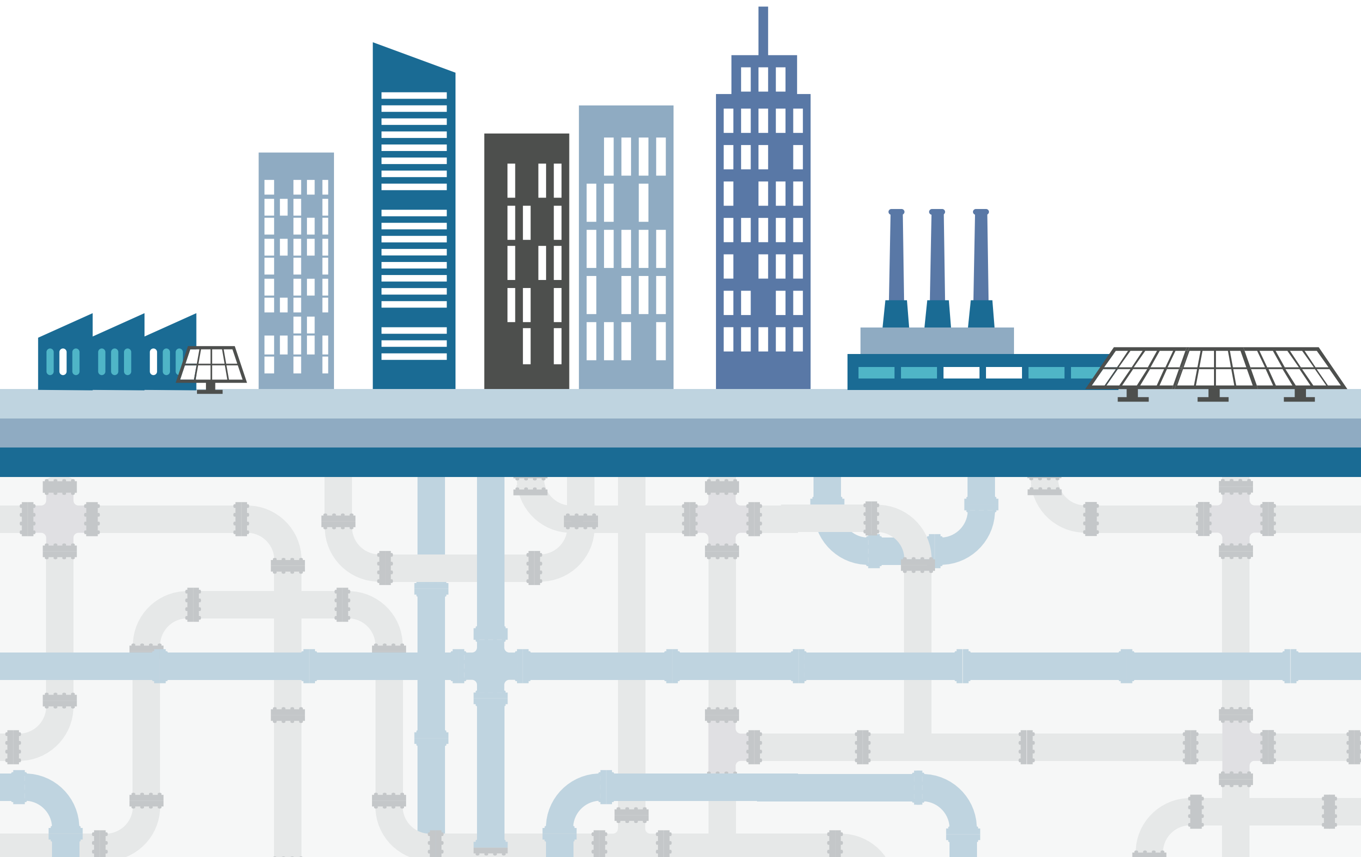
RENEWABLE ENERGY IN DISTRICT HEATING AND COOLING

EXECUTIVE SUMMARY



REmap
A Renewable Energy Roadmap

March 2017

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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Most countries could scale up renewable energy substantially in district heating and cooling.

