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A methodology is proposed to reduce heat losses in UK district heating networks and challenging the fourth generation of district heating definition

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Technologies and Systems

Introduction

Heat losses are high in the UK

From a sample of 38 DH systems and 22,162 residential consumers, we have monitored 43% of heat losses between 1/7/17 and 30/6/18.

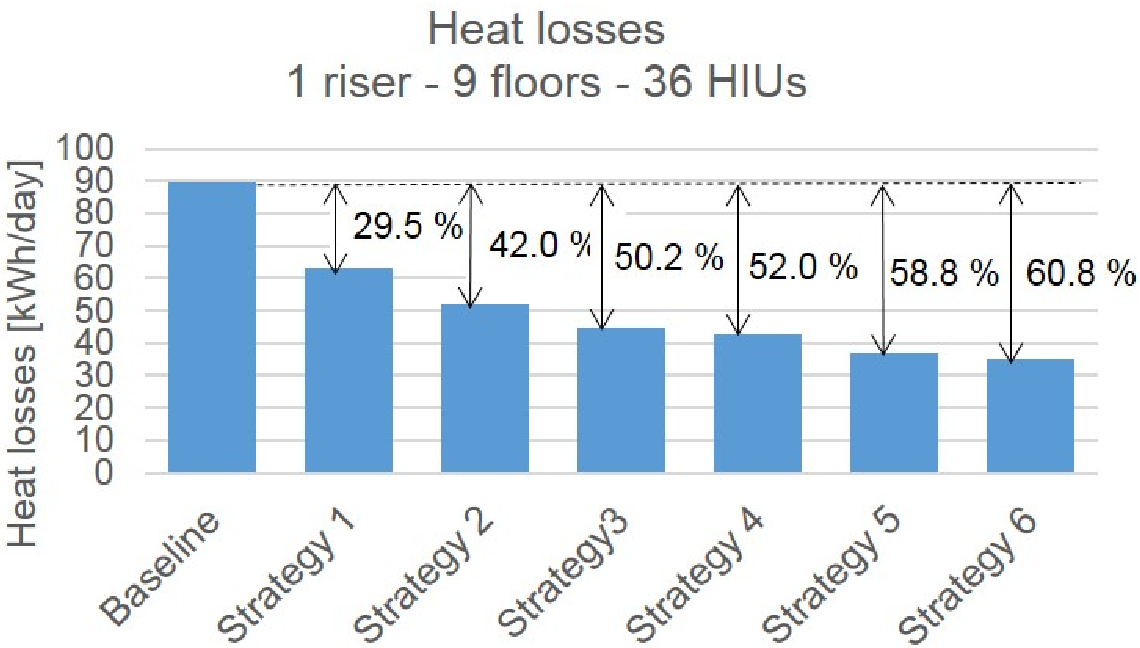
1) Heat generated: 152,615 MWh
2) Residential heat sold: 77,932 MWh
3) Total heat sold: 87,756 MWh
4) Thermal losses: 64,859 MWh (42.5% of heat losses)

Introduction

Effect of the heat losses on residential heat consumptions for Blocks of flats.

1) The average heat consumption by these dwellings is of 9.6 kWh/day or 3500 kWh/year. This is less than planned.
2) These heat losses in the Blocks delay the need to turn the space heating demand on. Hence, the heat lost in Blocks also has for effect to reduce consumers’ heat demand and less heat is sold to the consumers.

The Proposed Strategy



Baseline As currently designed in the UK

Strategy 1 Increasing the insulation layer

Strategy 2 Reducing the return temperature

Strategy 3 New pipe sizing methodology

Strategy 4 Increasing the flow temperature

Strategy 5 Removing consumers' plate heat exchanger

Strategy 6 Adding a cylinder at all consumers

Baseline

a) In the UK, pipes are usually sized based on 250 Pa/m. So 250 Pa/m was assumed to occur at peak heating load on all pipes except for the final pipes connecting each HIU to their laterals.

