

- REPORT -Open source hourly software tool

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### Abstract

The project aims at the implementation of an open source software tool, with a solid base on two EPBD<sup>[1]</sup> standards<sup>[2]</sup>, suited for future use in the CEN-EN12977-2, Solar Keymark, CEN-EN12976, revised Ecodesign and Energy label and use in commerce.

The project main objectives are:

- to demonstrate the potential of the software tool for the performance determination of a solar thermal system
- to make available the software tool for public evaluation of its usefulness in several applications like certification and regulations

For this purpose the methods in the standards have been translated in software code, a simple user interface has been developed and the whole package is validated against TRNSYS.

The SolTherm software is 'open source', meaning the source code is available for distribution but under management (vAConsult). The software is limited to one simulation model describing typical European pumped solar thermal systems for water heating, space heating and combination

For the purpose of this project software has been developed, based on the EPBD standards, including a simple user interface. The software is supplied as:

- a complete working software program
   The software can be downloaded and is available for testing by experts. The user manual is included in annex I.
- a so called DLL describing the model and base methods
   The software can be linked to other user interfaces and other processes.

The validation showed:

- The SolTherm results seem to be systematically better than the TRNSYS results.
   It is noted that the EPBD methods assume a well-designed (optimally) designed system:
   SolTherm results show the best possible performance of the system under investigation.
- Commonly the accuracy of TRNSYS is assumed to be +/- 5%. The deviation of the Sol-Therm results are within that limit.

Taking into account that the number of input parameters of SolTherm is much smaller than TRNSYS, the results are (surprisingly) good. It is noted that these results could be worse for not optimally designed systems, not typical applications and system layouts that are more difficult to fit into the standard model included.

 The good validation results extend from preheaters to solar plus supplementary water heaters and solar thermal combination heaters.
 The system 8 is equipped with an external heat exchanger for the hot water service. The method applied in the SolTherm software is very basic and could be improved.

The software could be applied in:

- the framework of the member states building regulations,
- for the determination of the solar thermal system performance,
- the framework of the CEN EN12977-2 standard,
- the framework of the CEN EN12976-2 standard,
- Solar Keymark certification and
- ErP regulations, especially for space heating.

<sup>&</sup>lt;sup>1</sup> Energy Performance of Buildings Directive

<sup>&</sup>lt;sup>2</sup> EN 15316-4-3:2017 and EN 15316-5:2017

# Content

F	preword	I	.5
1	Intro	duction	.6
	1.1	Terms	.6
	1.2	Scope	.6
	1.3	Limitations	.6
2	The	software "SolTherm"	.8
	2.1	The input parameters	.8
	2.2	The methods	.8
3	Valid	lation	.9
	3.1	Calculation results	.9
	3.2	Evaluation of the results 1	1
4	Eval	uation of the applicability of the software 1	2
	4.1	Value in the framework of EPBD 1	2
	4.2 determ	Value of the hourly EPBD standards for solar thermal system performance ination	12
	4.3	EN12977-2	2
	4.4	EN12976-2	2
	4.5	Value of SolTherm in (CEN) certification 1	2
	4.6	Ecodesign / energy label 1	3
5	Cond	clusions 1	4
6	Prop	osals for further research1	5
	6.1	Further validation and management of the software 1	5
	6.2	Implementation in EN 12976 1	5
	6.3	Implementation in the EN 12977-2 1	5
	6.4	Revision of EN 15316-4-3 and EN 15316-5 1	5
	6.5	SolTherm in ErP 1	5

Annex I	User manual
Annex II	Validation results
Annex III	Adopted methods for heat exchangers
Annex VI	Automatic settings of tank volumes
Annex V	Validation against EN 15316-4-3 method 2 (Fchart)
Annex VI	Software description

# Foreword

The project aims at the implementation of an open source software tool, with a solid base on two EPBD <sup>[3]</sup> standards <sup>[4]</sup>, suited for future use in the CEN-EN12977-2, Solar Keymark, CEN-EN12976, revised Ecodesign and Energy label and use in commerce.

The project main objectives are:

- to demonstrate the potential of the software tool for the performance determination of a solar thermal system
- to make available the software tool for public evaluation of its usefulness in several applications like certification and regulations

For this purpose the methods in the standards have been translated in software code, a simple user interface has been developed and the whole package is validated against TRNSYS.

<sup>&</sup>lt;sup>3</sup> Energy Performance of Buildings Directive <sup>4</sup> EN 15316-4-3:2017 and EN 15316-5:2017

# 1 Introduction

### 1.1 Terms

The SolTherm software is 'open source', meaning the source code is available for distribution.

The SolTherm application (user interface and the model) is distributed as an executable to prevent any unmanaged changes to the code. The application can be used for free by experts that co-built the application or users that are interested in evaluating its use. Since this is the first version of the software published, users need to be aware of future changes that can influence the results and that the code is not 'perfect' (yet).

Until a formal management structure is built around the SolTherm software, it will be managed fully by vAConsult.

Other software developers can develop their own user interface around the core of the software. vAConsult is planning to do so in the near future, for a payed and supported version of the software.

### 1.2 Scope

The software is limited to one simulation model describing typical European solar thermal systems for water heating, space heating and combination heating (see figure 1).

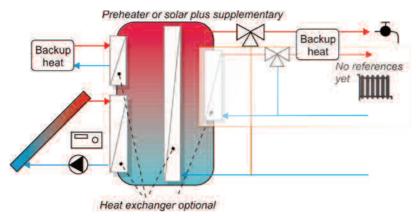


Figure 1 - a graphical impression of the solar thermal system that can be handled by the model.

### 1.3 Limitations

The software is limited to pumped solar thermal systems with a layout as shown in figure 1. Other models, describing a deviating system layout can be added in future.

It is noted that the methods from the EPBD standards are based on solid science, but are not at the same level of detail as can be expected from a scientific model like TRNSYS. Throughout the methods, assumptions are made for simplification to limit the number of input parameters.

- The methods from the standards are meant to judge upon the performance of a product as part of the total evaluation of a building (EPBD). The tools are not specifically developed for designing purposes; the product is assumed to be well designed. (e.g. a tank for heating purposes is assumed to be big enough to cover the heat load)
- For practical EPBD purposes the number of input parameters are limited to the essentials. As a result effects of more detailed input parameters will not be evaluated by the methods.
- The standards offer basic methods for application in a simulation model of a heating system. Although the EN 15316-5:2017 describes a sort of sequential calls to the base

methods, a detailed model is not included. The model applied in the SolTherm software is an addition to the standards.

- The SolTherm model includes a simple method for the backup heater that is also an addition to the standard. The detailed methods for backup heaters, as described in the EN15316-series and resulting in the heater efficiency, are not (yet) implemented.
- The hourly method of the EN15316-4-3 (collector) is designed to be linked with the methods of the EN15316-5 (tank). Other parts of the EN15316 series should be evaluated for their possibilities to link to the tank methods.

### 2 The software "SolTherm"

For the purpose of this project software has been developed, based on the EPBD standards, including a simple user interface. The software is supplied as:

- a complete working software program The software can be downloaded and is available for testing by experts. The user manual is included in annex I.
- a so called DLL describing the model and base methods The software can be linked to other user interfaces and other processes.

The software is developed in the Microsoft Visual Basic (2008) development environment. This development tool can be downloaded for free (Express edition) or bought from Microsoft (professional edition). Alternatively, the software is available for free as open source from several development groups (e.g. SharpDevelopment).

The dynamic link library (.DLL) can be applied in all Microsoft products, ranging from Visual Studio to Excel workbooks and software tools applied in laboratories.

#### 2.1 The input parameters

The input parameters, describing the solar thermal system and its components, are the same as reported by the datasheets for the Solar Keymark for a collector, a heat storage tank and a controller. Only a minor number of extra input parameters are needed, that could be defined as fixed values in the framework of a certification scheme.

Additionally the system design parameters are needed like backup heater(s) rated power output and control type and the location of the piping and the tank. Moreover, the reference conditions need to be given: climate and water heating and space heating load sequences.

### 2.2 The methods

The methods in the standards are applied. When needed changes are introduced, and missing elements are added.

The main changes are:

- The sequence of calls of the base methods (='the model') has been revised considerably.
- The method for an internal heat exchanger (indirect heat input and output) has been improved (see Annex III)
- More changes had to be implemented in the software, that are not yet fully documented in this report. A full list of revisions of the original standards needs to be drafted in a follow up project and put forward to the CEN TC228 for a future revision of the standards.

The main extensions are:

- A model for typical European solar thermal systems. The 'model' is the sequence of calls to the base methods described in the standards.
- The following methods have been added:
  - A simple method for an external heat exchanger (see Annex III)
  - A method for direct (volume) heat input
  - A method for internal heat conduction
  - A method for the iteration control
- Some specific control aspects for the backup heater in combi systems have been (provisionally) added
- Methods have been added to automatically determine the tank volumes and the distribution of the heat losses and the internal heat conduction.

# 3 Validation

SolTherm has been validated against TRNSYS for eight different solar systems: 5 solar water heaters and 3 combi systems.

No	Type <sup>[1]</sup>	Acol m <sup>2</sup>	Vsto litres	Climate <sup>[2]</sup>	Load WHS <sup>[3]</sup>	Load SHS <sup>[4]</sup>	Remarks
1	SWH-PH	2.28	100	ErP-AVG	ErP-PH-L, ErP- PH-XL, ErP- SPS-L, ErP- SPS-XL	None	
2	SWH-PH	3.78	225	ErP-AVG	ErP-PH-L, ErP- PH-XL, ErP- SPS-L, ErP- SPS-XL	None	
3	SWH-SPS	4.02	250	ErP-AVG	ErP-SPS-L, ErP-SPS-XL	None	
4	SWH-PH	2.37	124	ErP-AVG	ErP-PH-L, ErP- PH-XL, ErP- SPS-L, ErP- SPS-XL	None	
5	SWH-SPS	4.29	391	ErP-AVG	ErP-SPS-L, ErP-SPS-XL	None	
6	SC-SPS	14.04	889	Spec ITW	ITW_PH_Comb	ITW-NE50	
7	SC-SPS-PH	13.98	956	Spec ITW	ITW_PH_Comb	ITW-NE50	
8	SC-SPS	10.06	703	Spec ITW	ITW_PH_Comb	ITW-NE50	

Table 1 - solar thermal systems used for the validation. Load

[1] SWH: solar water heater, SC: solar combi, PH: preheater, SPS: solar plus supplementary

[2] ErP-AVG: average climate according to the ErP regulation for solar water heaters, Spec ITW: supplied by ITW

[3] Water heating load sequence

[4] Space heating load sequence

### 3.1 Calculation results

The TRNSYS calculations are performed by ITW. The results for the backup heater heat contribution are presented in figure 2 and the results for the annual pump power contribution are presented in figure 3. System number 1 to 5 are water heaters and number 6 to 8 are combisystems. The detailed results are available in the annex II.

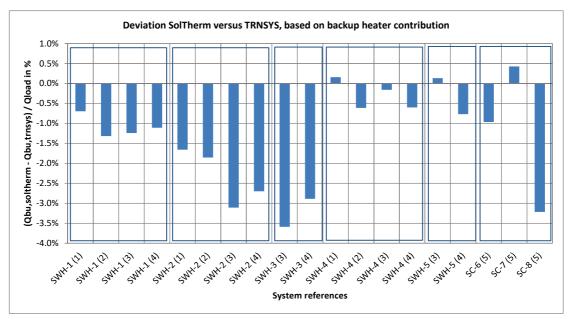


Figure 2 - validation results of SolTherm against TRNSYS. The results are shown for the heat contribution of the backup heater(s) (= $Q_{bu}$ ,...).

#### Notes:

- The deviation is defined on the backup heater contribution (=Q<sub>bu</sub>). This term is applicable for both preheaters and solar plus supplementary systems.
- SWH: solar water heater, SC: solar combi systems
- (1): ErP load profile L for preheaters, (2): ErP load profile XL for preheaters, (3): ErP load profile L for solar plus supplementary systems, (4): ErP load profile XL for solar plus supplementary systems, (5): special loads for water and space heating supplied by ITW.
- Negative deviations mean a better solar contribution for the SolTherm prediction. A high backup heater contribution, represents a low solar contribution.
- For water heaters the 'Qload' is equal to the water heater heat load. For combi systems the 'Qload' is equal to the sum of water and space heating heat load.

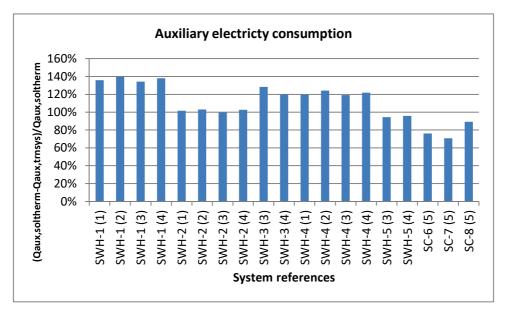


Figure 3 validation results of SolTherm. The results are shown for the prediction of the (auxiliary) electricity consumption (= $Q_{aux}$ ).

#### Notes:

- The electricity consumption (=Q<sub>aux</sub>) is calculated from the collector pump operation time, summed with the standby electricity consumption of the collector pump control for 24 hours and 365 days.
- SolTherm calculates on average a 11% higher consumption with a standard deviation of 21%.

### 3.2 Evaluation of the results

- The SolTherm results seem to be systematically better than the TRNSYS results. It is noted that the EPBD methods assume a well-designed (optimally) designed system: SolTherm results show the best possible performance of the system under investigation.
- Commonly the accuracy of TRNSYS is assumed to be +/- 5%. The deviation of the Sol-Therm results are within that limit.

Taking into account that the number of input parameters of SolTherm is much smaller than TRNSYS, the results are (surprisingly) good. It is noted that these results could be worse for not optimally designed systems, not typical applications and system layouts that are more difficult to fit into the standard model included.

 The good validation results extend from preheaters to solar plus supplementary water heaters and solar thermal combination heaters.
 The system 8 is equipped with an external heat exchanger for the hot water service. The method applied in the SolTherm software is very basic and could be improved.

The SolTherm calculated electricity consumption is on average higher than the TRNSYS results.

The deviation is related to the total heat demand small ( $\leq \pm 1\%$ ), but in absolute numbers significantly large. It is noted that SolTherm calculates with an hourly calculation step, without taking into account the settings of the on/off pump control and heat capacity of the collector loop. An inaccurate pump operation time calculation is to be expected.

# 4 Evaluation of the applicability of the software

### 4.1 Value in the framework of EPBD

After revision of the standards involved, based on the lessons learned during development of the SolTherm software, the accuracy of the hourly method would be much better  $(\pm 3\%)$  than the currently available monthly method (assumed:  $\pm 20\%$ ).

### 4.2 Value of the hourly EPBD standards for solar thermal system performance determination

The complete set of new hourly EPBD standards, offer a unique possibility to define methods for the performance determination of heating systems with solar thermal contribution. As such it would built upon the solar thermal component standards to open up a new field of accurate and unambiguous (solar thermal) system performance methods.

It is noted that each of the standards in the EN 15316 series is equipped with an hourly method. However, these methods are not (yet) validated in combination with the EN 15316-5 (tank).

### 4.3 EN12977-2

The SolTherm model can be applied in the EN 12977-2 framework, offering a welldocumented, unambiguous and well-referenced (CEN standard) simulation model. The Sol-Therm software offers a better accessibility for many test institutes than the currently assumed TRNSYS model.

However, there are some issues to consider:

- According to EN12977-2 the collector pump control should be evaluated. This is not included in SolTherm; an optimal working pump control is assumed.
- The EPBD methods assume a well-designed system. None optimal system designs may not be evaluated correctly. A dedicated validation sequence may be needed. This could be an in-situ test or a laboratory test.

#### 4.4 EN12976-2

The EN 12976 contains two methods: DST and CSTG. The DST method (ISO 9459-5) approach can be adopted to the SolTherm model.

In terms of tools this would imply linking an existing parameter identification tool to the Sol-Therm dynamic link library (=.DLL, that is the model without the user interface), and defining the set of parameters to be identified.

The model would be different to the current (P-model) and the identified parameters of tests performed cannot be used with the new tool. However, it is expected that the current test results and test procedure could be used in this new, SolTherm based, tool.

Moreover, introducing this new method, could bring the EN 12976 approach and that of the EN 12977-2 closer together.

#### 4.5 Value of SolTherm in (CEN) certification

Keymark certification is based on existing CEN standards. SolTherm is based on those standards, but has additions and alterations. Solar Keymark has experience with anticipating

on future revisions on standards. As such the SolTherm model could be introduced as an acceptable method in EN 12977-2 and Solar Keymark certification.

### 4.6 Ecodesign / energy label

If the SolTherm model could be seen as compatible with the hourly methods of the involved EPBD standards, the model would be a much better tool in Ecodesign and energy labelling than the current SOLCAL method or the method for space heating.

### 5 Conclusions

- The new EPBD standards EN 15316-4-3 and EN 15316-5, limited to the hourly methods, appear to form a good base for dedicated software tools. However, the methods need a further development and revision to be fully applicable. The revision can be based on the lessons learned in this project.
- The SolTherm software, based on the EPBD standards with improvements and limited to the validation sequences involved, appear to be accurate enough for EPBD purposes and solar thermal system certification. The accuracy is within the accuracy interval of TRN-SYS.
- The software is applicable for the typical European solar thermal water heaters, space heating systems and combination heating systems. Thermo-syphon systems are not evaluated.
- The SolTherm software can be used in the framework of EN 12977-2 but will require minor revisions of that standard. Moreover, a validation procedure needs to be drafted. As a result the software can also be applied in the Solar Keymark certification scheme for custom built systems.
- The SolTherm software could be applied in the EN 12976, limited to DST, when linked to
  parameter identification software and after the parameters have been defined. It is expected that the current test results can be handled by this alternative method. As a result
  the software can also be applied in the Solar Keymark certification scheme for factory
  made solar water heaters.