Around the world, a switch to renewable energy sources for centralised heating and cooling can help meet rising urban energy needs, improve efficiency, reduce emissions and provide cost-effective temperature control.

A switch to renewable energy sources for district heating and cooling (DHC)[1] can help meet rising urban energy needs, improve efficiency, reduce emissions and provide cost-effective temperature control. In the right conditions, DHC offers a cost-effective and energy efficient option for residential and commercial buildings. However, DHC supply is currently dominated by fossil fuels, such as coal and gas. There is significant potential to upgrade existing systems and create new networks using solid biofuels, solar[2] and geothermal technologies, with significant benefits for energy security, human health and climate change mitigation.

Only a few countries have taken advantage of their renewable resource potential for DHC or created policies to promote further uptake. Those with policies promoting renewable-based district heating include Denmark, Sweden and Switzerland. Denmark, with ambitious decarbonisation policies already uses high shares of renewables in DHC. Otherwise, renewable DHC still plays a modest role in most countries.

To drive future growth, a better understanding is needed of the potential for renewables in DHC, as well as their costs and benefits. This study examines the current status of renewable DHC systems in nine countries. It quantifies the potential, costs, benefits and investments required to ramp up renewables in these systems to 2030, in line REmap, the global roadmap from the International Renewable Energy Agency (IRENA). The global renewable energy roadmap (REmap) programme charts a pathway double the share of renewables in the world's energy mix by 2030.

The nine countries examined here – China, Denmark, Germany, Poland, Switzerland, Japan, the United States (US), Kuwait and the United Arab Emirates (UAE)[3] – together accounted for some 40% of the total energy used in DHC across the world in 2015. These countries represent both cold and hot climates, high and low population densities, and various patterns of historic growth in energy demand. They also vary greatly in their current use of DHC, the share of energy supplied by renewables, existing policies and plans for renewable-based DHC, and costs for renewable energy technologies.[4] Technology options for each market up to 2030 were assessed by IRENA based on data collected from national experts and other credible

1 Throughout this report, DHC is defined as the centralised heating or cooling of water, which is then distributed to multiple buildings through a pipe network.

2 Throughout the report, the solar thermal systems discussed relate to solar thermal installations only. Heat from heat pumps powered by solar photovoltaic (PV) panels is not considered.

3 For each country, either district heating, district cooling or both district heating and cooling is considered. Countries are ordered accordingly throughout the report.

4 For Japan and the US, the potential for renewables in both district heating and district cooling was assessed; for Kuwait and the UAE, district cooling only was assessed; for the others, only the potential for district heating was assessed.

third-party resources, such as those from project developers, technology licensors and other relevant stakeholders.

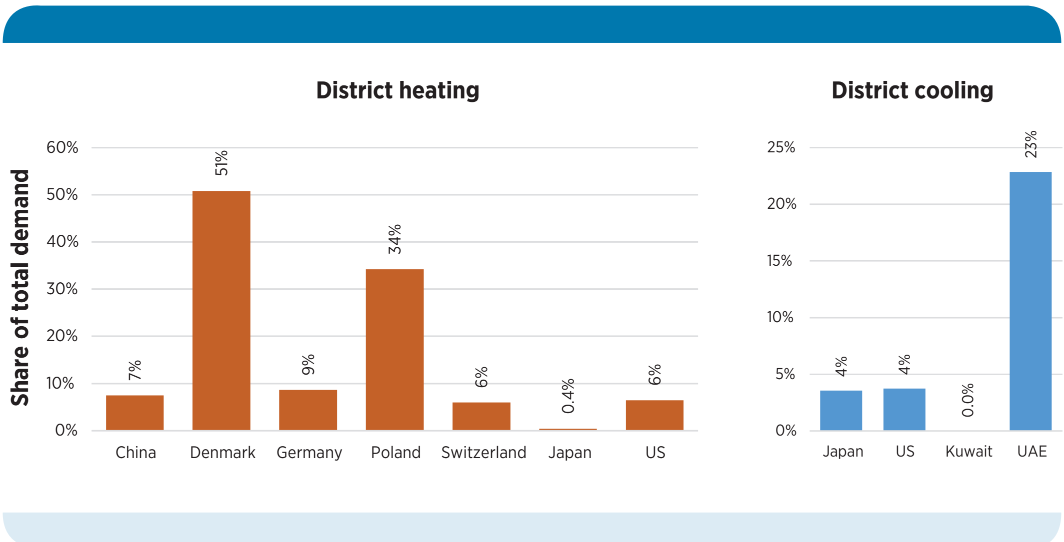
Case studies from 21 projects around the world reveal insights based on actual experience of deploying renewable DHC. These case studies have informed a detailed exploration of barriers, along with policy-making and project development opportunities. Based on this information, the study identifies key action areas for national and city policy makers to scale up renewables in DHC.

