UNEP

DISTRICT ENERGY IN CITIES

Unlocking the Potential of Energy Efficiency and Renewable Energy

United Nations Environment Programme

UNEP in collaboration with

COPENHAGEN CENTRE ON ENERGY EFFICIENCY
SE4ALL EE HUB

I.C.L.E.I
Local Governments for Sustainability

UN HABITAT
FOR A BETTER URBAN FUTURE

JOINT FOREWORD FROM ACHIM STEINER, KANDEH K. YUMKELLA, JOAN CLOS AND GINO VAN BEGIN

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.

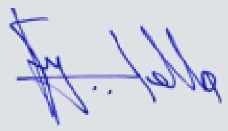
The UNEP report ***District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy*** identifies modern district energy as the most effective approach for many cities to transition to sustainable heating and cooling, by improving energy efficiency and enabling higher shares 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.

Achim Steiner
UN Under- Secretary General and UNEP Executive Director



Kandeh K. Yumkella
UN Under-Secretary-General, Special Representative of the Secretary-General for SE4ALL and CEO of SE4ALL

Joan Clos
Executive Director of UN-Habitat

Gino Van Begin
ICLEI Secretary General

CONTENTS

CONTENTS

LIST OF FIGURES

LIST OF BOXES

LIST OF TABLES

LIST OF CASE STUDIES

Case studies for each of the 45 champion cities can be found online, along with a decision tree to help guide cities through district energy development and a technology table that provides an overview of the major district energy technologies. Please visit www.unep.org/energy/des.

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This report has been prepared by UNEP in collaboration with the Copenhagen Centre for Energy Efficiency (C2E2), ICLEI – Local Governments for Sustainability and UN-Habitat. It is the first major publication of the Global District Energy in Cities Initiative and contributes to the Sustainable Energy for All (SE4ALL) Global Energy Efficiency Accelerator Platform.

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SUPERVISION AND COORDINATION

Martina Otto, former Head of Policy Unit, Energy Branch (UNEP), now Deputy Head of the Secretariat, Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC)

Djaheezah Subratty, Officer in Charge, Policy Unit, Climate, Energy and Environmentally Sound Technologies Branch (UNEP)

REPORT AUTHOR AND RESEARCH DIRECTOR

Lily Riahi, Policy Unit, Climate, Energy and Environmentally Sound Technologies Branch (UNEP), who also carried out all the interviews.

CONTRIBUTORS

Botosani, Romania, case study 2.5: **Alexander Sharabaroff** (International Finance Corporation – IFC); **Ovidiu Iulian Portariuc** (City of Botosani)

Project finance, Section 3: **Benjamin Hickman**, Policy Unit, Climate, Energy and Environmentally Sound Technologies Branch (UNEP)

Copenhagen, Denmark, case study 3.10 and Aberdeen, U.K., case study 3.11: **Michael King** (Carbon Trust)

V-NAMAs, initial experiences, Section 4: **Konrad Ritter** (Kritter Advisory Services)

Vertical integration and case study 4.5, Section 4: **Maryke van Staden** (ICLEI); **Prema Govender, Axel Olearius** and **Tobias Zeller** (Deutsche Gesellschaft für Internationale Zusammenarbeit – GIZ)

INTERVIEWEES AND SURVEY RESPONDENTS

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RESEARCH AND PROJECT SUPPORT

Giulia D'Angiolini (UN-Habitat); **Pedro Filipe Paralta Carqueija** (C2E2); **Tim Farrell** (C2E2); **Benjamin Hickman** (UNEP); **Patricia Lightburn** (Ministry of Natural Resources, Department of Strategic Affairs, Canada); **Mona Ludigkeit** (ICLEI); **Ana Marques** (ICLEI); **Kathy Mirzaei** (York University)

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REVIEWERS AND DATA CONTRIBUTORS

Chris Baber (City of Vancouver, Canada); **Carl Bernadac** (Agence Française de Développement – AfD); **Loeiz Bourdic** (Urban Morphology Institute); **Brad Bradford** (IDEA); **Ken Church** (Natural Resources Canada); **Jan-Olof Dalenbäck** (Chalmers University); **Bernard Debano** (Dalkia Utilities Services Plc); **John Dulac** (IEA); **Jose Etcheverry** (York University, Canada); **Paul Fay** (City of Frankfurt, Germany); **Sabine Froning** (Vattenfall); **Helen Santiago Fink** (UNEP); **Yann Françoise** (City of Paris, France); **Stefan Gsänger** (World Wind Energy Association); **Oddgeir Gudmundsson** (Danfoss District Heating); **Ghita Hannane** (UNEP); **Kalle Hashmi** (International Renewable Energy Agency – IRENA); **Bilal Hassan** (IRENA); **Yuill Herbert** (Plan4DE); **Michael Kerr** (IFC); **Nawon Kim** (Asian Development Bank); **Michael King** (Carbon Trust); **Heinz Kopetz** (World Bioenergy Association); **Krzysztof Laskowski** (Euroheat & Power); **Birger Lauersen** (Danish District Heating Association); **Astrid Madsen** (City of Rotterdam, The Netherlands); **Gaëll Mainguy** (Veolia Institute); **Ana Marques** (ICLEI); **Eric Martinot** (Beijing Institute of Technology); **Nick Meeton** (HUBER SE); **Kadri Nassiep** (South African National Energy Development Institute – SANEDI); **Peter North** (City of London, U.K.); **Julia Panzer** (Danfoss District Energy); **Katrina Pielli** (U.S. Department of Energy); **Stéphane Pouffary** (ENERGIES 2050); **Emmanuel Py** (World Bank); **Laxmi J Rao** (MIT); **Sherie Amor Reesor** (independent consultant); **Konrad Ritter** (Kritter Advisory Services); **Serge Salat** (Urban Morphology Institute); **Stefan Schurig** (World Future Council); **Michael Schwan** (Siemens AG); **Alexander Sharabaroff** (IFC); **Ted Sheldon** (Province of British Columbia, Canada); **Ralph Sims** (Massey University); **Ken Smith** (District Energy St. Paul, USA); **Virginia Sonntag O'Brien** (independent consultant); **Rian van Staden** (Intelligent Renewable Energy); **Sanjeev Tamhane** (UNEP); **Jan Eric Thorsen** (Danfoss District Energy); **Rob Thorton** (IDEA); **Georges Valentis** (Veolia Institute); **Paul Voss** (Euroheat & Power); **Kamila Waciega** (Veolia); **Nicholas You** (Guangzhou Institute for Urban Innovation); **Romain Zissler** (Japan Renewable Energy Foundation)

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John Christensen, Director, UNEP DTU Partnership; **Arab Hoballah**, Chief, Sustainable Lifestyles, Cities and Industry (UNEP); **Vincent Kitio**, Chief, Urban Energy Unit, UN-Habitat; **Sophie Loran** (UNEP DTU Partnership); **Eric Martinot** (Beijing Institute of Technology); **Jyoti Prasaud Painuly** (C2E2); **Mark Radka**, Chief, Climate, Energy and Environmentally Sound Technologies Branch (UNEP); **Maryke van Staden**, Director of the carbonn Center, ICLEI World Secretariat; **Merlyn van Voore**, Special Advisor on Climate Change (UNEP); **Eric Usher**, Head, UNEP Finance Initiative

EDITING, DESIGN AND LAYOUT

Lisa Mastny, editor
Caren Weeks, design

EXECUTIVE SUMMARY

Paris has developed Europe's first and largest district cooling network, part of which uses the Seine River for cooling. The Paris Urban Heating Company serves the equivalent of 500,000 households, including 50% of all social housing as well as all hospitals and 50% of public buildings, such as the Louvre Museum. The district heating network aims to use 60% renewable or recovered energy by 2020.

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 (CO_2) 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 (GW_{th}), followed by the United Arab Emirates (10 GW_{th}) and Japan (4 GW_{th}).

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.

REAPING THE MULTIPLE BENEFITS OF DISTRICT ENERGY SYSTEMS

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

GREENHOUSE GAS EMISSIONS REDUCTIONS

District energy allows for a transition away from fossil fuel use and can result in a 30–50 per cent reduction in primary energy consumption. Denmark has seen a 20 per cent reduction in national CO_2 emissions since 1990 due to district heating, and many cities are turning to district energy as key components of climate action plans. District energy is a core strategy in putting Paris on the pathway to a 75 per cent reduction in CO_2 emissions by 2050; the city's waste-to-energy plants alone avoid the emission of 800,000 tons of CO_2 annually. In Copenhagen, recycling waste heat results in 655,000 tons of CO_2 emission reductions while also displacing 1.4 million barrels of oil annually. And Tokyo, Japan's, district heating and cooling systems use 44 per cent less primary energy and emit 50 per cent less CO_2 compared to individual heating and cooling systems.

AIR POLLUTION REDUCTIONS

By reducing fossil fuel use, district energy systems can lead to reductions in indoor and outdoor air pollution and the associated health impacts. In Gothenburg, Sweden, district heating production doubled between 1973 and 2010, while CO_2 emissions fell by half and the city's nitrogen oxide (NO_x) and sulphur dioxide (SO_2) emissions declined even more sharply. As the share of oil used in Sweden's district heating networks dropped from 90 per cent in 1980 to less than 10 per cent in 2014, the country's carbon intensity similarly declined. In China, the city of Anshan will reduce its use of heavily polluting coal by a projected 1.2 million tons annually through the pooling of separate networks and the capture of 1 gigawatt of waste heat from a steel plant in the city.

ENERGY EFFICIENCY IMPROVEMENTS

Linking the heat and electricity sectors through district energy infrastructure and utilizing low-grade energy sources, such as waste heat or free cooling, can greatly improve the operational efficiency of new or existing buildings. All buildings require basic efficiency measures; however, as the efficiency in a building improves, connecting to a district energy system can be more cost-effective than a full retrofit, as Frankfurt, Germany, discovered when evaluating its 12,000 buildings with historic façades. Experience in Rotterdam, the Netherlands, has similarly shown that above a certain threshold for energy efficiency labelling, district energy is more cost-effective than retrofits. Helsinki's CHP plants often operate at very high levels of primary energy efficiency, utilizing up to 93 per cent of the energy in their fuel source to produce electricity and heat. In Japan, the high efficiencies of CHP plants make it possible to reduce imports of natural gas relative to business as usual. And in many cities – such as Dubai in the United Arab Emirates – district cooling can result in 50 per cent reductions in electricity use compared to other forms of cooling.

USE OF LOCAL AND RENEWABLE RESOURCES

Through economies of scale and the use of thermal storage, district energy systems are one of the most effective means for integrating renewable energy sources into the heating and cooling sectors. District energy also enables higher shares of renewable power production through balancing. Several countries with high shares of wind and solar power – such as China, Denmark and Germany – have begun using district heat systems to utilize excess renewable electricity during periods of oversupply. In China's Inner Mongolia region, the city of Hohhot is piloting the use of curtailed wind to provide district heating in order to meet rising heat demand. In Germany, a key reason that the national *Energiewende* ("Energy Transition") policy promotes CHP is because it allows for the integration of higher levels of solar photovoltaics into the electricity grid.

RESILIENCE AND ENERGY ACCESS

District energy systems can boost resilience and energy access through their ability to improve the management of electricity demand, reduce the risk of brownouts and adapt to pressures such as fuel price shocks (for example, through cost-effective decarbonization, centralized fuel-switching and affordable energy services). In Kuwait City, where air conditioning accounts for 70 per cent of peak power demand and for more than half of annual energy consumption, district cooling could reduce peak demand by 46 per cent and annual electricity consumption by 44 per cent compared to conventional air-cooled systems. Botosani, Romania, was able to reconnect 21 large-scale district heating consumers by modernizing its district energy infrastructure to provide more-affordable heat. And Yerevan, Armenia, was able to provide heat below the price of residential gas boilers by opting for gas-fired CHP instead of gas boilers for its district heating network.

GREEN ECONOMY

District energy systems can contribute to the transition to a green economy through cost savings from avoided or deferred investment in power generation infrastructure and peak capacity; wealth creation through reduced fossil fuel expenditure and generation of local tax revenue; and employment from jobs created in system design, construction, equipment manufacturing, and operation and maintenance. In Bergen, Norway, electricity companies supported district heating because it reduced reinforcement costs and provided additional revenues. St. Paul, USA, uses district energy fuelled by municipal wood waste to displace 275,000 tons of coal annually and to keep US$12 million in energy expenses circulating in the local economy. In Toronto, Canada, the extraction of lake water for district cooling reduces electricity use for cooling by 90 per cent, and the city earned US$89 million from selling a 43 per cent share in its district energy systems, which it could use to fund other sustainable infrastructure development. Oslo, Norway's, employment benefits from district energy are estimated at 1,375 full-time jobs.

CITIES WORLDWIDE HAVE FOUND INNOVATIVE WAYS TO OVERCOME KEY BARRIERS TO DISTRICT ENERGY DEPLOYMENT

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 and savings, a lack of integrated infrastructure and land-use planning, and a lack of knowledge and capacity in structuring projects to attract investments. Data and accounting challenges include a lack of sufficient data on municipal heating and cooling, 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 600,000 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 Christchurch (New Zealand), GIFT City (India), Guelph (Canada), Hong Kong (China) and Port Louis (Mauritius).

HONG KONG

CHRISTCHURCH

PORT LOUIS

LOCAL GOVERNMENTS CAN PLAY MANY DIVERSE ROLES IN ADVANCING DISTRICT ENERGY SYSTEMS

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.

Of the 45 champion cities, 43 are using their ability to influence planning policy and local regulations to promote and accelerate district energy deployment through vision and target setting; integrated energy, land-use and infrastructure planning and mapping; connection policies; and waste-to-energy mandates. Over half of the 45 cities have district energy-specific targets, which either resulted from or are linked to broader energy targets (e.g., energy efficiency, greenhouse gas emissions, fossil fuel consumption, energy intensity).

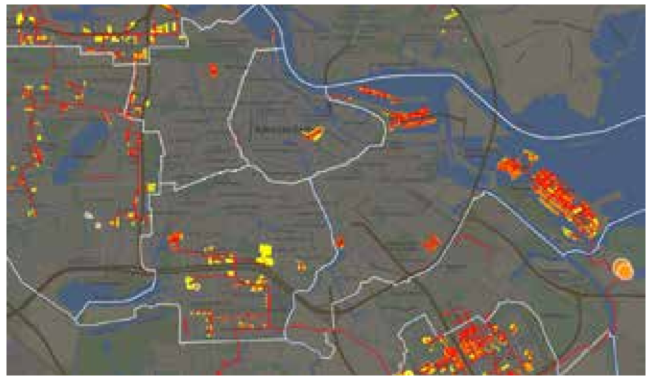
Integrated energy planning and mapping, supported by a designated coordination unit or a public-private partnership, is a best practice to identify synergies and opportunities for cost-effective district energy and to apply tailored policies or financial incentives within different areas of a city. Through such policies, the Greater London Authority envisions leveraging £8 billion (US$12.9 billion) of investment in district energy by 2030. In 2012 alone, the city's integrated energy and land-use planning policy resulted in £133 million (US$213 million) of investment in heat network infrastructure.

Across the 45 champion cities, local governments were ranked as the "most important" actor in catalyzing investment in district energy systems, playing a central role in addressing the associated risks and costs. Several cities – including Dubai (UAE), Munich (Germany), Tokyo (Japan), Paris (France) and Warsaw (Poland) – attracted more than US$150 million of investment in their respective district energy systems between 2009 and 2014.

Almost all of the 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. Other financial and fiscal incentives that local governments use 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 of the cities use demonstration projects as a tool to raise awareness and technical understanding of district energy app-lications and their multiple benefits, as well as to showcase their commercial viability. Vancouver, Canada, has developed a demonstration project capturing waste heat from the wastewater system, which has spurred private sector investment in other networks.

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. 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 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 the cost of connection and the ability to guarantee supply; CHP access to the retail electricity market; net metering policies and incentives for feed-in of distributed generation; customer protection policies, including tariff regulation; nodal development; 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.



City of Amsterdam, Interactive Maps, 'Energy from waste incineration and waste heat'. Map showing the existing district heat network in Amsterdam (red) with connected load (yellow) and sources of waste heat (orange).

Marina Bay, Singapore. Singapore piloted district cooling in Marina Bay by creating a 1.25 square kilometre zone with mandatory connection for commercial buildings.

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 33 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 million (US$2.6 million) and an annual concession fee of €7 million (US$9.1 million). The CPCU expects to achieve its 2020 target of 60 per cent renewable or recovered energy in the district heating network, which would lead to a net reduction in greenhouse gas emissions of some 350,000 tons of CO_2-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 2030, 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. Anshan'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 purchase. 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, secured a €27 million (US$33.8 million) grant from the Dutch government to reflect the equivalent avoided social costs of CO_2 and NO_X 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.

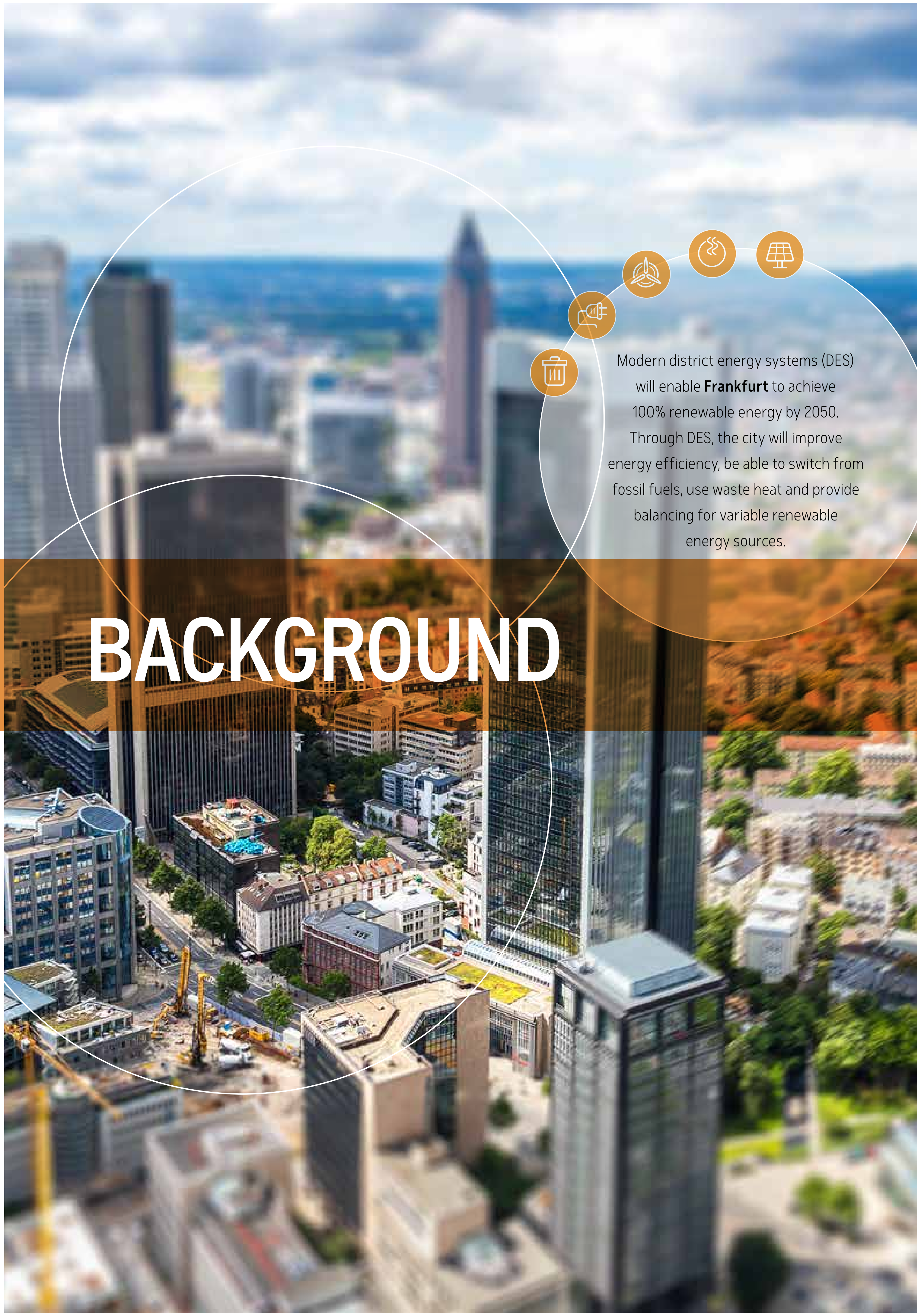
DECIDING NEXT STEPS TO ACCELERATE DISTRICT ENERGY

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

Multi-stakeholder discussion on V-NAMAs in Durban, South Africa.



CONTEXT

Accelerating the uptake of energy efficiency and renewable energy in the global energy mix is the single biggest contribution to keep global temperature rise under 2 degrees Celsius (°C) and to reap 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 solution 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.

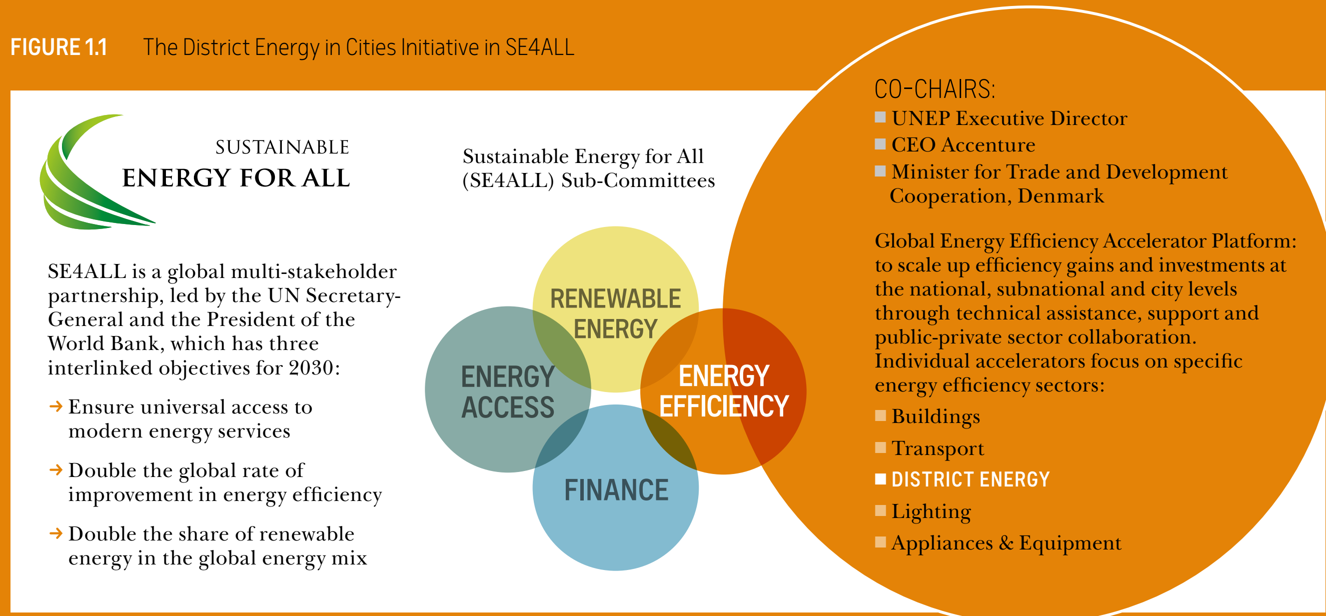
One of the least-cost and most-efficient solutions in reducing emissions and primary energy demand is the development of modern (i.e., energy-efficient and climate-resilient) and affordable district energy systems in cities. District energy systems pipe steam, hot water or cold water around a city for 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 (CO_2) 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 groundwater 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 neighbourhood and city level. It is about sharing energy among buildings to achieve optimum utilization of local heat sources. And it is about resource-efficient neighbourhoods 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.

FIGURE 1.1 The District Energy in Cities Initiative in SE4ALL



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 (C2E2), 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; 3) 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 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, 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 in order to gather expert and local stakeholder perspectives on the necessary parameters to ensure successful design, implementation and operations of modern district energy systems, including the barriers, challenges, successes and lessons learned. The interviewees included heads of industry associations, business people, financiers, researchers, consultants, academics, public advocates, policymakers, multilateral (intergovernmental) agency staff, utility managers, regulatory agency staff and city government officials. Surveys, using two rounds of structured survey questionnaires, were facilitated by C2E2, ICLEI, IDEA and UN-Habitat.

These interviews, surveys and consultations were the basis of all of the case study analyses and best practice recommendations in this report, unless otherwise referenced. Interviews and consultations were conducted as unstructured discussions, rather than as formal question-response sessions, and most conversations were held via telephone or email.

Additional input for the report was gathered 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 (CO_2) reduction and/or renewable energy development, and that also had enacted an 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 Ecoheat4EU report on *Best Practise Support Schemes* for district energy (Werner, 2011):

- In *consolidation* cities, district heating and cooling systems have reached a very mature, almost saturated market share above 50 per cent.
- 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.
- 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.

BOX 1.1

45 CITIES AROUND THE WORLD

THE 45 CHAMPION CITIES FOR DISTRICT ENERGY USE ARE:

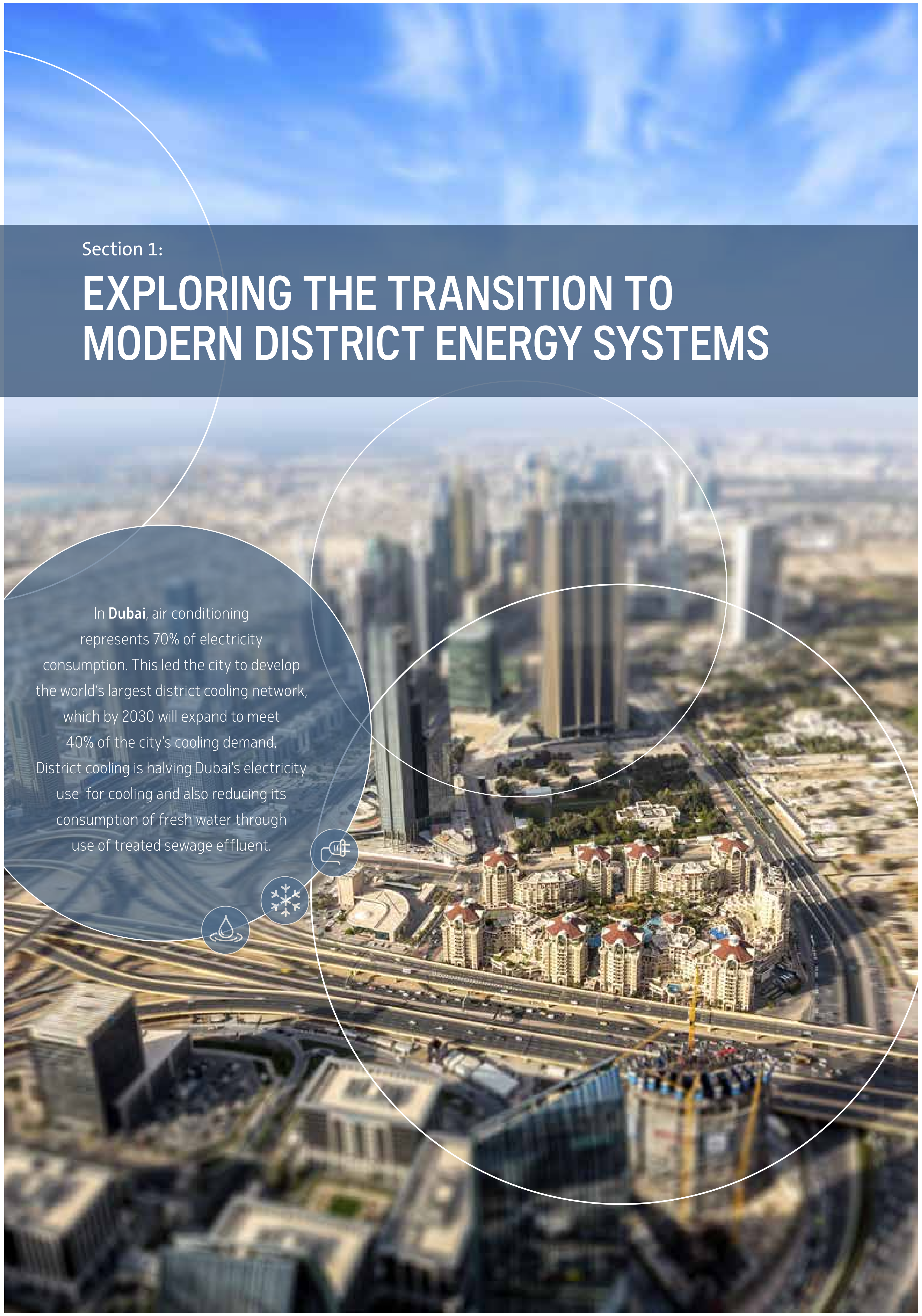
- **ABERDEEN**, U.K.
- **AMSTERDAM**, The Netherlands
- **ANSHAN**, China
- **ARLINGTON COUNTY**, USA
- **BERGEN**, Norway
- **BOTOSANI**, Romania
- **BREST**, France
- **CHRISTCHURCH**, New Zealand
- **COPENHAGEN**, Denmark
- **CYBERJAYA**, Malaysia
- **DOHA**, Qatar
- **DUBAI**, United Arab Emirates
- **FRANKFURT**, Germany
- **GENOA**, Italy
- **GIFT CITY**, India
- **GOTHENBURG**, Sweden
- **GUELPH**, Canada
- **GÜSSING**, Austria
- **HELSINKI**, Finland
- **HONG KONG**, China
- **IZMIR**, Turkey
- **KUWAIT CITY**, Kuwait
- **ŁÓDŹ**, Poland
- **LONDON**, U.K.
- **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
- **VÄXJÖ**, 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 3.6 million households), 6 GW of district cooling capacity (equivalent to approximately 600,000 households) and 12,000 kilometres of district energy networks*.