It is noted that the simulation model is not validated for thermos-syphon systems that often make use of the EN 12976 method. However, the P-model used in DST testing and calculations, is equally applied for both pumped and thermosiphon systems without specific adoptions to both solar loop types.

 The SolTherm software is a better method for the ErP than the current SOLCAL and the method for space heating (package label). The method should be put forward for the next ErP revision.

### 6 **Proposals for further research**

#### 6.1 Further validation and management of the software

Although the first validation results are very promising, a further validation by other stakeholders is needed.

For this purpose an user group is proposed, staffed with expert stakeholders, that takes over the management of the code from vAConsult and improves the code. This group is preferably staffed with organizations that are interested in applying the software in their work.

### 6.2 Implementation in EN 12976

If a research team can be interested in implementing the SolTherm model in DST testing, the following needs to be done:

- Link the core model (DLL) to parameter identification software
- Select the set of system parameters to be identified
- Validate the method using existing test data
- Revise the EN 12976 to include this method and, if needed, do the same for the ISO 9459-5.
- Allow the method to be applied in the context of the Solar Keymark certification scheme for factory made solar water heaters.

Funding of this work through a SCF project is advisable.

### 6.3 Implementation in the EN 12977-2

Implement the method on the level of Solar Keymark and gain experience with it for some time (learn and improve). In the following phase define a complete set of reference conditions and revise the EN 12977-2 accordingly.

### 6.4 Revision of EN 15316-4-3 and EN 15316-5

Analyse in detail the differences (changes and extensions) between the EPBD standards and the SolTherm software. Report the differences to the CEN TC 228, WG4 and ask for a revision of the involved standards. Doing so would increase the value of the SolTherm software significantly.

#### 6.5 SolTherm in ErP

The SolTherm method is better fitted to the needs of ErP then the current SOLCAL method and the ErP method for space heating. This approach should be put forward during the revision of the ErP.

### ANNEX I SolTherm user manual

SolTherm software is distributed with a simple user interface that is intended for use of evaluation of its methods. The software is not tested extensively and may contain faults and annoying 'habits'.

### I.1 Installing the software

The software can be installed on any PC with Microsoft Windows. If a new version becomes available, the installation procedure is repeated, overwriting the old version. The application maintains a database that will be saved on your PC (mydocuments).

### I.2 First use

Run the software. The software is distributed with 8 pre-set solar thermal systems in the database ready for use. These are the systems used for the validation and the only systems that also generate a validation report.

One of those systems is selected through the 'Solar devices' menu  $\rightarrow$  Select.

The input parameters are displayed at the left part of the screen and the results are shown at the right part of the screen.

### I.3 Input parameters

The input parameters are self-explaining. Be aware of the following:

3. Tank design for each loop

The locations of connections to the tank and the heat exchange rate are given per loop (collector, backup heater water heating, backup heater space heating, water heating service and space heating service).

Select all these loops sequentially in the input field: 'Tank\_loop' and enter the relevant data.

6. Backup heater

BWH (backup heater for water heating) or BSH (backup heater for space heating) type can be 'Not used': not included, 'Serial': e.g for a preheater solar system, 'Tank heating': connected to the (top of the) tank.

9. Reference conditions

Climate:

ErP_AVG	the European average climate used in the ErP
Imp_Athens	Athens according to EN12976-2 and Solar Keymark
Imp_Stockholm	Stockholm according to EN12976-2 and Solar Keymark
Imp_Wurzburg	Wurzburg according to EN12976-2 and Solar Keymark
WB_S_45	Climate file fitted to the space heating sequence: {SH_LP}
LoadProfileWH:	
None	no hot water service
ErP_PH_I_{x}	the load profiles according to the ErP for <i>preheater</i> type solar water heaters, where {x} is M, L, XL or XXL
ErP_SPS_I_{x}	the load profiles according to the ErP for <i>solar plus supplementary</i> type solar water heaters, where {x} is M, L, XL or XXL
ITW_Preheat_Combi	made available by ITW (DE)
SolKey-Wurzburg-{x}	EN12976-2 / Solar Keymark reference for <i>Wurzburg</i> hot water se- quences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or 600.
SolKey-Stockholm-	EN12976-2 / Solar Keymark reference for <i>Stockholm</i> hot water se- quences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or
	Page: 16 of 23

{x}	600.
SolKey-Davos-{x}	EN12976-2 / Solar Keymark reference for <i>Davos</i> hot water se- quences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or 600.
SolKey-Athens-{x}	EN12976-2 / Solar Keymark reference for Athens hot water sequences, where $\{x\}$ is 080, 110, 140, 170, 200, 250, 300, 400 or 600.
Load profiles:	
None	no hot water service

a sequence made available by ITW (DE)

# I.4 Program menus

SH LP

#### I.4.1 File menu

The menu 'File' offers two options: save the database with all changes and close the program.

#### I.4.2 Solar devices menu

Enter a 'New' solar device in the database, 'Select' solar device in the database or 'Delete' a solar device from the database.

#### I.4.3 Extra menu

The extra functions of the software are available through the menu.

Show details	Opens a window with tabs, offering the following:
Monthly values	
	series of tank temperatures in the clipboard.
Validation	Table with validation results (related to TRNSYS runs). Moreover, the
	results of EN 15316-4-3, method 2 (Fchart, monthly) is shown.
Tank definitions	A graphical representation of the tank parameters supplied.
References	A summary of the reference conditions
Report (Excel)	Produces an Excel report of the inputs and results
Batch	Opens a window to select multiple climates and loads, that will be exe-
	cuted and reported in an Excel workbook.

#### I.4.4 Batch processing

Multiple runs of the model can compiled in a batch file that through drag and drop (on datainput properties control, left side of the window) is entered into the program. The results of all the calculations are presented in a Excel workbook. The batch file is a text file.

```
*...These three commands must be present
>FileType;SolThermBatch
>Version;1
>Title;Systems with TRNSYS validation results
* ...Always start a run definition with >Device
* ...Always end a run definition with >Run
* ...Repeat this sequence as often as needed
*...Sequences for Solar water heater: 1
>Device;Solar water heater: 1
>Climate;ErP_AVG
>LoadSeqWhs;ErP_PH_I_L
>LoadSeqShs;None
>Run
Table 2 - example of the batch file
```

Page: 17 of 23

	SolTherm calculation results									
	Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		
SWH-1 (1)	3084	1623	1322	-1475	0	-1475	-2797	85		
SWH-1 (2)	3084	1671	2824	-1586	0	-1586	-4411	87		
SWH-1 (3)	3084	1547	1426	-1364	0	-1364	-2791	83		
SWH-1 (4)	3084	1625	2884	-1531	0	-1531	-4415	86		
SWH-2 (1)	5116	2262	809	-1988	0	-1988	-2797	82		
SWH-2 (2)	5116	2631	1914	-2497	0	-2497	-4411	90		
SWH-2 (3)	5116	2090	1034	-1756	0	-1756	-2791	78		
SWH-2 (4)	5116	2490	2120	-2295	0	-2295	-4415	88		
SWH-3 (3)	5438	2010	1292	-2791	0	-2791	-2791	75		
SWH-3 (4)	5438	2381	2452	-4415	0	-4415	-4415	83		
SWH-4 (1)	3206	1703	1244	-1553	0	-1553	-2797	84		
SWH-4 (2)	3206	1772	2718	-1693	0	-1693	-4411	86		
SWH-4 (3)	3206	1604	1377	-1414	0	-1414	-2791	81		
SWH-4 (4)	3206	1725	2796	-1619	0	-1619	-4415	85		
SWH-5 (3)	9537	2675	970	-2791	0	-2791	-2791	60		
SWH-5 (4)	9537	3353	1799	-4415	0	-4415	-4415	71		
SC-6	17190	3866	9519	-2771	-9079	-11850	-11853	41		
SC-7	17263	3905	9275	-2774	-1507	-4281	-11853	39		
SC-8	12370	3288	10104	-2774	-9052	-11826	-11853	49		

# ANNEX II Validation results

#### Where:

Q <sub>irr</sub>	Annual solar irradiation on collector plane
Q <sub>solar</sub>	Annual collector loop heat output
ΣQ <sub>bu</sub>	Sum of all applied backup heaters heat contribution
Q <sub>hw;out</sub>	Annual heat output (from the tank) for the water heating service
Q <sub>sh;out</sub>	Annual heat output (from the tank) for the space heating service
ΣQ <sub>sto;out</sub>	$= Q_{hw;out} + Q_{sh;out}$
$\Sigma Q_{load;req}$	Sum of both water and space heating heat loads
ΣQ <sub>aux</sub>	Annual auxiliary electricity consumption

SWH: solar water heater, SC: solar combi, PH: preheater, SPS: solar plus supplementary

 $\mbox{ErP-AVG}:$  average climate according to the  $\mbox{ErP}$  regulation for solar water heaters, Spec ITW: supplied by ITW

	SolTherm validation results (Qsoltherm - Qtrnsys)/Qload								
	Qirr	Qsolar	ΣQbu	Qhw;out Qsh;out		ΣQsto;out ΣQload;req		Qaux	
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
SWH-1 (1)	0.0%	0.6%	-0.7%	-0.7%	0.0%	-0.7%	0.0%	-0.8%	
SWH-1 (2)	0.0%	1.2%	-1.3%	-1.3%	0.0%	-1.3%	0.0%	-0.6%	
SWH-1 (3)	0.0%	1.0%	-1.2%	-1.2%	0.0%	-1.2%	0.0%	-0.8%	
SWH-1 (4)	0.0%	1.0%	-1.1%	-1.1%	0.0%	-1.1%	0.0%	-0.5%	
SWH-2 (1)	0.0%	2.4%	-1.7%	-1.7%	0.0%	-1.7%	0.0%	0.0%	
SWH-2 (2)	0.0%	2.2%	-1.9%	-1.9%	0.0%	-1.9%	0.0%	-0.1%	
SWH-2 (3)	0.0%	3.6%	-3.1%	-3.1%	0.0%	-3.1%	0.0%	0.0%	
SWH-2 (4)	0.0%	2.8%	-2.7%	-2.7%	0.0%	-2.7%	0.0%	-0.1%	
SWH-3 (3)	0.0%	3.5%	-3.6%	0.0%	0.0%	0.0%	0.0%	-0.6%	
SWH-3 (4)	0.0%	2.9%	-2.9%	0.0%	0.0%	0.0%	0.0%	-0.3%	
SWH-4 (1)	0.0%	-0.2%	0.2%	0.2%	0.0%	0.2%	0.0%	-0.5%	
SWH-4 (2)	0.0%	0.5%	-0.6%	-0.6%	0.0%	-0.6%	0.0%	-0.4%	
SWH-4 (3)	0.0%	-0.1%	-0.2%	-0.2%	0.0%	-0.2%	0.0%	-0.5%	
SWH-4 (4)	0.0%	0.4%	-0.6%	-0.6%	0.0%	-0.6%	0.0%	-0.3%	
SWH-5 (3)	0.0%	-1.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	
SWH-5 (4)	0.0%	0.5%	-0.8%	0.0%	0.0%	0.0%	0.0%	0.1%	
SC-6	0.0%	-1.1%	-1.0%	-0.2%	-0.1%	-0.3%	0.0%	0.1%	
SC-7	0.0%	0.8%	0.4%	-0.2%	0.0%	-0.2%	0.0%	0.1%	
SC-8	0.0%	1.2%	-3.2%	-0.2%	-0.2%	-0.4%	0.0%	0.1%	

The relative deviation is calculated by

$$\Delta Q_{xx} = \frac{Q_{bu;solterm} - Q_{bu;trnsys}}{\sum Q_{load}}$$

 $\Sigma Q_{load}$  is either the water heating load (water heaters) or the sum of the water and space heating load (combi systems).

1

	Climate:	ErP_AVG				Reference cli	mate region					
W	ater heating service:	ErP_PH_I_L				Water heatin	ig sequence					
Sp	bace heating service:	None				Space heatin	g sequence					
	Asol =	2.28	Total collec	tor reference d	area in m <sup>2</sup>							
08 iet)	Eo =	0.856	Zero loss co	ero loss collector efficiency in -								
EN ISO 9808 (SK datasheet)	a1 =	3.688	First order d	irst order collector heat loss coefficient in W/(K.m <sup>2</sup> )								
lSO data	a2 =	0.021	Second orde	er collector he	at loss coeffici	ent in W/(K2.	m²)					
EN (SK	IAM =	0.96	Incident an	gle modifier at	50° in -							
	Mcol =	0.046	Collector flo	ow rate in kg/(	s.m <sup>2</sup> )							
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K							
	Sol,loc =	HS	Location of	cation of the collector loop piping								
	Pcol,pmp =	20	Nominal ele	ominal electricyt consumption collector pump in W								
	Pcol,ctrl =	5	Standby ele	ctricity consur	nption of cont	roller in W						
	Vsto,tot =	100	Total tank v	volume in litres	5							
	Hsto,tot =	1.32	Total heat l	oss rate of the	tank in W/K							
	Htank =	0.75	Height of th	leight of the tank in m								
	Sto,loc =	HS	Location of	the tank								
	Vsto,automation:	Automation	1	Method to de	etermine volur	nes of the tan	k					
3/4 eet)	Hsto, automation:	Automation	ı	Method to di	stribute heat l	osses over the	e volumes					
EN 12977 3/4 (SK datasheet)	Csto,automation:	Automation	1	Method to dis								
129 dati	Nvol =	4	Number of	tank volumes								
EN (SK			Backu									
		Solar loop	WHS	SHS	WHS	SHS						
	Rh,inlet =	50%	0%	0%	0%	0%	Height of inlet (%	%)				
	Rh,outlet =	0%	0%	0%	100%	0%	Height of outlet (%)					
	Rh,therm =	100%	50%					ostat position (%)				
	Hexch =	544	0	0	0	0	D Heat exchanger rate in W/K					
			Backu	p heater								
		Solar loop	WHS									
'-5 eet)	Ttherm,on =		75		Thermostat s	-						
-77- she	Ttherm,off =	95	75	0	Thermostat s	etting off in <sup>o</sup>	С					
EN 12977 SK datash		Design type:			I							
EN 12977 (SK datashe		tput power:			0 Rated heat output in W							
J	- C	ontrol type:	Repeat	Repeat								
	Tsto,init =	Tsto,init = 10 /			Initial tank temperature in °C							
	Ti,hs =			re heated spac								
	tci =	tci = 1 Cal		time step in h								
Results:												
		Qirr			Qhw;out			ΣQload;req	Qaux			
		kWh	kWh		kWh	kWh		kWh	kWł			
	SolTherm	3084	1623		-1475	0		-2797	85			
tion	TrnSys	3084	1640		-1495	0		-2797	62			
Validation	ΔQ [kWh]	0			19	0		0	22			
20	ΔQ [%]	0.0%	0.6%	-0.7%	-0.7%	0.0%	-0.7%	0.0%	-0.8%			
>		0.070	0.070	0.770	-0.770	0.070	0.770	0.070	0.07			

2

	Climate:	ErP_AVG				Reference cli	mate region			
W	ater heating service:	ErP_PH_I_X	L			Water heatin	ig sequence			
Sp	bace heating service:	None				Space heatin	g sequence			
	Asol =	2.28	Total collect	or reference o	area in m <sup>2</sup>					
18 et)	Eo =	0.856	Zero loss co	llector efficien	cy in -					
EN ISO 9808 SK datasheet	a1 =	3.688	First order d	ollector heat l	oss coefficient	t in W/(K.m <sup>2</sup> )				
ISO data	a2 =	0.021	Second orde	er collector he	at loss coeffici	ent in W/(K2.	m²)			
EN ISO 9808 (SK datasheet)	IAM =	0.96	Incident ang	gle modifier at	50° in -					
C	Mcol =	0.046	Collector flo	w rate in kg/(	s.m <sup>2</sup> )					
	Hsol,loop =	4.29	Heat losses	eat losses collector loop piping in W/K						
	Sol,loc =	HS	Location of	ocation of the collector loop piping						
	Pcol,pmp =	20	Nominal ele	ctricyt consum	nption collecto	or pump in W				
	Pcol,ctrl =	5	Standby ele	ctricity consur	nption of cont	roller in W				
	Vsto,tot =	100	Total tank v	olume in litres	5					
	Hsto,tot =	1.32	Total heat le	oss rate of the	tank in W/K					
	Htank =	0.75	Height of th	leight of the tank in m						
	Sto,loc =	HS	Location of	ocation of the tank						
	Vsto,automation:	Automation	Method to determine volumes of the tank							
3/4 eet)	Hsto,automation:	Automation	Method to distribute heat losses over the volumes							
977 ash	Csto, automation:	Automation	n Method to distribute the internal convection							
129 dat	Nvol =					umber of tank volumes				
EN (SK			Backu	o heater	Heat o	output				
		Solar loop	WHS	SHS	WHS	SHS				
	Rh,inlet =	50%	0%	0%	0%	0%	Height of inlet (	%)		
	Rh,outlet =	0%	0%	0%	100%	0%	Height of outlet	(%)		
	Rh,therm =	100%	50%	50%			Height of thermostat position (%)			
	Hexch =	544	0	0	0	0	Heat exchanger	rate in W/K		
			Backup heater							
		Solar loop	WHS	SHS						
et) 5	Ttherm,on =		75		Thermostat s					
77-J	Ttherm,off =	95	75	0	Thermostat s	etting off in $^{\circ}$	С			
129 lata:	l	Design type:	Serial	Not used						
EN SK d		tput power:		0	Rated heat of	utput in W				
	C	control type:	Repeat	Repeat						
	Tsto,init =	10	Initial tank t	emperature ii	∩ °C					
	Ti,hs =	15	Temperatur	e heated spac	e in °C					
	tci =	1	Calculation	time step in h						
Results:										
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux	
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
	SolTherm	3084	1671	2824	-1586			-4411	87	
tion	TrnSys	3084	1724	2766	-1645	0	-1645	-4411	63	
alidat	ΔQ [kWh]	0	-53	58	58	0	58	0	25	
ValidationEN 12977-5EN 12977 3/4Validation::(SK datasheet)	ΔQ [%]	0.0%	1.2%	-1.3%	-1.3%	0.0%	-1.3%	0.0%	-0.6%	
			Fchart:	2540	EN 15316-4-3	3, method 2				
			∆Q [%]:	-6.4%						

