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HEAT LOSSES IN COLLECTIVE HEAT DISTRIBUTION SYSTEMS: AN IMPROVED METHOD FOR EPBD CALCULATIONS

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ABSTRACT

Heat losses in collective heat distribution systems can be reduced significantly in well-insulated and well controlled low-temperature networks. However, this reduction is not always rewarded for in legislative energy performance of building standards in Europe, since the applied simplified calculation methods can overestimate the distribution heat losses significantly, especially in those systems that distribute heat for both space heating and domestic hot water generation. Therefore in this paper, a general approach for the development of more accurate simplified heat loss calculation methods is proposed in the context of the EPBD-legislation. The approach is applied for the development of simplified calculation methods for a specific type of collective heat distribution system design and evaluated by comparison to dynamic simulation results for a case-study. The results demonstrate that using the proposed approach, it is possible to make good estimations of the yearly and monthly distribution heat losses in the system, by using a limited amount of input data from the EPBD calculations and design data from the network, thus avoiding the need for detailed dynamic simulations or in situ measurements.

INTRODUCTION

In the current evolution towards renewable energy supply in buildings, collective heat distribution systems (CHDS) are a promising solution for the distribution of renewable heat from a central generation plant to the heat consumers. The more so as distribution heat losses can be reduced significantly in well insulated and well controlled low-temperature networks. However, this reduction is not always rewarded for in the simplified heat loss calculation methods of the Energy Performance of Building Directive (EPBD) implementations in Europe, for example in Belgium, thus preventing the application possibilities of collective heat distribution systems and district heating.

In a previous study, simplified heat loss calculation methods (SCM) were compared to dynamic simulations (DSM) of a collective heat distribution system providing heat for both space heating (SH) and domestic hot water (DHW) production. Results showed that the simplified calculation methods largely overestimate the heat losses and possibilities to reduce this gap were explored [1]. The purpose of this study is to develop an improved simplified heat loss calculation method for a specific type of substation and network control, with no need for input data from dynamic simulations or measurements, using an approach that suits the EPBD calculations and, more specifically, is applicable to the Belgian EPBD calculation method.

The paper starts with an introduction to heat loss calculation methods in the context of the EPBD and the conclusions and perspectives from the previous study. Then the methodology of this study is explained: a dynamic simulation model of a collective heat distribution network, substations, a control system and EPBD-based energy demand profiles was developed and calibrated with lab test results of the substation. The heat losses in the system were also calculated using the Belgian EPBD heat loss calculation method. Finally, the dynamic simulation results are used to investigate improvements to the simplified calculation method.

STATE OF THE ART

In calculations of the energy performance of buildings in Europe according to the EPBD, the heat losses in collective heat distribution systems are usually incorporated. If the energy performance is calculated per month, the calculation of heat losses in the distribution network is based on the general formula:

$$Q_{loss,net,m} = t_{net,m} \times \sum_j \left(\theta_{net,m} - \theta_{amb,j,m}\right) \times \left(\frac{l_j}{R_{l,j}}\right) \; [MJ] \quad (1)$$

in which $t_{net,m}$ is the monthly operation time of the distribution network, $\theta_{net,m}$ is the monthly average temperature of the heat conducting medium in the network, l_j is the length of a pipe element *j*, $R_{l,j}$ is the linear thermal resistance of this pipe element and $\theta_{amb,,j,m}$ is the average temperature of the pipe environment. The parameters in the general equation (1) are defined according to the local legislative EPBD-implementations and standards and to the type of system. Dependent on the final use of the heat, three types of CHDS are recognised: systems that serve heat for space heating only, for domestic hot water only and for combined space heating and domestic hot water production. In this last type of systems, the collective heat is used to generate domestic hot water in the local substations.

In a previous study, the simplified heat loss calculation methods used in the Flemish (Belgian), Dutch and

European standards were reviewed [1-6]. It was found that the few available SCMs for combined SH and DHW production are not well adapted to the specificities and the design of this type of systems. Therefore the Flemish SCM was compared to the dynamic simulation results of a low-temperature CHDSs for both SH and DHW with different types of substations and network control strategies. It was found that the SCM largely overestimates the heat losses. This is mainly caused by an overestimation of the average temperature of the heat conducting medium in the distribution network, which is minimum 60°C and actually reflects the typical operation of a domestic hot water circulation loop. Secondly, the seasonal variation in heat losses was poorly approached by the SCM, because of the estimation of the average temperature of the heat conducting medium in the network and the assumption of a continuous operation of the system. These parameters are influenced by the control strategies (e.g. intermittent operation) and substation properties. An investigation of improvements to the SCM for the various types of the system led to the conclusion that simplified heat loss calculation methods can be significantly improved when the estimation of two influential parameters, that is the average temperature of the heat conducting medium and the working time of the system, reflects the actual design and operation of the systems. However, in the previous study dynamic simulations or measurements were needed to estimate these influential parameters. The aim of the current study is to compose more accurate EPBD based SCM while avoiding the need for input data from simulations or measurements. And in contrast to the previous study, where various types of substations and network controls were investigated, in this study a method is developed for one specific substation control type.

