DHC, CHP, and Renewables

- Robin Wiltshire
- BRE

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What is district heating?

- DH is a means for delivering heat to multiple buildings from a central energy centre
- It can deliver:
  - space heating, domestic hot water and industrial heat and
  - cooling by the means of heat driven chillers

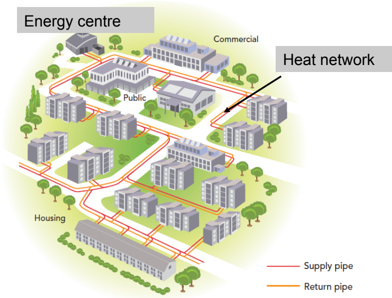
Energy centre supplying hot water to DH – Hillerod, Denmark © BRE

Basic parts of a DH scheme

energy centre containing the heat source/s

a heat distribution network used to deliver the heat to end users

hydraulic interface unit (HIU) e.g. heat exchangers, linking each customer to the wider heat distribution network



Schematic showing basic parts of DH scheme © BRE

Basic parts of a DH scheme

Scale of DH schemes

DH can be integrated within a single building, such as a block of flats - block heating

number of buildings on a single site e.g. such as a university campus or in close proximity e.g. several blocks of flats

DH schemes can serve a whole community, town or city centre



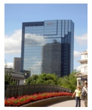
What are the advantages of using DH?

- Fuel flexibility
  - Enhances security of supply
  - switch whole communities to new and emerging technologies with ease
  - Buffer against prices volatility of traditional fuels
- Carbon savings– it offers the means to utilise residual and renewable energy sources
- Means to deliver affordable warmth
- Allows the use of larger more efficient low and renewable driven heating plant
- Simplify the supply of heat for the end user
  - Safety, space, maintenance

But DH is not always applicable – where to apply it?

- Areas of high heat demand density
  - High heat sales are required to offset the upfront capital investment required for a DH scheme
- Areas with a mix of building types
  - It is easier and more efficient to integrate efficient heat generating technologies e.g. CHP, biomass boilers when the aggregate profile is smooth
- Built up areas around sources of heat
  - The existence of a source of low cost heat can also be the catalyst to the development of a district heating network
- Other situations, e.g off gas grid locations

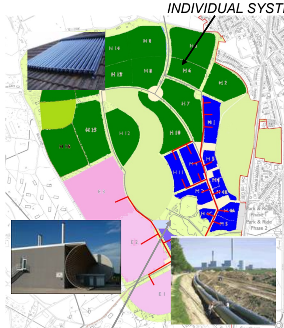



But DH is not always applicable – where to apply it?

- For areas of low energy demand the use of systems at the building level may be more appropriate
- For areas with a high concentration of energy demand, a district energy based solution is likely to be more appropriate.
- The answer is not always straightforward and a basic understanding of the issues around will be key to get the most adequate solution for each development

Area of houses INDIVIDUAL SYSTEMS



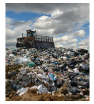
Area of mix use high dwelling density SUITABLE FOR DH

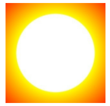
Developing DH for new build developments

- When the heat density is sufficient and the scale adequate new DH will result on the most cost effective manner to supply low carbon and renewable heat to new build developments
- As early on in the planning process considerations need to be given for
  - Allocating space for energy centre
  - Planning for the installation the DH network
  - Deciding on heat source and supply technology
  - Adopting building heating systems that are compatible with DH
  - Investigating the opportunities to expand the DH scheme beyond the development boundaries

Opportunities for carbon free heat DH

- DH pipes simply transport hot water from an energy centre to consumers
- DH is therefore technology blind, i.e. it offers the opportunity to use residual and renewable heat and to deliver it in the form of heat to the end consumer
- The fuel flexibility that DH offers can be used to shift from initially fossil fuel fired DH to cleaner sources of heat when they become available





Existing DH scheme

Residual (waste heat)
Industrial waste heat recovery


New heating plant
Aberdeen -CHP
- 1MW elect
- Circa 1.5MW hea

Heat supply sources for DH


Renewable source
Biomass (boiler, CHP)


Heat recovery from power generation
Gothenburg –CHP
- 260 MW elec
- 300 MW heat


Renewable source
Solar plant, 20,000 m2
Marstal, Denmark.