ΔQ [%]: -6.4%

3

		ErP_AVG				Reference climate region				
W	ater heating service:	ErP_SPS_I_I	_			Water heatin	ig sequence			
S	pace heating service:	None				Space heatin	g sequence			
	Asol =	2.28	Total collec	tor reference a	area in m <sup>2</sup>					
08 eet)	Eo =	0.856	Zero loss co	llector efficien	cy in -					
EN ISO 9808 (SK datasheet)	a1 =	3.688	First order d	collector heat l	oss coefficient	in W/(K.m <sup>2</sup> )				
ISO data	a2 =	0.021	Second orde	er collector hea	at loss coefficie	ent in W/(K2.	m²)			
EN (SK	IAM =	0.96	Incident an	gle modifier at	50° in -					
	Mcol =	0.046	Collector flo	ow rate in kg/(	s.m²)					
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K					
	Sol,loc =			the collector lo						
	Pcol,pmp =	20	Nominal ele	ectricyt consun	nption collecto	r pump in W				
	Pcol,ctrl =	5	Standby ele	ctricity consum	nption of conti	roller in W				
	 Vsto,tot =	100	Total tank v	olume in litres	Ĩ					
	Hsto,tot =		Total heat l	oss rate of the	tank in W/K					
	, Htank =		Height of th	-						
	Sto,loc =		Location of							
	Vsto,automation:		-		etermine volun	nes of the tan	k			
i/4 et)	Hsto,automation:			Method to dis	stribute heat la	osses over the	e volumes			
EN 12977 3/4 (SK datasheet)	Csto,automation:	Automation	1	Method to dis	stribute the int	ternal convec	tion			
129 data	Nvol =	4	Number of	tank volumes						
EN (SK			Backu	p heater	Heat c	output				
		Solar loop	WHS	SHS	WHS	SHS				
	Rh,inlet =	50%	0%	0%	0%	0%	Height of inlet (\$	%)		
	Rh,outlet =	0%	0%	0%	100%	0%	Height of outlet (%)			
	Rh,therm =	100%	50% 50% Height of thermostat position (%)							
	Hexch =	544	0	0	0	0	Heat exchanger	rate in W/K		
			Backu	p heater						
		Solar loop	WHS	SHS						
t)	Ttherm,on =		75	0	Thermostat se	etting on in $^{\circ}$	С			
7-5 heet)	Ttherm,off =	95	75	0	Thermostat se	etting off in $^{\circ}$	С			
L297 atas	I	Design type:	Serial	Not used						
EN 12977 (SK datash	Rated ou	tput power:	24	0	Rated heat ou	itput in W				
5)	C	ontrol type:	Repeat	Repeat						
	Tsto,init =	10	Initial tank	temperature ir	ı °C					
	Ti,hs =	15	Temperatui	re heated spac	e in °C					
	tci =	1	Calculation	time step in h						
esults:										
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qau	
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWl	
	SolTherm	3084	1547	1426	-1364	0	-1364	-2791	83	
noi	TrnSys	3084	1574	1392	-1399	0	-1399	-2791	62	
Validation	ΔQ [kWh]	0	-27	35	35	0	35	0	2	
a	ΔQ [%]	0.0%	1.0%	-1.2%	-1.2%	0.00/	-1.2%	0.0%	-0.8%	
>	4Q [70]	0.0%	1.070	-1.270	-1.270	0.0%	-1.270	0.078	-0.07	

4

	Climate:	ErP_AVG				Reference cli	mate reaion				
W	ater heating service:		ХL			, Water heatin					
	ace heating service:					Space heatin					
	_				. 2						
-	Asol =			tor reference o							
EN ISO 9808 (SK datasheet)	Eo =			llector efficien	2						
0 9 tasł	a1 =				loss coefficient						
N IS Aa	a2 =				at loss coeffici	ent in W/(K2.	m - )				
E (SI	IAM =			gle modifier at							
	Mcol =	0.046	Collector flo	w rate in kg/(	s.m <sup>-</sup> )						
	Hsol,loop =				piping in W/K						
	Sol,loc =		-	the collector l							
	Pcol,pmp =				nption collecto						
	Pcol,ctrl =	5	Standby ele	ctricity consur	nption of cont	roller in W					
	Vsto,tot =	100	Total tank v	olume in litres	5						
	Hsto,tot =	1.32	Total heat lo	oss rate of the	tank in W/K						
	Htank =	0.75	Height of th	e tank in m							
	Sto,loc =	HS	Location of	the tank							
	Vsto,automation:	Automation	1	Method to de	etermine volur	nes of the tan	k				
3/4 eet)	Hsto, automation:	Automation	ı	Method to di	stribute heat l	osses over the	volumes				
977 ash	Csto,automation:	Automation	1	Method to di	stribute the in	ternal convec	tion				
EN 12977 3/4 (SK datasheet)	Nvol =	4	Number of t	ank volumes							
EN (SK			Backu	o heater	Heat o	output					
		Solar loop	WHS	SHS	WHS	SHS					
	Rh,inlet =	50%	0%	0%	0%	0%	Height of inlet (	Height of inlet (%)			
	Rh,outlet =		0%	0%	100%	0%	Height of outlet (%)				
	Rh,therm =	100%	50%	50%			Height of therm	nostat position (%)			
	Hexch =	544	0	0	0	0	Heat exchange	r rate in W/K			
			Backu	o heater							
		Solar loop	WHS	SHS							
-5 eet)	Ttherm,on =		75		Thermostat s						
77-! shee	Ttherm,off =	95	75	0	Thermostat s	etting off in $^{\circ}$	С				
EN 12977 SK datashe		Design type:	Serial	Not used							
EN 12977-5 (SK datasheet)	Rated ou	tput power:	24	0	Rated heat of	utput in W					
÷	C	control type:	Repeat	Repeat							
	Tsto,init =	10	Initial tank t	emperature in	n °C						
	Ti,hs =	15	Temperatur	e heated spac	e in °C						
	tci =	1	Calculation	time step in h							
Results:											
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		
	SolTherm	3084	1625	2884	-1531	0	-1531	-4415	86		
io	TrnSys	3084	1671	2836	-1580	0	-1580	-4415	62		
Validation	ΔQ [kWh]	0	-46	49	49	0	49	0	24		
Va	ΔQ [%]	0.0%	1.0%	-1.1%	-1.1%	0.0%	-1.1%	0.0%	-0.5%		
			Fchart:	2742	EN 15316-4-3	3, method 2					
			AO [%]:	-3.2%							

ΔQ [%]: -3.2%

5

	Climate:	ErP_AVG				Reference cli	mate region				
W	ater heating service:	ErP_PH_I_L				Water heatin	ig sequence				
S	pace heating service:	None				Space heatin	g sequence				
	Asol =	3.782	Total collec	tor reference d	area in m <sup>2</sup>						
08 eet)	Eo =			llector efficien	,						
98 ( ashe	a1 =	3.77	First order o	collector heat l	oss coefficient	t in W/(K.m <sup>²</sup> )					
EN ISO 9808 (SK datasheet)	a2 =	0.014	Second orde	er collector he	at loss coeffici	ent in W/(K2.	m²)				
EN (SK	IAM =	0.92	Incident an	gle modifier at	50° in -						
	Mcol =	0.023	Collector flo	ow rate in kg/(	s.m <sup>2</sup> )						
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K	•					
	Sol,loc =	HS	Location of	the collector le	oop piping						
	Pcol,pmp =	20	Nominal ele	ectricyt consur	nption collecto	or pump in W					
	Pcol,ctrl =	5	Standby ele	tandby electricity consumption of controller in W							
	Vsto,tot =		Total tank v	olume in litres	5						
	Hsto,tot =			oss rate of the	tank in W/K						
	Htank =	1.7	Height of th	ne tank in m							
	Sto,loc =		Location of	the tank							
	Vsto,automation:				etermine volun	-					
3/4 neet	Hsto, automation:			Method to distribute heat losses over the volumes Method to distribute the internal convection							
977 tasł	Csto,automation:				stribute the in	ternal convec	tion				
EN 12977 3/4 (SK datasheet)	Nvol =	4		tank volumes							
EN (St				p heater		output					
		Solar loop			WHS						
	Rh,inlet =				0%			eight of inlet (%)			
	Rh,outlet =	0%			100%	0%	Height of outlet (%) Height of thermostat position (%)				
	Rh,therm =				0	0					
	Hexch =	345			0	U	Heat exchanger	rate in W/K			
		Color Joon		p heater							
	Ttherm,on =	Solar loop	WHS 75		Thermostat s	etting on in <sup>0</sup>	C				
7-5 ieet)					Thermostat s						
977 ashe	Ttherm,off =					etting ojj in	C				
EN 12977 (SK datash		Design type: tput power:			 Rated heat ou	staut in 14/					
(sk		Control type:				utput m vv					
	Tsto,init =	10	Initial tank	temperature in	n °C						
	Ti,hs =	15	Temperatui	re heated spac	e in °C						
	tci =	1	Calculation	time step in h							
Results:											
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		
	SolTherm	5116	2262	809	-1988	0	-1988	-2797	82		
io	TrnSys	5116	2329	763	-2034	0	-2034	-2797	81		
Validation	ΔQ [kWh]	0	-67	46	46	0	46	0	1		
Va	ΔQ [%]	0.0%	2.4%	-1.7%	-1.7%	0.0%	-1.7%	0.0%	0.0%		
			Fchart:	832	EN 15316-4-3	3, method 2					
			∆Q [%]:	0.8%							

ΔQ [%]: 0.8%

6

	Climate:	ErP_AVG				Reference cli	mate region					
W	ater heating service:	ErP_PH_I_X	Ľ			Water heatin	ig sequence					
Sp	bace heating service:	None				Space heatin	g sequence					
	Asol =	3.782	Total collect	tor reference d	area in m <sup>2</sup>							
08 tet)	Eo =	0.791	Zero loss col	llector efficien	cy in -							
EN ISO 9808 SK datasheet	a1 =	3.77	First order c	ollector heat l	oss coefficien	t in W/(K.m <sup>2</sup> )						
ISO data	a2 =	0.014	Second orde	er collector he	at loss coeffici	ient in W/(K2.	m²)					
EN ISO 9808 (SK datasheet)	IAM =	0.92	Incident ang	gle modifier at	50° in -							
	Mcol =	0.023	Collector flo	w rate in kg/(.	s.m <sup>2</sup> )							
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K							
	Sol,loc =	HS	Location of t	the collector lo	oop piping							
	Pcol,pmp =	20	Nominal ele	ctricyt consun	nption collecto	or pump in W						
	Pcol,ctrl =	5	Standby elec	ctricity consur	nption of cont	roller in W						
	Vsto,tot =	225	Total tank v	olume in litres	5							
	Hsto,tot =	1.67	Total heat lo	oss rate of the	tank in W/K							
	Htank =	1.7	Height of th	e tank in m								
	Sto,loc =	HS	Location of t	the tank								
	Vsto,automation:	Automation	ı	Method to de	etermine volur	mes of the tan	k					
3/4 eet)	Hsto,automation:	Automation	ı	Method to di	stribute heat l	losses over the	e volumes					
977 ash	Csto,automation:	Automation	ı	Method to di	stribute the in	ternal convec	tion					
EN 12977 3/4 (SK datasheet)	Nvol =	4	Number of t	ank volumes								
EN (SK			Backup	o heater	Heat	output						
		Solar loop	WHS	SHS	WHS	SHS						
	Rh,inlet =	49%	0%	0%	0%	0%	Height of inlet (	Height of inlet (%)				
	Rh,outlet =		0%	0%	100%	0%	Height of outlet (%)					
	Rh,therm =		50%	50%				ostat position (%)				
	Hexch =	345	0	0	0	0	Heat exchanger	rate in W/K				
			Backup	o heater								
		Solar loop	WHS	SHS								
7-5 ieet)	Ttherm,on =		75		Thermostat s							
77-5 sheet	Ttherm,off =	80	75	0	Thermostat s	etting off in °	С					
EN 1297 <sup>.</sup> K datash		Design type:	Serial	Not used								
EN 1297. (SK datash		tput power:	24		Rated heat of	utput in W						
		Control type:	Repeat	Repeat								
	Tsto,init =	10	Initial tank t	emperature ir	∩ °C							
	Ti,hs =		Temperatur	e heated spac	e in °C							
	tci =	1	Calculation	time step in h								
Results:			ſ									
		Qirr			Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux			
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh			
	SolTherm	5116	2631	1914	-2497	0	-2497	-4411	90			
ion	TrnSys	5116	2728	1832	-2578	0	-2578	-4411	87			
Validation	ΔQ [kWh]	0	-97	82	82	0	82	0	3			
- Va	ΔQ [%]	0.0%	2.2%	-1.9%	-1.9%	0.0%	-1.9%	0.0%	-0.1%			
			Fchart:	1984	EN 15316-4-3	3, method 2						
			۸Ο [%]:	1.6%								

ΔQ [%]: 1.6%

7

	Climate:	ErP_AVG				Reference cli	mate region				
W	ater heating service:	ErP_SPS_I_	L			Water heatin	ig sequence				
	bace heating service:					Space heatin					
	Asol =	3.782	Total collect	tor reference d	area in m <sup>2</sup>						
08 et)	Eo =	0.791	Zero loss co	llector efficien	icy in -						
980 Ishe	a1 =	3.77	First order c	ollector heat l	loss coefficient	t in W/(K.m <sup>2</sup> )					
EN ISO 9808 SK datasheet	a2 =	0.014	Second orde	er collector he	at loss coeffici	ent in W/(K2.	m²)				
EN ISO 9808 (SK datasheet)	IAM =	0.92	Incident ang	gle modifier at	:50° in -						
	Mcol =	0.023	Collector flo	w rate in kg/(	s.m <sup>2</sup> )						
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K						
	Sol,loc =	HS	Location of	the collector le	oop piping						
	Pcol,pmp =	20	Nominal ele	Nominal electricyt consumption collector pump in W							
	Pcol,ctrl =	5	Standby ele	tandby electricity consumption of controller in W							
	Vsto,tot =	225	Total tank v	olume in litres	5						
	Hsto,tot =	1.67	Total heat le	oss rate of the	tank in W/K						
	Htank =	1.7	Height of th	e tank in m							
	Sto,loc =	HS	Location of	the tank							
_	Vsto,automation:	Automation	ı	Method to de	etermine volun	mes of the tank					
3/4 eet)	Hsto, automation:	Automation	ı	Method to di	stribute heat l	osses over the	e volumes				
EN 12977 3/4 (SK datasheet)	Csto,automation:	Automation	۱	Method to di	stribute the in	ternal convec	tion				
129 ( dat	Nvol =	4	Number of t	ank volumes							
EN (SK			Backu	p heater	Heat o	output					
		Solar loop	WHS	SHS	WHS	SHS					
	Rh,inlet =		0%	0%	0%	0%	Height of inlet (				
	Rh,outlet =	0%	0%	0%	100%	0%	Height of outlet	(%)			
	Rh,therm =		50%	50%				ostat position (%)			
	Hexch =	345	0	0	0	0	Heat exchanger	rate in W/K			
				p heater							
		Solar loop	WHS	SHS							
r-5 eet)	Ttherm,on =		75		Thermostat s						
177- she	Ttherm,off =		75	0	Thermostat s	etting off in °	С				
EN 12977 SK datash		Design type:		Not used	••						
EN 12977 (SK datash		tput power: Control type:			Rated heat ou	utput in W					
	Tsto,init =			emperature ii							
	Ti,hs =			e heated spac							
Results:	tci =	1	Calculation	time step in h							
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
		kWh	kWh	kWh	kWh	kWh		kWh	kWh		
	SolTherm	5116		1034	-1756	0		-2791	78		
u	TrnSys	5116	2191	948	-1843	0	-1843	-2791	79		
Validation	ΔQ [kWh]	0	-101	87	87	0	87	0	0		
Val	ΔQ [%]	0.0%	3.6%	-3.1%	-3.1%	0.0%	-3.1%	0.0%	0.0%		
			Fchart:	1158	EN 15316-4-3	3, method 2					
			ΔΟ [%]:	4.4%							

