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Renewable heat policies

Delivering clean heat solutions for the energy transition

Ute Collier

INTERNATIONAL ENERGY AGENCY

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- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
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Energy efficient home with solar thermal and biomass heating, Germany
Photo: Ute Collier

Executive summary

Heat is the largest energy end-use and is a significant contributor to global CO_2 emissions. Heat accounted for over 50% of final energy consumption globally in 2015, with 60% of heat consumed in industry (including agriculture) and 40% in buildings. Heat is primarily produced by fossil fuels and its production is responsible for nearly 40% of energy-related CO_2 emissions, as well as locally contributing to air pollution problems. Much heat is being wasted, through inefficient buildings, appliances, and industrial processes. Cooling currently accounts for only 2% of total energy consumption but is growing rapidly, especially in emerging economies.

Renewable energy can play a key role in decarbonising and providing a cleaner heat supply. Renewables can produce heat directly (e.g. through bioenergy, geothermal or solar heat) and indirectly (through renewable electricity). Solutions are often complex and location-specific. District heating (and cooling) can enable the switch to renewable sources in urban areas. The shift to renewable sources of heat also needs to go hand-in-hand with improvements in the energy efficiency of buildings and industrial processes that require heat, as well as an increase in the use of excess heat.

Renewable heat has seen some growth in recent years but at a much slower rate than renewable electricity. Renewable heat (including renewable electricity used for heat) accounted for only 9% of global heat consumption in 2015, with growth of around 12% over the preceding five years, compared to a 31% growth for renewable electricity generation during the same period. Deployment has to accelerate to meet climate change targets. In many countries, this will bring with it other benefits, in particular a reduction in local air pollution and greater energy security. However, more rapid progress is hindered by multiple economic and non-economic barriers.

Policy intervention is needed to overcome barriers and has to be carefully designed to reflect specific national and local circumstances. Many countries already have some instruments to support renewable heat. The most common policy instruments applied are fiscal incentives (grants, subsidies, energy taxes) and obligations (e.g. building codes). Local authorities also play an important role in many countries, for example in local heat planning. Clear targets such as those established through the European Union Renewable Energy Directive are an important driver of rising deployment.

This paper examines the heat policies of nine member and partner countries of the International Energy Agency (IEA): China, Denmark, Finland, France, Germany, the Netherlands, Sweden, the United Kingdom, and the United States. While heat demand and the potential for renewable heat vary between the nine countries, this analysis identifies a number of policy approaches and contextual factors in common by countries that have either high or low shares of renewable heat:

- **Many countries that today have high shares of renewables in heat supply have had active heat policies (including ambitious targets) for some time.** Initially, policies have tended to focus on the development of district heating networks but over time, policies have shifted to supporting a switch from fossil fuels to renewables. In the case of Denmark, Finland and Sweden, this has been helped by abundant supplies of biomass, for use in district and individual heating, as well as in industry. While financial incentives have been important in many cases, there has also been a growing emphasis on carbon and energy taxation favouring renewable heat. Other critical policy instruments have been building codes and other regulations that promote renewable heat, as well as support for energy efficiency improvements. However, even these relatively successful countries need to do more to apply a broader energy-systems approach to heat policy, for example through effective sector coupling.

- **In countries with low shares of renewable heat, heat policy has generally not been a priority, as many of them have benefited from easy access to cheap supplies of fossil fuels.** In many cases, such as in the Netherlands, the UK and the United States, this means that most heat consumers are connected to extensive natural gas grids. Additionally, low energy taxation and a lack of district heating have tended to hinder the greater deployment of renewable heat in these countries. However, heat has risen up the policy agenda in many countries, and more active policies are being deployed.

Lack of renewable heat data makes it difficult to make an in-depth assessment of the effectiveness of policies and to compare the policy approaches of different countries. Few countries publish comprehensive renewable heat deployment figures, including cost data. There are high levels of uncertainty associated with some of the available data, especially for bioenergy.

Rapid progress in renewable heat deployment can be difficult to achieve. Slow renovation rates in the building stock and a slow turnover of heating appliances in both buildings and industry, coupled with multiple barriers; necessitate a long-term strategy for heat decarbonisation with a range of policy instruments. However, most countries will have some no-regrets options (e.g. producing biogas for heat from organic waste) which can be implemented more quickly and which bring multiple benefits. With the right strategy and policies a transition to clean heat for buildings and industry can then be realised over time.

Policy recommendations

To achieve a long-term clean energy transition and climate change goals, policy makers need to pay more attention to heat. Policy approaches will inevitably vary from country to country but recommendations for policy priorities that apply to countries which have certain shared characteristics include the following:

1. Countries with extensive district heating networks

a) Countries that already have high shares of renewable heat (40+%)

- Put more focus on sector coupling, especially in countries where there is also rapid growth of variable renewable power (e.g. incentivising the use of heat pumps for demand response).
- Ensure cost-optimal alignment between energy efficiency and heat policy (e.g. to avoid stranded district heating assets where they are the best option to supply renewable heat).
- Ensure biomass resources are allocated optimally between district heating and other sectors where they are needed for decarbonisation.

b) Countries with medium shares of renewable heat (20-40%)

- Set targets and develop strategies for further decarbonisation of district heating.
- Develop instruments to overcome non-economic barriers (e.g. support for developing supply chains).
- Incentivise options for renewable heat in industry, especially those that provide opportunities for connection to district heating through use of cogeneration or excess heat.

2. Countries with relatively low shares of renewable heat (10-20%) and some district heating

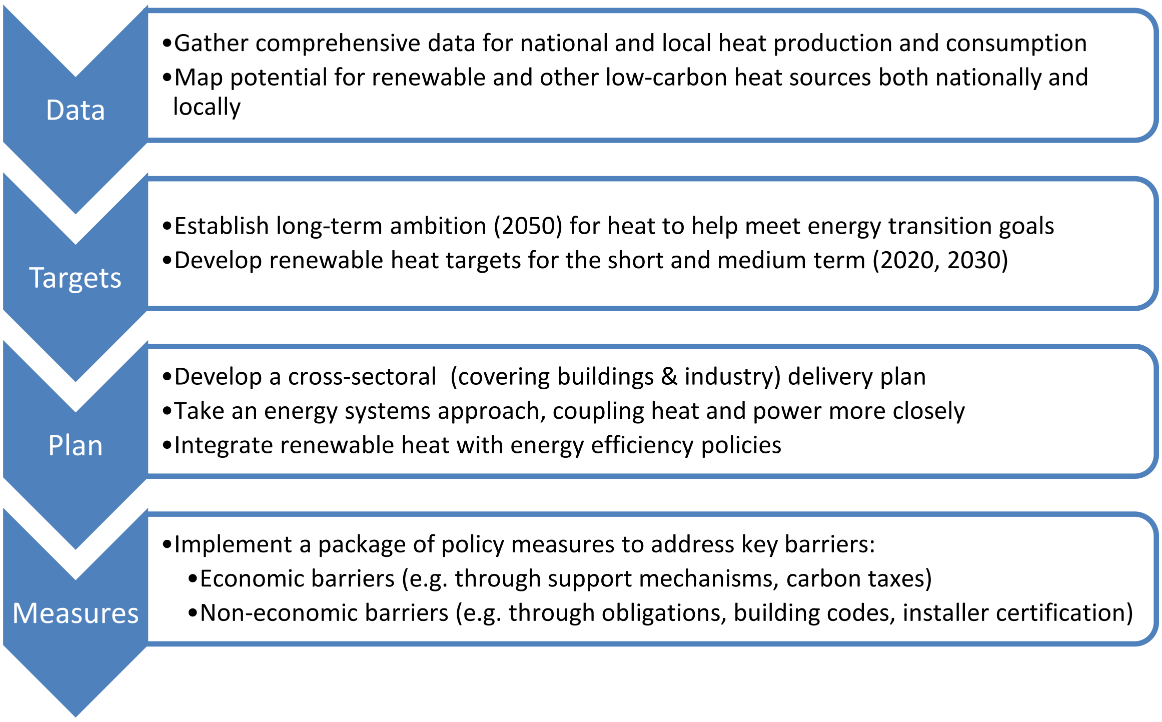
- Consider regulations for building renovation requiring a specific share of renewable heat (or connection to district heating).
- Incentivise accelerated district heating expansion focused on low-carbon heat sources.
- Ensure that energy taxes and other charges (e.g. surcharges for renewable electricity) do not disincentivise renewable heat, in particular the use of heat pumps.

3. Natural gas countries (extensive gas grids, low gas prices, very little renewable heat or district heating)

- Set clear targets, develop trajectories and strategies for increasing the share of renewable heat over time.
- Implement carbon pricing, with progressive increases over time.
- Develop effective regulations (e.g. building codes for new buildings that require the installation of renewable heat options to provide more market certainty).
- Support R&D into innovative options such as the production of hydrogen with renewables and its use in the gas grid.

4. Countries that currently have no renewable heat policy

To develop an effective heat policy from scratch, the following process is recommended:



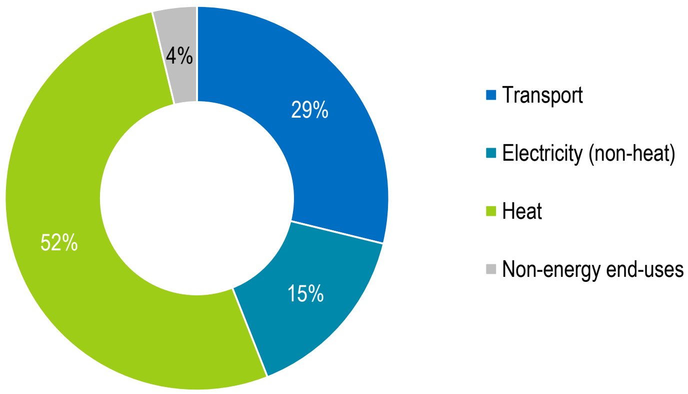
1. Introduction

It has been just over 10 years since the IEA's first publication on renewable heat: "*Renewables for heating and cooling: untapped potential*" (IEA, 2007), describing the potential for renewables in this sector as a 'sleeping giant'. Renewable heat has seen a 23% growth between 2007 and 2015 (the latest year for which data is available) but its potential remains largely *untapped* and the giant, whilst stirring, is still not fully awake. The Energy Transitions Commission, a group of leaders from across the energy, investment and other key sectors, has recently described the decarbonisation of heating, cooling and cooking as one of the largest prizes in the energy transition (Energy Transitions Commission, 2017).

In terms of progress, the contrast to renewable electricity is evident: in 2007, global direct renewable heat consumption[1] (12.7 exajoule[2] [EJ]) was higher than renewable electricity consumption (10.6 EJ). By 2015, renewable electricity had overtaken renewable heat, with 16.6 EJ vs 15.3 EJ in terms of total final consumption and is expected to continue deployment at a more rapid rate. Renewables are now larger than coal in terms of installed electrical capacity and there have been big cost reductions, especially for onshore wind and solar photovoltaics (PV).

These successes are no coincidence – renewable electricity has been a major focus of energy policy in a large number of countries, with extensive financial and other policy support schemes. At the same time, renewable heat has remained the Cinderella of energy policy, receiving relatively little attention from policy makers. Yet in terms of end-use, heat is much more important and accounts for more than half of total final consumption, compared to 15% for non-heat electricity use (Figure 1).

Figure 1 • Heat in global total final consumption, 2015



Sources: IEA (2017a), World Energy Statistics and Balances 2017 (database), www.iea.org/statistics/; IEA (2017b), World Energy Outlook 2017.
Notes: Heat includes electricity used to produce heat which accounts for just over 6% of heat consumption.

Key message • Heat dominates global energy consumption providing key services such as space heating, hot water and industrial process heat.

Slowly, the lack of attention being paid in policy circles appears to be shifting. For example, in 2016, the European Commission produced its first Heating and Cooling Strategy (EC, 2016a) and a number of new policies have been introduced across the globe in recent years. Heating and

[1] Excluding the traditional use of biomass and the use of renewable electricity for heating.

[2] 359 Million tonnes oil equivalent (Mtoe)

cooling of buildings is also one of seven 'Mission Innovation' challenges, aimed at achieving performance breakthroughs and cost reductions through scaling-up investment in energy research and development. Mission Innovation is supported by 18 countries and the European Commission (Mission Innovation, 2017).

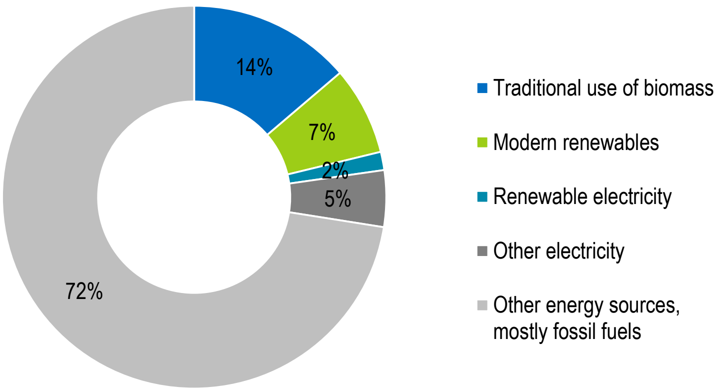
Since its initial 2007 report, the IEA has continued to work on various aspects of renewable heat (and heat more broadly), covering technologies, markets and policies (see e.g. IEA, 2014a). This paper builds on the IEA's previous work and provides an in-depth look at recent renewable heat policy developments in key countries. While focusing on renewable heat, it positions heat within the broader energy transition and stresses the importance of an energy systems approach, including energy efficiency. It aims to identify what policy approaches work and how to achieve a step-change in the deployment of renewable heat and other sustainable heat options.

In addition to this policy paper, the IEA has also recently produced two other publications covering aspects of renewable heat: a Technology Roadmap on the sustainable use of bioenergy (IEA, 2017c) and an Insights Paper on renewable energy for industry (IEA, 2017d).

Why does heat matter?

Globally, over half (52%) of final energy consumption is for heat, which in 2015 equated to 205 EJ (4 900 megatonne of oil equivalent [Mtoe]). Close to half of the heat produced is used for space and water heating in buildings and for cooking (which in parts of Africa and Asia is done through the traditional use of solid biomass, Box 1). The other half is consumed in industry, for instance to produce steam to drive industrial processes. Almost three-quarters of heat consumed is produced through the direct combustion of oil, coal, natural gas (Figure 2). Around 9% of total heat demand is met by 'modern' renewables (see section 2) and renewable electricity. This compares to a 24% share of renewables in global electricity generation in 2016.

Figure 2 • Total global energy consumption for heat, 2015



Sources: IEA (2017a), World Energy Statistics and Balances 2017 (database), www.iea.org/statistics/; IEA (2017b), World Energy Outlook 2017.

Key message • Fossil fuels continue to dominate global heat consumption. Heat is therefore an important contributor to CO_2 emissions.

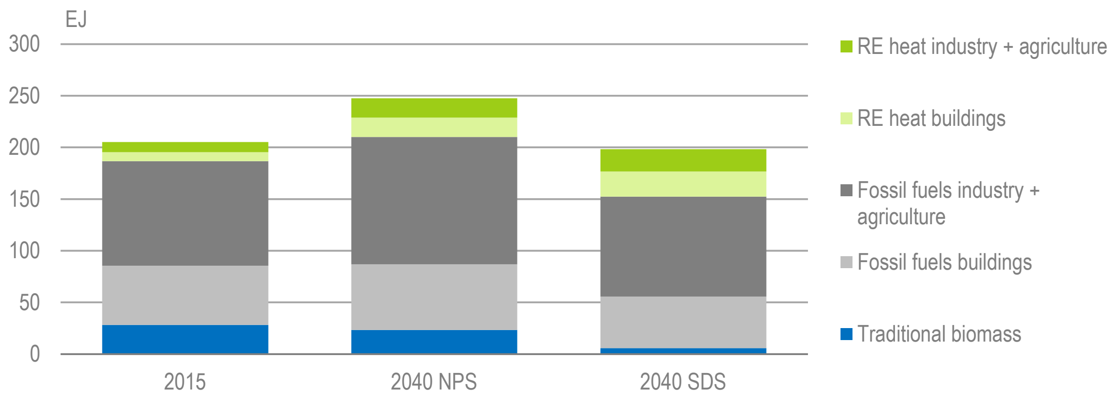
Data availability for renewable heat is limited, as most delivered heat is not metred, except when sold through commercial district heating systems. Data gaps are particularly significant for small-scale biomass, as it is collected directly by the user or sold in informal markets and not recorded.

