2nd International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 27-28 September 2016

SENSITIVITY ANALYSIS OF HEAT LOSSES IN COLLECTIVE HEAT DISTRIBUTION SYSTEMS USING AN IMPROVED METHOD OF EPBD CALCULATIONS

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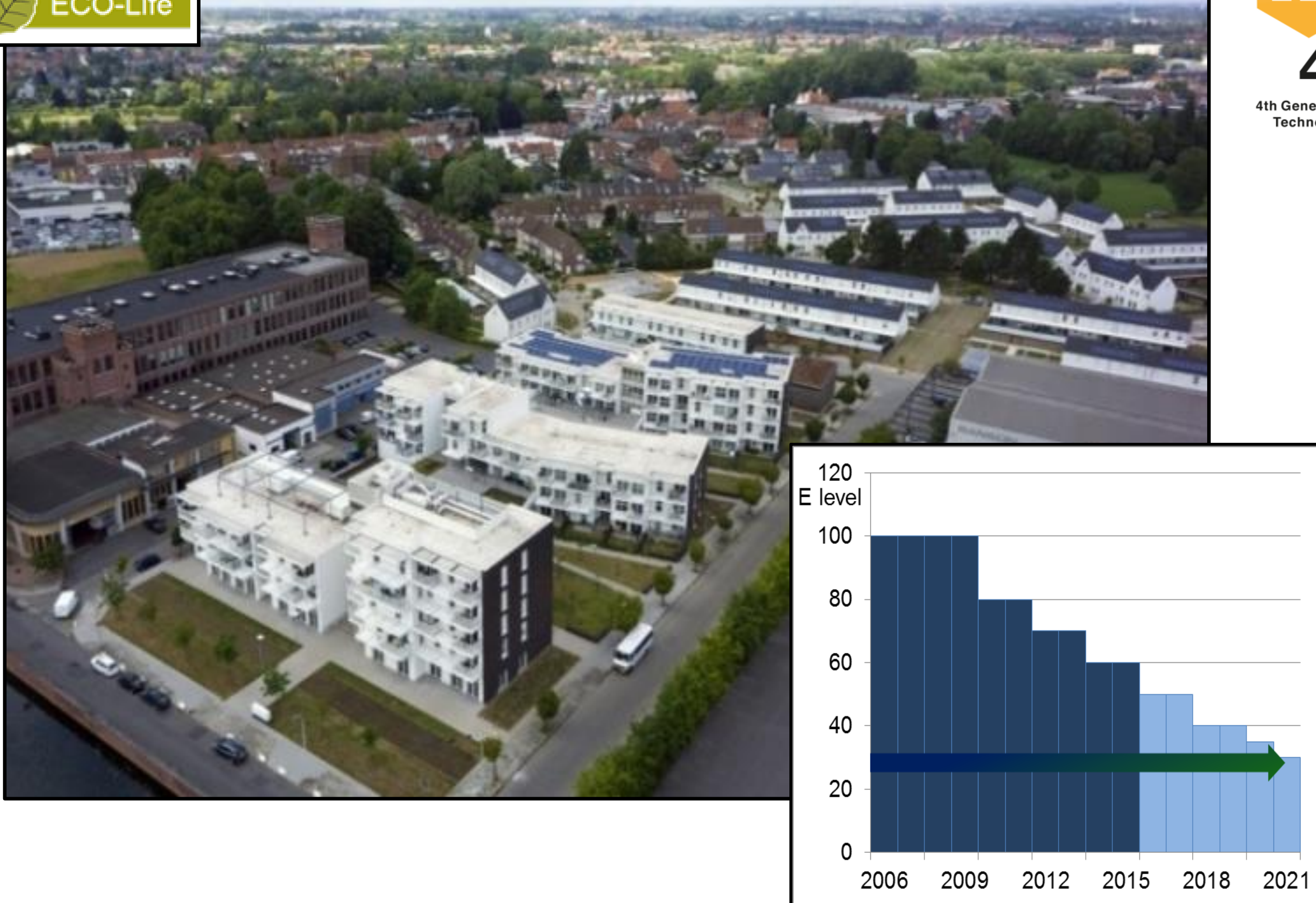
Collective Heating Systems: Effective Solution Towards Sustainability



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Collective Heating Systems: Effective Solution Towards Sustainability

- Heat Losses Calculation in Heat Distribution Systems: Simplified methods
- General approach for improved simplified calculation methods
- Sensitivity Analysis of Heat Losses in Heat Distribution System

Collective Heating Systems: Effective Solution Towards Sustainability

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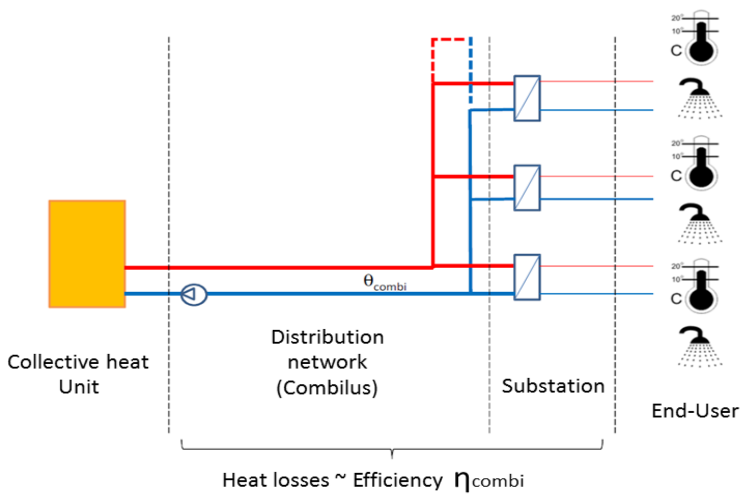
Simplified Heat Losses Calculation Methods

