Parliamentary Office of Science and Technology

postnote

March 2010 Number 353

RENEWABLE HEATING

Heating accounts for almost 50% of UK energy consumption and associated carbon dioxide emissions. Renewable heating technologies could therefore make a significant contribution towards carbon reduction and renewable energy targets. This POSTnote examines the available resources and technologies for supplying renewable heating and cooling in the UK and the policy options that could support their take up. This briefing does not consider insulation or changes in consumer behaviour that can affect the overall demand for heat.

Background

Heating is required to keep buildings warm, produce hot water, and to supply energy for industrial processes. In total, heating currently accounts for 46% of the UK's energy consumption[1] and 47% of UK carbon dioxide (CO_2) emissions[2]. In 2007, less than 1% of UK heat was generated from renewable sources (Figure 1). Gas boilers are currently the dominant technology for heating and hot water in UK buildings. Industry uses a more diverse mix of fuels for its heat needs, including larger proportions of carbon intensive oil-fired and electric heating.

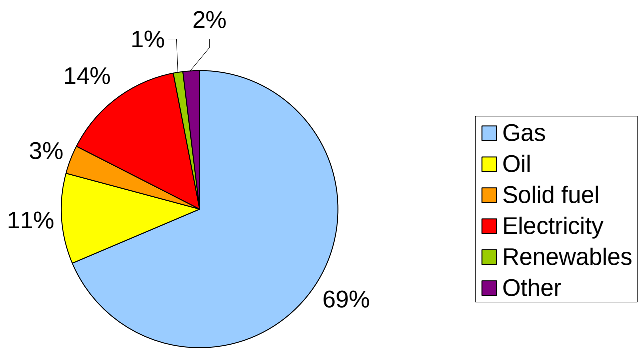

Figure 1 - Fuel mix for UK heat generation in 2007 (ref.1)

Meeting Heat Demand

Unlike electricity, heat cannot be transported efficiently over large distances. As a result, it must be generated close to where it is consumed, at a wide range of temperatures and scales. Some large industrial processes require heat in excess of 400ºC, while buildings are comfortable at 20ºC. Furthermore, the demand for heating in buildings varies widely with the design, age and fabric of the building, as well as with the season and the time of day. Thus, no single heat technology is the best at satisfying all types of heat demand all of the time.

Renewable Heat

Renewable energy is replenished by the Sun or the Earth at least as fast as it is consumed (see POSTnote 164). Renewable heat is defined in the Energy Act 2008 as heat generated from a range of renewable fuels and low-carbon technologies, discussed in more detail below. The UK has adopted an EU target to supply 15% of energy (heat, electricity and transport) from renewables by 2020. To achieve this target, government scenarios suggest that the UK could generate 12% of its heat from renewables.[3] This will require unprecedented growth (sustained at up to 90% per year[3]) in markets for renewable heating technologies. However, in the majority of cases, renewable heating is currently more expensive than fossil-fuel heating alternatives.

Renewable Heat Incentive

The government has proposed a Renewable Heat Incentive (RHI) to come into force in April 2011. This will provide regular payments to the owner of a renewable heating technology to bring costs in line with fossil-fuel heating. It is currently proposed that funds for the RHI will be raised through a tariff placed on fossil fuels used for heating, expected to result in a 14% increase in domestic gas bills by 2020 (equivalent to £104 a year on average), and a 20% increase for industry.[4]

Technologies

Solar Thermal

Solar Thermal (ST) devices collect the Sun's heat energy via solar panels mounted on roofs and use this heat to generate hot water. Even on a cloudy day, there is often enough sunlight falling on a roof to supply a household's hot water demand. In comparison, photovoltaic (PV) solar panels use sunlight to generate electricity.
Solar Thermal devices are widely deployed across Europe, and are currently responsible for the majority of

renewable heating installations in the UK. They can be installed to supplement central heating systems with hot water tanks in existing houses, where they typically supply up to 60% of hot water, but no space heating demand. As a result, the cost of a single unit of heat from ST is high compared with alternative renewable heating technologies (Table 1).

Table 1 Renewable Heating Technology Costs and CO_2 Emissions[5]

Technology	Heat Cost (p/kWh_{th})*	Fuel Emissions ($kgCO_2/kWh_{th}$)
Gas Boiler	6.7 - 16	0.23
Oil Boiler	8.1 - 14	0.32
Electric Heater	19 - 24	0.61†
Air Source Heat Pump	10 - 39	0.20 - 0.22†
Ground Source Heat Pump	10 - 32	0.14 - 0.17†
Biomass Boiler	11 - 24	0.031 ‡
Biomass District Heating	11 - 22	0.036 ‡
Solar Thermal	50 - 74	N/A

***1 kWh_{th} (kilowatt-hours thermal) is the amount of heat energy given off by a 100% efficient 1 kW electric heater left on for an hour. This would supply 5% of an average UK citizen's daily heat consumption.**

† Emissions based on a 2007 electricity grid rolling average.