Renewable source
Sheffield waste incineration plant
19 MWelec, 60 MW heat


Renewable source
Southampton geothermal

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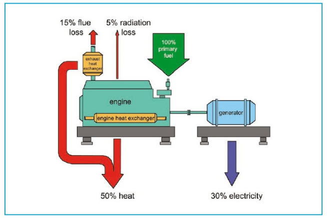
Combined heat and power (CHP)

What is combined heat and power?

- Combined heat and power refers to the simultaneous generation of heat and electricity
- For heat recovery, power plants should be located close to where a demand for heat exists
- CHP varies in scale, from a few kilowatts (micro CHP) to thousands of megawatts in power plants



CHP has higher efficiencies relative to conventional heat and electricity supply, i.e. less fuel is required to deliver a certain amount of energy

Source: GPG 388. Combined heat and power for buildings for buildings.

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What is combined heat and power?

- Different fuels and different scales:

1-1.5 MWe intenal combustion engine

Sheffield city wide DH scheme fired with heat from waste incineration

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What is combined heat and power?

- Can be both:
  - Power plants that are originally constructed for electrical generation and from which waste heat is recovered, e.g. large power stations

Heat recovery from power generation
Gothenburg –CHP, 260 MW elec, 300 MW heat

  - Power plants that are specifically designed for simultaneous generation of heat and power
    - *Smaller range of plants, e.g. CHP engines supplying either individual buildings (hospitals) or DH networks serving mix-use developments*
    - *Such plants are used to supply a year round base heat load, e.g. domestic hot water*

New CHP engine plant Aberdeen -CHP
1MW elect, 1.5MW heat

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Biomass

Biomass: the resource

Type of biomass

- Forestry materials
  - by-product of forestry activities
  - logs, thinning and tree maintenance, etc
- Energy crops
  - crop is grown for energy generation purposes
  - short rotation coppice willow or miscanthus
- Agricultural residues
  - crop residues such as straw
  - animal residue such as chicken litter
- Others
  - Industrial waste: recycled untreated timber from pallets and construction industry
  - Plant cuttings form parks, gardens, side roads, etc.

Biomass: the resource

Biomass fuel can be used as:

- Solid fuel
  - Woody biomass
    - *Logs, woodchips and pellets*
  - Animal residues
- Liquid fuel
  - Vegetable oil crops – bio fuel
- Gas fuel
  - A rich methane gas referred to as biogas can be obtained via the gasification of biomass (woodchips, animal residues, etc)

Pictures – example of solid biomass fuel - from top to bottom and right to left: woodchips, pellets, wood briquettes, biomass briquette made of compressed hay (Manufacturer: Ruf -Germany-. Picture source: Wikipedia)

Biomass heat only boilers

- Boilers can burn biomass:
  - As raw material, e.g. straw
  - As processed fuel, e.g. chips, briquettes, pellets, biogas, liquid biofuel
- Proven technology
- Boilers can be operated in (almost) fully automatic mode
- Choice of boiler depends on site specific factors:
  - space available for biomass storage,
  - availability of local fuel supply
  - local air quality regulations

150 kW pellet boiler

Biomass boilers vs. gas boilers

- Biomass boilers
  - generally have higher capital and maintenance costs
  - Require more space for boiler and for biomass storage
  - Fuel handling and delivery is more complicated though the process is highly automatic

Biomass combined heat and power

Biomass can also be used to generate heat and power

- Large scale
  - Solid biomass fuel can be used to raise steam for steam turbines for the generation of heat and electricity similar to conventional power stations
  - Proven application
- Smaller scale
  - Internal combustion engines can be used that are driven by either solid, gaseous and liquid biomass fuels
  - Some examples in the UK, but operation over the long term not yet seen