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

$$\eta = \frac{Q_{out,combi\ k,m}}{Q_{out,combi\ k,m} + Q_{loss,net\ m}}$$

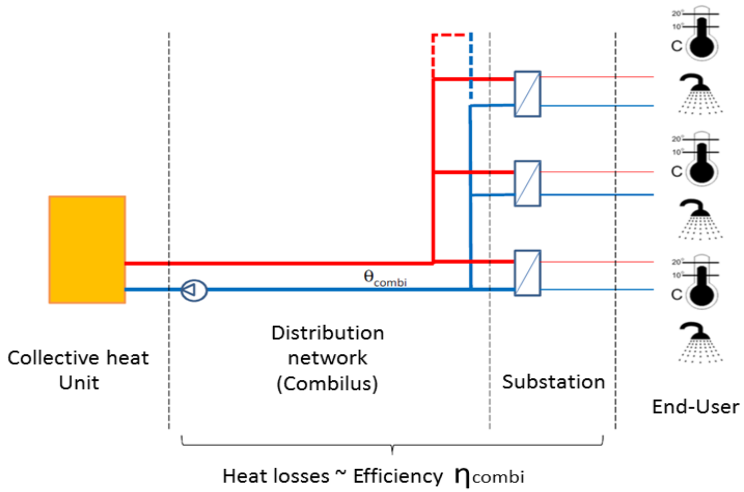


System type	t_{net}	θ_{net}	
Space Heating	~ design of the local space heating system		
Hot tapwater	Continuous	60°	~ hot tapwater circulation loop
Space heating + Domestic hot water	Continuous	≥ 60°	~ hot tapwater circulation loop

Simplified Heat Losses Calculation Methods

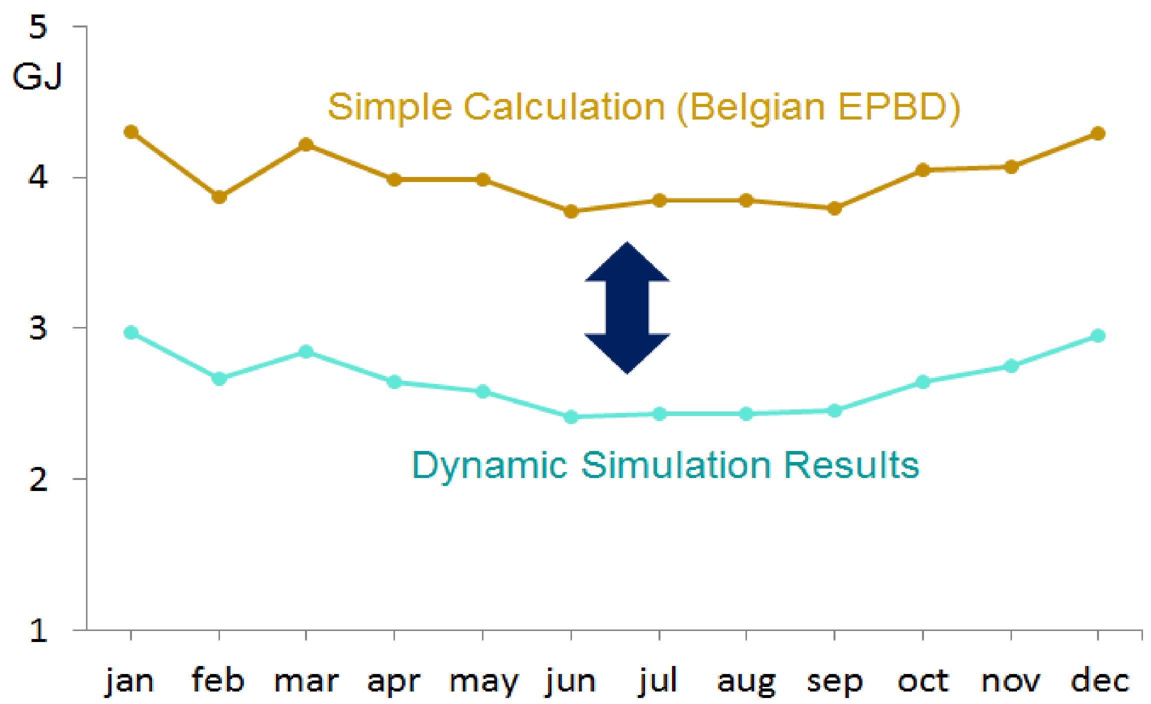
$$Q_{loss,net,m} = \underline{t_{net,m}} \times \sum_j \frac{l_j}{R_{l,j}} \times [\underline{\theta_{net,m}} - \theta_{amb,j,m}] \quad [MJ]$$

Parameters do not reflect design specifications and operation of systems with combined SH and DHW



- Overestimation of the average temperature of the heat conducting medium
- Seasonal variation in heat losses is poorly approached
- Assumption of a continuous operation of the system

Simplified Heat Losses Calculation Methods



In Collective heat distribution systems (CHDS) for low energy houses, existing EPBD implementations methods are not satisfactory, **preventing the application possibilities** of CHDS and district heating

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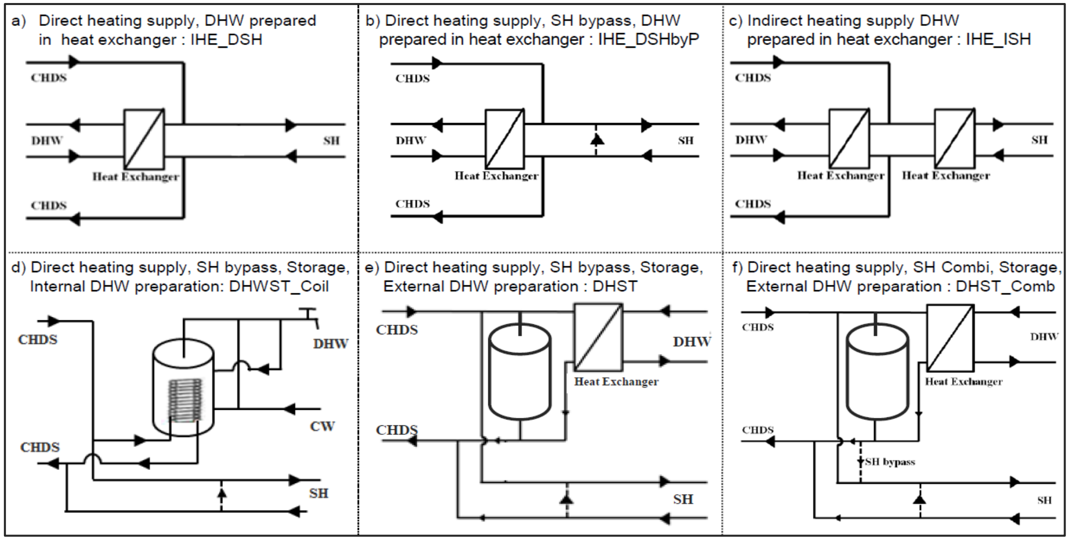
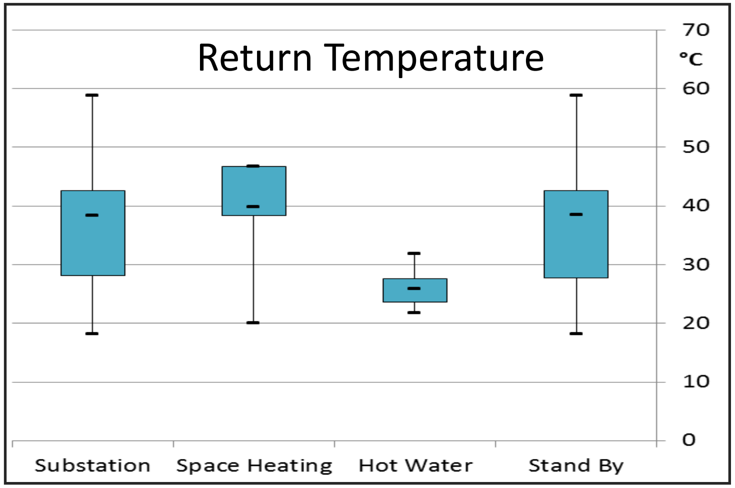
How to reflect operational conditions of CHDS with combined SH and DHW?