METHODOLOGY AND SIMULATIONS

The subject of this study is a small-scale collective heating system, providing heat for both space heating and domestic hot water in a multi-family building with 25 apartments (Fig. 1). This system contains the essential parts of a district heating system: central heat generation, a collective heat distribution network, 25 dwelling substations and energy demand functions for SH and DHW. The transient system simulation tool TRNSYS is used to make a dynamic simulation model of this system. The Flemish EPBD-calculations are the starting point for the simplified calculations [2, 3].

The design of the collective heat distribution system and the development of a dynamic simulation model are extensively explained in [7].

Energy demand

Since the goal is to evaluate the distribution heat losses according to SCMs and DSM, the energy demand of the buildings according to both simulations are to be similar. Starting from the heat demand calculations in the Flemish calculation software, a case-study building was designed with three types of apartments with different thermal performance. The building is a low-energy building, with net energy demand for space heating of the apartments between 15 and 30 kWh/m²/year. The domestic hot water demands are between 2,5 and 4 kWh/day per apartment. For the purpose of the dynamic simulations, SH and DHW profiles were designed with 30 sec. time steps. The space heating design temperature regime is 60/40°C and the domestic hot water regime is 60/10°C.

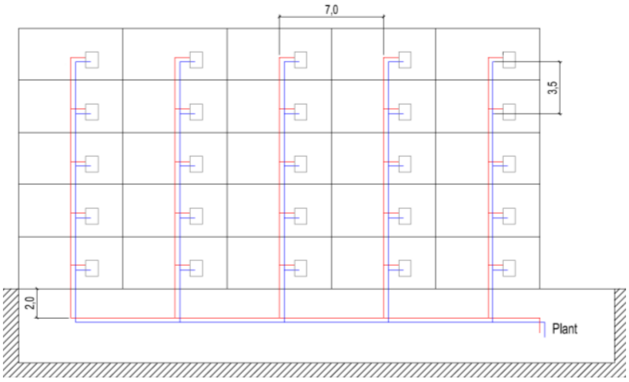

Fig. 1: Building and distribution network scheme

Substations

The case-study substation is equipped with a heat exchanger for transferring heat from the network to the domestic hot water, while the individual space heating systems are supplied with heat from the collective network. The return pipe of the space heating has a bypass which allows to regulate the flow rate in function of the required heat demand and supply temperature.

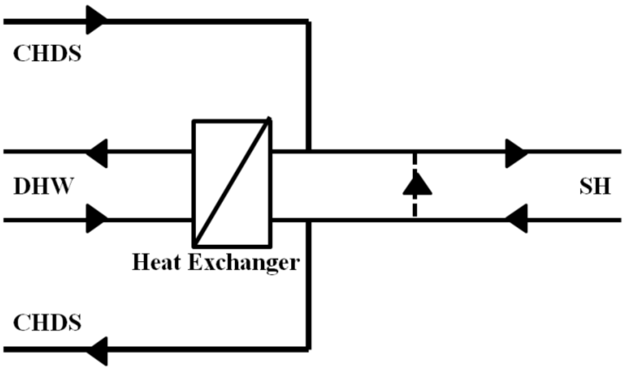

Fig. 2: Substation scheme [8]

The hot water temperature is controlled by a self-sensing temperature regulator that is embedded in the plate heat exchanger. This patented system gives a constant hot water temperature and a low return temperature to the district heating irrespective of volume and pressure flow [8]. In addition this control activates a minimum flow rate, "*idle flow*", through the heat exchanger in order to prevent it from cooling down and to keep it ready for DHW production during periods without demand. As a result, the recirculation of the primary heating medium through the collective heating network is controlled by the substation operation, dependent on the heat demand, the moment of the day or the season of the year. Fig. 3 presents the simulated return temperatures from the substation to the network per operation mode in January. During heat demand, the return temperature in the network is dependent on the space heating regime return temperature, which is on average 40°C, and the DHW return temperature of ca. 22°C. When there is no heat demand, the return temperature will stabilise around 42°C.