While demand for DHC varies widely according to climate, history and population density, the sector already forms a large part of energy use in some countries.

Heating and cooling is required throughout the year, but demand depends on climate conditions. In cold climates, home heating in winter accounts for the majority of energy use in buildings. In hot climates, cooling is needed in the summer months, with demand in emerging cities rising fast. In every region, hot water is needed throughout the year. In most countries, these needs are met by decentralised heating or cooling systems, such as boilers or air conditioners, installed in buildings.

Some countries have used centralised DHC systems for many decades. In former Soviet states and across northern Europe, DHC has long been widespread. In Denmark, Poland and parts of Germany, much of the existing building stock is connected to district heating networks. Centralised systems cover up to half of Denmark's heating demand and nearly a third of Poland's. In other countries, such as Japan and the US, district heating predominantly serves commercial and industrial users.

Figure ES1: Share of final annual heating and cooling demand met by DHC, 2014



Based on IRENA estimates

Only a few countries use district cooling systems on a large scale. Air conditioners remain the dominant cooling technology everywhere. District cooling systems are becoming more common in some European cities, like Helsinki, Paris and Stockholm. In hot climates, however, district-level systems offer even greater advantages. In the UAE, district cooling has grown to cover more than a fifth of the cooling load.

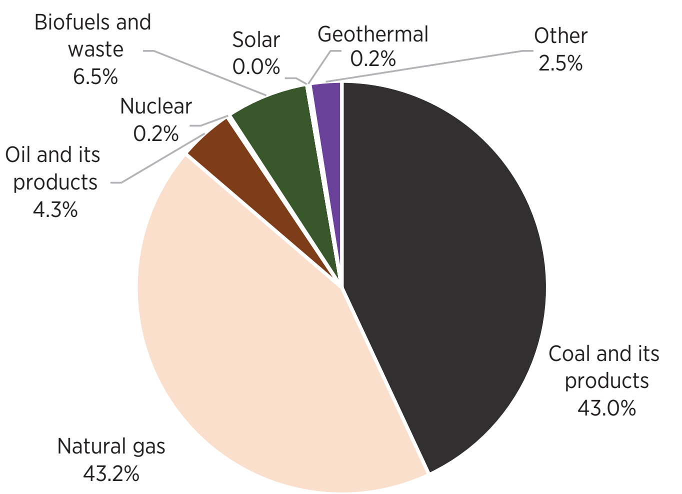
District systems can be a more efficient and cost-effective way to heat and cool urban areas. The economies of scale and increased generation efficiency associated with centralised production can significantly reduce costs. There is significant potential for DHC to help meet fast-growing energy demand in cities around the world.

Many countries envisage a growing role for DHC in their energy plans.

Today, in most countries, renewables account for only a minor proportion of the energy used in such systems. However, as this study shows, renewables could feasibly supply more than 20% of the energy needed for DHC within a few years, given the right policy and technology choices now.

Most DHC energy is currently provided by fossil fuels. Coal, for example, dominates the DHC energy mix in China, while natural gas is predominant in the US. In 2014, only about 5% of total district heat across the world was supplied from renewable energy.