ΔQ [%]: 4.4%

8

	Climate:	ErP_AVG				Reference clii	mate region			
W	ater heating service:	ErP_SPS_I_2	ХL			Water heating sequence				
Sp	bace heating service:	None				Space heating	g sequence			
	Asol =	3.782	Total collect	tor reference d	area in m <sup>2</sup>					
)8 et)	Eo =	0.791	Zero loss co	llector efficien	cy in -					
EN ISO 9808 (SK datasheet)	a1 =	3.77	First order c	ollector heat l	oss coefficient	t in W/(K.m <sup>2</sup> )				
lSO dati	a2 =	0.014	Second orde	er collector he	at loss coeffici	ent in W/(K2.ı	m²)			
EN (SK	IAM =	0.92	Incident ang	gle modifier at	50° in -					
	Mcol =	0.023	Collector flo	w rate in kg/(	s.m <sup>2</sup> )					
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K					
	Sol,loc =	HS	Location of	the collector lo	oop piping					
	Pcol,pmp =	20	Nominal ele	ctricyt consun	nption collecto	or pump in W				
	Pcol,ctrl =	5	Standby ele	tandby electricity consumption of controller in W						
	Vsto,tot =	225	Total tank v	olume in litres	ī					
	Hsto,tot =	1.67	Total heat lo	oss rate of the	tank in W/K					
	Htank =	1.7	Height of th	e tank in m						
	Sto,loc =	HS	Location of	the tank						
	Vsto,automation:	Automation	ı	Method to de	etermine volur	nes of the tan	k			
3/4 eet)	Hsto,automation:	Automation	ı	Method to dis	stribute heat l	osses over the	volumes			
EN 12977 3/4 (SK datasheet)	Csto,automation:	Automation	1	Method to di	stribute the in	ternal convect	tion			
129 dat	Nvol =	4	Number of t	ank volumes						
EN (SK			Backu	o heater	Heat o	output				
		Solar loop	WHS	SHS	WHS	SHS				
	Rh,inlet =	49%	0%	0%	0%		Height of inlet (%) Height of outlet (%)			
	Rh,outlet =	0%	0%	0%	100%	0%				
	Rh,therm =	100%	50%	50%				ostat position (%)		
	Hexch =	345	0	0	0	0	Heat exchanger	rate in W/K		
				o heater						
		Solar loop	WHS	SHS		0	~			
7-5 ieet)	Ttherm,on =		75		Thermostat s					
EN 12977-5 šK datasheet	Ttherm,off =	80			Thermostat s	etting off in	C			
EN 1297 <sup>.</sup> (SK datash		Design type:	Serial	Not used						
(SK		tput power: control type:	24 Repeat		Rated heat of	utput in vv				
				Repeat						
	Tsto,init =			emperature ir						
	Ti,hs =			e heated spac	e in °C					
	tci =	1	Calculation	time step in h						
Results:		0:		FOL	<u>Oh</u>		50.1	501	0	
		Qirr		ΣQbu	Qhw;out			ΣQload;req	Qaux	
	ColTherre	kWh	kWh	kWh	kWh		kWh	kWh	kWh	
<u>ر</u>	SolTherm	5116 5116	2490 2614	2120 2001	-2295 -2414	0	-2295 -2414	-4415 -4415	88 86	
Validation	TrnSys					0				
/alid	ΔQ [kWh]	0.0%	-124	119	119		119	0	2	
-	ΔQ [%]	0.0%		-2.7%	-2.7%	0.0%	-2.7%	0.0%	-0.1%	
			Fchart: ΔQ [%]:		EN 15316-4-3	s, metrioa 2				
				3.8%	1					

ΔQ [%]: 3.8%

	Climate:	ErP_AVG				Reference cli	mate region				
W	ater heating service:	ErP_SPS_I_I	L			Water heatin	ig sequence				
S	pace heating service:	None				Space heatin	g sequence				
	Asol =	4.02	Total collec	tor reference d	area in m <sup>2</sup>						
08 eet)	Eo =	0.8	Zero loss co	llector efficien	cy in -						
) 98 ashe	a1 =	3.99	First order o	collector heat l	oss coefficien	t in W/(K.m <sup>²</sup> )					
EN ISO 9808 (SK datasheet)	a2 =	0.0138	Second orde	er collector he	at loss coeffici	ient in W/(K2.	m²)				
EN (SK	IAM =	0.91	Incident an	gle modifier at	50° in -						
	Mcol =	0.017	Collector flo	ow rate in kg/(	s.m <sup>2</sup> )						
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/k	C					
	Sol,loc =	HS	Location of	the collector le	oop piping						
	Pcol,pmp =	20	Nominal ele	ominal electricyt consumption collector pump in W							
	Pcol,ctrl =	5	Standby ele	andby electricity consumption of controller in W							
	Vsto,tot =	250	Total tank v	olume in litres	5						
	Hsto,tot =	1.67	Total heat l	oss rate of the	tank in W/K						
	Htank =	1.7	Height of th	ne tank in m							
	Sto,loc =		Location of								
+	Vsto,automation:					mes of the tan					
EN 12977 3/4 (SK datasheet)	Hsto,automation:					losses over the					
1977 Itasl	Csto,automation:				stribute the in	ternal convec	tion				
N 12 K da	Nvol =	6		tank volumes	Uset						
E (S		Solar loop	WHS	p heater SHS	WHS	output SHS					
	Rh,inlet =	36%	81%		0%		Height of inlet (	0/ )			
	Rh,outlet =	0%	60%		100%			leight of outlet (%)			
	Rh,therm =		60%		10070	070	Height of thermostat position (%)				
	Hexch =		517		0	0	Heat exchanger				
			Backu	p heater							
		Solar loop	WHS								
-	 Ttherm,on =		60	0	Thermostat s	etting on in $^{\circ}$	С				
7-5 neet)	Ttherm,off =	90	65	0	Thermostat s	etting off in $^{\circ}$	С				
.297 Itasł	I	Design type:	Parallel	Not used							
EN 1297. (SK datash	Rated ou	tput power:	20	0	Rated heat o	utput in W					
- (S	C	ontrol type:	Repeat	Repeat							
	Tsto,init =	10	Initial tank	temperature ii	n °C						
	Ti,hs =	15	Temperatui	re heated spac	e in °C						
	tci =	1	Calculation	time step in h							
Results:											
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		
	SolTherm	5438	2010		-2791	0		-2791	75		
tion	TrnSys	5438	2108		-2791	0	-2791	-2791	59		
Validation	ΔQ [kWh]	0	-98	100	0	0	0	0	17		
2º	ΔQ [%]	0.0%	3.5%	-3.6%	0.0%	0.0%	0.0%	0.0%	-0.6%		
			Fchart:	1164	EN 15316-4-3	3, method 2					
			ΔQ [%]:	-4.6%							

ΔQ [%]: -4.6%

	Climate:	ErP_AVG				Reference cli	mate region			
W	ater heating service:	ErP_SPS_I_X	ХL			Water heatin	g sequence			
Sp	ace heating service:	None				Space heatin	g sequence			
	Asol =	4.02	Total collect	tor reference d	area in m <sup>2</sup>					
38 tet)	Eo =	0.8	Zero loss co	llector efficien	icy in -					
98( ishe	a1 =	3.99	First order c	ollector heat l	loss coefficient	t in W/(K.m <sup>2</sup> )				
EN ISO 9808 (SK datasheet)	a2 =	0.0138	Second orde	er collector he	at loss coeffici	ent in W/(K2.i	m²)			
EN (SK	IAM =	0.91	Incident ang	gle modifier at	:50° in -					
	Mcol =	0.017	Collector flo	w rate in kg/(	s.m <sup>2</sup> )					
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K					
	Sol,loc =	HS	Location of	the collector le	oop piping					
	Pcol,pmp =	20	Nominal ele	ctricyt consum	nption collecto	or pump in W				
	Pcol,ctrl =	5	Standby ele	ctricity consur	nption of cont	roller in W				
	Vsto,tot =	250	Total tank v	olume in litres	5					
	Hsto,tot =	1.67	Total heat lo	oss rate of the	tank in W/K					
	Htank =	1.7	Height of th	e tank in m						
	Sto,loc =	HS	Location of	the tank						
	Vsto,automation:	Automation	ı	Method to determine volumes of the tank						
EN 12977 3/4 (SK datasheet)	Hsto, automation:	Automation	1	Method to di	stribute heat l	osses over the	volumes			
977 ash	Csto, automation:	Automation	ı	Method to di	stribute the in	ternal convect	tion			
129 dat	Nvol =	6	Number of t	ank volumes						
EN (SK			Backu	o heater	Heat o	output				
		Solar loop	WHS	SHS	WHS	SHS				
	Rh,inlet =	36%	81%	0%	0%	0%	Height of inlet (	of inlet (%)		
	Rh,outlet =	0%	60%	0%	100%	0%	Height of outle	t (%)		
	Rh,therm =		60%	50%			Height of thern	nostat position (%)		
	Hexch =	486	517	0	0	0	Heat exchange	r rate in W/K		
				o heater						
		Solar loop	WHS	SHS						
-5 tet)	Ttherm,on =		60		Thermostat s	-				
	Ttherm,off =		65	0	Thermostat s	etting off in <sup>0</sup>	С			
EN 12977 SK datashe		Design type:	Parallel	Not used						
EN 12977 (SK datashe		tput power:	20		Rated heat ou	utput in W				
)	- C	control type:	Repeat	Repeat						
	Tsto,init =	10	Initial tank t	emperature ii	n °C					
	Ti,hs =	15	Temperatur	e heated spac	e in °C					
	tci =	1	Calculation	time step in h						
Results:										
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux	
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
	SolTherm	5438	2381	2452		0	-4415	-4415	83	
tion	TrnSys	5438	2509	2325	-4415	0	-4415	-4415	69	
Validation	ΔQ [kWh]	0	-128	127	0	0	0	0	14	
< S	ΔQ [%]	0.0%	2.9%	-2.9%	0.0%	0.0%	0.0%	0.0%	-0.3%	
			Fchart:	2315	EN 15316-4-3	3, method 2				
				2 10/						

ΔQ [%]: -3.1%

Title:	Solar water heater: 4
RunID:	TrnSys_4:

	Climate:	ErP_AVG				Reference cli	mate region				
Wa	ater heating service:	ErP_PH_I_L				Water heatin	g sequence				
Sp	ace heating service:	None				Space heatin	g sequence				
	Asol =	2.37	Total collect	tor reference d	area in m <sup>2</sup>						
)8 et)	Eo =			llector efficien							
EN ISO 9808 (SK datasheet)	a1 =	3.62	First order d	collector heat l	oss coefficient	t in W/(K.m <sup>2</sup> )					
ISO data	a2 =	0.016	Second orde	er collector he	at loss coeffici	ent in W/(K2.I	m²)				
EN (SK o	IAM =	0.93	Incident ang	gle modifier at	50° in -						
	Mcol =	0.037	Collector flo	w rate in kg/(	s.m <sup>2</sup> )						
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K						
	Sol,loc =	HS	Location of	the collector lo	oop piping						
	Pcol,pmp =	20	Nominal ele	ectricyt consun	nption collecto	or pump in W					
	Pcol,ctrl =	5	Standby ele	ctricity consur	nption of cont	roller in W					
	Vsto,tot =	123.5	Total tank v	olume in litres	5						
	Hsto,tot =	1.39	Total heat l	oss rate of the	tank in W/K						
	Htank =	0.5	Height of th	e tank in m							
	Sto,loc =	HS	Location of	the tank							
	Vsto,automation:	Automation	1	Method to de	etermine volun	nes of the tan	k				
3/4 eet)	Hsto, automation:	Automation	1	Method to di	stribute heat l	osses over the	volumes				
ashe	Csto,automation:	Automation	1	Method to di	stribute the in	ternal convect	tion				
EN 12977 3/4 (SK datasheet)	Nvol =	4	Number of t	tank volumes							
EN (SK			Backu	p heater	Heat o	output					
		Solar loop	WHS	SHS	WHS	SHS					
	Rh,inlet =	69%	0%	0%	0%	0%	Height of inlet (	ght of inlet (%)			
	Rh,outlet =	0%	0%	0%	100%	0%	Height of outlet (%)				
	Rh,therm =	100%	50%	50%			Height of therm	ostat position (%)			
	Hexch =	497	517	0	0	0	Heat exchanger	rate in W/K			
			Backu	p heater							
		Solar loop	WHS	SHS							
if)	Ttherm,on =		60	0	Thermostat s	etting on in °	С				
77-5 sheet)	Ttherm,off =	80	65	0	Thermostat s	etting off in $^{\circ}$	С				
EN 1297 SK datash	I	Design type:	Serial	Not used							
EN 12977 (SK datash	Rated ou	tput power:	20	0	Rated heat ou	utput in W					
<u> </u>	C	ontrol type:	Repeat	Repeat							
	Tsto,init =	10	Initial tank t	temperature ir	n °C						
	Ti,hs =	15	Temperatur	re heated spac	e in °C						
	tci =	1	Calculation	time step in h							
Results:											
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		
	SolTherm	3206	1703	1244	-1553	0	-1553	-2797	84		
ion	TrnSys	3206	1696	1248	-1549	0	-1549	-2797	70		
Validation	ΔQ [kWh]	0	6	-4	-4	0	-4	0	14		
Val	ΔQ [%]	0.0%	-0.2%	0.2%	0.2%	0.0%	0.2%	0.0%	-0.5%		
			Fchart:	1171	EN 15316-4-3	3, method 2					
			۸0 [%]∙	-2.6%							

∆Q [%]: -2.6%

	Climate:	ErP_AVG				Reference climate region					
W	ater heating service:	ErP_PH_I_X	L			Water heatin	ig sequence				
S	pace heating service:	None				Space heatin	g sequence				
	Asol =	2.37	Total collec	tor reference a	area in m <sup>2</sup>						
38 tet)	Eo =	0.842	Zero loss co	llector efficien	cy in -						
EN ISO 9808 (SK datasheet)	a1 =	3.62	First order d	collector heat l	loss coefficient	in W/(K.m <sup>2</sup> )					
ISO data	a2 =	0.016	Second orde	er collector hea	at loss coefficie	ent in W/(K2.	m²)				
EN (SK	IAM =	0.93	Incident ang	gle modifier at	50° in -						
	Mcol =	0.037	Collector flo	ow rate in kg/(	s.m <sup>2</sup> )						
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K						
	Sol,loc =	HS	Location of	the collector lo	oop piping						
	Pcol,pmp =	20	Nominal ele	ectricyt consun	nption collecto	or pump in W					
	Pcol,ctrl =	5	Standby ele	ctricity consun	nption of conti	roller in W					
	Vsto,tot =	123.5	Total tank v	olume in litres	5						
	Hsto,tot =	1.39	Total heat l	oss rate of the	tank in W/K						
	Htank =	0.5	Height of th	ne tank in m							
	Sto,loc =	HS	Location of	the tank							
	Vsto,automation:	Automation	1	Method to de	etermine volun	nes of the tan	k				
3/4 :et)	Hsto,automation:	Automation	ı	Method to distribute heat losses over the volumes							
EN 12977 3/4 (SK datasheet)	Csto,automation:	Automation	ı	Method to dis	stribute the int	ternal convec	tion				
129 data	Nvol =	4	Number of	tank volumes							
EN (SK			Backu	p heater	Heat c	output					
		Solar loop	WHS	SHS	WHS	SHS					
	Rh,inlet =	69%	0%	0%	0%	0%	Height of inlet (%	%)			
	Rh,outlet =	0%	0%	0%	100%	0%	Height of outlet (%)				
	Rh,therm =	100%	50%	50%			Height of therm	ostat position (%)			
	Hexch =	497	517	0	0	0	Heat exchanger	rate in W/K			
			Backu	p heater							
		Solar loop	WHS	SHS							
÷.	Ttherm,on =		60	0	Thermostat se	etting on in $^{\circ}$	С				
EN 12977-5 šK datasheet)	Ttherm,off =	80	65	0	Thermostat se	etting off in $^{ m o}$	С				
129 atas	I	Design type:	Serial	Not used							
EN 12977 (SK datash	Rated ou	tput power:	20	0	Rated heat ou	itput in W					
5	C	ontrol type:	Repeat	Repeat							
	Tsto,init =	10	Initial tank	temperature ir	∩ °C						
	Ti,hs =	15	Temperatur	re heated spac	e in °C						
	tci =	1	Calculation	time step in h							
Results:											
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qau		
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWl		
	SolTherm	3206	1772	2718	-1693	0	-1693	-4411	80		
uo	TrnSys	3206	1794	2691	-1720	0	-1720	-4411	69		
Validation	ΔQ [kWh]	0	-22	27	27	0	27	0	1		
Val	ΔQ [%]	0.0%	0.5%	-0.6%	-0.6%	0.0%	-0.6%	0.0%	-0.4%		

	Climate:	ErP_AVG				Reference cli	mate region				
W	ater heating service:	ErP_SPS_I_I	L			Water heatin	g sequence				
S	pace heating service:	None				Space heatin	g sequence				
	Asol =	2.37	Total collec	tor reference o	area in m <sup>2</sup>						
08 eet)	Eo =	0.842	Zero loss co	llector efficien	icy in -						
EN ISO 9808 (SK datasheet)	a1 =	3.62	First order d	collector heat	loss coefficient	t in W/(K.m <sup>2</sup> )					
ISC dati	a2 =	0.016	Second orde	er collector he	at loss coeffici	ent in W/(K2.	m²)				
EN (SK	IAM =	0.93	Incident an	gle modifier at	:50° in -						
	Mcol =	0.037	Collector flo	ow rate in kg/(	's.m <sup>2</sup> )						
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K						
	Sol,loc =	HS	Location of	the collector l	oop piping						
	Pcol,pmp =	20	Nominal ele	ectricyt consur	nption collecto	or pump in W					
	Pcol,ctrl =	5	Standby ele	tandby electricity consumption of controller in W							
	Vsto,tot =			olume in litres							
	Hsto,tot =			oss rate of the	tank in W/K						
	Htank =		Height of th								
	Sto,loc =		Location of	the tank							
	Vsto,automation:			Method to determine volumes of the tank Method to distribute heat losses over the volumes							
3/4 ieet	Hsto, automation:										
977 tasł	Csto,automation:				stribute the in	ternal convec	tion				
EN 12977 3/4 (SK datasheet)	Nvol =	4		tank volumes							
(St E				p heater		output					
		Solar loop	WHS		WHS	SHS					
	Rh,inlet =		0%		0%		Height of inlet (				
	Rh,outlet =	0%	0%		100%	0%	Height of outlet				
	Rh,therm =							ostat position (%)			
	Hexch =	497	517		0	0	Heat exchanger	rate in W/K			
				p heater							
		Solar loop	WHS								
r-5 eet)	Ttherm,on =		60		Thermostat s						
EN 12977-5 šK datasheel	Ttherm,off =				Thermostat s	etting off in °	С				
129 lata		Design type:									
EN 12977 (SK datash		tput power: Control type:			Rated heat of	utput in W					
	 Tsto,init =			temperature ii							
	Ti,hs =			re heated space							
	tci =			time step in h	enn c						
Results:		1	culculution	time step in n							
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		
	SolTherm	3206	1604	1377	-1414	0	-1414	-2791	81		
uo	TrnSys	3206	1601	1373	-1418	0	-1418	-2791	68		
Validation	ΔQ [kWh]	0	3	4	4	0	4	0	13		
Val	ΔQ [%]	0.0%	-0.1%	-0.2%	-0.2%	0.0%	-0.2%	0.0%	-0.5%		
			Fchart:	1392	EN 15316-4-3	3, method 2					
			AO [%]:	0.5%							

