Cool ways of using low-grade heat sources from cooling and surplus heat for heating of energy efficient buildings with new low-temperature district heating (LTDH) solutions.

Deliverable no.:   **D2.10**

Name of deliverable: **Calculator on savings for new high-efficient pipe types for internal distribution in buildings**

Revision no.:   **1.0**

Due date of deliverable: M12

Actual submission date: M17 (final)
     M12 (draft)

Start date of project: 1st October 2017

Duration: 48 months

Organisation name of lead contractor for this deliverable: Logstor A/S

Authors: Klaus G. Lauridsen (Logstor A/S)
Emanuele Zilio, Maja G. Minzari and Reto M. Hummelshøj (COWI Denmark A/S)
Arnela Kursumovic (Kraftringen Energi AB)

Disclaimer

Scope of deliverable

The purpose of this deliverable is to create a calculation tool to calculate the heat losses from distribution and service pipes in buildings. The tool was developed using the software Microsoft Excel and it allows the user to select the input data and customise the calculations.

Context of deliverable

The tool was developed in relation to the project COOL DH, which is the acronym for "Cool ways of using low-grade heat sources from cooling and surplus heat for heating of energy efficient buildings with new low-temperature district heating (LTDH) solutions". COOL DH is a research project funded by Horizon 2020, the biggest EU research and innovation programme.

The project will develop new solutions for low-temperature district heating networks, and as part of it, two real scale demonstration sites are going to be implemented. The first one is in the city of Høje-Taastrup in Denmark and the second one is located in the city of Lund in Sweden.

Perspective of deliverable

The heat losses from the distribution in pipes are often overseen, even though they can reach up to 10-15% of the total energy requirements in new and renovated buildings. Higher impact is expected during summer when the heat losses do not contribute to the space heating demand.

The implementation of a better pipe layout and the use of PUR insulated pipes, co-insulated pipes or twin pipes, known as DH pipes, can lead to a reduction of heat losses in buildings. The heat losses calculation tool can give an overview of the heat losses that can be expected in a distribution system implemented in a building.

Involved partners

Logstor A/S, COWI Danmark A/S and Kraftringen Energi AB (UTIL-SE)

Prepared by: Klaus G. Lauridsen (IND-DK) and Emanuele Zilio (COWI-DK)

Checked by: Maja G. Minzari (COWI-DK) and Arnela Kursumovic (UTIL-SE)

Approved by: Reto M. Hummelshøj (COWI-DK)

Summary

This note presents the calculation tool for calculating the heat loss from the distribution pipes in buildings. The tool was developed with Microsoft Excel. The note guides the user through the settings of Microsoft Excel to start the calculations and afterwards it gives an overview of the inputs that the user can select during the calculation.

Furthermore, the note shows how the results can be saved in the simulation tool and the possible errors that can be found during the calculation process.

Contents

1   Introduction

The following note introduces the Excel tool for the calculation of heat loss from the distribution pipes of domestic hot water or space heating systems.

1.1   Background

The heat losses in a district heating network are not only limited to the underground distribution pipes, but part of the heat loss is found in and between the buildings or building sections. In new and renovated low-energy buildings, the heat losses from pipes can be up to 15% of the total energy need. During summer, the heat losses are more relevant since they do not contribute in covering part of the heat demand. Pre-investigations indicate that heat losses can be reduced by 50-65% with a better pipe layout and use of PUR insulated pre-fabricated district heating pipes inside buildings. As it is shown in Figure 1, a better pipe layout in multi-family buildings can reduce the number of pipes used. The installation shafts can be optimized and aggregated to supply more than an apartment type.
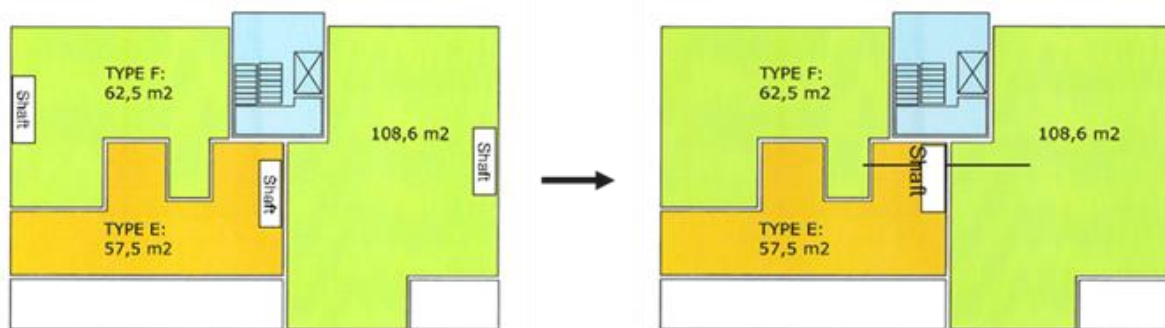
Figure 1. Optimised pipe layout in multi-family buildings