Heat demand varies significantly between countries, as a result of climate, efficiency of the buildings stock and heating equipment, level of economic development, and different industrial structures. Cold climates obviously mean a high space heating demand in buildings, although even there are large variations per square metre of floorspace depending on the energy efficiency of the building stock. In industry, the cement, chemicals and the iron and steel sectors are the largest consumers of heat in industry.

The majority of heat is used in the Northern hemisphere, by countries that have both significant space heating and industrial heat requirements. The world's largest heat consumer is People's Republic of China (hereafter, "China"), which accounted for 26% of the global total with 53.7 EJ in 2015. 70% of China's heat 2015 consumption was in industry, whereas in the European Union and the United States most of the demand occured in buildings (59% and 54% respectively).

In the IEA's World Energy Outlook, demand for heat is expected to grow under a scenario taking into account policies currently in place or committed to (New Policies Scenario – NPS). While renewable heat consumption would more than double to cover some of this increasing demand, fossil fuel consumption for heat still expected to grow, with growth in industry (+22%) double that of buildings (+11%). Even under a scenario with much higher levels of energy efficiency and renewable heat (Sustainable Development Scenario – SDS), fossil fuels would continue to dominate heat consumtion (Figure 3).

Figure 3 • World Energy Outlook heat consumption scenarios for 2040



Sources: IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics/; IEA (2017d), *World Energy Outlook 2017*.
Notes: NPS – New Policies Scenario, SDS – Sustainable Development Scenario

Key message • Despite energy efficiency efforts and growth in renewable heat, fossil fuels are could play a continuing role in heat provision for decades to come.

The demand for heat is an important contributor to CO_2 emissions and, in 2015, accounted for around 12.5 gigatonnes of CO_2, or 39% of annual energy-related emissions. Finding solutions to decarbonise the heat sector is therefore important to achieve the ambitious targets of the Paris climate change agreement.

Additionally, the burning of fossil fuels (specifically coal or oil) is a significant contributor to urban pollution, in particular through particulate matter (PM) emissions. For example, coal boilers used to supply district heating are a major cause of winter air pollution in a number of Chinese cities. PM emissions can also result from burning solid biomass for heating but strict emissions controls for boilers and stoves, in conjunction with appropriate fuels (e.g. pellets), can address these pollutants. Additionally, inefficient solid biomass combustion for cooking is a major problem in the developing world, with serious health impacts due to indoor air pollution (Box 1).

The main focus of this paper is on heating. However, cooling is also an important and fast-growing energy service demand in buildings, industry and transport. Space cooling accounts for around 2% of global energy consumption and most cooling demand is met by electrical appliances such as air conditioners.

As with heating, there is much scope for improving the energy efficiency of cooling appliances and applications. The good match between cooling demand and solar availability provides opportunities for distributed solar PV generation and self-consumption, which could be increased with some cold storage (e.g. ice storage). There are also direct renewables options for cooling with good potential (e.g. solar absorption chilling, geocooling).

The IEA recognises that cooling is an important and fast-growing energy service demand and will carry out further cooling analysis under the auspices of the Kigali cooling efficiency programme.

Box 1 • Cooking and the traditional use of biomass

The traditional use of solid biomass in the form of firewood, charcoal, manure and crop residues continues to play a major role in sub-Saharan Africa and parts of Asia, especially in rural areas. A third of the world's population - 2.5 billion people - rely on it to cook their meals (IEA, 2017d). This causes indoor air pollution and is associated with severe respiratory diseases, as well as being implicated in deforestation. It also requires substantial time and effort (usually by women and children) spent on fuel collection. However, people in these areas lack access to modern energy services and generally have little choice but to continue using biomass.

Between 2010 and 2015, globally the use of traditional biomass increased by 3%. However, its use is declining in some countries due to initiatives such as the Global Alliance for Clean Cookstoves, a public-private partnership with the goal of getting 100 million households to adopt clean and efficient cookstoves and fuels by 2020. In addition, 'Clean Cooking Solutions' is one of 11 Action Areas within the Sustainable Energy for All initiative and more than 50 countries have included clean cooking in their Paris climate change agreement pledges. Clean cooking is also included in the United Nations Sustainable Development Goals.

In many cases, traditional biomass use for cooking is replaced by liquefied petroleum gas (LPG), but renewable options include efficient solid biomass stoves, biogas systems, and solar stoves. Where grid access is available, electric cooking is also an option. Affordability of these alternative options is a major barrier to overcome.

2. Clean heat solutions

Heat decarbonisation and renewables

Heat can be produced through a variety of fuels and devices that can provide heat at different temperature levels, appropriate for the application it is needed for. Clean energy solutions for the heat sector are complex and in many cases application-specific. Renewables can play a role but are not necessarily a straight replacement for fossil fuel heat options. For example, solar thermal systems can support space heating but may require another system for back-up (e.g. a gas boiler), while some buildings require major energy efficiency upgrades to ensure that heat pumps work efficiently.

It is therefore necessary to consider a broader strategy for heat decarbonisation. In principle, a first step should be improvements in energy efficiency to cut down on both heat demand and heat waste wherever possible (Box 2). This can be done through better insulation of buildings, smarter building energy management, more efficient heating appliances and more efficient industrial processes.

Box 2 • Renewable heat and energy efficiency: integrated solutions

Heat demand levels are directly related to the energy performance of buildings, appliances or processes. Energy efficiency is an important and cost-effective first step, with renewable heat technologies providing solutions for decarbonising the heat demand that remains after energy efficiency improvements. Furthermore, in industry there will always be heat demand for certain processes such as drying.

To find the most effective solutions, both in terms of costs and emissions reduction, it is therefore important for policy makers to develop integrated policy approaches. Such integrated approaches are already common in the buildings sector, where many countries have policies or instruments that support both energy efficiency and renewable heat solutions:

- Building energy codes for new buildings often require specific levels of energy efficiency and a certain contribution from renewable heat (or connection to district heating), for example in Germany, Denmark, Israel and South Africa.
- Many financial incentive programmes for building energy retrofits include both energy efficiency and renewable heat measures (e.g. Germany, France, and sub-national programmes in the United States and Spain), sometimes offering higher levels of financial support when measures are combined (e.g. Germany).

The combination of energy efficiency and renewable heat is equally important for decarbonising industrial heat, but the industrial sector generally has received much less policy attention. In the European Union, in principle the imposition of a carbon price on energy-intensive industries through the European Union Emission Trading System (EU ETS) should encourage both energy efficiency and fuel switching to renewable energy. However, the effectiveness of the EU ETS has been affected by a low carbon price and other measures are needed.

Overall, both renewable heat and energy efficiency face a complex and often overlapping set of economic and non-economic barriers, which can be addressed through policy intervention. While integrated solutions for energy efficiency and renewable heat are highly desirable, there is significant scope for improvement in most countries.

However, it is not technically feasible to eliminate heat demand totally and in some cases (e.g. historic buildings, certain industrial processes) substantial reductions in demand can be difficult and/or expensive, so low-carbon and renewable heat supply options are needed. These include the following:

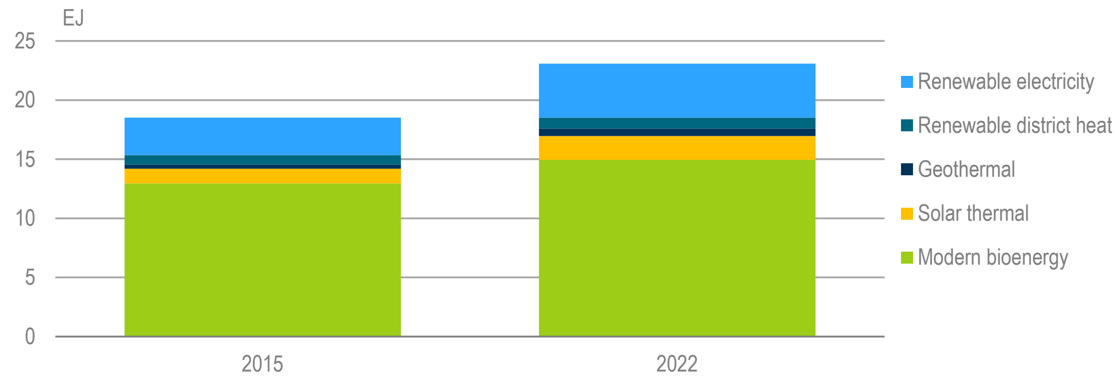
- Direct renewable heat options:
  - Solar thermal – often only used for water heating in buildings but also has good potential for supply to district heating systems and some industrial applications.
  - Biofuel boilers – can be used directly in buildings' heat systems, in district heating systems, or used to produce industrial process heat. Biofuels (solid biomass, biodegradable wastes, liquid biofuels or biogas) are often sourced locally but international trading of wood pellets is also taking place.
  - Biofuel cogeneration systems – can produce heat for district heating systems or industrial heat needs, as well as electricity.

- Biomethane injection into natural gas grids, with biogas produced from anaerobic digestion or solid biomass gasification and upgraded for injection.
- Geothermal – direct use of geothermal heat in industry, greenhouses, and district heating or large buildings.

- Renewable electricity used for heating. Particularly efficient when using heat pumps[3] which can be air-source, ground-source[4] or water-source based systems.

At present, bioenergy dominates renewable heat consumption but solar thermal and geothermal are expected to grow rapidly over the next few years, albeit from a small base (Figure 4). The use of electricity for heat (especially through heat pumps) is also expected to increase and together with a growing share of renewables in electricity generation, this will mean a rising share of renewable electricity in heat consumption. Another possibility for the longer term is to generate hydrogen from renewable electricity and turn it into storable and transportable hydrogen-rich fuels such as ammonia and others (see IEA 2017d), in particular for use in industry.

Figure 4 • Total final consumption of renewable heat by source 2015 and 2022



Sources: IEA (2017f), *Renewables 2017*.
Notes: Around 95% of renewable district heating is supplied from bioenergy.

Key message • Renewable heat consumption is on an upward trend, with bioenergy continuing as the most important renewable heat source.

There is generally no simple, single solution for decarbonising the heat supply of a country. A combination of options will have to be deployed, often varying depending on local conditions (e.g. whether a district heating network exists), resource availability (e.g. insolation levels, local or cross-border biomass supply, geothermal resources) and on specific applications (e.g. type of industrial heat demand).

District heating networks (Box 3) can be useful in that they provide the infrastructure for flexible heat supply that can be based on a range of sources. For example, in a given town or city, heat supply to its district heating system can come from a combination of geothermal, biomass, excess heat, and solar thermal. At the same time, supply to buildings not connected to the heat network could be from individual biomass boilers or heat pumps. Local industries might be using a mix of biomass, biogas and solar thermal, depending on specific process heat needs.

[3] Heat pumps provide a very efficient use of electricity for heating which utilises ambient renewable heat in the ground, air or water. However, in IEA statistics and scenarios heat pumps are counted as energy efficiency. Currently no global data is available on heat pump use.

[4] Sometimes ground-source heat pumps are described as geothermal. They make use of shallow, low-temperature solar heat stored in the ground rather than deep and/or high temperature heat, more conventionally understood as geothermal.

Box 3 • The role of district heating in scaling-up renewable heat deployment

District heating accounted for around 11% of global space and water heating energy consumption in 2013 (IEA, 2016) and continues to expand in many countries, including China. Generally, in highly-populated areas of cold climate regions with high heating demand, large-scale district heating systems, both existing networks and new investments, are feasible and cost-effective. In areas with low population density or low heat demand, the cost-effectiveness of district heating will depend on a number of factors such as linear heat demand and availability of low-cost supply (e.g. excess heat or geothermal). Even where there is no large district heating potential for the country as a whole, it may well be cost-effective in specific localities. Small-scale district networks are increasingly being deployed to service larger buildings or groups of buildings such as university campuses or hospitals.

In dense urban areas, district heating networks may offer the only option for using a significant share of renewables and other low-carbon heat, as individual biomass boilers, solar thermal systems or heat pumps may be constrained for reasons such as lack of available space, access or noise restrictions. District heating also provides opportunities for integrating short-term and seasonal thermal storage, for using excess heat (e.g. from industry), and for providing flexibility for variable renewable electricity generation through options such as power-to-gas or electric boilers.

Historically, most district heating networks have been run on fossil fuels (often linked to coal or gas combined heat and power plants), although some were set up specifically to exploit renewables (e.g. geothermal heat in Iceland). More recently, a growing number of district heating networks have integrated at least a proportion of renewable energies. Some district networks also supply cooling based on renewables or natural cooling (e.g. Paris uses cool water from the Seine River for its district cooling scheme). Expanding the supply of heat through district heating is a major plank of low-carbon heat strategies in some countries (e.g. the UK and Netherlands) and some cities (e.g. Paris, Munich and Vancouver).

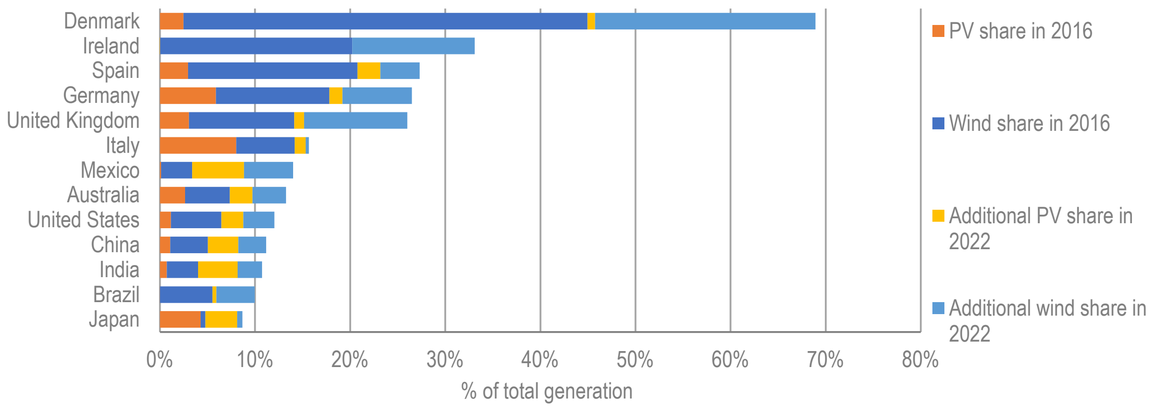
Options for the most cost-effective renewable heat supply for district heating vary between locations. In the Baltic States, district heating systems have switched away from imported natural gas to using local wood chips and pellets. In a number of Chinese (e.g. Baoding) and European cities (e.g. Bordeaux, Munich and Paris), geothermal heat from local hot aquifers is providing a cost-effective option, with the share of heat supply varying according to resource availability. Meanwhile, in Denmark, large-scale solar thermal systems are contributing renewable supplies to district heating grids in several towns (e.g. Silkeborg).

Highly insulated district heating pipes
Photo: Graphic Obsession

Heat and the energy transition

Energy systems are currently experiencing some fundamental changes, driven by policy (especially related to climate change), technological innovation (e.g. digitalisation), and economics (e.g. falling PV prices). Those three drivers interact and the resulting shift has been particularly marked in the electricity sector. Over the past 10 years or so, there has been rapid growth in renewable electricity, in particular from variable sources (wind and solar). In Denmark, the country with the highest shares, variable renewables reached more than 40% of power generation in 2016 and this is expected to increase to almost 70% by 2022 (Figure 5).

Figure 5 • Share of wind and solar PV in selected countries' power generation 2016 and 2022



Source: IEA (2017f), *Renewables 2017.*

Key message • Rising shares of variable renewable electricity sources require a new approach to the management of energy systems.