Figure ES2: Breakdown of fuel use in DHC systems worldwide, 2014



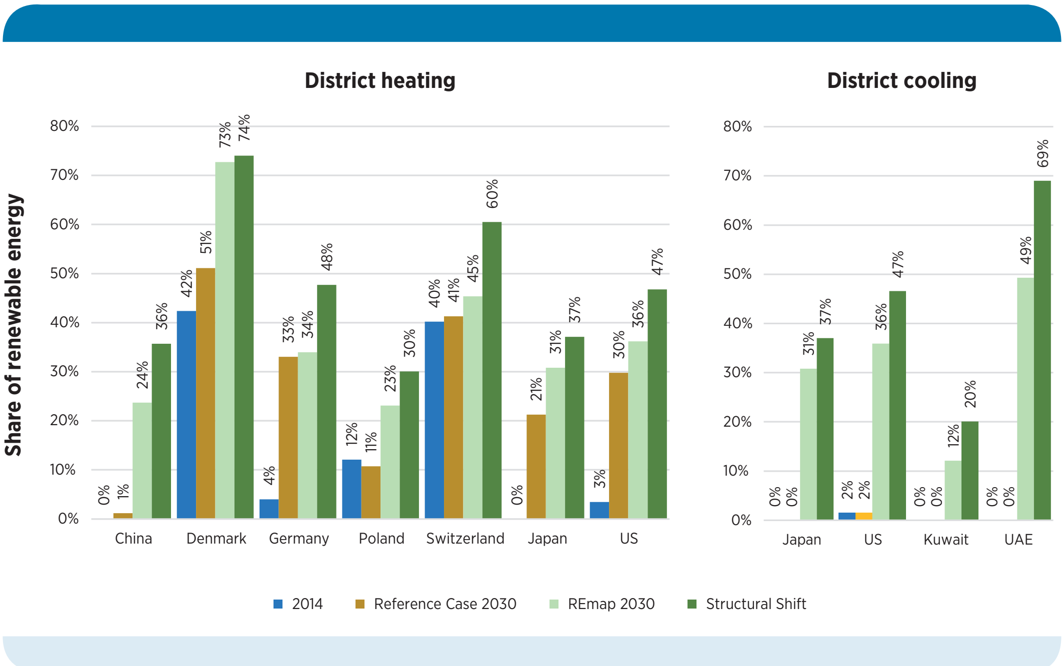
Source: International Energy Agency (IEA) (2016)

In a few countries, such as Denmark and Switzerland, renewable energy already provides more than 40% of district heat supply. When not based on fossil fuels, most district heating currently relies on waste and biofuels, with more limited roles for geothermal and solar heat. District cooling mostly uses electricity (for compression chillers) and natural gas (for absorption chillers). Renewable district cooling mainly involves free cooling schemes from nearby rivers, lakes and seawater.

This report examines the potential use of renewable energy in DHC up to 2030, based on three main technology pathways. The baseline "Reference Case" builds on the current national energy plans of each of the nine countries considered. The "REmap 2030" case includes the additional potential for renewables to be scaled up (in line with REmap) within the DHC capacity already planned, excluding any structural changes from decentralised to centralised systems. The third pathway, "Structural Shift", takes into account the potential for more DHC capacity and assumes all that new capacity can be supplied by renewable energy.

Most country plans foresee growing demand for district heating, but with only a moderate or static share of this coming from renewable energy sources. Germany is an exception, with district heating demand falling by 2030 because of ambitious energy efficiency improvements in the building sector. However, the share of district systems in total heating demand still rises, because the most energy savings are seen in buildings using decentralised systems. In the Reference Case, the renewable share of DHC moderately increases in several countries but

Figure ES3: Share of DHC generated using renewable heat



Based on IRENA estimates

is unchanged in others. District cooling use grows in the UAE, in particular. None of the other countries examined has considered renewables for district cooling in existing energy plans.

All nine countries assessed could increase the use of renewable energy in DHC. This potential was assessed for 16 renewable energy technology options (including solar, natural water, geothermal and biofuel solutions), taking account of technology costs, resource availability, land use and other criteria. Although renewable energy could theoretically satisfy all DHC demand in 2030, the realistic potential for deployment differs from country to country.

Findings for the **REmap 2030** case are as follows:

- **China**: The key market could realise a 24% renewable share in district heat generation, split equally between geothermal, bioenergy and solar. The further expansion of renewable energy is limited by recent additions of coal, which are expected to remain in the system for several decades.

