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LOW TEMPERATURE DISTRICT ENERGY SYSTEMS

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Abstract:

District energy (DE) is a means for delivering heat and/or cooling to multiple buildings from a central energy centre. DE spans a wide variety of scheme sizes, from a small group of buildings in the same neighbourhood through to city-wide schemes comprising thousands of connected buildings.

DE enables whole communities to benefit from low and zero carbon energy sources, including those which cannot easily be installed at the individual building level. The inherent fuel flexibility of DE infrastructure lends itself to the integration of thermal renewable technologies that are crucial to the overall reduction of carbon emissions: biomass, solar thermal, heat pumps, deep geothermal.

An important aspect of new building developments is their increasingly high standards of efficiency. In order for DE to remain an effective solution for such developments, heat losses need to be reduced. This can be achieved by means of lower temperature supply, which also extends the scope for using different sources of locally available waste and renewable heat.

1. What is district energy?

District energy is a means for delivering heat and/or cooling to multiple buildings from a central source. The countries that have developed this technology tend to have been those in which heating demands are of most concern, so that district heating (DH) is prevalent. However, even Northern cities have significant cooling demands, so that district cooling (DC) is a growing market.

There are three basic parts to a DH scheme (see Figure 1 left): an energy centre containing the heat source(s), a hydraulic interface unit (HIU) e.g. heat exchangers and a network of pipes to connect them.

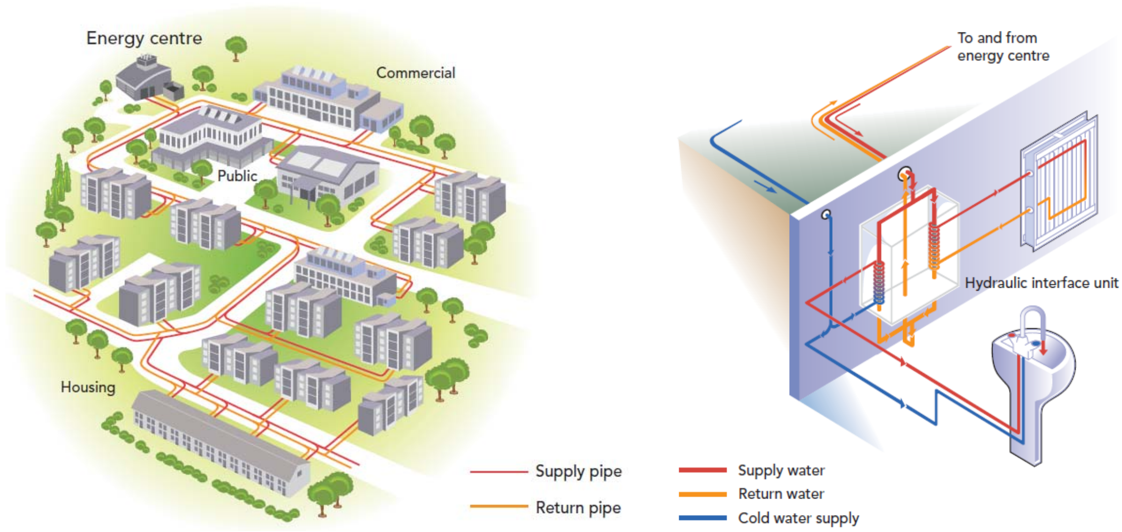

Figure 1: (left) The principles of DH, (right) The hydraulic interface unit. (Source: BRE)

2. District energy for new and future buildings

New buildings are generally more energy efficient than existing buildings. This trend will continue in the future due to the strengthening of the energy efficiency requirements that buildings will have to comply with.

An immediate effect of the strengthening in the energy efficiency standards for buildings is the reduction in the amount of energy that would be required to heat future buildings. This means that:

- Heating requirements are increasingly dominated by domestic hot water (DHW) rather than space heating. Figure 2 demonstrates this with three different energy efficiency scenarios for dwellings: base case, low energy and PassivHaus

- The annual heat profile will be flattened, see Figure 3: a year-round base heat load will remain but winter heating is much reduced.