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

Section 1:

EXPLORING THE TRANSITION TO MODERN DISTRICT ENERGY SYSTEMS



In **Dubai**, air conditioning represents 70% of electricity consumption. This led the city to develop the world's largest district cooling network, which by 2030 will expand to meet 40% of the city's cooling demand. District cooling is halving Dubai's electricity use for cooling and also reducing its consumption of fresh water through use of treated sewage effluent.

01

THIS SECTION LOOKS AT

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 50 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-exergy, 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.

1.1 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; CO_2 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.)

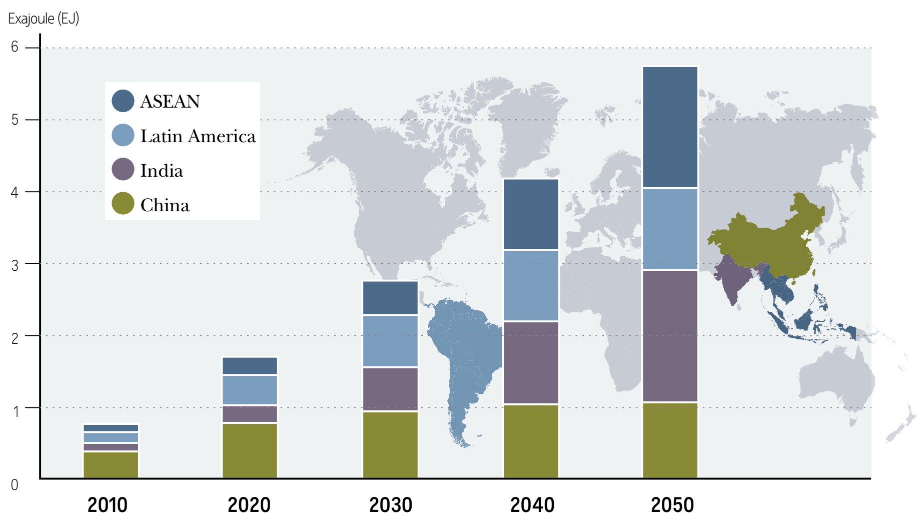
Contributions of district energy are significant and growing worldwide. District heating meets 12 per cent of heat demand in Europe* (Connolly et al., 2012) and 30 per cent in China (ADB, 2014), with China doubling its network length between 2005 and 2011 (IEA, 2014a). In Russia, district heating supplies 50 per cent of the heat demand in buildings. In several European cities, 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 (GW_{th}), followed by the UAE (10 GW_{th}) and Japan (4 GW_{th}) (Euroheat & Power, 2014). In South Korea, district cooling more than tripled between 2009 and 2011 (Euroheat & 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 30 per cent of forecasted cooling needs by 2030, avoiding 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 2030, the strain on the country's power system will only increase (IEA, 2013). 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 (Tembhekar, 2009).

* District heating accounts for approximately 12 per cent of the total residential and services heat demand in 2009 (Connolly 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

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.

1.1.1 DISTRICT 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-driven 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). HCFCs deplete the ozone layer, while their replacement with HFCs 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 CO_2 emissions by 2050 (UNEP, 2014).

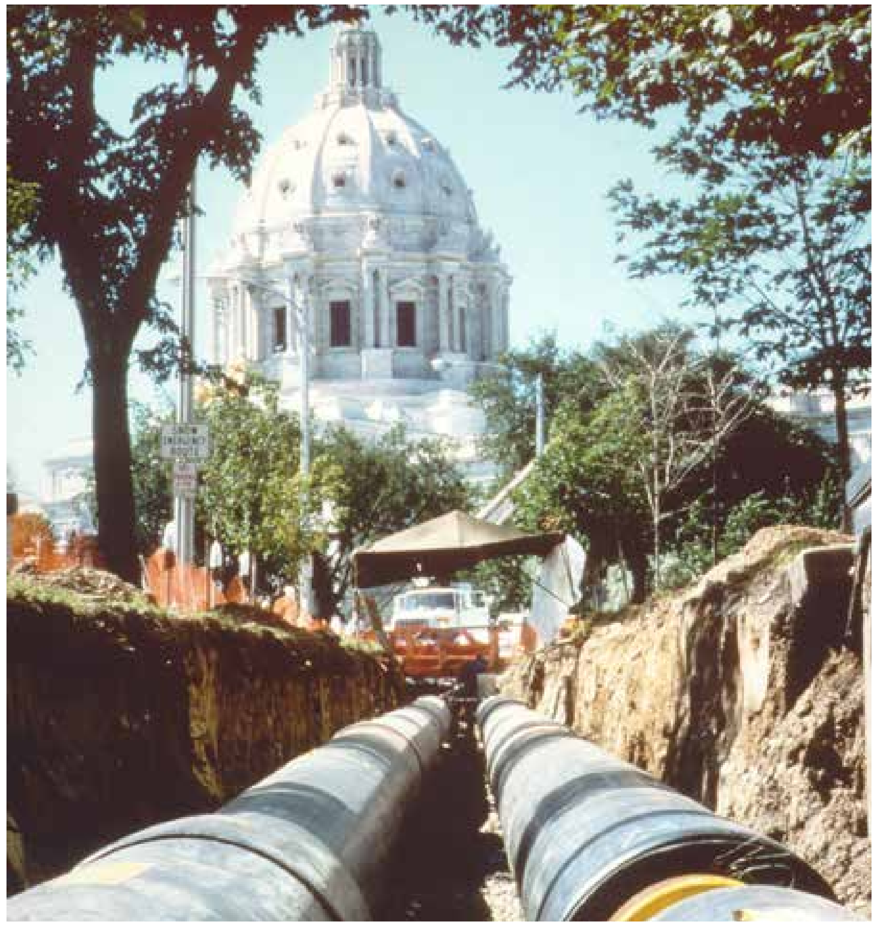
Some of the technologies used in district cooling are described in table 1.1. A comprehensive table of technologies is available online to accompany this report.

1.1.2 DISTRICT HEATING

District heating has been in use since the 1880s and has advanced significantly since then. Many district heating systems around the world require modernization (i.e., retrofitting) to bring them to a reliable standard. District heating enables the use of a variety of heat sources that are often wasted, as well as of renewable heat. Figure 1.3 shows the historical development of district heating systems, including their increased efficiency and diversification of heat sources. The future standard of district heating is referred to as "fourth-generation systems" and is the natural progression from a developed third-generation network.

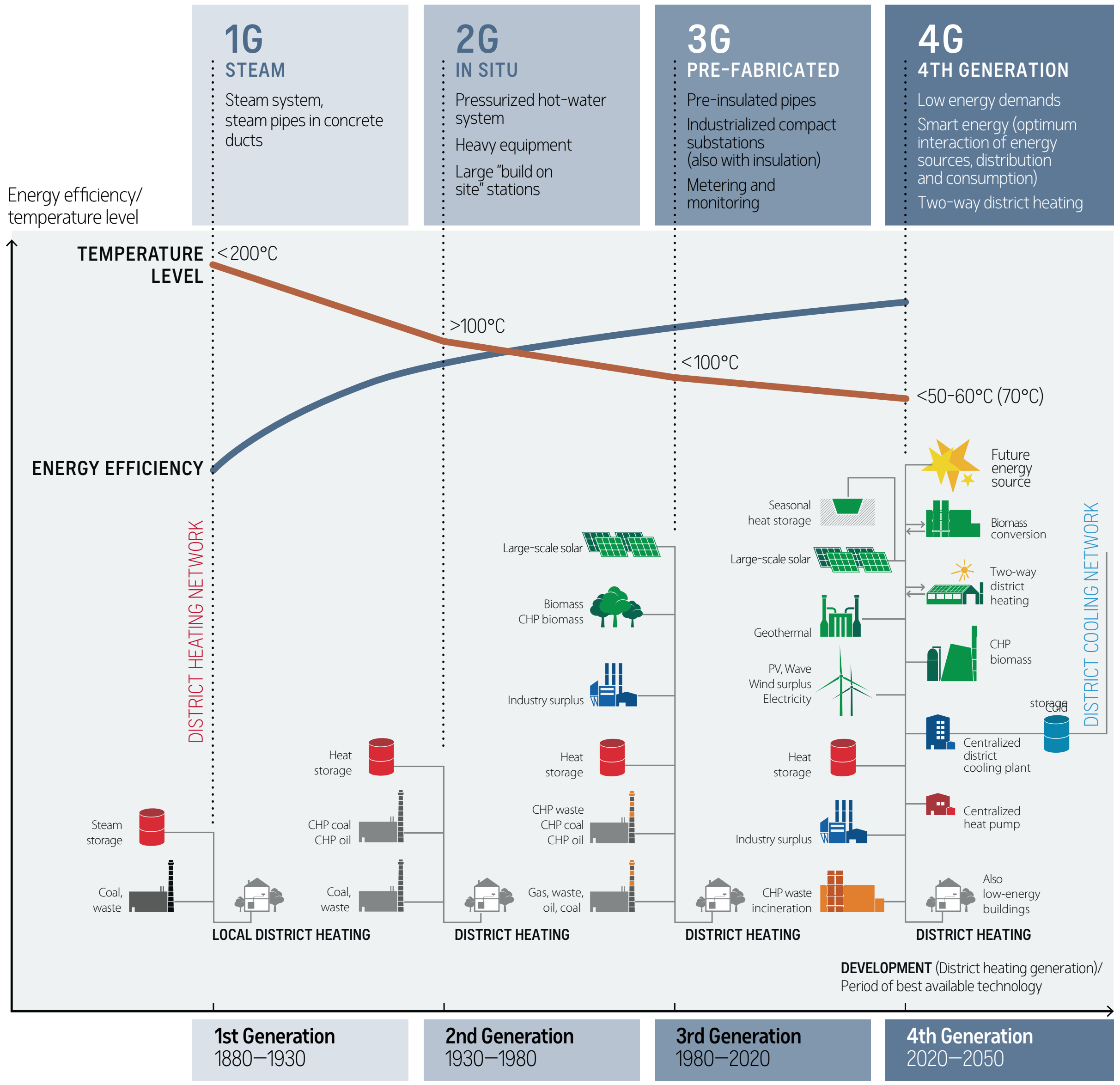
Fourth-generation systems operate at lower temperatures, resulting in reduced heat loss compared to previous generations, and they make it feasible to connect to areas with low energy density (e.g., areas with many low-energy buildings). The system can use diverse sources of heat, including low-grade waste heat, and can allow consumers to supply heat as well. Through heat storage, smart systems and flexible supply, these systems are an inexpensive solution for creating the flexibility required to integrate high levels of variable renewable energy into the electricity grid. Fourth-generation systems are located closer to load centres and generators than are traditional central-station generating plants, and the distributive nature and scale of these systems allows for a more nodal and web-like framework, enhancing accessibility to the grid through multiple points.

Some of the technologies used in district heating 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).



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



Source: Aalborg University and Danfoss District Energy, 2014

Installing a two-metre-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

TECHNOLOGY NAME	FUEL SOURCE AND CONVERSION TECHNOLOGIES	APPLICABILITY CONDITIONS/ CONSIDERATIONS	BENEFITS	EXAMPLES
DISTRICT HEATING				
GEOTHERMAL	**Fuel source:** Heat from brine (saline water) from underground reservoir **Conversion:** Heat exchangers	■ Favourable to supply baseload heat demand. ■ Location, depth and proximity of recharge wells in well field. ■ Potential uncertainty of resource available until wells drilled.	■ Cheap running costs and "fuel" for free. ■ Renewable energy source and environmentally friendly technology with low CO_2 emissions. ■ High operation stability and long lifetime. ■ Provides baseload, renewable heat.	**PARIS** is served by 36 geothermal district heating networks. **IZMIR** uses geothermal to provide heat that is over 35 per cent cheaper than residential gas consumption.
WASTE-TO ENERGY DISTRICT HEATING PLANT	**Fuel source:** Municipal solid waste (MSW) and other combustible wastes **Conversion:** Incineration	■ May need to be located far from the city due to potential local air pollution (although modern incinerators do not require large distances). ■ Some waste incinerators produce electricity as well as providing heat to a district heating network.	■ Utilizes the energy content in non-recyclable, combustible waste. ■ The remaining waste (bottom ash/slag) may be utilized in construction works, and it will no longer generate methane. ■ Waste incinerators produce very low-cost heat and often initiate development of a city's district heating network.	In **COPENHAGEN**, recycling waste heat results in 655,000 tons of CO_2 emissions reductions and displaces 1.4 million barrels of oil annually (Thornton, 2009). The new Amager waste incinerator plant just outside the city centre reflects improved emissions. **ŁÓDŹ** plans to build a waste incinerator to connect into the district heat network. The waste incinerator near **ROTTERDAM** delivers heat to part of the city and will result in 175,000 tons of CO_2 emission reductions by 2035.
DISTRICT HEATING BOILER	**Fuel source:** Sources include natural gas, oil products, electricity, biogas, coal, wood pellets, wood chips **Conversion:** Boiler	■ Depending on the fuel, can be used for peaking (gas, coal, electricity) or as baseload (wood chips, pellets, etc.).	■ Reduces overall system costs by providing peaking load (gas, oil, coal) that is unsuitable for waste heat sources such as from CHP, waste incinerators or industrial waste. ■ For biomass or biogas fuels, boilers can provide renewable and CO_2-free energy if the biomass is sustainably sourced or uses a local resource such as landfill gas.	District heating systems in all 45 champion cities use boilers as backup when baseload heat sources cannot meet peak demand. **ANSHAN** is upgrading its segregated district energy networks, which currently use only coal boilers, to include industrial waste heat capture, CHP and geothermal.
WASTE HEAT RECOVERY	**Fuel source:** Waste heat from an industrial process or low-grade heat from sewage **Conversion:** Heat exchangers	■ Needs consideration of how to price waste heat (see section 2.4.1 on waste tariff regulation). ■ Waste heat may not be able to guarantee supply and may require redundant backup boilers.	■ Recycling waste energy increases the energy efficiency of a city (as part of a circular economy). ■ For many cities, district heating is the only technology that enables the utilization of low-exergy waste heat in a city.	**VANCOUVER'S** South East False Creek Neighbourhood Energy Utility Demonstration Project (see case study 3.1) provides district heating for some 7,000 residential units, with 70 per cent of the heating energy obtained from raw wastewater. **LONDON** is exploring the capture of waste heat from the metro system and from electricity substations.
COMBINED HEAT AND POWER (CHP)	**Fuel source:** Sources include gas, biomass, coal, biogas, etc. **Conversion:** Second- or third-stage heat capture after steam turbine (or gas turbine for use of gas)	■ Power purchase agreements may not reflect local production benefits (see section 4.2). ■ Ideally used for baseload generation and can operate to follow heat demand or electricity prices. Best used in combination with boilers and storage.	■ A driving force behind district heating because it can produce high-exergy (see section 1.3.1) electricity at a local level in combination with waste heat. This greatly increases the primary energy efficiency of heating and electricity systems (see figure 1.4). ■ CHP plants provide district networks with large, centralized heat production that can allow for cost-effective fuel switching in the future if needed.	**VELENJE'S** 779 MW Šoštanj Thermal Power Plant provides heat to the city and electricity for one third of Slovenia. **VÄXJÖ** is a significant user of locally sourced biomass in CHP, which creates local jobs and provides clean, renewable heat. In **YEREVAN**, opting for gas-fired CHP development instead of gas boilers enabled the district heating network to provide heat below the price of residential gas boilers (see case study 4.4).

TABLE 1.1 Selected district heating and cooling technology options

TECHNOLOGY NAME	FUEL SOURCE AND CONVERSION TECHNOLOGIES	APPLICABILITY CONDITIONS/ CONSIDERATIONS	BENEFITS	EXAMPLES
DISTRICT HEATING				
HEAT PUMPS	**Fuel source:** A heat source (e.g., ambient air, water or ground, or waste heat from an industrial process) and energy to drive the process (electricity and heat) **Conversion:** Heat pump	▪ May be used as baseload generation or as peaking generation, depending on capital expenditure relative to electricity price. ▪ Heat pumps can utilize heat from: underground (steady temperatures are due to insulation from seasonal temperature variation rather than geothermal activity); sewage and wastewater; and even from return water in district cooling.	▪ Can convert electricity to heat at high efficiencies in times of surplus electricity generation. ▪ The coefficient of performance (COP) (the ratio of useful thermal energy produced to electricity consumed) can be greater than four. ▪ Utilizes energy at low temperature level (resource optimization).	**OSLO** airport uses a heat pump to cover both heating and cooling baseload needs throughout the year, using a groundwater reservoir. **MILAN** has three CHP plants; the electricity from two of these (“Canavese” and “Famagosta”) is used to power heat pumps connected to an aquifer under the city. **HELSINKI'S** Katri Vala heat pump captures 165,000 GWh of heat from the city's wastewater, making it the largest heat pump station in the world. **BREST** is exploring the connection of seawater heat pumps that will utilize steady ocean temperatures in winter to provide 5 MW of heat to its district heating network.
SOLAR THERMAL	**Fuel source:** Sun **Conversion:** Solar collectors	▪ Ground-mounted collectors can require significant land. ▪ Backup/peak load source is required (e.g., boiler).	▪ Renewable and CO_2-free energy source. ▪ District heating enables larger solar thermal systems to be developed, as buildings do not need to store heat or consume all heat produced.	**ST. PAUL** developed 2,140 m² of solar collectors with a thermal peak capacity of 1.2 MW_{th} to incorporate into the district heat networks. **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.

Helsinki's Katri Vala heat pump captures heat from the city's waste water.

A large solar thermal plant with heat storage connects to a district heating network in Brædstrup, Denmark.

TECHNOLOGY NAME	FUEL SOURCE AND CONVERSION TECHNOLOGIES	APPLICABILITY CONDITIONS/ CONSIDERATIONS	BENEFITS	EXAMPLES
DISTRICT COOLING				
ELECTRIC CHILLERS	**Fuel source:** Electricity **Conversion:** Electric chillers	▪ Still requires electricity for cooling, although a lot less. ▪ Any subsidies in commercial/residential electricity consumption must be accounted for to ensure that electric chillers are competitive.	▪ Electric chillers typically have much higher COPs than residential and commercial air-conditioning units (see figure 1.4), with many greater than seven, compared with modern residential and commercial air conditioners with COPs typically between two and four. ▪ Electric chillers use refrigerants with a lower global warming potential (GWP) as compared to decentralized air conditioning.	In **DOHA**, the Integrated District Cooling Plant at The Pearl, powered by various chillers, is the largest of its type, with a capacity of 130,000 tons of refrigeration (456 MW). The district cooling network in **PARIS** uses electric chillers to produce much of the cooling. This has led to 90 per cent less refrigerant emissions; 65 per cent less water used; 50 per cent less CO_2 emissions; 35 per cent less electricity used; and a 50 per cent improvement in primary energy efficiency.
FREE COOLING	**Fuel source:** Cold water from oceans, lakes, rivers or aquifers; waste cool of sources such as liquefied natural gas (LNG) terminals; pumping likely using electricity **Conversion:** Heat exchangers	▪ If load demand is high, may need backup sources. ▪ Plant is close to the buildings where the water is carried. ▪ Requires suitable cooling source. ▪ Environmental permitting cost. ▪ Provision of cooling can be seasonal.	▪ Use of renewables results in lower carbon emissions. ▪ Highly efficient electricity use reduces power consumption of the cooling system, particularly at peak, which can reduce the need for power infrastructure upgrades. ▪ Free cooling does not use “environmentally damaging” refrigerants for cooling unless supply water is not cold enough.	**TORONTO'S** district cooling system uses the new city water pipeline to extract cooling from deep in Lake Ontario, using pumps and heat exchangers and reducing the cost of cooling by 87 per cent (see case study 3.5). **PORT LOUIS** is developing a deep seawater cooling system that will take water from 1,000 metres below sea level to cool commercial buildings (see case study 3.12).
ABSORPTION CHILLER DRIVEN FROM SURPLUS HEAT OR RENEWABLE SOURCE	**Fuel source:** Surplus heat from waste incineration, industrial processes, power production **Conversion:** Integrating absorption chiller with heat source	▪ Absorption process often utilizes waste heat, enabling high levels of primary energy efficiency. ▪ Can be combined with CHP to produce cooling as well as heat (tri-generation) in a combined cooling, heating and power (CCHP) plant.	▪ Because heat demand is seasonal and low during summer, cooling production through an absorption chiller enables additional revenue for a CCHP. ▪ Particularly relevant for hot countries where combination with a power station allows for cool production exactly when power is most required. ▪ Absorption chillers do not use “environmentally damaging” refrigerants.	**LONDON'S** new Olympic Park development utilizes a 4 MW absorption chiller in the tri-generation plant to produce cooling during summer when heat demand is lower (see case study 3.8). **VELENJE'S** pilot project utilizing absorption chiller technology from waste heat has achieved significant electricity savings relative to normal cooling technologies, at a production cost that is 70 per cent that of normal cooling technologies.
THERMAL STORAGE				
COLD OR HEAT STORAGE	**Fuel source:** Cool or heat from district energy network or directly from district energy plant **Conversion:** Storage of hot water, cold water or ice	▪ Must consider storage capacity, discharge and charge rates, efficiency of storage, and the storage period (IEA-ETSAP and IRENA, 2013). ▪ Storage periods can range from a few hours and days to seasonal storage.	▪ As heating and cooling demand is typically seasonal, seasonal storage enables heat or cooling production to continue throughout the year, lowering the use of peaking capacity in a system. ▪ Cold storage on a network with electric chillers helps to further reduce peak electricity demand for cooling in a city by shifting production to other periods of the day.	**LONDON'S** Bunhill district heating network utilizes 115 m³ of hot water storage in combination with CHP to reduce the use of backup boilers to meet peak demand (see case study 3.2). **CYBERJAYA** utilizes both cold water storage (35,500 refrigeration-ton hours (RTh); 125 MWh) and ice storage (39,000 RTh; 137 MWh) (see case study 3.9).

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 30–50 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 93 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 brownouts.

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.

Air pollution in Shanghai, China (top). Commuters walking home during the 2003 New York blackout (bottom). The blackout prompted New York State to be a strong proponent of CHP at critical infrastructure facilities, after 58 hospitals lost power, whereas hospitals with CHP were able to operate as normal (Hampson et al., 2013; Hedman, 2006).

These multiple benefits and the ability to integrate renewable energy and energy efficiency have led commentators ranging from the *Wall 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 (Euroheat & Power, 2013; 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-user 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 2) and through the business model used (see section 3). 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).

TABLE 1.2 Benefits of district energy systems **to cities**

RESILIENCE-RELATED	ECONOMIC	ENVIRONMENTAL
■ Increased energy security and reduced dependence on fuel imports due to more-efficient use of primary energy and local resources ■ 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 ■ "Future-proofed" network allows for systems to be retrofitted easily with new and emerging technologies, without the need to install equipment in each building	■ Job creation through installation and operation and the increased reliance on local energy sources (local forest residues, landfill gas, renewables) ■ Additional income opportunities as interconnected systems allow for excess capacity and sharing with neighbouring systems ■ Local wealth retention from greater use of local resources, reduced fossil fuel imports and more-efficient primary energy consumption ■ Improvements in air quality that could reduce spending on health costs or environmental penalties ■ Possible relocation of businesses to the city due to increased energy security ■ Reduced consumption of fresh water in district cooling compared with conventional cooling systems ■ Significant dividends to the local government via the city ownership model of district energy ■ Monetary savings from reduced landfill use ■ Attraction of compact urban planning that can lead to reduced spending on energy, utilities, etc.	■ Substantial contribution to meeting city-wide greenhouse gas reduction targets ■ Huge potential to improve city-wide air quality through reduced burning of fossil fuels that produce sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulates ■ Decreased heat loss into the atmosphere, minimizing the heat-island effect in cities ■ 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 system) ■ 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
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:** insulation 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 20,000 toe of fossil fuels **PARIS:** dividend for the city of €2 million (US$2.6 million) annually **OSLO:** employment benefits estimated at 1,375 full-time jobs **GÜSSING:** urban rejuvenation, creation of more than 1,000 indirect jobs and entry of 50 new businesses **ST. PAUL:** US$12 million in energy expenses kept circulating in the local economy	**ANSHAN:** expected dramatic improvement in local air quality from reduced coal consumption as phases are built out **MILAN:** savings of 2.5 tons of particulate matter, 70,000 tons of CO_2, 50 tons of NO_x and 25 tons of SO_2 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

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

RESILIENCE-RELATED	ECONOMIC	ENVIRONMENTAL
▪ More-reliable energy source that can provide power and heat/cooling at times of disruption such as extreme weather or blackouts ▪ Insulation from energy price spikes and greater long-term certainty on heating and cooling bills because price is less reliant on fossil fuel prices	▪ Transparent reduction of heating and cooling bills in the long term compared to alternative technologies ▪ Ability for local authorities to target end-users experiencing fuel poverty ▪ Space savings from not having individual thermal energy production (e.g., freeing up of office space) ▪ 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 ▪ Additional income from building-level renewable hot water production through net metering	▪ Reduction of pollution produced in the home through heating and hot water production as a result of switching from coal and other fuels ▪ Health benefits from improved air quality ▪ Health benefits from greater utilization of the heating system by fuel-poor populations, due to more affordable provision of heat ▪ Improved safety as boilers, gas supply, etc. are kept out of the building
BOTOSANI: 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	**BOTOSANI:** following modernization, reconnection of 21 large-scale district heating consumers that previously had disconnected from the system but have now reconnected due to more affordable heat	**BOTOSANI:** annual abatement of a projected 684,100 tons of CO_2-equivalent of greenhouse gases

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

RESILIENCE-RELATED	ECONOMIC	ENVIRONMENTAL
▪ 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)	▪ Potential reduced energy imports due to lower primary energy consumption, improving balance of payments of the country ▪ Ability to use variable power generated from renewable energy, reducing the need for curtailing and backup power plants ▪ Deferred 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	▪ 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 ▪ Allows country to meet national/international targets for carbon emissions, renewables, energy efficiency, energy intensity and air quality ▪ Reduces consumption of environmentally damaging refrigerants in the cooling sector
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	**DENMARK:** 20 per cent reduction in national CO_2 emissions since 1990 due to district heating

1.3 ENERGY EFFICIENCY

1.3.1 TAKING ADVANTAGE OF LOW-EXERGY ENERGY SOURCES

"Wastewater flows combined with chillers and district cooling could meet approximately 30–35 per cent of the cooling demand of commercial buildings in many cities within temperate zones." *Nick Meeten, HUBER SE, 2014*

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 "exergy," meaning that they have high potential for useful mechanical work. Burning high-exergy 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-exergy energy sources. The high-exergy energy could then be saved for processes that do not have an alternative (Gudmundsson and Thorsen, 2013).

Air conditioning is a clear example of using high-exergy energy 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 on already-strained electricity networks and is inspiring action on developing district energy alternatives (see case studies 3.12 on Port Louis and 3.9 on Cyberjaya).

District energy infrastructure is the only way to utilize low-exergy, low-grade waste heat or free cooling sources for end-uses 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-exergy heating and cooling, and should turn instead to district energy. Cities should be taking advantage of free cooling sources such as rivers, lakes or seas; as well as waste heat sources such as metal smelting plants and other industrial processes, waste incineration, wastewater treatment plants, data centres and CHP plants.

Cogeneration in modern CHP plants is typically 80–90 per cent efficient, meaning that almost all of the primary energy burned is converted to useful final energy. The significant amount of heat captured in this process is frequently used in district heating. In contrast, conventional thermal power plants typically are only 30–50 per cent efficient and release huge amounts of waste heat to the local environment (IEA, 2014a). Figure 1.4 shows these relative differences in useful energy production and illustrates how, without district energy and CHP, fossil fuel consumption and CO_2 emissions are higher using conventional energy systems.

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 markets and to avoid having to operate in response to small fluctuations in heat demand. This also can allow 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 neighbouring 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 3.7 on Anshan) and adopting modern approaches to billing (see case study 4.4 on Yerevan). The World Bank's China Heat Reform and Building Energy Efficiency (HRBEE) Global Environment Facility (GEF) Project, completed in October 2013, 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 (m^2) of heating area, out of a total heated building stock of 8 billion m^2. 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 certifications 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 Frankfurt discovered when evaluating the city's 12,000 buildings that have historical façades. Similarly, in Rotterdam, as buildings become more efficient, it becomes more cost effective to pursue district energy, as figure 1.5 illustrates.