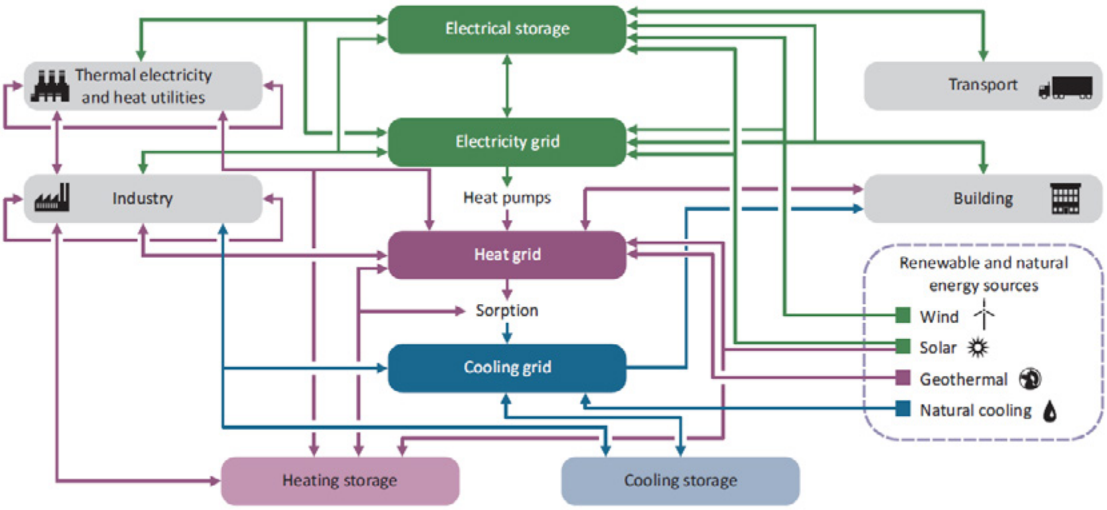
Dealing with high shares of variable electricity in power grids presents some challenges which can be addressed through greater energy system integration and sector coupling between electricity, heat and transport. At the same time, smart and efficient heat electrification through renewable electricity also provides opportunities for providing clean heat supply where other renewable options such as biomass or geothermal are not suitable or available.

The coupling of electricity and heat is by no means a new concept. Cogeneration (also known as combined heat and power) has long provided a way of increasing efficiency in thermal power generation (mainly from fossil fuels), with heat supplied either directly to industry or being fed into district heating grids (Figure 6). For example Denmark and Finland (see case studies below), have a large cogeneration capacity.

The ongoing energy transition towards a greater share of variable renewables provides new opportunities for coupling electricity and heat. Renewable electricity can be used to produce heat both in district heating networks and in individual buildings, preferably with efficient heat pumps. Thermal storage (diurnal and seasonal) can provide a cheap way of using excess renewable electricity even during times of low heat demand.

In countries where there is a high cooling demand, cooling networks and thermal storage can play a role. This complex type of coupling is still at an early stage in most countries but is becoming more important in, for example, Denmark and Germany. Optimal levels of sector coupling are unlikely to be delivered by the market alone, especially given the high capital costs of heat networks or thermal storage, hence policy intervention is needed.

Figure 6 • Coupling electricity and heat



Source: IEA (2014b), *Linking heat and electricity systems*.

Key message • Electricity and heat systems are likely to become increasingly interlinked, with a growing use of heat pumps and thermal storage.

Additionally, an energy system approach is needed to address the extensive use of biomass in renewable heat supply. Biomass resources will become increasingly valuable as countries move towards implementing their ambitious climate reduction targets. Overall sustainable biomass resource limits mean that over time, to achieve significant decarbonisation, biomass is likely to be most valuable in applications such as biomass with carbon capture storage and use to provide negative greenhouse gas emissions, or where no other solutions are available (e.g. for aviation biofuel production). This may restrict the role in the heating sector, except for some applications using local biomass and waste resources where logistics restrictions negate the use in other sectors (IEA, 2017b).

3. Barriers and policy solutions

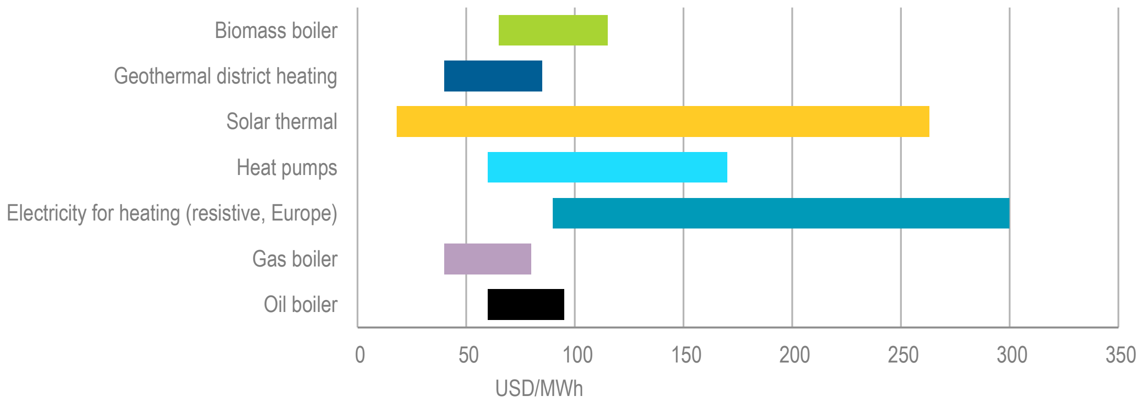
Heat markets are complex and fragmented, and generally less well understood than electricity markets. This complexity is a challenge for effective policy-making. On the demand side, heat demand in buildings varies immensely according to factors such as climate, building fabric efficiency, occupancy and behaviour; while in industry a multitude of processes have a range of heat requirements. On the supply side, there are many different space and water heating options offered, with numerous actors involved, from large multinational heating equipment manufacturers to small local installers. Renewable heat faces multiple barriers to compete in these markets, which are not necessarily open to competition.

Barriers can be divided into two groups, economic and non-economic. Both sets of barriers are important and often act together to deter consumers and industry investors from opting for a renewable heat solution. Some of these barriers (e.g. split incentives, fossil fuel subsidies) are in common with energy efficiency, which as discussed above is another key tool for heat decarbonisation.

Economic barriers

In terms of economics, both the costs of renewable heat options and those of fossil fuel alternatives span a wide range, even for applications in the same sector (see Figure 7 for a range of residential costs). They depend on many factors such as investment costs, local climatic factors (e.g. insolation levels), local resource availability (e.g. biomass) and energy taxation.

Figure 7 • Costs of residential renewable heat versus fossil-fuel alternatives (delivered heat)



Source: IEA (2017f), *Renewables 2017*.

Notes: Costs include capital and operational costs and assume a range of fuel and electricity prices. The range for heat pumps includes both air source and ground source systems, as delivered heat costs for these were relatively aligned.

Key message • In some countries, and for some applications, renewable heat options can compete with the incumbent technologies but often policy support is needed.

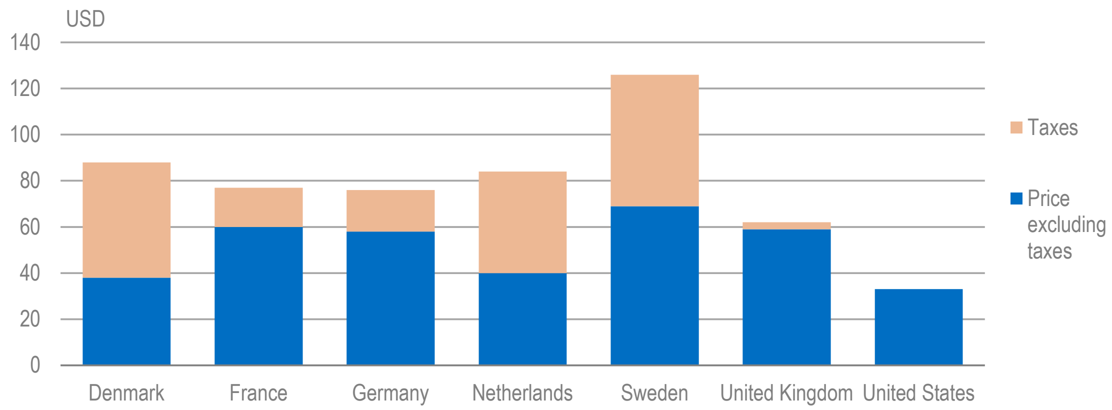
Typically, the competitiveness of renewable heat options depends on their capital and operating costs compared to fossil fuel alternatives. There are cases where renewable heat options can easily compete with fossil fuels and are even the preferred option. This is for example the case in the food and drink or paper and pulp industries, where often biomass residues are available at zero cost, which compensates for the generally higher capital costs of biomass boilers.

In many countries, natural gas is the incumbent heating fuel against which renewable heat options have to compete. Consumer gas prices, especially in the residential sector vary considerably between countries. While there is some variation in the base price of natural gas, the addition of taxes such as value-added tax and carbon tax results in a wide differential between some countries. In the case study countries[5], the United States has the lowest residential consumer gas price and Sweden the highest (Figure 8). In Sweden, taxation of fossil fuels has been a major driver for renewable heat, while low gas prices due to low taxes affect the competitiveness of renewable heat options in the United Kingdom and the United States.

However, even where a renewable heat option is competitive over the lifetime of the installation, consumers can still be put off by issues such as much higher capital costs. Therefore, policy intervention is often needed to initiate or accelerate the deployment of renewable heat. Table 1 discusses some of the most important economic barriers and some examples of how policies have attempted to address them.

[5] Excluding China and Finland for which no data is available.

Figure 8 • Gas prices per MWh for residential consumers including taxes, 2016



Source: IEA (2017g), *Energy Prices and Taxes 2017*.

Table 1 • Economic barriers and policy solutions for renewable heat

Barrier	Barrier explanation	Policy solutions	Policy examples
Capital costs	Higher capital costs than fossil fuel alternatives. Access to affordable finance and capital for renewable heat investments.	Investment support via grants and low interest loans. Heat generation-based subsidies to reduce payback periods and Energy Service Company approaches.	France zero-interest loans. Green mortgage schemes. Germany market incentive programme and Renewable Heat Incentive (RHI) in the United Kingdom.
No level playing field with fossil heating fuels	Externalities such as carbon or air quality impacts not included for fossil heating fuels. Fossil fuel subsidisation.	Energy taxation and carbon pricing. Removal of fossil fuel subsidies.	Carbon taxes in Nordic countries. Fossil fuel subsidy reform in countries such as India, Malaysia and Indonesia.
Current low and cyclical fossil fuel prices	Achieving running cost savings to pay back higher capital costs is more challenging. Reduced certainty over long-term competitiveness of renewable solutions versus fossil heating.	Adjustable energy/carbon taxes to provide price stability, ‘’floor’’ price. Mechanisms to increase liquidity and tradability of biomass fuels.	Currently not applied specifically to heat. Baltpool Exchange, Lithuania, ENplus certification, futures contracts for wood pellets.
Split incentives in the private rented sector	The building owner usually is required to invest in a renewable heating system, but the occupier/tenant receives the benefit of running cost reductions.	Grants and ESCO approaches. Measures to pass the initial investment cost on to a third party, or obligations (e.g. improvement in energy performance).	Green Deal scheme in the United Kingdom (now discontinued). Germany (Baden-Württemberg renewable heat law).
Lack of economies of scale resulting in higher system costs	In the early stage of market growth, developing supply chains can lead to higher system costs. Lack of district heating infrastructure in many countries reduces cost-effective opportunities to integrate renewable heat.	Long-term policy support measures to allow supplier base and supply chains to grow. Incentives for local authorities, cities and industry to encourage investment in efficient district heating schemes with low-carbon supply.	RHI in the United Kingdom. Heat Networks Delivery Unit funding in the United Kingdom. Fonds Chaleur in France.

Non-economic barriers

Like economic barriers, non-economic barriers vary widely between countries, sectors and specific renewable heat applications. Some of these are of a technical nature, while others are more to do with a lack of understanding of specific heat needs at the policy level and a lack of renewable heat options at the consumer end. Table 2 explores a range of non-economic barriers, together with some policy examples that have been deployed.

Table 2 • Non-economic barriers and policy solutions for renewable heat

Barrier	Barrier explanation	Policy solutions	Policy examples
Building suitability	Renewable heat options may not be suitable in certain buildings (e.g. apartments). Low energy efficiency in building stock results in higher peak loads and increased capital costs, as well as reducing system efficiency in the case of heat pumps.	Integrated energy efficiency and renewable heat grant schemes. Ensuring high efficiency through building codes.	Zero-interest loans for renovation in France and KfW programmes in Germany. EU Energy Performance in Buildings Directive.
Industrial heat requirements	Can be challenging for some renewable technologies to fully meet the temperature, pressure and quantity of heat required by some industrial users. Sometimes restrictions on biomass use due to stringent emission requirements.	Technology-related research, development and demonstration funding. Carbon taxation on industrial emissions to encourage use where possible.	Horizon 2020 funding in the European Union. EU ETS in the European Union.
Lack of awareness of and confidence in renewable heat technologies	Can apply to households, heating system specifiers and lenders. Perception of renewable systems as inferior in terms of user comfort, exacerbated by failures of previous poorly designed/installed systems.	Information programmes and advice provision (e.g. through energy agencies) Equipment certification and standards as well as after-installation technical support services.	RHI roadshows in the United Kingdom. Microgeneration Certification Scheme (MSC) in the United Kingdom.
Lack of supply chains & trained installers	Supply chains for fuels (e.g. biomass from agricultural residues) need to be established Need for trained workforce to undertake design/specification, manufacturing, installation and O&M.	Coordinated polies for agriculture, forestry and energy Training and certification programmes, better recognition of technology certification among countries.	Multiple. Pan-European Heat Pump Keymark scheme.
Distressed purchase and consumer inertia	Solution needed at short notice when existing boiler breaks down, tends to favour replacement with the same (e.g. fossil fuel) technology.	Renewable obligation for boiler replacement.	Germany (Baden-Württemberg renewable heat law).
Disruption and "hassle" factors	Retrofit installation of renewable heat systems may entail disruption (e.g. underfloor heating, biomass fuel storage). Renewable technologies also often require more space and can result in higher maintenance requirements.	District heating to allow off-site deployment. Installation of renewable systems during wider building renovation and regulations to ensure integration in new-build properties.	Municipality activities in Nordic countries. Merton Rule policies for commercial buildings in the United Kingdom.
Lack of heat data and statistics	Needed to select favourable locations for installations and develop supply chains. Also relates to heat demand mapping for planning of district heating networks.	Organisation and funding for heat mapping and zoning by local authorities.	Heat Networks Delivery Unit support in the United Kingdom, Denmark (zoning).

Policy instruments to tackle heat barriers

Despite the multitude of barriers that need to be addressed and the large contribution of heat to final energy demand and emissions, to date policy makers in most countries have primarily focused their renewables policies on electricity. For example, while around 150 countries have targets for renewable electricity, targets for renewable heating and cooling are only in place in 47 countries (REN 21, 2017).

Most common are targets for specific renewable heat technologies and these can be found both in OECD countries and in emerging economies. For example, South Africa originally set a solar water heating target in 2009. This has since been updated and the country now aims to have 5 million homes with solar thermal water heating by 2030. Thailand's 2015 Alternative Energy Development Plan includes heat targets for solar thermal, biomass, biogas and municipal waste to be reached by 2036. China's 13th Five Year Plan agreed in 2016 sets new targets for solar water heating, solid biomass and geothermal heat to be reached by 2020.

Very few countries have set themselves targets for a share of total heat demand derived from renewables. European Union countries are the exception; the European Union Renewable Energy Directive (RED) requires 20% of European Union final energy consumption to be met by renewables in 2020, with contributions from electricity, heating, cooling and transport. Under the RED, member states have established indicative heat shares in their National Renewable Energy Action Plans (NREAPs), and some have set specific renewable heat targets for 2020 and beyond. For example, France has a target to increase the share of renewables in final heat consumption to 38% by 2030, compared to 19.8% in 2015.

While targets are important for providing a sense of direction, their achievement will depend on the implementation of effective policy measures. Again, the global landscape of renewable heat measures is less extensive than for electricity. The joint IEA/International Renewable Energy Agency (IRENA) global renewable policy database lists 700 policy instruments in force for renewable electricity, yet only 175 for heating and cooling[6].

The most common policy instruments for renewable heat are:

- Financial instruments – most often grants, subsidies or tax credits; primarily for households and often connected to building renovation and energy efficiency (Box 2). In some countries, energy or carbon taxes have been applied.
- Building codes (mostly for new-build properties) that either require a certain share of heat to be supplied from renewables or specifically have a requirement for the installation of a solar thermal system for hot water generation.

In addition, countries often apply soft measures such as certification for installers or information campaigns.

In some countries (e.g. Canada, the United States and Germany), either measures are solely applied at regional/state level or there are additional measures at that level of government. Local authorities can also play an important role in setting requirements for buildings sector technologies, as they often have responsibility for the implementation (and sometimes the setting) of building codes. Most common are obligations for solar thermal water heating, which are in place for example in Barcelona in Spain, São Paulo in Brazil and Shenzhen in China. In San

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[6] For further information, refer to IEA/IRENA (2017), *Joint Policies and Measures database for renewable energy*: www.iea.org/policiesandmeasures/renewableenergy.