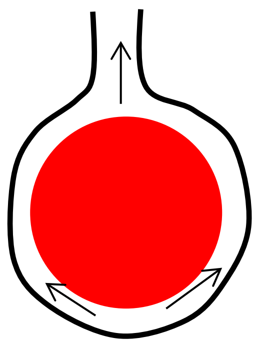
b) Pipes connecting the HIU are sized at the same size than the adapter fittings incorporated to them. In this case the adapters were all of 25 mm to guarantee a peak heating load of 37 kW: Instantaneous HIU supplying heat to supply simultaneously a shower and a washbasin.

c) Pipes are insulated with a phenolic layer of 20 mm and the flow and return temperatures are of 70 and 50 °C respectively.

Heat Loss calculation

The Natural convection factor and heat loss were calculated using the:

a) Nusselt number
b) Rayleigh number



$$\bar{h} = \frac{k}{D} Nu_D$$

$$Ra_L = \frac{g\beta(T_i - T_o)L^3}{\nu\alpha}$$

$$\overline{Nu_D} = \left\{0.6 + \frac{0.387 Ra^{1/6}}{[1 + (0.559/Pr)^{9/16}]^{8/27}}\right\}^2$$

Convection

$Q = h*A*(T_{solid} - T_{env})$

Minimum heat losses
In a Block at 21°C

Heat losses (Baseline)

Pipe diameter (mm)	25	32	40	50	65
Heating load (kW)	37	55	100	180	370
Fluid velocity (m/s)	0.9	0.8	1.0	1.1	1.35
Pressure drop (Pa/m)	400	250	250	250	250
Flow heat loss (W/m)	6.66	7.75	8.97	10.46	12.66
Return heat loss (W/m)	3.86	4.49	5.19	6.04	7.30
DHN length (m)	108	121.9	6.1	12.3	40.7
DHN heat loss (kWh/day)	27.26	35.80	2.08	4.86	19.50

Total heat loss per day = 89.5 [kWh]

Strategy 1 – Insulation thickness

Increasing the phenolic layer from 20 to 40 mm on all pipes

Pipe diameter (mm)	25	32	40	50	65
Flow heat loss (W/m)	4.83	5.5	6.23	7.12	8.41
Return heat loss (W/m)	2.83	3.21	3.64	4.15	4.9
DHN length (m)	108	121.9	6.1	12.3	40.7
DHN heat loss (kWh/day)	19.85	25.47	1.45	3.32	13.00

Total heat loss per day = 63.1[kWh]

Reduction = (1-63.1/89.5) = 29.5%

Strategy 2 – Reducing Return Temperature

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Reducing the return temperature from 50 to 40°C

Pipe diameter (mm)	25	27.5	34	43	56
Pressure drop (Pa/m)	200	250	250	250	250
Flow heat loss (W/m)	4.86	5.09	5.67	6.49	7.63
Return heat loss (W/m)	1.83	1.91	2.14	2.44	2.87
DHN length (m)	108	121.9	6.1	12.3	40.7
DHN heat loss (kWh/day)	17.34	20.49	1.15	2.63	10.26

Total heat loss per day = 51.86 [kWh]

Reduction = (1-51.86/63.1) = 17.8 %

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Strategy 3 - New Pipe Sizing Methodology – 70/40degC

Technical Note: Martin-Du Pan, O. Optimising pipe sizing and operating temperatures for district heating networks to minimise operational energy consumption, Building Services Engineering Research & Technology, 2018.

Pipe sizing at peak load – Maximum pipe sizing diameter

	Buried pipe		Pipe in heated space	
Network temperature	Flow (m/s)	Return (m/s)	Flow (m/s)	Return (m/s)
90/40degC	2.1	1.5	1.9	1.2
70/40degC	1.9	1.5	1.7	1.2
60/30degC	1.8	1.3	1.7	1.0

Strategy 4a – Increasing Flow Temperature to 90degC at Peak Load

1) Increase the flow temperature from 70degC to 90degC at peak load
2) Peak load is assumed to occur **33%** of the time

Additional benefit: The electricity to heat ratio reduces.