Different operation modes

=

Different types of energy use



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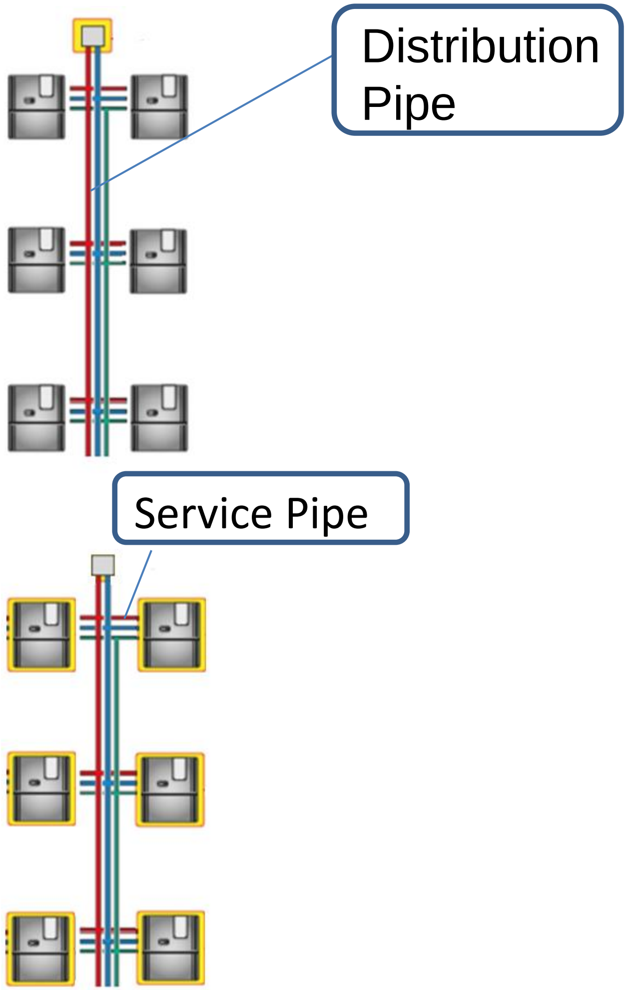

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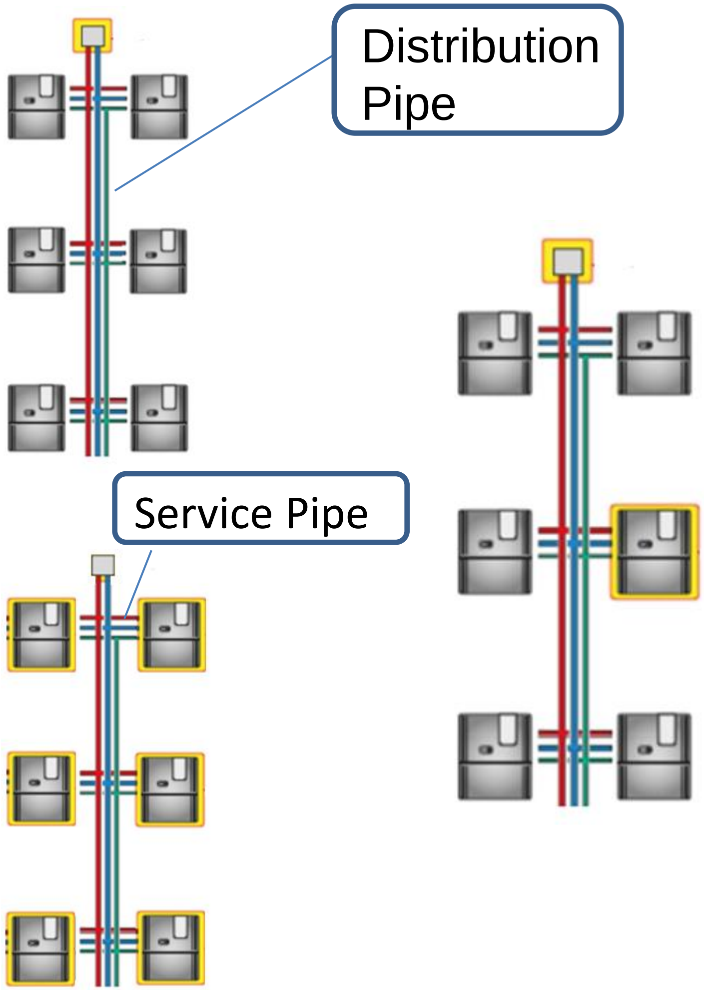
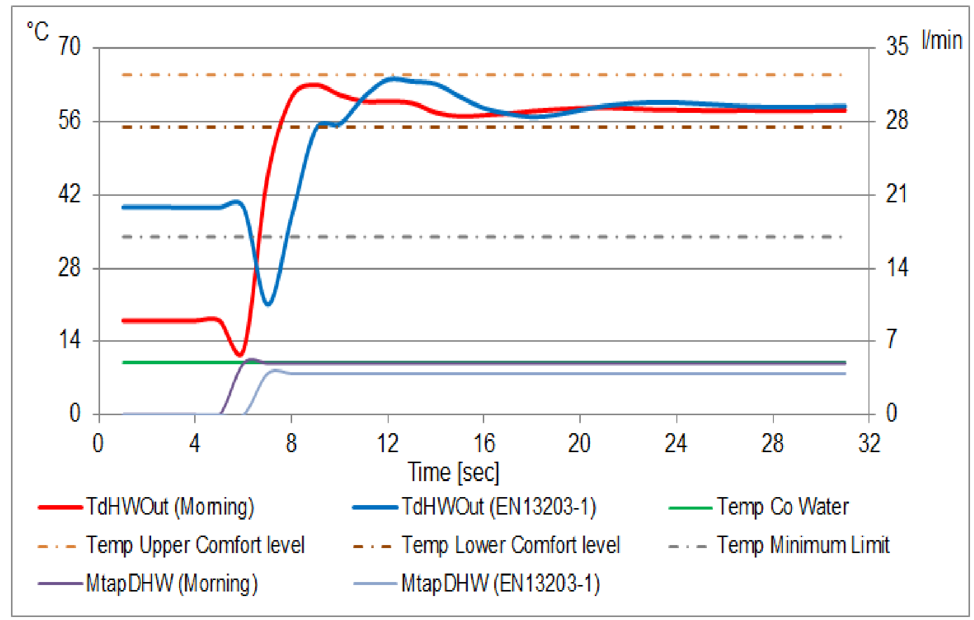