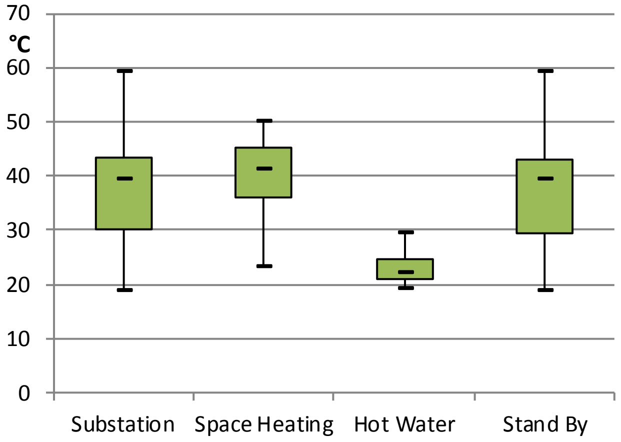

Fig. 3: Substation return temperatures

Distribution network

The collective heating system is a low-temperature system with fixed central supply temperature of 61°C. The distribution network consists of supply and return pipes, measuring 145m each (Fig. 1). There are no by-passes in the network and the central pump is a variable pump which can deliver very low flows. As a result the flow is driven by the substation control only. The internal pipe diameters are between 22 and 42 mm and the linear heat resistance is on average 8,5 mK/W. Heat losses through special and irregular elements (bearing structures, flanges, fittings…) are not considered in this study.

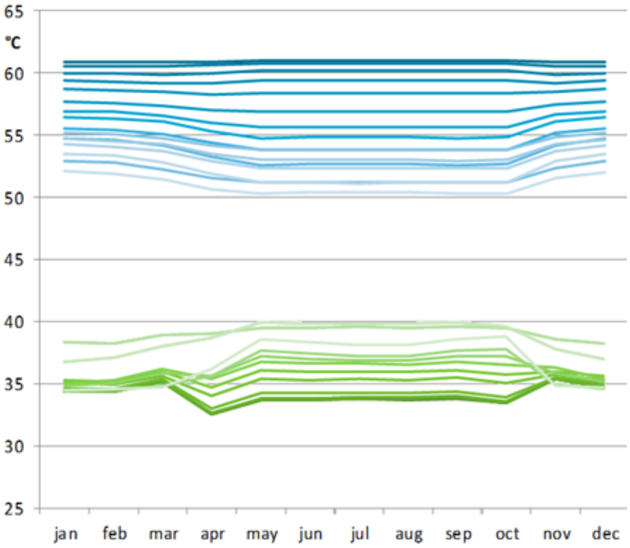

Fig. 4: Temperatures in the supply and return pipes

Fig. 4 presents the temperatures in the supply *(blue)* and return *(green)* pipes of the network, from the central main pipes *(dark)* to the substation connections *(light)* as a result of the dynamic simulations. The monthly average supply temperature in the network is clearly lower than the central heat supply temperature. This is a result of the cooling down of the network to min. 50°C at the substation connection during stand-by, when no flow or an extremely small flow appears.

The simulated heat losses of the network are illustrated in Fig. 5 *(DSM-Tot, DSM-Sup and DSM-Ret)*. The total heat losses of the network are about 32 GJ/year, or 8% of the total heat use in the collective heat distribution system. During summer, the heat losses are lower in absolute values, but relative to the heat use, they are higher (30%) than in winter (3%).

SIMPLIFIED CALCULATION METHOD SCM-0

First, the dynamic simulation results are compared to an existing simplified heat loss calculation method *SCM-0*, that is the Flemish/Belgian simplified calculation method for distribution heat losses in systems for combined space heating and domestic hot water production. The method starts from equation (1) and defines the monthly working time t_m of the system as the length of an entire month, and the average temperature of the heat conducting medium in the network is the maximum of 60°C and the monthly average temperatures in the space heating emission systems. In this case-study, the monthly average temperature in the space heating systems is 50°C, so $\theta_{net,m}$ is 60°C.

