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.

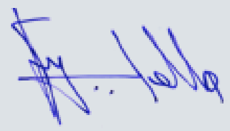
The UNEP report ***District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy*** identifies modern district energy as the most effective approach for many cities to transition to sustainable heating and cooling, by improving energy efficiency and enabling higher shares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

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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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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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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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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).

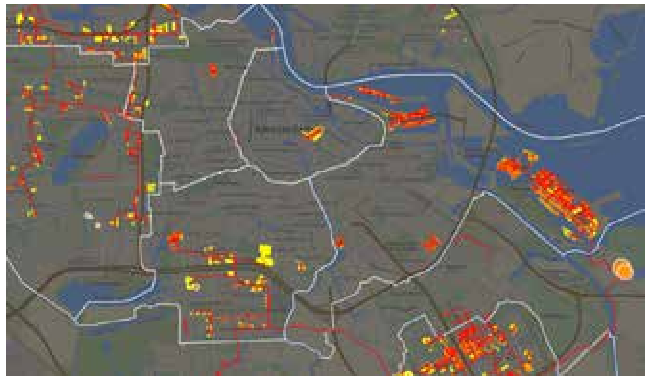
Integrated energy planning and mapping, supported by a designated coordination unit or a public-private partnership, is a best practice to identify synergies and opportunities for cost-effective district energy and to apply tailored policies or financial incentives within different areas of a city. Through 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).

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

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.