Domestic hot water comfort



- Waiting Time
- Wasting Water (Heat)

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How to reflect operational conditions of CHDS with combined SH and DHW?

- decomposition of the operation time into different 'operation modes', each having a suitable physical expression

- Cooled pipe cold water displaced by hot water at a time of domestic hot water demand due to substation cool down during standstill (Wasting water).

$$Q_{loss,net,m} = t_{net,m} \times \sum_{j} \frac{l_j}{R_{l,j}} \times \left[\theta_{net,m} - \theta_{amb,\mathrm{j},m}\right] \quad [MJ]$$

How to reflect operational conditions of CHDS with combined SH and DHW?

- decomposition of the operation time into different ‘operation modes’, each having a suitable physical expression

$$Q_{loss,combi\ k,m} = \underline{t_{heat,m}} \times \sum_j \frac{l_{combi\ k,j}}{R_{l,j}} \times [\underline{\theta_{combi\ k,heat,m}} - \theta_{amb,j,m}]$$

$$+\underline{t_{water,m}} \times \sum_j \frac{l_{combi\ k,j}}{R_{l,j}} \times [\underline{\theta_{combi\ k,water,m}} - \theta_{amb,j,m}]$$

$$+\underline{t_{standby,m}} \times \sum_j \frac{l_{combi\ k,j} - l_{tubing,combi\ k,j}}{R_{l,j}} \times [\underline{\theta_{combi\ k,standby,m}} - \theta_{amb,j,m}]$$

$$+Q_{loss,hx\ k,m} + Q_{loss,water,k,m} \qquad [in\ MJ]$$

How to reflect operational conditions of CHDS with combined SH and DHW?

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$$+Q_{loss,hx\ k,m} + \underline{Q_{loss,water,k,m}} \qquad [in\ MJ]$$

How to reflect operational conditions of CHDS with combined SH and DHW?

$$\eta = \frac{Q_{out,combi\ k,m}}{Q_{out,combi\ k,m} + Q_{loss,net\ m}}$$

$$f_{ctrl,combi\ k} = \frac{Q_{loss,combi\ k,m}}{Q_{loss,net\ m}}$$

$$\eta = \frac{Q_{out,combi\ k,m}}{Q_{out,combi\ k,m} + f_{ctrl,combi\ k} Q_{loss,net\ m}}$$

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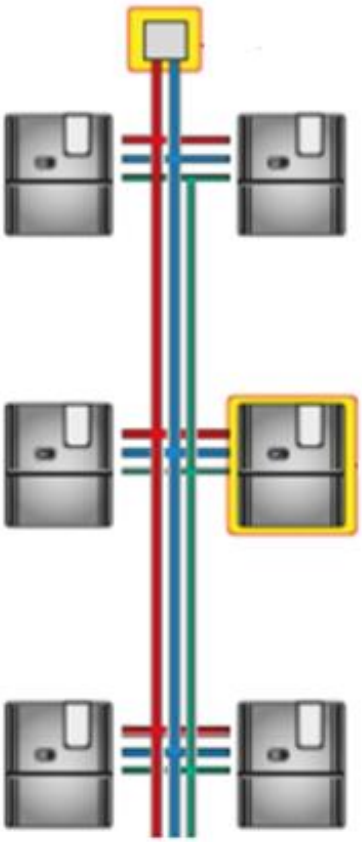
How to assess the impacts of some potential variations in the input variables, on the conclusions of the methodology?



Selected input parameters

- **Treturn_SHW** : Sanitary hot water return temperature
- **DgComb** : Degree of combination of substation
- **RatioHxc** : Ratio Heat Exchanger Parameters
- **RatioCtrl** : Ratio recirculation Control [% Pre-heating_On]
- **ServP_Lc** : Service pipe length

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Sensitivity Analysis and Factorial Design

Factorial Design

2^n { High level / Low level

Multilevel Factorial Design

I^k { Each ***k*** **factor** specific number of ***I*** **levels**

Sensitivity Analysis and Factorial Design

$$X_i = \frac{X_i - \frac{X_{iNInf} + X_{iNSup}}{2}}{X_{iNSup} - X_{iNInf}} = \frac{X_i - (\tilde{X}_i)}{X_{iNSup} - X_{iNInf}}, i = 1,2, \ldots, k$$

