# Consultation Paper – CONSP:04

## Distribution loss factors for heat networks supplying dwellings in SAP

Issue 1.0

**DOCUMENT REVISIONS**

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# 1. INTRODUCTION

The National Calculation Methodology for energy rating of dwellings (SAP) provides for heat loss from a communal heat network by increasing the total heat supplied by the network via a Distribution Loss Factor (DLF). The DLF is defined as the total heat supplied to the network by the heat generator(s) divided by the sum of the heat delivered from all network connections, e.g. individual dwellings. As such it covers the whole heat distribution network, including the heat loss between bulk customers and individual dwellings.

Table 12c of SAP 2012 (see Appendix A) contains default values for the DLF for communal heat networks. For new networks (1991 or later), whether supplying new or existing dwellings, the default values range from 1.05 to 1.10 depending on the temperature at which water flows through the network. Default values for older networks (1990 or earlier) range from 1.10 to 1.20.

Feedback was received from third parties, e.g. developers, housing associations and consultants, that the default DLF may be unrealistic, particularly when supplying dwellings with low space heating demand, e.g. new build apartments. Hence, an investigation was conducted to determine whether these default values are representative for heat networks supplying new dwellings. Internal heat losses from pipes within apartment block risers and corridors are included when determining the DLF, since these losses are not controlled and cannot therefore be considered useful to the dwelling.

# 2. ANALYSIS

Actual distribution loss factors, derived from monitored data for operational networks, were collated for 11 cases. Table 1 below summaries the distribution losses and DLF for each of the cases examined. It can be seen that the DLF ranges from 1.3 to 3.0 depending upon the particular characteristics of the development and network. The average is 2.0, nearly double the DLF for new networks contained in Table 12c of SAP 2012, and equivalent to distribution losses of 50%. For each case examined, Appendix B contains a brief description of the network and a table summarising the data obtained.

| Development | Distribution Losses (%) | Distribution Loss Factor |
|---|---|---|
| Case 1 | 66 | 3.0 |
| Case 2 | 61 | 2.6 |
| Case 3 | 66 | 2.9 |
| Case 4 | 43 | 1.8 |
| Case 5 | 32 | 1.5 |
| Case 6 | 34 | 1.5 |
| Case 7 | 32 | 1.5 |
| Case 8 | 40 | 1.7 |
| Case 9 | 23 | 1.3 |
| Case 10 | 61 | 2.6 |
| Case 11 | 47 | 1.9 |

**Table 1 - Actual Distribution Loss Factors for individual networks**

A report[1] was published in March 2015 by AECOM on behalf of the Department of Energy & Climate Change (DECC) that considered heat network performance, amongst other aspects. It concluded that average distribution losses for the three assessed networks covering the whole system, i.e. including internal pipework to the hydraulic interface unit (HIU) within each dwelling, equated to 28%, with a maximum of 43%. The marginally lower average losses may be due to the AECOM sample covering networks of varying age, whereas the sample considered for this report covered only new networks supplying new dwellings. New networks serving new dwellings, whilst potentially constructed to a good standard with lower distribution losses than older systems, tend to have proportionally higher distribution losses, relative to the number of connected dwellings. This may be due to the "peaky" nature of the heat demand, where the domestic hot water (DHW) load dominates, since new dwellings feature lower space heat demand than older dwellings.

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[1] Final Report: Assessment of the Costs, Performance, and Characteristics of UK Heat Networks, 26th March 2015. See: https://www.gov.uk/government/publications/assessment-of-the-costs-performance-and-characteristics-of-uk-heat-networks

This report is based on work which developed theoretical estimates of heat loss from drawings for actual installed pipework within a single development comprising three apartment blocks. The calculated losses for conventional temperature design was estimated at 20% (see Appendix C); whilst these were estimated at 17% if the system were a “low temperature design” (see Appendix D). Both of these are significantly above the defaults in SAP 2012 Table 12c.

Figure 1 below compares the actual and theoretical DLF obtained during the investigation for this report to the default value for “modern”[2] networks in Table 12c of SAP 2012. Actual figures are significantly above the theoretical values, indicating that much could be done to improve network performance. Nevertheless, both the theoretical and actual DLF figures are significantly above the SAP default value.

The actual DLF could likely be reduced through the adoption of good design, installation and operational practices, for example by compliance with the CIBSE/ADE *‘Heat Network: Code of Practice for the UK’*. However, even with compliance, Table 12c of SAP 2012 would remain inaccurate.

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[2] *“Modern pre-insulated piping system operating at 100ºC or below, full control system installed in 1991 or later, variable flow system”* – see SAP 2012 specification

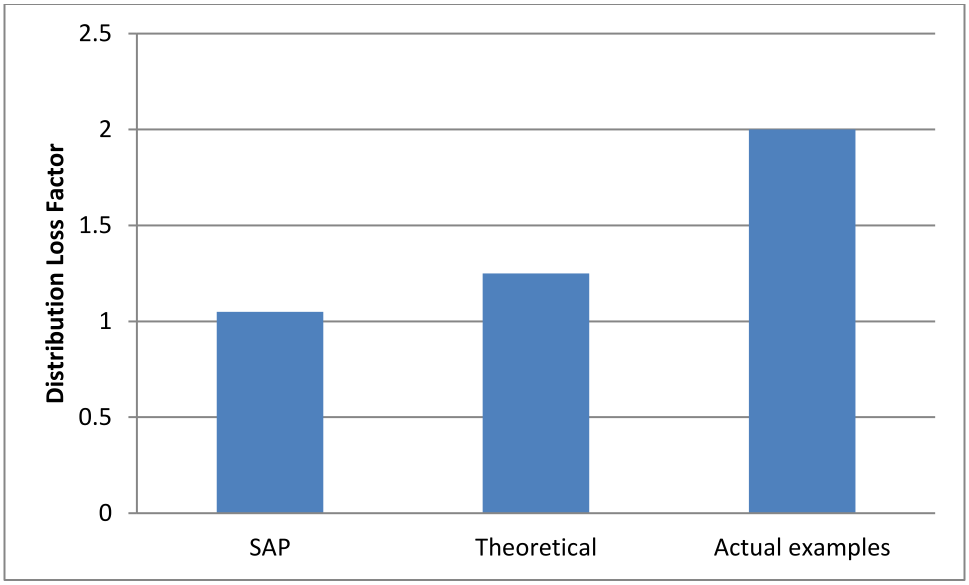


**Figure 1: Theoretical and actual distribution loss factors compared to the default value in SAP (for new-build dwellings)**

It is clear from the information available that specific calculations that estimate the heat network DLF or, where available, actual metered data for losses, are required for SAP calculations to improve accuracy.

Note: For the avoidance of doubt, this document and the DLF described herein considers distribution losses from the pipework between the heat generators and the connected dwellings and, where applicable, non-domestic buildings. The document does not consider the efficiencies of heat generators. Heat network performance data stored in the SAP Products Characteristics Database (PCDB) takes account of both heat generation efficiency and distribution losses.