District Energy St. Paul, USA – biomass CHP

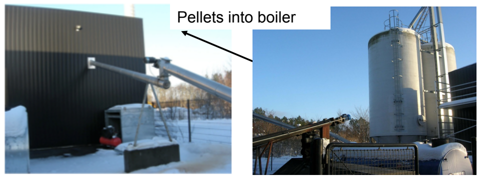
- Supplies heating to more than 187 buildings and 300 townhomes in the downtown Saint Paul area
- Hot water district heating delivered to customers year-round for space heating, domestic hot water and industrial process use
- Also provides cooling to 86 commercial buildings
- 32 km of heating pipes and 11km of cooling pipes
- Large biomass CHP plant is used to supply a large proportion of the heat requirement

Main energy centre - Biomass (woodchips) 28.5 Mwe/65 MWth

Delivery and handling of the biomass

- For the end user, the handling and delivery of the fuel for biomass applications is more complicated than conventional fuel , e.g gas, though nowadays the process is highly automatic
- As an example, below a biomass fired DH scheme of circa 2 MW boiler
- The fuel is automatically fed into the biomass boiler from the silo

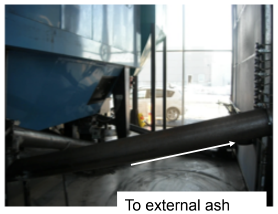
Biomass boiler



From silo into boiler

Delivery and handling of the biomass

- The exhaust gases are filtered using cyclones to reduce the particulate matters emitted to the atmosphere
- Ashes are automatically deposited to an external bunker



To external ash collection bunker

Ash collection bunker

Availability of biomass supply

- When sustainably sourced, biomass can be considered a renewable fuel
- Sourcing of biomass feedstock should avoid damage to the environment and food supplies
- Biomass is a carbon neutral fuel
- There is however net CO_2 released due to use of fossil fuel in the processing and transportation of the fuel to the point of use.
- Hence where possible, locally sourced biomass should be used

Transportation of biomass using lorries

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Planning implications of biomass fuel

- New biomass installations require regulatory approval e.g. air quality and in many cases planning consent
- Implications include:
  - Visual impact
    - *Particularly for installations in greenbelt and areas of outstanding beauty, e.g. energy centre, chimney height, etc*
  - Transport
    - *Large biomass installations will require frequent lorry deliveries that may have local transport impacts*
  - Environmental issues – air quality
  - Noise
    - *Arising from plant operation and transportation of the biomass*

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Waste: the resource

- Waste is produced from everyday processes and activities
- General classification:
  - Industrial and agricultural waste
  - Construction and demolition waste
  - Municipal solid waste (MSW)
    - *waste generated in a community including residential, commercial and institutional waste.*
    - *solid or semi-solid in form and excludes industrial hazardous wastes*
    - *residual waste: waste left from household sources containing materials that have not been separated out or sent for reprocessing.*

Source: www.tophazardouswaste.com/demolitionwaste.php

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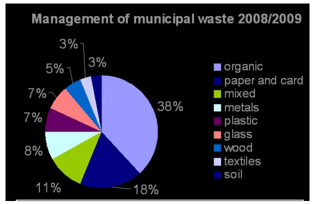
Waste: the resource

Composition of MSW:

- Organic materials
  - biomass raw materials such as paper, card, green and food waste, wood, etc.
  - organic synthetic products based on fossil fuels such as plastics
- Inorganic – inert materials
  - construction and demolition waste, dirt, rocks and debris



MSW waste composition on London.