When progressing from the "G" 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 29 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 lowers 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-passive buildings still benefit from hot water and cooling services.

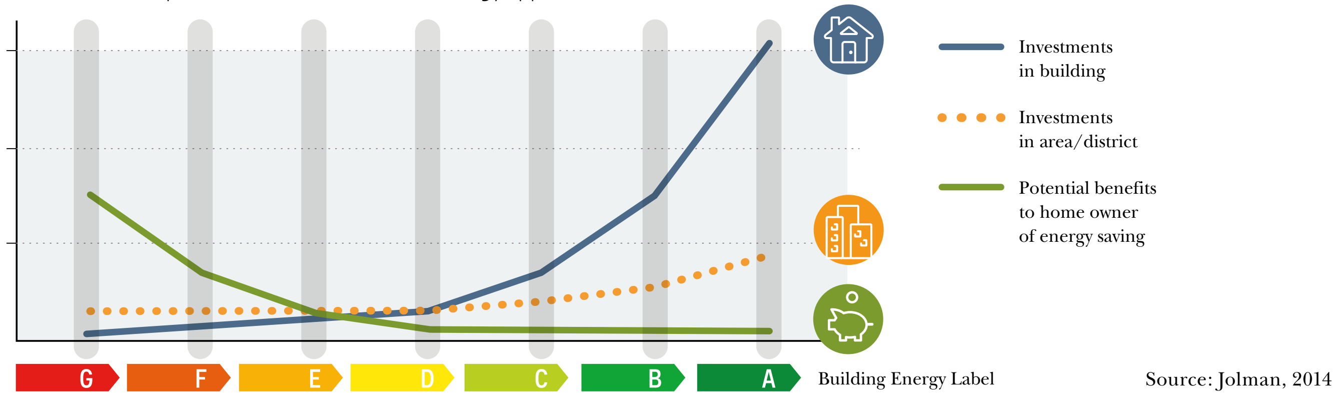
Achieving efficiency standards or certification through district energy is not always possible, however, and many existing energy standards or certification schemes currently do not reflect all of the efficiency benefits of district energy (see section 4.1).

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).

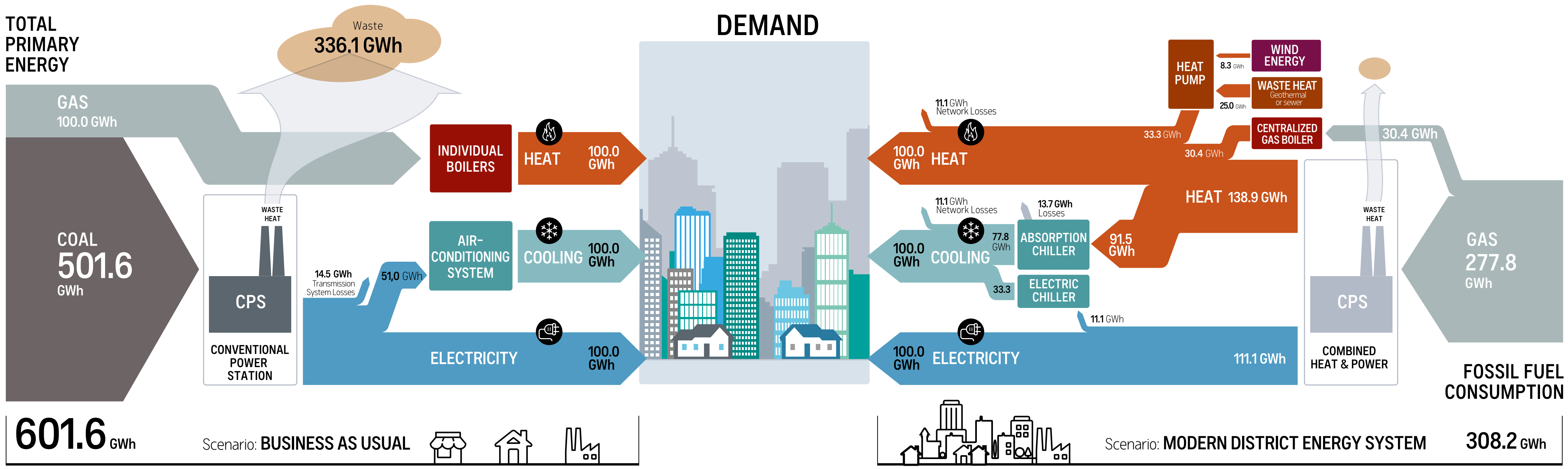
District energy also can provide affordable access to thermal energy by enabling communities to avoid many of the upstream investment costs associated with the power sector. In countries and cities with high demand for cooling, in particular, district cooling can reduce the high electricity demand for 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 1.5 Return on investment in Rotterdam from building-level efficiency improvements versus a district energy approach



Source: Jolman, 2014

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 stations is 33 per cent, with the most efficient being approximately 45 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.

1.4 RENEWABLE ENERGY

"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

District energy allows for the use of renewably generated heat and cooling, local waste heat, and energy-from-waste technologies, as described in table 1.1. In addition, the presence of district energy makes it possible to integrate greater amounts of variable electricity generation into an electricity grid system, which is key to decarbonizing the power sector (see figure 1.7).

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).

Middelgrunden offshore wind farm, 3.5 km from Copenhagen, Denmark. When built in 2000, 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

CASE STUDY 1.1

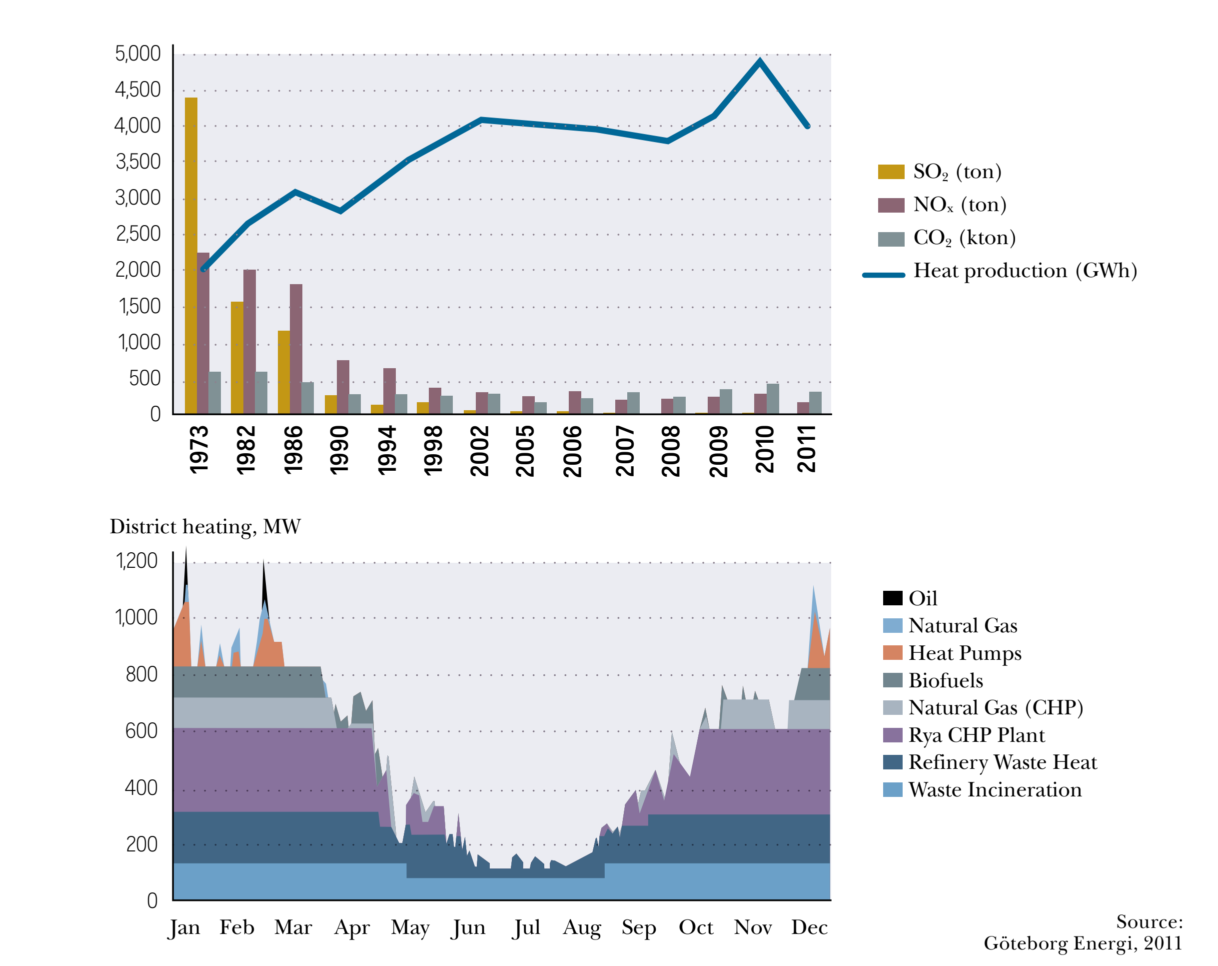
GOTHENBURG: FLEXIBILITY IN FUEL SUPPLY IN DISTRICT HEATING

Gothenburg's district heating system, initiated in 1953 with a CHP system 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 1,300 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 is 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 261 MW_{el} 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 CO_2, SO_2 and NO_x 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 CO_2 per MWh in 1980 to some 95 kg of CO_2 per MWh today.

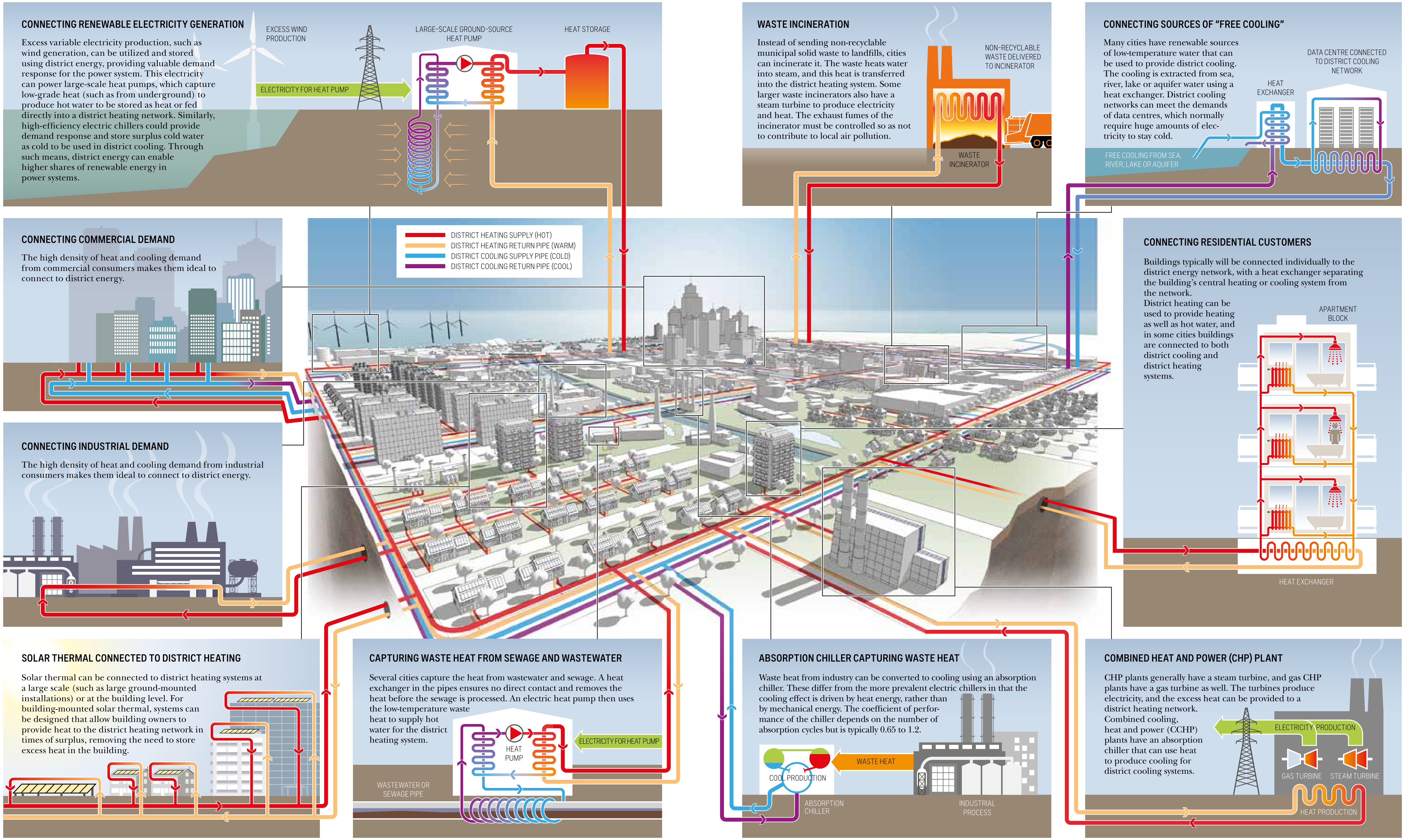
Gothenburg also has developed district cooling, using free cooling from the Göta River supplemented by absorption cooling.

FIGURE 1.6 Gothenburg's district heating production, 1973—2011, and the heating system's fuel mix and profile



Source: Göteborg Energi, 2011

FIGURE 1.7 Whole district energy system showing various end-users and the feeding in of heat and cooling souces (including renewables)



1.4.4 BALANCING

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 not 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.

HOHHOT

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 growing 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 energy-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 NO_x boilers; 74 km of district heating pipeline; and heat exchangers covering nearly 30 million m^2 of space heating. Upon completion, the project will avoid the use of some 848,500 tons of coal equivalent annually as well as emissions of 1.3 million tons of CO_2, 26,000 tons of particulate matter, 7,500 tons of NO_x and 9,000 tons of SO_2 (ADB, 2014).

GERMANY

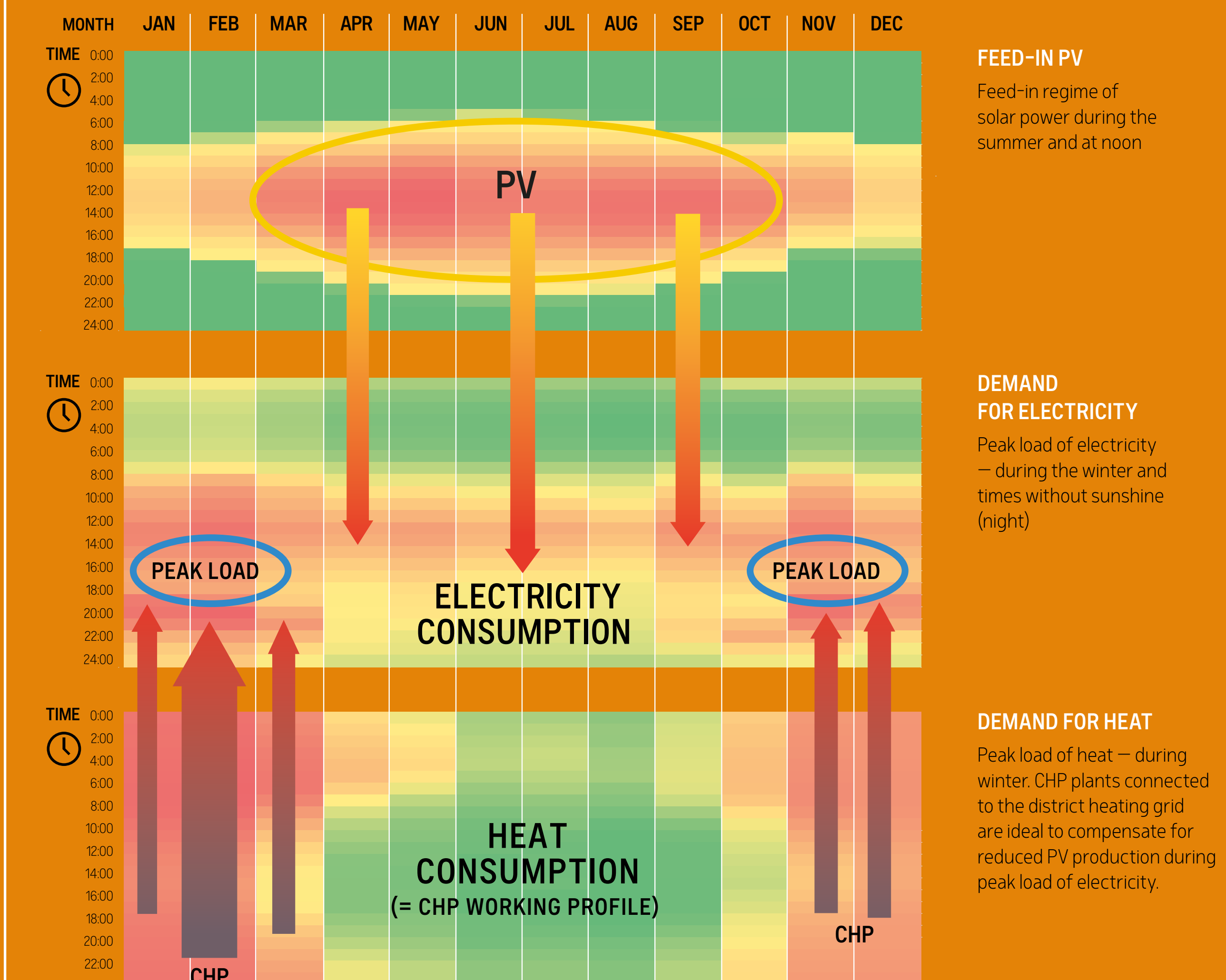
CASE STUDY 1.3

GERMANY'S *ENERGIEWENDE*

The high level of solar photovoltaic (PV) penetration in Germany's electricity market has caused difficulties for conventional thermal electricity production. However, this penetration highlights a synergy between CHP and PV production in the country. PV production can dominate electricity production during the daytime and in summer, but during the evening and in winter (when power demand is higher), it does not provide the power needed for the energy system. Due to their heat demand (which they must meet), it is in these periods that CHP plants are most required to run. As such, CHP generation can provide electricity when PV is less able to, as illustrated in figure 1.8. A key reason that Germany's *Energiewende* ("Energy Transition") policy promotes CHP is because it allows for the integration of higher levels of solar PV into the system.

Solar photovoltaic panels in a field in Bavaria, Germany.

FIGURE 1.8 Solar PV and CHP production profiles for electricity compared to electricity demand in Germany



Source: Lutsch, 2014

1.5 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 having only a short-term vision of the business case for district energy can be detrimental – and 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.

1.5.1 DISTRICT ENERGY CAPEX

■ **DEVELOPMENT COSTS:** These include the costs associated with prefeasibility studies, permitting applications, feasibility studies and planning applications.

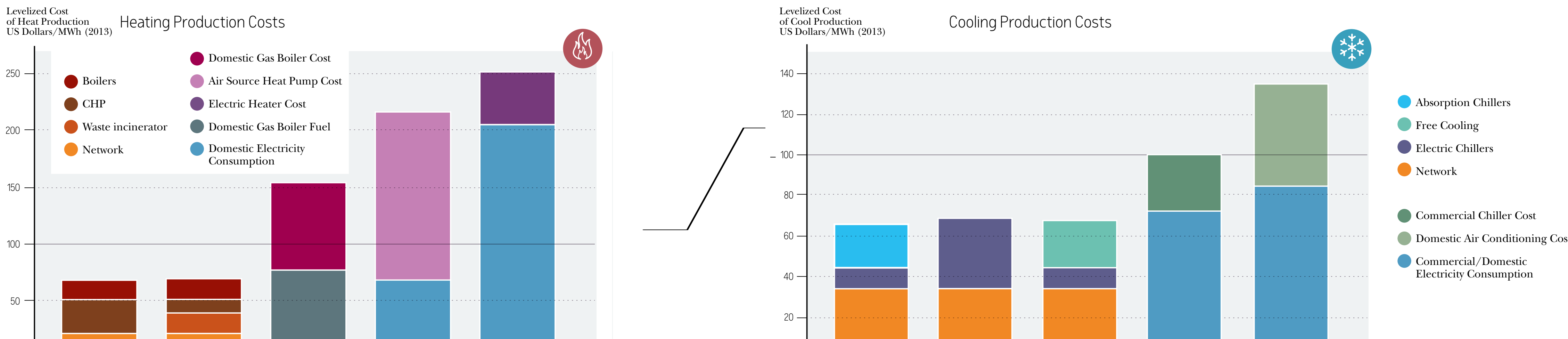
■ **PIPES AND NETWORK:** A key issue is the density of buildings, as this will affect the length and diameter of pipes necessary to connect them. Designing pipe routes to ensure the most effective network will reduce costs. Consideration needs to be given to "future proofing" the network by allowing sufficient pipe size to connect more 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 will benefit from the project). Integration with other utilities/systems (e.g., sewage, transport) can reduce installation costs by installing at 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 costs. Individual houses are far more expensive to connect than many apartments in a larger building.

■ **THERMAL PLANT AND THERMAL STORAGE:** The optimal location for the generating plant and any thermal storage is often influenced by the availability and value of land, potentially provided by the local authority. The CAPEX also includes construction of the energy centre (which contains the generation plant and control centre and needs to be sized to meet the load demand), as well as the cost of obtaining planning, construction and emission permits (particularly if a flue is necessary). Peaking and backup boilers and/or thermal storage must be designed to accommodate the shape of the load profile, and ancillary equipment (pumps, valves, fuel storage, water treatment, pressurization vessels and heat exchangers) is also necessary for operation of the 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.

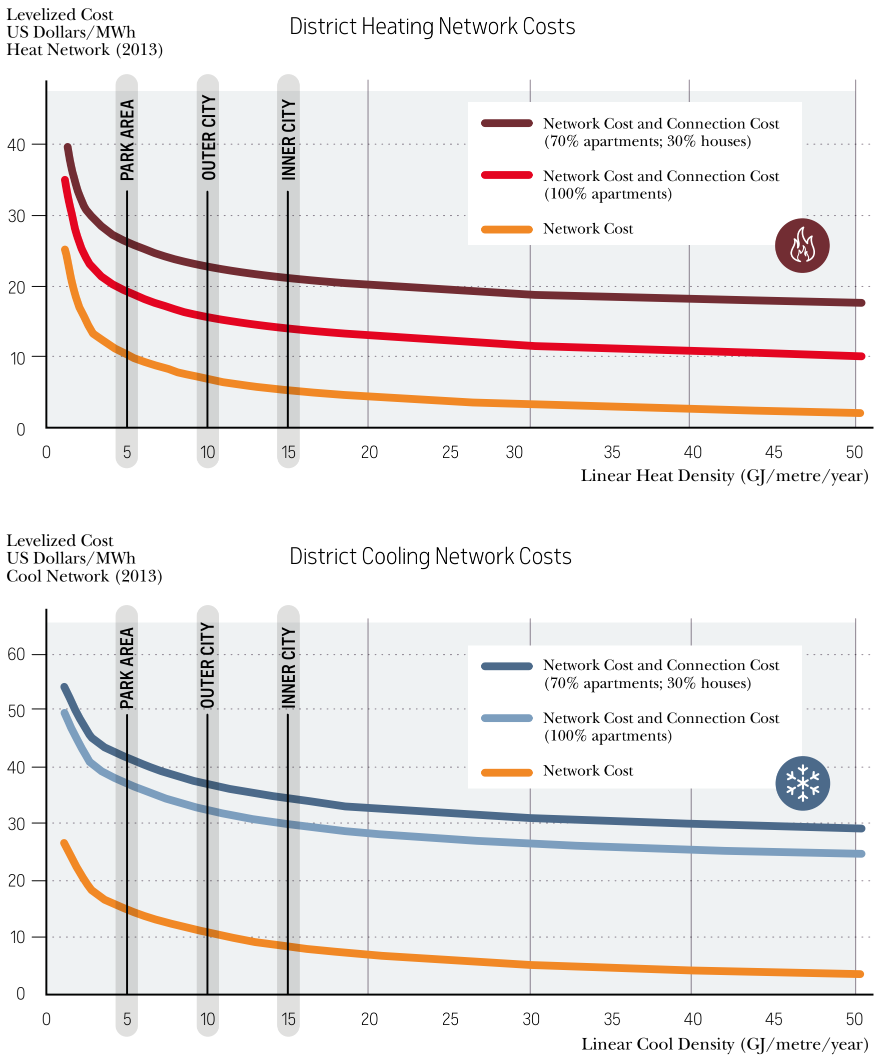
FIGURE 1.9 Levelized costs of district heating and cooling compared to decentralized production



Note: Prices will vary significantly by location and project, as described in sections 1.5.1–1.5.3. Network costs often constitute approximately half of the cost of district energy. In the examples provided, the district network cost is for a network with a linear heat/cool density of 15 GJ/metre/year, with 30 per cent of demand from individual houses and 70 per cent from apartments. Waste cost: –US$26/ton (negative). Gas price for district heating: US$38/MWh. Electricity price for district heating: US$102/MWh. Electricity price for district cooling: US$127/MWh. Steam price for district cooling: US$19/MWh. Electricity price for domestic: US$203/MWh. Gas price for domestic: US$76/MWh. Discount rate: 10%. Waste incinerator load factor: 80%. CHP load factor: 40%. District heat boiler load factor: 10%. Free cooling load factor: 62%. Electric chiller load factor: 30%. Absorption chiller load factor: 30%. Discount rate 10%.

Source: UNEP analysis based on Swedish District Heating Association, 2007; Pöyry and AECOM, 2009; Swedblom et al., 2014; Danfoss, 2014; Danish Energy Agency and Energinet.dk, 2012; Gudmundsson and Thorsen, 2013; Zabala, 2009; Persson and Werner, 2010; Euroheat & Power, 2008.

FIGURE 1.10 Network costs for district energy



Note: Linear heat/cool density is the energy consumed per year for each metre of network. A linear heat/cool density of 5 corresponds to networks running through parks, 10 refers to outer city areas and 15 or greater refers to inner-city areas. District cooling and heating network costs can vary significantly by country. Factors include (but are not limited to): local installation costs (which can account for 60 per cent of costs); availability of pipe and insulation in country; pipe width and pressure; linear heat or cool density; maximum system demand; number and size of connections; and costs of pumping. Discount rate: 10 per cent.

Source: UNEP analysis based on: Swedish District Heating Association, 2007; Pöyry and AECOM, 2009; Swedblom et al., 2014; Danfoss, 2014; Persson and Werner, 2010.

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 arboreal management; solar or geothermal heat; and waste heat from industrial processes or other buildings such as data centres.

OTHER: Other operating costs include labour for operation; maintenance; 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 diverse 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.

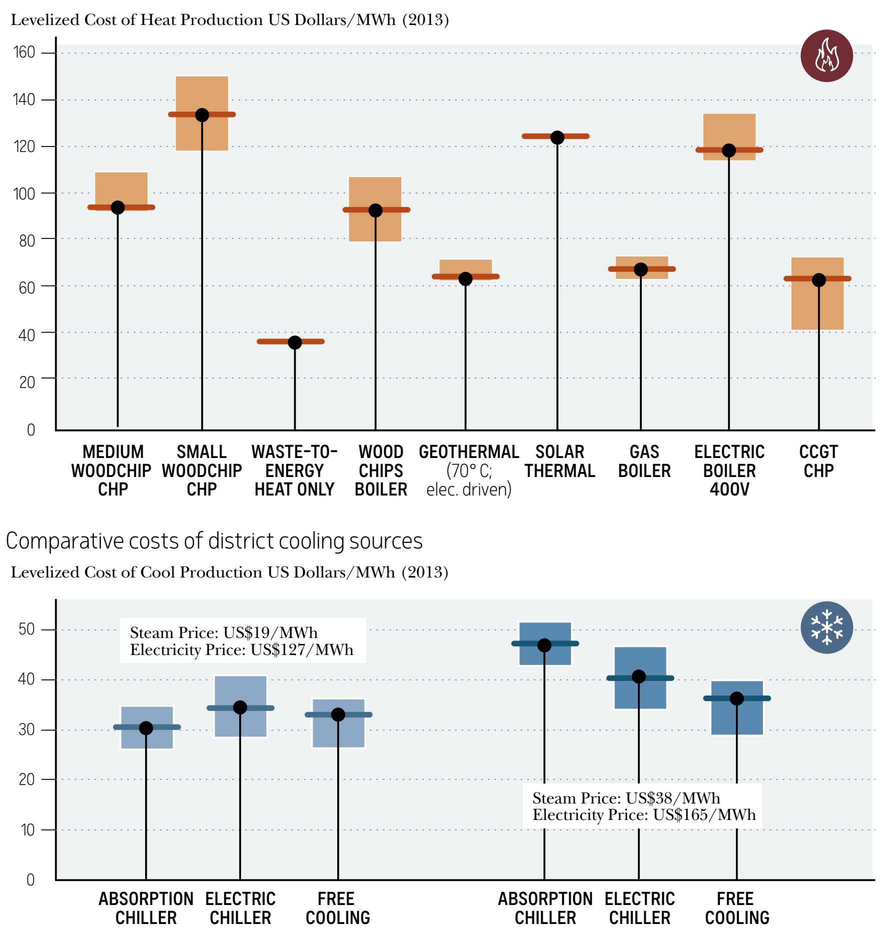
POWER: The majority of projects also derive revenues from power sales through CHP production. This power is usually delivered to a regional or national electricity grid, local distribution networks or specific local demand, depending on the CHP capacity and other factors. The power price (and its variability) 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 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.