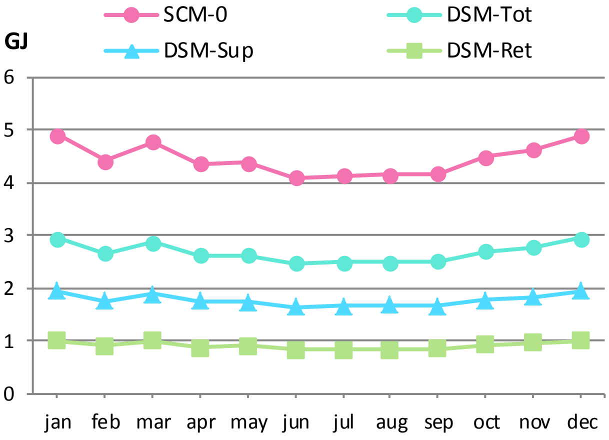

Fig. 5: Heat loss calculations: DSM and SCM-0

Fig. 5 illustrates the heat losses in the entire network according to SCM-0. In comparison to the simulated heat losses DSM-Tot, the heat losses are overestimated with about 50%. The main reason for this discrepancy is obviously the assumption of a continuous operation of the entire system at an average temperature of 60°C. This assumption actually reflects the behaviour of a typical DHW circulation loop, but is clearly quite different from the operation of the case-study system (see Fig. 4).

SCM+1

The development of an improved simplified calculation method starts with the subdivision of the monthly working time of the distribution system in three parts, according to three operational conditions of the substation that will influence the temperatures in the network: the time that the system delivers heat for space heating $t_{h,m}$, the time $t_{w,m}$ for domestic hot water generation and the time $t_{sb,m}$ that the system is in stand-by. For each part, a specific monthly average temperature of the heating medium in the network is calculated: $\theta_{combik,h,m}$, $\theta_{combik,w,m}$ and $\theta_{combik,sb,m}$. This method *SCM-1*, is expressed in equation (2):

$$Q_{loss,net,m} = t_{h,m} \times \sum_j \frac{l_j}{R_{l,j}} \times \left[\theta_{net,h,m} - \theta_{amb,\mathrm{j},m}\right] + t_{w,m} \times \sum_j \frac{l_{,j}}{R_{l,j}} \times \left[\theta_{net,w,m} - \theta_{amb,\mathrm{j},m}\right] + t_{sb,m} \times \sum_j \frac{l_j}{R_{l,j}} \times \left[\theta_{net,sb,m} - \theta_{amb,\mathrm{j},m}\right] \quad [in\ MJ] \tag{2}$$

Calculation of the working times

The working times for the three operation modes are estimated by use of information that is available in the EPBD calculation method, without the need for dynamic simulations or measurements. The three working times of the network are the average of the respective working times of each of the substations connected. First the working time per working mode is estimate for each individual substation or apartment.

The monthly working time for space heating of an apartment is based on the conventional monthly working time $t_{h,unit,m}$ of the heat emission system of the apartment unit that is connected to the substation, which is calculated according to the EPB calculation method. In case of a heat emission system with a constant supply temperature, equation (3) is applied:

$$t_{h,unit,m} = \frac{Q_{heat\,net,unit,m}}{[29 \times (H_{T,unit,m} + 0.27 \times V_{unit}) + 10 \times V_{unit}]} \quad [in\ Ms] \tag{3}$$

With $Q_{heat,net,unit,m}$ the monthly net energy demand for space heating in the dwelling unit (in MJ). V_{unit} is the volume of the unit (in m³) and $H_{T,unit,m}$ is the monthly average specific heat loss of the unit through transmission at design outdoor temperature (W/K).

For the estimation of the individual domestic hot water working times, a similar approach is used by estimating the conventional monthly working time for domestic hot water production. In contrast to the space heating case, this parameter is not available in the Flemish EPBD legislation. Therefore a formula is developed, based on available parameters:

$$t_{w,unit,m} = \frac{\sum_i Q_{water,bath,m}}{P_{water,bath,operation}} + \frac{\sum_i Q_{water,sink,m}}{P_{water,sink,operation}} [in\ Ms] \tag{4}$$

With $Q_{water,bath,m}$ and $Q_{water,sink,m}$ is the monthly energy demand for domestic hot water for baths (including showers) and sinks at the level of the substation (including secondary distribution heat losses). $P_{water,bath,operation}$ and $P_{water,sink,operation}$ are the average operational power (in W) at the secondary side for domestic hot water production for the use of baths/showers and sinks respectively. Fixed and standardised values for these parameters are estimated in this study with the aim of having realistic domestic hot water working times as a result (Fig. 6):

$$P_{water,bath,operation} = 10\ kW;\ P_{water,sink,operation} = 8\ kW$$

Finally, the individual stand-by period $t_{sb,unit,m}$ is the remaining time of the month when $t_{h,unit,m}$ and $t_{w,unit,m}$ are subtracted from t_m.