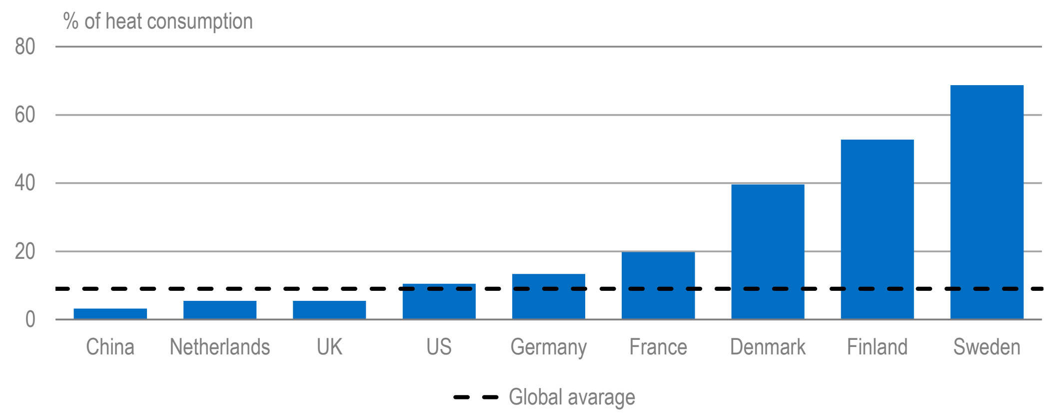
Francisco a solar obligation for new buildings from 2017 can be met either through solar thermal or solar PV.

Most countries have so far failed to develop policies that effectively target renewable heat deployment in industry. Some industrial sectors already use significant amounts of renewable heat, specifically biomass in sectors such as paper and pulp, and food and beverage. They often make use of residues, wastes or co-products produced on site but there is still much unexploited potential for renewable heat in other industry sectors. Some countries' support programmes (France's Fonds Chaleur, Germany's Marktanreiz Programme, and the UK Renewable Heat Incentive) include industrial applications. However, industry also often receives exemptions from carbon/energy taxes (e.g. in Germany and the United Kingdom), thus making the economics of renewable heat applications more challenging. There is also a need for policy support for further research and innovation to overcome technical challenges, especially in high-temperature applications.

4. Country case studies

This section examines renewable heat policies in more detail, focusing on a number of case studies chosen from IEA member and partner countries. In choosing the case studies, the aim was to gather a set of countries that are reasonably diverse in terms of their heat infrastructure, share of renewable heat, and policy approaches. In all the chosen countries heat accounts for a significant amount of final energy but the share of renewable heat varies (Figure 9).

Figure 9 • Share of renewable heat in heat consumption in the case study countries, 2015



Sources: Eurostat (2017a) and IEA analysis.

Notes: For European Union countries, this graph uses renewable heat data reported to Eurostat. For China and the United States, IEA final consumption data is used. The two definitions of renewable heat are not entirely compatible, as the European Union data includes heat pumps, whereas the IEA data includes only the share of renewable electricity used to produce heat.

Most of the countries chosen are in Europe where, due to the European Union Renewable Energy Directive, the most active renewable heat policies can be found. In addition, the world's two largest heat consumers, the United States and China, were picked on account of their global significance.

While each country is different in terms of heat demand, renewable resource availability and infrastructure, there are some characteristics that allow grouping the countries in four clusters:

- Countries that have achieved high renewable heat penetration (Denmark, Finland, Sweden)

- Countries that have lower shares but ambitious energy transition goals for which heat decarbonisation will be important (France, Germany)
- Countries with low renewable heat penetration and extensive natural gas grids (Netherlands, United Kingdom)
- The global top two heat consuming countries (China, United States)

While there are many differences between the countries in each cluster, there are certain similarities that allow comparisons and the drawing of policy lessons.

Policy-makers from these countries and other renewable heat policy experts were brought together at a workshop in Paris in February 2017. The following sections draw on the discussions at the workshop, as well as additional material.

Denmark, Finland, and Sweden: district heating as an enabler for high shares of renewable heat

A number of countries that have above-average climate-related heat demand also have extensive district heating networks. They were established decades ago with government support and operated with heat produced from fossil fuels, often from cogeneration. However, a number of countries with high district heating penetration now have high shares of renewables heat (Table 3) and this section examines how this switch has been achieved in three of them; Denmark, Finland and Sweden.

Table 3 • District heating and renewable heat shares in selected European countries

	Share of renewables in heat consumption 2015	Percentage of citizens served by district heating 2013	Heating Degree Days 2016 (European Union average 2904)	Main renewable heat source
Sweden	68.6%	52%	5125	Biomass
Iceland	63.4%	92%	4962	Geothermal
Finland	52.8%	50%	5338	Biomass
Latvia	51.8%	65%	4003	Biomass
Lithuania	46.1%	57%	3827	Biomass
Estonia	49.6%	62%	4208	Biomass
Denmark	39.6%	63%	3136	Biomass

Sources: Eurostat (2017a), Eurostat (2017b), Euroheat and Power (2016).

As discussed in Box 3, district heating can facilitate the deployment of renewable heat because of economies of scale and other issues such as siting. However, government policies facilitating a switch to renewables are still needed and the three countries covered in this section have all seen sustained policy intervention in the heat sector.

While the three case study countries all have experienced a rising contribution from renewables, this is not necessarily the case in other countries with extensive district heating systems. For example, in Poland 40% of households are connected to district heating but heat remains dominated by fossil fuels with an 80% share of coal due to the absence of policies incentivising renewable heat. Resource availability is obviously also an important factor, with Finland and Sweden having large solid biomass resources.

District heating is also less prevalent in countries that have most of their heat demand in industry although district networks can serve some industrial heat needs. For example, in Germany, over

40% of district heating energy supplies go to industry (BMWi, 2017a). However, European Union-wide, it is only 8% (EC, 2016b).

Denmark

Renewables supplied 39.6% of Denmark's heat demand in 2015, up from 20.6% in 2004 (Eurostat, 2017c). This is very close to Denmark's renewable heating and cooling share for 2020 of 39.8% targeted in its National Renewable Action Plan (NREAP). Renewable heat supply comes primarily (92%) from biomass and over half (54%) of the renewable heat is supplied through district heating systems.

While early district heating systems were developed in the 1920 and 30s, the real transformation of Denmark's heat sector started during the oil crises of the 1970s, when Danish heat supply was still dominated by individual oil boilers. To improve security of supply, the 1979 heat supply act introduced the concept of heat zoning in heat-dense areas suitable for collective heat systems and obligated municipalities to develop heat supply plans. The expansion of district heating played an important role in these plans and municipalities were given the option to make connection to district heating obligatory (Danish Energy Agency, 2017). Around half of district heating customers are covered by mandatory connections. District heating is considered as basic infrastructure and by law heat supply companies are not allowed to make profits, thus ensuring that heat prices stay relatively low.

The result of this comprehensive heat policy was that a 60% district heating target by 2000 was achieved, with district heat primarily supplied from fossil-fuel based cogeneration which was incentivised through a triple-tariff feed-in scheme. While this was phased out in 2000, a support scheme for biomass cogeneration remains in place. Since the mid-1990s, there has been a growth in renewable cogeneration plants. Biofuels together with municipal waste incineration accounted for 57% of total district heat generation in 2016 and the trend has been steadily increasing. Solid biofuels containing roughly equal shares of wood pellets, woodchips and straw, accounted for 35% of total supply. While woodchips and straw are domestically available, wood pellets are largely imported.

In 2012, Denmark adopted a new Energy Agreement which aimed to achieve fossil-fuel free energy system by 2050, with heating playing a key role (IEA, 2017g). Measures to achieve this include:

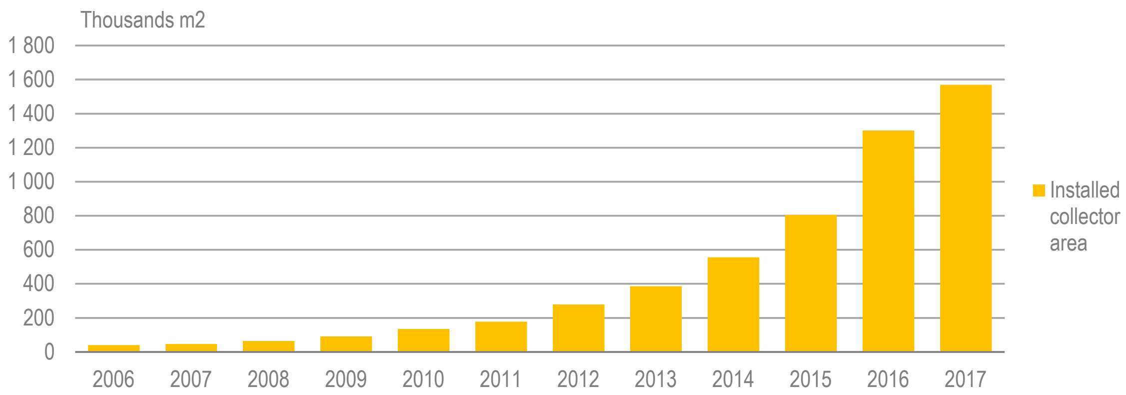
- Since 2013, no oil or gas heating has been allowed in new-build properties.
- From 2016, no new oil heating installations are allowed in existing buildings in areas supplied by district heating or natural gas.
- A scheme to promote energy retrofits in existing buildings.
- Financial support to achieve the targets including:
  - 13-25% investment subsidies for large-scale heat pumps for district heating systems chosen through tenders.
  - Premium tariff payments for biogas used in heating and for biomethane for grid injection. The tariff is paid per GJ of biogas used and increases or decreases annually depending on the price of natural gas.

In addition, Denmark has high energy and CO_2 taxes. As a result, Denmark's gas prices are high, with taxes making up 57.3% of household bills, the highest share in the European Union. Biomass used for heating is exempt from most taxes. Electricity used for heating benefits from a lower tax rate than for other electricity uses but the tax level is still significant, therefore acting as a disincentive to the more rapid deployment of heat pumps (IEA, 2017g).

One interesting recent development has been the rapid growth in deployment of large-scale solar thermal systems for district heating (Figure 10). As part of Denmark's energy efficiency ambitions, energy companies involved in the production and distribution of electricity, gas or district heating participate in an energy efficiency obligation scheme. The scheme requires the district heating sector to achieve energy savings of 0.1 Mtoe (4.1 petajoules - PJ) in the period 2016-20. Heat produced from solar energy is also allowed to be counted as energy savings.

As a result, Denmark has become one of the world-leading countries in integrating large-scale solar heating into district heating systems. The world's largest solar thermal plant to date entered operation in Silkeborg in Denmark at the end of 2016 and is expected to produce 80,000 MWh for use in the local district heating network, 20% of its annual heat demand. In total, more than 1.3 million m^2 of solar thermal collectors are in operation in Denmark and the Danish District Heating Association expects this to increase this to 2 million m^2 by 2020 and perhaps 5-8 million m^2 by 2030 (Lauersen, 2017). Prices for large-scale solar thermal installations have been falling helped by low interest rates and the cheap cost of land around some towns and villages with existing district heating.

Figure 10 • Solar district heating in Denmark – cumulative installed collector area



Source: PlanEnergi, data provided to the IEA.

Key message • The Danish experience shows that large-scale solar thermal can be a cost-effective option for deployment in district heating.

Denmark also uses its district heating systems to balance electricity from variable renewables. Globally, Denmark has the largest share of variable renewables in electricity supply, with more than 40% supplied from wind and solar energy in 2016. District heating schemes already provide some balancing services through electric boilers, heat pumps and storage. A 2014 study for the Danish Energy Agency suggested that this role could increase substantially, with one scenario estimating that more than one-third of heat demand in district heating could be met via electricity by 2050, while the use of biomass would be declining (Lauersen, 2017). However, taxes and regulations need to be better aligned to support further integration of heat and electricity systems and achieve potential synergies (IEA, 2017h).

Summary - key policy aspects Denmark:

- Long-term heat policy with ambitious targets and an effective regulatory framework.
- Comprehensive heat planning at local level, with district heating as public infrastructure.
- Energy taxation with exemptions for renewables.
- Regulatory measures restricting the use of fossil fuel heating.

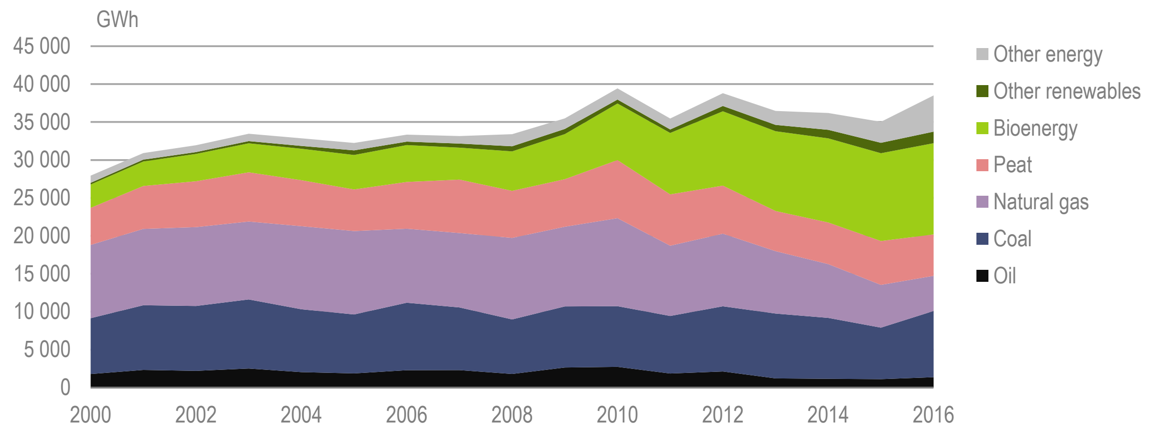
Finland

Finland has a cold climate, with the highest number of heating degree days[7] in the European Union – in 2015, 5338 versus an European Union average of 2904 (Eurostat, 2017a). This has provided a strong incentive for the development of efficient heating solutions, district heating first emerging in Finland in the 1950s. Today, much of the heating demand in Finnish cities is met through district heating (e.g. 90% in Helsinki, Box 4). Overall, district heating supplies 46% of the heat demand of buildings.

The installation of district heating networks, initially carried out by municipally-owned utilities, went hand in hand with the development of fossil fuel-based cogeneration plants for heat and power. Since the 1970s, there has been a transition towards the use of renewable fuels, encouraged by the widespread prevalence of available biomass. However, this transition has not gone as far as in Sweden.

In 2016, fossil fuels still accounted for more than half (52%) of district heat production (Figure 11). Apart from Ireland, Finland is only country which still uses a significant proportion of peat (12% in 2016), which is high in carbon emissions, for heating. However, the use of renewable fuels in the production of district heating almost quadrupled between 2000 and 2016, when it reached a share of 35%. Most of the renewable heat is produced from solid biomass in small- and medium-sized cogeneration plants.

Figure 11 • Finnish district heat production by fuel, 2000-16



Source: Statistics of Finland (2017a), *Production of electricity and heat.*

Key message • Fossil fuels continue to play a significant role in district heating in Finland but a planned coal phase-out by 2035 is expected to further increase the role of bioenergy.

In terms of overall heat demand, the contribution of renewables is higher at 57% in 2016. In industry, the share of renewable heat was over 70%. The biggest user of industrial heat is the forest industry, which uses its own fuels in production, such as black liquor and other wood fuels (Statistics Finland, 2017b).

While Finland has no specific renewable heat target for 2020, the current share of renewable heat exceeds the trajectory envisaged in its 2010 NREAP. The trajectory expected a 42% renewable heat share in 2015 and 47% in 2020 (Ministry of Employment and the Economy, 2010).

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[7] A standardised measurement designed to quantify the demand for energy needed to heat a building

Like Sweden, Finland was an early adopter of carbon taxation. However, both natural gas and peat have had special exemptions, which may at least partially explain why Finland has made less progress in heat decarbonisation, especially in the district heating sector. The tax was reformed in 2011 and has since progressively increased for both natural gas and peat. The use of peat for heating homes more than halved between 2010 and 2015.

The Government published a new Climate and Energy Strategy in November 2016. While this does not include a specific renewable heat target, it sets out the aims by 2030 to increase the share of renewable energy in energy consumption to approximately 50%, and the self-sufficiency in energy to 55%. Additionally, the use of coal will be phased out and wood-based energy is expected to expand (Ministry of Economic Affairs and Employment, 2017). This is particularly relevant for renewable heat, as coal still accounts for almost a quarter of district heat production.