Adapted from The Mayors draft MSW management strategy. January 2010. GLA

Organics include food and green garden waste

Source: Defra statistics 2009. accessed Dec 2009

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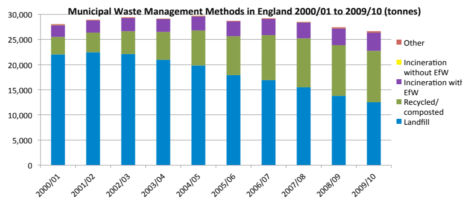
MSW – Background context

- Traditionally all MSW left after recycling and composting was diverted as untreated waste to landfill, but…
  - significant green house emissions due to methane release
  - high land costs
  - not a sustainable approach to the disposal of waste



Source: Defra statistics for municipal solid waste. http://www.defra.gov.uk/evidence/statistics/environment/wastats/bulletin10.htm

Accessed Dec 2010.

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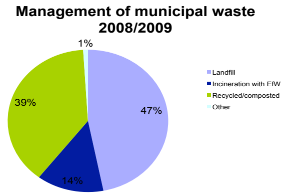
MSW – Background context

- As a result of the European Landfill directive:
  - the UK amount of biodegradable material sent to landfill compared to 1995 levels shall be reduced by:
    - *75% by 2010,*
    - *50% by 2013*
    - *35% by 2020*



Source: Defra statistics for municipal solid waste. http://www.defra.gov.uk/evidence/statistics/environment/wastats/bulletin10.htm Accessed Dec 2010.

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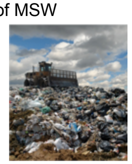
Waste to energy - MSW

For the purpose of this presentation WtE or EfW refers to the conversion of MSW into energy by the means of the following thermal processes

1. combustion (incineration) – established technology
2. gasification and pyrolisis – advanced treatment technology (ATT) - no UK long term track record
   - biochemical process
3. 3. anaerobic digestion (AD) - established technology but not for all compositions/types of MSW



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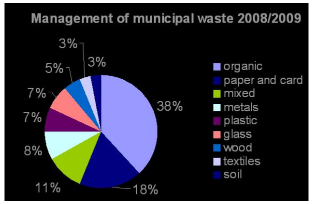
Waste to energy - MSW

- The biomass fraction in the MSW that is being burnt can be considered as a renewable energy source – non contributing to net carbon emissions
- Emissions arising from the thermal treatment of waste are regulated by the European Waste Incineration Directive (WID)



MSW waste composition on London.

Adapted from The Mayors draft MSW management strategy. January 2010. GLA

Organics include food and green garden waste

Source: Defra statistics 2009. accessed Dec 2009

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Waste Incineration

- Incineration of MSW
  - Combustion of waste in excess of air – temperatures can exceed 1000ºC
  - Established technology
  - It can deal with unprepared and unsorted waste
  - Any non-combustible material (metal, glass) remains as solid after the combustion process
    - –*solid ash*

Sheffield city wide DH scheme fired with heat from waste incineration

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Waste Incineration – not in my back yard

- Incineration of MSW
  - Waste incineration is widely used throughout Europe and worldwide
  - Denmark burns its 54% of its waste in heat and power stations
    - *Circa 30% of the heat supplying the Copenhagen city wide DH network uses waste incineration as the primary energy*
  - In England, in 2008, 14% of MSW was incinerated with some form of energy recovery (electricity only or heat and electricity)

The H. C. Ørsted and Avedøre power stations in Copenhagen

Photo: askeholst on Flickr

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Waste incineration – not in my back yard

Heat produced during the incineration of MSW is used to generate steam to drive a steam turbine producing 19 MW of electricity.

60 MW of residual waste is recovered and distributed to over 150 buildings across Sheffield

"While it is not possible to rule out adverse health effects from modern, well regulated municipal waste incinerators with complete certainty, any potential damage to the health of those living close-by is likely to be very small, if detectable. This view is based on detailed assessments of the effects of air pollutants on health and on the fact that modern and well managed municipal waste incinerators make only a very small contribution to local concentrations of air pollutants"

Source: The Impact on Health of Emissions to Air from Municipal Waste Incinerators. Health Protection Agency. Sep 2009

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State of ATT in the UK

- ATT refers to Advance Treatment Technologies
- They include the use of gasification / pyrolis technologies to obtain of a syngas for use in the generation of heat and power
- A track record of ATT in the UK does not exist but some installations exist elsewhere

Location of ENERGOS gasification plants.