ΔQ [%]: 0.5%

Climate: ErP_AVG						Reference climate region						
W	ater heating service:	ErP_SPS_I_X	XL			Water heating sequence						
Sr	pace heating service:	None				Space heating	g sequence					
	Asol =	2.37	Total collec	tor reference d	area in m <sup>2</sup>							
08 tet)	Eo =	0.842	Zero loss co	Zero loss collector efficiency in -								
EN ISO 9808 (SK datasheet)	a1 =	3.62	First order d	collector heat l	loss coefficient	t in W/(K.m <sup>2</sup> )						
ISC dat:	a2 =	0.016	Second orde	er collector he	at loss coeffici	ent in W/(K2.I	m²)					
EN (SK	IAM =	0.93	Incident ang	gle modifier at	50° in -							
	Mcol =	0.037	Collector flo	ow rate in kg/(	s.m <sup>2</sup> )							
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K							
	Sol,loc =	HS	Location of	ocation of the collector loop piping								
	Pcol,pmp =	20	Nominal ele	Iominal electricyt consumption collector pump in W								
	Pcol,ctrl =	5	Standby ele	ctricity consur	nption of cont	roller in W						
	Vsto,tot =	123.5	Total tank v	otal tank volume in litres								
	Hsto,tot =	1.39	Total heat loss rate of the tank in W/K									
	Htank =	0.5	Height of the tank in m									
	Sto,loc =	HS	Location of	the tank								
	Vsto,automation:	Automation	1	Method to de	etermine volun	nes of the tan	nk					
3/4 eet)	Hsto,automation:	Automation	Method to distribute heat losses over the volumes									
977 ash	Csto,automation:	Automation	1	Method to di	distribute the internal convection							
EN 12977 3/4 (SK datasheet)	Nvol =	4	Number of tank volumes									
EN (SK				p heater	Heat output							
		Solar loop	WHS		WHS	SHS						
	Rh,inlet =	69%	0%		0%		Height of inlet (%)					
	Rh,outlet =	0%	0%		100%	0%	Height of outlet (%)					
	Rh,therm =	100%	50%				Height of thermostat position (%)					
	Hexch =	497	517	0	0	0	0 Heat exchanger rate in W/K					
				p heater								
		Solar loop	WHS									
r-5 eet)	Ttherm,on =		60		0 Thermostat setting on in ° C							
977- Ishe	Ttherm,off =		65 0 Thermostat setting off in ° C									
EN 12977 (SK datashe		Design type:	Serial									
EN (SK i	Rated output power:		20		0 Rated heat output in W							
	Control type:		Repeat									
	Tsto,init =			temperature ir								
	Ti,hs =		Temperature heated space in °C									
	tci =	1	Calculation	time step in h								
Results:		0:	Quala	501	Ohumant	O alta aut	50 th a st	501	0			
		Qirr	Qsolar		Qhw;out			ΣQload;req	Qau			
		kWh	kWh		kWh	kWh	kWh	kWh	kWl			
	SolTherm	3206	1725			0	-1619	-4415	8			
Validation	TrnSys	3206	1742		-1646	0		-4415	7(			
/alid	ΔQ [kWh]	0	-17			0		0	1			
~	ΔQ [%]	0.0%	0.4%	-0.6%	-0.6%	0.0%	-0.6%	0.0%	-0.3%			
-			Fchart:		EN 15316-4-3							

	Climate:	ErP_AVG				Reference cli	mate region						
Water heating service: ErP_SPS_			L			Water heating sequence							
	pace heating service:				Space heating sequence								
	Asol =	7.05	Total collec	tor reference d	area in m <sup>2</sup>								
8 et)	Eo =	0.79	Zero loss collector efficiency in -										
980 shei	a1 =			collector heat l	,	t in W/(K.m <sup>2</sup> )							
EN ISO 9808 SK datasheet	a2 =			er collector he									
EN ISO 9808 (SK datasheet)	IAM =	0.95	Incident an	gle modifier at	50° in -								
Ŭ	Mcol =	0.011	Collector flo	ow rate in kg/(	s.m <sup>2</sup> )								
	Hsol,loop =	4 20	Host lossos	collector loop	nining in W//V								
	Sol,loc =			the collector lo									
	Pcol,pmp =		-	ectricyt consun		or numn in W							
	Pcol,ctrl =												
	Vsto,tot =			tandby electricity consumption of controller in W									
	Hsto,tot =			otal tank volume in litres otal heat loss rate of the tank in W/K									
	Htank =			otal neat loss rate of the tank in W/K leight of the tank in m									
	Sto,loc =		Location of										
	Vsto,automation:				etermine volun	nes of the tan	nk						
/4 et)	Hsto,automation:				termine volumes of the tank stribute heat losses over the volumes								
7 3, shee	Csto,automation:			Method to di									
EN 12977 3/4 (SK datasheet)	Nvol =			tank volumes									
EN 1 SK 0				p heater	Heat o	output							
)		Solar loop			WHS	SHS							
	Rh,inlet =	62%		0%	0%	0%	Height of inlet (%)						
	Rh,outlet =	0%	68%	0%	100%	0%	Height of outlet (%) Height of thermostat position (%) Heat exchanger rate in W/K						
	Rh,therm =	100%	68%	50%									
	Hexch =	445	354	0	0	0							
			Backu	p heater									
		Solar loop	WHS	SHS									
î, î	Ttherm,on =		60	0	Thermostat s	etting on in $^{\circ}$	С						
77-5 :heet)	Ttherm,off =	75	65	0	Thermostat setting off in ° C								
EN 1297 SK datash	I	Design type:	Parallel Serial										
EN 1297. (SK datash	Rated ou	tput power:	20	0	Rated heat output in W								
<u> </u>	C	Control type:		Repeat	••								
	Tsto,init =	10	Initial tank	temperature ir	∩ °C								
	Ti,hs =	15	Temperature heated space in °C										
	tci =	1	Calculation	time step in h									
Results:													
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux				
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh				
	SolTherm	9537	2675	970	-2791	0	-2791	-2791	60				
ion	TrnSys	9537	2646	974	-2791	0	-2791	-2791	64				
Validation	ΔQ [kWh]	0	29	-4	0	0	0	0	-4				
Va	ΔQ [%]	0.0%	-1.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%				
			Fchart:	871	EN 15316-4-3	3, method 2							
			ΔQ [%]:	-3.6%									

ΔQ [%]: -3.6%

	Climate:	ErP_AVG				Reference cli	mate region				
Water heating service: ErP_SPS						Water heating sequence					
	bace heating service:		Space heating sequence								
	Asol =	7.05	Total collector reference area in m <sup>2</sup>								
)8 et)	Eo =	0.79	Zero loss collector efficiency in -								
EN ISO 9808 SK datasheet	a1 =	3.721	First order d	collector heat l	oss coefficien	t in W/(K.m <sup>2</sup> )					
ISO data	a2 =	0.016	Second orde	er collector he	at loss coeffici	ent in W/(K2.	m²)				
EN ISO 9808 (SK datasheet)	IAM =	0.95	Incident an	gle modifier at	50° in -						
)	Mcol =	0.011	Collector flo	ow rate in kg/(.	s.m <sup>2</sup> )						
	Hsol,loop =	4.29	Heat losses	collector loop	piping in W/K						
	Sol,loc =	HS	Location of the collector loop piping								
	Pcol,pmp =	20	Nominal electricyt consumption collector pump in W								
	Pcol,ctrl =	5	Standby electricity consumption of controller in W								
	Vsto,tot =	391	Total tank v	iotal tank volume in litres							
	Hsto,tot =	2.5	Fotal heat loss rate of the tank in W/K								
EN 12977 3/4 (SK datasheet)	Htank =	1.24	Height of th	eight of the tank in m							
	Sto,loc =	HS	Location of	the tank							
	Vsto,automation:	Automation				nes of the tan	k				
	Hsto, automation:	Automation	n Method to distribute			ute heat losses over the volumes					
	Csto,automation:	Automation	Method to distribute the internal convection								
129 dat	Nvol =	6	Number of	tank volumes							
EN (SK			Backu	p heater	Heat	output					
		Solar loop	WHS	SHS	WHS	SHS					
	Rh,inlet =	62%	76%	0%	0%	0%	Height of inlet (%) Height of outlet (%)				
	Rh,outlet =	0%	68%	0%	100%	0%					
	Rh,therm =	100%	68%				Height of thermostat position (%)				
	Hexch =	445	354	0	0	0	Heat exchanger	rate in W/K			
				p heater							
		Solar loop	WHS								
et)	Ttherm,on =		60		Thermostat s						
EN 12977-5 SK datasheet	Ttherm,off =	75	65	0	Thermostat s						
129 lata		Design type:									
EN 12977-5 (SK datasheet)	Rated output power:				Rated heat of	utput in W					
		control type:									
	Tsto,init =			temperature ir							
	Ti,hs =			re heated spac	e in °C						
	tci =	1	Calculation	time step in h							
Results:				· · · · · · · · · · · · · · · · · · ·			1				
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		
	SolTherm	9537	3353		-4415	0	-4415	-4415	71		
ion	TrnSys	9537	3373	1765	-4415	0	-4415	-4415	74		
Validation	ΔQ [kWh]	0	-21	34	0	0	0	0	-3		
Va	ΔQ [%]	0.0%	0.5%	-0.8%	0.0%	0.0%	0.0%	0.0%	0.1%		
			Fchart:	1659	EN 15316-4-3	3, method 2					
			AO [%]:	-3.2%							

ΔQ [%]: -3.2%

Title: Buffer-Combi ITW RunID: TrnSys\_7:SC\_Par

	Climate:	WB_S_45				Reference cli	mate region				
W	/ater heating service:	heat_Combi			Water heatin	ig sequence					
S	pace heating service:	ITW_NE50				Space heatin	g sequence				
	Asol =	13.98	Total collector reference area in m <sup>2</sup>								
08 eet)	Eo =	0.777	Zero loss co	llector efficien	cy in -						
980 ashe	a1 =	4.026	First order d	ollector heat l	oss coefficient	t in W/(K.m <sup>2</sup> )					
EN ISO 9808 (SK datasheet)	a2 =	0.01	Second orde	er collector hed	at loss coefficie	ent in W/(K2.	m²)				
EN (SK	IAM =	0.988	Incident ang	gle modifier at	50° in -						
	Mcol =	0.011	Collector flo	w rate in kg/(	s.m <sup>2</sup> )						
	Hsol,loop =	4.84	Heat losses	collector loop	piping in W/K						
	Sol,loc =		Location of	ocation of the collector loop piping							
	Pcol,pmp =	20 Nominal electricyt consumption collector pump in W									
	Pcol,ctrl =			ctricity consun							
	Vsto,tot =	956.3	Total tank v	olume in litres							
	Hsto,tot =		Total heat le	oss rate of the	tank in W/K						
	, Htank =		Height of th	2	,						
	Sto,loc =		Location of								
	Vsto,automation:		-	Method to determine volumes of the tank							
/4 et)	Hsto, automation:				stribute heat lo	-					
EN 12977 3/4 (SK datasheet)	Csto,automation:			Method to dis							
	Nvol =			nber of tank volumes							
EN 1 SK d				p heater	Heat c	output					
		Solar loop	WHS		WHS	SHS					
	Rh,inlet =		100%	50%	0%	26%	Height of inlet (S				
	Rh,outlet =	0%	50%	30%	95%		Height of outlet (%)				
	Rh,therm =	40%	50%	30%			Height of thermostat position (%)				
	Hexch =	1444	0	0	1019	0	Heat exchanger rate in W/K				
			Backu	p heater							
		Solar loop	WHS	SHS							
	Ttherm,on =		48	37	Thermostat setting on in ° C						
'7-5 heet)	Ttherm,off =		55	40	Thermostat se	etting off in $^{\circ}$	С				
EN 1297 (SK datash		Design type:	Parallel	Parallel							
<pre>C 1 C da</pre>	Rated ou	tput power:	15	15	15 Rated heat output in W						
E (SI	C	Control type:	Repeat								
	Tsto,init =	35	Initial tank t	emperature ir	ı °C						
	Ti,hs =			e heated spac							
	tci =		,	time step in h							
Results:				,							
-		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux		
		kWh	kWh		kWh	kWh		kWh	kWh		
	SolTherm	17190	3866		-2771	-9079		-11853	41		
Ľ	TrnSys	17193	3736		-2797	-9088		-11853	53		
Validation	ΔQ [kWh]	-3	131		26	9		0	-13		
Vali	ΔQ [%]	0.0%	-1.1%		-0.2%	-0.1%		0.0%	0.1%		
			Fchart:		EN 15316-4-3						
			ΔQ [%]:	-11.2%							
			- C [/0].	11.2/0							

