District Heating - 
Consultant’s perspective on designing heat networks

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Buildings and Places

Rehau District Heating Seminar June 2016
AECOM District Heating examples

- CIBSE AM12 Combined heat and power for buildings (2013) - Lead author
- CIBSE / ADE Code of Practice for Heat Networks (2015) – lead author and current training provider
- ETI Heat Infrastructure Development Project (2015-2016)
- UK potential for District Heating for DECC (2009) (with Poyry)
- Manchester City Council DH Feasibility studies – City Quarter, Oldham Town Centre, Stockport Town Centre, New Smithfield. (2013)
- Salford City Council DH Feasibility – Salford Central (2016)
District Heating - The role of the engineer

**Preparation & briefing**

**Middlesbrough and South Tees Phase 1 District Heating Study**
Pre-feasibility study of potential heat networks. Detailed heat density and anchor load maps using GIS, and a multi-criteria analysis of identified heat clusters to select those with the most potential. High level network designs, technical and financial analyses conducted to assess carbon savings, capital costs and cash flows for the different network options.

**Crewe and Macclesfield Heat Mapping and Energy Master Plan**
Production of an Energy Master Plan to consider the feasibility of Decentralised Energy and District Heating, serving two areas within Cheshire East. Identifying and analysing energy production, demand, sale, and distribution, producing a financial appraisal, and creating a phased project plan with associated risks. Report highlighting the best options for serving the focused areas in the longer term, providing designs, spatial maps and financial models.

**Greater Manchester District Heating Study Phase 1**
Detailed feasibility studies for three schemes in Manchester, Civic Quarter Phase 1, Oldham town centre and Stockport town centre. AECOM made site visits to each potential customer to determine connection requirements and promote the benefits of connecting to the scheme. AECOM are producing business case documents and development plans and advised the councils on potential governance options and procurement processes. The feasibility studies and business cases were used by Manchester City Council to identify potential funders and support procurement.

**Feasibility**

**Coventry Heatline**
Design and contractual support for Coventry City Council in the development of a scheme connecting EfW plant via 6.6km of pipework to supply buildings in the city centre. The scheme currently supplies circa 9 GWh per year, to rise to 73 GWh per year over the next 25 yrs.

**Convoys Wharf**
Design and tendering of an Energy Centre and District Energy scheme within central London for a 3,500 residential unit mixed use development to be interfaced with SELCHP

**North West Cambridge**
Design of a low carbon district energy system incorporating a 3MWe CHP system and 22MW boiler system to serve the 500,000m² development from a new Energy Centre.

**Design**

**University College London District Heating Scheme**
Design, tendering, procurement and project management of a MTHW and Steam district heating scheme incorporating 3MWe CHP. Works all conducted on an operational site.

**Reading University**
Developing and commissioning an energy centre incorporating a 1.2 MWe Gas fired CHP, 10 MW total capacity high efficiency gas fired boilers, 100m³ thermal store to maximize the run time of CHP and capacity for future expansion to meet 10 years’ of campus needs.

**Birmingham District Energy Scheme**
Development and commissioning of three separate district energy networks across two areas. The networks use trigeneration CHP, providing heat, electricity and chilled water. Reductions of 38 – 50% of carbon emissions from the buildings connected to the networks. Total savings for on energy bills for the public and private sector customers connected to the network of £500,000 per year.

**Loughborough University District Heating Renewal**
The University appointed AECOM to develop the design for linking two of its district heating systems together and the replacement of the existing pipework. The appointment included determining pipework routes, developing technical specifications, producing tender documentation suitable for design and build contractors, providing technical support throughout the tender process, and providing on-going support during the construction process.

**Construction**

**Islington Bunhill CHP District Heat**
Appointed project managers in 2009 to take the Islington project forward from concept to construction. We wrote the brief for detailed feasibility studies, chaired the Technical Development Group and reviewed the tender documents. We assisted in adjudicating tenders for both construction and operation and maintenance. After the award of contracts, AECOM continued in this role through engagement with the contractor in finalising the design. AECOM are now retained by the Client to advise on the operational phase with respect to CO₂ savings and the performance of the operation and maintenance contracts.

**Olympic Park and Stratford City**
Providing financial services to Stratford City Developments Ltd to support the development of a site-wide energy network for the Olympic Park and Stratford City sites. Developing the financial model and business case for procurement of the ESCO and developing the Concession Agreement. As a result of a 40 year business case agreed with the ESCO with a Concessionaire Agreement in place for the site, Price Control Formulae were agreed and Customer Connection and Supply Agreements were completed. This project is now operational and expansion plans are underway.

AECOM are providing ongoing support to LLDC to enable the efficient connection of new developments as they come forward.