‡ Emissions relate to processes such as harvesting and transport, not combustion (emissions from which are captured in the growth cycle).

Geothermal

The molten core of the Earth and radioactive decay in the ground generate a substantial quantity of renewable heat. At depths of 5-15 km this is hot enough to be a source of hot water for heating buildings, and steam for industrial processes. Conventional geothermal technologies are mature, but are tightly constrained to suitable ground conditions (for example, the Southampton geothermal district heating scheme[6]). Devon and Cornwall (current trial sites) and the north of England are the most promising locations for more advanced geothermal technologies.

Heat Pumps

As sunlight travels through the atmosphere and falls on the Earth's surface, it warms the air and ground, resulting in a large store of ambient heat energy. However, this heat energy is at low temperatures, usually below that comfortable for homes and workplaces. Heat pumps use electricity to 'pump' this heat to higher temperatures and transfer it into buildings (Box 1). They operate on the same principle as domestic refrigerators, only in this case the outside air or ground is being (slightly) cooled. When run in reverse heat pumps can provide air-conditioning to cool the inside of buildings in summer. There are two main types.

Air Source Heat Pumps

Air Source heat pumps (ASHP) extract heat directly from the outside air and transfer it to water (in a water-based central heating system) or air inside buildings. The efficiency of ASHPs (Box 1) decreases during winter as the outside air becomes colder compared with inside, requiring more pumping. The electricity consumed by ASHPs is therefore seasonal. This requires investment in electricity network capacity – which is often ignored when calculating the cost of a single heat pump (Table 1) - that is utilised for only part of the year.

Box 1 Heat from Electricity

In 2007, 14% of UK heat was generated from electricity (Figure 1). Power stations typically require 2-3 units of fuel to generate 1 unit of high grade energy in the form of electricity. Once transmitted via the power grid, electricity can be converted almost entirely to heat energy in buildings by electric heaters. By comparison, it requires approximately 1.1 units of fuel (gas, oil or coal) to generate 1 unit of heat in buildings directly (in a boiler). Thus, heat generated from fossil-fuelled electric heaters has a larger quantity of fuel embodied within it, and therefore significantly higher CO_2 emissions relative to gas- or oil-fired heating (Table 1).

Heat pumps use a small quantity of electricity to raise heat from the surroundings to higher temperatures. The ratio of heat supplied to electricity consumed is called the Coefficient of Performance (COP). To guarantee reductions in CO_2 emissions in relation to current gas-fired heating (see Table 1), the COPs of heat pumps available in the UK need to improve. From 2020-2050, emissions from heat pumps will decrease as carbon emissions from electricity generation are reduced via the take up of nuclear, renewable fuels, and maybe Carbon Capture and Storage (CCS).

Ground Source Heat Pumps

Ground source heat pumps (GSHP) collect heat by laying pipes under large flat areas (for example, gardens or car-parks). Alternatively, where space is limited, vertical boreholes can be drilled, although this raises costs. The most energy efficient application of GSHPs is in commercial developments, where heat removed during summer (for air conditioning) could be stored underground and pumped back inside in winter.

Biomass Fuels

Renewable biomass fuels include wood from forestry, trimmings from parks and hedgerows, cereal straw from farms and wood pellets made from compressed sawdust (some of which could potentially be imported). In the longer term (2020-2050), dedicated energy crops such as willow, poplar or novel grasses might become available. Biomass fuels can also be produced from waste (Box 2). The government (via the Forestry Commission) has set a target to bring an additional 2 million tonnes of wood-fuel to the market by 2020.[7] This represents 50% of the wood potentially available in English woodlands. Biomass fuels emit no net CO_2 when they are burned, as the same amount of CO_2 is captured as the biomass grows.

Biomass Boilers

Burning biomass in boilers to generate heat, hot water or steam is feasible at a wide range of scales, from the household to industrial level. In the domestic sector, space constraints (for example, truck delivery with narrow driveways) and storage of bulky biomass fuels limit take up. Some estimates suggest biomass heat is feasible in only 2.6% of households.[8] This is compounded by concerns regarding air-quality in towns and cities. Natural gas is a relatively clean fuel, so a shift to biomass heating using current boiler technologies could result in a three-fold increase in particulate emissions (see POSTnote 272).