kWh         kWh <th></th> <th>Climate:</th> <th>WB_S_45</th> <th></th> <th></th> <th></th> <th>Reference cli</th> <th>mate region</th> <th></th> <th></th>		Climate:	WB_S_45				Reference cli	mate region			
Solution 1         10.00 Total collector reference area in m <sup>2</sup> Bool Solution 1         Coll Collector reference area in m <sup>2</sup> A 3.41 First arder collector head loss coefficient in WV/(Km <sup>2</sup> )           a 2         Coll Collector head loss coefficient in WV/(Km <sup>2</sup> )           A 3.41 First arder collector head loss coefficient in WV/(Km <sup>2</sup> )           A 3.41 First arder collector head loss coefficient in WV/(Km <sup>2</sup> )           A 3.41 First arder collector head loss coefficient in WV/(Km <sup>2</sup> )           A 3.41 First arder collector head loss coefficient in WV/(Km <sup>2</sup> )           A 3.41 First arder collector head loss coefficient in WV/(Km <sup>2</sup> )           Solution 1           Solution 1           Solution 1           Automation Method to distribute head in MV/K           Hat loss coll for the tank in M <th colspant="" mather<="" t<="" th=""><th colspan="2">Water heating service:</th><th>ITW_Prehea</th><th>at_Combi</th><th></th><th></th><th>Water heatin</th><th>ig sequence</th><th></th><th></th></th>	<th colspan="2">Water heating service:</th> <th>ITW_Prehea</th> <th>at_Combi</th> <th></th> <th></th> <th>Water heatin</th> <th>ig sequence</th> <th></th> <th></th>	Water heating service:		ITW_Prehea	at_Combi			Water heatin	ig sequence		
Store         Backup heater           Store         Sold and the sold of the set output in theset output in the set output in	Space heating service: ITW_NE			Space heating sequence							
Mcol =         0.011         Collector flow rate in kg/(s.m <sup>2</sup> )           Hsol,loop =         4.29         Heat losses collector loop piping in W/K           Sol,loc =         NHS         Location of the collector loop piping in W/K           Pcol,pmp =         20         Nominal electricyt consumption collector pump in W           Pcol,tim =         4         Standby electricity consumption of controller in W           Vsto,att =         889         Total tank volume in litres           Hsto,tot =         2.92         Total heat bass rate of the tank in W/K           Sto,loc =         NHS         Location of the tank in m           Sto,loc =         NHS         Method to determine volumes of the tank           Vsto,automation:         Automation         Method to distribute the losses over the volumes           Csto,automation:         Automation         Method to distribute the internal convection           Nvol =         100         Number of tank volumes         SHS           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         50%         50%		Asol =	14.04	Total collec	tor reference a	area in m <sup>2</sup>					
Mcol =         0.011         Collector flow rate in kg/(s.m <sup>2</sup> )           Hsol,loop =         4.29         Heat losses collector loop piping in W/K           Sol,loc =         NHS         Location of the collector loop piping in W/K           Pcol,pmp =         20         Nominal electricyt consumption collector pump in W           Pcol,tim =         4         Standby electricity consumption of controller in W           Vsto,att =         889         Total tank volume in litres           Hsto,tot =         2.92         Total heat bass rate of the tank in W/K           Sto,loc =         NHS         Location of the tank in m           Sto,loc =         NHS         Method to determine volumes of the tank           Vsto,automation:         Automation         Method to distribute the losses over the volumes           Csto,automation:         Automation         Method to distribute the internal convection           Nvol =         100         Number of tank volumes         SHS           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         50%         50%	08 iet)	Eo =	0.845	Zero loss co	llector efficien	cy in -					
Mcol =         0.011         Collector flow rate in kg/(s.m <sup>2</sup> )           Hsol,loop =         4.29         Heat losses collector loop piping in W/K           Sol,loc =         NHS         Location of the collector loop piping in W/K           Pcol,pmp =         20         Nominal electricyt consumption collector pump in W           Pcol,tim =         4         Standby electricity consumption of controller in W           Vsto,att =         889         Total tank volume in litres           Hsto,tot =         2.92         Total heat bass rate of the tank in W/K           Sto,loc =         NHS         Location of the tank in m           Sto,loc =         NHS         Method to determine volumes of the tank           Vsto,automation:         Automation         Method to distribute the losses over the volumes           Csto,automation:         Automation         Method to distribute the internal convection           Nvol =         100         Number of tank volumes         SHS           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         50%         50%	980 ashe	a1 =	4.341								
Mcol =         0.011         Collector flow rate in kg/(s.m <sup>2</sup> )           Hsol,loop =         4.29         Heat losses collector loop piping in W/K           Sol,loc =         NHS         Location of the collector loop piping in W/K           Pcol,pmp =         20         Nominal electricyt consumption collector pump in W           Pcol,tim =         4         Standby electricity consumption of controller in W           Vsto,att =         889         Total tank volume in litres           Hsto,tot =         2.92         Total heat bass rate of the tank in W/K           Sto,loc =         NHS         Location of the tank in m           Sto,loc =         NHS         Method to determine volumes of the tank           Vsto,automation:         Automation         Method to distribute the losses over the volumes           Csto,automation:         Automation         Method to distribute the internal convection           Nvol =         100         Number of tank volumes         SHS           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         49%         0%         97%           Rh,inket =         0%         50%         50%	ISO data	a2 =	<b>0.016</b> Second order collector heat loss coefficient in W/(K2.m <sup>2</sup> )								
Yesol, loop         4.29         Heat losses collector loop piping in W/K           Sol, loc         NHS         Location of the collector loop piping           Pcol, pmp         20         Nominal electricyt consumption of controller in W           Pcol, tH         4         Standay electricity consumption of controller in W           Pcol, tH         2.02         Total tank volume in litres           Histo, lot         889         Total tank volume in litres           Histo, lot alex         889         Total tank volume in litres           Histo, automation         Automation         Method to distribute the tank           Visto, automation:         Automation         Method to distribute the losses over the volumes           Visto, automation:         Automation         Method to distribute the lates concertion           Nvol =         10         Number of tank volumes         Stass           Rh, intert =         504         0%         97%           Rh, huttert =         50%         50%         Height of direct (k)           Rh, therm, off =         90         55         55           Therm, off =         90         55         55           Tate output were         15         15         15           Rated output power:         15	(SK	IAM =	0.985	Incident an	gle modifier at	50° in -					
Sol,loc =         NHS         Location of the collector loop piping           Pcol,pmp =         20         Mominal electricity consumption of controller in W           Visto,tot =         889         Total tank volume in litres           Histo,tot =         2.2.9         Total tank volume in litres           Sol,oc =         NHS         Location of the tank in W/K           Hank         1.844         Height of the tank in M           Sol,oc =         NHS         Location of the tank           Visto,automation         Automation         Method to determine volumes of the tank           Histo,automation         Automation         Method to distribute the internal convection           Note =         10         Number of tank volumes         SHS           Solar loop         WHS         SHS         WHS         SHS           Rh,intet =         24%         83%         0%         30%         41%           Note =         10         Number of tank volumes         Height of inter (%)         Height of inter (%)           Rh,intet =         24%         83%         0%         30%         41%         Height of inter (%)           Rhouttet =         10%         9%         0%         97%         49%         Height of thermostat position (%)		Mcol =	0.011	Collector flo	collector flow rate in kg/(s.m <sup>2</sup> )						
PCol,pmp =         20         Nominal electricity consumption of controller in W           Pcol,ctrl =         4         Standby electricity consumption of controller in W           Vsto,tot =         889         Total teak volume in litres           Hsto,tot =         2.92         Total heat loss rate of the tank in W/X           Htank =         1844         Height of the tank in m           Sto,loc =         NHS Location of the tank in M           Vsto,automation:         Automation         Method to distribute heat losses over the volumes           Csto,automation:         Automation         Method to distribute the internal convection           Nvol =         10         Number of tank volumes         SHS           Solar loop         WHS         SHS         WHS           Rh,inter =         24%         83%         0%         30%         41%           Nvol =         10         Number of tank volumes         Heat output         SHS           Rh,inter =         24%         83%         0%         30%         41%           Rh,inter =         24%         83%         0%         2989         Height of inter (%)           Rtex heat output power         55         55         Thermostat setting on in ° C         Thermostat setting of in ° C </th <th></th> <th>Hsol,loop =</th> <th>4.29</th> <th>Heat losses</th> <th colspan="6">leat losses collector loop piping in W/K</th>		Hsol,loop =	4.29	Heat losses	leat losses collector loop piping in W/K						
Store         Project 1 = 4 Storeby electricity consumption of controller in W           Vsto, tot =         889         Total tank volume in litres           Histo,tot =         2.92         Total heat loss rate of the tank in W/K           Histo,tot =         2.92         Total heat loss rate of the tank in M/K           Stoloc =         NHS Location of the tank in m           Stoloc =         NHS Location of the tank           Vsto,automation:         Automation Method to distribute heat losses over the volumes           Csto,automation:         Automation Method to distribute the internal convection           Nvol =         10         Number of tank volumes           Solar loop         WHS         SHS           Solar loop         WHS         SHS           Rh, hintet =         0%         9%           Solar loop         WHS         SHS           Rh, hintet =         0%         9%           Solar loop         WHS         SHS           Hexch =         1444         0         0         2989           Very Hexch         125         ST         Nethod to distribute the output in W/K           Backup heater         Solar loop         Height of thermostat position (%)           Ttherm, off =         90         S5		Sol,loc =	NHS	Location of	the collector lo	oop piping					
Stot, tot =         889 (1 total tank volume in litres 5, 0, 0c =         899 (1 total tank volume in litres 5, 0, 0c =           Visto, automation:         Automation         Method to determine volumes of the tank Histo, automation:         Automation           Visto, automation:         Automation         Method to distribute heat losses over the volumes Costo, automation:         Automation           Nvol =         10         Number of tank volumes         Heat output           Solar loop         WHS         SHS           Rh, inlet =         24%         83%         0%         30%         41%           Rh, inlet =         24%         83%         0%         30%         41%           Rh, outel =         0%         49%         0%         97%         49%         Height of inlet (%)           Rh, inlet =         24%         83%         0%         30%         41%         Height of inlet (%)           Rh, inlet =         0%         49%         0%         97%         49%         Height of inlet (%)           Rh, inlet =         0%         50%         50%         Thermostat setting on in ° C         Therm, off =         90         55         55         Thermostat setting of in ° C         Therm, off =         90         55         55         Thermostat s		Pcol,pmp =	20	Nominal ele	ectricyt consun	nption collecto	or pump in W				
Vision         2.92 Total head loss rate of the tank in W/K           Hank = Stoloce         1.844 Height of the tank in m Stoloce         NHS Location of the tank Heidot to distribute head losses over the volumes Automation:           Vision         Automation:         Automation Method to distribute head losses over the volumes Solar loop         WHS           Not         10         Number of tank volumes         Head output Solar loop         Head output WHS         SHS           Rh,inlet         24%         83%         0%         30%         41%         Height of inlet (%)           Rh,inlet         24%         83%         0%         30%         41%         Height of inlet (%)           Rh,inter         50%         50%         50%         90%         97%         49%         Height of inlet (%)           Rh,inter         50%         50%         50%         50%         Height of inlet (%)           Rh,inter         50%         50%         50%         Formostat setting on in ° C           Therm,off         90         55         55         Thermostat setting of in ° C           Therm,off         90         55         55         Thermostat setting of in ° C           Therm,off         20         Temestat setting of in ° C         Eacl output power         Ti		Pcol,ctrl =	4	Standby ele	ctricity consun	nption of cont	roller in W				
Htank =         1.844         Height of the tank in m           Sto, out comation:         Nutomation:         Method to determine volumes of the tank           Htank =         NHS         Location of the tank           Method to distribute heat losses over the volumes           Coto,automation:         Method to distribute the internal convection           Nvol =         Backup heater         Heat output           Solar loop         WHS         SHS           Rh,nottet =         Advomation         Method to distribute the internal convection           Nvol =         Backup heater         Heat output           Solar loop         WHS         SHS           Rh,nottet =         Backup heater           Solar loop         WHS         SHS           Therm,onf =         Sol         Sol         Sol           Therm,onf =         Sol         Sol         Therm,ont =         Sol           Therm,onf =		Vsto,tot =	889	Total tank v	olume in litres	5					
Sto,loc =         NHS Location of the tank           Vsto,automation:         Automation         Method to determine volumes of the tank           Hsto,automation:         Automation         Method to distribute heat losses over the volumes           Sto,loc =         Nvol =         10         Number of tank volumes           Nvol =         10         Number of tank volumes         SHS           Nvol =         Solar loop         WHS         SHS         WHS         SHS           Rh,intet =         24%         83%         0%         30%         41%         Height of inlet (%)           Rh,buttet =         0%         49%         0%         97%         49%         Height of outlet (%)           Height of inlet (%)         Height of outlet (%)         Height of outlet (%)         Height of outlet (%)           Height of outlet (%)         Height of outlet (%)         Height of outlet (%)         Height of inlet (%)           Height of outlet (%)         Height of outlet (%)         Height of outlet (%)         Height of outlet (%)           Height of outlet (%)         Height of outlet (%)         Height of outlet (%)         Height of outlet (%)           Height of outlet (%)         Height of outlet (%)         Height of outlet (%)         Height of outlet (%) <tr< th=""><th></th><th>Hsto,tot =</th><th>2.92</th><th>Total heat l</th><th>oss rate of the</th><th>tank in W/K</th><th></th><th></th><th></th><th></th></tr<>		Hsto,tot =	2.92	Total heat l	oss rate of the	tank in W/K					
Vsto,automation         Automation           Note and the set of the tark with the target of		Htank =	1.844	Height of th	leight of the tank in m						
Hsto,automation:         Automation         Method to distribute heat losses over the volumes           Csto,automation:         Automation         Method to distribute the internal convection           Nvol =         10         Number of tank volumes           Backup heater         Heat output           Backup heater         Heat output           Solar loop         WHS         SHS           Rh,inlet =         24%         83%         0%         30%         41%           Rh,outlet =         0%         49%         0%         97%         49%           Height of inlet (%)         Rh,inlet =         24%         83%         0%         30%         41%           Height of thermostat position (%)         Height of inlet (%)         Height of inlet (%)         Height of inlet (%)           Rh,interm =         50%         50%         Does the ter         Solar loop         Height of inlet (%)           Height of inlet (%)         Rheater         Solar loop         WHS         SHS         Height of inlet (%)           Ttherm,ont =         50         50         Thermostat setting on in ° C         Thermostat setting off in ° C           Design type:         Parallel         Serial         Serial         Serial         Serial      <		Sto,loc =	NHS	Location of	the tank						
Solar loop         WHS         SHS         WHS         SHS           Rh,inlet         24%         83%         0%         30%         41%         Height of inlet (%)           Rh,outlet         0%         49%         0%         97%         49%         Height of inlet (%)           Rh,outlet         0%         49%         0%         97%         49%         Height of inlet (%)           Rh,outlet         0%         50%         50%         Height of inlet (%)         Height of inlet (%)           Hexch         1444         0         0         2989         0         Heate exchanger rate in W/K           Solar loop         WHS         SHS         SHS         Heater         Solar loop         WHS         SHS           Solar loop         WHS         SHS         SHS         SHS         Heater         Solar loop         WHS         SHS           Therm,onf         50         50         Thermostat setting on in ° C         C         C         C         C         Control type:         Thermostat setting off in ° C         C         C         C         C         Control type:         Thermostat setting off in ° C         C         C         C         C         C         C		Vsto,automation:	Automation	1	Method to de	etermine volur	nes of the tan	k			
Solar loop         WHS         SHS         WHS         SHS           Rh,inlet         24%         83%         0%         30%         41%         Height of inlet (%)           Rh,outlet         0%         49%         0%         97%         49%         Height of utlet (%)           Rh,outlet         0%         50%         50%         Height of utlet (%)           Rh,therm         50%         50%         Height of utlet (%)           Hexch         1444         0         0         2989         Heat exchanger rate in W/K           Solar loop         WHS         SHS         Heat exchanger rate in W/K         Heat exchanger rate in W/K           Solar loop         WHS         SHS         SHS         Thermostat setting on in ° C         Design type:         Parallel         Serial           Therm,off         9         55         55         Thermostat setting off in ° C         Design type:         Parallel         Serial           Rated output power:         15         15         Rated heat output in W         Control type:         Temperature heated space in °C         Calculation time step in h           Results:         Qir         Qsolar         ZQbu         Ohwyout         Oshyout         Xoloyout         Xo	3/4 eet)	Hsto,automation:	Automation	Method to distribute heat			osses over the	e volumes			
Solar loop         WHS         SHS         WHS         SHS           Rh,inlet         24%         83%         0%         30%         41%         Height of inlet (%)           Rh,outlet         0%         49%         0%         97%         49%         Height of inlet (%)           Rh,outlet         0%         49%         0%         97%         49%         Height of inlet (%)           Rh,outlet         0%         50%         50%         Height of inlet (%)         Height of inlet (%)           Hexch         1444         0         0         2989         0         Heate exchanger rate in W/K           Solar loop         WHS         SHS         SHS         Heater         Solar loop         WHS         SHS           Solar loop         WHS         SHS         SHS         SHS         Heater         Solar loop         WHS         SHS           Therm,onf         50         50         Thermostat setting on in ° C         C         C         C         C         Control type:         Thermostat setting off in ° C         C         C         C         C         Control type:         Thermostat setting off in ° C         C         C         C         C         C         C	977 ash	Csto,automation:	Automation	1	Method to dis	stribute the in	ternal convec	tion			
Solar loop         WHS         SHS         WHS         SHS           Rh,inlet         24%         83%         0%         30%         41%         Height of inlet (%)           Rh,outlet         0%         49%         0%         97%         49%         Height of utlet (%)           Rh,outlet         0%         50%         50%         Height of utlet (%)           Rh,therm         50%         50%         Height of utlet (%)           Hexch         1444         0         0         2989         Heat exchanger rate in W/K           Solar loop         WHS         SHS         Heat exchanger rate in W/K         Heat exchanger rate in W/K           Solar loop         WHS         SHS         SHS         Thermostat setting on in ° C         Design type:         Parallel         Serial           Therm,off         9         55         55         Thermostat setting off in ° C         Design type:         Parallel         Serial           Rated output power:         15         15         Rated heat output in W         Control type:         Temperature heated space in °C         Calculation time step in h           Results:         Qir         Qsolar         ZQbu         Ohwyout         Oshyout         Xoloyout         Xo	129 dat	Nvol =	10	Number of	tank volumes						
Rh,inlet =       24%       83%       0%       30%       41%       Height of inlet (%)         Rh,outlet =       0%       49%       0%       97%       49%       Height of outlet (%)         Rh,outlet =       50%       50%       0       Height of inlet (%)         Rh,therm =       50%       50%       Height of thermostat position (%)         Hexch =       1444       0       0       2989       0       Heat exchanger rate in W/K         Solar loop       WHS       SHS       Ttherm,on =       50       50       Thermostat setting on in ° C         Ttherm,off =       90       55       55       Thermostat setting of in ° C       Ttherm,off *       90       55         Design type:       Parallel       Serial             Ttherm,off =       20       Temperature in °C             Tsto,int =       35       Initial tank temperature in °C             Results:       1       Coludation time step in h       XWh       XWh       XWh       KWh       KWh         KWh       KWh       KWh       KWh       KWh       KWh </th <th>EN (SK</th> <th></th> <th></th> <th>Backu</th> <th colspan="3"></th> <th></th> <th></th> <th></th>	EN (SK			Backu							
Rh, outlet =         0%         49%         0%         97%         49%         Height of outlet (%)           Rh, therm =         50%         50%         50%         0         Height of thermostat position (%)           Hexch =         1444         0         0         2989         0         Heat exchanger rate in W/K           Backup heater         Solar loop         WHS         SHS         Thermostat setting on in ° C         Thermostat setting of in ° C           Ttherm, on =         50         50         Thermostat setting of in ° C         Thermostat setting of in ° C           Rated output power:         15         15         Rated heat output in W         Control type:         Repeat           Tiths =         20         Temperature heated space in °C         ZQload;req         Qu           Kesults:         Qirr         Qsolar         ZQbu         Qhw;out         Qsh;out         ZQload;req         Qu           SolTherm         17263         3905         9275         -2774         -1507         -4281         -11853           Mug         KWh			Solar loop	WHS	SHS	WHS	SHS				
Rh,therm         50%         50%         50%         Height of thermostat position (%)           Hexch =         1444         0         0         2989         0         Heat exchanger rate in W/K           Backup heater         Solar loop         WHS         SHS         50         50         Thermostat setting on in ° C           Ttherm,on =         50         50         Thermostat setting off in ° C         Design type:         Parallel         Serial            Rated output power:         15         St Rated heat output in W         Kated output power:         Rated output power:         15         Rated heat output in W           Control type:         Repeat         Repeat          KWh         <		Rh,inlet =	24%	83%	0%	30%	41%	Height of inlet (	%)		
Hexch =         1444         0         0         2989         0         Heat exchanger rate in W/K           Solar loop         WHS         SHS         SHS         Thermostat setting on in ° C         Thermostat setting off in ° C           Ttherm,on =         90         55         55         Thermostat setting off in ° C         Design type:         Parallel         Serial            Rated output power:         15         15         Rated heat output in W         Serial            Tsto,init =         35         Initial tank temperature in °C         Tinhs =         20         Temperature heated space in °C            Tici =         1         Calculation time step in h         XQload,req         Qu           KWh         KWh         KWh         KWh         KWh         KWh           SolTherm         17263         3905         9275         -2774         -1507         -4281         -11853           SolTherm         17266         3997         9326         -2797         -1512         -4309         -11853           SolTherm         17266         3997         9326         -2797         -1512         -4309         -11853           SolTherm         17266		Rh,outlet =	0%	49%	0%	97%	49%	Height of outlet	(%)		
Solar loop         WHS         SHS           Ttherm,on =         50         50           Ttherm,off =         90         55         55           Design type:         Parallel         Serial            Rated output power:         15         15            Tsto,init =         35         Initial tank temperature in °C            Ti,hs =         20         Temperature heated space in °C            Ti,hs =         20         Temperature heated space in °C            Ti,hs =         20         Temperature heated space in °C            tci =         1         Calculation time step in h            Results:         Qirr         Qsolar         XQbu         Qsh;out         XQsto;out         XQload;req         Qu           kWh           SolTherm         17263         3905         9275         -2774         -1507         -4281         -11853            TrnSys         17266         3997         9326         -2797         -1512         -4309         -11853 <th></th> <th>Rh,therm =</th> <th>50%</th> <th>50%</th> <th>50%</th> <th></th> <th></th> <th>Height of therm</th> <th>ostat position (%)</th> <th></th>		Rh,therm =	50%	50%	50%			Height of therm	ostat position (%)		
Solar loop         WHS         SHS           Ttherm,on =         50         50           Ttherm,off =         90         55         55           Ttherm,off =         Parallel         Serial         75           Tthermostare         Tthermostare         75         75           Tthermostare         Repeat         Repeat         76           Tthermostare         Temperature heated space         76         76           Ttherm         Qolar         Qolar         700         2000d;req         Qolar           Results:         TrnSys         17266         3997         2777		Hexch =	1444	0	0	2989	0	Heat exchanger	rate in W/K		
Second				Backu	p heater						
Ttherm,off =9055Thermostat setting off in ° CDesign type:ParallelSerialRated output power:15Thermostat setting off in ° CControl type:RepeatRepeatReted to utput in WControl type:RepeatRepeatReted to utput in WControl type:RepeatRepeatCTi,hs =20Temperature heated space in °CTti,hs =20Temperature in °CTti,hs =20Temperature heated spaceSolTherm17263390592774-15072428-11853SolTherm172663997-2777			Solar loop	WHS	SHS						
Design type:ParallelSerialRated output power:1515Rated heat output in WControl type:RepeatRepeatReade heat output in WTsto,init =35Initial tank temperature in °CTi,hs =20Temperature heated space in °Ctci =1Coludition time step in hResults:QirrQsolar $\SigmaQbul<$ Qhw;outQsh;out $\SigmaQsto;out$ $\SigmaQload;req$ QqResults:1726339059275-2774-1507-4281-11853of therm1726339979326-2797-1512-4309-11853of therm1726639979326-2797-1512-4309-11853of therm1726639979326-2797-1512-4309-11853of therm0.0%0.8%0.4%-0.2%0.0%-0.2%0.0%0.0%trueKehrt:7868EN15316-4-3, method 2	if o	Ttherm,on =		50							
Control type:       Repeat       Repeat       Repeat          Tsto,init =       35       Initial tank temperature in °C       C         Ti,hs =       20       Temperature heated space in °C       C         tci =       1       Calculation time step in h       C         Results:       Qirr       Qsolar       ΣQbu       Qhw;out       Qsh;out       ΣQsto;out       ΣQload;req       Qir         KWh       KU       C       C       C	77-5 shee	Ttherm,off =	90	55	55	Thermostat s	at setting off in ° C				
Control type:       Repeat       Repeat       Repeat          Tsto,init =       35       Initial tank temperature in °C       C         Ti,hs =       20       Temperature heated space in °C       C         tci =       1       Calculation time step in h       C         Results:       Qirr       Qsolar       ΣQbu       Qhw;out       Qsh;out       ΣQsto;out       ΣQload;req       Qir         Kwh         SolTherm       17263       3905       9275       -2774       -1507       -4281       -11853       C         SolTherm       17263       3997       9326       -2797       -1512       -4309       -11853       C         SolTherm       17266       3997       9326       -2797       0.0% <th>129 ata:</th> <th>I</th> <th>Design type:</th> <th>Parallel</th> <th>Serial</th> <th colspan="4">Serial</th>	129 ata:	I	Design type:	Parallel	Serial	Serial					
Control type:       Repeat       Repeat       Repeat          Tsto,init =       35       Initial tank temperature in °C       C         Ti,hs =       20       Temperature heated space in °C       C         tci =       1       Calculation time step in h       C         Results:       Qirr       Qsolar       ΣQbu       Qhw;out       Qsh;out       ΣQsto;out       ΣQload;req       Qir         Kwh         SolTherm       17263       3905       9275       -2774       -1507       -4281       -11853       C         SolTherm       17263       3997       9326       -2797       -1512       -4309       -11853       C         SolTherm       17266       3997       9326       -2797       0.0% <th>EN SK d</th> <th>Rated ou</th> <th>tput power:</th> <th>15</th> <th>15</th> <th colspan="4">15 Rated heat output in W</th> <th></th>	EN SK d	Rated ou	tput power:	15	15	15 Rated heat output in W					
Ti,hs =       20       Temperature heated space in °C         tci =       1       Calculation time step in h         Results:       Qirr       Qsolar       ΣQbu       Qhw;out       Qsh;out       ΣQsto;out       ΣQload;req       Qa         KWh       KUh       KUh       KUh	5	C	control type:	Repeat	Repeat						
tci = 1       Calculation time step in h         Results:         Qirr       Qsolar       ΣQbu       Qhw;out       Qsh;out       ΣQsto;out       ΣQload;req       Qa         KWh       K       K       K       K       K       K       K       K       K       K       K       K       K		Tsto,init =	35	Initial tank	temperature ir	∩ °C					
SolTherm         Ω17263         3905         9326         -2774         -1507         -4281         -11853           SolTherm         17263         3905         9326         -2797         -1507         -4281         -11853         -11853           SolTherm         17266         3997         9326         -2797         -1512         -4309         -11853 <th></th> <th>Ti,hs =</th> <th>20</th> <th>Temperatui</th> <th>re heated spac</th> <th>e in °C</th> <th></th> <th></th> <th></th> <th></th>		Ti,hs =	20	Temperatui	re heated spac	e in °C					
Qirr         Qsolar         ΣQbu         Qhw;out         Qsh;out         ΣQsto;out         ΣQload;req         Qa           kWh         kWh<		tci =	1	Calculation	time step in h						
kWh         kWh <th>Results:</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th>	Results:										
SolTherm         17263         3905         9275         -2774         -1507         -4281         -11853           No         TrnSys         17266         3997         9326         -2797         -1512         -4309         -11853           AQ [kWh]			Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux	
Image: sector			kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
ΔQ [kWh]        3        92        50         23         5         28         0           ΔQ [%]         0.0%         0.8%         0.4%         -0.2%         0.0%         -0.2%         0.0%		SolTherm	17263	3905	9275	-2774	-1507	-4281	-11853	39	
Fchart:         7868         EN 15316-4-3, method 2	ion	TrnSys	17266	3997	9326	-2797	-1512	-4309	-11853	55	
Fchart:         7868         EN 15316-4-3, method 2	lidat	ΔQ [kWh]	-3	-92	-50	23	5	28	0	-16	
	Va	ΔQ [%]	0.0%	0.8%	0.4%	-0.2%	0.0%	-0.2%	0.0%	0.1%	
ΔΟ [%]: -11.9%				Fchart:	7868	EN 15316-4-3	3, method 2				
				∆Q [%]:	-11.9%						