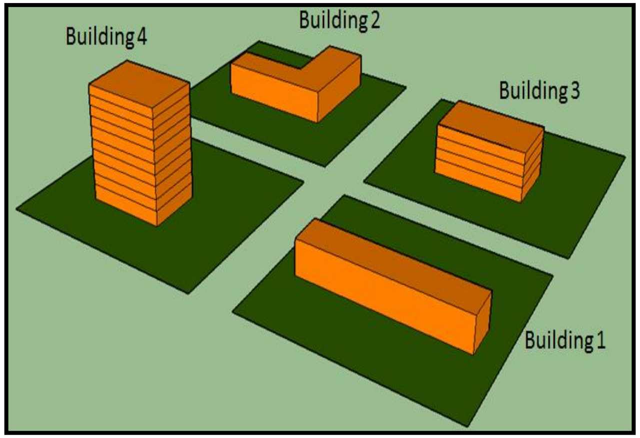
$$\hat{y}_i = b_0 + \sum_{l=1}^{k} b_l x_l + \sum_{l=1}^{k} \sum_{j=l+1}^{k} b_{lj} x_l x_j + \varepsilon$$

The **Standardized Regression Coefficients** provides a measure of the effect of the variation of an input on the variation of the output, while all other input parameters equalize their expected value.

Sensitivity Analysis and Factorial Design

Multilevel Factorial Design

I^k — Each ***k* factor** specific number of ***I* levels**

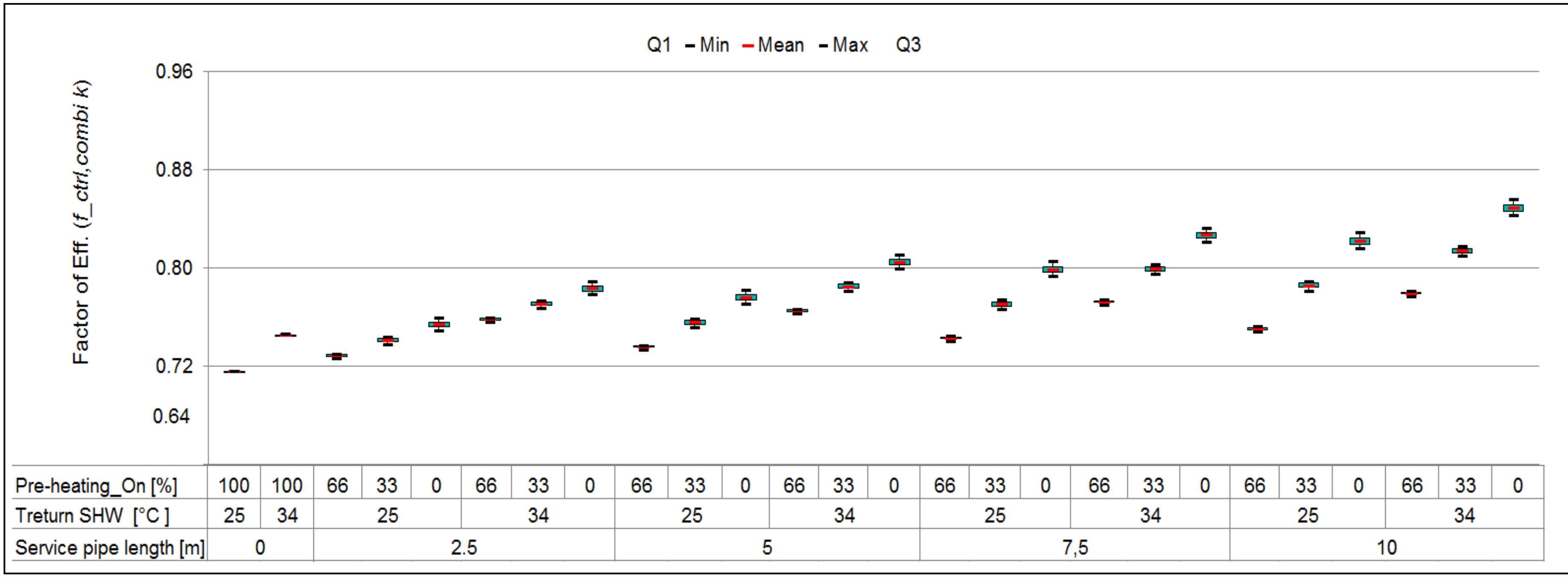


Parameter	Variable Name	Level					
		1	2	3	4	5	6
Sanitary Hot Water return temperature [°C]	Treturn_SHW	25	34	-	-	-	-
Degree of combination of substation (Yes /Not)	DgComb	Yes	Not	-	-	-	-
Ratio Heat Exchanger Parameters {Rhx} [%]	RatioHxc	100 Max	75 Max	50 Max	100 Midd	25 Max	0 Max
Ratio recirculation Control (Pre-heating_On) [%]	RatioCtrl	0	33	66	100	-	-
Service pipe length (individual per apartment) [m]	ServP_Lc	0	2,5	5	7,5	10	-

156 Combinations: SCENARIOS

Combilus Systems Sensitivity Results

Study Case Typology: Building 1 (13 Apartments)