- **Denmark:** An already high renewable share of 42% could reach 73%. The country will remain a global leader in large-scale solar energy, which can be expanded to meet 13% of total district heat demand by 2030, complemented by geothermal and bioenergy.

- **Germany:** Despite an overall decline in district heat demand, the expected addition of new heating networks allows the integration of more renewable energy capacity. REmap suggests a shift from bioenergy to geothermal (7% of district heating) and solar heat (6%), thereby diversifying supply to reach a renewable energy share of 34% by 2030.

- **Poland:** In the expected modernisation of ageing district networks, new coal-fired systems would satisfy just over half of its demand by 2030. Yet with different policies, renewables could contribute approximately a quarter of the total, predominantly through solid and gaseous biofuels.

- **Switzerland:** High electricity and natural gas prices up to 2030 create a favourable business case for renewable energy. The country's unutilised biomass resource could play an important role in the fuel mix by 2030 if biomass supply costs are competitive. Biomass would meet 27% of total district heating energy demand. Geothermal and solar district heating could be expanded further to cover 17% and 2% of total district heating demand, respectively, by 2030.

- **Japan:** Up to 30% of total DHC generation could be renewable-based by 2030. Bioenergy is expected to be the main resource for district heating, while solar energy and free natural cooling from water bodies will contribute to district cooling.

- **US:** Electric and absorption heat pumps are already cost-effective, and biomass resources are available in large quantities across the country. According to REmap, the share of renewables in district heating could rise to 36% by 2030. Natural water and solar cooling could contribute 14% and 22% of total district cooling demand, respectively.

- **Kuwait:** The country has significant potential for renewable-based district cooling, which could reach 12% of total generation, mainly from seawater.

- **UAE:** Specific policy targets, ample renewable resources and experience with clean technologies point to a promising future for renewable district cooling, which could rise to nearly half of cooling in the country under REmap.

The potential for a structural shift – *i.e.* adding new renewable-based DHC capacity – varies greatly by country. Denmark, with significant existing capacity, can only accommodate another 5%, while Switzerland could add about 30%. These differences largely reflect the projected penetration of DHC in the Reference Case; in some countries this reaches its limit, whereas in others significant additional potential remains.

The economic rationale for scaling up renewables in DHC becomes particularly compelling when the costs of pollution and carbon dioxide emissions are taken into account

Because of economies of scale, DHC is generally more cost-effective than decentralised systems. However, distribution infrastructure (including pipes and substations) constitutes a significant additional investment on top of generation costs. Overall cost-competiveness, therefore, depends partly on whether DHC uses existing networks or new capacity that requires new infrastructure. Centralised generation in existing networks costs 41% less than generation with new, decentralised capacity, analysis shows. Cost-competitive renewable energy options are available in many countries, especially with technologies using low-cost biomass residue as feedstock, and with geothermal heat and solar collectors. For district cooling, renewable options generally remain more expensive than conventional chillers in the countries evaluated, given the expected trends in energy prices to 2030.

The business case for increasing renewables in DHC hinges on technological diversification, as well as taking emissions reduction and health benefits fully into account. The REmap scenario for DHC comes with extra costs. If viewed in economic terms, reductions in carbon emissions and healthcare expenditure (due to avoided air pollution) entail savings, which can be maximised through the use of a diverse mix of renewable energy technologies. Many of these are expected to be more cost-effective by 2030 than their non-renewable counterparts. However, the REmap case, with its forward-looking policy and technology choices, also includes renewable energy technologies that might not yet be strictly cost-effective. In several countries, implementing the technology mix identified in REmap entails higher costs compared to the conventional approach.