	Climate:	WB_S_45				Reference cli	mate region		
Water heating service		ITW_Prehea	at_Combi			Water heatin	ig sequence		
S	pace heating service:	ITW_NE50				Space heatin	g sequence		
	Asol =	10.06	Total collec	tor reference c	irea in m <sup>2</sup>				
08 eet)	Eo =	0.831 Zero loss collector efficiency in -							
0 98 ashe	a1 =	3.44	3.44 First order collector heat loss coeffici						
EN ISO 9808 (SK datasheet)	a2 =	0.0176	Second orde	er collector hea	at loss coeffici	ent in W/(K2.	m²)		
EN (SK	IAM =	0.84	Incident ang	gle modifier at	50° in -				
	Mcol =	0.02	Collector flo	llector flow rate in kg/(s.m <sup>2</sup> )					
	Hsol,loop =	4.84	Heat losses	collector loop	piping in W/K	•			
	Sol,loc =	NHS	Location of	the collector lo	oop piping				
	Pcol,pmp =	20	Nominal ele	ectricyt consun	nption collecto	or pump in W			
	Pcol,ctrl =	4	Standby ele	ctricity consun	nption of cont	roller in W			
	Vsto,tot =	703	Total tank v	olume in litres					
	Hsto,tot =	3.87	Total heat l	otal heat loss rate of the tank in W/K					
	Htank =	1.54	Height of th	right of the tank in m					
	Sto,loc =	NHS	Location of	ecation of the tank					
	Vsto,automation:			Method to determine vol			k		
3/4 neet	Hsto, automation:								
977 tasł	Csto,automation:		Number of tank volumes		stribute the in	ternal convec	tion		
EN 12977 3/4 (SK datasheet)	Nvol =	9							
E (SI				p heater		output			
		Solar loop	WHS		WHS	SHS			
	Rh,inlet =	49%		60%	11%		<ul> <li>% Height of inlet (%)</li> <li>% Height of outlet (%)</li> <li>Height of thermostat position (%)</li> </ul>		
	Rh,outlet =	3%	56%	28%	99%	55%			
	Rh,therm = Hexch =	48%	100%		-3000	0			
		1102			heater		00 0 Heat exchanger rate in W/K		
		Calariaan							
		Solar loop			Thormostate	atting on in <sup>0</sup>	C		
7-5 ieet)	Ttherm,on =		49			hermostat setting on in $^\circ$ C hermostat setting off in $^\circ$ C			
977 ashe	Ttherm,off =	90 Design type:				etting ojj in	C		
EN 12977 (SK datash		tput power:			 Rated heat of	utput in W			
EI (SK		control type:							
	Tsto,init =	35	Initial tank	temperature ir	ı °C				
	Ti,hs =	20	Temperatur	re heated spac	e in °C				
	tci =	1	Calculation	time step in h					
Results:									
		Qirr	Qsolar	ΣQbu	Qhw;out	Qsh;out	ΣQsto;out	ΣQload;req	Qaux
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
	SolTherm	12370	3288	10104	-2774	-9052	-11826	-11853	49
ion	TrnSys	12372	3436	9723	-2798	-9072	-11870	-11853	55
Validation	ΔQ [kWh]	-2	-147	381	24	20	44	0	-6
Val	ΔQ [%]	0.0%	1.2%	-3.2%	-0.2%	-0.2%	-0.4%	0.0%	0.1%
			Fchart:	9028	EN 15316-4-3	3, method 2			
			۸0 [%]∙	-9.1%					

ΔQ [%]: -9.1%

## Annex III Adopted methods for the heat exchangers

The EN 15316-5:2017 does not include a method for the calculation of heat exchangers. For that reason the following methods have been added.

## III.1 Tank integrated heat exchangers

This situation is assumed to be an indirect heat input / output in terms of the base methods. The method III.1 is applied in combination with one of the applicable methods in III.2, III.3 or III.4.

The outlet temperature is calculated according to the following formula:

$$T_{outlet} = T_{sto(i)} + \frac{P_{exch}}{H_{exch}}$$

where

 $T_{sto(i)}$  is then current and new tank temperature of tank volume I in <sup>o</sup>C

P<sub>exch</sub> is the heat exchanged in W

 $H_{exch}$  is the heat exchange rate in W/K

In case of zero requested heat exchange, the method destroys the temperature stratification of the tank over the involved tank volumes <sup>[5]</sup>.

## III.1.1 Distribution of heat exchange over the tank volumes

The required heat is distributed over the involved volumes according to the following formula:

$$T_{sto(i)} = T_{sto(i)} + \frac{V_{sto(i)} \cdot (T_{sto(i)} - T_{in})}{\sum V_{sto} \cdot (T_{sto} - T_{in})} \cdot \frac{Q_{req}}{V_{sto(i)} \cdot tci \cdot \rho \cdot C_p}$$

where

T<sub>sto(i)</sub> is then current and new tank temperature of tank volume I in <sup>o</sup>C

V<sub>sto(i)</sub> is the volume of tank volume I in litres

 $T_{in}$  is the inlet temperature in <sup>o</sup>C

 $\mathsf{Q}_{\mathsf{req}}$  is the required heat exchange in kWh

 $V_{\text{sto}(i)} \quad \text{ is the volume of tank volume i in litres} \\$ 

 $\rho$  is the density of water in kg/litres (=1)

 $C_P$  is the specific heat in kWh/(kg.K) (=0,00116)

t<sub>ci</sub> is the calculation time step in hours

## III.1.2 Heat exchange with defined volume

This situation occurs for preheater types of solar thermal systems with a temperature controlled backup heater in series.

The method is much the same as for direct heat input and output and results in a new requested heat input or output, based on the potential heat contents of the tank. The heat is exchanged according to the method described in III.1.1: Distribution of heat exchange over the tank volumes.

<sup>&</sup>lt;sup>5</sup> If this is not intended, do not call the method with a zero heat exchange.

# III.1.3 Heat exchange with fixed inlet temperature

The required heat exchange is corrected for the potential heat in the tank. The heat is exchanged according to the method described in III.1.1 Distribution of heat exchange over the tank volumes.

## *III.1.4* Floating temperature heat exchange

This situation is applicable for heat sources where the heat output is related to the return temperature from the tank. In this case an iteration loop is needed. Using the floating temperature method, results in faster converge of the calculations.

The requested heat is exchanged as is, without taking into account the temperature levels in the tank. The heat is exchanged according to the method described in III.1.1 Distribution of heat exchange over the tank volumes. The required inlet temperature is assumed to be 10K higher than the tank temperature at the inlet.

# III.2 External heat exchanger

This system layout is assumed to be a direct input / output of the tank (volume) at a temperature offset determined by the heat transfer rate of the heat exchanger.

$$\Delta T_{offset} = \frac{P_{exch}}{H_{exch}}$$

where

 $P_{exch}$  is the heat exchanged in W

H<sub>exch</sub> is the heat exchange rate in W/K

## Annex IV Automatic setting of tank parameters

## IV.1 Tank volumes

SolTherm allows for unequal volumes in the tank in order to limit the number of calculation volumes. As a consequence the volumes need to be determined with care.

The input of the method are, the obvious tank specifications, and the relative heights of the inlets, outlets and thermostat positions. The method determines the content volume of each volume and translates the relative heights inputs to volume numbers.

The following rules are applied:

- At least two volumes for each connected (and operational) loop connected to the tank
- The total volume of the volumes between the inlet and outlet of a loop should correspond to the intended situation
- A further, more detailed, description of the method should be drafted.

## IV.2 Inlet and outlet locations in terms of volume numbers

## IV.3 Tank heat loss distribution

The method calculates the tank diameter from its volume and height. The heat losses are distributed to the ratio of the surface area of each volume.

## IV.4 Internal heat conduction

The method is very basic. A basic heat conduction of 0.5 W/(m.K) is assumed and an extra 0.5 is added for each volume with a heat exchanger.

## Annex V Validation against EN 15316-4-3 method 2 (Fchart)

The EN 15316-4-3 method 2 is the so called 'Fchart' method, that calculates the performance with a monthly time step and is using the same input parameters as the Method 3 (hourly time step and base for the SolTherm software). The results are shown in figure 4.

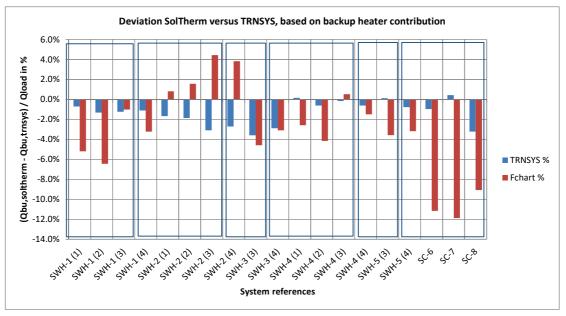


Figure 4 - SolTherm compared to TRNSYS and Fchart.

The SolTherm results correspond with the TRNSYS results with an average deviation of -1,4% and a standard deviation of 1,2%.

The SolTherm results correspond with the Fchart results with an average deviation of -3,1% and a standard deviation of 4,5%.

## Conclusion:

The SolTherm results are significantly better than the Fchart results.

## Annex VI Software description

### 1 General software design

The software is subdivided into four main parts:

 User interface

 Project:
 SolTherm\_V2

 Class:
 n.a.

 Status:
 Not described in this documentation in detail

 Program to give the user control of the simulation model: input data, start calculation and display the results.

 [User interface] calls:
 [User interface supporting methods] and [Simulation model]

- User interface supporting methods

Project: SolTherm Class: cls\_SolTherm\_Support Status: Described in this documentation The class exposes methods to support the data input for **[Simulation model]** and **[User interface]** that can optionally be called by **[User interface]**.

- Simulation model

Project: SolTherm Class: clsSolThermModel002 Status: Described in this documentation The class contains a simulation model for a typical solar thermal system for water heating, space heating or combination heating. [Simulation model] calls: [Base methods model]

#### Base methods model

- Project: SolTherm
- Class: Several classes
- Status: Described in this documentation

The class contains several methods describing physical processes needed by the simulation model.

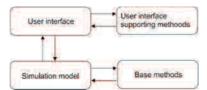


Figure 1- graphical representation of the main structure of the software. The user interface communicates with the simulation model and can make use of the user interface supporting methods. The simulation model communicates with the base methods from the standards

The software is developed in Microsoft Visual Basic 2008 and made available as the code and as a DLL.

### 2 User interface

The user interface is only marginally described to allow software developers to develop their own user interface. A basic example of the code of the user interface:

Code:	Remarks:
Public clsSolTherm As New cls_SolTherm.clsSolThermModel002	Declare the link to the simulation model
Public clsSupport As New cls_SolTherm.cls_SolTherm_Support	Declare the link to supporting methods (optional)
Insert code to load all the model input data	Optionally use the methods from clsSupport
clsSolTherm.CR.Clear_All()	Clear all previously calculated results
clsSolTherm.CR.Init(24 * 365 - 1)	Initiate the results with the number of hours (in this case one full year)
clsSolTherm.Execute()	Run the simulation model
clsSolTherm.CR.CalcMonthlyValues()	Calculate all the monthly and annual results
luceut cede te display the recults	

...Insert code to display the results

## 3 User interface supporting methods

#### 3.1 Hourly data for the climate

The function is called according to:

## clsSolTherm. vcoClimate= clsSupport. LoadData\_LoadData\_Climate ( Arg1, Arg2)

Arg1:	[Text] File name of the sequence or a keyword for one of the following built in sequences, according to					
	Keyword:	Description:				
	ErP_AVG	the European average climate used in the ErP				
	Imp_Athens	Athens according to EN12976-2 and Solar Keymark				
	Imp_Stockholm	Stockholm according to EN12976-2 and Solar Keymark				
	Imp_Wurzburg	Wurzburg according to EN12976-2 and Solar Keymark				
	WB_S_45	Climate file fitted to the space heating sequence: {SH_LP}				
Ara2.	Tomporature of a boa	tod room				

Arg2: Temperature of a heated room

The function returns a new set of climate data contained in the structured variable: VariableCollectionOf\_Climate.