CONNECTION CHARGES: Users typically must pay for their connection to a district energy network. This can be either a one-off payment or a fixed tariff applied per year or month (explicitly covering maintenance and other works that are consumption independent). In some settings, a large building consumer that is near to the network and that is willing to sign a long-term service agreement may avoid connection charges if the forecasted revenue provides a suitable return on investment for the plant, mains and service pipes.

OTHER: Other revenue sources may include subsidies for renewable/CHP heat, carbon trading and avoided penalties for local carbon compliance policies.

FIGURE 1.11 Centralized plant costs and operational costs for district energy



Note: Centralized plant costs are estimates based on available data and will vary significantly by country. Such variance is caused by (but is not limited to): load factor; local fuel prices currently and in the future; fuel prices at point of consumption (i.e., electricity consumed may have higher price than average annual electricity price); installation and labour costs; capacity of installation; land prices; cost of finance; development costs; any subsidies and tax incentives. UNEP has calculated CHP and waste-to-energy heat prices based on the lowest heat price possible based on fuel prices and electricity price received (prices detailed below) as well as on CAPEX and OPEX payments. Waste cost: – US$26/ton (negative). Wood chips: US$169/ton. Gas: US$38/MWh. Electricity price received for CHP/Incinerators: US$102/MWh. Electricity price for cooling: US$127–US$165/MWh. Steam price for absorption chillers: US$19–US$38/MWh. Discount rate: 10 per cent. Waste incinerator load factor: 80 per cent. All CHP plants load factor: 40 per cent. District heat gas/electric boiler load factor: 10 per cent. District heat wood chip boiler load factor: 40 per cent. Geothermal load factor: 80 per cent Free cooling load factor: 62 per cent. Electric chiller load factor: 30 per cent. Absorption chiller load factor: 30 per cent.

Source: UNEP analysis based on: Pöyry and AECOM, 2009; Swedblom et al., 2014; Danish Energy Agency and Energinet.dk, 2012; Danfoss, 2014; Gudmundsson and Thorsen, 2013; Zabala, 2009; Euroheat & Power, 2008.

1.6 CATALYSTS

"Utilizing waste heat to provide end-use services, such as heating in buildings, is best achieved through district heating. In Brest, we incinerate 125,000 tons of municipal solid waste a year, providing enough waste heat for 85 per cent of our network's heat demand."

Alain Masson, 1st VP of Brest Métropole

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 Japan, the 2011 Fukushima nuclear accident was a major catalyst for focusing on energy efficiency and district energy. The event prompted **TOKYO** to develop a cogeneration facility with an independent transmission network, making it possible to supply power to affected areas in times of natural disasters or other emergencies.

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.

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 baseload heat to local heating networks.

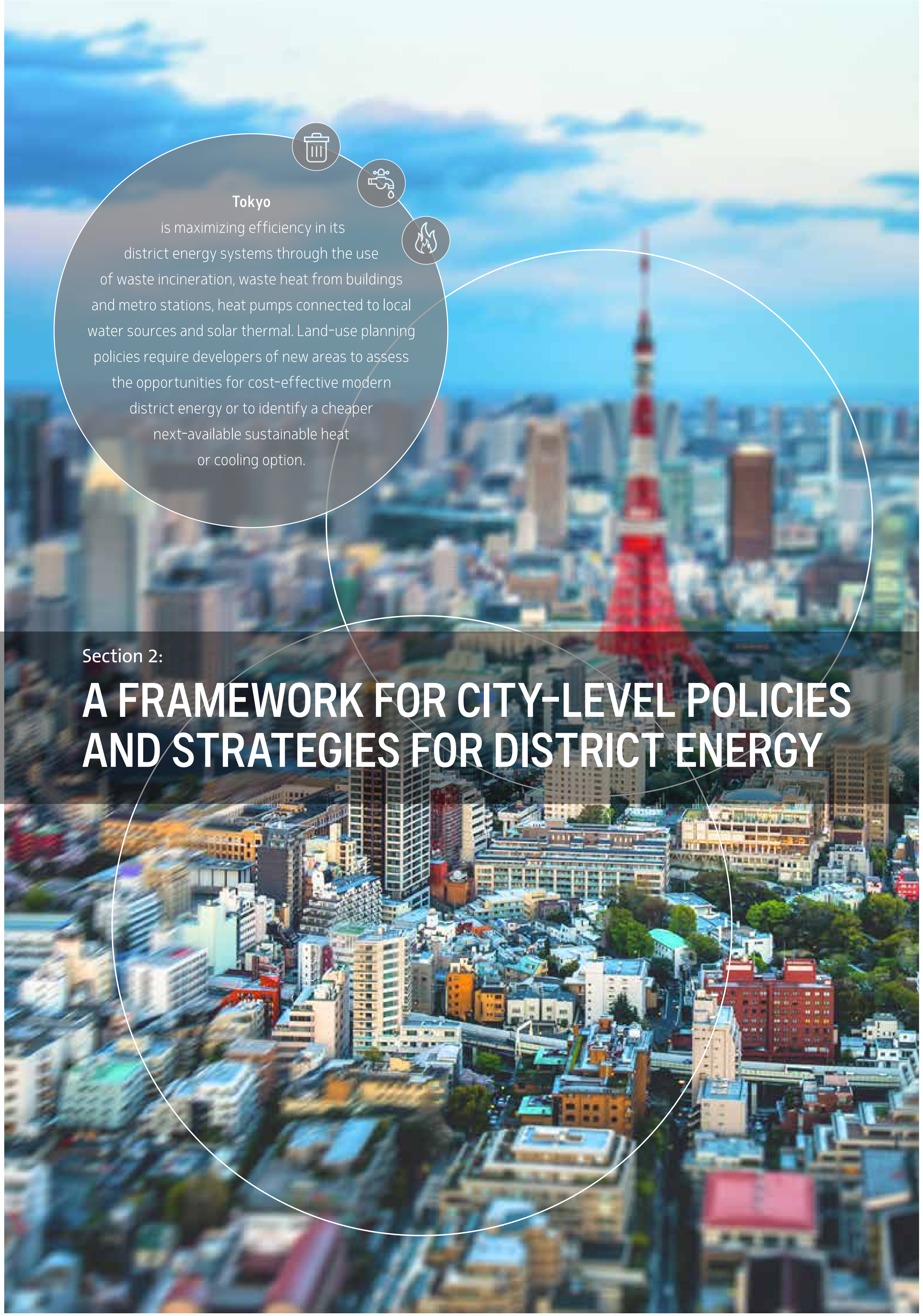
PARIS developed district heating in 1927 to overcome local air quality issues and to address the challenge of delivering huge amounts of fuel to distributed users in the city centre. Today, large portions of the city are connected to district heating, including the Louvre museum, delivering the heat-demand 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 Enwave 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 ageing 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.



Section 2:

A FRAMEWORK FOR CITY-LEVEL POLICIES AND STRATEGIES FOR DISTRICT ENERGY

02

THIS SECTION LOOKS AT

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.

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.

Heizkraftwerk West CHP plant in Frankfurt, Germany.

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 action among various stakeholders and to mobilize support from other levels of government (see case

TABLE 2.1 Policy activities that local governments are undertaking in their role as planner and regulator

POLICY INTERVENTION AREA	DESCRIPTION OF POLICY ACTIVITY
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 CO_2 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

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

studies 2.14 on Sonderborg and 2.5 on Botosani). 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 *emerging* cities, energy efficiency improvements from district energy (relative to status quo heating and cooling technologies) are driving deployment. In *refurbishment* cities, energy efficiency through district energy is a key driver in enabling energy independence and affordability.

* Note that a heat and cooling assessment is different from energy mapping, which combines the assessment data with a GIS exercise/spatial mapping of heating/cooling resources and nodes of consumption.

Air-conditioning units on a house in Singapore, 2013.

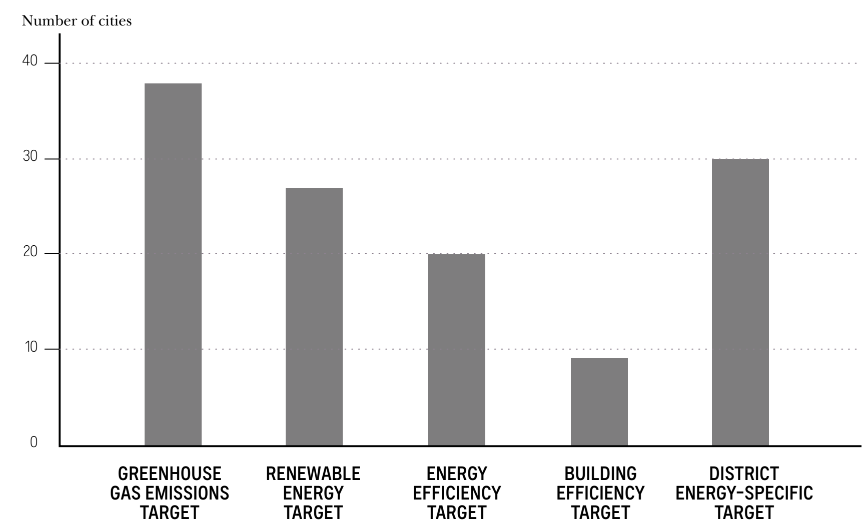
■ **DEVELOPING AN ENERGY STRATEGY:** To develop an energy strategy, a city needs to undertake a holistic study of municipal energy use and needs, from which it can identify goals and pathways for realizing specific socio-economic benefits, both now and into the future. A key requirement of such study 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 underestimate 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 overstating 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 1.3.3, 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.

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



■ **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).

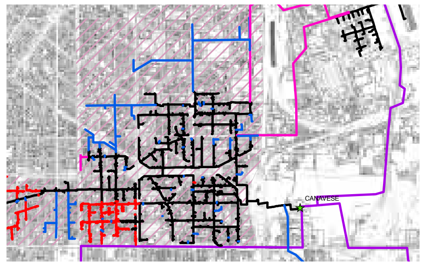
Most cities that are active in district energy started with broader targets, such as targets for CO_2 and greenhouse gas emissions, energy intensity, fossil fuel consumption, energy efficiency (either for the city overall or for individual sectors, such as buildings) and renewable energy (see table 2.2). 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 legitimize a city-wide energy plan focused on scaling up district energy (see case studies 3.1 on Vancouver and 3.12 on Port 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 CO_2 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.

Łódź, Poland has a vast district heating network, which in 2011 supplied approximately 60 per cent of the city's heating demand (top).

DISTRICT ENERGY TARGETS MOST OFTEN ARE SEEN IN CONSOLIDATED OR REFURBISHMENT CITIES AND CAN INCLUDE THE FOLLOWING:
(see table 2.2 for more detailed examples)

- **EXPANSION OF THE DISTRICT ENERGY SYSTEM** by the total amount of homes (or unit equivalent) connected to the system, or by development type (e.g., Anshan, Helsinki)
- **TARGET TO INTERCONNECT SEGREGATED DISTRICT ENERGY NETWORKS** through transmission pipes (e.g., Frankfurt, Anshan)
- **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, Łódź)



A portion of Milan's district heating network, connected to the Canavese 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.

TABLE 2.2 Targets and strategies for district energy that correspond to broader climate or energy targets, in selected champion cities (the full table for all 45 cities is available online)

CITY	CO_2 EMISSIONS REDUCTION TARGET	RENEWABLE ENERGY* AND/OR ENERGY EFFICIENCY TARGET	DISTRICT ENERGY-RELATED GOALS	FEATURES
AMSTERDAM	■ 40% by 2025; ■ 75% by 2040 (from 1990 base)	■ All new building development climate-neutral by 2015 ■ 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 ■ 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	■ 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 ■ Multi-stakeholder partnerships for planning and implementation
BERGEN	■ 50% by 2030 (from 1991 base)	■ 95% renewable energy supply ■ Replace oil-based heating (14% of greenhouse gas emissions)	■ Use district heating in all new buildings and major renovations within the concession area for district heating ■ Waste incinerators must utilize 80% of energy (higher than national target of 50%)	■ Network developed based on waste incinerator energy efficiency target
COPENHAGEN	■ 20% by 2015 (from 2005 base) ■ Carbon-neutral by 2025	■ By 2025: 100% renewable energy supply, 20% reduction in heat 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 35% today) ■ By 2016, ban oil-fired installations in existing buildings where district heating (or gas) is available	■ 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
DUBAI	■ 20% reduction from buildings by 2030	■ 30% reduction in energy demand by 2030 ■ 5% renewable electricity by 2030	■ Meet 40% of cooling capacity through district cooling (up from 20% in 2011) by 2030 ■ Use district cooling in all new developments by 2030 ■ Incorporate thermal energy storage into all new district cooling plants, representing at least 20% of the design capacity of the plant by 2030	■ Use of treated sewage effluent water instead of fresh water ■ Reduced investment in power infrastructure
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 2020 (from 1990 base) ■ Carbon-neutral by 2050	■ 20% share of renewables in energy production in 2020 (up from 7% in 2013)	■ By 2015, cooling capacity of over 200 MW ■ By 2020, expand cooling to new residential areas	■ Captures heat from district cooling return water, for zero-waste ■ Tri-generation ■ Utility-set target
HONG KONG	■ Reduce carbon intensity 50–60% by 2020 (from 2005 base)	■ By 2020, reduce coal to less than 10% of the electricity generation mix ■ By 2030, 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 be 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 a total of 390,000 + (8 million m²/100) = 470,000 REU.

2.2.2 ENERGY MAPPING

"A combination of energy modelling and mapping of the local conditions using a high geographical resolution is crucial for district heating analysis, since the potential for expansion is dependent on local heat resources and demands." *Heat Roadmap Europe 2050, 2012*

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., 2013; Persson et al., 2012). Further data and layers of analysis can be added over time, depending on the policy objectives and goals.

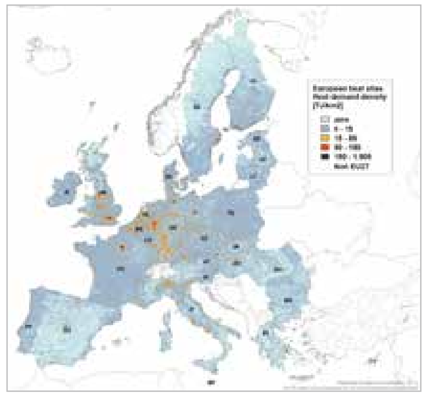
Energy maps for district energy can contain, among other variables, data on:

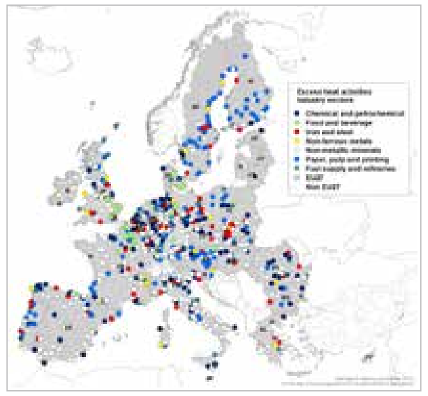
- Existing and projected energy consumption by sector, fuel source or neighbourhood; the resulting emissions and pollution; and an understanding of the load profile
- Present and future building density and use type (residential, commercial, etc.)
- Sources of surplus or industrial heat supply
- Large 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 2.3)
- 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 best be 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 2.2.3) 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., 2013).

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 could 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.





Energy maps from the Heat Roadmap Europe *showing heat demand density (top) and locations of major energy-intensive industries with considerable volumes of excess heat (bottom) (Connolly et al., 2013).*

AMSTERDAM

CASE STUDY 2.1

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 this changeover, which can represent an obstacle for the expansion of a district energy system.

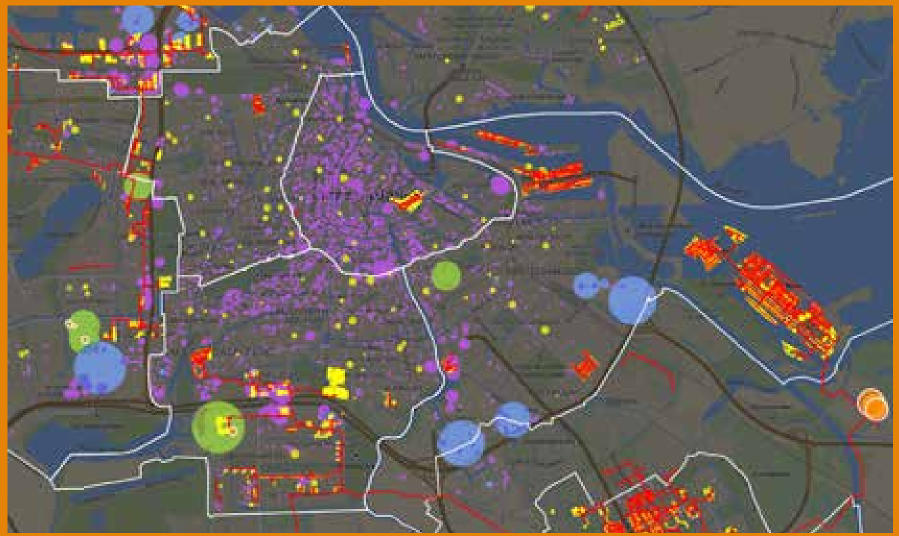
The City of Amsterdam has developed an Energy Atlas to inform the local energy strategy, implement the right combination of measures and technologies, and build the business case for supplying district energy to households and companies. The city collects the data and presents it via the city website, using an "open data" philosophy that enables full access to the information collected. In a second step, the data is analysed together with the different stakeholders to identify opportunity areas or zones for district heating, cooling and power. The aim is to develop "what if" scenarios for adding or changing infrastructure such as transformers or data centres, or retrofitting the existing building stock, and to optimize urban plans for energy efficiency.

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) projects; and to "create space" and provide matchmaking services by bringing together different stakeholders interested in business case development. Using the Energy Atlas has enabled the city to transform Zuidoost, an existing 300 hectare mixed-use area, and to establish cooperation among various industrial partners on the exchange of energy and the use of excess waste heat from data centres. The maps provided these stakeholders with insight into the thermal management in the area and allowed 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 flows 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.

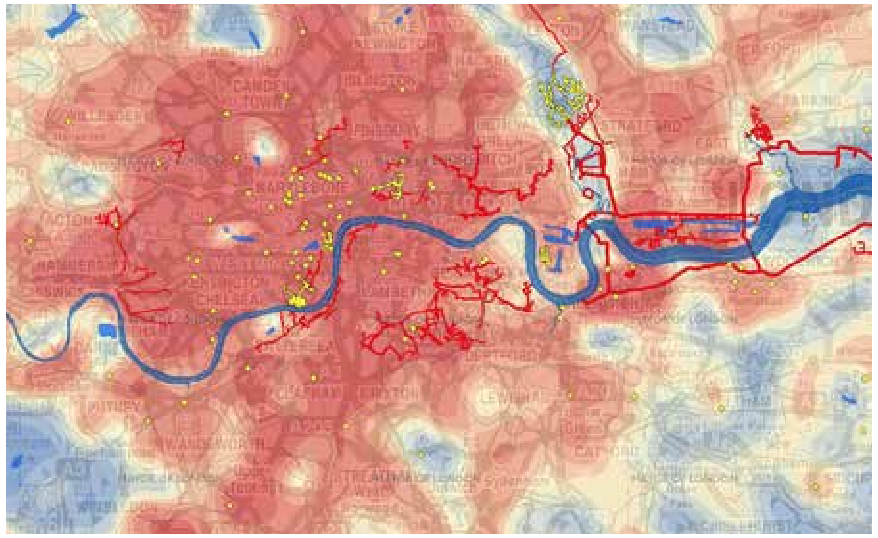


City of Amsterdam, Interactive Maps, 'Energy from waste incineration and waste heat'. The map shows the existing district heat network in Amsterdam (red lines) with connected load (yellow squares) and suppliers of heat (orange circles). The map also shows potential residual or waste heat sources from hospitals (green circles), data centres (blue circles), supermarkets (yellow circles) and offices (purple circles).

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).

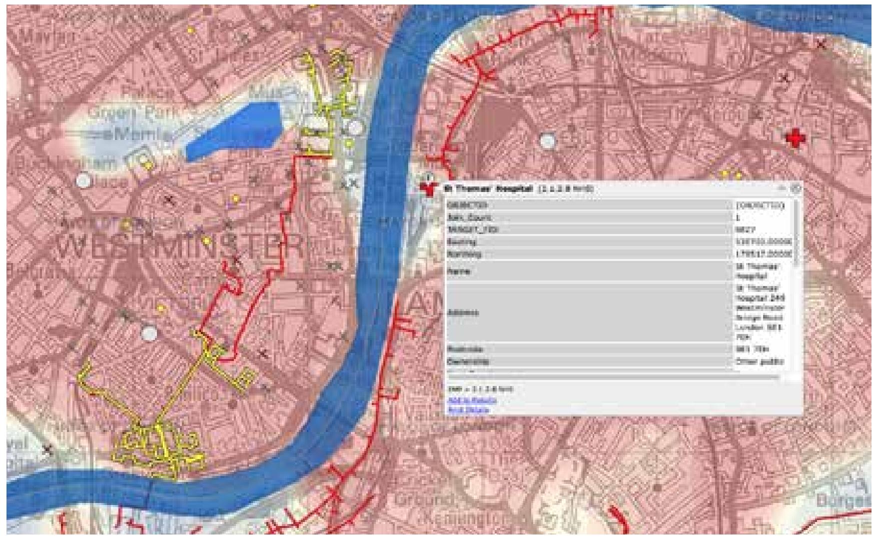
Figure 2.2 shows London's heat density in combination with current networks (yellow lines), current CHP plants (yellow diamonds) and potential networks (red lines). The existing network at the top of the image is the Olympic Park and Stratford City development project (discussed in detail in case study 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's Hospital, which consumes 59 GWh of fuel per year (see section 3.2).

FIGURE 2.2 London Heat Map



Source: GLA, 2014

FIGURE 2.3 London Heat Map: Westminster and Pimlico networks



Source: GLA, 2014

2.2.3 HOLISTIC ENERGY PLANS: INTEGRATING ENERGY IN INFRASTRUCTURE AND LAND-USE PLANNING

"You often have land-use folks saying let's put the buildings here, and transport planners saying how do we get people moving around – and then almost as an afterthought, folks say, well, how do we provide energy to the neighbourhood? In Vancouver, we pioneered the integration of these various issues into our community building and urban planning."

Sadhu Johnston, City of Vancouver, 2014

City of Vancouver, Canada

An energy plan is a road map of project developments and policy interventions to help a city realize the articulated goals of its energy strategy. Energy plans that aim to realize district energy-related goals must be developed in a holistic and integrated way, assessing and coordinating the various stakeholders necessary for implementation. To identify synergies and opportunities for cost-effective district energy, such plans need to analyse the impact of (and interaction between) energy, land use and infrastructure – including waste, water, buildings and transport (see case studies 2.2 on Bergen and St. Paul, and 2.3 on Tokyo). Mixed-use zoning and the encouragement of high energy density areas (through compact land use) is "strongly correlated with lower greenhouse gas emissions" by reducing transport and energy consumption (Seto et al., 2014). District energy relies on such mixed-use zoning and high energy density to be economical, as described in section 1.5. The importance of mixed-use zoning and compact urban form for district energy is discussed further below.

Synergies between energy, land use and infrastructure are vital to realizing the district energy developments or objectives defined in the energy plan. Collaboration with city-owned or private wastewater or transport utilities may help to reduce costs in project development and construction. Additionally, other utilities either may already be providing heat and cooling to the city (such as electricity or gas utilities) or could in the future (such as wastewater treatment and water purification utilities). To ensure the most cost-effective district energy system, these utilities and city departments need to integrate energy planning within all city developments (see section 2.4.1 for a discussion of a city's role as provider of services and how this can benefit district energy).

Holistic energy planning also can allow a city to promote and/or designate areas or zones that have favourable conditions for district energy development or expansion, and to apply tailored policies or financial incentives on a case-by-case basis (see section 2.2.4 on connection policies). These zones can be selected based on the mapping exercise. Some cities designate franchise zones for district energy companies, effectively giving them exclusive license to operate in this zone. This zoning also can enable the local authority to negotiate or regulate end-user tariffs in exchange for the operator licence, thereby ensuring that district energy is the most cost-effective option for providing heat and cooling (see case study 4.2 on Norway). In addition to customer protection, this is particularly important to building owners who may be implicated by mandatory connections.

BERGEN and ST. PAUL

CASE STUDY 2.2

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.

Lake Lille Lungegårdsvannet in Bergen, Norway.

St. Paul, through integrated energy planning, similarly used the construction of a light-rail line to extend the city's district energy infrastructure several kilometres to a major industrial customer.

Combining the development of infrastructure with district energy development can lead to significant cost savings. At least 60 per cent of the network costs of district energy (i.e., excluding heat/cool production) is from the installation costs of pipes, as roads need to be dug up to install the infrastructure, causing costly disruption and the need to replace parts of the road surface. If such disruption and earthworks could occur at the same time as other infra-structure, costs can be reduced dramatically (Swedish District Heating Agency, 2007).

Wood chip CHP plant in St. Paul, USA.

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 box 2.1)
- 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 Østergaard, 2014).

BOX 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.

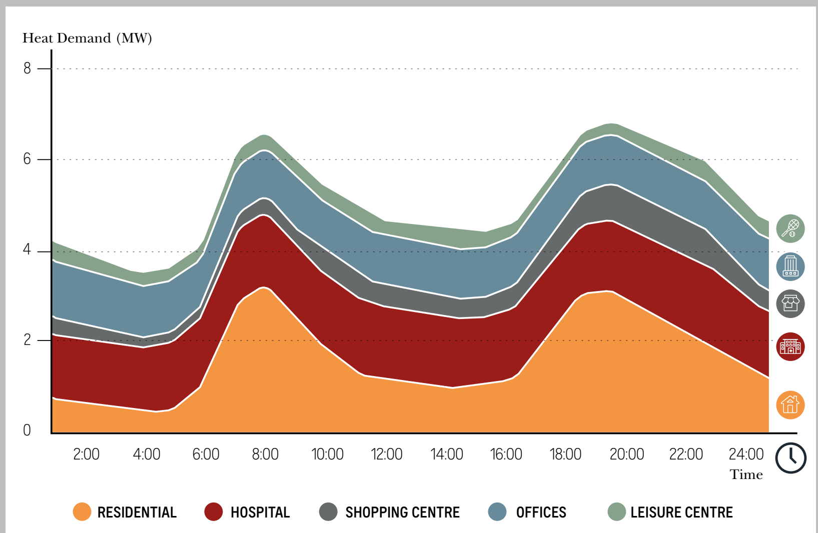
Having a smoother, less-profiled energy demand lowers the unit costs related to district energy infrastructure per square metre of building. A smoother profile reduces the need for less-desirable generation capacity, such as boilers and chillers, and allows for maximization of more-profitable and efficient capacity, such as CHP (which runs best as baseload 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 demand) are, the less pipe is needed to connect them, greatly decreasing costs and losses (King and Parks, 2012).

Figure 1.10 demonstrates the range of network costs that can occur as linear cool density increases: a 278 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 33 km of network (linear cool density: 30 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 Dalkia

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 stadiums, can be effective anchor loads and sources of capacity.

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

■ **CITY-WIDE MANDATORY CONNECTION POLICIES** are often used to enforce connection to district energy schemes. These policies typically target new developments but can also target 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 model).

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 Łódź, 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 a limited area. This bylaw then can be extended as the system grows. In Hong Kong, all non-domestic buildings in the Kai Tak development must connect to the district cooling system, including hotels, hospitals, shopping centres, government offices and the planned multi-purpose stadium. Vancouver used a service-area bylaw to mandate connections within the Southeast False Creek Official Development Plan area, and the service area has since been extended to accommodate growth. In Rotterdam, building codes in the two concession areas for district heating require that buildings connect to the network, a stipulation that was core to the business case for the concessions. German municipalities can also use building codes to oblige buildings to connect to district heat networks (Schönberger, 2013).

Oslo, Norway (top). Stade Francis le Blé in Brest (bottom). Connecting stadiums, leisure centres, hospitals and other anchor loads diversifies the load, making the district energy system more efficient.

LONDON

CASE STUDY 2.3

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 CO_2 emissions. The supply of energy efficiently is part of these assessments, and, as such, major development proposals must develop along a heat hierarchy of:

Bunhill CHP plant in Islington, London. The tower is a large heat storage unit that reduces the need to provide heat from the district heating system's backup gas boilers.