To encourage the further development of renewable heat, a number of incentive schemes are currently in place:

- Biogas and biomass cogeneration plants can receive a “heat bonus” on their electricity feed-in premium.
- Investment grants are available to companies, municipalities and farmers for heat pump, geothermal, biogas, biomass, and solar thermal installations.

For Finnish buildings not connected to district heating networks or the gas grid (which is concentrated in the South of the country), heat pumps are attractive options. A slump in construction and cheap oil prices were responsible for a decline in heat pump installations in recent years but this reversed in 2016, when more than 60,000 heat pumps were installed, taking the Finnish total to around 800,000 (SULPU, 2017). Finland is the 5th largest heat pump market in the European Union in terms of total numbers. However, on a per household basis, Finland’s heat pump sales are 3.5 times those of France, the largest heat pump market in the European Union (EHPA, 2017). The majority of installations are for ground-source heat pumps due to greater efficiencies, but recently the growth has been dominated by air-source heat pump sales. Large-scale heat pumps also operate in district heating and cooling plants (Box 4).

Factors driving the growth of heat pumps in Finland include the increase in fossil fuel taxation, government subsidies to encourage the switch from heating oil to electricity-based heating and a building code with energy performance standards that take into account the carbon intensity of a building’s heat supply (Hannon, 2015).

Box 4 • Helsinki district heating – towards 2050 carbon neutrality

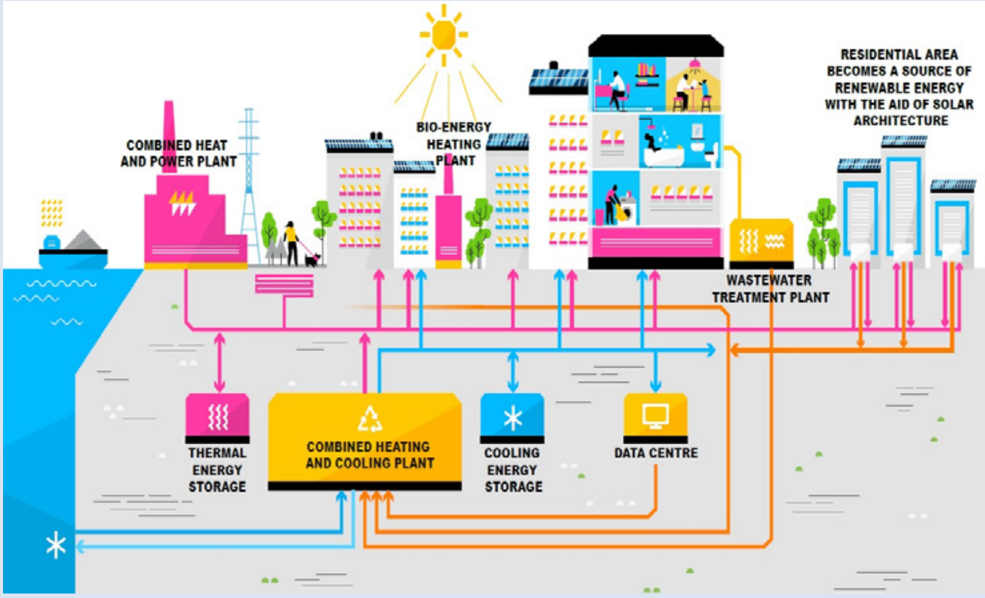
In Helsinki, more than 90% of heat demand is met by district heating. The network is operated by Helen Ltd, which is owned by the City of Helsinki. There is also a growing cooling demand, with around 360 buildings currently connected to district cooling. 80% of district cooling is based on energy that would otherwise be wasted. Currently, much of the heat supplied is fossil fuel based, albeit from very efficient coal and gas cogeneration plants.

Helen’s contribution from renewable heat has been growing steadily (mainly from co-firing with wood pellets), with a target to increase the use of renewable energy sources to 20% by 2020. A new biomass boiler will start operation in 2018 and the city council decided in 2015 that the Hanasaari coal cogeneration plant is to be replaced by renewables by the end of 2024.

One of the innovative solutions is the Katri Vala plant, the world’s largest combined district heating and cooling plant, with a capacity of 90 MW for heating and 60 MW for cooling. The plant operates five heat pumps from purified sewage water, district cooling return water and sea water. It also includes underground thermal storage. Further options being looked at include biomass cogeneration and excess heat from sources such as data centres (Figure 12).

Helsinki City Council voted in September 2017 for a new city strategy including the goal to turn Helsinki carbon neutral by 2035. This will require innovative solutions to achieve further heat decarbonisation.

Figure 12 • Helen's energy system



Source: Helen Ltd

Summary - key policy aspects Finland:

- Extensive district heating originally established by municipal energy companies.
- Progressively increasing carbon taxes.
- Ambitious renewables and coal phase-out targets.
- Range of renewable heat support measures.

Sweden

Sweden has the largest share of renewable heat production in the European Union with 68.7% of heat demand met by renewables in 2015, up from 46.7% in 2004. Heating and cooling has already exceeded the 2020 NREAP trajectory of 62.1% and accounts for the largest share of Sweden's RED contribution. The share of renewable heating is high in both district heating and individual heating. Further decarbonisation will be needed to meet the ambitious targets set by a new Climate Change Law in June 2017. This will require Sweden to become a net-zero carbon emitter by 2045.

Like in Denmark and Finland, Sweden's district networks were developed as a public good by the municipalities. Most of them were built from the 1950s to the mid-1990s. Similar to Denmark, the real transformation of the energy sector goes back to the oil price shocks in the 1970s. Energy taxes have been the main driver in this transformation:

- Sweden introduced an energy tax on natural gas used in heating in 1985 and a carbon tax on fuels in 1991, in addition to a tax on heating oil that has been in place since the 1950s. Biomass has been exempt from these taxes.

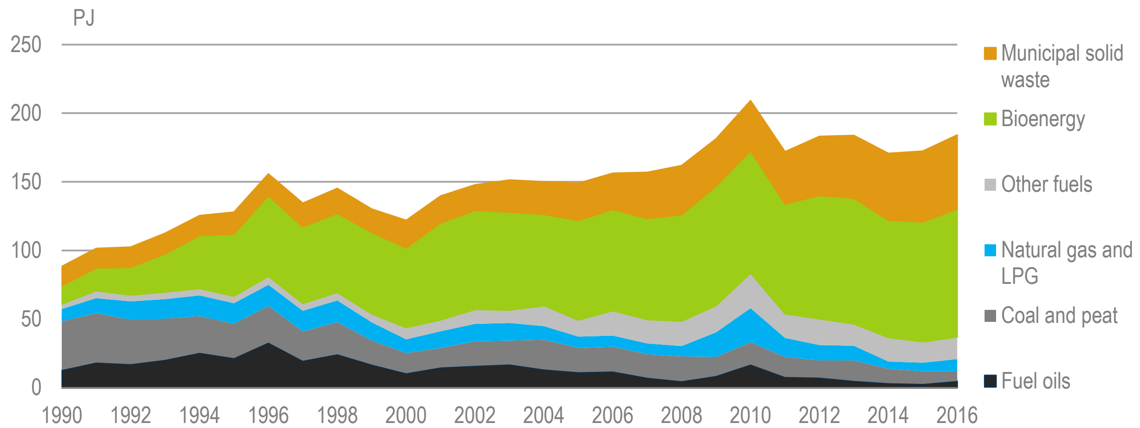
- These taxes have risen substantially over time. In 2017, the carbon tax rate was USD 135 (1 156 Swedish krona) per tonne of CO_2 (tCO_2) for natural gas, with the energy tax adding another USD 52.

As a result, Sweden's households pay by far the highest natural gas prices in the European Union (USD 0.126, EUR 0.114 per kWh). In 2016, 45% of the price was made up by taxes, compared to, for example, taxes of just 7% in the UK, the country with the lowest tax level (Eurostat, 2017b) (Figure 8). Cogeneration plants in the European Union ETS are exempt from the tax while heat only plant pay 80%.

This taxation has resulted in a switch away from individual fossil fuel heating to district heating and heat pumps. In 2015, district heating supplied 60% of heat demand and over time, the high energy taxes have resulted in the transition from heating oil to biomass. When the carbon tax was introduced in 1991, it almost doubled the price of coal and made biomass the most competitive fuel for heat production (Di Lucia and Ericsson, 2014). Since then, a landfill ban on combustible waste in 2002 has resulted in increasing amounts of solid waste being burnt in cogeneration plants. Biomass and municipal solid waste now account for 80% fuel input into district heating (Figure 13).

Biomass also dominates the heating market overall. However, in one or two family dwellings, heat pumps have a share of 52%, a total of around one million heat pumps. Sweden has used a relatively large share of electricity for heating since the 1980s due to most electricity being generated by hydropower and nuclear power (80% of generation in 2016). While initially heating was supplied through inefficient resistive heating, now heat pumps dominate this market segment. Additionally, large-scale heat pumps are deployed in district heating networks.

Figure 13 • Consumption of fuel in Swedish cogeneration and heat-only plants, 1990-2016



Source: SCB (2017), *Consumption of fuels for steam and hot water production, by type of fuel and type of production type.*

Key message • Sweden's district heating system has gradually shifted away from fossil fuels to bioenergy and municipal waste.

Sweden now relies primarily on energy taxation to support renewable heat, although there are some tax credits for the installation of heat pumps or solar thermal in buildings (Patronen, 2017). The renewable heat technologies that perform best under this regime are biomass and heat pumps, whereas solar thermal has not been competitive and has seen little deployment in recent years.

For renewable heat supply to district heating, the 2003 market-based electricity certificate programme has been incentivising biomass-based cogeneration. However, some plants reached the time limit on receiving certificates in 2013, so an increasing amount of cogeneration production is now from plants that do not receive certificates (Friberg, 2017).

In parallel to energy taxation, tightening building codes over time have resulted in Sweden now having the most efficient building stock in the European Union. Building codes for new buildings also encourage the use of renewable heat, which helps to improve the energy performance rating of buildings. However, low electricity prices now hamper cogeneration development and falling energy demand due to high levels of energy efficiency has resulted in a saturation of the heat market. This has begun to undermine the business case for some district heating investments, as low heat demand makes them uneconomic.

Summary - key policy aspects Sweden:

- Long-term heat policy and ambitious targets.
- High energy and carbon taxes with exemptions for renewables.
- Effective building codes improving energy performance.
- District heating established as public infrastructure.

Germany and France: the role of heat in the energy transition

Both Germany and France have ambitious targets to fundamentally transform their energy systems. In Germany, the *Energiewende* (energy transition) has been discussed since the 1980s and initially mainly referred to the power sector. In 2010, the *Energiekonzept* (energy concept) widened this and identified the greater use of renewable heating and cooling as one of the largest challenges (BMWi, 2010). In France, the Energy Transition Law (*La loi relative à la transition énergétique pour la croissance verte*) was passed in 2015, setting a target of 32% of renewables in final energy consumption by 2030, which will require a significant contribution from heat.

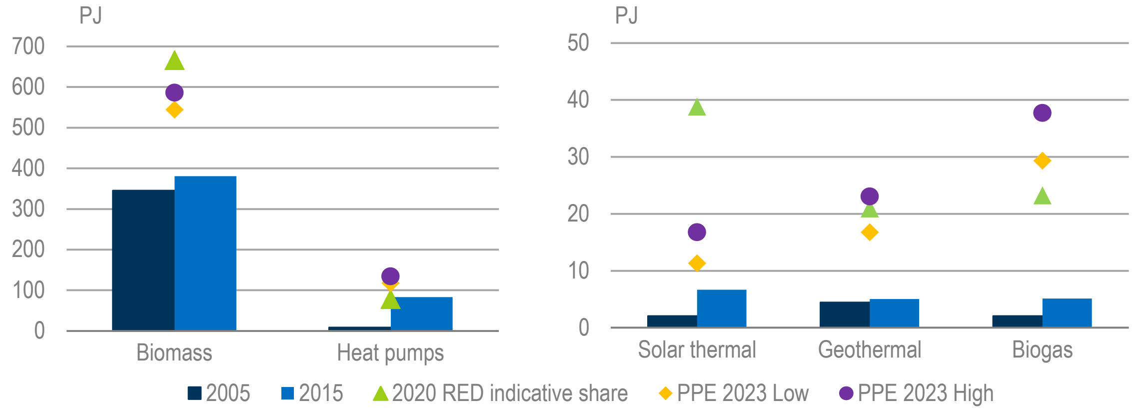
France

France is unusual in that it has a relatively large share of electric heating, with around 8 million (31%) buildings heated electrically, mostly through resistive heating. This is a consequence of the dominant role of nuclear power in the French electricity sector. While France has had a long-standing policy to promote nuclear power, under the Hollande presidency (2012-17) it began to implement policies to reduce its contribution. The 2015 Energy Transition Law (MEEM, 2016a) aims to transform France's energy system by more than doubling renewable energy by 2030. For heat, specific aims include:

- 38% of renewables in final heat consumption by 2030 (up from 19.8% in 2015).
- Renewables (and waste) in district heating / cooling to increase five-fold by 2030.
- Regional plans for biomass mobilization.

The *Programmation pluriannuelle de l'énergie* (PPE - Multi-Annual Energy Plan), published in 2016 (MME, 2016b), set out details for achieving the 38% target by 2030, including interim targets for 2018 and 2023 for individual technologies. The targets defined in the PPE for 2020 are actually less ambitious than those that were previously set out in France's 2012 NREAP, which aimed at a 33% share of renewables in heating and cooling by 2020, as part of achieving the overall RED target of 23%. By the time the PPE was developed in 2016, deployment had already fallen behind to such an extent that it became clear the target could not be achieved and lower PPE targets were set. However, the new targets still look very ambitious for some technologies, such as biomass and biogas, where deployment continues to lag behind (Figure 14).

Figure 14 • Renewable heat consumption by technologies versus 2020 and 2023 targets



Sources: MEEM (2016b), *Programmation pluriannuelle de l'énergie* and MEEM (2017), *Chiffres clés des énergies renouvelable.*

Key message • France has ambitious targets for renewable heat technologies but progress has been slow except for heat pumps.

France's renewable heat policy consists of distinct measures for different sectors. For industry and commercial applications, funding is channelled through the *Fonds Chaleur* (Heat Funds), while residential installations receive support through a set of measures:

- The *Fonds Chaleur* (Heat Funds) programme, set up in 2009, provides support for renewable and waste heat installations in the commercial and industrial sectors, as well as district heating projects. It is administered by ADEME, the French environment and energy agency, and includes subsidies for both project support (40-80%) and for project execution (25-80% of costs). The total annual budget is currently USD 243 million (EUR 220 million). Between 2009 and 2015, the programme supported 3600 projects, with an average cost of USD 4.4 (EUR 4)/MWh_{th}. In 2015, biomass projects accounted for 44% of funds distributed and around 27% went to district heating projects (Chabrillat, 2017).
- In the residential sector, tax credits (30% of capital costs) are the main incentive for renewable heat deployment, together with a reduced value added tax (VAT) rate of 5.5%. Additionally, a zero-interest loan (maximum USD 33 000, EUR 30 000) is available for renewable heat installations in the course of building renovation if combined with energy efficiency measures; biomass boilers and air-source heat pumps being the most successful technologies (SFGAS, 2017). For new-build homes, the 2012 building code (*Régulation thermique*) requires the installation of at least one renewable energy source, although this requirement is not heat specific.

France has also established a system of carbon taxation, currently USD 24/tCO_2 (EUR 22/tCO_2), with the Energy Transition Law requiring this to increase further to USD 62/tCO_2 (EUR 56/tCO_2) by 2020. This should help improve the competitiveness of renewable heat options, even if natural gas and heating oil prices remain low.

France is lagging behind the leading countries in Europe in district heating which supplies only around 6% of households, a similar figure to Germany but well below the European Union average of 13%. Around half of the district heat is supplied from fossil fuels but there is a growing share from biomass (14.8%) and waste (28.7%), plus a small contribution from geothermal sources (3.8%). Most geothermal plants are located in the Paris region, with currently 44 production sites (Box 5).

Studies have suggested a significant additional potential for district heating in France (e.g. Fedene/SNCU, 2015) – up to four times current supplies and much higher for some cities and regions. District heating (including investment costs) has been shown to be very competitive with other options, including electric heating, heat pumps and individual condensing gas boilers (Alternatives Economiques, 2017). It is increasingly being recognised as an important part of the energy transition, with the Fonds Chaleur funding a number of district heating projects. There is also a reduced VAT rate of 5.5% for supply of heat from district heating and an option for local authorities to mandate connection to district heating networks for new buildings and those undergoing major renovations. However, the renewables in district heating target of the Energy Transition Law will be challenging to achieve, even with these measures.