Based on these considerations, the Excel calculation tool developed in this deliverable aims to help the user to calculate the heat loss from a heating system and simulate different solutions. The user can implement the system's data and get an overview of the heat loss results, which can help with the optimisation of the installation and the choice of the materials. Furthermore, different pipe layouts can be tested to give an insight on the best solution.

2 Excel settings – Solver add-in

The workbook uses the Excel add-in called "Solver", which is a tool used for solving what-if analysis. It gives an optimal (maximum or minimum) value for a formula in one cell called objective cell, which is subject to constraints or limits. Solver modified the values of a group of cells or simply variable cells (decision variable) to satisfy the limits in the constraint cells and optimise the result in the objective cell (1).

If the Solver add-in is not activated in the user's Excel version, it is necessary to activate it before starting with the heat loss calculations. The following guidelines shows the steps to activate the Solver add-in (2):

1. Click on the "File" tab and then click on "Options".
2. In the "Add-ins" section, select "Solver Add-in" and click the "Go" button as shown in Figure 2.
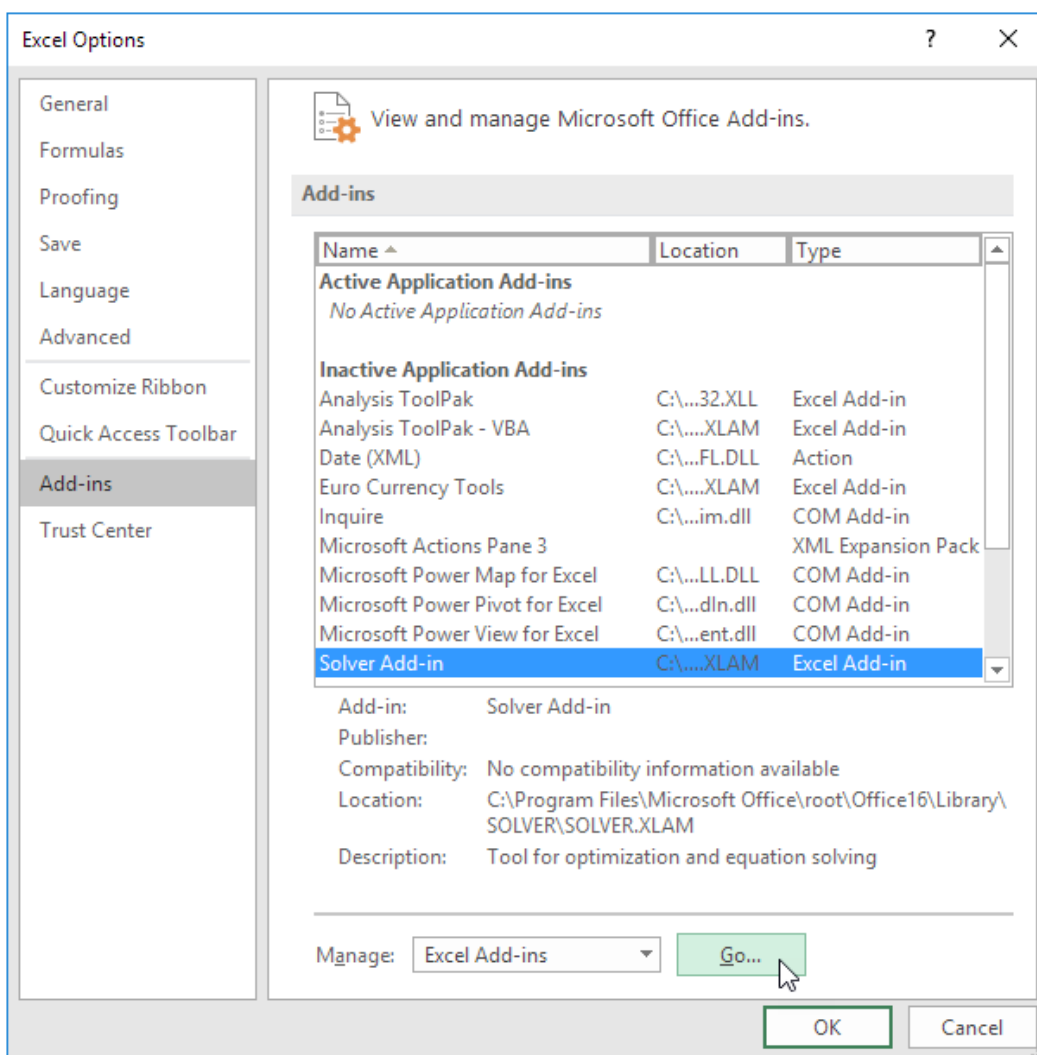
Figure 2. Select the Solver Add-in in the window