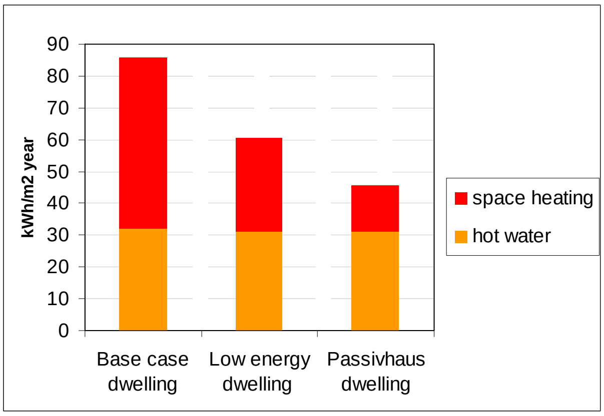

Figure 2: Annual space heating and domestic hot water requirements of new and future buildings

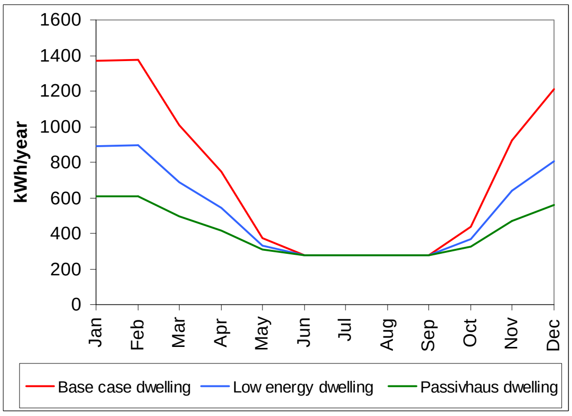

Figure 3: Monthly space heating and domestic hot water requirements of new and future buildings

Work carried out within Annex VIII of the IEA District Heating & Cooling (IEA DHC) programme[1], and further work currently progressing within the current Annex IX examines the role of DE in new and future buildings.

Within this work, and through associated research at BRE, modelling has been carried out of three representative UK new-build residential developments with different dwelling densities: detached house development, mixed residential development and blocks of flats.

Figures 4 and 5 below show the relative heat distribution losses, from which the following is **concluded**:

- For the same dwelling density, moving from the (new-build) base case dwelling to *PassivHaus* standard could double the relative heat distribution losses, although this is more pronounced for lower dwelling density developments
- The greater the dwelling density the less sensitive the relative heat distribution loss is to linear heat density
- Despite the lower heat demand of new and future buildings, the heat distribution loss of well-designed DH schemes supplying high dwelling density developments, such as blocks of flats, is small relative to the total amount of heat delivered by the heat network.

[1] www.iea-dhc.org

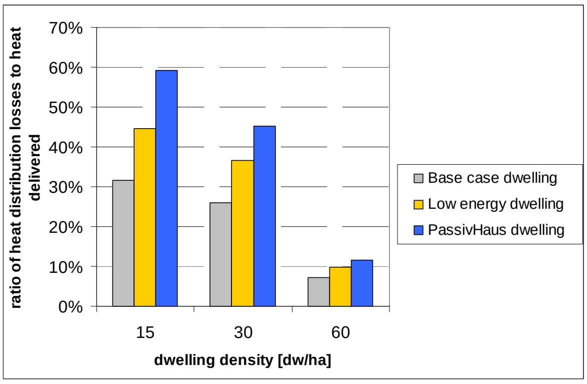

Figure 4: Variation of ratio of heat distribution losses to heat delivered with dwelling density calculated with TERMIS for single pipe systems

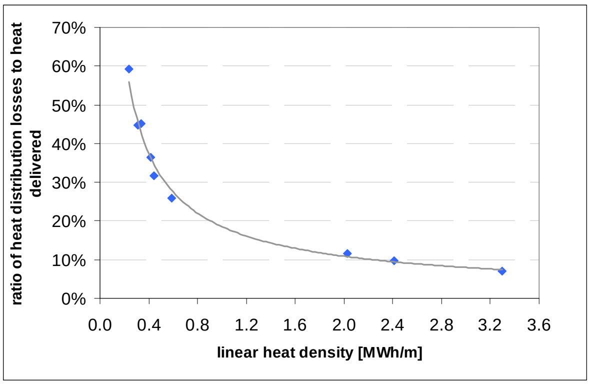

Figure 5: Variation of ratio of heat distribution losses to heat delivered with the linear heat density calculated with TERMIS for single pipe systems