Box 5 • Paris – geothermal heat developments

Greater Paris has the largest concentration of deep geothermal wells linked to district heating networks in the world (Bloomberg, 2015). Geothermal heat was first exploited in the Paris region in the 1960s, with expansion during the 1970s as a response to the oil price shocks. Recent years have seen a new boom in geothermal heat development thanks to the support available from the Fonds Chaleur. Most of the geothermal systems exploit the warm waters of the Dogger aquifer at a depth of 1500 to 2000 metres. With water temperatures of 55 to 85° degrees Celsius, supply can go directly into district heating networks.

The latest plant that was put into operation in early 2017 extracts water at 30°C from the shallower Albien aquifer from a depth of 650 metres and then uses heat pumps to increase the temperature (Engie, 2017). The Clichy-Batignolles plant is rexpected to supply over 80% of the heat requirements of a new 54-hectare highly energy efficient housing development for 7 500 people.

The plant received more than EUR 2.2 million (USD 2.5 million) from the Fonds Chaleur and other public funds to support a total investment of EUR 12 million (USD 13.3 million). In addition, investment in renewable heat earns exemptions from the carbon tax, and the heat sold benefits from a reduction in value added tax rate from 20% to 5%.

Geothermal heat plant Clichy-Batignolles.
Photo: Ute Collier

Summary – key policy aspects France

- Ambitious targets for renewable heat for 2030 but deployment is lagging behind.
- Cost-effective renewable heat support for medium and large-scale installations under the Fonds Chaleur programme.
- A range of residential sector incentives.

Germany

For a long time, the German *Energiewende* (energy transition) mainly focused on electricity. However, as heat accounted for 44% of total final energy consumption in Germany and two-thirds of industrial energy consumption in 2016 (BMWi, 2017b), longer-term CO_2 targets cannot be met without a major shift away from fossil fuels in heat. This has been recognised by the government and heat is receiving more policy attention.

In 2016, 13.4% of heat consumption came from renewables, a significant increase from only 4.4% in 2000, although the share of renewable electricity grew over the same period much more rapidly, from 6.2% to 31.7% (BMWi, 2017b). There is a federal government target of 14% renewables in heat by 2020 which, according to government projections, is likely to be met. Currently, 87% of the renewable heat supplied is from biomass. Overall, only 6% of renewable heat is supplied through district heating systems.

There is an *Energiewende* target for an "almost" climate-neutral buildings sector by 2050 that will require a major scaling-up of energy efficiency and renewable heat. There has been recognition by the federal government that more needs to be done to achieve the buildings target. In November 2015, it published a strategy for buildings that found the target cannot be achieved under a "business as usual" scenario with current policies such as building codes and market incentive programmes (BMWi, 2015). Industrial process heat, which accounts for one-quarter of total final energy consumption, has so far received less policy attention than buildings.

There are two main policy instruments for promoting renewable heat in Germany – regulations for a certain share of renewable heat (mostly applied to new homes) and a financial support programme:

- Under the Federal Renewable Energies Heat Law (EEWärmeG), there is an obligation for a certain percentage of heat demand to be met by renewable energy in new-build properties. The actual percentage depends on the technology chosen, but heat pumps are now being installed in almost a quarter of new homes (BDEW, 2017). Connections to district heating, or additional energy efficiency measures, are alternative ways to meet the obligation. For public buildings, the renewable heat obligation also applies to building renovations. Furthermore, one of the German states, Baden-Württemberg, has an obligation for renewable heat when heating systems are replaced (Box 6). At Federal level, there have been discussions about merging the renewable heat and energy efficiency laws to ensure a better harmonisation of those two areas (Jung, 2017).
- Under the *Marktanreiz* (market incentive) programme, a combined total of USD 332 million (EUR 300 million) per year is available for support either by the Federal Office of Economics and Export Control (BAFA) through grants for small-scale renewable heat systems or by the German Development Bank (KfW) through low-interest loans for larger-scale applications (including industry and in district heating). For residential buildings, there is a bonus for combining energy efficiency and renewable heat in renovation projects. Support for renewable heat was increased in 2015 to accelerate deployment. However, the overall sum is still only a fraction of the support for renewable electricity which in 2017 amounted to USD 26.8 billion (EUR 24.2 billion).

Deployment figures for the BAFA grants (Table 4) show that after a dip in 2015, supported deployment increased significantly in 2016. This reflects the higher rates of subsidies that started in April 2015 but took some time to feed through to the market. BAFA grants accounted for around 29% of solar thermal total installations and around 17% of heat pump installations (BSW Solar, 2017; BDH, 2017b).

Table 4 • Deployment supported under the Marktanreiz programme: residential and commercial sector installations

Number of installations	2014	2015	2016
Solar thermal	23,000	17,000	28000
Biomass	28 000	16 400	28 300
Heat pumps	4 500	3 700	11 300
Total support	EUR 124 million (USD 137 million)	EUR 92 million (USD 102 million)	EUR 190 million (USD 210 million)

Sources: BAFA (2017), Report 2016/2017; BAFA (2016), Report 2015/2016; BAFA (2015), Report 2014/15.

In addition, the introduction in 2016 of an energy label for existing installed heating appliances (*Energielabel für alte Heizungsanlagen*) should raise awareness of the inefficiency of old heating appliances. This is expected to increase the replacement rate of heating appliances and promote the installation of renewable heating technologies.

Box 6 • Leadership in renewable heat policy – Baden-Württemberg

Baden-Württemberg, Germany's third most populous state, has set a target for 80% of its energy requirements to be supplied from renewables by 2050. It has its own renewable heat law (EWärmeG) which requires existing buildings to have 15% of their heat supplied from renewable sources when a heating system is replaced. This is a rare example where renewable heat is mandatory in existing (rather than new-build) buildings. The law was first introduced in 2008 and revised in 2015.

Compliance data is patchy, but the share of renewable heat in the state increased from 10.3% in 2008 to 15.6% in 2016. The generation of solar thermal heat increased by over 80% during the same time period, while that from heat pumps quintupled (UM BW, 2017). However, it appears as if there may have been some unintended consequences. Industry market data for 2016 suggests that the renewable heat obligation has resulted in a slow-down of the replacement rate for old and inefficient heating appliances (BDH, 2017a).

Baden-Württemberg is also trying to increase the share of renewable heat in district heating systems. It has an incentive programme that supports the following:

- Construction of new heat networks (subsidies are additional to federal subsidies).
- Local heat planning by local and district authorities.
- Awareness raising about district heat networks.

While Germany expects to meet its 2020 renewable heat target, considerable challenges remain to achieve its long-term energy and climate targets. An important task will be the decarbonisation of district heating supply, as well as extension of district heating networks in certain areas. In Germany, unlike in Sweden and Denmark, district heating remains primarily fossil-fuel based. 83% is supplied from cogeneration plants but in 2015, only 12% of the heat was produced from renewable sources and coal still contributed 42% (Pfnür et al, 2016).

As of July 2017, a new support programme (*Wärmenetzsystem 4.0*, Heat Networks 4.0) is available that offers grants of up to 60% of investment costs for innovative new heating and cooling networks that are at least 50% based on renewable heat.

There is also a growing interest in coupling the electricity and heat sectors, using heat networks as a way to balance the outputs of variable renewable power sources. For example, the city of Frankfurt expects this to make a major contribution towards achieving its 100% renewable energy target (Fiebig, 2017).

Summary – key policy aspects Germany:

- Ambitious targets under the energy transition but focus to date mostly on renewable electricity.
- Building code obligations for renewable heat as a driver in new-build homes.
- A generous subsidy programme, with extra incentives when linked to energy efficiency improvements.

The United Kingdom and the Netherlands: competing with natural gas

A switch to renewable heat is particularly challenging for countries that have the majority of properties connected to the gas grid, especially where, like in both the Netherlands and the UK, there are a large number single-family homes and fewer apartment buildings. Neither country has an extensive district heating network, with 4% of the population served in the Netherlands and 2% in the UK 2% (Euroheat and Power, 2016). Low-cost individual gas boilers dominate the heating market in both countries.

Netherlands

The Netherlands, together with the UK, has the lowest share of renewable heat in the European Union, with only 5.5% of heat demand met by renewables in 2015 (Eurostat, 2017c). Like the UK, the Netherlands has an extensive gas network and very little district heating, supplying only around 4% of households. Natural gas accounts for 78% of heat supplied and became dominant as a result of large indigenous gas reserves in the Groningen Gas Field, the largest in Europe. However, output from Groningen has reduced significantly in recent years, raising concerns about gas imports and energy security. The accord of the new Dutch coaltion government aims to further reduce output from Groningen.

The Dutch government has recognised the need to tackle the heat sector. In 2015, the Minister of Economic Affairs published a Heat Vision statement. This suggested a twin strategy of reducing heat demand through energy efficiency and switching to renewable heat sources. It identified great potential for the use of thermal energy storage, geothermal, solar thermal, biomass, heat pumps, as well as industrial excess heat. In areas with dense heat demand, district heating is expected to play a greater role, whereas heat pumps would dominate in less densely populated areas (Kleefkens, 2015).

Subsequently, the Dutch 2050 Energy Agenda, published in 2016, set a goal for an 80 to 95% reduction in CO_2 emissions by 2050. Low temperature and high temperature heat were listed as two out of four focal areas for achieving this goal (Ministry of Economic Affairs Netherlands, 2016), with both improvements in energy efficiency and moving heat supply away from gas identified as key areas for action.

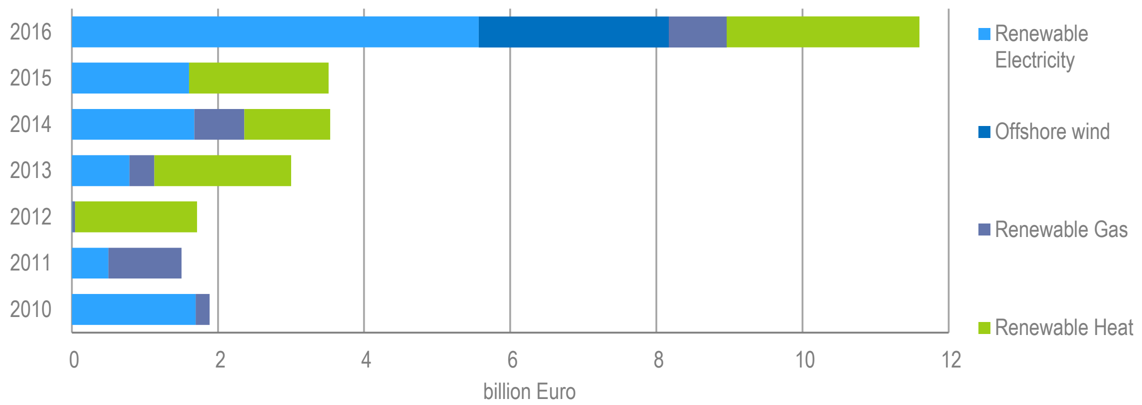
The new governing coalition accord published in October 2017 further strengthens Dutch climate change targets and aims at a 49% CO_2 reduction by 2030. As part of this, the role of gas in the heating of buildings is to be reduced. This will involve an amendment of the Heat Act, which will remove the right to a gas connection, initially for new houses. Further measures to reduce the role of gas in heating are currently being explored.

There is already significant activity at the municipal level to promote a switch away from gas heating. Amsterdam City Council published a plan in 2016 aimed at phasing all gas heating and cooking by 2050. Subsidies are available for building owners who want to switch to other types of heating and the district heating network is being expanded. Furthermore, in 2017, 30 municipalities, including the largest cities Amsterdam, Rotterdam and Utrecht, signed a 'Green Deal' (a government-supported sustainability initiative) for 'gas-free districts'. Each of the municipalities is implementing a set of measures to make some existing districts gas-free.

Currently, the main support instrument for renewable heat in the Netherlands is the Stimulation of Sustainable Energy Production Scheme (Stimulering Duurzame Energieproductie - SDE+), a combined support scheme for renewable electricity, biogas, and renewable heating technologies. The SDE+ is a feed-in premium allocated via a tendering procedure. The tender is organised in steps, starting with the cheapest options and moving on to more expensive ones until the budget limit is reached. This tends to benefit low-cost renewable heat and biogas options.

In 2012, 2013 and 2015, renewable heat accounted for the majority of the SDE budget. In 2016, the overall budget was much larger, with the majority going to renewable electricity. Renewable heat still received similar support as the years before but did not receive a bigger share of the budget as not enough new good projects came through the tendering process (Figure 15).

Figure 15 • SDE budget allocations according to technology, 2010-16



Source: RVO (2017), *SDE+ Tables*.
Note: Budget allocations are for the lifetime of the project (generally 15 years) winning the tenders in each specific year.

Key message • Renewable heat technologies play an important role in the Dutch renewable energy support scheme SDE.

Other instruments available for renewable heat support include grants under the Sustainable Energy Investment Subsidy scheme (Investeringssubsidie duurzame energie - ISDE) for the support of small renewable heating installations in homes and businesses (e.g. EUR 650 for solar thermal and EUR 1500 for ground source heat pumps). These are levels similar to those available under Germany's *Marktanreizprogramm*.

The Dutch government has highlighted the need for significant innovation to make further progress in heating and cooling. This could include the use of aquifers for heat storage, hybrid heat pumps (with gas for peak loads) and a better alignment between energy efficiency, residual heat and renewables (De Vries, 2017).

Summary – key policy aspects Netherlands:

- Historic focus on indigenous natural gas makes switch to renewable heat difficult.
- Long-term targets for CO_2 to 2050 with recognition of importance of heat decarbonisation.
- The SDE+ scheme with tenders where heat has proven to be competitive against renewable electricity.

United Kingdom

Like the Netherlands, the UK has a very low share of renewable heat, with only 5.5% of heat consumption met by renewables in 2015. This compared to 22.7% of electricity generation (Eurostat, 2017c). Most of the heat in buildings is supplied by individual gas (75%) or oil (8%) boilers (CCC, 2016). This reflects the housing stock (much of which is composed of low-density single-family dwellings), extensive gas networks and low gas prices. District heating networks are very limited, supplying only about 2% of UK heat demand, primarily from natural gas boilers and small co-generation plants. Some small district heating schemes have recently deployed biomass boilers (e.g. Sheffield Road Flats in Barnsley).

The combination of the United Kingdom's target under the RED and the ambitious long-term greenhouse gas emission targets under the 2008 Climate Change Act have resulted in a greater government focus on renewable heat policy. Part of this effort has been to take a more strategic approach, with the publication of a heat strategy in 2012 and a follow-up paper in 2013 (DECC, 2013). Key aspects of this focused on buildings and industrial heat decarbonisation and the role of heat networks. Subsequently, the government set up a Heat Networks Delivery Unit, made some funding available for district heating networks, and developed a set of industrial carbon reduction and energy efficiency roadmaps.

The centrepiece of the United Kingdom's approach has been the introduction of a long-term support programme for renewable heat, the Renewable Heat Incentive (RHI),[8] with payments based on heat generated. The RHI was initially introduced for commercial and industrial applicants in 2011 and then extended to the domestic sector (homes) in 2014. The aim of the RHI is to incentivise the uptake of renewable heating technologies by providing an attractive rate of return to compensate for the higher investment costs of some renewable technologies, as well as other non-economic barriers. Payments under the non-domestic RHI are based on heat meter readings, while in the domestic sector heat output is estimated.

Due to a very thorough monitoring system for RHI deployment, the United Kingdom now has some of most comprehensive renewable heat deployment statistics available globally, covering technologies and sectors where they are deployed. Biomass boilers dominate the scheme overall, with heat pumps (in particular air-source heat pumps (ASHPs)) also having a significant share in the residential sector (Table 5).