3.   In the new window check the "Solver Add-in" and then click "OK" as shown in Figure 3.
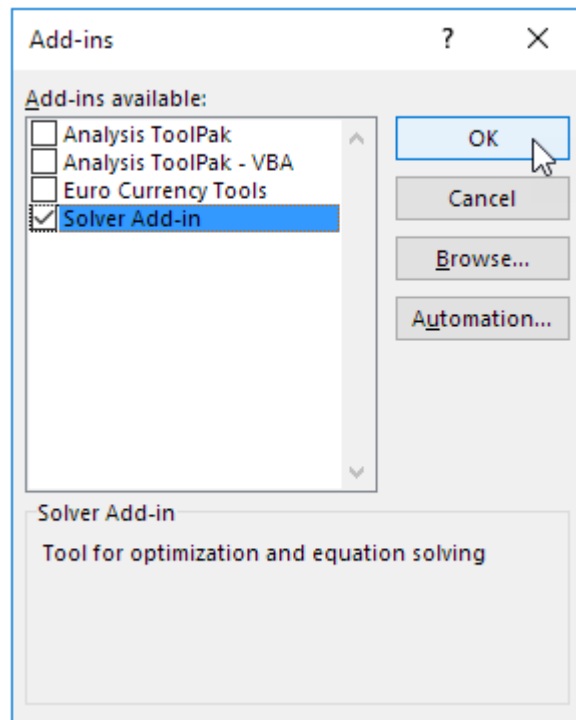
Figure 3. Select Solver Add-in in the Add-ins window

4.   The Solver Add-in is now active and can be found on the "Data" tab as shown in Figure 4.
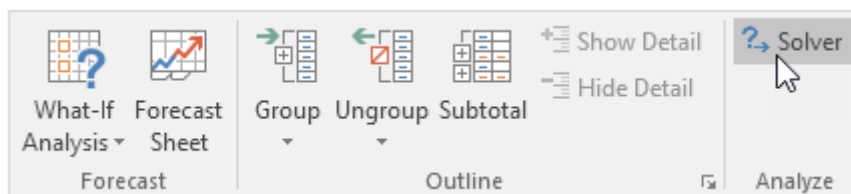
Figure 4. "Data" Tab where it is possible to find the Solver Add-in

Once the Solver is activated, it is possible to start with the heat loss calculations. However, the user has not to directly activate the Solver on the "Data" tab.