26 Categories

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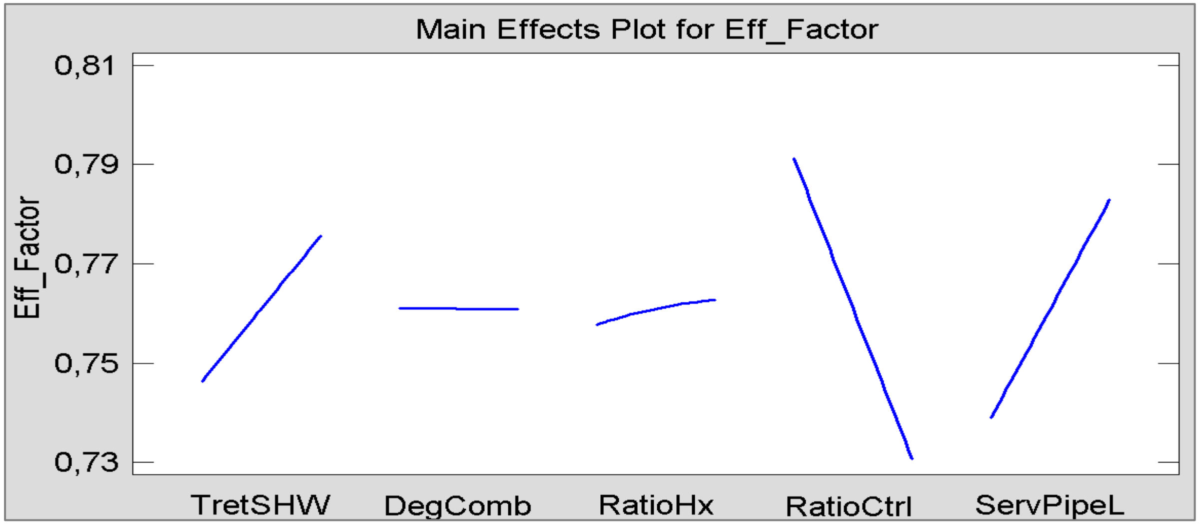
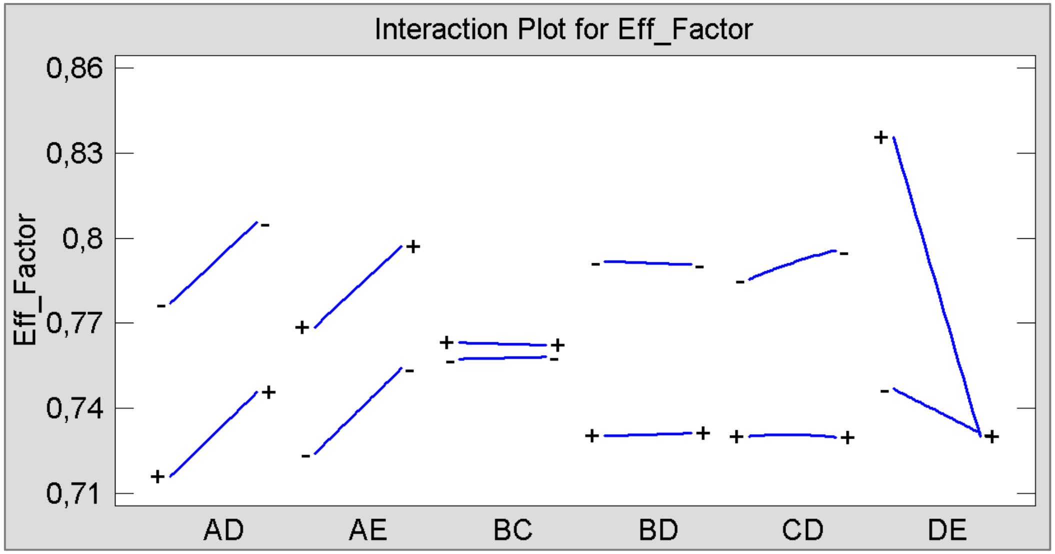
How to reduce the number of Categories?



