Cogeneration and On-site Power Production

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Hotting up for heat pumps

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Energy policy in Europe has been dominated by matters electric for a very long time; even cogeneration tends to be measured by its electrical output. But heat pumps are emerging as one of the key low-carbon technologies to lower the carbon content of heat - rather than power - supplies, writes Steve Hodgson.

Heat pumps represent one of the most important technologies targeted to achieve Europe's transition from a heating market based on fossil fuels (mainly natural gas-fired boilers) to one based on lower-carbon alternatives. Other technologies and fuels likely to contribute are solar thermal, CHP/cogeneration, biomass/biogases, district heating (at least partly fuelled by municipal waste, biomass and/or biogases) and, counter-intuitively, direct electric heating. The last option is included as policy moves to decarbonise electricity generation will eventually yield low-carbon electricity.

Heat pumps come in several different types, according to the heat source used and how it is distributed within the home or building. Air-to-water heat pumps, i.e., those that source heat from outside air and use it to heat water inside the building, are the most numerous in new installations in most of Europe, with air-to-air systems second. As well as for heating, air-to-air systems are commonly used in Italy, Spain and other parts of southern Europe to provide air conditioning.

Sweden is unusual in having a mature market dominated by ground source heat pumps. Sweden started to expand its use of the technology in the 1970s, when the oil price shock and a lack of access to natural gas caused the government to promote heat pumps.

Sales of heat pumps of all types are dominated by the domestic sector, although sales for commercial buildings are increasing.

Heat has emerged onto energy policy agendas in the last few years as politicians have realised not only the huge contribution that energy used for heat makes to CO₂ emissions, but also the inevitable connections between electricity and heat use. Regular readers of COSPP have no problem seeing the connection between heat and power, particularly when both are supplied locally by CHP systems, but legal and regulatory frameworks for the two energy forms have previously been very separate.

Buildings, where heat pumps are usually employed, are responsible for more than 40% of energy use and a third of greenhouse gas emissions worldwide, according to the European Heat Pump Association (EHPA). So the scope for carbon savings is enormous. In the UK, almost half of the total energy consumed is for heating, rising to over three-quarters of non-transport energy use. Although that includes heat used for cooking and manufacturing goods, the majority is used to heat buildings and hot water, and to keep homes and offices cool in hot weather - all areas where heat pumps could play a part.

In Europe, led by the UK with the world's first long-term financial support programme for renewable heat - the Renewable Heat Incentive (RHI) - several countries and the EU itself are encouraging the growth of renewable and low-carbon alternatives to fossil fuel-based heating systems. The increased use of heat pumps is also being encouraged by programmes to make buildings more energy efficient - from basic building regulations to ambitious plans to require low or zero-carbon buildings in the future. As governments across Europe progressively reduce the allowable heating energy use per unit of floor area in homes and buildings, heat pumps become more attractive.
The European market

So what is the state of Europe's heat pump market? Its health is connected, to an extent, to that of housing and commercial building construction, which has still to emerge from recession. But heat pumps have begun to recover anyway. 2013 saw the first return to modest growth since 2008, and the EHPA expects higher growth this year. Some 770,000 heat pumps were sold in EU countries during 2013, a rise of 3% on 2012 figures, according to data released by the EHPA in July. This translates to a heat generating capacity of 24 GW added during the year.

The size of national heat pump markets varies considerably, and the overall picture depends largely on movement in the biggest markets, particularly Sweden and France, says the EHPA. Sales were up in 15 of the 21 countries surveyed, and negative trends in 2012 for four countries (Portugal, Spain, Sweden and Finland) were reversed into growth last year. After France and Sweden, the largest markets are Germany, Italy, Norway and Finland.

The 2013 sales figure is approaching double that of a decade ago, according to EHPA data. Sales peaked in 2008 at slightly more than 800,000 units, and have been fairly steady since. More than six million heat pumps of various types have been installed across the continent, with a combined generating capacity of over 200 GW.

Air-to-water and air-to-air heat pumps dominate the picture, with ground source models holding a distant third place, mainly due to their popularity in Scandinavian countries.

Intervention by national governments, rather than a return to construction growth, has been instrumental in restoring health to the heat pump market over the last year, says Thomas Nowak, Secretary General of the Association, particularly where policy measures affect the energy efficiency of buildings. For example, it makes little short-term economic sense to invest in a heat pump in Germany today, says Nowak, yet people do because of government encouragement programmes and a longer-term awareness of rising fossil energy prices.

High initial investment costs and short-term decision horizons both work against heat pumps, as do high electricity costs.

At growth rates of 3% per year, it would take quite some time to see heat pumps approach their overall potential in Europe, which might eventually reach a presence in 100% of new buildings and half of refurbishment projects, says Nowak. In a fully decarbonised heat market, biomass could contribute up to 30% of the total before a large-scale biomass import programme became necessary, he says, leaving 70% of the market to be met by heat pumps, solar thermal and other technologies. This will include contributions from individual heat pumps and those used within district heating systems, plus hybrid heat pumps in which little gas is burned during particularly low exterior temperatures.

This is a very long-term aim, of course, several decades ahead, although the mature heat pump markets of Sweden and Switzerland already show the way forward. Progress will depend on the swift implementation of existing legislation throughout Europe, and continued consistent support for low-carbon heating and cooling.