# 3. PROPOSED CHANGES TO SAP

## 3.1 Summary

Based on the information available, the following recommendations are made for the SAP 2016 revision:

- For Design-stage SAP assessments, a DLF of >= 1.2 can be manually entered by the SAP assessor. The entered DLF will require a suitable formal notification by the Property Developer to be supplied to the SAP assessor; this must confirm the design target DLF and confirm understanding that any shortfall may result in dwellings being non-compliant with Building Regulations at the as-built assessment stage.

- For As-built SAP assessments, a default DLF of 1.5 is proposed if the heat network is designed and commissioned in accordance with the CIBSE/ADE '*Heat Networks: Code of Practice for the UK'*. This will require that the SAP assessor receives evidence via a certificate or headed letter from both the Network designer and commissioning engineer, who have undergone competent persons training.

- For either design-stage or as-built SAP assessments, a default DLF for new dwellings supplied by heat networks should be introduced if the heat network is not designed and commissioned in accordance with the CIBSE/ADE '*Heat Networks: Code of Practice for the UK'*. A value of 2.0 is proposed. This would incentivise actual heat losses to be determined and performance data supplied to the PCDB and/or compliance with the Code of Practice.

- For the purposes of SAP assessments, either design-stage or as-built, the network specific heat loss, expressed as a DLF, can be determined using actual consumption data and entered in the Product Characteristics Database (PCDB). Provision for this was introduced in SAP 2012[3].

- Where network heat losses are calculated from the design for the purpose of PCDB entry, rather than based on actual consumption data, the calculated DLF should be multiplied by an in-use factor (this will be applied directly within the PCDB data record). An in-use factor of 1.15 is proposed (see Appendix E).

[3] See: http://www.ncm-pcdb.org.uk/sap/page.jsp?id=19

• The conditions[4] in SAP Section C3.1 which, if met, currently allow the default values in Table 12c to be used, should be deleted.

• For undertaking RdSAP assessments of existing buildings, SAP 2016 Table 12c should be amended to specify Distribution Loss Factor by dwelling age[5], which accordingly relates to dwelling heat load and therefore implied network heat density - See APPENDIX F: Revised default DLF values for existing dwellings.

| **Age Band** | **Year range** | **Distribution Loss Factor** |
|---|---|---|
| A | Pre 1900 | 1.2 |
| B | 1900-1929 | 1.26 |
| C | 1930-1949 | 1.33 |
| D | 1950-1966 | 1.37 |
| E | 1967-1975 | 1.41 |
| F | 1976-1982 | 1.43 |
| G | 1983-1990 | 1.45 |
| H | 1991-1995 | 1.46 |
| I | 1996-2002 | 1.48 |
| J | 2003-2006 | 1.49 |
| K | 2007 onwards | 1.5 |
| New dwelling | | 2.0 |

[4] "*1) The only dwellings connected to any part of the network are flats, or; 2) The total trench length of the network is no longer than 100 metres, or; 3) The linear heat density is not less than 2 MWh/year per metre of network"*

[5] This will utilise RdSAP data, which records the dwelling age band during the assessment.

| | | |
|---|---|---|
| New dwelling connected to heat network designed and commissioned in accordance with *“Heat Networks: Code of Practice for the UK”* | | 1.5 |

**Table 2: Revised Table 12c for SAP 2016**

- For SAP assessments utilising default DLF values, the existing SAP assumption that electrical pumping energy required for distribution equals 1% of the space and water heating energy requirement will be retained. For heat networks that are entered in the PCDB actual electrical pumping energy will be recorded.

## 3.2 Distribution Loss Factor input process for SAP 2016

Figure 2 displays the proposed process for inputting heat network DLF values into SAP software. It is proposed that default DLF values for networks compliant and not compliant with the CIBSE/ADE ‘*Heat Networks: Code of Practice for the UK’* are entered in the PCDB for selection by the SAP assessor. This will facilitate future amendment if sufficient data becomes available.

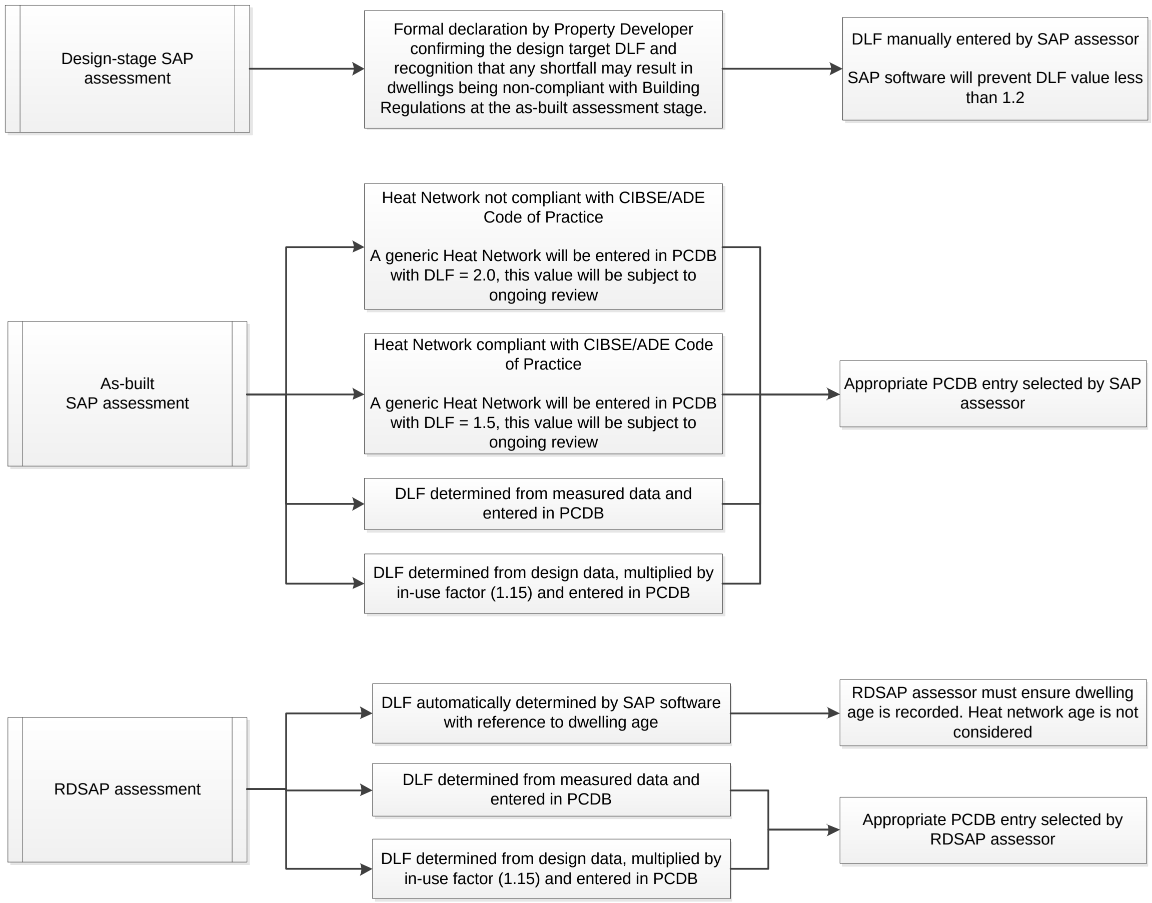


Figure 2 - Distribution Loss Factor input process for SAP 2016

## 3.3 Impact of proposed changes

Table 3 illustrates the effect upon SAP Dwelling Emission Rate (DER) and SAP Rating for two example dwelling types. For newer dwellings (post 1967) the greatest impact may be a change in SAP Rating, though none of these examples were lower than “Band E”.