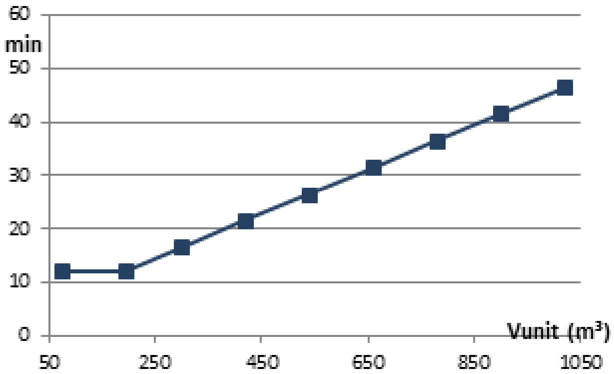

Fig. 6: Daily working time for domestic hot water

Calculation of the monthly average temperatures in the network

The monthly average temperature of the heating medium in the network for each operational mode is the average of the temperatures in the supply and return parts of the network, measured in the network at the substation connections for each working mode.

The monthly average supply temperature at the substation is equal for all working modes, since it is dependent on the design supply temperature:

$$\theta_{sup,net,h,m} = \theta_{sup,net,w,m} = \theta_{sup,net,sb,m} \tag{5}$$

Therefore, it is the maximum of all individual design supply temperatures for SH and DHW at the secondary side, assuming an efficiency of 100% of the heat exchange between primary and secondary circuits. For example in the case-study, the supply temperature is 60°C, the maximum of space heating design supply (60°C) and DHW design supply (also 60°C).

The monthly average return temperatures $\theta_{ret,net,h,m}$, $\theta_{ret,net,w,m}$ and $\theta_{ret,net,sb,m}$ result from a time-weighted average of the return temperatures for the respective functions in each of the *n* substations, for example:

$$\theta_{ret,net,h,m} = \frac{\sum_{unit=1}^{n} t_{h,unit,m} \times \theta_{ret,unit,h}}{\sum_{i=1}^{n} t_{h,unit,m}} \tag{6}$$

The return temperature for space heating of an individual unit is influenced by the operation of the substation, the space heating temperature regime and control and the primary supply temperature. For example, in the case study, it is 40°C.

The DHW temperature regime at the secondary side of the network is 60/10. Using data from the product information of the substation, the average return temperature at the substation assigned is 22°C [8].

The return temperature during stand-by is a characteristic of the network control, and in this case also of the substation. For example in a traditional substation with high flow recirculation, this temperature equals the supply temperature. Based on the product information and laboratory test results of the case-study substation, the average return temperature during stand-by is estimated for this specific substation. It is set to 42°C, independent of the primary supply temperature of the substation [8].

Results for SCM+1

The *SCM+1* method is now applied to the case-study collective heating system and compared to the dynamic simulation results. The working times and average supply and return temperatures are calculated starting from the design data of the substation (see Table 1).

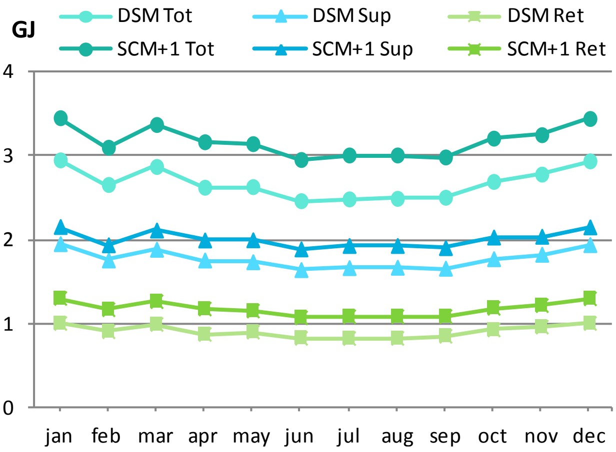

Fig. 7: Heat loss calculations: DSM and SCM+1

Using the *SCM+1* method, the estimation of the total heat losses in the system is 25% lower than in the original *SCM-0* method, but is still ca. 20% higher than the dynamic simulation results. In the supply pipes, the heat losses are overestimated with 13% on a yearly basis. The reason for this overestimation is that the yearly average supply temperature is lower than the design supply temperature of 60°C, as a result of the cooling down of the supply pipes during stand-by (see Fig. 4). The heat losses in the return part of the system are overestimated with 29%. This can be explained by the average return temperature during stand-by, which will decrease as a result of the cooling down of the network during stand-by periods shortly after a heat demand, when the heat exchanger is still warm and the idle flow is not yet activated.