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 CO_2 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-in-lieu contribution to account for the shortfall in CO_2 emission reductions. In 2012, this planning policy resulted in significant commitments to new district heating systems, including:

- £20 million (US$32 million) of investment in a new, high-efficiency CHP plant able to produce 29 MW of electricity and a similar amount of heat. From 2010 to 2012, a total of 74 MW_{el} of CHP electrical capacity – roughly the amount required to supply 150,000 homes – was secured through the planning process.
- £133 million (US$213 million) of investment in heat network infrastructure for approximately 53,000 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 areas). In Velenje, new facilities must connect to the district heating network except in exceptional circumstances where connection would be irrational, in which case heating is permissible by electricity and renewable technologies. Other cities that have "connect...unless" policies include Amsterdam, London and Tokyo (see case study 2.3). Such policies also help the city mitigate the cost of feasibility studies by placing the onus on the developer.

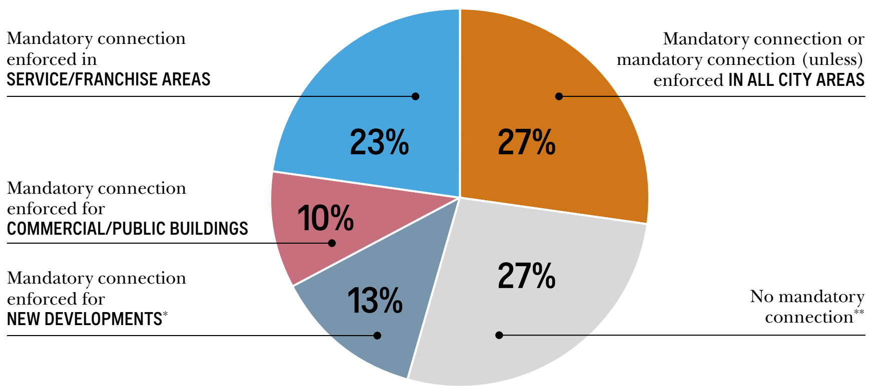
MANDATORY DISTRICT ENERGY DEVELOPMENT THROUGH ZONING POLICIES may, for example, require district energy systems in new development areas that are over a certain size and that cannot connect into other networks, and/or if district heating is the best available technology to provide sustainable heat services. In London, "major developments" must consider creating a CHP network if they cannot connect to a district energy network (see case study 2.3). Similarly, in Tokyo, if a new development area will be over 50,000 m², it has to develop a district energy system if it cannot connect to a network, unless this is not technically feasible or the next-available sustainable heat or cooling option is more economic (see case study 2.4). In Vancouver, as part of Parklane's River District development, rezoning conditions required connecting to a district energy utility if available, which incentivized Parklane (as the landowner and master planner) to create its own private district energy utility with a mix of individual developers in the neighbourhood.

POLICIES TO ENCOURAGE CONNECTIONS

Aside from making it mandatory for buildings to connect to district energy, to consider connection if it is cost effective, or to develop district energy systems, other types of incentives can be used to encourage connection and reduce investor risk. Such policies may not be as effective as mandatory connections in alleviating load risk, but they are often easier for a local authority to enact. These policies include:

- Density bonus, 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. Norwegian national policy also bans some technologies as a direct incentive for district energy connections (see section 4.1).
- 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 SEFC NEU has transparent heat tariffs and connection costs, which encourage connections (see case study 3.1).
- Streamlined rezoning 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. Vancouver is considering bringing this compatibility into green building standards.
- Clear credit towards green building requirements, whereby local green building standards account for district energy in their certification schemes, thus encouraging building owners to connect (e.g., Frankfurt, Sonderborg).
- 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).

FIGURE 2.5 Connection policies by type in the 45 champion cities



* Vancouver and Tokyo have this policy, but only for new developments over a certain size, and were not counted for this.

** Cities that are still developing their first district energy network are not included here because their connection policy is undecided.

TOKYO

CASE STUDY 2.4

TOKYO: INTEGRATING LAND USE, BUILDINGS AND DISTRICT ENERGY

"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*

Under its District Energy Planning System for Effective Energy Utilization, the city of Tokyo implemented several policies to promote district energy. For example, new developments above 50,000 m^2 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 m^2 or residential developments that exceed 20,000 m^2 in total floor area, developers also are 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.

2.3 LOCAL GOVERNMENT AS FACILITATOR: ENABLING ACTIONS TO LEVERAGE FINANCE

"Several economic and institutional barriers to investment in district energy can be overcome by facilitative action of local governments."

Maryke van Staden, ICLEI – Local Governments for Sustainability, 2014

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 easing 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 by reducing project risk through subsidies (such as feed-in tariffs or renewable energy certificates), grants, funds, environmental

* The economic barriers to district energy systems result from the capital costs associated with the construction of plant, 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

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

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

taxes (such as polluter taxes and carbon pricing) and value-added tax 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 drive district energy forward by creating favourable urban planning, energy regulations and local policies, as described in section 2.2.

■ **DEBT PROVISION AND BOND FINANCING:** 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.

■ **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 guarantor 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 (US$176 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).

■ **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 (US$6.7 million) in grants from the London Development Agency (now dissolved) and the Homes and Community Agency (see case study 3.2).

■ **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 NEU project (see case study 3.1)

Rotterdam was able to secure a €27 million (US$33.8 million) grant from the Dutch government to reflect the equivalent avoided social costs of CO_2 and NO_X 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. Port 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 seawater district cooling project. Project CELSIUS, a grant programme provided by the EU, is financing innovative demonstration projects in London, Rotterdam, Gothenburg, Genoa and Cologne (see section 3.5).

Brest has attracted a €9 million (US$11.2 million) grant from ADEME (Agence de l'Environnement et de la Maîtrise de l'Énergie) that will help double the heat network in the city and surrounding area and install seawater heat pumps, biomass boilers and heat storage. This national grant is financed from the country's "Heat Fund" to projects that reduce CO_2 emissions and imports of fossil fuel.

■ **INTERNATIONAL OR NATIONAL FUNDS OR LOANS:** Significant international and national funds are being directed to district energy networks in cities, both for initial development and for rehabilitation. Cities can lobby for such funds to be made available to projects. Velenje was able to secure a €729,000 (US$911,000) long-term loan from Slovenia's Eco Fund for its district cooling system that is based on absorption chillers using waste heat. Across Europe, EU Structural Funds play a key role in helping local and national governments modernize dilapidated district heating infrastructure (see case study 2.5 on Botosani) (Sharabaroff, 2014).

* Provision of guarantees (as well as of recourse debt/general obligation bonds) is risky for municipalities and can affect their borrowing capacity; thus, guarantees normally would be provided for socially, economically or environmentally critical projects. Some municipalities are wary of setting a precedent that could lead lenders to demand loan guarantees for all large infrastructure projects, making them less inclined to use recourse debt, general obligation bonds and loan guarantees.

BOTOSANI

CASE STUDY 2.5

BOTOSANI: LEVERAGING INTERNATIONAL FINANCE FOR MODERN DISTRICT ENERGY

In the north-eastern Romanian town of Botosani (population 115,000), 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 assessed the project and provided a long-term debt to Botosani to help secure the municipality's co-financing requirement.

As a result of the project, a state-of-the-art 8 MW_{el} CHP plant and two 52 MW_{th} heat-only boilers were installed, replacing an oversized and inefficient heat capacity of 560 MW_{th} prior to the project; in addition, 6.5 km (dual-pipe) of transmission and 14.3 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 €45.7 million (US$57.1 million), with the IFC providing a loan of some €8 million (US$10 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 CO_2-equivalent, and 21 large-scale district heating consumers that had formally disconnected from the system re-connected following project completion.

Source: Sharabaroff, 2014

The new CHP plant and boiler system in Botosani, Romania.

OSLO

CASE STUDY 2.6

OSLO'S CLIMATE AND ENERGY FUND

The City of Oslo established a Climate and Energy Fund in 1982. 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 1.3 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.

TORONTO

CASE STUDY 2.7

TORONTO'S REVOLVING FUND MODEL

Toronto established the non-profit Toronto Atmospheric Fund (TAF) in 1991 with CAD$23 million (US$20.2 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 solutions lay in leveraging capital. Today, TAF provides grants and loans, undertakes special projects and creates partnerships.

TAF's assets generate around CAD$1.5 million (US$1.3 million) in revenue annually for grants and special projects. Total project funding since inception has been about CAD$30 million (US$26.3 million). TAF provided CAD$80,000 (US$70,000) in 2002 for a feasibility study and subsequently loaned CAD$1 million (US$0.87 million) to help finance a tri-generational 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.)

Toronto's deep-water cooling system captures cooling from Lake Ontario (see case study 3.5).

■ **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 deferral on principal repayment for the first 3–5 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 redeployed 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 (Sharabaroff, 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 urban 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).

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

2.3.2 CITY ASSETS

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 3.8 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 230 MW (see section 2.4.4 on the city as a consumer for more examples).

Some cities may need to finance refurbishments to modernize their district heating systems. Selling a portion of the district heating system can inject the capital needed for such improvements. Warsaw has the largest district heating system in the EU, supplying 136 km² of floor space and meeting 76 per cent of the city's heating requirements. In 2011, Warsaw sold 85 per cent of its publicly owned district heating company, SPEC, to Veolia Polska S.A. (until recently Dalkia Warszawa S.A.) for PLN44 billion (US$446 million). Veolia Polska S.A, which now operates the system, has pledged to invest PLN1 billion (US$310 billion) during 2012–2018 to finance essential upgrades, including the 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);
- pilot new policies for uptake by the city council or national government; and
- build local and institutional capacity and confidence.

Local governments commonly use demonstration projects to facilitate market development, raise awareness of potential investors and accelerate private sector engagement. Cities need to develop well-documented demonstration projects to prove the potential benefits and payback periods of district energy systems – thus supporting the business case and facilitating access to more traditional financing sources – as well as to generate both public and local government support. In Vancouver, the use of a demonstration project made it easier to gain the confidence of institutional and private condominium developers, who traditionally are not interested in taking on unfamiliar technologies, assuming project development risk or losing control of critical construction schedules (see case study 3.1).

AMSTERDAM

CASE STUDY 2.8

AMSTERDAM'S SMART CITY INITIATIVE AND TAX-FREE ZONE FOR DEMONSTRATION PROJECTS

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 CO_2 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 centres). All of the acquired knowledge and experience is shared via the ASC platform, helping to accelerate the city's climate and energy programmes.

INDIA – GIFT CITY

CASE STUDY 2.9

INDIA'S GUJARAT INTERNATIONAL FINANCE TEC-CITY (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 it 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 deliver 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.

The system initially will represent 10,000 refrigeration tons (35 MW), combined with 10,000 refrigeration ton-hours of storage (35 MWh), and will later add to this as buildings are developed and connected. Developing the initial phase will reduce risk in future phases, lowering the cost of the project.

District cooling in the city will demonstrate the benefits of having a diversified load, as the system will connect different types of buildings (residential, commercial, retail and convention centres). The system also will use a refrigerant that has a lower global warming potential (GWP) than the decentralized chillers that otherwise would have been installed. Carbon reductions from the use of an environmentally friendly refrigerant as well as from the higher system efficiency are expected to count towards green building ratings in the city.

Development of a new city.

2.4 LOCAL GOVERNMENT AS PROVIDER AND CONSUMER

"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

Frankfurt, Germany

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.

2.4.1 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. Anshan, 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

POLICY INTERVENTION AREA	DESCRIPTION OF POLICY ACTIVITY
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)	■ Utility mandates and incentives ■ Interconnection policies and incentives ■ Waste-heat tariff regulation and customer protection policies ■ Investment in, or partnership with, other utilities
PROCUREMENT, PURCHASING, INVESTMENT (sections 2.4.4)	■ 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

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

PARIS

CASE STUDY 2.10

PARIS URBAN HEATING COMPANY: CAPTURING MULTIPLE SOCIO-ECONOMIC BENEFITS

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 twofold: 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 catalysts for district energy). After World War II, the city of Paris became a 33 per cent shareholder in the Paris Urban Heating Company (CPCU), which, 90 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 500,000 households (including all of the city's hospitals, half of all social housing units, and half of all public buildings) and interconnects 13 towns (including Paris). Heat is produced at eight facilities – including two cogeneration facilities and three waste-to-energy plants – that have a combined total of 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 CO_2 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.

The Forum des Halles (left) and Louvre Museum (right) in Paris are both heated by CPCU as well as being cooled by Climespace, the city's district cooling provider.

2.4.2 MUNICIPAL UTILITY INTERCONNECTING RESOURCES AND NETWORKS

For cities that are beginning to develop district energy networks, development often happens in a nodal manner: systems develop in segregated "blocks" that are not interconnected. The city-wide systems in Anshan, Copenhagen, Milan, Oslo, Paris, Rotterdam and Sonderborg all started with a small plant serving a large anchor load or several small buildings. As nodal networks expand, they may be interconnected to create greater economies of scale through transmission backbones (see figure 2.6).

Local governments can direct the expansion and integration of district energy networks through municipal utilities, enabling technical and economic efficiency improvements. Many *consolidated* cities have network interconnection plans that rely on municipal ownership of utilities to progress. In the absence of such ownership, it is difficult for the private sector to deliver the business model for interconnection.

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.

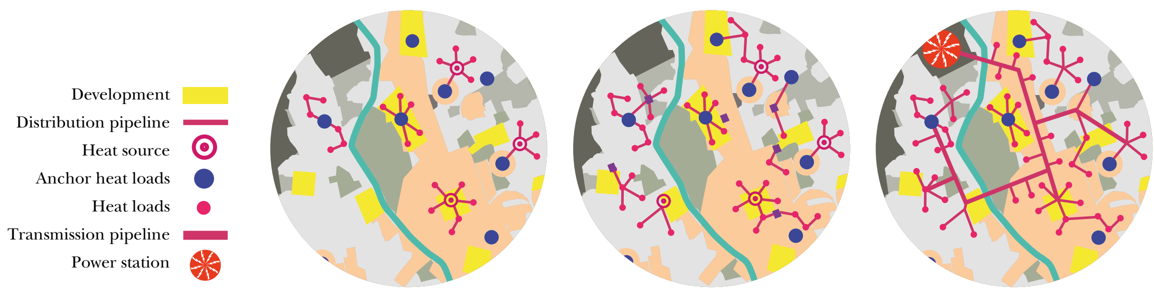
Cities worldwide are emulating Copenhagen's model of nodal development leading to the interconnection of municipal utility transmission because of its demonstrable efficiencies and its ability to connect larger heat sources to the network. The key role of municipal ownership in developing transmission 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 3.7).

In Milan, A2A will expand the currently segregated networks into three large heat networks by 2016, and these will then be interconnected via a ring around the city. This is to meet a larger proportion of the city's heat demand which, by 2020 will be 50 per cent higher than the 590 GWh of heat supplied in 2014. This will enable Milan to exploit the most efficient plants in its system, such as three large CHP plants, a waste incinerator and groundwater heat pumps. A2A is planning the district heating network development in coherence with the urban planning instruments (i.e., an urban master plan and district plans).

Sonderborg's ZERO Carbon Roadmap considers transmission pipelines to connect the area's islanded district heating networks, as a way to green its network sources and create cost efficiency. The main heating network draws heat from multiple complementary renewable sources, including a waste incineration facility, a geothermal facility, straw- and wood chip-burning boilers, heat-driven heat pumps and solar heat facilities. Although just 36 per cent of the area's buildings currently are connected to district heating, the ambition is to grow this number to around 55 per cent by switching existing buildings that burn natural gas for space heating to district heating.

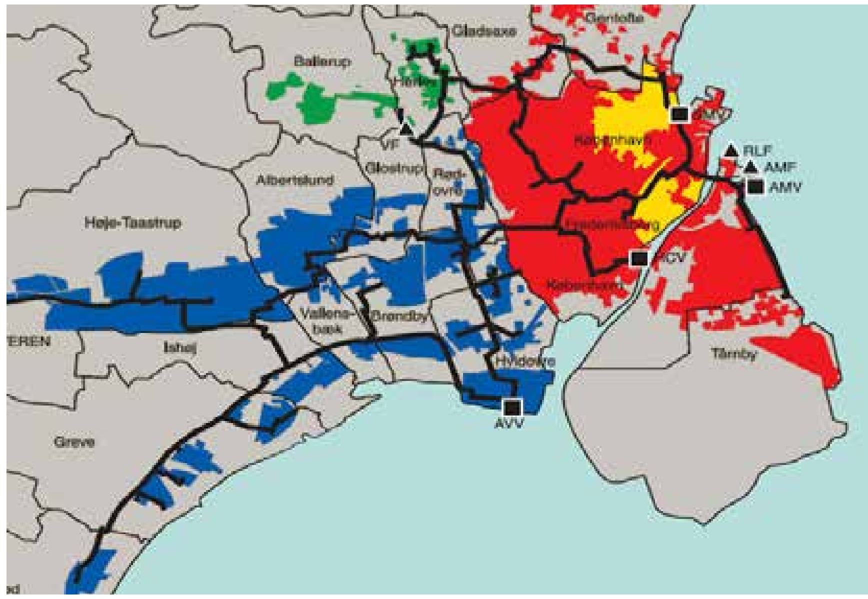
FIGURE 2.6 Nodal development of district energy systems in a city



1. Nodal networks develop around anchor loads, often linked to new development, served by a small heat source.
2. Networks expand and larger heat sources start to emerge to meet growing demand.
3. Networks begin to link in order to share excess heat capacity. Original heat sources are replaced as they reach the end of their life, potentially with waste heat from a power station. A transition main will carry large volumes of heat over long distances.

Source: King and Parks, 2012

FIGURE 2.7 Copenhagen's district heating networks, including transmission lines



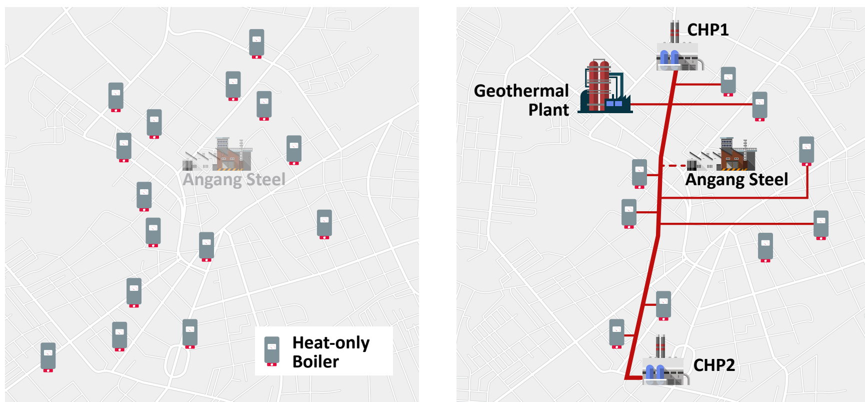
Source: Ramboll, 2014

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 decentralized 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 3.3) 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 83 per cent share that Velenje has in the public utility that owns the plant.

FIGURE 2.8 Nodal development of Anshan's district heating network



Source: Danfoss, 2014

ROTTERDAM

CASE STUDY 2.11

ROTTERDAM: CAPTURING WASTE HEAT THROUGH INVESTMENT IN TRANSMISSION

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 (Hawkey and Webb, 2012).

In 2010, the city decided to invest €38 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 expand the district heating network, the city sought and obtained support from several large housing cooperatives, building developers and energy companies to meet the target of connecting the equivalent of 150,000 households to the network. In addition, a local ordinance was introduced making it mandatory to connect new buildings to the network in order to reduce the risk for the district energy companies in the north and south.

In 2013, 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.

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 emphasized 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 utilization of waste heat.

* Eneco is owned by Dutch municipalities. Rotterdam is the largest shareholder, with a 32 per cent stake. Warmtebedrijf Rotterdam comprises two public companies with limited liability. Rotterdam holds 88 per cent of shares in Warmtebedrijf Infra N.V. and 50 per cent of shares in Warmtebedrijf Exploitatie N.V.

2.4.3 WASTE TARIFF REGULATION

"[Göteborg Energi] has enough capacity in its installations to meet the heat demand of its customers even if both of the two waste heat supplying refineries shut down tomorrow."

Göteborg Energi representative, 2014

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 uses and their benefits). Waste heat sources, which tend to be more plentiful than waste cooling 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:

- the cost of connection to waste energy and any running costs (e.g., electricity running a heat pump; the cost of avoided electricity generation),
- 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
- any incentives needed to encourage the waste heat provider to connect to the network (and shift away from its core business practice).

CONNECTION COSTS: Connecting waste heat to a district energy system can require capital-intensive equipment and adaptation of the waste heat supplier's infrastructure. Equipment to divert waste heat from its normal outlet is required, as well as heat exchangers. Heat pumps are required if the heat produced is too low for direct input to the heat network. Such a fixed rate should be reflected in a heat tariff or in agreed upon off-take levels that will effectively pay off the fixed costs of the connection. Such a fixed return for the connection is particularly important where useful heat production is a significant diversion from normal business practices and risk of the connection may have to be removed from the provider as much as possible.

WASTE INCINERATORS AND CHP PLANTS: Waste incinerators and CHP plants may have the price of their waste heat valued at the opportunity cost of the electricity that could have been produced instead of the heat (by providing heat to a district network, the electrical efficiency can decrease). For example, if the decrease in electrical efficiency is 14 per cent (i.e., 45 per cent electrical efficiency is reduced to 39 per cent), then the opportunity cost will be 14 per cent of the electricity price at that point, and this is how much the heat produced should cost. For a CHP plant, this could be the wholesale cost of electricity at any given moment. For a waste incinerator, the power purchase price may be fixed and low to reflect the fact that the incinerator's core business is combustion of waste and not electricity generation.

Such a methodology for calculating the waste heat price of CHP or a waste incinerator assumes that the heat supplier is focused on electricity production. This is often not the case, and the heat supply is integral to delivering heat to a network. In such a case, an opportunity cost approach may not be appropriate and the heat should be priced such that the heat supply has a positive net present value. This requires analysis of the typical running patterns of the CHP plant or waste incinerator (i.e., the heat load profile), which may mean that the CHP plant receives an average price that is higher than the average wholesale price (as the wholesale price is higher when it is cold and heat demand is higher).

NO GUARANTEES: Some providers of waste heat are unable to guarantee heat, particularly in the long term. This is a reflection of heat supply being a waste product of the provider's core business, with the core business being more profitable and dependent on external factors such as product demand and weather. Providers of waste energy are able to predict the amount of heat they will be able to deliver, but the lack of guarantee means that redundancy will be required in the network.

For example, extraction of heat from sewage has no guarantee of heat delivery, as sewage is received at a given temperature over which the wastewater treatment company has no control. Similarly, industrial waste heat, such as from a steel plant, may not be able to provide long-term guarantees, as a steel plant is unlikely to adapt operation significantly to ensure sufficient heating for the district heat network. Waste incinerators whose principle activity is combustion may be more flexible in their maximum provision of heat and more willing to enter contracts to guarantee supply.

This is why, after several years of negotiation with industry in the harbour area, Rotterdam has so far managed to connect waste heat only from an incinerator. By having a heat transport network, however, it will be easier to get more suppliers in the future. With that, the long-term guarantees can drop, because there are alternatives. The connection to the waste incinerator is considered to be the first step. The lack of guarantee of heat provision from waste heat means that the heat typically will have a low purchase price because the network will have to make additional expenditures in heat production elsewhere in the system to alleviate the risk of loss of waste heat.

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 connecting 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 redundancy 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 3.2 MW heat pump that is designed to meet 30 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 3.1). 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.

INTEGRATION 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 dump heat into the drinking water system (see case study 3.5).

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 of waste incineration. Connecting waste 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 metro 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.

GOTHENBURG

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 Gõteborg 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 wintertime, Gõteborg Energi monitors the price of producing heat on an hourly basis in order to settle the price for waste heat. 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 Gõteborg Energi and the Gothenburg refineries, it is now used in many other cities in Sweden as well.

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 customer 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 centre's new district energy system, as part of the earthquake rebuild. Public sector organizations have been the 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 longer-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.

* Demand load is the amount and flow rate of energy that consumers require to maintain desired comfort levels in a building or development. Demand is equal to a volume of energy consumed over time, normally a one-hour period, and frequently is defined by a seasonal peak period such as the middle of winter for heating and middle of summer for cooling. At the household level, demand load is not evenly distributed throughout the day or year and varies depending on the activities of occupants. Public buildings and commercial office space often have larger and steadier demand loads driven by schedules and advanced energy management control systems.

EU

CASE STUDY 2.13

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

Through its Project CELSIUS grant programme, the EU is pioneering innovative business models and technologies 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 Bunhill energy centre.

Source: Celsius, 2014

2.5 LOCAL GOVERNMENT AS A COORDINATOR AND ADVOCATE

"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 Carou, City of Toronto, 2014

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.

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.

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

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

POLICY INTERVENTION AREA	DESCRIPTION OF POLICY ACTIVITY
MARKET FACILITATION AND CAPACITY-BUILDING (section 2.5.1)	■ Dedicated city unit or coordination mechanism to facilitate the development of bankable projects through capacity-building, trainings, project structuring, multi-stakeholder engagement
AWARENESS-RAISING AND OUTREACH (section 2.5.2)	■ Outreach through public media and education campaigns; awards; community events; website; publications; geospatial energy, infrastructure and emissions mapping; information centres
ADVOCATING FOR DISTRICT ENERGY AT OTHER LEVELS OF GOVERNMENT (section 2.5.3)	■ 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

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

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. Planned systems 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, trainings, 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 stake-holders 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 in ensuring 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 10–20 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 collecting 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).

2.5.2 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 centres. 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 undeveloped and where knowledge about the technology is likely to 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 promote fuel switching, 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 customers; 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.

SONDERBORG

CASE STUDY 2.14

SONDERBORG: A PUBLIC-PRIVATE PARTNERSHIP TO IMPLEMENT A ZERO-CARBON STRATEGY.

"We already notice remarkable CO_2 reductions created by the transition to green district heating. A unanimous City Council is committed to Sonderborg's climate vision, and thanks to our ProjectZero project we succeed in involving the citizens – in their private homes, in business and education. It is with great satisfaction that, at the same time, we create growth and green jobs." *Erik Lauritzen, Mayor of Sonderborg, 2014*

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, Syd Energi; the Danish national energy company, DONG Energy; the Danfoss fund; the Nordea 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 goals. The plan shows how energy-efficient solutions and community engagement will reduce energy consumption by 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.

LINAK, a global producer of electric linear actuator systems, is a participating local company that has used energy efficiency initiatives to reduce its energy consumption for heating by 30 per cent and for power by 20 per cent. Large solar PV systems, together with green district heating and wind power from local turbines, will ultimately make the company CO_2-neutral.

ProjectZero has also demonstrated on a large scale that a field energy advisor can motivate citizens to energy retrofit their homes. Such advisors have visited some 1,200 Sonderborg-area homes, and 65 per cent of the homes took investment actions following the visit. The retrofits, together with other ProjectZero initiatives, have resulted in the creation of 700 new local jobs.

Solar thermal plant (left) and CHP plant (right) in Sonderborg.

FRANKFURT

CASE STUDY 2.15

FRANKFURT'S ENERGY AGENCY AND THE EXPANSION OF CHP

"We set up a new structure in 1990 to deliver these policy targets. Municipal energy policy was a new concept. We made it happen."

Werner Neumann, Frankfurt's Energy Agency, 2013

Frankfurt has created an Energy Agency that acts as an arms-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 (Fay, 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.

Waste incineration plant in Frankfurt's Nordweststadt with a capacity of 525,000 tons per year.

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 been 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. Oslo 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.