| Age Band | | Semi-detached | | | | Flat | | |
|---|---|---|---|---|---|---|---|---|
| | | SAP 2012 | SAP 2016 | % Change | | SAP 2012 | SAP 2016 | % Change |
| | | | | | | | | |
| A | Distribution Loss Factor | 1.2 | 1.2 | 0% | | 1.2 | 1.2 | 0% |
| (Pre 1900) | SAP Score and Rating | 47 E | 47 E | | | 52 E | 52 E | |
| | Dwelling Emission Rate (kgC/m$^2$/yr) | 87.34 | 87.34 | 0% | | 69.25 | 69.25 | 0% |
| | | | | | | | | |
| D | Distribution Loss Factor | 1.2 | 1.37 | 14% | | 1.2 | 1.37 | 14% |
| (1950-1966) | SAP Score and Rating | 51 E | 45 E | | | 59 D | 55 D | |
| | Dwelling Emission Rate (kgC/m$^2$/yr) | 78.92 | 89.71 | 14% | | 61.09 | 69.37 | 14% |
| | | | | | | | | |
| E | Distribution Loss Factor | 1.2 | 1.41 | 18% | | 1.2 | 1.41 | 18% |
| (1967-1975) | SAP Score and Rating | 51 E | 44 E | | | 59 D | 54 E | |
| | Dwelling Emission Rate (kgC/m$^2$/yr) | 78.51 | 91.76 | 17% | | 60.9 | 71.1 | 17% |
| | | | | | | | | |
| G | Distribution Loss Factor | 1.1 | 1.45 | 32% | | 1.1 | 1.45 | 32% |
| (1983-1990) | SAP Score and Rating | 63 D | 54 E | | | 71 C | 64 D | |
| | Dwelling Emission Rate (kgC/m$^2$/yr) | 57.04 | 74.29 | 30% | | 39.77 | 51.52 | 30% |
| | | | | | | | | |
| J | Distribution Loss Factor | 1.05 | 1.49 | 42% | | 1.05 | 1.49 | 42% |
| (2003-2006) | SAP Score and Rating | C 70 | C 62 | | | 75 C | 68 D | |
| | Dwelling Emission Rate (kgC/m$^2$/yr) | 42.39 | 58.88 | 39% | | 32.2 | 44.52 | 38% |

Table 3 – Impact of proposed changes upon example dwellings

# APPENDIX A: SAP2012 Table 12c

**Table 12c: Distribution loss factor for group and community heating schemes**

The following Distribution Loss Factors (DLF) are used when one of the conditions stated in SAP Appendix C3.1 applies, it must otherwise be calculated.

| Heat distribution system | Factor |
|---|---|
| Mains piping system installed in 1990 or earlier, not pre-insulated medium or high temperature distribution (120-140ºC), full flow system | 1.20 |
| Pre-insulated mains piping system installed in 1990 or earlier, low temperature distribution (100ºC or below), full flow system. | 1.10 |
| Modern higher temperature system (up to 120ºC), using pre-insulated mains installed in 1991 or later, variable flow system. | 1.10 |
| Modern pre-insulated piping system operating at 100ºC or below, full control system installed in 1991 or later, variable flow system | 1.05 |

**Table 4: SAP 2012 Table 12c**

Note: A full flow system is one in which the hot water is pumped through the distribution pipework at a fixed rate irrespective of the heat demand (usually there is a bypass arrangement to control the heat delivered to heat emitters). A variable flow system is one in which the hot water pumped through the distribution pipe work varies according to the heat demand.

## APPENDIX B: Actual heat loss from networks supplying new dwellings

The actual heat loss from heat networks can vary from the default figures in Table 12c of SAP2012 for a range of reasons relating to specification and installation. Therefore, information has been gathered regarding the actual distribution losses in new heat networks serving new residential developments.

Owners and operators of new heat networks serving new residential developments were contacted to explore what data they had available and their willingness to share it. Approaches were made to 15 organisations, these included housing associations, energy services companies, local authorities and trade associations.

Contact was made with 7 housing associations serving the London area, as the vast majority of new networks serving new build developments are located in London due to stringent planning requirements. Only 3 of these housing associations were able to provide data.

Several energy service companies were also approached to provide information but no data was forthcoming. The companies suggested that many of their new networks serving new dwellings were either being built or in the initial stages of operation, meaning the energy performance available was not representative of how the network is intended to operate in the long term.

Additionally, two local authorities with new networks serving new dwellings were approached but no data was forthcoming.

The two trade associations serving the district heating industry (CHPA[6] and UKDEA) were also contacted by telephone and email to make them aware of the information collection exercise.

[6] Now renamed: The Association for Decentralised Energy

The data includes information collected directly from Housing Associations, as well as data from other sources. The anonymous cases for which information was available are described below.

Heat meter readings for connected dwellings and non-domestic buildings were sought. The fuel consumption of central boilers over the metered period was determined and after correcting for boiler efficiency (assumed as 80%) the heat supplied to the network was determined. In all but one case either a CHP plant (Combined Heat & Power) was not present or was not operational. A CHP plant was present and operational in one assessed case; the assessment therefore included CHP supplied heat in addition to that supplied by the connected boilers.