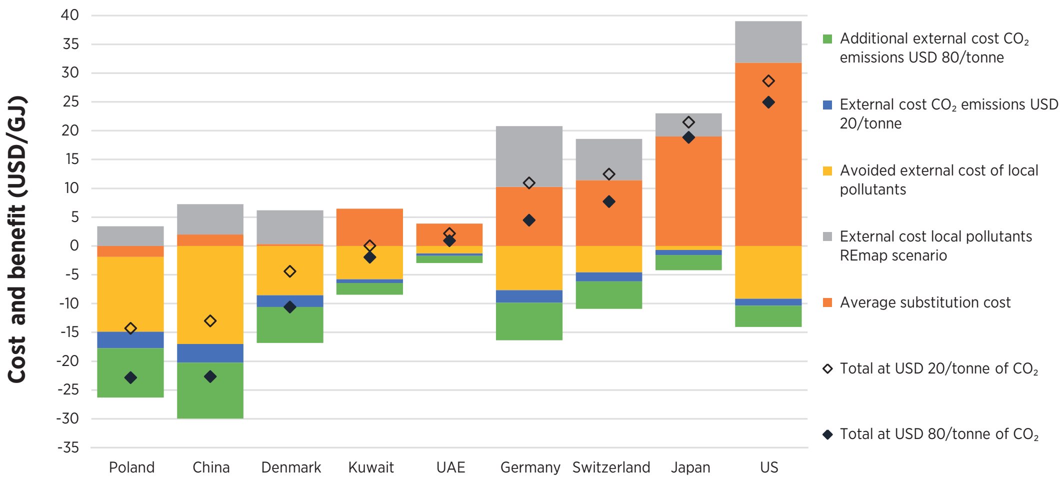
Increased solid biofuel use, notably, would add to the external costs of local air pollution from DHC systems if technologies fuelled with natural gas are replaced. Solid biofuel use, however, can be complemented with the deployment of other renewable energy and low-carbon technology solutions, such as heat pumps coupled with renewable power or biogas.

Only in Poland would the substitution of non-renewable with renewable district heating unambiguously reduce costs, even without examining externalities. This is mainly due to the assumed potential for cost-effective conversion of coal power plants to biomass. When reduction of costs from air pollution and carbon dioxide emissions is accounted for, REmap offers net savings in China, Denmark and Kuwait, as well as in Poland.

Investments in renewable energy capacity for DHC need to be scaled up significantly to capture the potential in the sector. Under existing plans and policies (Reference Case), average annual investment in renewable DHC capacity in the nine countries combined amounts to USD (US dollars) 1.4 billion between now and 2030. To achieve the additional renewable energy potential identified in REmap, this would have to increase to USD 9.6 billion per year. The Structural Shift pathway would require significantly higher investments, reaching USD 17.8 billion per year (excluding additional network investments of USD 6.6 billion per year).

Fulfilling the potential for renewable energy in DHC across the world requires annual investment of USD 90 billion between now and 2030. This represents about 12% of the total annual investment needed to double the share of renewables in the global energy mix. Additional investments in efficiency and DHC system modernisation could further increase the total needed. Those factors, however, are beyond the scope of the present study.

*Figure ES4: Additional costs and benefits of REmap options**



*Countries sorted according to rising net cost at USD 20 per metric tonne CO_2.
Based on IRENA estimates

Optimising system operation, achieving economies of scale, mitigating risks, integrating storage and holistic urban planning are all essential to accelerate the deployment of cost-effective DHC systems

Several key factors strengthen the business case for renewable-based DHC. First, optimised operation can greatly improve the cost-effectiveness of DHC systems. This implies sufficient demand for heating and cooling over the lifetime of a system, so that revenues compensate for high upfront investments. Economies of scale, achieved through larger networks, can also reduce costs. Meanwhile, with emerging technologies, gradual expansion can reduce project risks in comparison to large, one-off investments. As an example, solar district cooling can be achieved through solar thermal collectors to drive an absorption heat pump. Demonstration projects can be a starting point, with the option to expand once technology acceptance is sufficient and commercial viability is established. In many locations, more information is needed about resource availability, especially for geothermal and natural water cooling.