3 Heat loss calculations

3.1 Inputs section

The inputs area allows the user to insert the characteristics of the system for the calculation of the heat loss. There are three sections, for the different pipes in the systems, such as horizontal pipes (distribution), vertical pipes (distribution) and the service pipes. Figure 5 shows the inputs area for the horizontal pipes.

INPUTS

HORIZONTAL PIPES

Pipe

Name of the pipe	Pipe Test 1	
Usage time [%]	100%	
Pipe type	Single	
Inner Diameter, d1 [mm]	10,0	
Outer Diamater, d2 [mm]	15,0	
Pipe material λp [W/(mK)]	0,33	Pex

Insulation

Insulation thickness [mm]	15,0	
Insulation material λi [W/(mK)]	0,035	PU foam*
Emissivity [-]	0,85	Non-metalic

Temperatures

Ts - Supply [°C]	60
Tr - Return [°C]	30
Ta - Pipe surroundings [°C]	20,0

Length

Pipe length [m]	10,00

Flow rate

Volumetric flow rate [L/s]	0,100

TWIN

|	
Distance between pipes [mm]	

Horizontal_Calc	SaveHorizontal	DeleteRow_Hor

Figure 5. Overview of the inputs for the horizontal pipes

Figure 6 shows the different pipes in two DHW systems examples. The system on the left considers a district heating unit at the user, while the one on the right considers a common substation. The aim of the heat losses calculation tool is to calculate the heat losses from the distribution pipes in the building;

therefore, the heat losses from the district heating unit or the substation are not considered in the calculations.
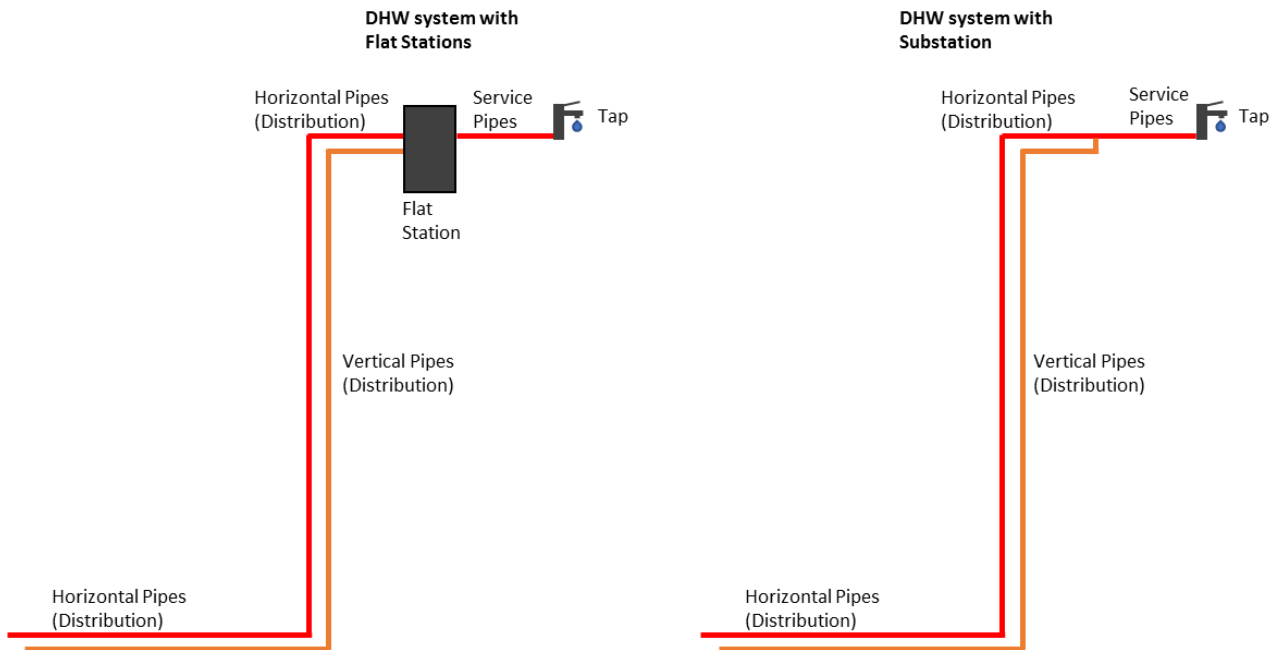
Figure 6. Representation of the different pipes in case of a DH-unit system and a main substation system

Every section is then divided in subsections, where it is possible to insert specific information of the pipe, in order to calculate the heat losses.