**Anonymous Case 1**

This new development, constructed in 2008, consists of approximately 110 dwellings spread across two apartment blocks. The apartments are heated by a heat network supplied by modular gas boilers in a basement plant room. Heat consumption data for each individual dwelling covering the period shown in Table 5 below was obtained. During the same period the gas consumed in the plant room was obtained, together with the boiler efficiency. The data showed distribution losses of 66%, equating to a distribution loss factor of 2.96.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 1/5/13 – 1 /5/14 | 835.705 | 281.994 | 66 | 2.96 |

Table 5: Distribution loss factor data for case 1

**Anonymous Case 2**

This is a new multi-phase development. Approximately 90 dwellings were included in the first phase which was completed in the period up to mid-2012. The dwellings are heated from a site heat network supplied by an energy centre containing central gas boilers. Heat consumption data and gas consumption data relating to the first phase was available for a 407 day period between August 2012 and October 2013. A boiler efficiency of 85% was applied to the gas consumption to estimate the heat supplied to the network. As shown in Table 6 below, distribution losses of 61% were recorded, resulting in a distribution loss factor 2.57. It may be that the high distribution losses from this project are in part due to extra supply capacity for later construction phases.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 21/8/12 – 2/10/13 | 796.7 | 311.6 | 61 | 2.57 |

Table 6: Distribution loss factor data for case 2

**Anonymous Case 3**

The first phase of this multiphase development contains approximately 130 dwellings. The dwellings are connected to a heat network supplied from a basement energy centre containing central gas boilers. Heat consumption data for individual dwellings was obtained from heat meter readings. The gas consumption of the central boilers over the same period was also obtained and a boiler efficiency applied to determine the useful heat supplied into the network. As shown in Table 7 below, the analysis showed distribution losses of 66%, resulting in a distribution loss factor of 2.92. Again, the very high distribution losses from this project may be in part due to including capacity to supply later phases.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 10/5/11 – 1/1/12 | 758.018 | 259.804 | 66 | 2.92 |

Table 7: Distribution loss factor data for case 3

## Anonymous Case 4

This new development, which is part of a wider regeneration initiative, was completed in 2007. Approximately 70 dwellings and 3 community buildings are included in the development and served by a heat network. As can be seen in Table 8 below, heat losses of 43% were calculated, resulting in a distribution loss factor of 1.76.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 5/6/13 – 1/4/14 | 566.373 | 320.923 | 43 | 1.76 |

Table 8: Distribution loss factor data for case 4

## Anonymous Case 5

This new build development of approximately 40 flats was handed over by the construction company in 2012. The flats are served by a site heat network. As shown in Table 9 below, the monitored distribution losses amounted to 32%, resulting in a distribution loss factor of 1.46.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 31/5/12 – 3/4/13 | 426.637 | 291.410 | 32 | 1.46 |

Table 9: Distribution loss factor data for case 5

## Anonymous Case 6

This new development of approximately 70 dwellings was constructed prior to 2012. A site heat network supplies heat to the dwellings in the development. Table 10 below highlights that the heat distribution losses were 34%, resulting in a distribution loss factor of 1.51.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 1/4/2013 –31/3/14 | 627.312 | 414.855 | 34 | 1.51 |

Table 10: Distribution loss factor data for case 6

**Anonymous Case 7**

Handed over by the construction company in 2012, this small new development contains approximately 90 flats. The flats are heated from a site heat network supplied by gas boilers. As shown in Table 11 below, the distribution losses equated to 32% resulting in a distribution loss factor of 1.47.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 1/4/13 – 28/3/14 | 780.586 | 530.963 | 32 | 1.47 |

Table 11: Distribution loss factor data for case 7

**Anonymous Case 8**

This network serves a new build development on a former government site in London. Approximately 110 flats are connected to the heat network which is supplied by gas boilers. Table 12 below highlights that the distribution losses were 40% resulting in a distribution loss factor of 1.66.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 1/1/13 – 31/1/14 | 1068.379 | 644.467 | 40 | 1.66 |

Table 12: Distribution loss factor data for case 8

**Anonymous Case 9**

This new development consists of approximately 320 dwellings completed in 2011 and 2012. It is served by a site heat network supplied by gas fired CHP and gas boilers, although the gas CHP has not operated since installation. While the individual dwellings are heat metered, heat meter readings were only available for certain periods. Similarly, gas consumption data for the energy centre was only available for specific periods. Due to the disjointed nature of the data it was only possible to match the consumer heat consumption and boiler gas consumption data for a 3 month period in the winter 2012/13. A boiler efficiency of 80% was applied to the gas consumption data to determine the heat supplied into the network. During this winter period the heat distribution losses were 23%, resulting in a distribution loss factor of 1.31, as shown in Table 13 below. However, the distribution loss factor over the whole year, including the low demand/efficiency summer period, is likely to be significantly higher.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| Nov 2012 to Jan 13 (inclusive) | 528.8 | 405.2 | 23 | 1.31 |

Table 13: Distribution loss factor data for case 9

**Anonymous Case 10**

This case is a new development of 325 dwellings supplied by a site heat network. As shown in Table 14 below, the network had distribution losses of 61%, equating to a distribution loss factor 2.58.

| Time period | Heat supplied to the network (MWh) | Heat supplied to customers (MWh) | Distribution losses (%) | Distribution Loss Factor |
|---|---|---|---|---|
| 3/4/13 – 1/4/14 | 2153.235 | 835.487 | 61 | 2.58 |

Table 14: Distribution loss factor data for case 10

**Anonymous Case 11**

Constructed between 2011 and the end of 2013, this new development is heated by a site heat network supplied by a gas fired CHP and top-up/back-up boilers[7]. Time periods where plant room metered data corresponded with dwelling heat metered data were identified, although for large periods these two sets of data did not coincide. However, the heat distribution loss for a 3 month period in the spring of 2013 was identified. During this period the reported distribution losses were 47%, resulting in a distribution loss factor of 1.89.

**Other feedback on distribution loss factors**

The g15 represents London's 15 largest housing associations, providing homes for around 1 in 10 London residents. Their members manage around 410,000 homes[8] and approximately 134 heat networks[9]. As such, their members have been responsible for initiating many new heat networks in the last decade supplying new build residential property, largely in response to planning policy.

The g15 group undertook a piece of research in 2012 and 2013 entitled G15 Communal Heating experience[10]. This examined around 8 research case studies in detail, as well as circa 40 other projects in lesser detail. In the case studies reviewed for the project, the metered efficiency between the fuel entering the central boilers and heat delivered to the dwellings ranged between 28.6% and 47.3%. Assuming a central boiler efficiency of 75%, Table 15 below estimates the upper and lower distribution losses and corresponding distribution loss factors. The distribution losses varied from 37% to 62%, resulting in distribution loss factors from 1.6 to 2.6, again significantly above the figures in SAP Table 12c.

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[7] Confidential report produced by UCL Energy Institute for new build developer

[8] Information retrieved from g15london.org.uk on the 22 August 2014

[9] Figure in presentation by Robert Greene at National Housing Federation Conference (2012)

[10] Presentation given by Robert Greene at National Housing Federation Conference (2012)

| | Distribution losses (%) | Distribution Loss Factors |
|---|---|---|
| Upper | 62 | 2.6 |
| Lower | 37 | 1.6 |

Table 15: Distribution loss factors derived from range in the g15 study

## Possible reasons for high distribution loss factors

Various reasons for the high distribution loss factors have been proposed including:

- Little and intermittent demand for heat in new apartments but water temperatures in pipes are maintained at all times
- Overly pessimistic assumptions about the diversity of hot water loads leading to oversized pipes
- Poor installation of pipework and heat exchangers

## Analysis of anonymous cases

Unfortunately, many of the anonymous cases featured less than one calendar year of data, meaning that drawing conclusions for these would not be robust. However, cases 1, 5, 6, 7, 8 and 10 did feature a calendar year[11] and are presented in Table 16.

| Case | Number of dwellings | Heat supplied to dwelling (kWh) | DLF |
|---|---|---|---|
| | | | |
| 1 | 110 | 2564 | 2.96 |
| 5 | 40 | 7285 | 1.46 |
| 6 | 70 | 5927 | 1.51 |
| 7 | 90 | 5900 | 1.47 |
| 8 | 110 | 5859 | 1.66 |
| 10 | 325 | 2571 | 2.58 |

[11] With exception of case 8, which featured 13 months of data - such a variation was not considered to effect analysis.