Source: Energos, part of the ENER-G Group

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Integrated waste management

A holistic approach to waste should consider integrated waste management technologies:

- Waste reception, handling and pre-treatment
- Thermal/biological treatment
- Energy recovery
- Clean-up of emissions

Benefits of a municipal waste management strategy

- Reducing amount of waste
- Reusing and recycling of existing waste materials
- Increasing flexibility and security of energy supply
- Reducing greenhouse emissions
  - when using the organic fraction of waste as fuel
  - avoiding emissions from landfill
- Achieve economical savings

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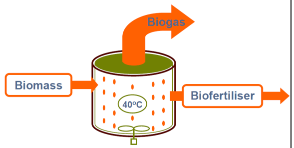
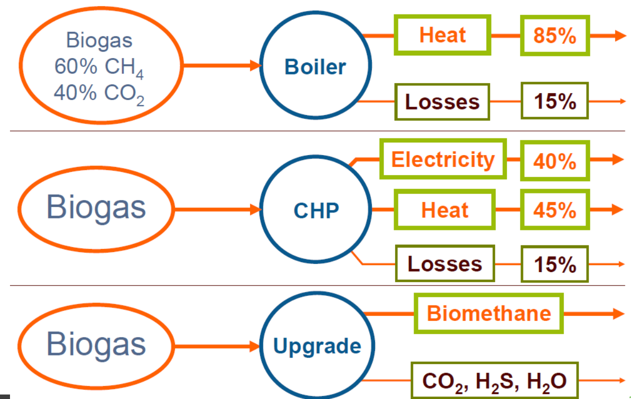
Anaerobic Digestion (AD)

What is AD?

- AD is a term for four natural biological processes which together create a methane rich gas and a useful fertiliser
- AD can be used as part of the process to treat biodegradable waste
- Several feedstocks ranging from purpose grown energy crops to sewage sludge
- Several configurations of Wet and Dry AD;
  - Batch or continuous
  - Temperature: Mesophilic or thermophilic
  - Solids content: High solids or low solids
  - Complexity: Single stage or multistage



Biogas uses



AD in practice – small scale

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AD in practice – large scale

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AD in practice – large scale

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Biomethane injection to the gas grid

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AD scenarios within the UK - On farm AD

Agri-Food & Biosciences Institute, Northern Ireland

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AD scenarios within the UK - On farm AD

- Processing material arising on the farm, e.g. manure, energy crops & vegetable waste.
- Land available for beneficial use of digestate
- Planning normally straightforward
- Environmental permitting supposedly light-touch
- Scale typically from 100kW to 1.0MW
- Capital cost typically from £500k to £2.5m
- Annual income typically from £120k to £1.2m
- Revenue costs depend on feedstock
- Capital grant a possibility.

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Commercial AD Plant

- New 45,000 tonnes per year BiogenGreenfinch food waste AD plant in Northamptonshire

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AD scenarios within the UK – Commercial AD

- Processing domestic food waste, commercial food waste, food processing waste, possibly with farm materials.
- Land required for beneficial use of digestate.
- Planning a challenging & lengthy process.
- Environmental permitting very stringent.
- Scale typically from 1MW to 2MW.
- Capital cost typically from £5m to £10m.
- Annual income typically from £2m to £4m.
- High revenue costs.
- Capital grant a possibility for demonstrators.