**Commissioning**

**Operation & maintenance**

**Customer expectations/obligations**
District Heating – Key Issues discussed today

- Loads and diversity
- Operating temperatures
- Type of space heating system
- Type of hot water heating system
- Operating pressures
- Variable volume control and pumping energy
- Hydraulic separation
- Metering Strategy

All of the above are linked – Cannot consider in isolation
Assessing Thermal Demand and Consumption

- Identify the buildings/loads
- DECC Heat Map uses some variety of sources
- Gather data – quality of information reduces risk
- Develop and understand energy profiles – resolution to reflect level of information available and stage of feasibility being undertaken

Hierarchy:

1. Detailed sub-metering
2. Half hourly metered data
3. Monthly metered data
4. Annual metered data
5. Bespoke benchmarks
6. Generic benchmarks (TM46)

Repeat as required
Diversity – what is it?

- Mix of building types – residential, commercial, leisure, existing, new build
- Usage at different times of day/year
- Usage for different loads - DHW; space heating; process heating

Why is it important?

- CHP and other low carbon plant operates optimally at continuous output
- Diverse loads provide year round baseload
- Increases CO₂ savings and financial viability
- For residential demands can reduce peak demand significantly
Importance of Diversity in the servicing of dwellings

- Mr. Smith lives alone in a one bedroom apartment, in a 50 dwelling block on a newly built 3,000 dwelling development. Mr. Smith has a shower for 5 minutes on a bitterly cold winters day. Mr. Smith requires a source able to provide 33 kW for both the hot water demand and the heating requirements.

<table>
<thead>
<tr>
<th>Option</th>
<th>Dwellings</th>
<th>Space Heating Div</th>
<th>Domestic Hot Water Div</th>
<th>Occupancy</th>
<th>Undiversified Demand</th>
<th>Diversified Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combi Boiler</td>
<td>1</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>33 kW</td>
<td>33 kW</td>
</tr>
<tr>
<td>Communal Boiler</td>
<td>50</td>
<td>100%</td>
<td>11.2%</td>
<td>100%</td>
<td>1,650 kW</td>
<td>264 kW</td>
</tr>
<tr>
<td>Central Boiler</td>
<td>3,000</td>
<td>100%</td>
<td>4.1%</td>
<td>100%</td>
<td>99,000 kW</td>
<td>9,119 kW</td>
</tr>
</tbody>
</table>

- Review difference in capital cost and operational cost including value of space taken.
Importance of diversity in the servicing of dwellings
Importance of diversity in the servicing of dwellings

![Graph showing the diversity factor vs. number of dwellings for Danish DS 439, Swedish DHA, and TU Dresden.](image-url)
Importance of monitoring – Guru Systems

Capacity Required

- Guru Curve
- Guru Curve plus Losses
- BS 6700
- BS 6700 plus 3kW
- DS 439
- DS 439 plus 3kW
- Sites

www.gurusystems.com/
Importance of monitoring – Guru Systems

www.gurusystems.com/
Importance of monitoring – Guru Systems

Capacity Required

KWCapacity Required Per Customer

Number of Customers on Scheme

Guru Curve   Guru Curve plus Losses   BS 6700   BS 6700 plus 3kW   DS 439   DS 439 plus 3kW

www.gurusystems.com/
Considering Operating temperatures

• Trend is towards lower temperatures, low return temperatures generally improve scheme efficiency
• Target lower temperatures to reduce heat losses ⇒ reduced OPEX
• Design to maximise temperature difference to reduce volume flows, pipe sizes and thermal stores ⇒ reduced CAPEX
• Impact on heat source – gas-engine, steam turbine, heat pumps
• Consider compatibility with existing heating systems ⇒ increased Flow/Return
• For existing systems fit TRVs to increase radiator temperature drop and reduce return temp
• Consider legionella risk if domestic hot water storage used
• Consider underfloor heating with low return temperatures
Type of heating systems

**Space heating:** radiators, air handling units, underfloor heating, fan-coil units

**Hot water heating:** centralised, distributed, storage or instantaneous

DH can be used with all systems but system type impacts on the DH design and operation

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Secondary Flow Temp °C</th>
<th>Secondary Return Temp °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiators</td>
<td>Max 70</td>
<td>Max 40</td>
</tr>
<tr>
<td>Fan-coil units</td>
<td>Max 70</td>
<td>Max 40</td>
</tr>
<tr>
<td>Air handling unit</td>
<td>Normally 45</td>
<td>Max 40</td>
</tr>
<tr>
<td>Underfloor heating</td>
<td>Normally 65</td>
<td>Max 40</td>
</tr>
<tr>
<td>DHWS with coil</td>
<td>Normally &gt; 55</td>
<td>Max 45</td>
</tr>
<tr>
<td>DHWS with Plate Heat Exchanger</td>
<td>Normally 70+</td>
<td>Max 25</td>
</tr>
</tbody>
</table>
Select your plant

1. **Diversified** demand load phasing
2. Turndown
3. Resilience requirements
4. Decarbonise
5. Thermal hierarchy
6. Barriers
7. Design margins
8. Flexibility
9. Repeat

It all comes back to cost over the life time of the project. **Client best value, not lowest cost.**
Low carbon plant

Technologies available

- Co-generation
- Tri-generation
- Heat Pumps
- Fuel Cells
- Anaerobic Digestion
- Biofuel
- Waste energy capture

Each technology has unique cost, installation and operational requirements.