MILAN

CASE STUDY 2.16

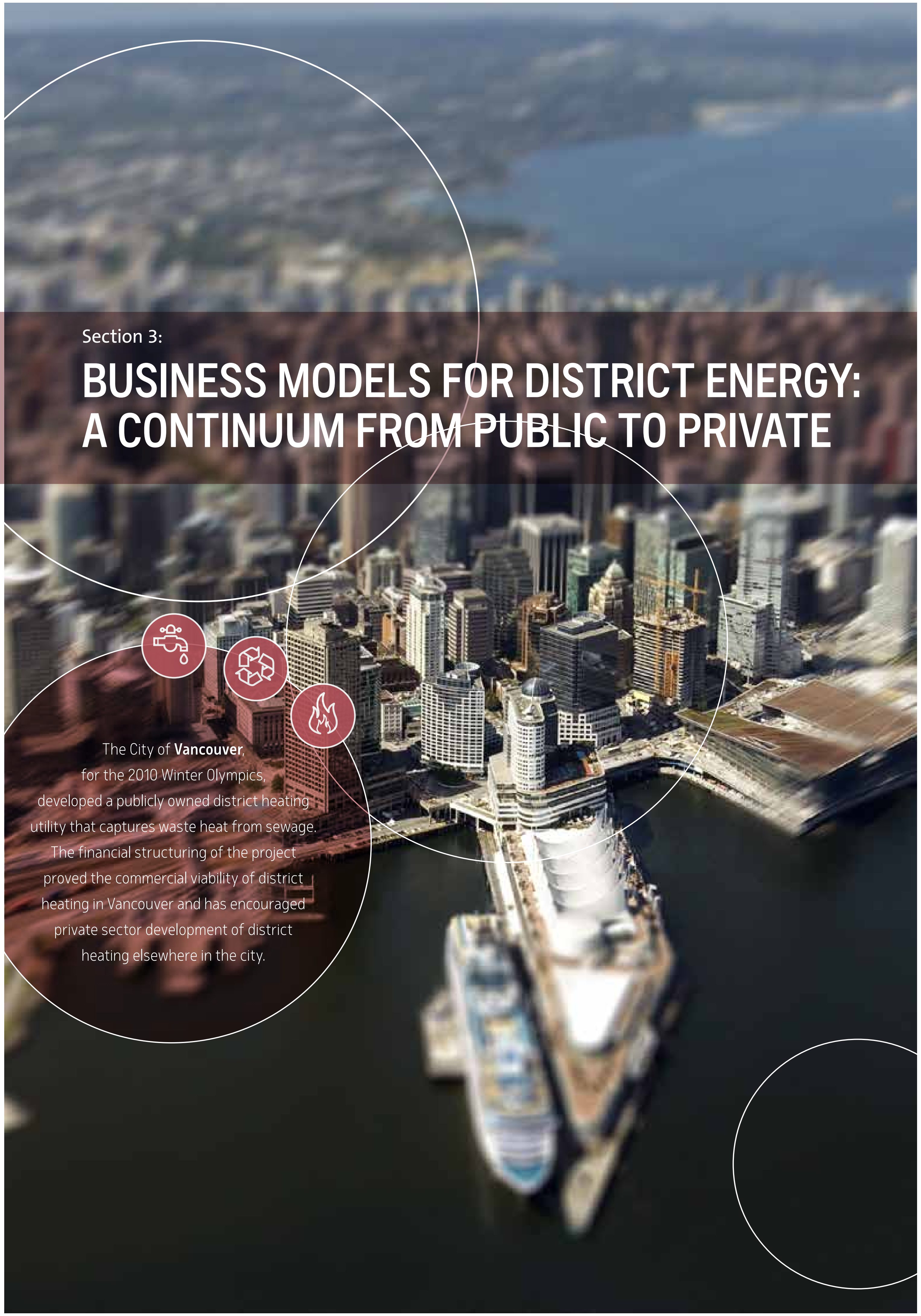
MILAN'S ENERGY HELP DESKS AND DISTRICT ENERGY RETROFITS

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 infrastructural 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 retrofitting 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.

Vilnius, Lithuania, has developed a modernization programme that could cut heat tariffs by 22 per cent and achieve the lowest price for heat in the country at 18.4 Lithuanian cents (6.1 U.S. cents) per kWh, saving the city LTL 150 million (US$50 million) per year (The Baltic Course, 2014).



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.

03

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 a wholly privately owned Special Purpose Vehicle 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/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

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.

Laying district cooling pipes in Dubai, UAE.

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.

Table 3.1 categorizes the various business models highlighted in this publication according to the financial ROI and the degree of control and risk appetite of the public sector.

In assembling the project finance for a district energy project, two further considerations need to be made:

- The project needs to be built before it can begin to deliver revenues. This is referred to as the investment/revenue time lag. To reduce this lag, the network should be built from the generation plant outwards, placing priority on any anchor loads.
- The project will likely be developed in stages, requiring waves of capital investment. Taken together with the investment/revenue time lag, enough headroom needs to be built into the model to cope with these fluctuations in investment and to avoid cash-flow problems. This headroom also must account for debt repayments relative to operating income to ensure that the project meets debt service requirements.

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 1.2), 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 also may wish to showcase the business case for district energy projects in the city by developing demonstration projects (see section 2.3.3). 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 is the norm will influence 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

FINANCIAL RETURN ON INVESTMENT	DEGREE OF CONTROL AND RISK APPETITE OF PUBLIC SECTOR	TYPE OF BUSINESS MODEL	EXAMPLES
LOW	↑ High	Wholly public	■ District energy to meet social objectives related to housing or fuel poverty
MEDIUM / LOW	↑ High	Wholly public	■ Public sector demonstrating the business case of district energy systems ■ Public sector looking to create projects that will improve its cash flow ■ Public sector lowering the IRR by allowing cheaper energy tariffs than the private sector would
MEDIUM / HIGH	→ Medium	Public/private hybrid	■ Public/private joint venture ■ Concession contract ■ Community-owned not-for-profit or cooperative
HIGH	↘ Medium / Low	Private (with public facilitation)	■ Privately owned project with some local authority support, perhaps through a strategic partnership

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 *refurbishment* 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 (0–15 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 3.2 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 3.3), multiple neighbouring municipalities have ownership over the utilities that provide district heating. This reflects the ability of district energy to supply multiple cities through interconnection.

Because a city typically has a high degree of control over the demand groups targeted for district energy – particularly any anchor loads that are connected – energy demand is typically lower risk (see section 2.4.2). Moreover, customers are connected that may not be prioritized under a private scheme, such as customers with a low connection capacity or those in social housing (e.g., Brest). The local authority may take a utility approach to tariffs by applying a standard charge for a specific customer group, such as residential consumers, allowing for more equitable billing (rather than, say, basing the connection charges and tariffs on a building's location within the network). This also encourages expansion of the system: because network costs are borne by all users equally, more connections will lower the overall cost.

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 2.3), 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)

VANCOUVER

CASE STUDY 3.1

SEFC NEU IN VANCOUVER: A "WHOLLY PUBLIC" MODEL

The City of Vancouver created and fully owns the South East False Creek Neighbourhood Energy Utility (SEFC NEU), which developed, owns and operates a district heating network based on various renewable sources. The network currently captures waste heat from a relocated and expanded sewer pump station that is co-located with the NEU Energy Centre; however, it has been designed to accept heat energy from future new connections of waste heat and renewable energy sources.

The city opted to develop the district heating system for several reasons. A tight development schedule (in time for the 2010 Winter Olympics) meant that there was insufficient time to secure a private utility and to obtain the necessary approvals for a private system. The city also wanted to showcase new models of heating and to prove their commercial viability by developing a demonstration project. Moreover, the city was able to secure considerable grants and low-cost financing.

The system became fully operational in 2010, only five years after the first feasibility study. The City of Vancouver controlled 17 per cent of the initial system load (25 per cent of the initial floor area) and, as part of a neighbourhood-wide development plan, was able to implement a service-area bylaw to ensure connection of the remaining loads (see section 2.2.4). An estimated 90 per cent of the area's heating floor space is residential (servicing some 16,000 people), in addition to commercial and institutional facilities. Because the network is publicly owned, connection costs and energy tariffs are transparent, enabling the city to provide building owners with tariff cost comparisons and evidence of savings (e.g., from not having to build and maintain boilers or on-site systems). This encouraged new connections, including from private developers, who often are not interested in building risky heating systems and/or losing control over heat production.

The total cost of the project was CAD$32 million (US$31 million) in 2010, with the costs fully covered through utility customer rates. The utility was 100 per cent financed by debt that the City of Vancouver raised through its strong access to credit; however, the rates on the debt were structured as if the project was financed by 60 per cent debt and 40 per cent equity. This was done to demonstrate commercial viability to the private sector and also to give the city flexibility to divest at a future date without any impacts on customer tariffs. The 60:40 ratio is based on the regulated capital structure of private utilities in British Columbia.

The debt raised by the city included: CAD$17.5 million (US$17 million) at 5 per cent interest from the Capital Financing Fund, an internal city fund; a CAD$10.2 million (US$9.9 million) loan at a low interest rate from the Government of Canada's federal Gas Tax Fund; and a CAD$5 million (US$4.9 million) loan at 1.7 per cent interest from the Federation of Canadian Municipalities Green Municipal Fund. The return allowed to equity was set at 10 per cent, reflecting a baseline 8.47 per cent return set by the British Columbia Utilities Commission for low-risk benchmark utilities, and a 1.53 per cent risk premium determined by the NEU related to construction, operating, financial and revenue risks (Seidman and Pierson, 2013).

Since the development of the SEFC's district heating network as a demonstration project, one additional district heat network (River District Energy) has been privately developed in the city. The owners of two legacy steam-heat systems also are establishing plans to convert these from natural gas to renewable sources of energy.

SEFC NEU Energy Centre

(Arup, 2014), which aims to improve efficiency through pooled networks, will be far cheaper through public backing (an IRR of 16.6 per cent) than private sector financing (an IRR of 9.24 per cent), even though the anticipated cash flow revenues are the same in both cases. The difference is due to lower risks and financing costs because of public backing.

Public projects with higher IRRs that have been developed as an SPV may be able to afford some commercial or blended debt, taking some of the risk burden off the local authority. Alternatively, projects may be completely or partially financed publicly but with rates that are artificially high, so that they represent rates similar to commercial debt and with ROIs for equity at similar levels as in the private sector (see case study 3.1 on Vancouver). Under such a financial structure, a project can demonstrate the commercial viability of a district energy system while still benefiting from the local authority's complete involvement.

CONTROL: Because the local authority or public utility has complete control and ownership of the district energy project, it has the benefit of receiving all of the profits, which it can then either reinvest in the project (e.g., to reduce energy tariffs) or use to fund other projects. Once the project is built out, costs and revenues will stabilize, and the project will have an asset value above the level of the investment. This provides the local authority with several choices moving forward:

- Continue operating the project, which allows the local authority to retain control of energy tariffs and to use the returned profits to fund other projects.
- If the project was initially set up as an SPV or subsidiary, then it is easier to sell the project to the private sector. Assets can be pooled or split, and control 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 2.3.1). 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, Warsaw sold an 85 per cent share of its publicly owned district heating utility to provide funds for essential upgrades to the network (see section 2.3.2).
- 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.

LONDON

CASE STUDY 3.2

BUNHILL HEAT AND POWER IN LONDON: A "WHOLLY PUBLIC" MODEL

After undertaking a series of heat-mapping exercises of London's Islington Borough, the local Council prioritized the development of a "cluster" of heat comprising five Council-owned housing estates that had existing communal heating systems, as well as two Council-owned leisure centres, including a swimming pool. The resulting district heat network uses a 1.9 MW_{el} CHP plant with thermal storage and serves 850 apartments in addition to the two leisure centres. A second phase being developed will utilize waste heat from a city-owned subway line and a privately owned electricity switching station (Islington Council, 2013).

Islington Council considered connecting the project to an existing, nearby heat network, but because that network charged a high tariff for its heat, the Council would have been unable to meet its affordable warmth objectives. Instead, the Council developed the project internally, as this was deemed far cheaper (by 55 per cent), but it tendered the design, construction and operation of the network (over 10 years) to an external contractor.

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 £4.2 million (US$6.7 million) in grants from the London Development Agency (now dissolved) and the Homes and Community Agency. The second phase has been funded in cash by the Council (£2.7 million, or US$4.3 million) as well as from an EU Project CELSIUS 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.

BERGEN

CASE STUDY 3.3

BKK VARME IN BERGEN: A "WHOLLY PUBLIC" MODEL

In 2003, an SPV, BKK Varme AS, was created to own and operate Bergen's district heating network. Under a 35-year contract, it receives all of the heat produced by a waste incinerator owned by BIR Afvallsenergi. This heat, piped to the network through a 12 km pipe, constitutes the majority of the heat needed in the district system. The waste incinerator produces electricity and heat but maximizes heat delivered to the network to meet demand. The incinerator burns waste as it arises in Bergen, rather than storing summer waste for incineration in winter when heat demand is higher (as Oslo does).

Although BKK Varme AS is effectively a public utility, the local authority has limited involvement in its management and operations. BKK Varme has two owners: BKK AS, an electricity utility based in Bergen; and BIR AS, a waste management company that owns BIR Afvallsenergi. BKK AS and BIR AS are owned by multiple local authorities, but these authorities do not use their shareholding to direct activities towards local policy objectives. However, the local authority in Bergen has targeted district heating growth in its Climate Action Plan and needs to prioritize and stimulate the use of district heating.

Municipalities directed BIR AS to use energy from the incinerator at an efficiency level of 80 per cent, higher than the 50 per cent required in Norwegian law. Both of these efficiency shares require the use of heat and not just electricity production. After unsuccessfully approaching various industrial players to obtain the heat, BIR AS approached BKK AS to explore the creation of district heating. The 80 per cent efficiency requirement was considered a crucial factor in the development of district heating.

The local authority granted BKK Varme AS a permit to enable it to connect new buildings to the network. BKK Varme AS has been granted two additional permits, for heat generation from waste wood, in two suburbs of Bergen.

Approximately 25–30 per cent of Bergen's connected load is from a hospital, which is the location of backup gas boilers. Although this anchor load is important to the business model, it is not viewed as crucial. BKK Varme AS focuses on connecting older buildings that have water-based heating systems (heated by oil, backed up with electricity), as these are far easier to connect than electricity-based systems. The resulting reduction in backup electricity and the connection of new builds has led to avoided network costs. Although initially there was interest in capturing some of these benefits in the business model, it was deemed too difficult

The initial phase of district heating development in Bergen, consisting of the pipeline from the incinerator to the city as well as 100 GWh per year of connected demand, cost NOK600–700 million (US$84–98 million) and benefited from a national grant of NOK12 million (US$1.7 million), or 2 per cent of costs. Since the development of BKK Varme AS, the Norwegian government has begun to provide grants of up to 20 per cent through a publicly owned company, Enova. BKK Varme AS will invest NOK200 million (US$32 million) in district heating and cooling up until 2025 (Hawkey and Webb, 2012).

BREST

CASE STUDY 3.4

RENEWABLE HEAT IN BREST: A "WHOLLY PUBLIC" MODEL

The city of Brest and adjacent small cities, collectively known as Brest Métropole, developed a district heat network around the commissioning of a waste incinerator in 1988 that produces 130 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 CO_2 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 seawater 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).

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 Sotraval, 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.

The original section of the network was financed by Dalkia and the new extensions of the network are now financed by Brest Métropole, as the previous contract between Dalkia and the city did not permit a return on any additional finance committed by Dalkia.

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 some control, but it also wants private sector participation to bring in expertise and/or private capital. A challenge with such projects is ensuring that all parties have a clear, agreed vision of what the objectives are and how they will be achieved.

Under the hybrid approach, the local authority has a wider range of options for business models. Three options discussed here are the public and private joint venture, the concession contract, and the community owned not-for-profit or cooperative.

3.3.1 PUBLIC AND PRIVATE JOINT VENTURE

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

RISK AND GOVERNANCE: Risk can be shared between partners, each of which may have a skillset related to that risk. The public sector (i.e., local authority) can underwrite the sales risk, guaranteeing to commit to long-term heat/cool off-take contracts, and can deal with regulatory barriers to project development. The private sector party, meanwhile, can take on the design, construction and operation risk, transferring this risk away from city taxpayers and on to private sector equity holders. The private party can also benefit from connecting to the network, providing the project with guaranteed demand and potentially granting itself preferential rates.

In a pooled asset model, such as with Empower in Dubai (see case study 3.6), the different actors combine skillsets through a single company or utility. In a split asset model, these skillsets are separated into the different functions of the district energy system, such as the public sector being responsible for waste incineration and transmission (see case studies 3.7 on Anshan and 2.11 on Rotterdam) and the private sector for CHP heat production (see case study 4.4 on Yerevan). Between these entities, contracts will exist that define off-take and tariffs.

SOURCES OF FINANCE: In this model, both the private and public sectors provide equity. Debt is based on the project's future cash flow but can be underwritten by either party. 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, to sell out to 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.

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 3.8 on London's Olympic Park). 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 Cyberjaya). 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 may allow 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 or utility with the concession (private sector or public-private) bears completely the risks of designing, building and operating the district energy system. 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 tariffs it can charge due to local competition or by contractual levels set to avoid monopolization of energy distribution.

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 centre; however, they rely on their overall corporate balance sheet to raise the capital for system development (Seidman 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.

TORONTO

CASE STUDY 3.5

ENWAVE ENERGY CORPORATION IN TORONTO: A POOLED ASSET MODEL

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, impeding its ability to implement innovative solutions. As a result, TDHC was restructured into the for-profit Enwave Energy Corporation, with 43 per cent city ownership and 53 per cent ownership by BPC Penco 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 (263 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 Penco have since exited the project, selling Enwave to Brookfield Asset Management for CAD$480 million (US$429 million). This netted the City Council CAD$168 million (US$150 million), or CAD$100 million (US$89 million) more than it had invested.

DUBAI

CASE STUDY 3.6

EMPOWER IN DUBAI: A POOLED ASSET MODEL

Dubai has developed the world's biggest district cooling network, meeting a demand equivalent to 1 million tons of refrigeration annually (3,510 MW). The network requires just half the energy of the air-conditioning units it replaces, and thermal storage makes it possible to reduce 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.

ANSHAN

CASE STUDY 3.7

DISTRICT HEATING IN ANSHAN: A SPLIT ASSET MODEL

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 m^2, 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 COWI, 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, with the networks' existing coal 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 m^2 connected in phase one and 10 million m^2 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 in 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 Bengang Steel, the city government of Benxi and Danfoss on the province's first replication project, with a scope of 160 MW of surplus heat.

Source: Danfoss, 2014

LONDON

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 tri-generation combined cooling, heat and power (CCHP) energy centres at Stratford City and Kings Yard on 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.

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 Athletes Village, Olympic Park and Stratford City. Because district energy is not regulated in London, the concession provides connection, supply and service levels. Public land and guaranteed connections enabled the financial viability of the project, which cost over £100 million (US$160 million) and was fully financed by Cofely.

The two energy centres are designed to eventually provide a maximum of 200 MW of heat (up from 100 MW today), 64 MW of cooling (up from 18 MW today, reflecting a 4 MW absorption chiller supplemented by two 7 MW ammonia chillers) and 30 MW of low-carbon electricity (up from 3.5 MW today). In addition, 27.5 MWh of heat storage and 4.7 MWh of cool storage have been developed. The energy centres currently run on gas but are designed to switch between gas and biomass in the future. Most consumers are expected to save 5–10 per cent on their overall energy bills.

CYBERJAYA

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 30–50 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 190,000 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, which is 92 per cent owned by the Malaysian Ministry of Finance), under a build-own-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 18,300 refrigerant tons (64.2 MW), built in two stages between 1998 and 2012 and complemented by ice storage (35,500 refrigeration ton-hours; 125 MWh), cold water storage (39,000 refrigeration ton-hours; 137 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 30 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 centres, this can reach 80 per cent. Annual cost savings through district cooling are 39 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).

CONTROL: The governance structure is via representatives elected by the members. In return for debt underwriting, the local authority may require or be offered representation on the board.

Strøget Street, Copenhagen, Denmark.

COPENHAGEN

CASE STUDY 3.10

HØJE TAARSTRUP FJERNVARME IN COPENHAGEN: A COOPERATIVE MODEL

Høje Taarstrup 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 Taarstrup Fjernvarme purchases heat from the municipally owned transmission company, which itself buys heat from privately owned power stations in the surrounding areas. Høje Taarstrup 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 Taarstrup Fjernvarme made a profit of £189,000 (US$302,000) on heat sales totalling £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.

3.4 THE "PRIVATE" BUSINESS MODEL

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 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 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.

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.

Port Louis, Mauritius

ABERDEEN

CASE STUDY 3.11

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 water-based communal heating 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 £219,000 (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 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.

PORT LOUIS

CASE STUDY 3.12

PORT LOUIS'S SEA WATER AIR CONDITIONING (SWAC) PROJECT: A "PRIVATE" BUSINESS MODEL

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 5.5 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 464 MW (National Assembly, 2011). It will also enable the City of Port Louis to reduce its carbon footprint by 40,000 tons of CO_2 annually. The water pumped from the sea will be made available to entrepreneurs to promote and develop various applications in the field of ocean industries (Cunha, 2014).

The SWAC system is being developed by a local company, Sotravic Ltd., at an estimated cost of MUR4 billion (US$130 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 concessional 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 Sue, 2014; Capital, 2014; AfDB, 2014). The project is expected to be extended to a second city, Ebene, to replace the conventional air-conditioning systems of data centres.

3.5 EXPANDING THE BUSINESS MODEL VIA ADDITIONAL INNOVATIVE PRACTICES

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 Kuwait 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).

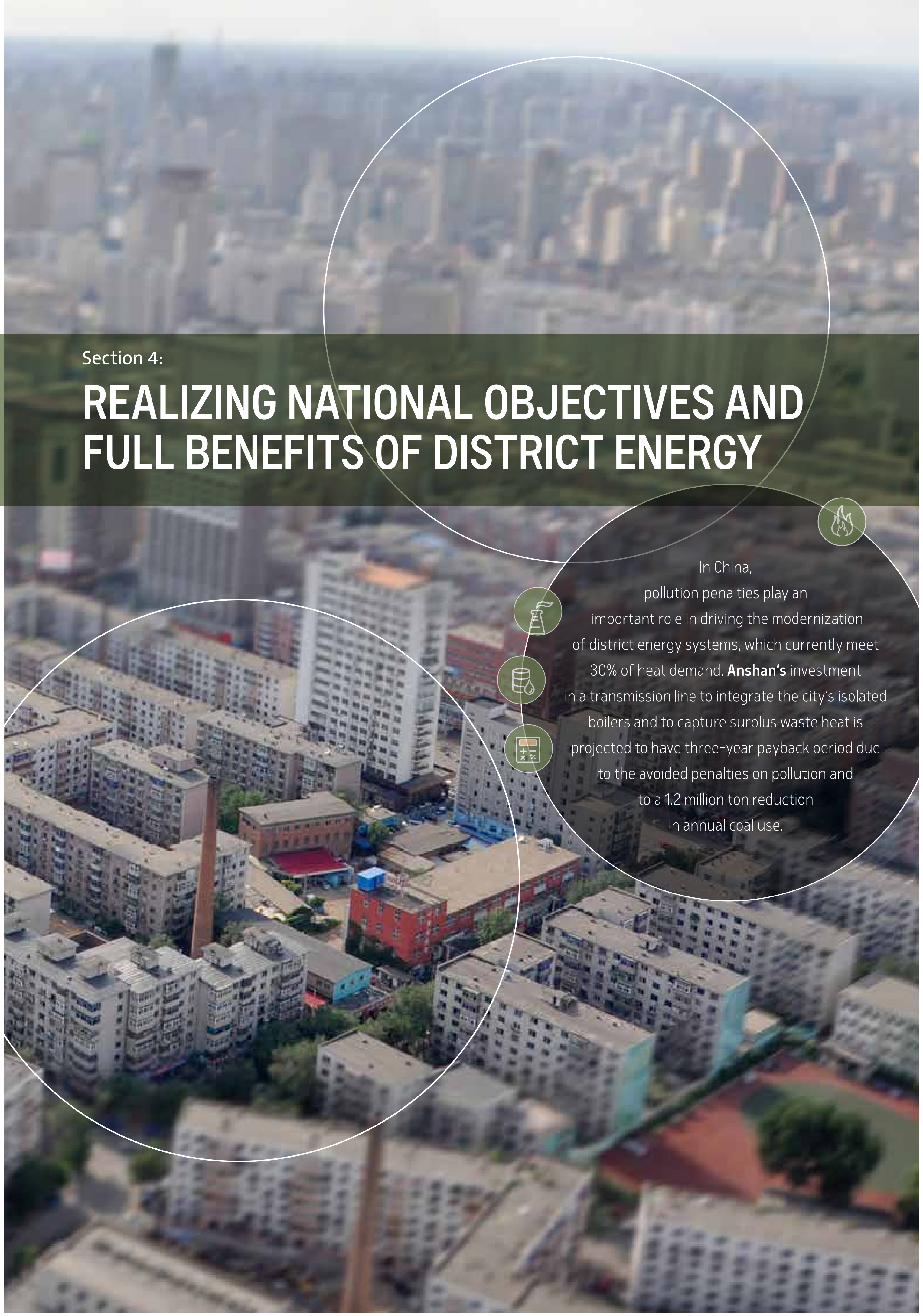
District cooling is a technology that is slowly building traction in some developing country cities because of its ability to alleviate stresses on power systems caused by air conditioning (see case studies 3.9 on Cyberjaya and 3.12 on Port Louis). The benefits of district cooling are felt by various 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 electricity 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 replacement of refrigerants such as HCFCs and HFCs 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 3.6) 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 waste 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 3.2 and 3.3. 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 municipal, regional and national 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 3.3.1.

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.



Section 4:

REALIZING NATIONAL OBJECTIVES AND FULL BENEFITS OF DISTRICT ENERGY

In China, pollution penalties play an important role in driving the modernization of district energy systems, which currently meet 30% of heat demand. **Anshan's** investment in a transmission line to integrate the city's isolated boilers and to capture surplus waste heat is projected to have three-year payback period due to the avoided penalties on pollution and to a 1.2 million ton reduction in annual coal use.

04

THIS SECTION LOOKS AT

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** , if it exists, often comes from the national level. Tariffs can be regulated so that district energy is priced at the alternative technology costs, or they can be effectively indirectly regulated by controlling the profits of district energy companies or the costs that they can pass on to consumers. Variations on these two tariff regimes are present in many cities, and the choice will depend largely on the existing energy market structure and on its level of regulation and liberalization.

- **A VERTICALLY INTEGRATED GOVERNANCE STRUCTURE** is key to optimize 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 Dulac, IEA, 2014

CHP and wind development in Denmark from 1985 (top) to 2009 (bottom) as a result of strong national policies for renewables and district heating. The maps show centralized (red circles) and decentralized (orange circles) CHP plants, onshore and offshore wind power (green circles) and interconnectors (Lauersen, 2014).

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).

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 mis-aligned 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 4.3 explores how some cities are accessing new climate financing mechanisms for emerging economies and developing countries, such as Nationally Appropriate Mitigation Actions (NAMAs).

4.2 DE-RISKING INVESTMENT

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).

However, local governments are key to implementation (for example, to help reduce load risk; see section 2). Clear planning guidance and regulations that provide local governments with a mandate to act are the most important national lever to unlock cost-effective deployment of district energy systems, by creating market demand and limiting associated capital investment risk. Any national vision should be set to create a coherent and enabling framework for local action, with related support (Chittum and Østergaard, 2014).

Renewable CHP plants, such as this wood-fired plant in St. Paul, USA, could provide the primary energy efficiency improvements and renewable heat that could count towards an improved efficiency label for a building.

4.2.1 COHERENT ACCOUNTING PRINCIPLES: ENERGY EFFICIENCY LABELS AND STANDARDS

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 (2013) 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.

Best practice examples exist in Finland and Germany, where building codes set primary energy efficiency standards for new buildings and where different sources of heat have different coefficients. The higher the coefficient, the more difficult it is to achieve the standards, as the primary energy efficiency is lower. Both countries require that a certain share of the energy used come from renewable sources. District heating based on CHP/surplus heat and/or renewable energy is automatically considered to fulfill this criterion.

The energy-saving ordinance in Germany aims to reduce the primary energy demand of buildings to save resources and lower greenhouse gas emissions. Either using more insulation or more efficient systems engineering or primary energy sources can fulfill the obligations. The system therefore reflects the efficiency benefits of modern district energy (Euroheat & Power, 2013). The Pearl Rating System used in Abu Dhabi is another example of coherent energy efficiency accounting in design, planning and implementation.

4.2.2 DEVOLVED RESPONSIBILITY

As the policy and business models reviewed in sections 2 and 3 demonstrate, any vision for district energy will require strong involvement of local authorities that can wield relevant planning (and mapping) authority, including over new development. Local authorities also act as the brokers of relationships with the owners of social housing, public buildings and other anchor loads that are likely to form the core of the schemes. This requires that national governments set a regulatory framework that explicitly devolves the relevant authority to local governments, for example in the areas of mandatory connection policies, energy master planning and mapping, energy service provision, and building codes (see section 2). Such devolution has occurred successfully in Norway (see case study 4.2). Mapping in particular requires a resolution that can be achieved only through localized modelling of energy use in a city, and cities are the ideal leaders in developing local mapping and planning.

Experience indicates that local governments are best placed to alleviate the risks associated with district energy schemes. The devolution of authority at the national level within a coherent and enabling framework can enable local governments to use their authorities to manage risks – and locate finance – for district energy projects that have long development periods (10–20 years), multiple phases and potential multiple owners/developers (particularly in the private sector).

As part of the devolution of authority over district energy, national governments commonly encourage or mandate local authorities to create cost-effective energy or 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).

4.2.3 SUPPORTING CITY-LEVEL CAPACITY AND COORDINATION

Devolved responsibility to the local level, as discussed in section 4.1.2, has to be matched with the relevant financial and capacity support for energy mapping, project planning, related organizational development, appropriate commercial arrangements and technical quality control. Even in the case of not having multiple owners, such as in a public-utility model, time is required to develop the balance sheet of the utility to be able to expand a district energy network to this long-term vision. Early-stage finance often comes in the form of a grant directed at specific stages of development, such as the creation of a team in a city or public utility, individual project finance, project demonstration or the creation of a revolving fund.