The data of each specific pipe must be entered in the light-red highlighted cells as show in Figure 7.

Inner Diameter, d1 [mm]	20,0

Figure 7. Light-red highlighted cells where the inputs can be inserted

The pipe material (lambda value) can be chosen from a drop-down menu as shown in Figure 8. The same drop-down menu is applied for the insulation materials as well as the emissivity of the external layer of the insulation.

Pipe material λp [W/(mK)]	0,33	Pex	▾

Figure 8. Drop down menu to choose pipe material as well as insulation material

If the user cannot find a specific value in the drop-down menu, it is possible to select "User defined value:", which gives the possibility to type in a specific value in the dark-red highlighted cell that appear on the right, as shown in Figure 9.

Pipe material λp [W/(mK)]	20,0	User defined value:	20

Figure 9. Possibility to type in a user defined value

3.1.1 Pipe section

In the pipe section, the user can insert the pipe's features:

- *Name of the pipe*: it is possible to set a name or a reference to the pipe.
- *Usage time*: it allows the user to define the percentage of time (in a year) that is expected to have flow through the specific pipe. The number is given in percentage, in the range 0-100%.
- *Pipe type*: it is possible to choose between single or twin pipes.
- *Inner diameter*: it defines the inner diameter of the media pipe.
- *Outer diameter*: it defines the outer diameter of the media pipe.
- *Pipe material*: it defines the lambda value of the media pipe.

Regarding the pipe type, the difference between single and twin pipe models is shown in Figure 10, which shows the simulation model for a single pipe and in Figure 11 shows the simulation model of a twin pipe. When the "single" pipe is selected, the calculation tool calculates the heat losses from a couple of single pipes that are insulated individually. The results give the average heat loss for the supply and return pipes together.
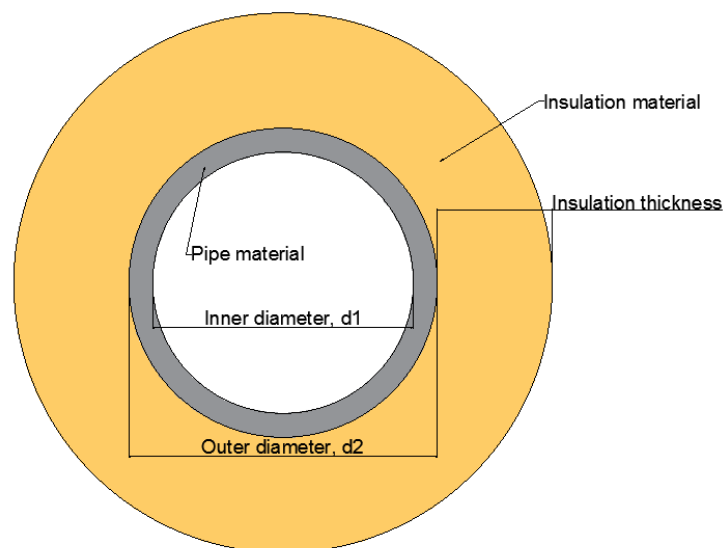
Figure 10. Simulation model of a single pipe