The system should be compatible for both today’s needs and have the potential to adapt to possible future technologies. Networks can outlast primary energy movers, 2 or 3 times over.
Low carbon plant

315 gCO₂/kWh

- Gas: 18100 MW (51.8%)
- Nuclear: 7500 MW (21.5%)
- Coal: 2800 MW (7.9%)
- French IC: 2000 MW (5.7%)
- Other: 1600 MW (4.6%)
- Storage: 1300 MW (3.6%)
- Dutch IC: 1000 MW (2.9%)

Variation of heat emissions factor with electricity emissions factor:

- Direct electric
- Gas boiler at 85%
- CHP at 37%
- Heat pump (COP 3.5)
- Individual heat pump (COP 2.5)

CO₂ emissions per kWh heat (g/kWh) vs. CO₂ emission per kWh electricity (g/kWh)

- Electric heating preferred
- CHP preferred
Develop the network

• Pipe is a major component of the cost
• Longer pipes – higher costs and heat losses
• Soft / hard dig
• Existing utilities / road crossings
• Land ownership
• Pipe material, single or twin pipe
• Plastic pipe – cheaper and quicker to install – need to design for material strength (<80°C)

Manage unwanted thermal pollution
• Ensure the loads are accurate - diversify
• Use less pipe – more verticals, less laterals
• Use smaller pipes – maximise delta Ts and reduce mean temperatures
• Better insulation – NES Y50 enhanced specification
• Manage residual thermal pollution

Assess the losses
Operating pressures and pumping

Maximum pressure for pipeline (16 bar if steel, 6 bar if plastic)

Maximum pressure for building components:
Heat exchangers if indirect connection (c10bar)
Heat emitters (radiators) if direct connection (c7 bar)

Minimum pressure to avoid cavitation (related to temperature)

Minimum static pressure for pumps (NPSH)
Check max/min pressures at highest /lowest point of network
Variable Volume Control and Pumping Energy

• Essential to use variable volume control for DH network and customers heating system:
  o i.e. two-port control valves not three-port
  o reduces pumping energy as volumes fall on part-load
  o pressure drops also reduce on part-load
  o maximises benefit from variable speed pumps
  o may need multiple pumps for optimum efficiency
  o maintains low return temperatures and hence low heat losses
Pipe sizing

- Optimum pipe size balances capital cost with pumping energy cost and heat loss cost

- Key equations:
  - Heat demand $Q \text{ (kW)} = m \text{ (kg/s)} C \text{ (kJ/kgK)} \Delta T \text{ (K)}$
  - $m \text{ (kg/s)} = \text{density} \times \text{cross-section area} \times \text{velocity}$
  - Pump power = volume flow rate $\times$ pressure rise / pump efficiency
  - Pressure drop in pipe = $4 \times f \times (L/d) \times (\frac{1}{2} \rho v^2)$
    Note: $f$ is a variable – see Moody chart

- Typical velocities for optimum sizing:
  - 1m/s below 100mm
  - 2m/s below 200mm
  - Max of 3m/s for larger (water hammer limit)

- Note: pump power is proportional to $flow^3$ and inversely to $d^5$
Design optimisation of heat networks

![Graph showing costs and optimisation in heat networks](image)

- Total costs
- Pipe costs, CCN
- Pump costs, CCP
- Heat loss costs, CHL
- Pumping costs, CP

Optimisation
Hydraulic separation

- Direct connection – DH water used by heat emitters
- Indirect connection – DH water separated from heating system by heat exchanger

- Direct connection – lower cost, less maintenance, no loss of temperature, but constraint on temperatures and pressures, more risk from leaks
- Indirect connection – less risk of contamination, DH temperatures and pressures are less constrained
- Blocks of flats – could use direct connection to each dwelling and indirect connection to the block
Visualise Physical Interaction

Energy Centre
Energy Centre design and build fit-out. Interface at pair of isolation valves within EC.

Residential Houses
Network terminates at HIU with fiscal heat meter. Maintenance of HIU may be placed upon network operator. Meter remains under ownership of the operator.

Residential Flats
Network terminates at PHEX with check heat meter. Vertical element and HIUs installation and/or maintenance may be placed upon network operator. Meter remains under ownership of the operator.

Commercial Accommodation
Network terminates at PHEX with fiscal heat meter.

Commercial Units
Network terminates at PHEX with fiscal heat meter.

District Energy Network distribution pipework installation
Extent of distribution pipework operation and maintenance from Energy Centre valves to secondary side of PHEX/HIU (first point of heat transfer)

Extent of distribution pipework operation and maintenance from Energy Centre valves to secondary side of PHEX/HIU (first point of heat transfer)
Lastly - Metering Strategy

• Domestic heat meters
  o Generally included for new build
  o Technical ‘fairness’ within blocks of flats
  o Social ‘fairness’ between customers (income)
  o Risk of people not using their heating
  o Maintenance of building fabric
  o For low carbon, low production cost heat is it cost-effective?

• Types of Meter - Prepayment, remote meter reading, smart meters