The European Investment Bank's (EIB's) European Local Energy Assistance (ELENA) initiative provides a technical assistance facility to kick-start large energy efficiency and renewable energy programmes (see case study 4.1). This includes sharing costs on the technical support that is necessary to prepare, implement and finance the investment programme (e.g., feasibility and market studies, programme structuring, business and financial plans, energy audits, tendering procedures) ready for EIB funding (EIB, 2012).

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 companies and/or cities, representing a significant investment before any construction begins. For small projects in cities with relatively little district energy, this process can take three years until procurement and construction contracts are developed, and up to seven years for area-wide networks. In addition, capturing city-wide benefits in business models is a time-consuming aspect of the development process and has to be done on a city-wide basis, unless these benefits are already captured in national policies (see section 4.2). Some local authorities capture these benefits by evaluating them on a project-by-project basis; however, this is a slow and fragmented approach to scaling up district energy.

Another emerging option is to create a revolving fund that allows cities to develop and sell built-out projects to the private sector, and to finance other areas in the city to achieve the longer-term vision of a city-wide district energy system. Toronto envisages such a revolving fund model following the successful sale of its Enwave heating and cooling utility to the private sector, netting the city council US$150 million (see case study 3.5).

This is similar to a model recently developed by R20 (Regions of Climate Action) to facilitate the development of bankable low-carbon and climate-resilient projects, and to reduce the energy-market investment risk for these projects. Through a trust fund, R20 sets up a local development team in a city to build capacity, aggregate customers and ensure bankable projects, leveraging a non-profit model. The team takes a share of the capital expenditure when the project gets invested (R20, 2014).

In some cases, long-term financing may still be required if the selling of district energy systems cannot achieve the price required, typically because heating or cooling from district energy is more expensive than next-available technologies because the full benefits have not been priced in. Section 4.2 discusses how national governments are levelling the playing field.

BOX 4.1 LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED) CERTIFICATION

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/or 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 now earn credits for efficiency improvements, renewable energy supplies and refrigerants (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 4.2 EU LEGISLATION ON HEAT PLANNING

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 – or, 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

* 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).

** Legislative Decree n.102

LONDON

CASE STUDY 4.1

LONDON'S DECENTRALIZED ENERGY DELIVERY UNIT

With €3.3 million (US$4.15 million) in seed funding from the European Investment Bank's ELENA facility, London established the Decentralised Energy Project Delivery Unit (DEPDU) in August 2011 to provide city boroughs and other project sponsors with technical, financial and commercial assistance in developing and bringing district energy projects to market. Whereas the Decentralised Energy Master Planning (DEMaP) programme (see section 2.2.2) helped build capacity, support local authorities in identifying projects (based largely on the London Heat Map) and create energy plans, the Decentralised Energy Programme provides support for the commercialization of such projects.

To date, the Greater London Authority has supported local authorities and other parties in taking seven district energy projects to market with a total investment of £42.3 million (US$53.2 million). The programme is actively supporting a pipeline of 22 district energy projects with a total investment potential of £304 million (US$382.3 million). Of these, five were in an advanced development stage in late 2014 and were expected to be brought to market within 12 months.

Through the programme, London also established the *London Heat Network Manual* (GLA and Arup, 2013) to provide standardized guidance for developers, network designers and energy producers on the delivery and operation of district energy projects (Gagliardi La Gala, 2014).

BERGEN

CASE STUDY 4.2

NORWAY: DE-RISKING DISTRICT ENERGY DEVELOPMENT AND INCORPORATING MACRO-ECONOMIC BENEFITS

Norway is the world's fastest growing district heating market. Traditionally, the country used its local hydropower resources for electric heating; however, two key drivers – renewable energy and energy efficiency – led to a new national vision on district energy. In 2010, Norway adopted a 10-year target to deploy 10 TWh of modern district energy by 2020, equivalent to 16 per cent of the heat market. The country aims to increase the use of district heating from renewable fuels, decrease the use of electric power for heating and increase the use of waste-to-energy plants to replace fossil fuels.

The Norwegian licensing framework has served as an enabling framework for district energy planning and implementation at the local level. The national government requires an aspiring district heat provider to develop a detailed development plan that includes evidence of the socio-economic and environmental benefits of district heating relative to other options. This provides the licence holder the validity to operate as the sole supplier of heat in a specified area, which de-risks investment, enables local authorities to mandate connections, protects consumers by establishing service standards and requiring tariffs to be competitive with the next fuel/technology alternative (in this case, electric heat), and provides a level playing field by requiring the socio-economic benefit analysis in the cost-assessment criteria.

These principles are a key best practice in both tariff regulation (see section 4.2) and devolved planning authority to the local level (see section 4.1.2). This is similar to the approach also taken in the EU with regard to cost-effectiveness assessments and local implementation (see box 4.2).

Norway has enacted several national policies that are key to district energy development. For example: all buildings over 500 m² must use 60 per cent renewable heat and are banned from electrical and fossil fuel-based heating (exemptions can be claimed for passive houses); installation of oil-only boilers is forbidden in all new and refurbished buildings; the landfilling of organic waste is prohibited; and 50 per cent of energy must be recovered from waste incineration.

Norway has a financial support scheme for renewable heat production for district energy companies and for small-scale renewable heat production, with a maximum of 30 per cent support per project (on average 15–20 per cent). The objective is to change the energy system by increasing the use of renewables in the heating sector – making the system more flexible – and to improve security of supply. Financial support is also available to encourage substantial investments in waste incineration plants.

Source: Hawkey and Webb, 2012; Euroheat & Power, 2013

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).

Brest, France

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 (EcoHeat4EU, 2012; Werner, 2011). This is through the benefits of energy efficiency. In Sweden, a CO_2 tax was critical to the country's energy transition strategy. The City of Växjö noted that the CO_2 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 CO_2 tax as the most important national policy for district energy in the city (see case study 1.1).

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 CNY7.8 million (US$1.3 million), 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), SO_2 and CO_2 (Ximeng, 2013). 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 incinerator.

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).

CHP plant in Łódź, Poland (top).
Historic façades in Frankfurt, Germany (bottom).

4.3.2 OPERATIONAL SUPPORT FOR CHP/ PRICING CHP BENEFITS

Pricing-in CHP benefits is important to creating a level playing field (see section 1 and section 2.4.3) (IEA, 2014b). In some energy markets, decentralized energy projects do not have full access to the electricity retail market and have to sell excess power into the wholesale market at much lower prices. This is a key barrier to entry for decentralized power producers that hope to participate in district energy schemes (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 ROI to engage the private sector in delivery. Cities such as Velenje, Łódź 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 43 per cent in order to produce more heat (a 14 per cent decrease) could set the tariff for heat at 14 per cent of the wholesale electricity price (very low) (Gudmundsson and Thorsen, 2013). For other CHP plants, which may have must-runs 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. Yerevan 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

Tariff regulation is an important aspect of district energy that can ensure consumer protection in a naturally monopolistic market. Tariff 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. Levying specific costs at individual consumers can be important to insulate uninvolved 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.

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.

LONDON

CASE STUDY 4.3

LONDON'S "LICENCE LITE": FACILITATING PEER-TO-PEER ENERGY SALES BASED ON NOMINAL "WHEELING" CHARGES FOR USE OF LOCAL WIRES

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 conveyance 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 ROI 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).

YEREVAN

CASE STUDY 4.4

YEREVAN: USING A MULTI-PART TARIFF TO ENCOURAGE EFFICIENT AND AFFORDABLE HEAT

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, the country imported 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, regular interruptions 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 electricity). 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. Avan, a residential district in Yerevan with 32,000 residents, was selected as a pilot project. The district heating network had stopped supplying heat in 2003 (and hot water in 1994) and had previously operated at only 50 per cent efficiency. The existing state of the heat supply sector and the limited municipality budget made it clear that private sector involvement was necessary.

To reduce commercial risks and attract private sector involvement, the UNDP–GEF project team recommended regulatory changes that would guarantee electricity tariffs and heat tariffs for a project. The heat tariff was determined from on-the-ground market research that would ensure that the tariff was well below the cost of heat from individual house appliances, thus ensuring a high rate of connections to the improved district network. The heat tariff is multi-part, thus encouraging reduction in demand-side consumption, but the fixed element of the tariff ensures that the fixed costs of the connection are paid off. The electricity tariff was calculated to cover all other revenues needed to meet the required return on investment for the private sector. This final electricity tariff – a feed-in tariff – was close to the marginal thermal power plant on the Armenian power system.

The team recommended that a public-private partnership was the best model for reducing commercial risk and hence heat tariffs. The public sector role would be to have some ownership but also to remove institutional barriers and offer favourable conditions to investment. This led to the Yerevan municipality giving free use of heat supply assets to the new 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 very 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 GWh annually and save 10,200 tons of CO_2-equivalent. In 2006, the heat supply company ArmRusCogeneration CJSC was founded, with the majority of shares owned by foreign investors and a minority held by the municipality of Yerevan.

Source: UNDP, 2012

Avan district, Yerevan, Armenia

Furthermore, district energy operators may not be able 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 district energy. For example, pricing district heating against the residential gas price may mean that the business model for district energy makes the most sense if it is mostly gas CHP producing the heat. Or, pricing district cooling against the residential electricity price 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 are given a monopoly over a licence area, which helps to ensure that costs are low enough for the regulated tariff (see case study 4.2). 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 efficient operation, 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 cost, customers experience savings in 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-alternative technology.

In Denmark, the national government determines which costs can be recovered in district heating prices, and these can then be levied on consumers. If a consumer is singularly responsible for 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). National oversight ensures that district heating companies charge fair tariffs and do not pass on costs that should not be incurred by the consumer. Furthermore, consumers are able to evaluate their tariff against other tariffs nationally, as district heating companies must publicly report the breakdown of fixed and variable costs each year (Chittum and Østergaard, 2014).

The tariff regulation of passing costs on to consumers (as opposed to setting the price at the next-available technology cost) has meant 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). Denmark also has profit controls on district heating companies, capping the profits that they can make and requiring excess profits to be used to reduce heat tariffs. Japan has taken a similar approach to heat pricing, where the Heat Supply Business Act fixes the tariff to include all initial costs, and the price is approved by the national government, leading to inflexible pricing.

In the Canadian province of British Columbia, district energy utilities are regulated by the British Columbia Utilities Commission, which enforces a capital structure and allowable return on equity, essentially limiting the profits of the utilities. This translates explicitly to the charging of an allowable average tariff. In Vancouver, public ownership also means that the tariff structure is extremely transparent, further encouraging connections (see case study 3.1).

TARIFF NOT REGULATED. In the absence of regulatory authority from the national level, local authorities can still influence tariffs through active participation in and ownership of district energy in their cities. This could be through concessions given out with requirements on tariff levels, or public ownership reducing costs and eliminating profits to reduce tariffs (see case study 3.2 on Bunhill Heat and Power). For some markets, 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). 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 could own, and have paid for, 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) recommends setting district heating prices against the cost of the next-alternative technology, which in the U.K. is normally natural gas boilers (the manual recommends the same for district cooling prices). Such tariffs are unlikely to be regulated heavily in the future, and individual district heating companies could use varying tariff structures. Such a model is likely to work well, particularly because mandatory connection is unlikely in London and because district heat networks will be developed, with many heat sources being from gas CHP. As London decarbonizes heat further in the future, different pricing structures are likely to emerge, particularly if district heat costs diverge from gas prices.

For countries where energy is subsidized at the consumer level (for example, for electricity or natural gas), such subsidies should be considered by the relevant authority and also be allowed to pass through district energy 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 1) such low prices should be allowed to pass through district cooling prices to keep district cooling competitive, and 2) flat-priced electricity tariffs should be passed to the district cooling operators, or subsidies somehow should be redirected to storage at the district cooling level, stimulating more-efficient and timely electricity use.

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.

Restoring Christchurch's landmark Diamond Jubilee Clock Tower after the 2011 earthquake.

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; Leidreiter et al., 2013; NREL, 2010). 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 Yujiapu, China; Samui Island, Thailand; and Da Nang, Vietnam as the first three case studies. And in 2013, 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 emissions 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 government 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 demand significant capacity and/or resources from local authorities. As seen in the case of district energy, national governments have started to provide 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 joint 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 mobilize local and provincial actors for achieving national mitigation targets through cost-effective incentive packages and MRV systems.

4.4.2 SOME INITIAL EXPERIENCES WITH V-NAMAS

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.

- **OWNERSHIP FOR V-NAMAS IS TYPICALLY SHARED AT THE NATIONAL LEVEL BETWEEN THE LEAD AGENCY FOR NAMA DEVELOPMENT AND RELEVANT SECTOR MINISTRIES.** This is a complex task, and it took 6–12 months to establish a workable institutional arrangement. In Indonesia, the Ministry for National Development Planning (BAPPENAS), which has overall responsibility for NAMA development, took the lead and engaged with the Ministry of Public Works (PU) on developing a V-NAMA for municipal solid waste. Ultimately, other sector ministries also had to be engaged, such as the Ministry of Environment (KLH), for matters related to waste recycling as well as for MRV, and the Ministry of Energy for waste-to-energy matters.

  In South Africa, the Department of Environmental Affairs (DEA, which has overall responsibility for NAMA development) engaged with the Department of Energy (DoE, responsible for energy efficiency and demand-side management support mechanisms for municipalities) and with the Department of Public Works (DPW, the owner of public buildings and responsible for building standards) to develop a V-NAMA for energy efficiency in public buildings at all levels of government, with a focus on provincial and municipal buildings. It could build on an existing taskforce on building energy efficiency that had just been set up between DoE and DPW, and which greatly facilitated the process. There is a need to clarify the roles, and manage expectations, of national agencies that invest efforts in developing V-NAMAs without being the primary beneficiaries (which should be the subnational actors).

- **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 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.** 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 (RAD-GRK). 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.

- **V-NAMA AS FUNDING MECHANISM: DESIGNING A CLIMATE FINANCE MECHANISM FOR SUBNATIONALS.** National governments struggle 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-NAMA they would 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.

SOUTH AFRICA

CASE STUDY 4.5

V-NAMA SOUTH AFRICA: A MODEL FOR HOW LOCAL AND NATIONAL GOVERNMENTS CAN SUPPORT EACH OTHER FOR A COMMON PUBLIC OBJECTIVE

In 2009, the South African government committed to reduce the country's emissions 34 per cent from business-as-usual levels by 2020 and 42 per cent by 2025. For an effective climate change response, the government approved the *National Climate Change Response White Paper* in 2011, introducing eight Near–term Priority Flagship Programs. The V-NAMA programme on energy efficiency in public buildings forms part of the Energy Efficiency and Energy Demand Management Flagship.

GIZ, under BMUB's International Climate Initiative, cooperates with three national ministries, four provinces (Eastern Cape, Free State, Gauteng and KwaZulu–Natal) and nine municipalities in this programme. Approximately 75 public buildings – such as administration buildings, schools and hospitals – build the test bed for the implementation of energy efficiency measures, MRV systems as well as business models to mitigate greenhouse gas emissions. The implemented MRV system will be based on existing reporting mechanisms in the field of energy in South Africa.

The proposal for the "Energy Efficiency in Public Buildings Programme in South Africa" V-NAMA consists of a financial and a technical component. In the financial component, it is envisaged to set up an Energy Efficiency Fund hosted by the Development Bank of Southern Africa (DBSA) to ensure a more cost-effective use of national grants. The fund would provide concessional funding to provinces and municipalities for effective energy efficiency interventions by piloting innovative subsidy mechanisms (such as reverse auctions, competitive grants, performance-based subsidies and pre-feasibility studies). An additional service planned within the financial component is to provide provinces and municipalities with centralized procurement, pre-qualified contractors, etc.

The technical component is divided into a policy and an institutional capacity component. The policy component is established to create enabling conditions for private investments in public building energy efficiency and for introducing green building standards for public buildings. An important part of the strategy is to enable private sector investments through energy service companies, for example through public-private shared-savings ESCO contracts. Thus, an important part of the policy component is setting up a standardized approach ("cookbook") to sign three-plus year contracts with ESCOs, which so far is a challenging activity for South African provinces and municipalities.

The institutional capacity component includes setting up an institution to provide services for municipalities. Hence, less experienced and smaller municipalities will be supported in their energy efficiency proposals, procurement, MRV requirements, etc. So-called Energy Efficiency Managers will support provinces and municipalities in accessing funds and developing projects. Another part of the capacity component is to set up a Green Building Project Management Office to advocate, communicate and promote sustainable construction in the different spheres of government.

The proposed Energy Efficiency in Public Buildings Programme would, given appropriate international and national funding, lead to estimated annual reductions of 100,000 MWh of electricity consumption and 95,000 tons of CO_2 after five years of implementing efficiency measures in approximately 1,000 buildings. Two alternative scenarios have been developed, and other options are possible to meet donor- or investor-specific priorities. In addition to the high mitigation effect, the programme seeks to provide accompanying co-benefits such as energy consumption and related costs, improved service quality of public administrations in retrofitted buildings, job creation in different regions and on different skill levels, and better vertical and horizontal coordination between different spheres of government and government departments.

Source: Contribution from Tobias Zeller, Prema Govender (GIZ) and project country partners, 2014. A more detailed description of the case can be found at http://bit.ly/1wBHOzI.

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 subnationals.

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 uses", "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 grants for infrastructure investments that local governments are incapable of operating sustainably.

The V-NAMA pilots have initiated a more regular exchange in which the national government gains insight in local priorities and creative solutions, and the local government can understand some of the constraints imposed by national policies and international donors on support programmes. This communication channel has also improved the horizontal flow of information between sector ministries and between city-level agencies around climate action. It remains a challenge to institutionalize such mechanisms independently of the V-NAMA teams, which currently maintain and energize this dialogue through continuous communication, workshops and capacity-building.

V-NAMA AS A PROMOTER FOR PRIVATE SECTOR INVOLVEMENT IN LOCAL CLIMATE ACTION. Increasingly, the target of climate finance will not be (only) to support subnational governments themselves, but to attract stronger involvement of the private sector in delivering local services. For example, in South Africa, the V-NAMA proposes a "shared savings" business model for private ESCOs to engage for the first time, with their own capital, in energy efficiency in municipal buildings. The intention is to ensure financial sustainability of NAMA programmes once pilot initiatives and grant support have been exhausted.

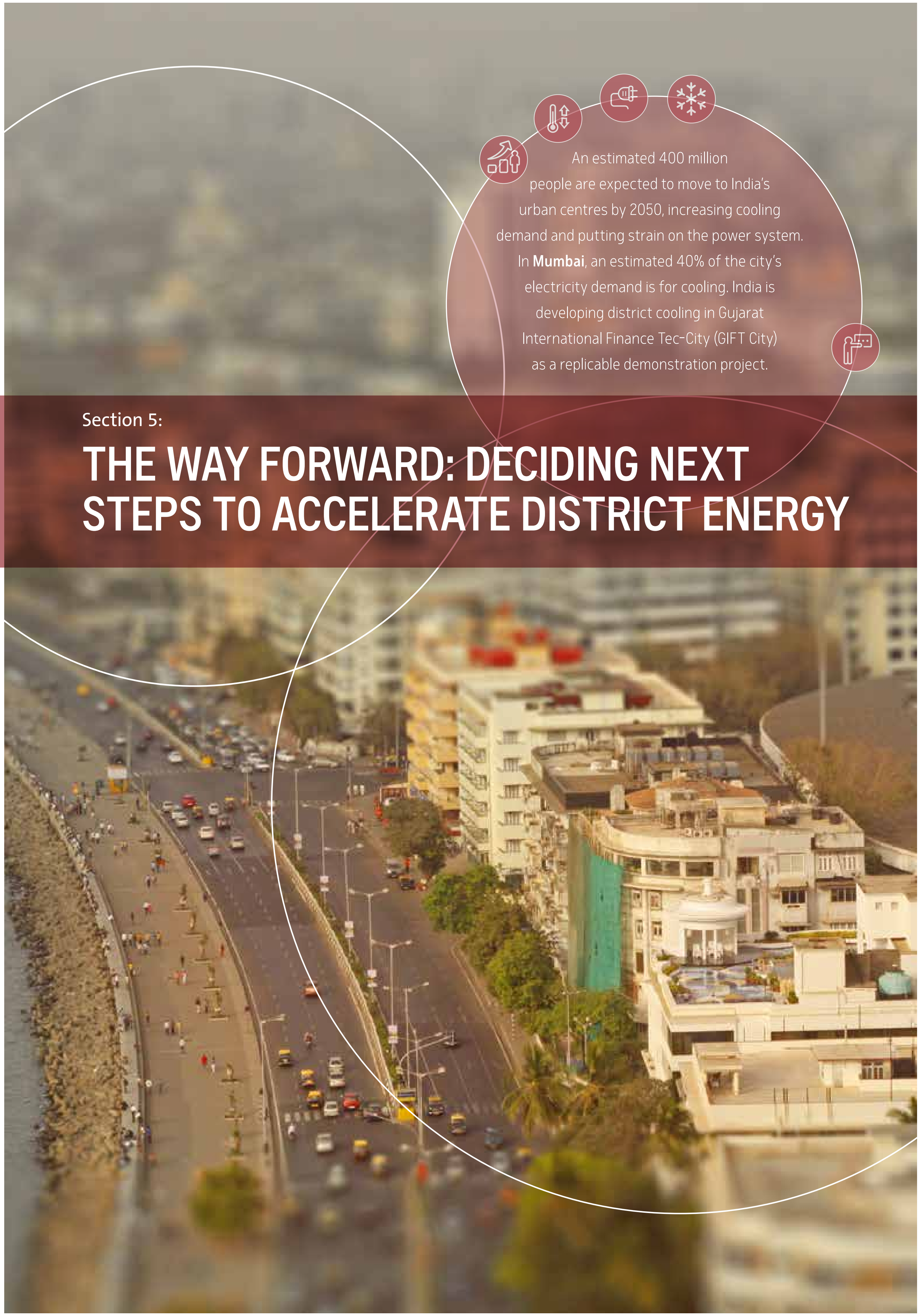
Multi-stakeholder discussion on V-NAMAs in Durban, South Africa.

4.4.3 POTENTIAL APPLICATION OF V-NAMAS TO DISTRICT ENERGY

District energy at the city level presents 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 pro-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.



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

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

5.1 WHY?

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.

5.1.1 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.

Individual air-conditioning units (top) and gas boilers (bottom) are just two of the technologies that district energy can replace.

5.2 WHEN?

"We celebrated 100 years of district energy at the Toronto University, and the conclusion we came to was that if you own buildings and pay the bills for energy, then you would come up with this solution 100 years ago as they did. The policy challenge for us is how to translate that model to the rest of the city. The way that we have done it is to take multiple approaches – such as mapping potentials and leading by example through demonstrations – that enable us to be ready and nimble to act when it is the right opportunity. The multiple benefits of district energy mean that it can emerge as a solution to multiple crises." *Fernando Carou, City of Toronto, 2014*

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 *refurbishment* 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 opportune 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.

ACROSS THE 45 CHAMPION CITIES, CATALYSTS FOR DISTRICT ENERGY INCLUDED:

CATALYST	EXAMPLES
Fuel poverty	Case study 3.2 on **London** See online case study on **Vilnius**
Reduction in electricity consumption at peak	Case study 3.12 on **Port Louis**
Energy intensity targets	**Hong Kong** in table 2.2
Air emissions	Case study 3.7 on **Anshan**
Extreme weather events or natural disasters	Earthquake in **Christchurch** See section 2.3.3
Waste management	Case study 3.3 on **Bergen** **St. Paul** in table 1.1
Geopolitical events affecting energy prices	**Växjö** in section 1.4.2 See online case study on **Velenje** **Copenhagen** in table 1.4
Public works	Case study 3.5 on **Toronto**
New-area development or redevelopment	Case study 3.6 on **Dubai**
Industrial activity	Case study 2.15 on **Rotterdam**
Urgent maintenance on existing systems	Case study 2.5 on **Botosani**
HVAC cycle	See online case study on **Seattle**
Availability of international finance and capacity-building programmes	Case study 4.4 on **Yerevan**
Energy efficiency in buildings	**Amsterdam** in table 2.2
100% renewables targets	**Frankfurt** in table 2.2

For additional discussion, see section 1.6.

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 CO_2; 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 CO_2 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.

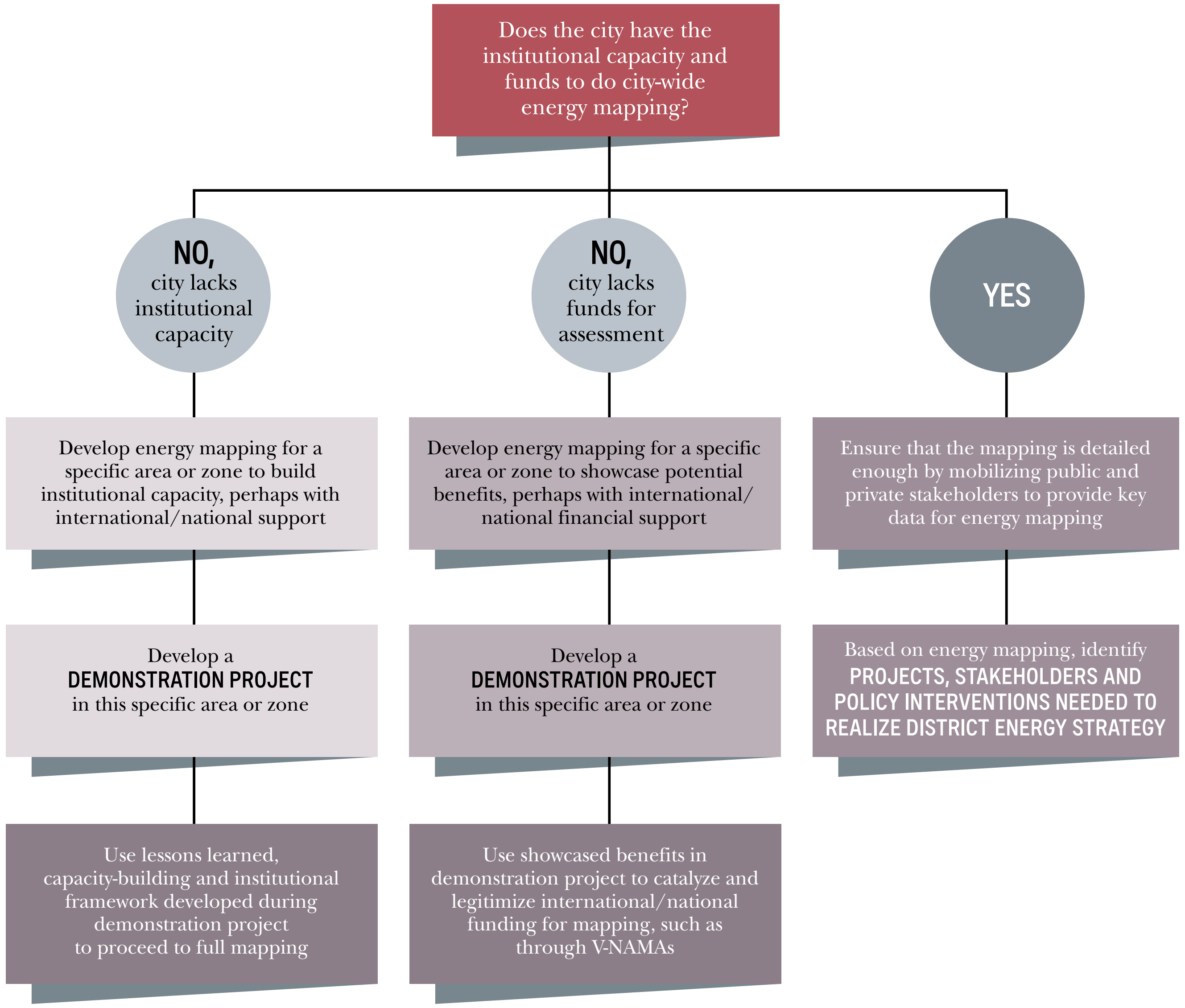
5.3.2 ENGAGE IN ENERGY MAPPING

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 map 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 3.12 on Port Louis).
- Consider seeking funding for demonstration projects at the national or international level, such as through V-NAMAs (see section 4.3), development bank grants and EU structural funds (see section 2.3), as long as the potential benefits for the project (CO_2 mitigation; demand reduction, etc.) are highlighted (see case study 4.4 on Yerevan).
- 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 stepwise 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



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 CO_2, fossil fuels or pollutants such as SO_2, NO_X 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 taxes. Such benefits are critical to the leveraging of finance from national or international funds. With regard to the benefit associated with CO_2 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.