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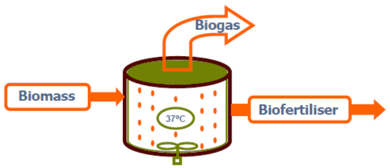
Anaerobic Digestion
A Low-Carbon Process



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Connecting Renewable Generation to DH

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Marstal solar thermal DH plant, Denmark

- Constructed between 1996 and 2003
- 1994 circa 9,000 m2 connected to DH network
- 2003 expanded to over 18,000 m2, circa 13 MW thermal
- 18 MW back/top-up waste oil boilers
- Provides hot water and space heating to over 1,400 customers

Source:SUNSTORE 4. Project no. 249800. Rev 26.02.2010 WWW.solarmarstal.dk

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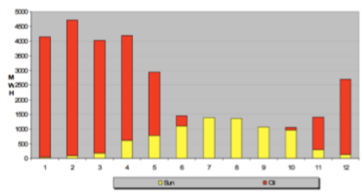
Marstal solar thermal DH plant, Denmark

Measured data:

- Solar plant nearly 100% of demand in 3 summer months
- 28% of total DH network heat demand (2007-2008)
- 2 to 3 kWh electricity to produce 1 MWh solar heat



Marstal solar thermal DH performance for 2006

Source:SUNSTORE 4. Project no. 249800. Rev 26.02.2010 WWW.solarmarstal.dk

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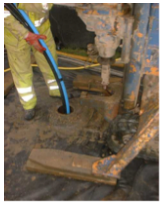
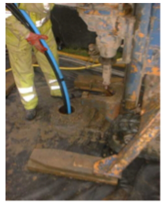
Heat pumps in DH

- Using heat pumps to provide district heating serving blocks of flats or even larger DH systems is technically viable
- However, there are practical difficulties for the integration of heat pumps in DH networks, i.e. poor performance for generating the temperatures required for hot water

Heat pumps in DH

- Advances in heat pump technology have produced pumps that use carbon dioxide as a refrigerant
- It is claimed that they are able to operate more efficiently when producing higher temperature outputs, i.e. DHW
- However, within the UK, applications are limited to a few installations and they supply individual buildings
- More research is required to further understand the role of using heat pumps for DH in the UK context

Opportunities for residual/renewable heat DH in the UK

- DH share in the UK is likely to expand in the following manner:
  - Consolidation of existing large city centre schemes by increasing the number of customers they serve
  - Connection of smaller fossil fuel powered city centre island schemes to develop larger DH city wide networks
  - New smaller DH schemes serving new residential led mixed-use developments of over several hundred dwellings
- The opportunities for using residual and renewable heat to fire DH schemes needs to be seen within this context

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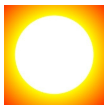
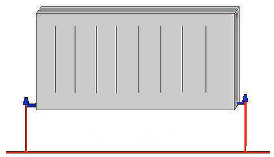



Increasing the availability of heat sources

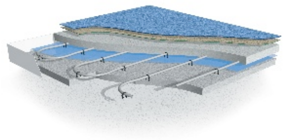
- Traditional heating systems in the UK, e.g. radiators, have been designed to operate at high flow/return temperatures of 82º/71ºC
- This means that in order for such systems to perform adequately, water at high temperature is required
- This limits the availability of heat sources that could be used to supply useful heat to such buildings,
  - e.g. it will not be possible for hot water at 60ºC to adequately supply the heating requirements of such buildings



Conventional radiators are designed to deliver useful heat at temperatures of no less than 80°C

Increasing the availability of heat sources

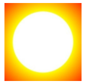
- The use of heat sources for buildings with conventional heating systems are limited to those sources of heat that are able to deliver such high temperatures
- However, for new/retrofitted buildings, the use of heating systems that are designed to operate and deliver the required heat at lower temperatures is possible
  - e.g. use of low temperature under floor heating systems or larger radiators



Underfloor heating systems are able to deliver useful heat at about 40ºC

Issues around integrating renewables into DH

- The use of biomass boilers and solar thermal is in principle a sensible approach
- In the heating season the biomass boiler provides the majority of the heating load with the solar thermal contributing when the solar resource is enough
- In the summer season, when the solar resource is the highest, and the heating demand the lowest the solar can provide all or the majority of the hot water requirements



BUT

… the excessive solar thermal production in summer combined with the the slow responsiveness of large biomass boilers means that the biomass boiler can continue producing heat even when this is not required what would cause overheating of the system