Regarding the twin pipe model, the supply and return pipes are embedded together in the same insulation. Also, in this case, the heat loss result gives the average heat loss from the twin pipe as combination of the supply and return pipe.
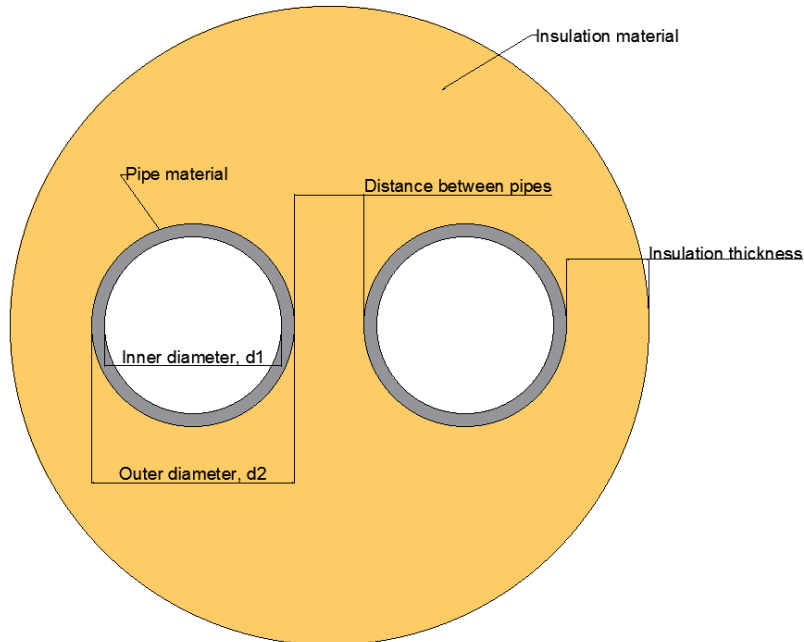
Figure 11. Simulation model of a twin pipe

3.1.2 Insulation section

In the insulation section, the characteristics of the insulation layer can be inserted.

- *Insulation thickness*: specify the thickness of the insulation layer.
- *Insulation material*: it defines the lambda value of the insulation material.
- *Emissivity*: it defines the emissivity of the external layer of the insulation material. The number must be in the range 0-1.

3.1.3 Temperatures section

In this section it is possible to insert the water temperature in the pipes as well as the characteristics of the environment that surrounds the pipe.

- *Ts - supply*: water temperature in the supply pipe.
- *Tr - return*: water temperature in the return pipe.
- *Ta - surroundings*: temperature of the environment/air that surrounds the pipe. It is assumed that the air that surrounds the pipe is 1°C higher than the shaft where the pipe is placed.

In the service pipes section, it is possible to define only the supply temperature, since the service pipes do not consider the return/circulation pipes.

3.1.4 Length section

In this section, the length of the pipe can be inserted.

- *Pipe length*: it defines the length of the pipe/s that have the same characteristics.

3.1.5   Flow rate section

In the flow rate section, it is possible to define the flow rate expected in the selected pipe. It is used to calculate the water velocity in the pipe.

- *Volumetric flow rate:* it defines the volumetric flow rate through the pipe.

3.1.6   TWIN section

In the TWIN section, it is possible to define the distance between the media pipes in case of twin pipes. This number is not considered in the heat loss calculation for single pipes. Therefore, the cell can be empty during heat losses calculation from single pipes.

- *Distance between pipes*: it defines the distance between the two media pipes in case of twin pipes.

3.2   Operation buttons

Once the features of the specific pipe are typed in, it is possible to proceed with the heat loss calculation. As shown in Figure 12, there are three operation buttons. The "Calc" button is used to calculate the heat loss from the pipe. It must be clicked every time there is a change of the data set. It is important to click it after every change in order to update the heat loss results.
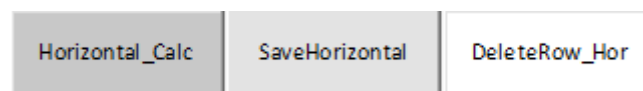
Figure 12. Operation buttons for the heat loss calculations in case of horizontal pipes

When the outputs/results are optimised, by clicking the "Save" button it is possible to save the results and the pipe's feature in a table, as it will be presented in Chapter 4.

If the results saved in the table are not optimised and it is necessary to change them, by clicking on the "Delete" button it is possible to delete the last line of the result's table.