As reliance on solar and wind energy grows, DHC systems will offer increasingly attractive synergies. Mismatches between load patterns and supply from these variable renewable resources, including direct use of solar heat, can already be balanced to a great extent with thermal storage facilities. Storage is expected to become even more integral, with DHC systems coming to play a pivotal role in enabling variable renewable power integration. With power-to-heat solutions (heat pumps, electric boilers), excess electricity generated when there is abundant sun or wind can be used to produce district heat or cooling. This can subsequently be stored (*e.g.* heat in hot water tanks, or cold in the form of ice). These applications are only used in a few places today but have significant potential as countries become increasingly dependent on variable renewables.

The introduction of renewable DHC in dense urban environments calls for careful planning. Some renewable energy technologies entail considerable space requirements, which need to be addressed either through smart integration within the city or by using resources outside the city core. For example, solar collectors could be integrated into the urban environment through landfill sites and the rooftops of large commercial buildings. Geothermal wells on the urban fringe can be connected to networks that serve consumers throughout the city. If such solutions can be identified, dense urban areas with existing networks offer good conditions for renewable-based DHC systems. The more customers can share upfront costs, the lower the cost will be for system establishment or conversion.

Cities expanding their DHC networks are especially suitable for renewable DHC. The expansion of existing networks provides the change to optimise design parameters and achieve overall improvements, such as minimisation of the network temperature. New networks provide even more freedom to set the system's operating parameters, thereby allowing higher shares of renewables. However, new networks come with barriers, too, such as higher investment costs and a limited set of customers.

Areas for action exist at both the national and city levels

While DHC systems may be integral to a country's energy infrastructure, they are often operated at city level. Both national and city policy makers must play their part for the full potential of renewable energy in DHC to be captured.

***National* policy makers** need to:

- **Encourage and facilitate renewable energy adoption in the DHC sector.** In some countries, this includes creating a level playing field and improving the business case for renewable energy use in DHC. Countries can also set specific medium- to long-term targets, which are mostly absent at the moment. Setting predictable and realistic targets provides a clear indication to businesses and investors that there is a market for a certain technology. Finally, regulatory changes may be required to capture the full potential of renewables. For example, in some countries, heat production from otherwise curtailed electricity is not possible under current regulations. This limits the opportunities for DHC systems to balance out variable renewable power.

- **Expand renewable resource assessments and promote demonstration projects for emerging technologies.** The availability and suitability of renewable resources for DHC is often unclear. National resource assessments around key demand centres (*e.g.* major cities, industrial sites) can be more efficient in terms of time and cost than case-by-case project feasibility assessments. These can include an evaluation of geothermal conditions, the energy potential from water bodies, or the local availability of biomass feedstock. For emerging technologies, such as solar district cooling or power-to-heat applications, demonstration projects have a significant positive effect on investor and customer confidence.

***City* policy makers** need to:

- **Develop an understanding of the local renewable resource base, identify demand patterns for heating and cooling, and explore synergies with existing infrastructure.** A broad understanding of the local renewable resource base is needed in order to identify the most appropriate technologies. Ideally, such knowledge ought to build on and complement national resource assessments. Local demand patterns for heating and cooling must also be understood in order to determine the viability of renewables to balance energy supply and demand. Where DHC systems are already in place, opportunities can be identified to replace inefficient or polluting fossil fuel plants. The availability of suitable renewable resources may strengthen the business case for new networks to replace conventional decentralised generation. In addition, synergies should be explored with the urban environment and infrastructure. For example, rooftops and urban wasteland might provide suitable sites for solar collectors. Meanwhile, street-level excavations to install DHC network piping may be combinable with other urban infrastructure projects.

- **Engage with a broad set of stakeholders.** DHC networks often encompass different sectors and stakeholders, including water utilities, municipal waste processers, the power sector and large industrial energy users. Their involvement in planning to increase the share of renewables is vital to ensure a stable and efficient operation of DHC systems. When integrating emerging technologies and novel applications, research institutes can help uncover the unknowns in the project. Other cities and projects can provide valuable insights and expertise. Various city networks provide platforms to share lessons from past successes and mistakes. These include, for instance, the C40 Cities Climate Leadership Group, ICLEI – Local Governments for Sustainability[5], the United Nations Environment Programme (UNEP) and the Global Covenant of Mayors for Climate and Energy.

5 Founded in 1990 as the International Council for Local Environmental Initiatives.

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