As a conclusion, the proposed improvements lead to a better estimation of the heat losses, but a better estimation of the temperatures during stand-by time will probably lead to further improvements of the SCM.

SCM+2

In the *SCM+2* method, the general approach from *SCM+1* method is maintained, that is the splitting up of the monthly working time in three parts, as expressed in equation (2). The proposed adaptation is an improved estimation of the supply and return temperature at the substation during stand-by periods, $\theta_{sup,sb,m}$ and $\theta_{ret,unit,sb,m}$.

The behaviour of the substation during the stand-by period is one of the essential characteristics of the case-study substation [8]. After a heat demand for space heating or domestic hot water, the supply temperature at the heat exchanger will decrease from the substation design supply temperature $\theta_{sup,net,h,m}$ to a minimal temperature $\theta_{sup,min,sb}$ that is allowed to keep the heat exchanger hot. When this value is reached, an idle flow is activated and the temperature at the supply side is maintained in order to keep the heat exchanger hot. A simplified estimation of the average supply temperature of the substation during stand-by is therefore:

$$\theta_{sup,sb,m} = \frac{\theta_{sup,net,m} + \theta_{sup,min,sb}}{2} \qquad (7)$$

Likewise, at the primary district heating return pipe of the substation, the temperature after a heat demand will decrease starting from $\theta_{ret,h,i}$ or $\theta_{ret,w,i}$ (dependent on whether the previous demand was for space heating or domestic hot water). Then, when the heat exchanger has cooled down and the idle flow is activated, the return temperature of the idle flow goes to $\theta_{ret,sb,i} = 42°C$. The average temperature during stand-by can be estimated in a simplified way according to equation (8):

$$\theta_{ret,unit,sb,m} = \sum_n \frac{\frac{t_{h,unit,m} \times \theta_{ret,unit,h} + t_{w,unit,m} \times \theta_{ret,unit,w}}{t_{h,unit,m} + t_{w,unit,m}} + \theta_{ret,unit,sb}}{2} \qquad (8)$$

	Space Heating	DHW	Stand-by
SCM+1	$t_{h,unit,m} = \mathbf{2,5} \frac{h}{day}\ in\ jan$	$t_{w,unit,m} = \mathbf{0,5} \frac{h}{day}$	$t_{sb,unit,m} = \mathbf{21} \frac{h}{day}\ in\ jan$
	$\theta_{sup,unit,h} = \mathbf{60}\ °C$	$\theta_{sup,unit,w} = \mathbf{60}\ °C$	$\theta_{sup,unit,sb} = \mathbf{60}\ °C$
	$\theta_{ret,unit,h} = \mathbf{40}\ °C$	$\theta_{ret,unit,h} = \mathbf{22}\ °C$	$\theta_{ret,unit,sb} = \mathbf{42}\ °C$
SCM+2	$t_{h,unit,m} = \mathbf{2,5} \frac{h}{day}\ in\ jan$	$t_{w,unit,m} = \mathbf{0,5} \frac{h}{day}$	$t_{sb,unit,m} = \mathbf{21} \frac{h}{day}\ in\ jan$
	$\theta_{sup,unit,h} = \mathbf{60}\ °C$	$\theta_{sup,unit,w} = \mathbf{60}\ °C$	$\theta_{sup,unit,sb} = \mathbf{55}\ °C$
	$\theta_{ret,unit,h} = \mathbf{40}\ °C$	$\theta_{ret,unit,h} = \mathbf{22}\ °C$	$\theta_{ret,unit,sb} = \mathbf{39}°C\ in\ jan$

Table 1: Average working times and temperatures

Results for SCM+2

In Table 1 the working times and temperatures according to the *SCM+2* method are given. As a result of the estimation of the supply temperature during stand-by, the average temperature $\theta_{sup,net,m}$ at the supply side of the substation, decreases to around 55°C. This leads to a much better estimation of the heat losses (see Fig. 8). Also at the return part of the network, the estimation of the heat losses comes much closer to the DSM results, with over- and underestimations of about 20% during winter and summer respectively. When the heat losses are aggregated to yearly values, the supply, return and total heat losses equalise the DSM results.