Table 16 – Anonymous cases featuring a calendar year of data

Figure 3 plots these cases and displays the observed trend of higher DLFs for dwellings with lower heat loads. Whilst there are only two cases with DLFs higher than 2.5 (cases 1 & 10), there is remarkable agreement with the trendline.

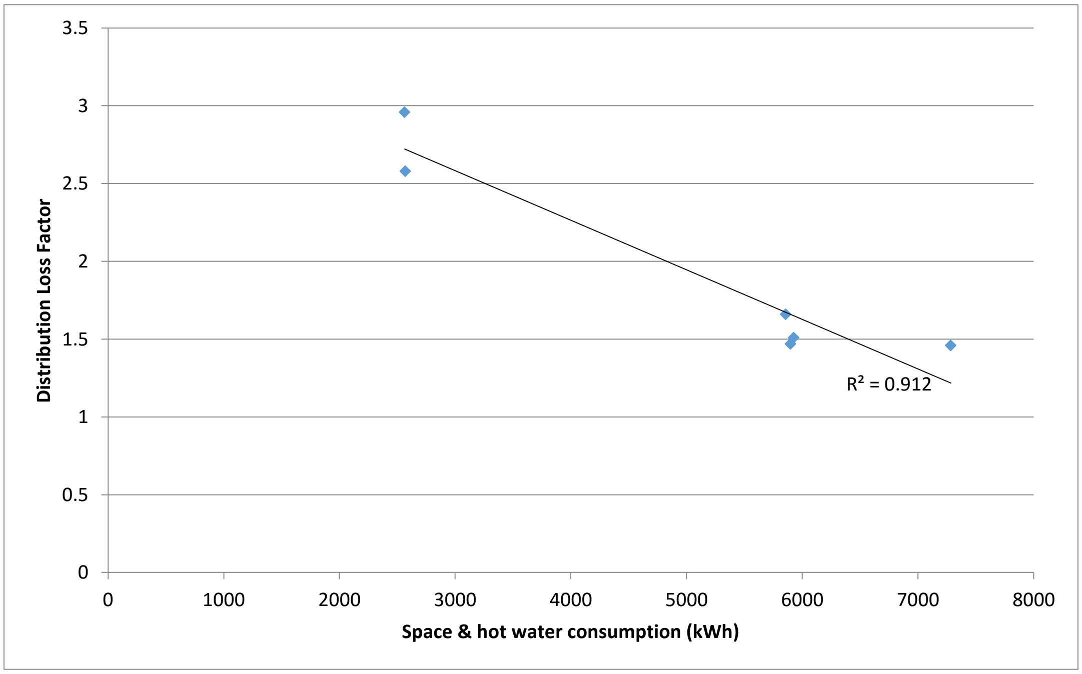


Figure 3 – Distribution Loss Factor Vs Space & hot water consumption for selected anonymous cases

For the above anonymous cases, consideration was given to purported inaccuracies in heat meter readings, particularly due to the low observed heat consumption of dwellings with high DLFs. Based on field observations of poor performing heat networks it is considered that such low dwelling heat loads (for apartments/flats) are plausible. This is partially due to the high performance building fabric associated with new-build apartments, the small exposed area of this fabric, and potential heat gains from distribution pipework and overheating communal areas.

For new-build dwellings connected to a heat network, a default DLF of 2.0 is considered an appropriate compromise; see Section 2 and conclusions from g15 study above.

A concession for heat networks designed and commissioned in accordance with the CIBSE/ADE '*Heat Networks: Code of Practice for the UK'* is considered appropriate and in this case a default DLF of 1.5 can be awarded, subject to an auditable log of compliance being provided to the SAP assessor.

For the purpose of defining a maximum default DLF for existing dwellings connected to a heat network and built since 2007, a DLF of 1.5 is considered an appropriate compromise[12]. This DLF is applied irrespective of heat network age.

[12] This agrees with SAP 2012's current provision for DLFs where calculation is not possible. SAP 2012 Appendix C3.1 states: *"If the distribution loss factor cannot be calculated from scheme data a value of 1.5 should be used."*

## APPENDIX C: Calculated heat loss (new network and new dwellings)

The following information was sourced from an actual built example. A heat network was installed to supply three apartment blocks, containing approximately 200 apartments. The heat network is supplied from an energy centre in the basement of the development. Heat is distributed at basement level to multiple risers which run up through the apartment blocks. In one of the blocks further lateral pipework is used to distribute the heat to individual dwellings.

The pipe lengths are taken from the as-built drawings.

The length of pipework split according to pipe diameter was obtained. At each diameter the heat loss per meter of pipe was calculated for specific pipe insulation thicknesses and thermal conductivity values. The product of these variables was used to determine heat loss.

The calculated estimates contained in the sections below do not account for additional losses, e.g. flanges. Neither do the estimates account for factors which may cause additional heat loss from poor installation.

The following assumptions have been made:

- Lambda value of 0.040 W/mK
- Minimum insulation thickness of 50mm
- Flow temperature of 80˚C
- Return temperature of 50˚C
- Average external temperature 15˚C

The sub-sections below consider the heat loss in the individual apartment blocks connected to the network and the heat loss from the basement pipework connecting the networks together.

### Heat loss from first block

The first block of flats contains 18 dwellings. The accommodation is spread over 6 storeys with each storey containing 3 flats, thus the network uses a traditional core layout. Assuming an average heat consumption of 3,000kWh/dwelling, the total annual heat consumption of the block is 54,000 kWh, as shown in Table 17 below.

| Number of storeys | Number of flats per floor | Total number of flats | Annual Heat consumption (kWh / dwelling) | Total Annual Heat Consumption (kWh) |
|---|---|---|---|---|
| 6 | 3 | 18 | 3,000 | 54,000 |

Table 17: Annual heat consumption of flats in the first block

This block contains a significant amount of lateral distribution pipework on each storey. This is due to there being only one riser. This is the least efficient layout of heat distribution of the three blocks considered and could be a contributory factor to overheating in internal corridors.