3. Reducing heat distribution losses

Reduction of heat distribution losses is an important aspect of improving DH network performance, and has therefore been investigated mainly in countries with a history of DH. The IEA DHC programme has and is undertaking research looking at the use of DH to supply heat to areas of low heat demand density ([Zinko et al, 2008] for instance). Heat distribution losses can be reduced by:

- using higher performance pipes
- using smaller pipe diameters, e.g. through the use of local hot water storage or booster pumps
- reducing the heat network operating temperature

3.1 Lowering flow and return heat network temperatures

In order to enable the use of low temperature DH systems a heat distribution system able to deliver useful heat at lower temperatures has to be used. This may be achieved, for example, by means of bigger than usual radiators or under floor heating and in-wall systems. Additionally, the heating emitters and controls and the hydraulic interface between the heat network and the building heating systems will have to be suitably designed, in order to minimise the heat network return temperature.

[Dittmann et al 2008] suggested that a means to further reduce the return temperature of the heat would be to connect customers to the return pipes. In this situation, it is likely that the return temperatures are suitable for space heating but not for domestic hot water provision. This might be solved by using other supplementary energy sources at the building level.

4 Low temperature district energy

4.1 Low and very low temperature networks

District Energy networks are based on the principle of transporting energy from its source to a number of users. The higher the energy density of the energy carrier, the smaller is the needed mass flow and the further it is economically viable to pump it. DH has thus traditionally been operated at temperatures exceeding 100°C, although lower temperature systems often using plastic pipes (for temperatures lower than 90°C) have also been developed. The possibility of lower temperature systems has recently attracted attention; consequently Annex X of the IEA DHC research programme seeks to examine the potential of lowering supply and return temperatures (e.g. 50°C/20°C; 70/40; 75/30).

Even lower supply temperatures provide the possibility to extend still further DH's environmental potential by accessing heat from sources formerly considered as with little to no value like minewater or ground heat. It is important though to combine these networks with appropriate measures on a building level, e.g. well-insulated fabric and underfloor and in-wall heating.

These emerging alternatives allow the DH network to be adapted to demand and locally available resources, including a range of renewable sources. In an urban context with, for example, industrial waste heat at 100+ºC, a relatively high supply temperature will be preferably used. However, if ground heat is the major source available lower flow temperatures may be appropriate, whether with centralised or decentralised heat pumps. As the temperature is much closer to the ambient temperature, the heat loss from the pipes is much smaller. Using plastic pipes for low temperature networks has the potential to decrease the capital cost and therefore economic viability considerably.

5 Integrating renewable energy into district energy systems

DE networks can play an important part in the gradual transition towards a low carbon future, as a system that brings fuel flexibility to adapt to and integrate renewable technologies as they come along. Technologies like gas-fired CHP are likely to remain important for some time to come, in using fossil fuels in a more efficient way, and acting as a catalyst to the expansion of DH infrastructure and reducing carbon emissions now. Such a network can equally well use heat from biomass-fired plant, solar thermal or even in the future a hydrogen fuel cell.

As the characteristics of each renewable energy system (RES) are different, so are the benefits of integrating one into a DH network: in a densely built area for example, supply and storage of sufficient fuel for a number of individual biomass boilers can pose a problem. One central energy station at a suitable place solves not only that problem but offers economies of scale for sales and transport issues. The space for solar thermal systems or ground source heat exchangers to supply high-rise apartment buildings with heat may well exceed their own footprints. A DH network can be used to transport the heat from nearby energy-harvesting fields with less intense energy demands to the high-demand area.

Thermal storage has an important role in matching supply and demand dynamics, especially with stochastic heat production of some RES like solar thermal systems and prominent peak loads of daily use. Networks lead to a slight levelling of demand, especially in mixed-use areas, capping peak loads and allowing RES to be sized more cost-effectively. While individual storage tanks in buildings are well established for regular charging and discharging, storage opportunities at a larger scale seem to be more cost-effective for seasonal storage.

Within Annex IX of the IEA DHC research programme, work has examined the way in which a heat network could function in the future through connected buildings being able to receive or donate energy.

