE. The power that is measured in watts. Wattage is a measure of electrical power, measured in watts.

WATT-HOUR. A unit of electrical energy equal to 1 watt-hour, or the energy consumed or generated by a device rated at 1 watt operating for 1 hour.

WAGE. The amount of money that is paid to an employee for their work.

WAGE INEquality. A condition in which wage differences exist between different groups of workers.

WEIGHTED AVERAGE COST OF CAPITAL (WACC). The proportionally weighted cost of various sources of capital that is required to ensure that the investment and future payments break even given a set discount rate and lifetime.

WATER-TO-ENERGY. The transformation of water into energy. Water can be used as a heat source to produce electricity or to produce hydrogen.

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District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy highlights key technology options available to communities to provide heating and cooling services in a cost-effective manner and with low environmental impacts. The findings of this report should be studied carefully by all policymakers and private developers who are endeavoring to achieve a more sustainable future.

Ralph Sims, Professor at Massey University, New Zealand and member of the Scientific and Technical Advisory Panel of the Global Environment Facility

"District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy" provides a critical set of information to cities as they develop action plans to meet sustainability, energy and climate goals. By providing thoughtful analysis of both key barriers and successful best practices, this handbook helps decision-makers quickly identify important issues and successful practices from around the world. Overall, the District Energy in Cities initiative offers a great platform for cooperation among cities, the private sector and multilateral development institutions.

Alexander Sharabaroff, Operations Officer (Energy), International Finance Corporation

"District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy" is a timely, comprehensive and useful knowledge tool. This publication provides a pragmatic, high-level analysis of major issues - including technological solutions, costs, business models, and the roles and capacities of the public and private sectors - and offers the way forward. It includes an extremely useful set of nearly 40 specific, practical examples of best practices from around the world. Overall, the District Energy in Cities initiative offers a great platform for cooperation among cities, the private sector and multilateral development institutions.


"With the publication of District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy, UNEP has made a hugely valuable contribution to the climate and energy debate. Not only does it rightly identify the specific challenges of supplying low-carbon heat in the urban environment as a necessary element of the general energy transition, it provides highly practical advice and analyses for policymakers on how this can be achieved. An elegant demonstration of the power of thinking globally whilst acting locally, UNEP’s effort to drive the emergence of district energy as a solution for cities in the right direction at the right moment!"

Paul Voss, Managing Director, Euroheat & Power

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