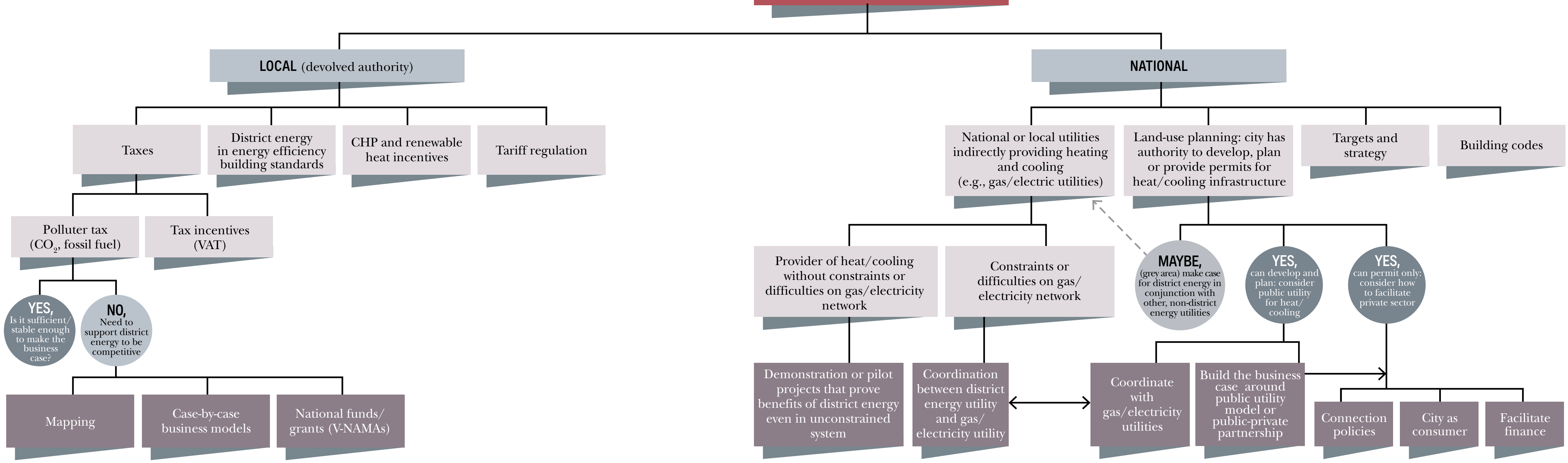
Cities will often need to collaborate with national or regional utilities that are indirectly responsible for heating and cooling (such as those providing electricity for air conditioning). This collaboration will be dependent on how heating and cooling currently affects their business model, such as 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 Norway). 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.

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



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 5.3). 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 comprises 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/countries. Twinning 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.

FIGURE 5.3 Key steps in developing a district energy system

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

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 response will depend on local conditions, including a city's social, 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 powers in 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, as has been done 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 ensuring 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 Agen-cy; partnering with the private sector to leverage their expertise (e.g., Anshan); and developing demonstration projects (e.g., Vancouver).

■ **COORDINATION AND COOPERATION BETWEEN MULTIPLE STAKEHOLDERS AND INTERESTS:** A strong – often public – champion is required to develop a customer base 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 centres.

■ **HIGH COST OF FEASIBILITY STUDIES:** A local authority runs high risk 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., Łódź; Velenje) or designate district energy high-priority and opportunity zones (e.g., Vancouver's Neighbourhood Energy Strategy, Hong Kong's district cooling zones, Singapore's district cooling zone in Marina Bay). 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 sufficient demand. Local governments can also provide loan guarantees, as in Aberdeen; leverage international finance, as in Botosani; or develop a revolving fund to reduce the costs of finance, particularly for projects that have high public benefit, as in Toronto.

■ **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 have 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 of the specific decisions and measures associated with the establishment of a given system can and must be made at a local level, coherent and coordinated multi-level 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 encounter difficulties in developing countries due to 1) the delay in building up local capacity and 2) the delay in devolving financial sources (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 the less beneficial option. 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.

5.7 FURTHER AREAS OF RESEARCH

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.

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LIST OF INTERVIEWEES, SURVEY RESPONDENTS AND WORKSHOP PARTICIPANTS

INTERVIEWEES AND SURVEY RESPONDENTS

ABERDEEN, SCOTLAND, U.K.: **Michael King** (Carbon Trust)

AMSTERDAM, THE NETHERLANDS: **Ger Baron** (Amsterdam Economic Board); **Frodo Bosman, Bob Mantel** and **Stef Le Fèvre** (City of Amsterdam)

ANSHAN, CHINA: **Alfred Che Wei** and **André Hansen** (Danfoss China)

ARLINGTON COUNTY, VIRGINIA, USA: **Rich Dooley** (Arlington County Department of Environmental Services)

AUSTIN, TEXAS, USA: **Lucia Athens** (Office of Sustainability, City of Austin)

BELO HORIZONTE, BRAZIL: **Anna Maria Louzada** and **Drummond Nogueira**

BERGEN, NORWAY: **Øystein Haaland** (University of Bergen); **Alexander Svanbring** (BKK Varme AS)

BONTANG CITY, BORNEO, INDONESIA: **Fakhrie Wahyudin** (Regional Development Planning Board of Bontang City)

BOSTON, MASSACHUSETTS, USA: **Bradford Swing** (City of Boston, Office of the Mayor, Environment, Energy and Open Space)

BOTOSANI, ROMANIA: **Ovidiu Iulian Portariuc** (City of Botosani); **Alexander Sharabaroff** (International Finance Corporation)

BREST, FRANCE: **Bernard Debano** and **Gilles Le Guevel** (Dalkia Utilities Services Plc); **Pierre-Yves Clavier** and **Alain Masson** (City of Brest)

CAPE TOWN, SOUTH AFRICA: **Mark Borchers** (Sustainable Energy Africa); **Marco Geretto, Brian Jones** and **Sarah Ward** (City of Cape Town)

CHRISTCHURCH, NEW ZEALAND: **Tim Taylor** (Energy Efficiency and Conservation Authority, City of Christchurch)

COCHIN, INDIA: **Tony Chammany** (Cochin Municipal Corporation)

COPENHAGEN, DENMARK: **Jørgen Abildgaard** (City of Copenhagen); **Anders Dyrelund** (Rambøll Energy Denmark); **Mette Reiche Sørensen** (Aalborg University)

DUBAI, UNITED ARAB EMIRATES: **Camille Ammoun** (Dubai Executive Council); **Ahmad Bin Shafar** and **Samer Khoudeir** (Empower)

ETHEKWINI MUNICIPALITY, DURBAN, SOUTH AFRICA: **Susanna Godehart** and **Derek Morgan** (Energy Office, eThekwini Municipality)

FORT MCMURRAY, CANADA: **John W. McKay** (Regional Municipality of Wood Buffalo)

FRANKFURT, GERMANY: **Paul Fay** (Municipal Energy Agency, City of Frankfurt)

GENOA, ITALY: **Pietro Libbi, Marie Merello** and **Gloria Piaggio** (Office of Energy Planning, City of Genova)

GIFT CITY, INDIA: **Emani Kumar** (ICLEI – South Asia); **Laxmi J Rao** (MIT)

GUELPH, ONTARIO, CANADA: **Alex Chapman** (City of Guelph); **Rob Kerr** (Guelph Municipal Holdings Inc.)

GÜSSING, AUSTRIA: **Joachim Hacker** and **Michaela Skolnik** (European Centre for Renewable Energy Güssing GmbH); **Vinzenz Knor** (City of Güssing)

GOTHENBURG, SWEDEN: **Patrik Arvsell, Jonas Cognell, Bengt Göran Dalman** and **Helena Nordström** (Göteborg Energi); **Maja Högvik** (City of Gothenburg)

HELSINKI, FINLAND: **Petteri Huuska** (City of Helsinki); **Marko Riipinen** (Helen Group)

HONG KONG, CHINA: **CY Ma** (Electrical and Mechanical Services Department, Hong Kong Special Administrative Region)

IRAN (SEVERAL CITIES): **Saba Zardkanlou** (Renewable Energy Organization of Iran)

IZMIR, TURKEY: **Sinan Arslan** (Izmir Geothermal Energy Corp.)

KERIO VALLEY DEVELOPMENT AUTHORITY (KVDA), KENYA: **Hisila Manandhar** (Architect/ Urban Planner)

KUWAIT CITY, KUWAIT: **Osamah Alsayegh** (Kuwait Institute for Scientific Research); **Abdulaziz Al-Shalabi** (Institute for Sustainable Resources, University College London); **Abdullatif Ben-Nakhi** (College of Technological Studies, Public Authority for Applied Education and Training colleges (PAAET), Kuwait)

ŁÓDŹ, POLAND: **Wiesław Adamski** and **Jarosław Głowacki** (Heat Distribution Network Department, Dalkia); **Mariusz Postół** (Technical University of Łódź)

LONDON, U.K.: **Celeste Giusti, Roberto Gagliardi La Gala** and **Peter North** (Greater London Authority); **Michael Liebreich** (Bloomberg New Energy Finance)

MARSTAL, DENMARK: **Lasse Kjærgaard Larsen** (Marstal District Heating)

MILAN, ITALY: **Pierfrancesco Maran, Marta Papetti, Laura Veronese** and **Bruno Villavecchia** (City of Milan)

MOGALE CITY, GAUTENG, SOUTH AFRICA: **Hester Huisamen** (Mogale City Local Municipality)

MUNICH, GERMANY: **Florian Bieberbach, Elisabeth Endres** and **Sonja Schmutzer** (Stadtwerke München GmbH)

NAIROBI, KENYA: **Rose Muema** (Nairobi City County)

NEW YORK CITY, USA: **John H. Lee** (New York City Mayor's Office of Long Term Planning and Sustainability)

OSLO, NORWAY: **Øystein Ihler** (Department of Environment Affairs and Transportation, City of Oslo)

PALO ALTO, CALIFORNIA, USA: **Lindsay Joye** (City of Palo Alto Utilities)

PARIS, FRANCE: **Sébastien Emery, Nicolas Savtchenko** and **Yann Françoise** (City of Paris); **Laurence Poirier-Dietz** (Climespace S.A.)

PORT LOUIS, MAURITIUS: **Fabiani Appavou** (Ministry of Environment and Sustainable Development, Mauritius)

RIYADH, SAUDI ARABIA: **Naif M. Alabbadi** and **Saad Almuhanna** (Saudi Energy Efficiency Center)

ROTTERDAM, THE NETHERLANDS: **Astrid Madsen** (City of Rotterdam)

SAN FRANCISCO, CALIFORNIA, USA: **Danielle Murray** (formerly San Francisco Department of the Environment; currently Austin Energy, City of Austin)

SAN JOSÉ, COSTA RICA: **Huberth Méndez Hernández** (FUDEU-CR); **Manuel Salas** (Vector Green)

SANTIAGO DE CALI, COLOMBIA: **Martha Cecilia Landazábal Marulanda** and **Sindy Nova Pérez** (Santiago de Cali Administrative Department of Environmental Management – DAGMA)

SEATTLE, WASHINGTON, USA: **Christie Baumel** (Office of Sustainability and Environment, City of Seattle); **Brad Bradford** (International District Energy Association)

SEOUL, SOUTH KOREA: **ChoongYeol Peter Ye** (Korea Transport Institute)

SINGAPORE: **Eric Yee Lik Chang** and **Tjong Kiun Jin** (Energy Market Authority of Singapore)

SONDERBORG, DENMARK: **Nicolas Bernhardi** and **Peter Rathje** (ProjectZero); **Morten Kragh** (LINAK A/S)

ST. PAUL, MINNESOTA, USA: **Ken Smith** (District Energy St. Paul)

SYDNEY, AUSTRALIA: **Chris Derksema** (City of Sydney)

TOKYO, JAPAN: **Yuko Nishida** (Bureau of Environment, Tokyo Metropolitan Government)

TORONTO, ONTARIO, CANADA: **Fernando Carou** (Environment & Energy Division, City of Toronto); **Jose Etcheverry** (York University, Sustainable Energy Initiative); **Rob McMonagle** (Green Economy Sectors Development Office, City of Toronto)

VANCOUVER, BRITISH COLUMBIA, CANADA: **Chris Baber** and **Kieran McConnell** (Neighbourhood Energy Utility, Vancouver); **Sadhu Johnston** (City of Vancouver); **Ted Sheldon** (Climate Action Secretariat, Ministry of Environment, Province of British Columbia)

VÄXJÖ, SWEDEN: **Henrik Johansson** (City of Växjö); **Johan Saltin** (Växjö Energi AB)

VELENJE, SLOVENIA: **Peter Virtič** (University of Maribor); **Boštjan Krajnc** (KSSENA, Energy Agency of Savinjska, Šaleška and Koroška Region)

VILNIUS, LITHUANIA: **Vytautas Stasiunas** (Lithuania District Heating Association)

WARSAW, POLAND: **Leszek Drogosz** and **Marcin Wróblewski** (Infrastructure Department, Warsaw City Hall)

WELLINGTON, NEW ZEALAND: **Nigel Taptiklis** (Wellington City Council)

WOKING, U.K.: **John Thorp** (Thamesway Energy)

YEREVAN, ARMENIA: **Diana Harutyunyan** and **Marina Sargsyan** (United Nations Development Programme – Armenia); **Michael Rustamyan** (ArmRusCogeneratsia – CJSC)

WORKSHOP PARTICIPANTS

"DON'T WASTE THE WASTE: HARNESS WASTE STREAMS, REJECT HEAT AND RENEWABLES THROUGH DISTRICT ENERGY"

WORKSHOP HOSTED BY UNEP, UN-HABITAT AND ICLEI AT THE WORLD URBAN FORUM 7, MEDELLIN, COLOMBIA, 9 APRIL 2013

Chris Baber, Neighbourhood Energy Utility Manager, City of Vancouver, Canada

Carl Bernadac, Deputy Director, Regional Office for Andean Countries and Energy Senior Specialist, Agence Française de Développement (AFD)

Marco Geretto, Spatial Planning & Urban Design Department, City of Cape Town, South Africa

Kalle Hashimi, Chief of Capacity Building, International Renewable Energy Agency (IRENA)

Arab Hoballah, Chief, Sustainable Consumption and Production, UNEP

Rose Muema, Chief Officer, Urban Planning & Housing, Nairobi City, Kenya

Mary Jane Ortega, Regional Director for South America, ICLEI

Stéphane Pouffary, Chief Executive Officer, ENERGIES 2050

Konrad Ritter, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

David Wilks, Lead Climate Change Specialist, Inter-American Development Bank

"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, UN CITY, COPENHAGEN, DENMARK, 17 JUNE 2014

Roberto Gagliardi La Gala, Senior Project Officer, Transport and Environment, Greater London Authority

Mia Nordström, Business Strategy, Regional Development Lead, Vattenfall

Johan Saltin, Växjö Energy

Maryke van Staden, Low Carbon Cities Program Manager, Director of the carbonn Center, ICLEI

Fleming Voetmann, Head of Public Affairs & Leadership Communication, Danfoss District Energy

Paul Voss, Managing Director, Euroheat & Power

GLOSSARY

ABSORPTION CHILLER. A refrigeration machine that uses heat energy to generate chilled water. "Direct-fired" absorption chillers use fuel to produce heat, which then produces cool. "Indirect-fired" chillers use waste heat, such as from power stations, to produce cool. Absorption chillers do not use HCFCs.

ANCHOR LOAD. A heat or cooling demand that is significantly large, predictable and (often) nearly continuous. Used to help initiate initial district energy development due to long-term guarantee of demand. Many are publicly owned buildings and can include hospitals, government buildings, leisure centres, stadiums and data centres.

ANCILLARY SERVICES. Services necessary to maintain reliable power supply due to short-term fluctuations in expected demand and supply. They include rapid dispatch and voltage control.

BASELOAD GENERATION. Generation that provides heat, cooling or power for the steady minimum load (baseload) of the energy system due to its ability to continuously supply energy and its cost-competitiveness with other technologies.

BIOGAS. Gas created from the breakdown of organic matter in the absence of oxygen that is used as a replacement for natural gas.

BOILERS. A technology used to heat water for a district heat network. Boilers use fossil fuels, biomass, biofuels (including biogas) and electricity. They provide backup capacity in case of equipment failure, and help meet peak demand. Boilers can provide baseload generation in some cases.

BOND. A financial product in which an investor loans money to a government or corporation that borrows the money for a defined period of time at a fixed interest rate.

CAPACITY PAYMENT. Payment made in some electricity markets to generators to keep power plants available.

CAPITAL EXPENDITURE (CAPEX). Upfront costs that bring a project to market. For a district energy system, these include development costs, pipes and network, thermal plant and storage.

COEFFICIENT OF PERFORMANCE (COP). The ratio of heating or cooling provided to electrical energy consumed. This will depend on exact operating conditions, and thus the EER is often used in conjunction with the COP, or multiple COPs at various operating conditions.

COMBINED HEAT AND POWER (CHP) PLANT (OR TRI-GENERATION). A power plant that is capable of utilizing excess heat produced in power production for an external process such as district heating.

COMBINED COOLING, HEAT AND POWER (CCHP) PLANT. A power plant that is capable of utilizing excess heat produced in power production for an external process such as district heating, but that can also use heat to produce cooling for an external process such as district cooling if needed.

COMPACT LAND USE. Planning an urban area to maximize utility of land through high densities. Compact land use helps prevent urban sprawl and leads to reduced infrastructure costs and demand.

CONNECTION POLICY. A policy used to encourage connection of consumers in order to create a minimum level of absolute load certainty for the district energy system.

CONSOLIDATION CITIES. Cities in which district heating and cooling systems have reached a very mature, almost saturated market share above 50 per cent.

DEMONSTRATION PROJECT. Testing of a new technology or policy that relates to district energy. Such projects often have strong public sector support due to the widespread benefits and technology acceleration that they can achieve.

DEVELOPMENT-BASED LAND-VALUE CAPTURE (DB–LVC). Capturing the land-value increase as land is urbanized to finance infrastructure investment.

DISCOUNT RATE. The interest rate used in discounted cash-flow analysis to determine the present value of future cash flows. The discount rate takes into account the time value of money as well as the risk and uncertainty of future cash flows.

DISTRICT ENERGY/ DISTRICT ENERGY SYSTEMS. The provision of thermal energy at a district level through district heating and/or district cooling.

DISTRICT HEATING. The system by which hot water or steam is pumped through pipes around a "district" to meet heat demand. Heat is produced at large centralized energy centres in a more efficient process than decentralized heat production.

DISTRICT COOLING. The system by which cold water is pumped through pipes around a "district" to meet cooling demand, replacing air conditioning and building-level chillers. Cold water is produced at large centralized energy centres in a more efficient process than decentralized cool production.

ELECTRIC CHILLER. An electricity-driven compression chiller that can produce cooling. The economies of scale of large-scale chillers (up to 10,000 refrigeration tons) mean that they have a higher EER and may use HCFCs with lower GWPs than decentralized production. Large machines are connected into district cooling systems.

ENERGY EFFICIENCY RATIO (EER). The ratio of the cooling capacity of a chilling machine to the total electrical input under certain specified tests. These specified tests seek to identify the most likely efficiency of the machine under normal conditions rather than the maximum efficiency (which may be specified as the COP).

ENERGY LABEL OR BUILDING ENERGY CERTIFICATE. A certificate or label that classifies a building's energy efficiency by grading the thermal efficiency of the building, but it may also include the primary energy efficiency of heat supplied to the building.

ENERGY MAPPING. Mapping of a city's local heating or cooling demand in order to understand current and future energy use, infrastructure, emissions and available resources. Mapping can also incorporate land-use and infrastructure planning in order to best plan district energy systems.

ENERGY TRANSFER STATION (ETS). An interconnection between the district energy system and the consumer's hot water or chilled water system through a heat exchanger. This means that the district energy system (primary circuit) does not flow throughout each building, and the thermal energy is transferred to a building's secondary circuit.

EXERGY. The potential for useful mechanical work. High-exergy fuels include coal, biofuels and natural gas. Low-exergy energy sources include low-temperature waste heat from industry.

EXPANSION CITIES. Cities where district heating and cooling systems appear in some areas, but the total market share remains low (15–50 per cent).

FEASIBILITY STUDY. A study that is used to assess the economic and technical viability of a project.

FEED-IN TARIFF. Payment per unit of energy produced made to a generator, which is designed to replace any market price received. A feed-in tariff is used to provide more certainty than a wholesale energy price and to subsidize a technology.

FREE COOLING. The utilization of low-temperature sources such as aquifers, rivers, lakes and seas to provide cooling to district cooling networks.

GEOGRAPHIC INFORMATION SYSTEM (GIS). Computer software designed to analyse, manage and present geographical data. In district energy, it is used in energy-mapping exercises.

GEOTHERMAL ENERGY. Capturing the internal heat of the earth to provide heat for power or heating. Due to the large-scale nature of geothermal, it is often used for heat provision with district heating.

GLOBAL WARMING POTENTIAL (GWP). An index that identifies the overall climate impacts of a specific emission (e.g., HCFCs) and relates the impact of that emission to the emission of an equivalent mass of CO_2.

HEAT EXCHANGER. Equipment used to extract thermal energy from one system and to transfer it into another system while keeping flows of water/steam separate.

HEAT PUMP. Equipment that uses electricity to extract energy from a low-temperature heat source to provide high-temperature heat.

HYDROCHLOROFLUOROCARBON (HCFC). A refrigerant used worldwide in refrigeration and air conditioning that is being phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer because it depletes stratospheric ozone.

HYDROFLUOROCARBON (HFC). A refrigerant used to replace HCFCs in electric chillers. HFCs do not deplete the stratospheric ozone layer, but many have high GWP, making it critical to phase out HFCs in cooling.

HYDRONIC HEATING OR COOLING. Heating or cooling systems based on water circulation around a building.

INTERNAL RATE OF RETURN (IRR). The discount rate that makes the net present value of all cash flows from a particular project equal to zero. The higher the IRR of a project, the more desirable it is for investment.

JOINT COOPERATION AGREEMENT (JCA). A business model where the private sector and local authority sign agreements for mutual benefit in a district energy scheme relating to tariffs, connection policies and energy sources. Often called a Strategic Partnership Model.

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED). An internationally recognized 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 useful for district energy because the load is more varied, and hence smoother.

NATIONALLY APPROPRIATE MITIGATION ACTIONS (NAMAS). Any 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 also may encompass policies, strategies and research programmes that lead to longer-term emissions 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 starter networks or demonstration projects envisioned.

NODAL DEVELOPMENT. The initial development of district energy in segregated "nodes" within a city, which consist of small networks. These nodes can then be interconnected in the future.

OPERATIONAL EXPENDITURE (OPEX). The running costs of a project after initial development and construction. For a district energy system, these include: fuel, operation, maintenance, local and state taxes, electricity, insurance, water, chemicals, service contracts for primary equipment and management of projects.

REFRIGERATION TON (RT), OR TON OF REFRIGERATION (TR). A unit of power, approximately equivalent to 3.51 kW, used to describe the heat-extraction capacity of cooling equipment.

REFRIGERATION TON-HOUR (RTH). A unit of cooling energy, approximately equivalent to 3.51 kWh, that refers to one TR of cooling capacity producing cooling for one hour.

RESIDENTIAL EQUIVALENT UNIT (REU). A unit of energy consumption 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 m^2 of commercial or industrial floor space.

REFURBISHMENT CITIES. Cities where district heat has high market shares, but the systems need some refurbishment in order to increase customer confidence, energy efficiency and profitability.

RENEWABLE ENERGY CERTIFICATE (REC). A subsidy scheme where generators are provided with a certificate per unit of renewable energy generation. Certificates have a market value and are received in addition to the market energy price.

RETAIL ELECTRICITY PRICE/ RETAIL RATE. The electricity price paid by consumers of electricity, which includes generation, transmission and distribution costs.

RETURN ON INVESTMENT (ROI). A financial metric that is dependent on both a project's Internal Rate of Return (IRR) and its Weighted Average Cost of Capital (WACC), and that indicates the profits that a project will receive.

REVOLVING FUND. A financing mechanism often initiated from public funds to support strategic investments without necessitating direct public ownership. The fund helps bring projects to completion and then may exit projects to recapitalize the fund so that it can be redeployed to other projects.

SOLAR THERMAL. A renewable energy technology that produces useful heat from the energy of the sun. Large-scale solar thermal can be connected into district heat networks.

SPECIAL PURPOSE VEHICLE (SPV) OR SUBSIDIARY. A project financing tool that creates a separate company to own the project, separating 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 of heat or cool to be stored and utilized in the future.

WASTE HEAT. Any heat source that is not normally utilized to its full potential, as it typically requires infrastructure to connect it (e.g., waste heat from power stations, steel mills, transport and incinerators).

WASTE-TO-ENERGY OR WASTE INCINERATION. Burning of municipal solid waste to reduce waste going to landfill and also to produce useful energy for electricity and/or heat generation. The heat produced can be fed into a district energy network.

WEIGHTED AVERAGE COST OF CAPITAL (WACC). The proportionally weighted cost of various debt provided to the project as well as equity and its required return. WACC essentially represents the interest to be paid by the project on the initial investment.

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LIST OF ACRONYMS

ADB	Asian Development Bank
AfDB	African Development Bank
ASC	Amsterdam Smart City
APEC	Asia-Pacific Economic Cooperation
BAPPENAS	Ministry for National Development Planning (Indonesia)
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
C2E2	Copenhagen Centre on Energy Efficiency
CAD	Canadian dollars
CAPEX	capital expenditure
CBD	Central Business District
CCHP	combined cooling, heat and power
CHP	combined heat and power
CNY	Chinese yuan
COP	coefficient of performance
CPCU	Paris Urban Heating Company
DB-LVC	Development-Based Land-Value Capture
DBSA	Development Bank of Southern Africa
DEA	Department of Environmental Affairs (South Africa)
DEMaP	Decentralised Energy Master Planning (United Kingdom)
DEPDU	Decentralised Energy Project Delivery Unit (United Kingdom)
DEWA	Dubai Energy and Water
DoE	Department of Energy (South Africa)
DPW	Department of Public Works (South Africa)
EER	energy efficiency ratio
EIB	European Investment Bank
ELENA	European Local Energy Assistance
ESCO	energy service company
ETS	energy transfer station
EU	European Union
GEF	Global Environment Facilty
GIFT City	Gujarat International Finance Tec-City
GIS	geographic information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLA	Greater London Authority
GW	gigawatt
GWh	gigawatt-hour
GW_{th}	gigawatt-thermal
GWP	global warming potential
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HRBEE	Heat Reform & Building Energy Efficiency project (China)
ICLEI	International Council for Local Environmental Initiatives
IEA	International Energy Agency
IFC	International Finance Corporation
IKI	International Climate Initiative
IMAR	Inner Mongolia Autonomous Region (China)
IRR	Internal Rate of Return
JCA	Joint Cooperation Agreement
KLH	Ministry of Environment (Indonesia)
kWh	kilowatt-hour
LEED	Leadership in Energy and Environmental Design
LNG	liquefied natural gas
LTL	Lithuanian lita
MRV	measurable, reportable and verifiable
MUR	Mauritian rupee
MW	megawatt
MW_{el}	megawatt-electric
MWh	megawatt-hour
MW_{th}	megawatt-thermal
NAMA	Nationally Appropriate Mitigation Action
NDRC	National Development and Reform Commission (China)
NOK	Norwegian krone
NPV	net present value
ODA	Olympic Development Authority (United Kingdom)
OPEX	operational expenditure
PLN	Polish złoty
PPA	power purchase agreement
PU	Ministry of Public Works (Indonesia)
PV	photovoltaic
REC	renewable energy certificate
REN21	Renewable Energy Policy Network for the 21st Century
REU	residential equivalent unit
ROI	return on investment
RT	refrigeration ton
SE4ALL	Sustainable Energy for All
SEFA	Sustainable Energy Fund for Africa
SEFC NEU	Southeast False Creek Neighbourhood Energy Utility
SPV	special purpose vehicle
SWAC	Sea Water Air Conditioning
TAF	Toronto Atmospheric Fund
TDHC	Toronto District Heating Corporation
TSE	treated sewage effluent
TWh	terawatt-hours
UAE	United Arab Emirates
UK	United Kingdom
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
V-NAMA	Vertically Integrated Nationally Appropriate Mitigation Action
VAT	value-added tax
WACC	weighted average cost of capital

DISTRICT ENERGY IN CITIES

Unlocking the Potential of Energy Efficiency and Renewable Energy

www.unep.org
United Nations Environment Programme
P.O. Box 30552 Nairobi, Kenya
Tel.: ++254-(0)20-762 1234
Fax: ++254-(0)20-762 3927
E-mail: uneppub@unep.org
UNEP

"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 endeavouring 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 tactics from peer cities as they move forward with district energy."*

Katrina Pielli, Senior Policy Advisor, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy

"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."*

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

"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 challenge of supplying low-carbon heat to the urban environment as a necessary element of the general energy transition, it provides highly practical advice and analysis for policymakers on how this can be achieved. An elegant demonstration of the value of thinking globally while acting locally, UNEP's effort to drive the emergence of district energy as a solution for cities is the right initiative at the right moment!"*

Paul Voss, Managing Director, Euroheat & Power

For more information, contact:
UNEP DTIE
Energy Branch
15 rue de Milan
75441 Paris Cedex 09, France

Email: unep.tie@unep.org
www.unep.org/energy/des

For the full report, please visit www.unep.org/energy/des