In particular, the work focuses on future buildings featuring very low heat loss factor, long cool-down time constant, passive and active solar, active thermal storage and sophisticated energy management. Due to their exceptionally low energy consumption it may appear impractical to connect them to a DE system. However, these buildings are capable of peak load shedding, off-peak charging of thermal storage and can act as a source of distributed thermal energy to the DE network when they have surplus energy.

Examples of Renewable Energy DH

DE networks provide the possibility to integrate several different RES plants and technologies. This diversification of energy sources leads to increased energy security and supply resilience. While there is a strong potential for the physical integration of RE in networks, there are still uncertainties on how best to integrate them. The next Annex X of the IEA DHC programme will focus on this.

A selection of schemes (there are of course many more examples, but these have been examined as part of a BRE study) in the UK and elsewhere are shown in the table below:

Scheme	Country	Supply technologies	Scale of the network
Sheffield	UK	Municipal waste CHP, gas and oil back-up	City centre, non-domestic and domestic
Southampton	UK	Gas CHP, deep geothermal heat, fossil fuel boilers	City centre, principally non-domestic
Barnsley	UK	Biomass boilers	Several small networks
Grosvenor, London	UK	Gas CHP, biomass, gas boilers	Small new-build residential
Chalvey, Slough	UK	ST, biomass, ASHP, GSHP	Research rig at 10 houses
VEKS	Denmark	Municipal waste CHP, gas/oil CHP, deep geothermal	Whole city
Hillerod	Denmark	Gas CHP, biomass, solar field	Town scheme
Eksta	Sweden	Biomass, individual dwelling solar thermal	Small new-build residential network
Malmo	Sweden	Building–integrated solar thermal, ground source heat pumps	New-build development with connection to city scheme

The observation and lessons from the site visits carried out as part of this project include:

Municipal Waste Heat

Heat recovery from the use of Municipal Solid Waste serves two direct purposes: it diverts waste from landfill and uses the energy potential of waste. Using heat from waste incineration – with or without electricity production – has often been the primary driver for the introduction of DH networks. The use of this heat reduces the operation cost for heating; the unused running cost can then be used to pay for the capital cost of the infrastructure investment.

Geothermal

The Southampton District Energy scheme is a primary example where the available geothermal heat had been the primary driver for the development of the scheme. It is a perfect example where only a district solution could have provided the benefits associated with this energy source. The available temperature of 74ºC has lead the design as a low temperature network (now viewed as a necessity more generally with district heating schemes in order to secure better levels of energy efficiency).

Biomass

Barnsley Metropolitan Borough Council is located in a former mining area. In 2004, it introduced a Biomass Implementation Policy setting biomass as the standard solution for the future. This has led to being far ahead of government targets for carbon emissions. Barnsley MBC successfully trialled the use of biomass in existing coal fired boilers; only the air flow rate had to be changed, so that biomass could be burned in the same boilers without any major changes.

Gas fired CHP and biomass

Grosvenor Waterside is an example of a new development in London, subject to planning requirements of the Greater London Authority including the use of DH and a certain share of renewable where viable. This example shows the difficulty in operating gas-fired CHP and biomass together at this scale, both of which work best when run as many hours as possible.

The operation of several different heat plants in tandem is quite complex, taking into account the technical and operational limits and performances of the different technologies. For instance, using CHP to cover the base load means that the biomass boiler will supply part of the peak load, which may become an issue due to slower response.

Building integrated solar thermal

The Bo01 area in the Western Harbour is a new development of approximately 1000 residential units built in 2001, served by 100% renewable energy supply averaged over the year. Solar collectors are connected at a building level separated by a heat exchanger from the district heating network. Operation has been trouble-free and fluctuations between heat demand and supply are levelled out through the connection to the main DH network of the City of Malmo that serves as a convenient buffer. This enables more useful heat to be derived from the solar panels than if they were stand-alone.

The aquifer in the bedrock underneath the Harbour is used as a seasonal storage to produce both heat and cold. The heat from the summer is saved for the winter; it is pumped up with a large heat pump to the required temperature. Cold from the winter is saved for the summer and is distributed by a separate cooling network.

The Bo01 scheme is rare as it supplies 100% from RES. It does this however only over an entire year and would not work without being balanced by the network of the city of Malmo. While the HP could supply heat all year round, it would not be economical to do so, having the connection to a larger network. It would have to be connected to the supply flow and not the return.