Biomass boilers have a greater potential in industry, where biomass can provide a renewable source of the high-temperature heat required by many industrial processes. At these larger scales, biomass fuels for combined heat and power generation (CHP, see below) could become more cost effective. In total, it is envisaged that biomass will provide more than 50% of any renewable heat demand.[3] However, estimates of the total quantity (including imports) and cost of available biomass remain uncertain.[3]

Box 2 Energy from Waste

Waste resources that can be used as fuel for renewable heat include sewage (see POSTnote 282), animal manure, food waste, biodegradable fractions of domestic waste and wood recovered from furniture or building deconstruction. Waste resources could potentially supply 8% of UK heat demand.[9]

Technologies

Technologies for the separation of wastes have been developed to satisfy recycling targets. A key innovation is the waste autoclave process which uses steam to separate out the biodegradable fraction of mixed waste. Improved methods for measuring the renewable content of mixed waste, in particular municipal solid waste, are required to allow classification as a renewable fuel.

Waste Policy

In its 2007 Waste Strategy, the government targeted a 45% reduction in household waste not re-used, recycled or composted from 2000 levels by 2009. It also targeted an increase in the recovery of municipal waste from 53% in 2010 to 75% by 2020. EU Waste Directive 2008 allows energy generated from waste to count towards recycling targets only if a highly efficient process is used.

The Waste Infrastructure Delivery Programme (WIDP) was established in England to support local authority investment in residual waste treatment, increasing recycling levels, and energy recovery. However, there is currently no focussed policy to ensure that energy recovery is completed in the most efficient way. Fixed contracts with power generators can lock waste streams into electricity production for 20 to 30 years. Alternative uses, including direct heat generation, might be more energy efficient and emit less CO_2.

Biogas and Biomethane

Biogas (a renewable gas) can be produced from biomass and waste in two ways:

- anaerobic digestion (AD) captures the methane emitted as biomass rots. Biogas from AD is widely deployed in Germany, where it is used for small-scale power generation.
- gasification converts solid fuels into a gas by heating them up in the absence of air. Commercial deployment of gasification is unlikely before 2020.

After AD or gasification, the resulting biogas can be burned in a boiler for heating or to generate electricity. Alternatively, the gas produced can be cleaned to meet the required standards for injection into the national gas grid. This cleaned biogas is nearly identical in composition to natural gas (mostly methane) and is often called biomethane. Calculations suggest that if all UK waste biomass resources (Box 2) were used, biomethane could substitute for 48% of domestic gas consumption.[10] Supplying biomethane as a renewable heating fuel would entail minimal disruption to consumers, as it would use the existing gas infrastructure and could be burned in existing gas boilers. Similarly, renewable bio-oils, produced from waste oil or oil-seed-rape, could be used in existing oil-fired boilers.

District Heating Networks

District Heating (DH) networks connect heat-generating technologies to locations of demand by transporting heat as steam or hot water in pipes. Consumers purchase heat from the network directly (rather than gas or electricity), avoiding the cost of installing and maintaining boilers within their own buildings. However, the piping infrastructure, and connecting buildings to the network, results in significant extra costs (Table 1). DH is widespread in central Europe and Nordic countries, supplying more than 50% of domestic and commercial heat demand in Sweden, Finland and Denmark. Limited UK uptake (DH supplies less than 2% of total UK heat demand[11]) can be attributed to a historical lack of policy support, consumer resistance (although the extent of this is debated), and low domestic gas prices.[12]

Renewable district heating in the UK is currently supplied from geothermal sources, or from boilers burning biomass or waste-derived fuels (Box 2). District heat networks form a flexible infrastructure capable of integrating a range of renewable heating technologies. These can include solar thermal panels and heat pumps as well as waste heat from existing power stations (although this can lead to less efficient power generation). District heat networks can also support Combined Heat and Power (CHP) generation from renewable fuels (for example biomass, waste, or biogas).

Combined Heat and Power

CHP technologies are based on conventional power generation. However, rather than discharging surplus heat (through a cooling tower or into the sea), in a CHP system this wasted heat is used for industrial process heating, or sent to a district heating network. This can increase the overall energy efficiency of the system.

Reducing Emissions

The government has a target to reduce carbon dioxide (CO_2) emissions by 34% by 2020 compared with 1990 levels, increasing to an 80% reduction by 2050. As renewable heat technologies typically have lower CO_2 emissions than conventional heating systems (Table 1), they are supported under a range of policies that aim to reduce CO_2 emissions.

Business and Industry

The EU Emissions Trading System (see POSTnote 354) aims to provide a financial incentive for large industrial users of heat to switch to low-carbon, renewable heating fuels (principally biomass). In the UK, the Carbon Reduction Commitment Energy Efficiency Scheme (CRC) will establish an emissions trading system between large

UK public and private sector organisations. In the short term this is expected to promote the take up of low-cost energy-saving measures, such as insulation. In the longer term (2015-2020) it could also support the adoption of renewable heating technologies.

New Buildings
The Department of Communities and Local Government controls new building developments through the National Planning Policy Statements and the Planning Inspectorate. Compliance with the relevant parts of the building regulations has required carbon dioxide emissions to be controlled since 2006. There is a consensus in the industry that regulations are the most effective driver for the take up of renewable heat in new-build developments.