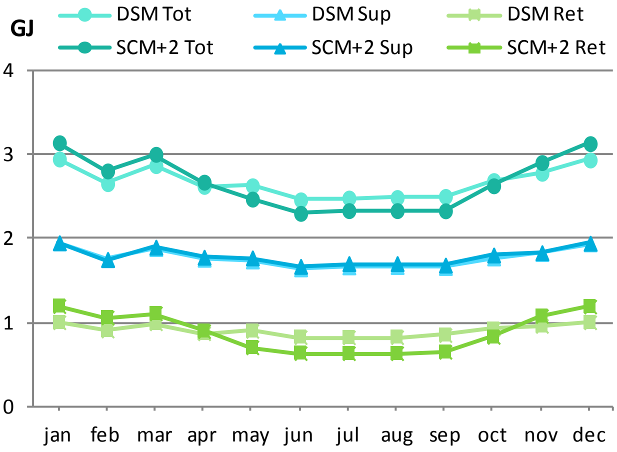

Fig. 8: Heat loss calculations: DSM and SCM+2

SCM+3

A third alternative *SCM* that is explored, starts from splitting the monthly working time in four parts, instead of three parts, through a portioning of the stand-by time $t_{sb,m}$ into a day time $t_{sb,day,m}$ and night time $t_{sb,night,m}$. The specific monthly average temperature of the heating medium in the network is now calculated for each of the four parts: $\theta_{combik,h,m}$, $\theta_{combik,w,m}$ and $\theta_{combik,sb,day,m}$ and $\theta_{combik,sb,night,m}$.

$$Q_{loss,net,m} = t_{h,m} \times \sum_j \frac{l_j}{R_{l,j}} \times \left[\theta_{net,h,m} - \theta_{amb,\mathrm{j},m}\right] + t_{w,m} \times \sum_j \frac{l_j}{R_{l,j}} \times \left[\theta_{net,w,m} - \theta_{amb,\mathrm{j},m}\right] + t_{sb,\mathrm{day},m} \times \sum_j \frac{l_j}{R_{l,j}} \times \left[\theta_{net,sb,day,m} - \theta_{amb,\mathrm{j},m}\right] + t_{sb,\mathrm{night},m} \times \sum_j \frac{l_j}{R_{l,j}} \times \left[\theta_{net,sb,night,m} - \theta_{amb,\mathrm{j},m}\right] \quad [in\ MJ] \tag{9}$$

Calculation of the stand-by parameters

The calculation method is based on the *SCM+1* and *SCM+2* methods, with the exception of the estimation of the stand-by working times $t_{sb,day,m}$ and $t_{sb,night,m}$, and the temperatures $\theta_{net,sb,day,m}$ and $\theta_{net,sb,night,m}$.

The subdivision of the stand-by time starts from the assumption that in a dwelling, and certainly in a dwelling with a low heat demand, there is a period of 8 hours per day (at night) with no heat demand. The individual working time for stand-by during the night $t_{sb,night,m}$ is therefore a period of 8 hours per day:

$$t_{sb,night,unit,m} = 0{,}3 \times t_m \tag{10}$$

Subsequently, the rest of the stand-by period takes place during the rest of the day:

$$t_{sb,day,unit,m} = t_{sb,unit,m} - t_{sb,night,unit,m} \tag{11}$$

Since no heat demand is assumed during night time, the average supply temperature to the substation goes to the minimal supply temperature that is maintained by the idle flow:

$$\theta_{sup,net,sb,night,m} = \theta_{sup,min,sb} = 50°C \tag{12}$$

Likewise, the return temperature goes to the return temperature during idle flow:

$$\theta_{ret,net,sb,night,m} = \theta_{ret,unit,sb} = 42°C \tag{13}$$

During daytime, heat demand and stand-by periods are alternated, so the stand-by is defined by cooling-down after a heat demand and idle flow recirculation, for both supply and return temperatures, the expressions (14) and (15) are similar to equations (7) and (8):

$$\theta_{sup,net,sb,day,m} = \frac{\theta_{sup,net,m} + \theta_{sup,min,sb}}{2} \tag{14}$$

and

$$\theta_{ret,net,sb,day,m} = \sum_i \frac{\frac{t_{h,unit,m} \times \theta_{ret,unit,h} + t_{w,unit,m} \times \theta_{ret,unit,w}}{t_{h,unit,m} + t_{w,unit,m}} + \theta_{ret,unit,sb}}{2} \tag{15}$$

Results for SCM+3

A comparison of *SCM+3* and DSM results (see Fig. 9) indicates that this method is a possible alternative to *SCM+2*. The supply heat losses are estimated slightly lower than in the previous method, and the return heat losses are estimated slightly higher, but on a yearly basis, the results equalise the results of the DSM. Moreover, this method gives a little better approximation of the seasonal behaviour in the return and total heat losses.