The lateral and riser pipework installed in the block varies between 25mm and 65mm in diameter. The length of pipework, split according to pipe diameter, is contained in Table 18 below. Taking account of the lambda value and thickness of the insulation, together with the temperature difference between the pipework and surroundings, the heat loss per metre of pipework is provided for each diameter of pipe. The standing heat loss from the pipework was estimated at 2.4kW, with an annual heat loss of 21.2MWh.

| Pipe Diameter (mm) | Total length of pipe (m) | Heat loss per metre of pipe (W/m) | Total heat loss for pipe (W) | Annual heat loss from pipe (kWh) |
|---|---|---|---|---|
| 65 | 86 | 14.0 | 1,204 | 10,547 |
| 50 | 36 | 12.0 | 432 | 3,784 |
| 40 | 18 | 10.5 | 189 | 1,656 |
| 25 | 66 | 9 | 594 | 5,203 |
| **TOTAL** | **206** | **N/A** | **2,419** | **21,190** |

Table 18: Annual heat loss from lateral and riser pipework in the first block

As shown in Table 19 below, the heat network distribution losses within the block were estimated at 28%. These are high due to the significant amount of lateral distribution pipework supplying the flats on each storey. The CIBSE/ADE '*Heat Networks: Code of Practice for the UK'* suggests best practice design would avoid the use of any distribution pipework in corridors, use shared risers and hence have minimal branch lengths into dwellings.

| | Total Annual Heat Consumption (kWh) | Annual heat loss within block (kWh/a) | Total heat supplied into network within the block (kWh/a) | Annual heat loss within block (%) | Distribution loss factor within block |
|---|---|---|---|---|---|
| **Total** | 54,000 | 21,190 | 75,190 | 28.2 | 1.39 |

Table 19: Distribution losses within first block

**Heat loss from second block**

The main block contains 150 dwellings and varies in height with the highest element reaching 10 storeys. As shown in Table 20 below, the total heat consumption of the dwellings in the block is estimated at 450MWh per annum.

| Number of storeys | Number of flats per floor | Total number of flats | Annual Heat consumption (kWh / dwelling) | Total Annual Heat Consumption (kWh) |
|---|---|---|---|---|
| Up to 10 | Variable | 150 | 3,000 | 450,000 |

Table 20: Annual heat consumption of the flats in the second block

The main block contains 8 risers and the flats per storey vary from 8 at the lower levels to 4 on the top storey. In this case, lateral distribution pipework on each storey has been eliminated by passing the risers directly up through the apartments.

The riser pipework diameter installed in the block varies between 22mm and 50mm. The length of pipework, split according to pipe diameter, is contained in Table 21. The heat loss per metre of pipework rises from 8.5W/m up to 12.0W/m as the diameter increases. The standing heat loss from the pipework was estimated at 4.2kW, with annual heat loss of 36.9MWh.

| Pipe Diameter (mm) | Total length of pipe (m) | Heat loss per metre of pipe (W/m) | Total heat loss for pipe (W) | Annual heat loss from pipe (kWh) |
|---|---|---|---|---|
| 50 | 72 | 12.0 | 864 | 7,569 |
| 40 | 156 | 10.5 | 1,638 | 14,349 |
| 32 | 72 | 10.0 | 720 | 6,307 |
| 25 | 108 | 9.0 | 972 | 8,515 |
| 22 | 2 | 8.5 | 17 | 149 |
| **TOTAL** | **410** | **N/A** | **4,211** | **36,888** |

**Table 21: Annual heat loss from riser pipework in the second block**

The distribution losses were estimated at 7.6% of the heat supplied to the block's network as shown in Table 22 below. Accepting that additional pipework is still required to link the risers at basement level (see section 3.4 below), the efficient design of the distribution pipework has significantly reduced the percentage heat losses.

Section 3.9 of the new CIBSE/ADE *'Heat Network: Code of Practice for the UK'* –suggests that best practice would be to achieve a heat loss from the heat network within the building of less than 15% of the estimated annual heat consumption of the building. Hence, the 7.6% losses are significantly better than this suggested value.

| | Total Annual Heat Consumption (kWh) | Annual heat loss within block (kWh/a) | Total heat supplied into network within the | Annual heat loss within block (%) | Distribution loss factor within block |
|---|---|---|---|---|---|

| | | | block (kWh/a) | | |
|---|---|---|---|---|---|
| **Total** | 450,000 | 36,888 | 486,888 | 7.6 | 1.08 |

Table 22: Distribution losses within second block

**Heat loss from third block**

This block contains 38 flats and is 10 storeys in height with each floor usually containing 4 flats. The total heat consumption of the block is estimated to be 114,000kWh per annum as shown in Table 23 below.

| Number of storeys | Number of flats per floor | Total number of flats | Annual Heat consumption (kWh / dwelling) | Total Annual Heat Consumption (kWh) |
|---|---|---|---|---|
| 10 | 4 | 38 | 3,000 | 114,000 |

Table 23: Annual heat consumption of the flats in the third block

The block contains 4 sets of risers. As with the second block, the risers are passed through individual apartments, which eliminate lateral distribution pipework above the basement level.

The riser pipework diameter installed in the block varies between 25mm and 50mm. The length of pipework, split according to pipe diameter, is contained in Table 24 below. The heat loss per metre of pipe work rises from 9.0W/m up to 12.0W/m as the diameter of the pipe work increases. The standing heat loss from the pipework was estimated at 0.9kW, with annual heat loss of 8.2MWh.

| Pipe Diameter (mm) | Total length of pipe (m) | Heat loss per metre of pipe (W/m) | Total heat loss for pipe (W) | Annual heat loss from pipe (kWh) |
|---|---|---|---|---|
| 50 | 24 | 12.0 | 288 | 2,523 |
| 40 | 6 | 10.5 | 63 | 552 |
| 32 | 12 | 10.0 | 120 | 1,051 |

| | | | | |
|---|---|---|---|---|
| 25 | 52 | 9.0 | 468 | 4,100 |
| **TOTAL** | **94** | **N/A** | **939** | **8,226** |

Table 24: Breakdown of heat loss from distribution pipework within the third block

At 6.7% the distribution losses (see Table 25) within the block are similar to those within the main block (the second block). As with the second block, this reflects the efficient way that heat is distributed within the block where multiple risers are used in preference to fewer risers and lateral pipework.

| | Total Annual Heat Consumption (kWh) | Annual heat loss within block (kWh/a) | Total heat supplied into network within the block (kWh/a) | Annual heat loss within block (%) | Distribution loss factor within block |
|---|---|---|---|---|---|
| **Total** | 114,000 | 8,226 | 122,226 | 6.7 | 1.07 |

Table 25: Distribution losses with third block

**Heat loss from distribution in basement to the base of the cores**

The pipework in the risers is connected by lateral pipework in the basement. The first block is on the left hand side, the main block is located centrally and the last block is on the right hand side.