Solar thermal fields

In Hillerod 95% of the municipality or 15000 houses are supplied with heat form the DH network. The heat is supplied by the following sources: 80% gas CCGT CHP, 4% gas boilers, 14% wood pellet boilers and 2% solar thermal fields.

This emphasises the enduring reliance on fossil sources even when there is integration of renewables, and the need to devise new operational modes to increase the potential of renewables. One of these methods is to operate at lower temperatures. At Hillerod this is done for a small network in Ullerødbyen operating at 60°C supply. The solar thermal efficiency is also raised if it is connected to the return, even though it will need to be boosted further for all but the lowest temperature systems.

Biomass with solar thermal

Eksta is a housing company providing housing for 2,700 flats, schools, day care centres, and other buildings. In total, they operate 18 networks consisting of small developments of a dozen of houses to around 500 houses with non-domestic buildings.

They use biomass as the predominant fuel with solar thermal back-up. The latter supplies only 5-10% of the annual heat demand of each scheme but requires very little maintenance. All of the schemes follow the same principle: prioritise the use of solar thermal as the first heat source, biomass next with oil for back-up during maintenance and top-up for extremely cold days.

The biggest integration issue Eksta experienced is the large inertia of their larger biomass boilers. When the ST installations suddenly produce a lot of heat, e.g. on a sunny spring day, the large biomass plant will still produce heat for a few hours, which could overheat their system. To bring the boiler back into operation will also take a few hours. They thus had to switch the biomass boiler off and use the back-up oil boiler. The solution they found is to use a smaller biomass boiler that can modulate down easily and has smaller inertia.

Integrating a variety of renewable sources

VEKS runs a city-wide scheme for the west of Copenhagen, and seeks to increase the share of renewable sources to supply their network. Biomass is currently the principal renewable energy source used, but its potential is regarded as transitory for 10-15 years. Emphasis is therefore placed on maximising the benefits of existing resources by focusing on CHP, and increasingly the future role for geothermal plants and large scale HPs driven by wind power. This scale of scheme will be important as a balancing agent for smart electrical grids.

Low temperature networks and renewables integration

Chalvey is a pilot scheme in Slough, UK, examining 4 different renewable technologies and using a low temperature network. In may be regarded as an experimental rig; some of the early issues arising include and plans for he future include:

- the benefit of low temperature operation: the solar thermal installation achieves a higher overall energy yield as the heat can be harvested earlier in the morning, later in the evening and similarly in the colder season
- a key integration issue for low temperature is to adapt the heating systems to deliver comfort in the buildings and a low return temperature for system efficiency. Underfloor and/or in-wall heating or larger radiators are effective ways
- the potential for integrating the heat pump with solar thermal with the former elevating the temperature only to 45ºC and the solar thermal raising the temperature further to 55 ºC is also being looked at. In this way the heat pump COP is raised significantly
- another mode of operation is to use excess heat from the solar thermal installation to recharge the boreholes for the Ground Source Heat Pump, increasing/ stabilising the ground temperature and thus increase/ stabilise the efficiency.

6. Conclusions

The following can be concluded:

- Despite the lower heat demand of new and future buildings, heat distribution losses of well-designed DH schemes supplying high dwelling density developments, such as blocks of flats, are small compared with the total heat delivered by the heat network.
- Techniques exist in order to reduce the heat distribution losses of a DH network. They include the use of high performance pipes: for pre-insulated twin pipes heat distribution losses can be reduced by 20-30% compared with pre-insulated single pipe systems.
- Other techniques exist that can be used to reduce heat distribution losses, e.g. using smaller diameter pipes with local hot water storage, or using booster pumps installed at the customer heat station.
- DE networks lend themselves to integrating different RES technologies and fuels, increasing energy security and supply resilience. While there is a strong potential for the physical integration of RE in networks, there are still a lot of uncertainties on how best to integrate them. DE networks have a transformative role towards a low carbon future, particularly in combination with CHP plants.
- DE is already a LowEx approach as it routinely recycles heat that would otherwise be thrown away. Using waste heat is often a prerequisite for thermal power stations for its economic viability.

- Low and very low temperature networks allow accessing different sources of heat to increase flexibility in matching demand with locally available heat sources.

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