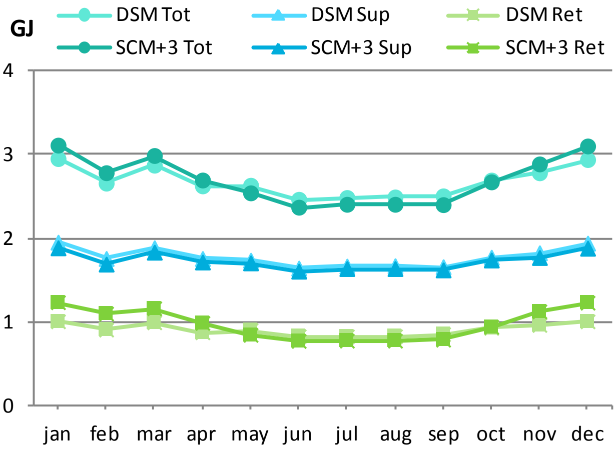

Fig. 9: Heat loss calculations: DSM and SCM+3

DISCUSSION

In this study, an improved method for calculation of the heat losses in collective heat distribution systems in the context of the EPBD legislation was investigated for a specific kind of substation and control. Three alternative methods were investigated and applied to a case-study low-temperature network connected to low-energy apartments. All of them showed improvements to the original method SCM-0, and especially method SCM-2 and SCM-3 seem promising. However, to find out which of these is the most robust method, the case-studies will need to be extended to buildings with different energy demand, heating system designs and network properties.

The main purpose for the development of simplified calculation methods is to avoid the need for detailed and time-consuming dynamic simulations or in situ measurements in order to enable a relatively quick and accurate estimation of the yearly energy performance with a reasonable amount of inputs. In this study, the methods were developed for compliance with the European Energy Performance of Building Directive, and more specifically the Flemish and Belgian legislative calculation methods in line with this Directive. This implies that when application in other building energy performance calculation methods is intended, small adaptations might be needed, dependent on the available parameters in these methods, for example those parameters that are related to the working time of the CHDS, the space heating and hot water systems. However this study demonstrates that a good estimation of the distribution heat losses is possible by use of simplified calculation methods and proposes a convenient calculation approach.

OUTLOOK

The future perspectives of this study include the evaluation of the three SCM's on a different case-study in the residential sector. In contrast to the present case-study, this would be a less-insulated and medium-temperature CHDS connected to dwellings with a higher energy demand. A second perspective is the validation of the DSM's and SCM's through comparison with measurements in a real life case-study: a low-temperature residential CHDS in the city of Kortrijk in Belgium [9].

CONCLUSIONS

In this paper, simplified calculation methods for estimation of the distribution heat losses in collective heat distribution systems in context of the EPBD-legislation were developed and compared to the dynamic simulation results of a case-study low-temperature CHDS. The paper demonstrates that it is possible to make accurate estimations of the yearly distribution heat losses in the system, and to approach the monthly and seasonal variation in heat losses quite well, by using a limited amount of input data from the EPBD calculations and design data from the network, thus avoiding the need for detailed dynamic simulations or in situ measurements.

A general approach for the development of SCM's for distribution heat losses was elaborated and evaluated. In this approach the operation of the CHDS is analysed in terms of the different operational conditions that appear as a result of the system design and their effects on the supply and return temperatures and the flow rates in the system. Therefore the general structure of a SCM is a decomposition of the working time of the CHDS into working times per operational mode, for example: the time that the system delivers heat for space heating, domestic hot water production or recirculation. Then for each of the working times of the system an average supply and return temperature is defined (see equations 2 and 9). This approach offers a manageable and effective framework for simplified distribution heat loss calculations and is flexible to a variety of CHDS designs. Dependent on the design and control of the CHDS, the operational modes and characteristics can be identified.

The general structure was applied to a specific type of CHDS technology, in which the circulation of the primary heating medium through the network is entirely controlled by the substation control and operation. Three simplified calculation methods were developed, only using parameters available in the local EPBD-calculation method and the information of the design and product information of the components in the system. The methods were evaluated by use of dynamic simulations of a case-study system. All of them were improvements to the original SCM in which the working times were not decomposed, and the second and third method did result in a very good estimation of the distribution heat losses.

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