A: Treturn_SHW
B: DgComb
C: RatioHxc
D: RatioCtrl
E: ServP_Lc



Combilus Systems Sensitivity Results

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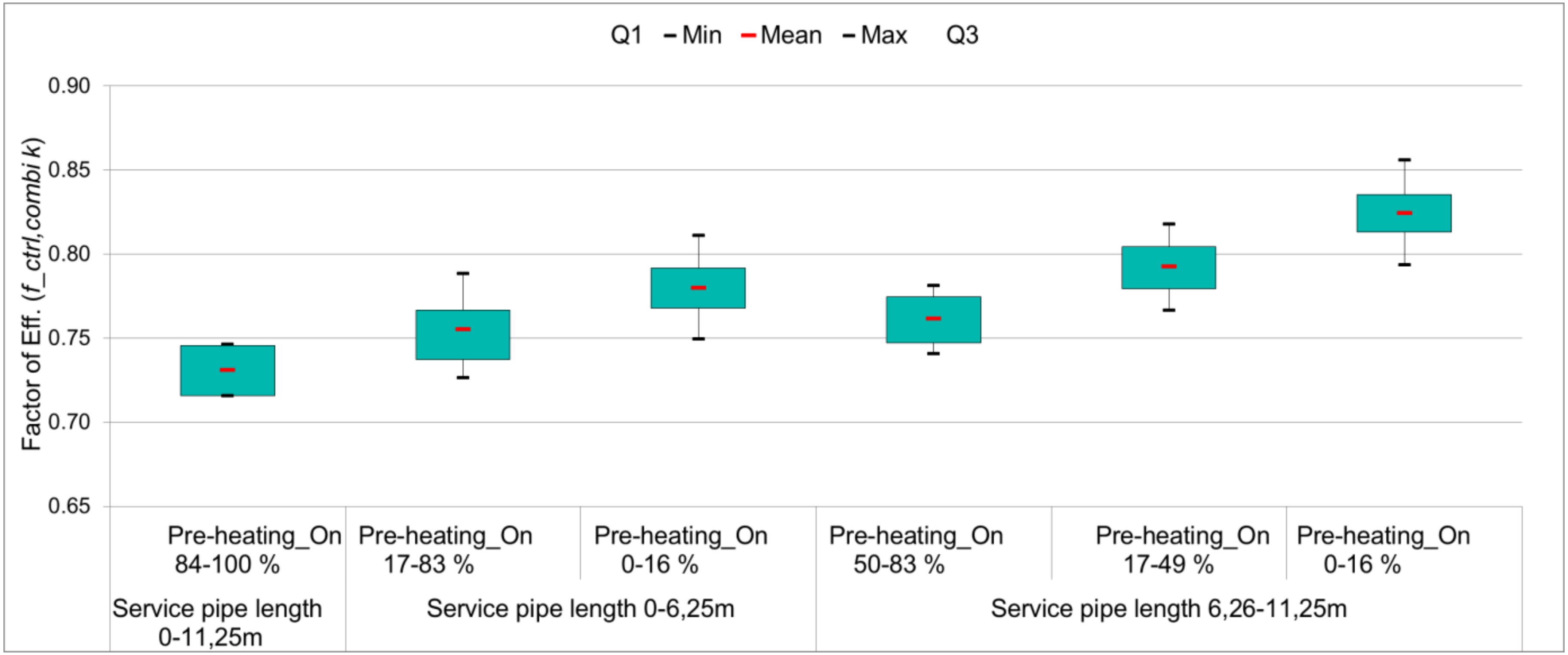
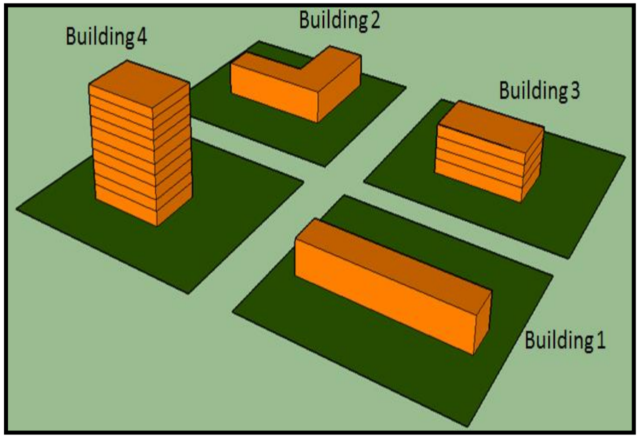
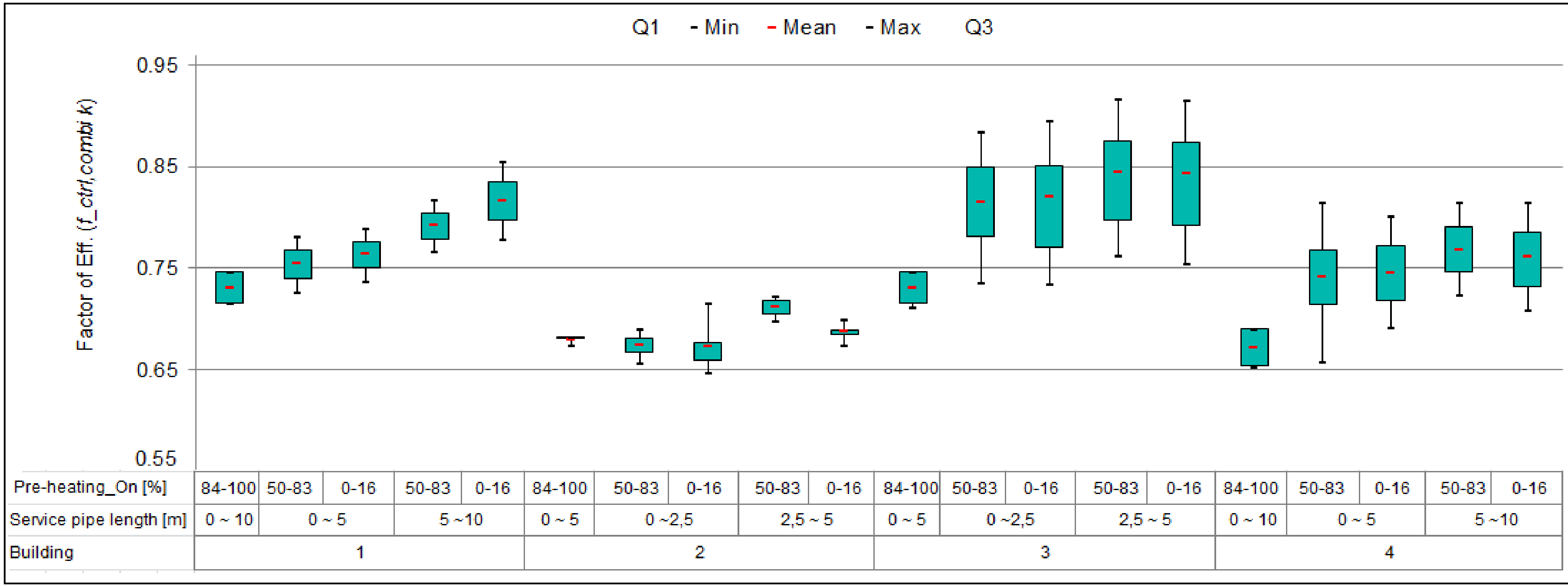


Influence of Building typology on the Sensitivity analysis results



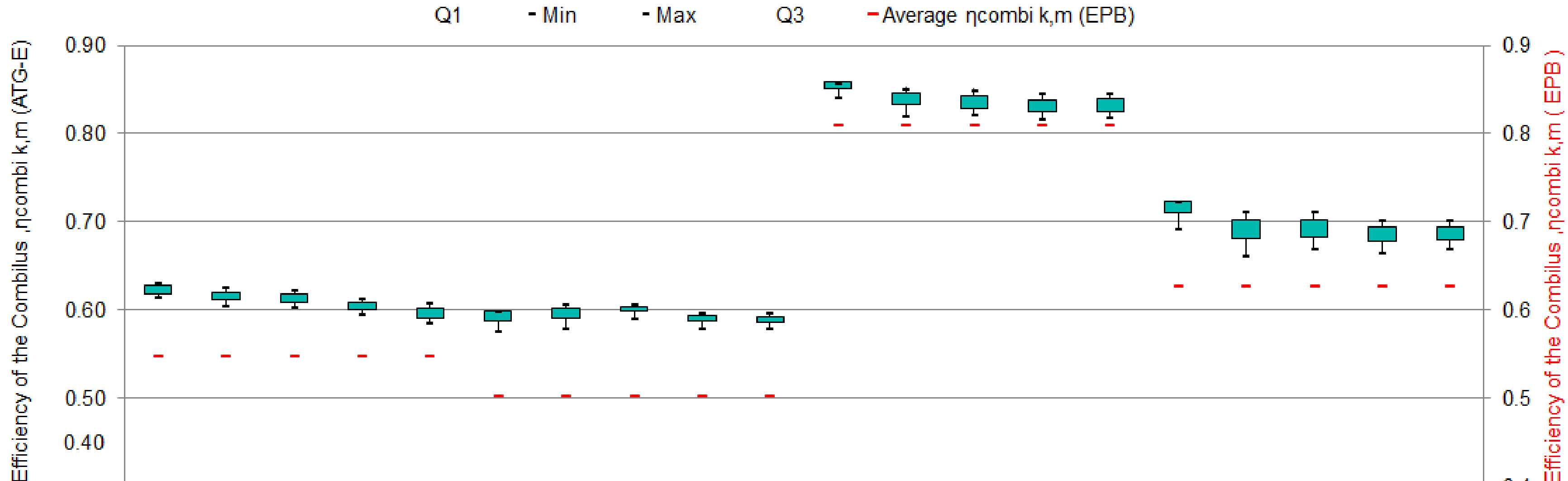
Combilus system indicator	Building 1	Building 2	Building 3	Building 4
Number of apartments	13	24	25	49
Average heat supplied by apartment (GJ/year)	16	8	16	6
Ratio of heat for space heating and DHW	2,8	1	2,2	0,9
Pipe length per apartment (m)	42	13	12	13
Average thermal resistance of the network (mK/W)	4,5	2,4	5,2	5,2