The three buttons are available for all the different typologies of pipes, such as horizontal pipes, vertical pipes and service pipes.

3.3   Output overview

Underneath the inputs area, it is possible to have an overview of the results of the heat loss calculations, as shown in Figure 13. The outputs change when the pipe's data are modified, therefore it is important to press the "Calc" button to update the results every time there is a change in the data set since the solver has to be run. If the "Calc" button is not clicked, the results are not optimised, and in the Outputs section the user can see the results from the last simulation. The button "Delete Outputs" allows the user to empty the results area.

Figure 13. Output area with an overview of the heat loss results

The outputs give a first overview of the results and, once they are considered correct by the user, the results can be saved in the main tables as shown in the next chapter.

4 Results tables

As it is shown in Figure 14, the results from the heat loss calculation can be saved in a table. The table gives an overview of the pipe's features used in the calculation as well as the heat loss results. In particular, the results show the heat loss from one meter of pipe, the heat loss for supply and return and the energy loss from the supply and return in an entire year.

Horizontal Pipes					*Insert* the name of the project							
Name of the pipe	Pipe type	Inner Diameter, d1 [mm]	Outer Diamater, d2 (pipe) [mm]	Insulation thickness [mm]	Ts - Supply [°C]	Tr - Return [°C]	Length [m]	Flow rate [L/s]	Velocity [m/s]	Average heat loss (Supply+Return) [W/m]	Average heat loss (Supply+Return) [W]	Average heat loss (Supply+Return) [kWh/yr]
Pipe Test 1	Single	10,0	15,0	15,0	60	30	20,00	0,0300	0,76	9,6	192,0	1682,0
Pipe Test 2	Single	16,0	22,0	20,0	60	30	20,00	0,0800	0,80	10,2	204,7	1793,2
Pipe Test 3	Single	20,0	28,0	25,0	60	30	20,00	0,1100	0,70	10,3	206,6	1809,9
									SUM		603,3	5285,1

Figure 14. Overview of the table where the results of the heat loss calculations are saved

5 Calculation tool accuracy

The calculation tool was tested and compared with the results obtained with similar tools available online (e.g. Rocktec from Rockwool A/S). Three different types of insulation were used during the comparison, each one characterised with a different U-value. The test was conducted with two different sets of temperatures for the supply/return pipes and with two different diameters of the media pipes.

As results of the simulation test, the Excel tool calculated a heat loss on average between 10% and 20% higher than other tools. The difference can be due to the different calculation methods and the possible approximation of the different models, considering that the comparison tool is probably based on a theoretical calculation. Therefore, the results obtained with the Excel simulation tool guarantee to be on the safe side.

Regarding the comparison with real life measurements, it is planned to compare the results from the Excel calculation tool with the results obtained from the measurements that will be conducted in the Explorion building, which is located in the COOL DH demo site in the city of Lund.

6   Errors

6.1   Calculation errors

In order to avoid possible errors in the calculation process, it was decided to advise the user in case of possible errors. For example, Figure 15 shows the error when one or more inputs are missing, and therefore the heat calculation cannot be performed.
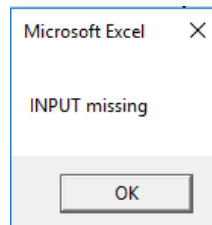

Figure 15. Error that shows one or more input missing

Figure 16 shows the error when there is a mistake in the pipe's diameters, in particular when the inner diameter is bigger than the outer diameter.
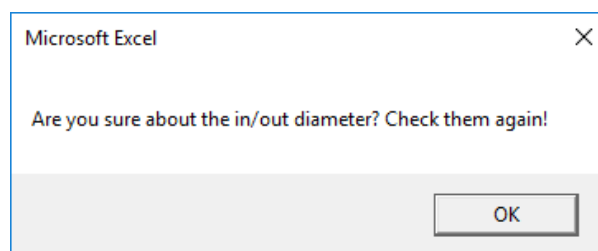