As shown in Table 26 below, the lateral distribution pipework in the basement varies in diameter from 65mm up to 300mm. In total, 484m of lateral pipework is installed, with over half the length occurring at two diameters, i.e. 100mm and 150mm. Due to larger diameter pipework, the unit losses are higher than within the individual blocks, e.g. 43.5W/m at 300mm. The standing heat loss from the pipework was estimated at 10.3kW, with annual heat loss of 90.7MWh.

| Pipe Diameter (mm) | Total length of pipe (m) | Heat loss per metre of pipe (W/m) | Total heat loss for pipe (W) | Annual heat loss from pipe (kWh) |
|---|---|---|---|---|
| 300 | 1 | 43.5 | 44 | 381 |
| 150 | 183 | 25.0 | 4,575 | 40,077 |
| 125 | 80 | 22.0 | 1,760 | 15,418 |
| 100 | 180 | 19.0 | 3,420 | 29,959 |
| 65 | 40 | 14.0 | 560 | 4,906 |
| **TOTAL** | **484** | **N/A** | **10,359** | **90,740** |

Table 26: Heat loss from lateral distribution pipework at basement level

**Heat loss from whole distribution system**

The heat loss from the lateral pipework in the basement accounted for just over half (58%) of the total distribution losses, with the pipework in the blocks accounting for the remainder.

As shown in Table 27 below, the cumulative heat loss from the whole network amounted to 20% of the heat supplied into the network, resulting in a distribution loss factor of 1.25. Although this figure only includes calculated losses due to the pipework and does not include any in-use corrections (e.g. for installation quality), it is significantly above the default in Table 12c of SAP2012.

| | Total Annual Heat Consumption (kWh) | Annual heat loss (kWh/a) | Total heat supplied into network (kWh/a) | Annual heat loss (%) | Distribution loss factor within |
|---|---|---|---|---|---|
| Total (whole) | 618,000 | 157,044 | 775,044 | 20.3 | 1.25 |

Table 27: Distribution loss factor for the whole system

# APPENDIX D: Calculated heat loss example for low temperature network

The following information is drawn from the same as-built example shown in Appendix C, but instead assumes a “low temperature design”.

As with the Appendix C example, the calculated estimates do not take account of additional losses, e.g. flanges. Neither do the estimates take into account factors which may cause additional heat loss from poor installation.

The following assumptions have been made:

- Lambda value of 0.040 W/mK
- Minimum insulation thickness of 50mm
- Flow temperature of 70˚C
- Return temperature of 40˚C
- Average external temperature of 15˚C

As shown in Table 28 below, the cumulative heat loss from the whole low temperature network amounted to 16.9%, resulting in a distribution loss factor of 1.20. While these theoretical figures are lower than for the conventional temperature network, they are still significantly higher than the distribution loss factor for new networks in Table 12c of SAP2012.

| | **Total heat supplied into network (kWh/a)** | **Annual heat loss (kWh/a)** | **Annual heat loss (%)** | **Distribution loss factor** |
|---|---|---|---|---|
| Total (whole) | 743,636 | 125,636 | 16.9 | 1.20 |

**Table 28: Distribution loss factor for the whole system**

## APPENDIX E: In-use factors

The PCDB allows for heat network performance data to be entered; however, when such data is derived from theoretical design values an in-use factor is applied. This PCDB data record will remain valid for a period of two years. After this time it will revert to the appropriate default DLF or preferably a DLF based on actual metered data.

Using the DLFs from the above actual example cases would suggest an in-use factor of 1.6 (i.e. 2.0 / 1.25) could be applied to the calculated DLF. However, the cases described above may represent some of the worst performing new networks and this might not be representative.

Therefore, taking into account the above, using the value of the 1st quartile DLF (1.5) may more accurately reflect the actual in-use performance that may be expected over time as design and commissioning practices improve. Using this figure would give an in-use factor which could be applied to the calculated DLF of 1.2, i.e. 1.5/1.25.

Since the default DLF for heat networks designed and commissioned in accordance with the CIBSE/ADE *'Heat Network: Code of Practice for the UK'* is 1.5 and giving consideration to the likely positive performance impact through reporting design performance via the PCDB, an in-use factor of 1.15 was selected.

The in-use factor is applied irrespective of compliance with the CIBSE/ADE *'Heat Network: Code of Practice for the UK'*.

# APPENDIX F: Revised default DLF values for existing dwellings

BRE reviewed available data from the English Housing Survey (EHS) and observed that 88% of English housing connected to communal heat networks were purpose built flats[13]. Therefore, due to the variability of other dwelling type samples, purpose built flats were exclusively selected as the dwelling type for this analysis. Figure 3 displays the space and hot water consumption (as calculated under SAP assumptions) for a large EHS sample that was weighted to represent the entire English housing stock, but irrespective of whether connected to a heat network. A trend-line was devised to characterise the relationship between space and hot water consumption Vs. dwelling age.

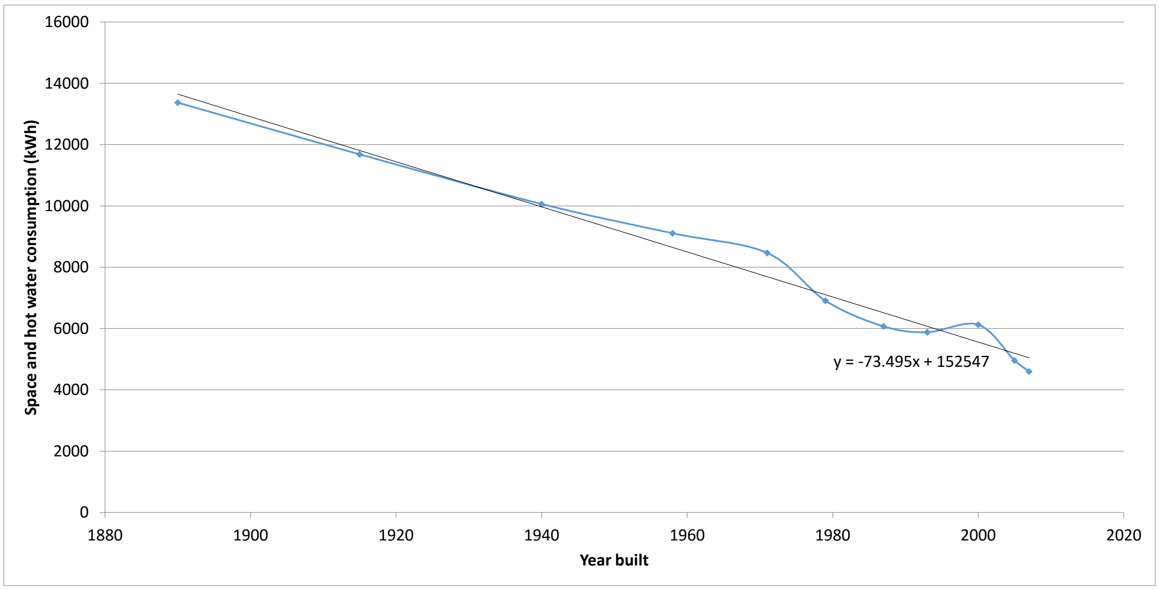


**Figure 4 – Space & hot water load for purpose built flat vs Year built**

Figure 5 displays the modelling results from the BRE Information Paper: '*IP 3/11 – The Performance of District Heating in New Developments*' to show the relationship between the DLF and linear heat density for a pre-insulated single-pipe heat network[14]. These values were determined for three heat network layout designs using TERMIS software.