The Efficiency Corrector Factor is significantly Case Specific Sensitive



Combilus system indicator	Building 1	Building 2	Building 3	Building 4
Heat supplied by apartment (GJ/year)	16	8	16	6

The *Combilus Efficiency* results highlight the importance of an accurate determination of the *Corrector Factor*



Pre-heating_On [%]	84-100	50-83	0-16	50-83	0-16	84-100	50-83	0-16	50-83	0-16	84-100	50-83	0-16	50-83	0-16	84-100	50-83	0-16	50-83	0-16
Service pipe length [m]	0 ~ 10	0 ~ 5		5 ~10		0 ~ 5	0 ~2,5		2,5 ~ 5		0 ~ 5	0 ~2,5		2,5 ~ 5		0 ~ 10	0 ~ 5		5 ~10	
Building	1					2					3					4				

Cases 1 and 2 present the lowest *Combilus Efficiency* (Largest heat losses)

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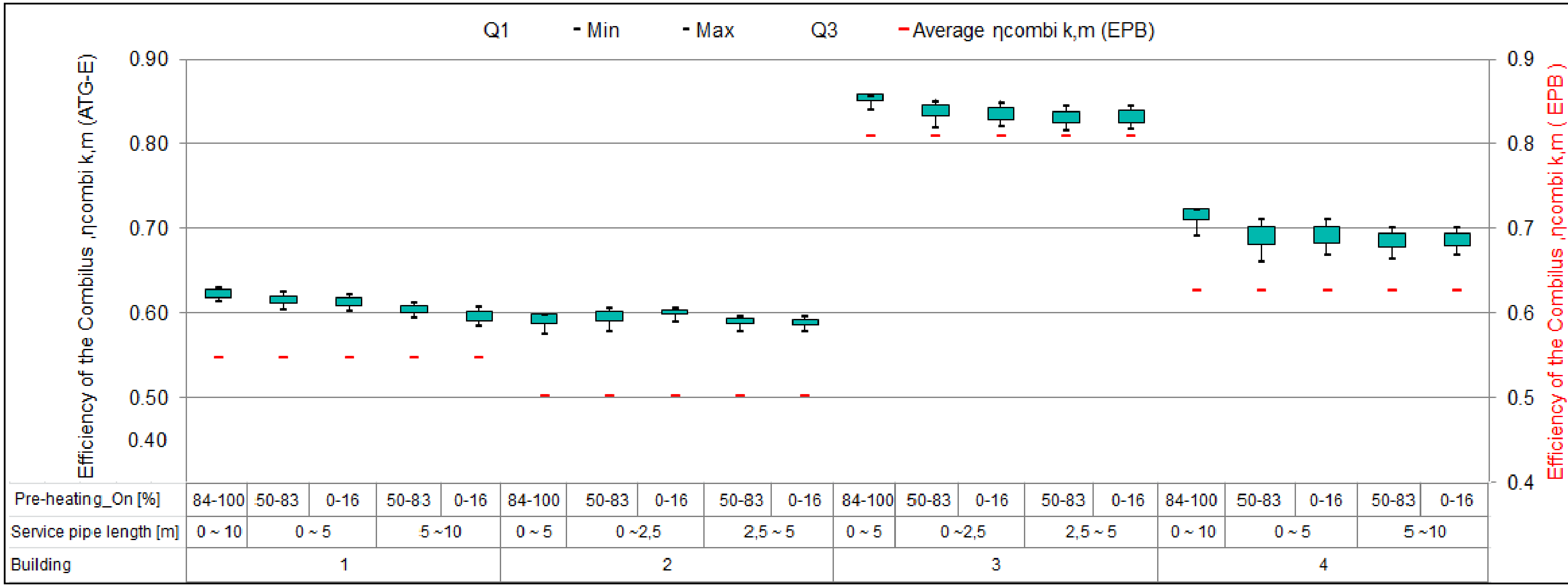

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Summary

1. The method developed allows to assess a large number of variants of combilus systems on a project basis.

2. A comparison of the sensitivity of heat losses in four different buildings typologies was conducted.

3. Results denote that the *Efficiency Corrector Factor* is significantly case specific sensitive.

4. Following combilus system specification has significant impact on the final results:

   a) Average heat supplied by apartment

   b) Pipe length per apartment

   c) Average thermal resistance of the pipe

Summary

5. The method is in principle implementable in the Belgian EPB standard providing the definition of fixed values for a number of device-specific parameters

6. The methods can also be implemented by expanding or refining the existing table with correction factors of the efficiency of the combilus.

    a) creating additional categories,
    b) descriptions expand within each category and refine
    c) table values split between correction for pipe losses and heat losses of heat exchangers.

Thank you

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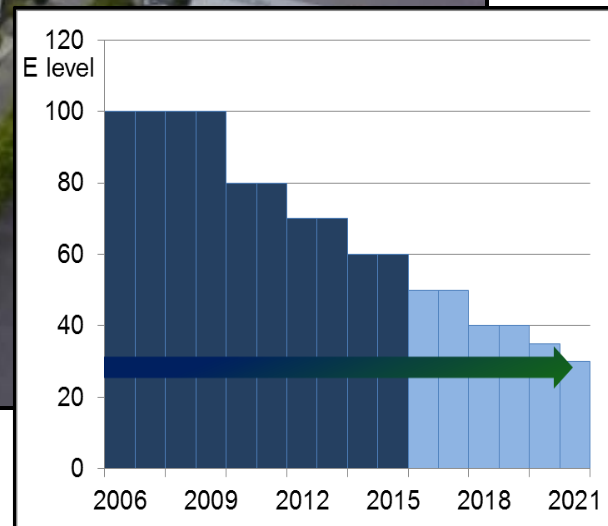

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