Figure 16. Error that shows a mistake in the in/out diameters dimension

Figure 17 shows the error in the heat calculation. This means that the Solver add-in cannot calculate an optimized result. This could be due to an error in the typed inputs or a situation where the inputs are not reasonable, and it is not possible to find a result.
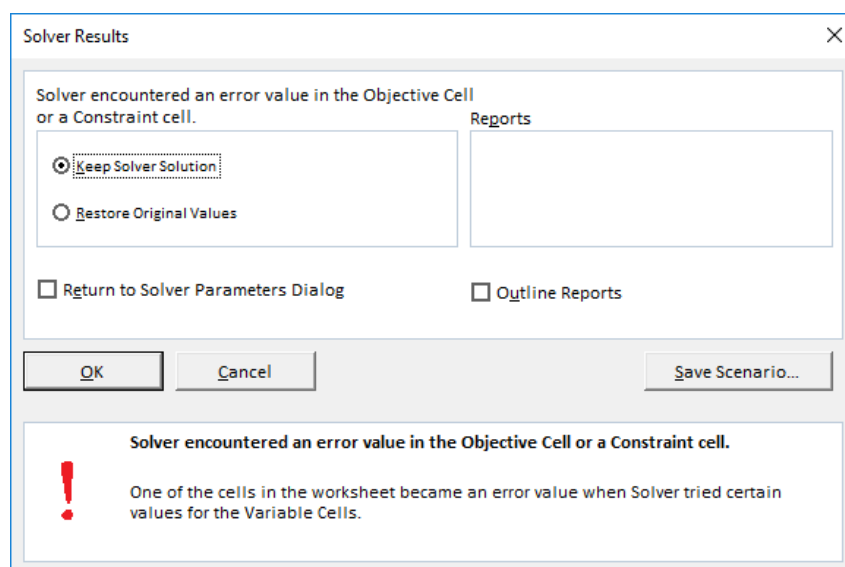

Figure 17. Error in the heat loss calculation. the Solver add-in cannot calculate the optimal solution

6.2 Excel version error

In case of undesired errors during the calculation (for example: Run-Time error '53': File Not Found: Solver32.dll) due to the different versions of the Excel software, it is possible to try the following solution:

1. Go to File > Options > Add-Ins > Manage Add-Ins Go Button (at the bottom)

2. Uncheck Solver add in.

3. Completely close all Excel spreadsheets and programs.

4. Open Excel.

5. Add the solver add-in back to Excel as it was shown in Chapter 0.

7   Applications of the calculation tool

The Excel calculation tool can be used in the design phase of a domestic hot water system as well as a space heating system in a building, when the pipes are not embedded inside the construction materials, but they are surrounded by air.

The tool can give an overview of the overall heat loss from the piping system as well as it can help with the design of the piping system itself, since it gives the possibility of testing different solutions. The user can type in all the segments that compose the system and choose different combinations of pipe materials and type of insulations. The tool has already a pre-defined list with the most common materials used in technical installation. Anyway, it gives also the possibility to choose personalized values.

The results obtained from the calculations show the heat losses for each segment in watt per meter, the total loss in the segment and the energy calculate for a year, considering the percentage of time that it is expected to have water circulating in the pipe. Moreover, it gives the total loss in watt and the total energy loss in kWh per year. In this way, it is possible to calculate easily the economy of the heat loss.

The tool can be directly used and tested during COOL DH project. In particular, it can be tested with the real-life installation results obtained from the measurements that will be conducted in the Explorion building, which is going to be part of the demo site in the city of Lund. Lastly, the Excel calculation tool can be used in the design process of the new town hall in the city of Høje-Taastrup, which is part of the second demo site of COOL DH project. Here a completely new building is going to be built.

8   References

(1) Microsoft Office, Excel solver add-in guideline. Available online at: https://support.office.com/en-us/article/define-and-solve-a-problem-by-using-solver-5d1a388f-079d-43ac-a7eb-f63e45925040

(2) Excel Easy, Solver Add-in guideline. Available online at: https://www.excel-easy.com/data-analysis/solver.html#load-solver-add-in