Zero Carbon Homes
The government has set a target for all new housing developments to be comprised of 'zero carbon homes' by 2016 (a 150% reduction in measured CO_2 compared to 2006). This poses a significant challenge for the design, planning and construction of new homes. CO_2 reductions are allowed to be achieved by exporting renewable heat to other local developments via a district heat network.

Existing Buildings
Of the buildings that will be standing in the UK in 2050, it is estimated that 70% have already been built. Retrofitting existing buildings therefore accounts for a significant fraction of any market for renewable heat. The government's Low Carbon Buildings Programme provides grant support for the purchase of heat pumps and biomass boilers. The Community Energy Saving Programme also supports the installation of renewable heating technologies in low-income households.

Consumer Issues
As proposed, the Renewable Heat Incentive (RHI) will make renewable heating technologies more cost competitive with fossil-fuel alternatives. However, high initial purchase costs (Table 1) could constrain take up unless innovative methods of financing are developed. Proposed methods include:
- establishment of energy service companies ;
- provision of low-interest 'green' loans from banks;
- Pay As You Save (PAYS) schemes;
- billing for heating via council tax.

Energy service companies (ESCOs) may be made up of members from the local authority, energy suppliers, equipment manufacturers, the community, and energy experts. They are capable of raising finance for renewable heating technologies at a lower cost than individual consumers. This business model is particularly applicable to managing renewable district heating or CHP.

Low-interest 'green' loans have also been suggested. These could assist in overcoming the up-front cost barriers to renewable heat. Within PAYS schemes consumers pay the supplier for a renewable heating technology over its lifetime. If repayments are lower than their predicted energy bill savings, then financial and carbon savings can be made from day one. However, it may be the case that current models for the ownership of domestic energy technologies are not sustainable. Ownership of heat pumps or biomass boilers could transfer to local authorities, who would receive RHI payments and then charge residents for heat consumption and the loan of the heating technology.

Fuel Poverty
Any household spending more than 10% of its income on heating is considered to be in fuel poverty. As of December 2009, there are an estimated 6 million such households. It is thought that fuel poverty contributes to an additional 20,000 winter deaths annually. The government is under a statutory duty in England to end fuel poverty in vulnerable households (those in receipt of certain benefit payments[13]) by 2010, and in all households by 2016. Renewable heat could help to alleviate fuel poverty in some cases, for example when replacing expensive electric heating in houses situated off the gas grid (Table 1). However there are fears that a tariff on fossil-fuel heating to support the forthcoming RHI will increase levels of fuel poverty.

Overview
- Government targets to achieve 12% of heat from renewables by 2020 will require rapid and extensive uptake of renewable heating technologies.
- A wide range of technologies is already technically available for the supply of renewable heat, including solar thermal systems, air and ground source heat pumps, biomass boilers, biogas and biomethane production, and renewable district heat and CHP.
- A Renewable Heat Incentive has been proposed which will make renewable heating more cost competitive with fossil-fuel alternatives.
- Renewable heating technologies have high up-front costs and long payback periods. Innovative financing methods are therefore required to support take up.
- Renewable heating could contribute significantly to the government's targets for CO_2 emissions reduction.

Endnotes

1 *Digest of UK Energy Statistics* (DUKES), July 2009
2 *Meeting the Energy Challenge*, HMG White Paper, May 2007
3 *UK Supply Curve for Renewable Heat*, NERA and AEA, July 2009
4 *Renewable Heat Incentive Consultation*, DECC, Feb 2010
5 Technology costs and ranges are calculated from ref.3 and fuel costs from annex to ref.4, CO_2 emissions from fuels are calculated from Defra published figures. Ranges for emissions from heat pumps represent the COPs achieved for various building conditions
6 *Southampton District Energy Scheme*, M Gearty, 2008
7 *A Woodfuel Strategy for England*, Forestry Commission, 2007
8 *Biomass & Bioenergy*, Jablonski et al, July 2008, pp 635-653
9 *UK Biomass Strategy*, DEFRA, DfT and DTI, May 2007
10 *Potential for Renewable Gas in the UK*, National Grid, Jan 2009
11 *Potential and Costs of District Heating*, Pöyry, April 2009
12 Heat; Call for Evidence, BERR, January 2008
13 *A Decent Home: Definition...*, DCLG, June 2006, §6.26

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology.
POST is grateful to Dr Alex Dunnett for researching this briefing, to the Grantham Institute for Climate Change for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Michael H O'Brien, at POST.
The Parliamentary Office of Science and Technology, 7 Millbank, London, SW1P 3JA; Tel: 020 7219 2840; email: post@parliament.uk
www.parliament.uk/parliamentary_offices/post/pubs2010.cfm