Table 5 • Key RHI statistics as of end of September 2017

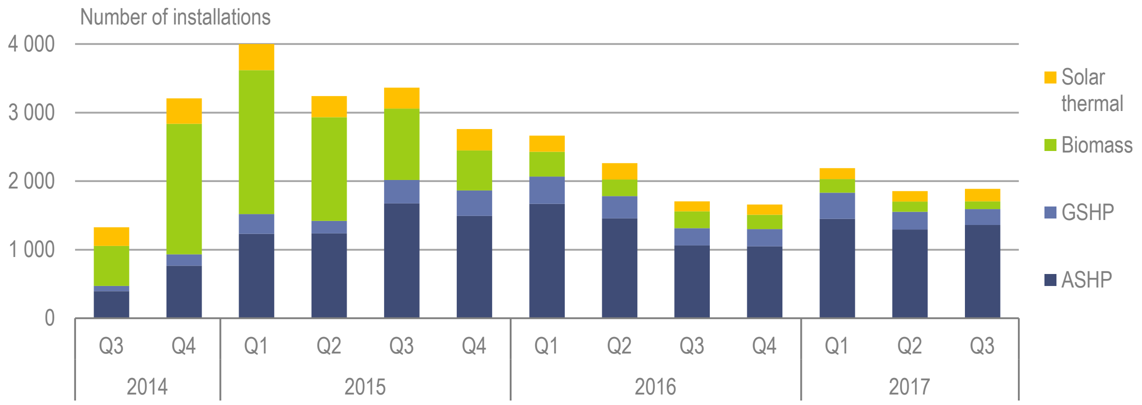
	Non-domestic scheme	Domestic scheme
Total number of accredited installations	17 636	63 086
Installed capacity (MW_{th})	3 351	Not available
Heat generated	17 590 GWh (since November 2011)	2 056 GWh (since April 2014)
Key technologies	Biomass boilers (91% of capacity)	Biomass boilers (54% of heat generated), air-source heat pumps (29%), ground-source heat pumps (16%)
Key sectors	Agriculture (27%), accommodation (31%)	Off-gas grid (72%), detached houses + bungalows (72%)
RHI estimated budget April 2017 to April 2018	611 million pounds (GBP) (USD 619 million)	GBP 103 million (USD 122 million)

Sources: BEIS (2017b), *RHI deployment data: September 2017*; BEIS (2017a), *RHI deployment caps.*

[8] The RHI currently operates only in England, Wales and Scotland. A separate scheme introduced in Northern Ireland was suspended in February 2016 for budgetary reasons.

RHI spending has been consistently below budget (CCC, 2017) and furthermore there was a slowdown of RHI accreditations following a reduction in the biomass tariffs (20% for the domestic tariff and 15% for small commercial installations) from April 2015. This resulted in a sharp reduction in the deployment of biomass boilers under the scheme, without a corresponding increase from other technologies. Non-domestic installations saw a reduction of 30% (by capacity) from 2015 to 2016, while the number of domestic scheme installations fell by even more dramatically by 200% (Figure 16). Subsequent to further tariff revisions from January 2017, deployment has seen a small increase, especially for air-source heat pumps whose tariffs were increased by 25%.

Figure 16 • Domestic RHI accredited installations by technology, 2014-17



Source: BEIS (2017), *RHI deployment data: September 2017*.

Note: Excludes so-called legacy systems that were installed after the announcement of the plans to introduce the RHI and the actual launch of the domestic RHI.

Key message • Despite various tariff adjustments under the RHI, uptake of renewable heat technologies in the UK remains slow.

In parallel to the RHI, the government has also committed to funding for district heating networks which currently only supply around 2% of the UK's heat. The GBP 320 million (USD 432 million) Heat Networks Investment Project (HNIP) capital investment programme is expected to support up to 200 projects by 2021 through grants and loans and other mechanisms.

Funding can go to projects that use a minimum of 50% renewable or waste heat, or alternatively 75% cogenerated heat. Potentially, the networks could therefore still fully supplied by fossil fuels. A first round of funding of GBP 24 million (USD 32 million) was announced in 2017, supporting 9 projects that will deliver heat to 5,000 homes. In addition, there are further support measures available at the devolved level in Scotland (e.g. zero-carbon loans for renewable heat and a district heating loan fund).

Aside from the RHI and HNIP programme, the UK lacks several of the policies that have been effective in other European Union countries:

- There is no obligation to install renewable heat options in new-build properties.
- No carbon or energy taxes for domestic consumers and tax rates on natural gas are very low compared to elsewhere, with only VAT payable at 5% (see Figure 8).
- Lack of regulations on heat zoning or connection to heat networks (except for new developments in London), making the business case for these difficult.
- No major building renovation support schemes that link energy efficiency and renewable heat deployment.

These factors will make it difficult for the UK to reach its overall renewables target under the RED (although with the UK planning to leave the European Union, this may no longer be relevant), and the longer-term heat decarbonisation needed for meeting its carbon budgets. According to the Committee on Climate Change (2016), a credible new strategy and a much stronger policy framework is needed for decarbonising heat in buildings.

Summary – key policy aspects United Kingdom:

- Long-term (2050) policy commitment through the Climate Change Act but slow progress.
- High levels of support through the RHI are needed as other policy levers are absent.
- Detailed renewable heat statistics are produced to support policy.

China and the United States: the top two global heat consumers

China and the United States are the two countries that consume the largest amount of heat. Together, they accounted for 37% of global heat consumption in 2015. Renewable heat remains underdeveloped in both countries, with its share at only 3% in China and 10% in the United States. However, there has been a recent push to improve this with China's 12th and 13th Five Year Plans including ambitious renewable heat targets and several states in the United States developing plans to increase renewable heat deployment. Compared to European Union countries, renewable heat data for these two countries is poor which makes the assessment of policy impact difficult.

China

In China, while two-thirds of heat demand is in industry, space and water heating demand is growing. China's largest cities are in climate zones that have cold winters and in many cases also hot summers. As the country's population has become increasingly urbanised with higher levels of income, demand for heating and cooling has increased rapidly. Residential heat demand (including electricity used for heating but excluding traditional biomass) increased from 7.0 EJ in 2007 to 10.6 EJ in 2015, an increase of 55% (IEA, 2017e). Growth in industrial production (especially energy-intensive sectors such as iron and steel) also resulted in a 31% increase in industrial heat demand over the same period.

Space heating demand in China is increasingly being met by district heating systems. District heating networks in China currently cover around 8.5 billion square metres (m^2) of buildings floor area, having nearly tripled since 2005 (IEA, 2017h). Heat supply in these systems is dominated by coal boilers and coal-fired co-generation plants which are a major cause of local air pollution.

Currently, renewables contribute only around 1% to meeting district heating demand and 2% to overall heat demand. However, the district heating systems do provide a good basis for heat decarbonisation and the integration of renewable heat sources. A recent report by the International Renewable Energy Agency (IRENA, 2017a) has suggested that a 24% renewable share in district heat generation by 2030 is feasible, split equally between geothermal, bioenergy and solar. There is also some scope for the use of electric boilers and heat pumps to assist with the integration of wind generation. A new IEA report has analysed options for diversifying district heating in China and provides policy recommendations (Box 7).

The Chinese government has recognised the need to switch heating to cleaner sources. The 12th Five Year Plan (2011-15) included targets for solar water heating and geothermal heat. The target for solar (400 million m^2 of solar water heaters collector surface) was overachieved, with 440 million m^2 installed and China now has the world's largest installed capacity of solar thermal

(309 GW_{th}). In cities, district heating systems do not supply hot water (as they are often steam-based), and solar thermal provides a cost-effective option for hot water supply.

There have been some subsidies for solar water heaters at times, but most of the growth has been achieved without central government intervention because of the low cost of the systems. There are also some local policies that support solar thermal. For example, Shenzhen requires all new homes to install solar water heaters. However, growth in solar thermal has slowed down in recent years after the record deployment of 2013 (Figure 17), in part due to a slowing housing market. In both 2014 and 2015, the solar thermal market fell by 17% compared to the previous year.

Box 7 • District heating in China – options for diversification

China has the largest district energy system in the world, with more than 200 000 kilometres of networks providing heat to close to 9 billion square metres of building space. With China's rapid urbanisation and increasing demand for thermal comfort, energy use in heating and cooling systems is set to rise even higher over the coming decades, placing heavy pressure on energy supply and the environment. Coal still accounts for about 90% of the energy consumed for district heat production, and carbon emissions from district heat have increased by 30% since 2010. Coal district heating boilers are one of the major sources of air pollution in the Northern part of China.

"*District energy networks in China – options for optimisation and diversification*" (IEA, 2017h) is a new report produced by the IEA in collaboration with Tsinghua University Building Energy Research Centre. The report was supported by the National Development and Reform Commission of China and highlights cost-effective options and business models that can decarbonise and optimise district energy systems.

China has significant potential to improve the overall efficiency of its district heating network by recovering excess heat, as well as improving the energy performance of the building stock. Furthermore, it can use its abundant renewable resources, especially geothermal power, biomass and solar thermal, to diversify supply and reduce coal use in district heating (and cooling). Geothermal district heating is already well advanced in some cities. Xiong county in Hebei province (which has 390 000 residents, part of the recently declared Xiong'an New Area) generates all its heat from geothermal sources.

China has already made significant progress towards cleaner district heating. However, despite competitive prices, especially at larger scales, it is still difficult for many renewable heat options to compete with fossil fuels, and particularly coal, in China. Existing heat pricing tariffs based on the cost of coal might be an obstacle to the development of renewable options.

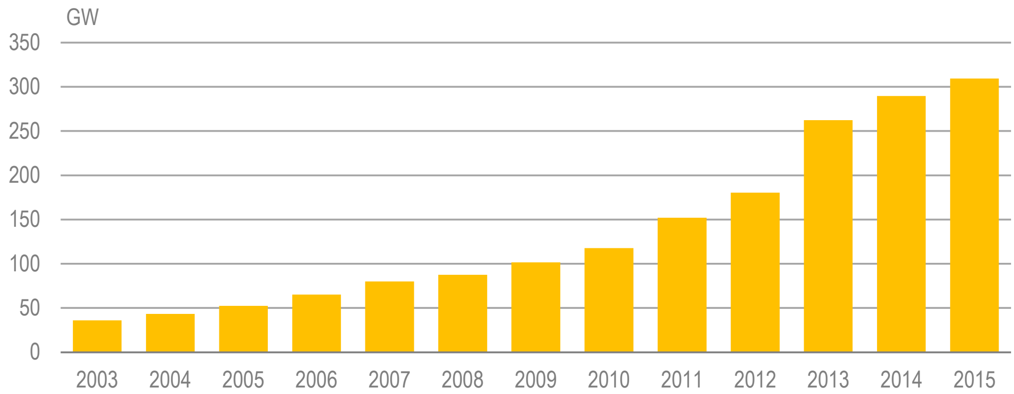
Further action is needed to pursue key policies and technological developments that will improve the energy intensity and emissions footprint of district heating and cooling systems. Policy frameworks should consider how heat pricing tariffs and market conditions either encourage or discourage integration of renewable energy sources.There is a window of opportunity for action, given the large expected growth of district energy networks in the coming two decades, and in some cases policy could take significant time to implement.

For geothermal heat (including heat pumps), the 12th plan target was to supply 1.2 million homes and 580 million m^2. By the end of 2014 a total of 390 million m^2 of buildings were heated by either heat pumps or geothermal district heating, and the area served by geothermal district heating had increased 2.8 times from 2009 (Zheng, 2015). However, this is still a very small contribution to overall heat supply, accounting for around 1% of district heating supply.

The 13th Five Year Plan (2016 to 2020) includes new ambitious targets for solar thermal, geothermal and biomass heat:

- Solar thermal – a further 400 million m^2 to be installed, to reach a total of 800 million m^2.
- Geothermal – a total 1.6 billion m^2 to be connected.
- Biomass – scale-up from around 8 million tonnes (Mt) in 2016 to 30 Mt by 2020.

Figure 17 • Cumulative solar thermal capacity in China, 2003-15



Source: IEA-SHC (2017), *Solar Heat Worldwide.*

Key message • Despite a recent slow-down, China has seen some impressive growth in solar thermal deployment. A further doubling of capacity is expected by 2020.

Reaching these targets will reduce the urban air pollution impacts related to heating which is a priority for the Chinese government. To help achieve this, China has announced a programme of pilot cities for clean heating. The cities chosen will receive between 0.5 and 1 billion yuan (USD 75 million to 150 million) per year for three years to implement clean heating solutions. Furthermore, in December 2017, a clean heating plan specifically for the northern heating area was issued. The five year plan aims to cut coal consumption by 74 million tons by 2019 and 150 million tons by 2021, to be replaced by cleaner sources including renewables (IEA, 2017i).

For geothermal, a development plan was issued by the government in 2016 to help achieve the 13th Five Year Plan target. Recently, state-owned Sinopec Corp has announced plans to create 20 smokeless cities nationwide replacing coal with geothermal energy, covering 100 million m^2 during the 13th Five Year Plan period (Geothermal Resources Council, 2017).

Summary – key policy aspects China

- Ambitious targets in five year plans and good track record of achieving them.
- Rapid deployment of solar thermal water heating without subsidies.
- Air pollution concerns an important driver for shifting urban heating to renewables.

United States

Renewable heat accounted for around 10.5 % of United States heat consumption in 2015. There is a lack of comprehensive data on heat generally and on renewable heat deployment specifically. The best information available is for the residential sector, where natural gas is the main space heating fuel in almost half of households. Electricity supplies space heating in 36% of households, as well as water heating in 45% of households. A total of 12 million households (around 10%) use heat pumps. Most of these are in the more humid regions of the US which have milder winters. Biomass is rarely used as a main heating fuel (only 2% of homes) but somewhat more common as a secondary heating source, used in about 8% of households (EIA, 2017). Some water heating is done through solar thermal which in the United States is primarily used for pool heating. In 2015, the United States accounted for 4% (17.4 GW_{th}) of global solar thermal installed capacity, compared with 11.3% of the global total in Europe (IEA-SHC, 2017).

Unlike the European Union countries and China, at the Federal level, the United States does not have specific targets for renewable heat, nor a clear policy. However, several states have adopted renewable heating and cooling plans or strategies. For example, Vermont's 2016 comprehensive energy plan establishes a goal to increase the share of renewable heat from 20% to 30% by 2025 (Vermont Department of Public Service, 2016).

There have been federal tax credits for various renewable heat technologies available since 2006 but most expired at the end of 2016. As of 2017, the only remaining tax credit (30%) is for solar thermal which is due to run to 2022. It is available for both new and existing homes through the Residential Renewable Energy Tax Credit and for commercial applications through the Business Energy Investment Tax Credit.

Other incentives are available in many states. Examples include:

- Sales tax exemptions in many states for various renewable heat technologies.
- For wood stoves and biomass boilers, tax incentives and rebates in eleven states (Alliance for Green Heat, 2017).
- New York State is offering a range of incentives for biomass heating systems, air and ground source heat pumps, as well as biodiesel blended with conventional heating oil (New York State, 2017).

Additionally, some states have incorporated renewable heat into their Renewable Portfolio Standards (RPS) that historically focused on electricity generation (Stori, 2017):

- Out of the 29 US states that have RPS schemes, 12[9] provide for the inclusion of renewable heat technologies. These vary in terms of which technologies are eligible, the most common being solar thermal.
- As of 2014, New Hampshire was the first state requiring a specific portion of its RPS come from heat. Over 10 MW_{th} of capacity has been added to the RPS. By 2025, 2% of energy will have to come from thermal renewables, as part of an RPS of 24.8%.

There are also some municipal level instruments. For example New York City, the largest municipal consumer of heating oil in the country, in October 2012 set a city-wide 2% biodiesel requirement for heating oil, increasing to 5 percent in 2017. Two downstate New York counties have recently passed legislation to introduce a 5% biodiesel obligation in 2018 (Biofuels Digest, 2017).

Evaluating the success of the federal and state-level policies is difficult, as very little deployment data linked to specific policies is published. For example, there is no data available on the uptake of tax credits for renewable heat or deployment under the RPS. The California Solar Initiative is the one exception, with detailed statistics available for the programme which started in 2010 (Box 8).

District heating plays a small role in the United States, although it has a number of long established district heating networks, for example in New York. Currently, district heat is primarily supplied by gas, with significant contributions also from coal and oil. A recent study by IRENA identified scope for increasing the share of renewables in district heating and cooling to

[9] Arizona, Washington DC, Maryland, Massachusetts, Nevada, New Hampshire, North Carolina, Pennsylvania, Texas, Wisconsin have mandatory RPS programmes, while in Indiana and Utah they are voluntary.

36%, mainly based on a large potential for biomass, as well as some solar thermal and geothermal (IRENA, 2017b).