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[13] English housing is considered representative of all UK housing for the purpose of this analysis.

[14] It is recognised that heat networks connected to older dwellings may not be pre-insulated or pre-insulated to a poorer standard. This was ignored for the purpose of this analysis.

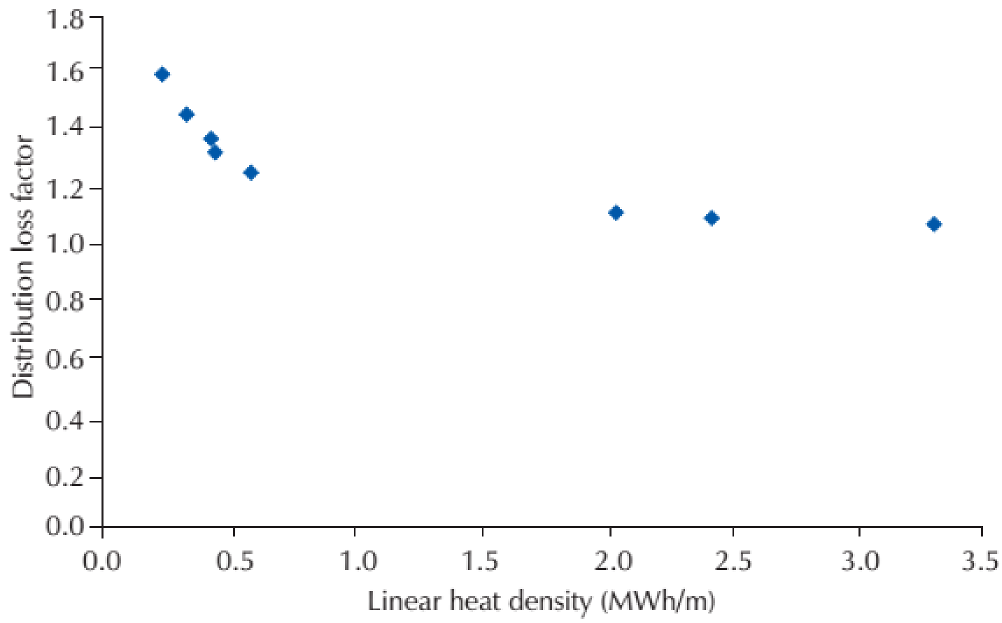


**Figure 5 – Distribution loss factor for a pre-insulated single-pipe district heating network[15]**

Extracting and approximating the range of apparent DLF values from Figure 5, which is not specific to dwelling type, a range of 1.1 to 1.6 is apparent, which supports much of the findings and analysis within this document. Given this analysis, a range of 1.2[16] to 1.5[17] was selected for inferring the change in DLF with age of dwelling (all types), and associated heat load, using the relationship (gradient) displayed in Figure 4. The results are displayed in Figure 6 and are used as the basis for the proposed SAP 2016 Table 12c – see Table 2.

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[15] *'Figure A1: Distribution loss factor for a pre-insulation single-pipe district heating network',* © IHS, reproduced with permission from BRE IP 3/11

[16] Equals current assumption in SAP 2012 Table 12c for *"Mains piping system installed in 1990 or earlier, not pre-insulated medium or high temperature distribution (120-140ºC), full flow system"*

[17] See Appendix B of this document

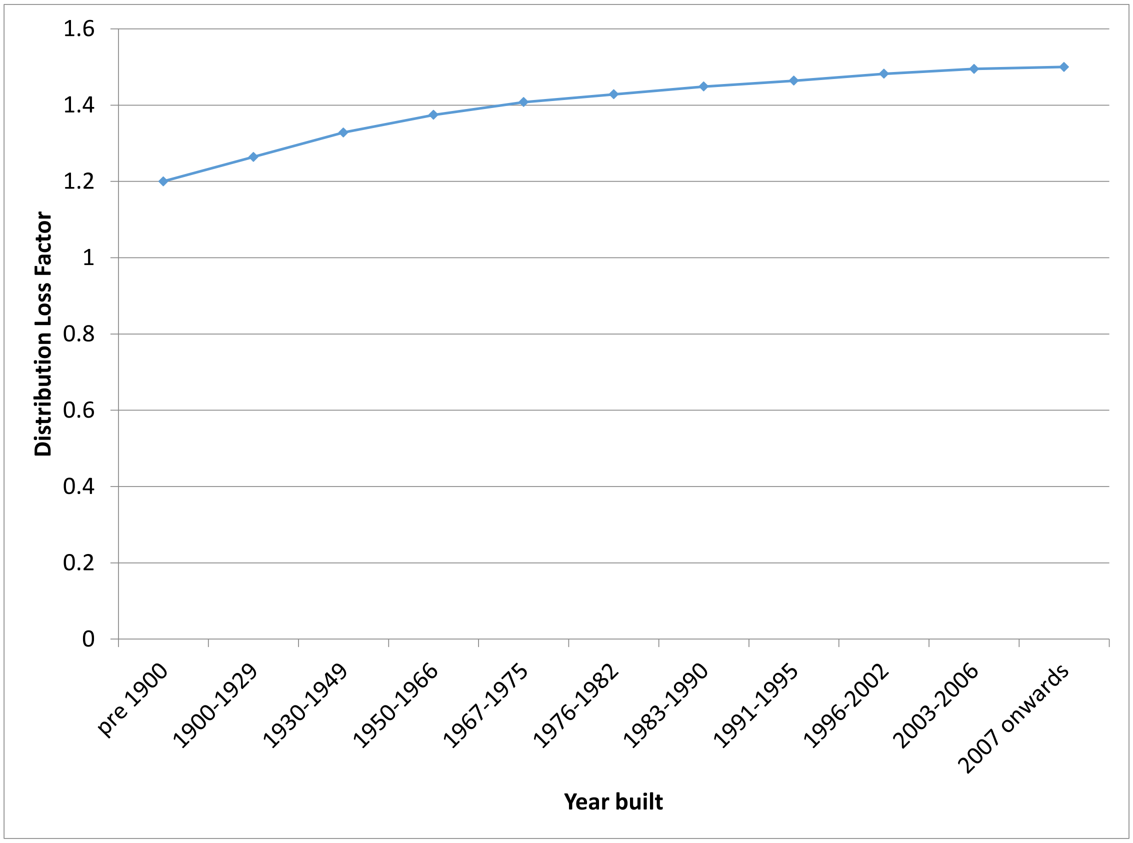


**Figure 6 – Distribution Loss Factor Vs Year dwelling built (SAP year class)**