Building refurbishment projects are more of a challenge for heat pumps than new build, as building fabric and existing heat distribution systems often need to be upgraded. Indeed, attention to minimising heat losses due to building fabric details needs to be rigorous, and the refurbishment of existing buildings is one area where hybrid heat pumps can be useful. With hybrids, around three quarters of the total heat supplied comes from the heat pump, with the remaining quarter from a small gas-fuelled boiler installed as part of the system. Heat pumps can work effectively even when external air temperatures are very low, says Nowak, but building fabric detailing needs to be very, very good - better, perhaps - to burn a little gas.

Analysis carried out by Ecofys for the EHPA suggests that an ambitious heat pump development scenario could cut emissions from the building sector in Europe by nearly half by 2030. However, this would require significant intervention into heat markets by all Member States.

Looking more widely, the International Energy Agency (IEA) has calculated that China could reduce the expected growth in consumption of natural gas by half through the high penetration of heat pumps for space and water heating there. The analysis was presented as part of the IEA's Energy Technology Perspective 2014, in a scenario in which energy system reform gave the world a 50/50 chance of limiting the average global temperature increase to 2°C. The same scenario, involving high penetration of heat pumps, would cut total EU gas consumption by 30%.

But, to achieve these figures, much more effort is needed from policymakers, researchers and industry, said the IEA.
The technology

Although reaching the potential for heat pumps in Europe will take time, the process will be accelerated as capital costs for units fall, and this will happen as the industry responds to gradually increasing sales. Heat pumps have been around for a long time and the basic technology is relatively mature - but that's not to say that they cannot be improved. Nowak doesn’t see any fundamental new ideas on the horizon, but improvements currently being made by manufacturers of heat pump units are:

- Capacity modulating units;
- The ability to provide cooling and heating at the same time; and
- Smarter controls.

Control is a particularly important area, both within units and as part of the integration of heat pumps within wider energy systems. There’s a good deal of debate in Europe about energy technologies required to balance the intermittent output of renewable electricity generation, and the EHPA’s Nowak suggests that thermal storage and heat pumps are a better solution than others being mentioned, such as batteries. Excess electricity generation can be converted to heat in a heat pump and stored, either in an insulated thermal storage vessel or within the building fabric itself.

Smarter heat pumps

Smarter controls within and around heat pumps can only accelerate their adoption, agrees Lindsay Sugden, who runs the heat pumps advisory service at Edinburgh-based consultancy Delta Energy & Environment. The intention with hybrid heat pumps is to maximise the use of the heat pump and minimise the use of the associated small gas-fuelled boiler. But the system can be controlled to optimise costs or emissions, and hybrid heat pumps can also be used alongside thermal storage facilities. The term 'smart heat pumps' really refers to the use of electrically-powered heat pumps, alongside thermal storage again, as a demand-side response to variations in electricity flows and prices due to intermittent generation from renewables. Heat pump electricity use can be modulated down, or shut down, during periods of grid stress, with operating times shifted to off-peak periods, when generated heat is stored. Stored heat is then called for use when needed.

Scotland’s Inverness Marina uses an 8 kW heat pump to harness seawater heat for space heating Credit: NIBE Energy Systems

Sugden also talks of another smart use of heat pumps - heat contracting - by which manufacturers supply the heat pump to a customer at no capital cost, instead charging per kWh for its heat output.

Sugden concludes that utilities have plenty of reasons to become engaged with the technology as an add-on service to gas and electricity supply, partly because of the demand management possibilities. Utilities in the UK, the Netherlands, France and Germany are said to be studying the situation. UK utilities are increasingly engaged with heat pumps. E.ON UK works with social housing providers on heat pump installations, while British Gas is involved in trialling and development new solutions, including smart and gas heat pumps.
Heat into the future

Policymakers and regulators across Europe have turned their attention to the contribution that decarbonising heat supplies can make to meeting carbon emission targets, alongside measures to lower the carbon-based part of electricity generation and supply. It's early days so far, but it is expected that heat pumps - alongside other low-carbon heating technologies - are set for a period of considerable growth.

*Steve Hodgson is Contributing Editor on COSPP.*

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Types of heat pump

Air source heat pumps

Air source heat pumps use the ambient energy in outside or exhaust air for heating, cooling and preparation of hot water. They can be installed as compact units entirely inside or outside the house. Heat is commonly distributed inside the house by a hydronic distribution system or by air using fan coils or a ducted ventilation system. Recent technical developments allow for efficient use in almost all climatic regions.

Water source heat pumps

Water source heat pumps use energy stored in ground, surface or sea water. Where ground water is easily available it is accessed by two boreholes. One is used as the water source, the second is used to reinject the water into the ground. The heat pump extracts heat from the water and makes it available for heating, cooling and preparation of hot water, as before. Water source heat pumps profit from particularly high efficiency due to the excellent temperature characteristics of water as an energy carrier.

Ground source heat pumps

Ground source heat pumps use energy stored in the ground for heating, cooling and preparation of hot water. They extract heat from the ground by either a vertical or horizontal collector. Heat is commonly distributed by a hydronic distribution system or by air. Ground source heat pumps can be operated efficiently by employing the consistent temperature level of the ground.

*Source: EHPA*