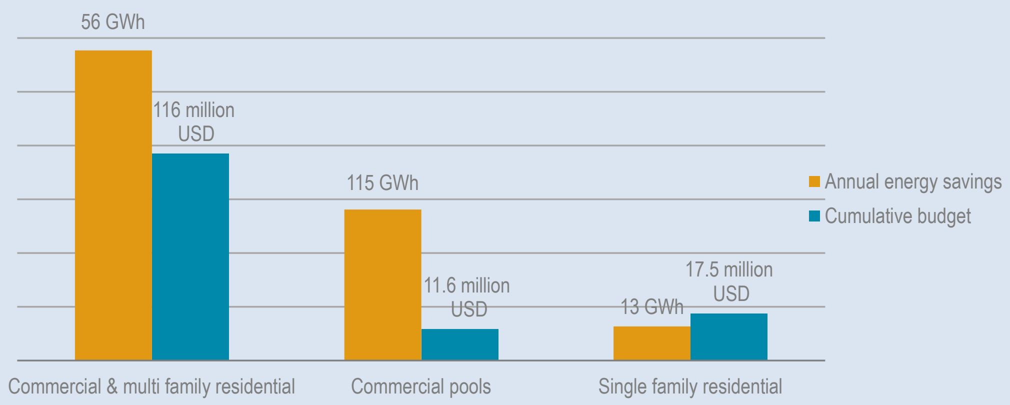
Box 8 • The California Solar Initiative

The California Solar Initiative (CSI) is a key element of a broader campaign run jointly by the California Energy Commission and the California Public Utilities Commission to increase the deployment of solar PV and solar thermal systems in the state. For solar thermal, the goal is to install 585 million therms (0.06 EJ) of gas-displacing solar hot water systems by the end of 2017.

CSI is a solar rebate programme for the customers of three investor-owned utilities - Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas & Electric (SDG&E). The programme supports the installation of solar systems (PV or solar water heating) in homes and businesses. The solar thermal part of the programme has been running since May 2010 and has a cumulative budget of around USD 300 million of which USD 50 million are for low income households.

By December 2017, with just over half the budget spent, CSI had funded 7280 solar thermal installations, with cumulative savings of 6.4 million therms. Costs are much lower for large systems, especially commercial pool systems (average costs 0.21 USD/kWh of fossil fuel energy saved), than for those in single family homes (average costs 1.30 USD/kWh) (Figure 18).

Figure 18 • Savings achieved versus budget spent, California Solar Initiative (cumulative 2010-17)



Notes : Data effective as of 1 December 2017, annual energy savings compared to gas or electric water heating replaced.
Source: Go Solar California (2017) California Solar Thermal Statistics.

Summary – key policy aspects United States

- Absence of targets and clear policy on renewable heat at federal level.
- Most policies and incentives at state level but not all states participate.
- Lack of data across multiple programmes makes assessment of effectiveness difficult.

Case studies summary

The case studies have looked at nine countries which are very different in terms of their heat demand, infrastructure, building stock, industrial structure, renewable heat resources and other relevant circumstances. Policy approaches therefore also vary considerably, as summarised in Table 6.

Table 6 • Policy summary

Country	Targets	Summary
Denmark	• 39.8% share of RE heat by 2020 (NREAP) • 2035 all heat from renewables	• Long-term heat policy with ambitious targets and effective regulatory framework • Comprehensive heat planning at local level, with district heating as public infrastructure. • Energy taxation with exemptions for renewables. • Regulatory measures restricting the use of fossil fuel heating.
Finland	• 47% share of RE heat by 2020 (NREAP estimated trajectory)) • 50% renewable heat supply and 55% domestic energy supply by 2030	• Extensive district heating originally established by municipal energy companies. • Progressively increasing carbon taxes • Ambitious renewables and coal phase-out targets • Range of renewable heat support measures
Sweden	• 62.1% share of RE heat by 2020 (NREAP estimated trajectory) • Country will be net-zero carbon by 2045	• Long-term heat policy and ambitious targets • High energy and carbon taxes with exemptions for renewables • Effective building codes improving energy performance • District heating as public infrastructure
France	• 38% of renewables in final heat consumption by 2030 • Renewable heat in district heating x5 by 2030	• Ambitious targets for renewable heat for 2030 but deployment is lagging behind. • Cost-effective renewable heat support for medium and large-scale installations under the Fonds Chaleur programme • A range of residential sector incentives.
Germany	• 14% renewable heat by 2020 • Almost climate neutral buildings by 2050	• Ambitious targets under the energy transition but focus to date mostly on renewable electricity. • Building code obligations for renewable heat as a driver in new-build homes. • A generous subsidy programme, with extra incentives when linked to energy efficiency improvements
Nether-lands	• 8.7% share of RE heat by 2020 (NREAP expected share) • 2050 CO_2 reduction target and heat identified as focal area for reductions	• Historic focus on indigenous natural gas makes switch to renewable heat difficult • Long-term targets for CO_2 to 2050 with recognition of importance of heat decarbonisation • Renewable heat projects have been competitive with renewable electricity in the SDE+ scheme
UK	• 12% of RE heat by 2020 (NREAP indicative share) • Carbon budgets to 2032 and 80% CO_2 reduction target for 2050. Indicative ambition for low-carbon heat in the budgets	• Long-term (2050) policy commitment through Climate Change Act • High levels of support through the RHI are needed as other policy levers are absent • Detailed renewable heat statistics are produced to support policy
China	13th plan: • Solar thermal 400 million m^2 • Geothermal 1.6 billion m^2 • Biomass scale-up to 30 Mt by 2020	• Ambitious targets in five year plans and good track record of achieving them • Rapid deployment of solar thermal water heating without subsidies • Air pollution an important driver for shifting district heating to renewables
United States	• No heat or renewable energy targets at federal level • Some state level targets	• Absence of targets and clear policy on renewable heat at federal level • Some state level initiatives • Lack of data makes assessment difficult

Given the different approaches to policy, it is not surprising that the renewable heat shares vary considerably between the countries, ranging from almost 70% in Sweden down to as little as 3% in China (Figure 9). Six of the countries have a heat share above the global average of 9%.

One common observation for all nine countries is that renewable heat support policies have generally focused on buildings through a variety of financial incentives and, in some countries, policies to support renewables in district heating. There are fewer policy instruments for industrial heat, although some support is available (e.g. France Fonds Chaleur).

5. Policy assessment and recommendations

Identifying best practice in renewable heat policies

Globally, progress on renewable heat deployment has been slow and more is needed to ensure global climate targets are met. The case studies have identified a number of policy successes, showing how countries can progress towards a transition from a fossil-fuel system to cleaner heat options. However, they have also shown that the context for renewable heat deployment varies enormously between countries – with resource potentials, heat demand and physical infrastructure all affecting the choice of renewable heat options and of policy approaches.

Assessing the effectiveness of individual policies and making comparisons between countries is not straightforward. Ideally, an assessment would include evaluating the following:

- The adequacy of targets.
- The appropriateness of the chosen policy instruments to address identified barriers.
- Progress in deployment.
- The cost-effectiveness of deployment.

However, for many countries, relevant data to assess all of these factors is not available. Most countries do not publish detailed statistics on heat demand or comprehensive renewable heat deployment figures. There is some market data for specific technologies (e.g. for solar thermal IEA-SHC provides some deployment and cost data), although it does not cover all countries. This compares poorly with electricity, where there are extensive data available on deployment. Policy evaluation of key policy instruments is also rarely available.

In the absence of detailed data, it is useful to make a high level assessment of whether countries have a number of best practice policy elements needed to deliver deployment towards long-term energy transition and heat decarbonisation aims. These include:

- Long-term ambition for renewable heat across sectors (or at least in buildings), as well as targets for short and medium term (2020, 2030).
- Being on track to achieve short/medium-term targets.
- Delivery plans for achieving targets.
- Instruments to address the main economic barriers (e.g. support mechanisms, carbon taxes).
- Instruments to address the main non-economic barriers (e.g. certification).
- Taking a broader energy-system approach (including sector coupling, integration with energy efficiency policy, prioritisation of bioenergy in difficult-to-decarbonise sector).
- Good deployment statistics to allow policy evaluation (e.g. assessment of cost-effectiveness) and policy revision as needed.

Table 7 provides a high level assessment of the policies of the nine countries covered in this paper.

Table 7 • Policy assessment summary

	DK	FIN	SWE	FRA	GER	NL	UK	CHN	United States
Renewable heat targets	⊖	⊖	⊖	⊖	⊖	⊖	⊖	⊖	×
Targets on track	✓	✓	✓	×	✓	×	×	✓	n/a
Delivery plan	✓	✓	✓	✓	✓	✓	✓	✓	×
Economic instruments	✓	✓	✓	✓	✓	✓	✓	⊖	⊖
Non-economic instruments	✓	✓	✓	✓	✓	✓	✓	⊖	×
Broader energy system approach	⊖	⊖	⊖	⊖	⊖	⊖	⊖	⊖	×
Data & policy evaluation/revision	⊖	⊖	⊖	⊖	⊖	⊖	✓	⊖	×

Legend: ✓ Good/comprehensive; ⊖Partial/some/no information available; × None/inadequate.

Notes: Targets – Denmark, Finland, Netherlands, Sweden and the UK only have indicative renewable heat trajectories (not firm targets) in their NREAPs. Progress for these countries has been assessed against these trajectories.

Not one of the nine countries has a fully comprehensive approach to heat policy but some cover more areas than others. In general, the European Union countries tend to have the most developed renewable heat policies, driven by the need to meet the 2020 renewable energy targets under the RED. Particularly weak is the United States, the world's second largest heat producers/consumers.

The three countries which have achieved the highest shares of renewable heat penetration amongst the case study countries (Denmark, Finland and Sweden) have a number of features and policies in common:

- A long-term approach to heat policy going back decades.
- Long-term goals for renewables and heat decarbonisation.
- Good biomass resources.
- Extensive district heating networks established over decades, generally with central and/or local government support.
- Carbon/energy taxation that benefits renewables.
- Other measures to tackle non-economic barriers such as heat zoning and building codes.

Those with a low penetration of renewable heat lack many of these features. Obviously, some such as the lack of biomass resources or the absence of district heating networks, are difficult to overcome, especially in the short- to medium term. Others such as carbon taxation may face political opposition.

Weaknesses observed across countries include a lack of comprehensive deployment figures and consistent policy evaluation. Furthermore, most countries' renewable heat policies do not properly employ an energy systems approach. Sector coupling has become a theme in a few countries but is not yet fully integrated into policy. Alignment with energy efficiency policy is usually at best limited to a few measures (e.g. building codes for new buildings).

Renewable heat policy recommendations

Approaches to renewable heat policy will have to vary between countries, reflecting different circumstances (e.g. building stock, industrial heat demand, resource potentials) and specific barriers that need to be overcome. However, drawing on the country case analysis, it has been possible to identify a set of recommendations that apply to types of countries which have certain shared characteristics:

1. Countries with extensive district heating networks

a) Countries that already have high shares of renewable heat (40+%)

- Put more focus on sector coupling, especially in countries where there is also rapid growth of variable renewable power (e.g. incentivising the use of heat pumps for demand response).
- Ensure cost-optimal alignment between energy efficiency and heat policy (e.g. to avoid stranded district heating assets where they are the best option to supply renewable heat).
- Ensure biomass resources are allocated optimally between district heating and other sectors where they are needed for decarbonisation.

b) Countries with medium shares of renewable heat (20-40%)

- Set targets and develop strategies for further decarbonisation of district heating.
- Develop instruments to overcome non-economic barriers (e.g. support for developing supply chains).
- Incentivise options for renewable heat in industry, especially those that provide opportunities for connection to district heating through use of cogeneration or excess heat.

2. Countries with relatively low shares of renewable heat (10-20%) and some district heating

- Consider regulations for building renovation requiring a specific share of renewable heat (or connection to district heating).
- Incentivise accelerated district heating expansion focused on low-carbon heat sources.
- Ensure that energy taxes and other charges (e.g. surcharges for renewable electricity) do not disincentivise renewable heat, in particular the use of heat pumps.

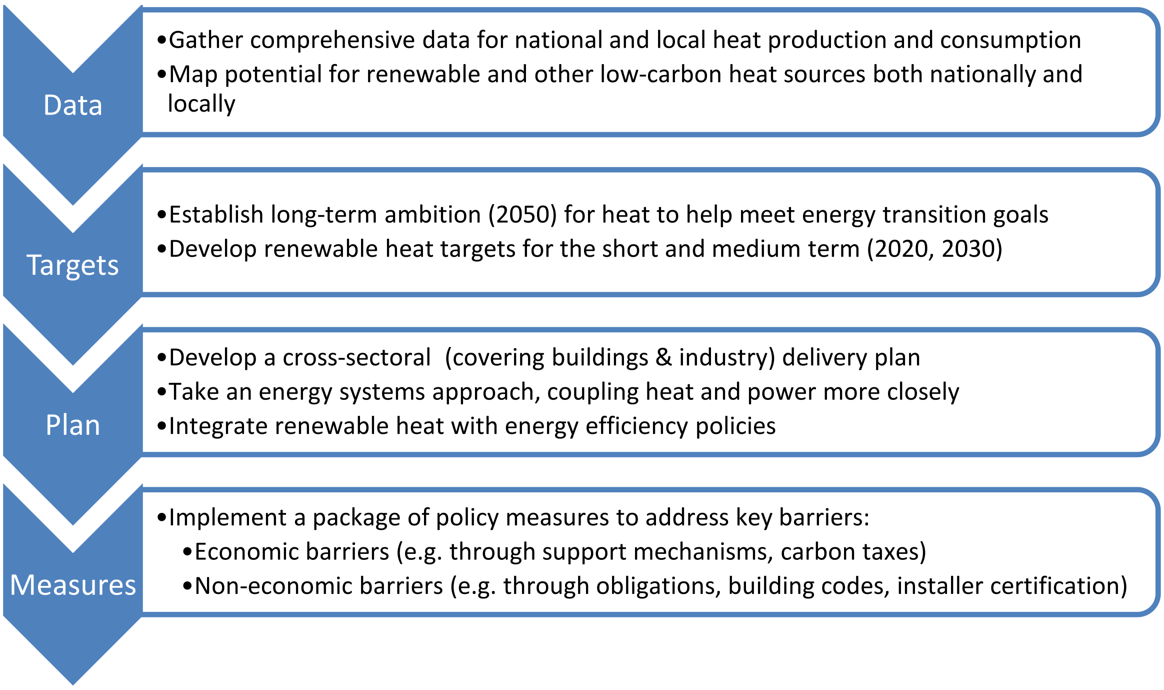
3. Natural gas countries (extensive gas grids, low gas prices, very little renewable heat or district heating)

- Set clear targets; develop trajectories and strategies for increasing the share of renewable heat over time.
- Implement carbon pricing, with progressive increases over time.
- Develop effective regulations (e.g. building codes for new buildings that require the installation of renewable heat options to provide more market certainty).
- Support R&D into innovative options such as the production of hydrogen with renewables and its use in the gas grid.

4. Countries that currently have no renewable heat policy

Figure 19 proposes some general policy recommendations for countries setting out to develop renewable heat policies:

Figure 19 • Key steps for establishing effective renewable heat policies



Finally, it has to be acknowledged that the most successful countries have made public investments and implemented measures, such as taxation, over decades. Renewable heat is an area where rapid progress can be difficult to achieve due to for example slow renovation rates in the building stock and slow turnover of heating appliances in both buildings and industry. However, most countries will have some no-regrets options (e.g. producing biogas for heat from organic waste) which can be implemented more quickly and which bring multiple benefits. With the right strategy and policies a transition to low-carbon heat for buildings and industry can then be realised over time.

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Glossary

Acronyms and abbreviations

BAFA	Federal Office of Economics and Export Control (Germany)
CO_2	Carbon dioxide
CSI	California Solar Initiative
EEWärmeG	Federal Renewable Energies Heat Law (Germany)
EU	European Union
EU ETS	European Union emissions trading system
FIT	Feed-in tariff
HNIP	Heat Networks Investment Project
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISDE	Investeringssubsidie duurzame energie [Sustainable Energy Investment Subsidy scheme]
LPG	Liquefied petroleum gas
NREAP	National Renewable Energy Action Plan
PM	Particulate matter
PPE	Programmation pluriannuelle de l'énergie [Multi-Annual Energy Plan]
PV	Photovoltaics
RED	Renewable Energy Directive of the European Union
RHI	Renewable Heat Incentive
RPS	Renewable Portfolio Standard
SDE+	Stimulering Duurzame Energieproductie [Sustainable Energy Production Scheme]
VAT	Value added tax

Units of measure

C	Celcius degrees
EJ	Exajoule
GWh	Gigawatt hour
GWth	Gigawatt thermal
m^2	Square metre
Mt	Million tonnes
Mtoe	Megatonne of oil equivalent
MW	Megawatt
MWh	Megawatt hour
MW_{th}	Megawatt thermal
PJ	Petajoule

Currency codes

EUR	Euro
GBP	United Kingdom Pound Sterling
USD	United States Dollar

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