The data is read from a text file, that can contain multiple sequences, the following conventions:

- Empty lines and lines preceded with '\*' are iqnored

Lines preceded with the ">" sign are assumed to be commands					
>DocType;vA_ShSeq		Not used			
>Title;{Title of the space he	eating sequence}	Not used			
>Reference;{add your own	reference}	Not used			
>Description;{add any des	criptive line of text}	Not used			
>Dated;{Date of creation}		Not used			
>Author;{reference to sour	rce}	Not used			
- One line for each hour, wit	th columns separate	d by '; ', according to:			
- 1th column: Hour					
- 2th column: Tamb	Outside air tempera	ature in oC			

- 3th column: Isol Solar irradiation on the collector plane in W/m<sup>2</sup>

## 3.2 Hourly data for the water heating service

The function is called according to:

clsSolTherm. vcoHotWater = clsSupport. LoadData\_Hotwatersequence (Arg1, Arg2)

Arg1:	[Text] File name of the sequence or a keyword for one of the following built in sequences, according to					
	Keyword:	Description:				
	None	No hot water service				
	ErP_PH_I_{x}	the load profiles according to the ErP for preheater type solar water heaters, where {x} is M, L, XL or XXL				
	ErP_SPS_I_{x}	the load profiles according to the ErP for <i>solar plus supplementary</i> type solar water heaters, where $x$ is M, L, XL or XXL				
	ITW_Preheat_Combi	made available by ITW (DE)				
	SolKey-Wurzburg-{x}	EN12976-2 / Solar Keymark reference for <i>Wurzburg</i> hot water sequences, where $\{x\}$ is 080, 110, 140, 170, 200, 250, 300, 400 or 600.				
	SolKey-Stockholm-{x}	EN12976-2 / Solar Keymark reference for <i>Stockholm</i> hot water sequences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or 600.				
	SolKey-Davos-{x}	EN12976-2 / Solar Keymark reference for <i>Davos</i> hot water sequences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or 600.				
	SolKey-Athens-{x}	EN12976-2 / Solar Keymark reference for <i>Athens</i> hot water sequences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or 600.				

Arg2: Number of hours of the sequence. Typically 24x365 hours for a complete year

The function returns a new set of hot water service data contained in the structured variable VariableCollectionOf\_HotwaterDemand.

The data is read from a (built in) text file, that can contain multiple sequences, according to the following conventions:

- Empty lines and lines preceded with '\*' are ignored
- Lines preceded with the ">" sign are assumed to be commands

>DocType;vA_ShSeq	Not used		
>Title;{Title of the water heating sequence}	Used, for built in sequences only (=keyword)		
>Reference;{add your own reference}	Not used		
>Description;{add any descriptive line of text}	Not used		
>AddInfo;EN12976-2;TcwDyn;{∆T <sub>amplit</sub> };{Ds}	Used, only for EN12976-2 / Solar Keymark sequences		
>Dated;{Date of creation}	Not used		
>Author;{reference to source}	Not used		
One line for each hour, with columns separate	d by '; ', according to:		
- 1th column: Hour of the year			

- 2th column: Qreq Required hot water demand in kWh
- 3th column: Tcw Cold water temperature in oC
- 4th column: Thw Hot water temperature in oC
- 5th column: Fhw Mass flow rate in I/m

The sequence should be defined for no more than the first 24 hours (0..23). The function will repeat the sequence for grant total of Args2 hours.

#### Note

The sequences according to EN12976-2 / Solar Keymark are defined with a cold water temperature related to the day number of the year, according to:

$$T_{cw} = T_{cwavg} + \Delta T_{amplit} \cdot SIN(2 \cdot \pi \cdot \frac{Day - D_s}{365})$$

Moreover, the sequence consists of one draw off at solar noon + 6 hour.

The sequence is defined through the >AddInfo;EN12976-2;TcwDyn;.. command. The draw off is defined by one draw off at 20h: Wurzburg, 19h: Stockholm, 19h: Davos and 18h: Athens, Tcw equal to  $T_{cw,avg}$  and Qreq based on  $T_{cw,avg}$ .

#### 3.3 Hourly data for the space heating service

The function is called according to:

#### clsSolTherm. vcoSpaceHeating = clsSupport. LoadData\_SpaceheatingService (Arg1)

 Arg1:
 [Text] File name of the sequence or a keyword for one of the following built in sequences, according to Keyword:

 Description:

None	No not water service
SH_LP	a sequence made available by ITW (DE)

The function returns a new set of space heating service data contained in the structured variable VariableCollectionOf\_SpaceHeatingDemand

The data is read from a text file, that can contain multiple sequences, the following conventions:

- Empty lines and lines preceded with '\*' are iqnored
- Lines preceded with the ">" sign are assumed to be commands
  - >DocType;vA\_ShSeq
     Not used

     >Title;{Title of the space heating sequence}
     Not used

     >Reference;{add your own reference}
     Not used

     >Description;{add any descriptive line of text}
     Not used
  - >Dated;{Date of creation} Not used
  - >Author;{reference to source} Not used

One line for each hour, with columns separated by '; ', according to:

- 1th column: Hour
- 2th column: Tsh\_high Space heating flow temperature in oC (distribution inlet)
- 3th column: Tsh\_low Space heating return temperature in oC (distribution return)
- 4th column: Msto Flow rate [kg/h]

#### 3.4 Hourly data for the backup heater

The function is called according to:

#### clsSolTherm. LoadData\_BackupHeater= clsSupport. LoadData\_SpaceheatingService (Arg1, Arg2, Arg3, Arg4)

Arg1:	Keyword for one of the fol	lowing built in sequences	according to
/ugi.		iowing built in bequeilees,	according to

0		
	Keyword:	Description:
	Manual	According to Arg4 sequence
	Repeat	Continuously in operation at Arg2 kW
	Nightly backup	23:00h – 06:00h at Arg2 kW
Arg2:	Rated heat output in kW	

Arg3: Number of hours of the sequence. Typically 24x365 hours for a complete year

Arg4: ';' delimeted list of rated heat output in kW for each hour

The function returns a new set of space heating service data contained in the structured variable VariableCollectionOf\_BackupHeater

### 3.5 TankLayout\_volumes

The size of each volume of the tank is determined based on the other tank definitions

#### vcoTank = clsSupport.TankLayout\_Volumes ( Arg1, Arg2)

- Arg1: vcoTank as VariableCollectionOf\_Tank
- Arg2: Boolean array with loops in operation

The function returns a revised set of tank specifications contained in the structured variable VariableCollectionOf Tank

#### 3.6 TankLayout\_HeatLosses

The distribution of the heat losses over the tank volumes is determined, taking into account the higher losses on the bottom and top volume.

vcoTank = clsSupport.TankLayout\_HeatLosses ( Arg1, Arg2)

- Arg1: vcoTank as VariableCollectionOf Tank
- Arg2: Boolean array with loops in operation

The function returns a revised set of tank specifications contained in the structured variable VariableCollectionOf\_Tank

#### 3.7 TankLayout\_Conduction

The distribution of the internal heat convection over the tank volumes is determined, taking into account the higher losses on the bottom and top volume.

#### vcoTank = clsSupport.TankLayout\_Conduction ( Arg1, Arg2)

- Arg1: vcoTank as VariableCollectionOf\_Tank
- Arg2: Boolean array with loops in operation

The function returns a revised set of tank specifications contained in the structured variable VariableCollectionOf\_Tank

## 4 Simulation model

#### 4.1 Main method: Execute

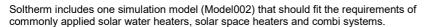
The method is called according to:

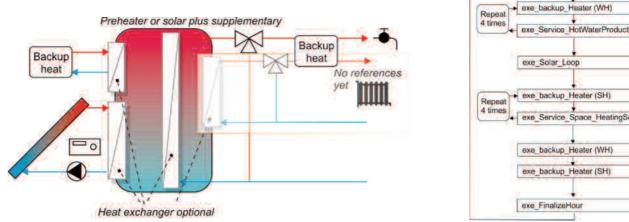
...Load the models input parameters

Dim clsSolTherm as new cls\_SolTherm.clsSolThermModel002

#### clsSolTherm.Execute

....Read the calculation results





Start

Next hour

Figure 2 - graphical representation of the solar thermal system that is handled by model 002

#### Remarks:

The model handles the input and output heat sequentially and not parallel. This could lead unrealistic results. For that reason the call to the backup heater and the hot water and space heating method is repeated four times.

#### 4.2 Sub method: exe\_Solar\_loop

The sub method calculates the solar thermal heat input into the tank and is called from the main method (execute). Since the collector output is related to the storage return temperature, a iteration loop is applied.

Dim clsSolTherm as new cls\_SolTherm.clsSolThermModel002 clsSolTherm.exe\_Solar\_loop({Hourno})

#### 4.3 Sub method: exe\_Backup\_Heater

The sub method calculates the backup heater input into the tank and is called from the main method (execute). Dim clsSolTherm as new cls\_SolTherm.clsSolThermModel002

clsSolTherm .exe\_Backup\_Heater({Hourno}, vcoBackup, "WHS")

#### where:

vcoBackup is the reference to the structured variable: VariableCollectionOf\_BackupHeater, holding either the specifications of the backup heater for water heating, of space heating. "WHS" or "SHS" signifies the backup heater for water or space heating.

#### 4.4 Sub method: exe\_HotWaterProduction

The sub method calculates the heat for the requested hot water heat demand and is called from the main method (execute)

Dim clsSolTherm as new cls\_SolTherm.clsSolThermModel002 clsSolTherm . exe\_Service\_HotWaterProduction({Hourno})

#### 4.5 Sub method: exe\_Service\_SpaceHeatingService

The sub method calculates the heat for the requested space heating demand and is called from the main method (execute)

Dim clsSolTherm as new cls\_SolTherm.clsSolThermModel002 clsSolTherm . exe\_Service\_SpaceHeatingService({Hourno})

#### 4.6 Sub method: exe\_FinalizeHour

The sub method calculates the storage heat losses and the effect of the internal heat conduction on the tank temperatures and is called from the main method (execute).

Dim StoFinal As New clsStorageHeatlosses(vcoTank, tci, TstoAmb) StoFinal.Execute(ID.Tsto) Dim cls As New clsSupportingMethods(tci) Tsto = cls.VertHeatConduct(Tsto, vcoTank)

## 5 Base methods model

The base methods are described in the referred standards and are documented in the source code.

Since this is the first time that the methods in the EN 15316 series are put to the test, improvements can be found and are introduced in the software. It is intended to summarize those changes for future revision of the involved standards. The EN 15316-5:2017 outline suggests a sort of sequential use of the methods. This approach has been discarded, while the methods are applied.

#### 5.1 clsSolarCollector

Reference: EN 15316-4-3:2017, method 3

Called from: Simulation model

The method describes the function of the collector and collector loop and is intended to be connected to a method for the heat storage tank (EN 15316-5:2017).

The method includes a iteration to find the average collector temperature, needed for the collector efficiency curve.

Changes from the EN 15316-4-3:

- The iteration control has been elaborated (see 5.6)
- Minor other changes may have been introduced and shall be elaborated in the next phase of the development.

#### 5.2 clsStorageDirectInOut

Reference: EN 15316-5:2017, 6.4.3.4 and D.1 (volume withdraw)

Called from: Simulation model (e.g. hot water withdrawal for hot water service)

The method describes a volume withdrawal from the tank that is applicable for several kinds of heat input and output.

Changes from the EN 15316-5:2017:

- The outline of the method has been respected and improved
- The method for heat input has been added
- Other changes shall be elaborated in the next phase of the development.

#### 5.3 clsStorageIndirectInOut

Reference: EN 15316-5:2017, 6.4.3.8 and D.3

Called from: Simulation model (e.g. heat input from collector loop)

The method describes heat input to and output by an integrated heat exchanger from the tank and is called from several processes in the simulation model.

Changes from the EN 15316-5:2017:

- The outline of the method has been respected and improved
- Additions to model the internal heat exchanger
- Other changes shall be elaborated in the next phase of the development.

#### 5.4 clsStorageHeatlosses

Reference: EN 15316-5:2017, 6.4.3.10

Called from: Simulation model at the end of each time step

The methods describes the method to calculate the heat losses of the tank.

Changes from the EN 15316-5:2017:

- The outline of the method has been respected and improved
- The function of the maximum thermostat in the tank has been relocated to the methods for heat input and output.
- Other changes shall be elaborated in the next phase of the development.

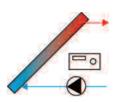
#### 5.5 clsSupporting methods

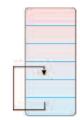
### 5.5.1 RestoreTempStratification

Reference: EN 15316-5:2017, 6.4.3.9

Called from: Simulation model at the end of each heat input and output

The method rearranges the tank temperatures to its natural state (high at the top and low at the bottom).







#### Changes from the EN 15316-5:2017:

- The outline of the method has been respected and improved
- The method is not called at the end of a time step, but after each heat input or output
- Other changes shall be elaborated in the next phase of the development.

#### 5.5.2 VerticalHeatConduct

Reference: Not included in the standards

Called from: Simulation model at the end of each time step

The method calculates the adjustments of the tank temperatures due to temperature differences. The method has been added for the special case of solar thermal systems, that often work with big temperature differences in the tank.

Changes from the EN 15316-5:2017:

- The method has been added and shall be elaborated in the next phase of the development.

#### 5.6 IterationControl

Reference: Not included in the standards

Called from: simulation model

The iteration control is not described in the standards, but has been added for convenience. The methods is very basic and could be improved in future.

Changes from the EN 15316-5:2017:

- The method has been added and shall be elaborated in the next phase of the development.

## 6 Public variables

## 6.1 Structured input variables

VariableCollection	Of_SolarLoop		
AsolMod	Double	m2	Aperture area collector module
Eo	Double	-	Collector zero loss efficiency
a1	Double	W/(m2.K)	Collector heat loss coefficient
a2	Double	W/(m2/K2)	Collector heat loss coefficient
IAM	Double	-	incidence angle modifier
ColCap	Double	J/(K.m2)	Effective thermal capacity
Mcol	Double	kg/s/m2	mass flow rate collector loop per m2
PcolPmp	Double	W	Pump power solar collector pump
PcolCtrl	Double	W	Pump power solar controler
NsolMod	Double	-	Number of solar collector modules
SOL_LOC	String	-	location of collector loop 'HS': heated space 'NHS': not heated space 'OUT': outside
HsolLoop	Double	W/K	Heat losses solar loop
Tsto_sol_max	Double	оС	Thermostat setting solar loop
VariableCollection	Of_BackupHeat	er	
ВасТуре	Integer		Type of backup heater (0)=Not used, (1)=Serial, (2)=Tank heating
Pbu()	Double	W	Rated heat output for 24 hours for each hour of the year
CtrlType	String		Only for user interface
Tsto_bu_max	Double	oC	the maximum storage temperature heated (thermostat setting)
Tsto_bu_on	Double	оС	the lower temperature limit for backup heater on
VariableCollection	Of_Tank		
Nvol	Integer	-	Number of storage volumes (index=0: bottom)
Vsto()	Double	I	Volume of each volume in the tank
Vsto_auto_type	Integer		Only for user interface
Hsto_auto_type	Integer		Only for user interface
Csto_auto_type	Integer		Only for user interface
TstoInit	Double	oC	Initial storage temperature
Hsto_tot	Double	W/K	Total heat loss coefficient of the storage tank
Hsto()	Double	W/K	Heat loss coefficient of the storage volume per volume
TnkHeight	Double	m	Tank Height
Csto_tot	Double	W/(m.K)	Total effective vertical heat conductivity
Csto()	Double		Effective vertical heat conductivity per volume
STO_LOC	String	-	location of storage 'HS': heated space 'NHS': not heated space

			'OUT': outside
lposInlet()	Integer		Volume numbersinlet (0:solar loop, 1:backup heater water heating, 2: backup heater space heating, 3: water heating loop, 4: space heating loop
lposOutlet()	Integer		Volume numbers outlet
lposTherm()	Integer		Volume number thermostat
RhPosInlet()	Double		Only for user interface
RhPosOutlet()	Double		Only for user interface
RhPosTherm()	Double		Only for user interface
Hexch()	Double	W/K	Exchange rate of heat exchanger for each loop 0 to 4. 0=no heat exchanger, >0 tank integrated heat exchanger, <0 external heat exchanger
Vsto_tot	Double	oC	Total volume of the storage tank
Tsto()	Double	оС	Storage water temperature for each volume
VariableCollection	Of_Climate		
ClimType	String		
Ti_hs	Double		
lsol()	Double	W/K	Solar irradiation on collector plane
Tair(,)	Double	оС	(0,Hour): Heated space, (1,Hour): not heated space, (2,hour): outside
VariableCollection	Of_HotwaterDe	mand	
HwsType	String		Only for user interface
Qsto_out_req()	Double	kWh	Requested heat output per hour
Fsto()	Double	l/m	Flowrate of drawoff per hour
Tsto_in()	Double	оС	Inlet temperature (cold water) per hour
Tsto_out_min()	Double	оС	Minimum outlet temperature per hour
VariableCollection	nOf_SpaceHeati	ngDemand	
ShsType	String		Only for user interface
Qsto_out_req()	Double	kWh	Requested heat output per hour
Tsh_on	Single	оС	On temperature space heating
Tsh_off	Single	оС	Off temperature space heating
Msto()	Double	kg/h	Flowrate
Tsh_high()	Double	К	Inlet temperature (cold water)
Tsh_low()	Double	к	Minimum outlet temperature

#### 6.2 Structured output variables

6.2.1 Class: CollectionOfResults The class holds all registered calculation results in a class: TypeToHoldCalcResults. The class is exposed through: Dim clsSolTherm as new cls\_SolTherm.clsSolThermModel002

clsSolTherm.CR.{output variable name of type TypeToHoldCalcResults }

The calls exposes the following methods:

Clear all	Clear all variables
Init({LastInit})	Initialize the structure of variables for LastInit hours+1
CalcMonthlyValues	Calculate the monthly totals for all variables

6.2.2 Class: TypeToHoldCalcResults The class holds calculation results for each hour, that is accessible through the following methods:

Clear	Clear the variable
Init({LastInit})	Initialize the variable for LastInit hours+1
Value(Index)	Get or set the value for element Index
Add(Index, Value)	Adds value to the current value at Index
AnnualTot	Gets the annual total
MonthlyTot	Gets a array with the monthly totals
CalcMonthlyValues	Calculates the monthly values
MonthTot	Gets a array with the monthly totals