Flow diameter (mm)	11	13.5	18	24.5	35
Return diameter (mm)	**13.5**	**16.5**	**22.5**	**30**	**43**
Flow (@90degC) heat loss (W/m)	4.91	5.27	5.90	6.79	8.20
Flow (@70degC) heat loss (W/m)	3.56	3.80	4.21	4.81	5.77
Return heat loss (W/m)	1.44	1.54	1.75	2.00	2.44
DHN length (m)	108	121.9	6.1	12.3	40.7
DHN heat loss (kWh/day)	14.13	17.06	0.96	2.21	8.81

Total heat loss per day = 43.15 [kWh]

Reduction = (1-43.15/44.57) = 3.19 %

Strategy 4b – Increasing Flow Temperature to 90degC at Peak Load

1) Increase the flow temperature from 70degC to 90degC at peak load
2) Peak load is assumed to occur **10%** of the time

Additional benefit: The electricity to heat ratio reduces.

Flow diameter (mm)	11	13.5	18	24.5	35
Return diameter (mm)	**13.5**	**16.5**	**22.5**	**30**	**43**
Flow (@90degC) heat loss (W/m)	4.91	5.27	5.90	6.79	8.20
Flow (@70degC) heat loss (W/m)	3.56	3.80	4.21	4.81	5.77
Return heat loss (W/m)	1.44	1.54	1.75	2.00	2.44
DHN length (m)	108	121.9	6.1	12.3	40.7
DHN heat loss (kWh/day)	13.3	16.05	0.90	2.07	8.26

Total heat loss per day = 40.59 [kWh]

Reduction = (1-40.59/44.57) = 8.93 %

Strategy 5a – Removing PHX at the consumers

Removing a plate heat exchanger at the consumer enables to supply and return fluid at a lower temperature of approximately 5degC. So both temperatures would be:

At Peak load

T_{flow} : 85degC instead of 90degC
T_{return} : 35degC instead of 40degC

At Base load

T_{flow} : 65degC instead of 70degC
T_{return} : 35degC instead of 40degC

Strategy 5a – Removing PHX at the consumers

Assumed: Peak load 33% and Baseload 67% of the time

Flow diameter (mm)	11	13.5	18	24.5	35
Return diameter (mm)	**13.5**	**16.5**	**22.5**	**30**	**43**
Flow (@85degC) heat loss (W/m)	4.56	4.88	5.46	6.28	7.57
Flow (@65degC) heat loss (W/m)	3.12	3.35	3.74	4.30	5.19
Return heat loss (W/m)	1.04	1.12	1.27	1.47	1.79
DHN length (m)	108	121.9	6.1	12.3	40.7
DHN heat loss (kWh/day)	12.03	14.55	0.82	1.89	7.59

Total heat loss per day = 36.89 [kWh]

Reduction = (1-36.89/43.15) = 14.5 %

Strategy 6a – Adding a DHW Cylinder at the Consumers

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Removing the instantaneous DHW units enable to use smaller pipe diameters on the HIU connections to the laterals.

Additional benefit: It simultaneously flattens the daily heating load.

Flow diameter (mm)	5.9	13.5	18	24.5	35
Return diameter (mm)	**7.4**	**16.5**	**22.5**	**30**	**43**
Flow (@85degC) heat loss (W/m)	3.89	4.88	5.46	6.28	7.57
Flow (@65degC) heat loss (W/m)	2.67	3.35	3.74	4.30	5.19
Return heat loss (W/m)	0.87	1.12	1.27	1.47	1.79
DHN length (m)	108	121.9	6.1	12.3	40.7
DHN heat loss (kWh/day)	10.24	14.55	0.82	1.89	7.59

Total heat loss per day = 35.10 [kWh]

Reduction = (1-35.10/36.89) = 4.85 %

Conclusion

Heat losses must and can be reduced in UK district heating network. Compared to the Baseline and by progressively applying these six strategies, the heat losses are reduced and compared to the Baseline:

1) A thicker insulation layer reduced the heat losses to 71% compared to the Baseline
2) Reducing the return temperature from 50°C to 40 °C reduces the heat losses to 58%
3) The proposed new pipe sizing methodology reduces the heat losses to 50%
4) Increasing the flow temperature to 90°C instead of 70 °C reduces the heat losses to 48%
5) Removing consumers' PHX reduces the heat losses to 41%
6) Adding a cylinder at all consumers reduces the heat losses to 39%

So the heat losses can be more than halved compared to the Baseline

Questions

Thank you very much!

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