In the summer season, the use of smaller biomass biomass boiler is required, to increase the responsiveness of the system

Summary

- The integration of renewable energy sources in large DH schemes supplied by several heat sources can work well as the wider heat network can act as a back-up in periods where this is required
- The use of renewable energy sources in smaller DH schemes, similar to the majority of UK DH schemes coming forward, presents technical challenges that require careful consideration:
  - The operating organisation needs to take responsibility of managing the system on the ground to ensure reliable and uninterrupted supply of heat for the customer, i.e. quality of service provided.
  - It needs to acknowledge that such systems need more engagement and day-to-day care than simpler systems such as individual gas and boilers.
  - It needs qualified staff to deal with the particularities of the technology. The system needs to be adapted to changes to ensure optimal operation.

Bo01, Western Harbour in Malmo, Sweden

- The Bo01 area in the Western Harbour is a new development of approximately 1000 residential units
- Built in 2001 and served by 100% renewable energy supply averaged over the year but not at every moment.
- Electricity is generated by a 2 MW offshore wind turbine and 120 m2 of PV installed on one building.

Roof mounted solar thermal colelctors feeding the wider DH network in Western Harbour in Malmo, Sweden

Bo01, Western Harbour in Malmo, Sweden

- Heat is produced by solar collectors placed on 10 different buildings of 1400 m2 in total and by a heat pump (HP) connected to an aquifer where heat is stored seasonally.
- 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
- The network in the Western Harbour is served by 65ºC

Roof mounted solar thermal collectors feeding the wider DH network in Western Harbour in Malmo, Sweden

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Bo01, Western Harbour in Malmo, Sweden

- The solar collectors are connected on a building level separated by a heat exchanger from the network
- While every plumber should be able to do repairs, not everyone would be able to do the initial design.
- To prevent 10 different systems (different operation, maintenance), the network planners insisted on standardised systems for each building

Roof mounted solar thermal collectors feeding the wider DH network in Western Harbour in Malmo, Sweden

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Bo01, Western Harbour in Malmo, Sweden

- The aquifer in the bedrock underneath the Harbour is used as a seasonal storage of 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.

Roof mounted solar thermal collectors feeding the wider DH network in Western Harbour in Malmo, Sweden

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Bo01, Western Harbour in Malmo, Sweden

- The Bo01 scheme supplies 100% from RES only over an entire year
- It would not work without being balanced by the network of the city of Malmo
- Bo01 is an example of ST installations in an urban context;
- Some of the installations are integrated into the architectural design

Roof mounted solar thermal collectors feeding the wider DH network in Western Harbour in Malmo, Sweden

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Barnsley Metropolitan Borough Council

- Barnsley Metropolitan Borough Council located in a former mining area
- In 2004, introduced a Biomass Implementation Policy setting biomass as the standard solution for the future
- Planning requirements only ask for options appraisal for renewable sources
- Applicants need to make the case why biomass should not be implemented if they don't want to use it

Biomass DH in Barnsley

Barnsley also benefits from the existence of a number of small district heating networks that have been maintained successfully until today, totalling 24 networks supplying from <20 units up to 166 units.

To this date, a number of these networks has been changed to biomass, and another ones are in the pipeline, totalling 12 MW heat.

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Barnsley Metropolitan Borough Council

- Tradition with coal fired boilers, transition to biomass is from one solid fuel to another; changes to the system are minimal
- Barnsley MBC trialled the use of biomass in existing coal fired boilers; the experience was positive
- Implementing minimal changes, biomass could be burned in coal boilers without even changing the infrastructure
- It was thus possible to transition from a carbon intensive fuel to a carbon neutral fuel without changing the infrastructure

Biomass DH in Barnsley

Barnsley is surrounded by wooded areas. At the time of the implementation of the first biomass plant, there was however no supply chain in place.

In the meantime, companies have started that secure the constant supply of wood chips from local forestry management and coppices. ESCOs are in place for the supply of fuel but the assets are all owned by Barnsley MBC.

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