vA Consult

- 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 [1] standards [2], 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 SolTherm 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.

[1] Energy Performance of Buildings Directive

[2] EN 15316-4-3:2017 and EN 15316-5:2017

Content

Foreword

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

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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.

[3] Energy Performance of Buildings Directive

[4] 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).

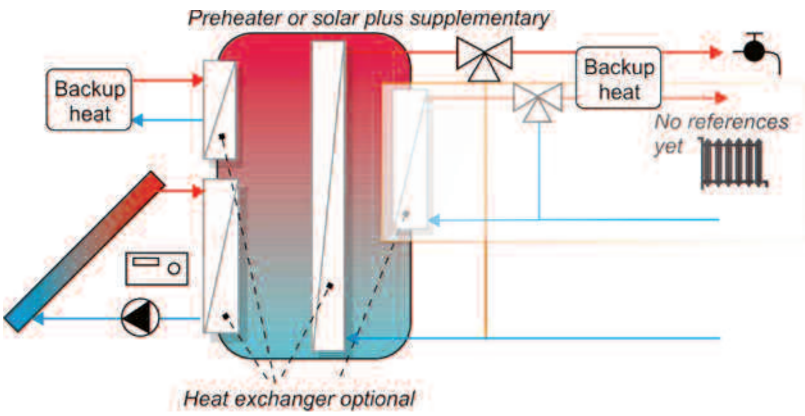


Figure 1 - a graphical impression of the solar thermal system that can be handled by the model.

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.

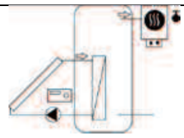
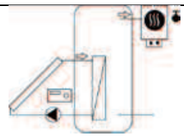
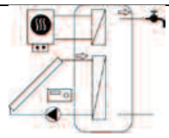
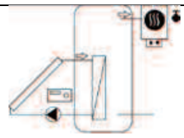
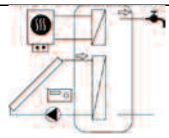
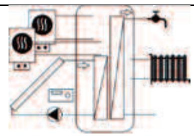
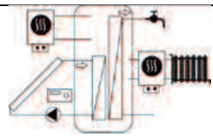
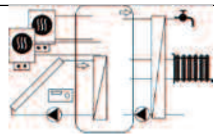
No	Type [1]	Acol m²	Vsto litres	Climate[2]	Load WHS [3]	Load SHS [4]	Remarks
1	SWH-PH	2.28	100	ErP-AVG	ErP-PH-L, ErP-PH-XL, ErP-SPS-L, ErP-SPS-XL	None	
2	SWH-PH	3.78	225	ErP-AVG	ErP-PH-L, ErP-PH-XL, ErP-SPS-L, ErP-SPS-XL	None	
3	SWH-SPS	4.02	250	ErP-AVG	ErP-SPS-L, ErP-SPS-XL	None	
4	SWH-PH	2.37	124	ErP-AVG	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 combi-systems. The detailed results are available in the annex II.

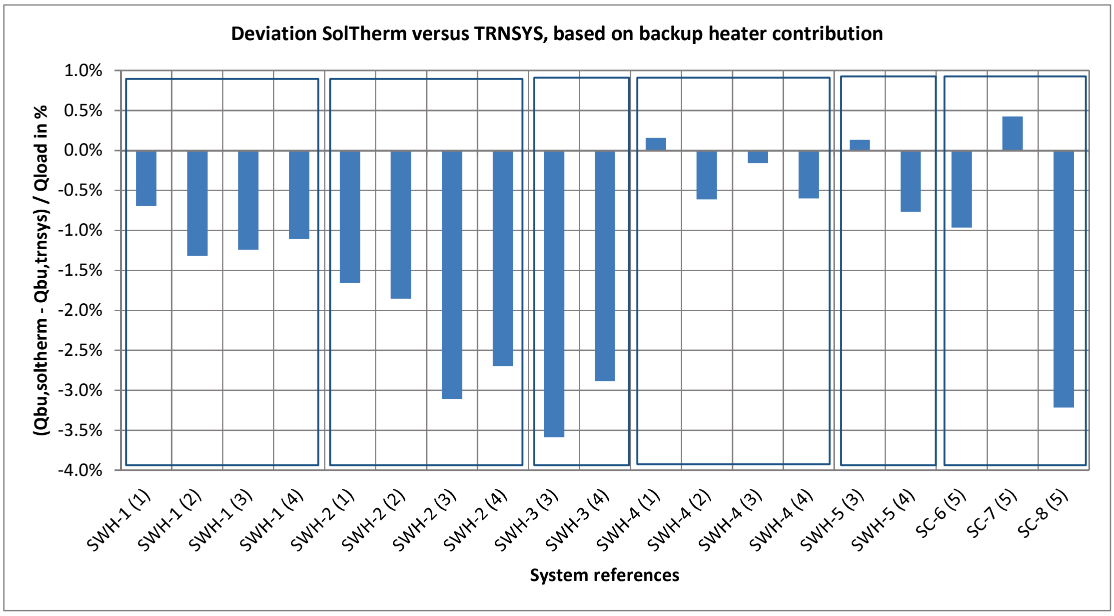


Figure 2 - validation results of SolTherm against TRNSYS. The results are shown for the heat contribution of the backup heater(s) (=Q_{bu},…).

Notes:

- The deviation is defined on the backup heater contribution (=Q_{bu}). 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.

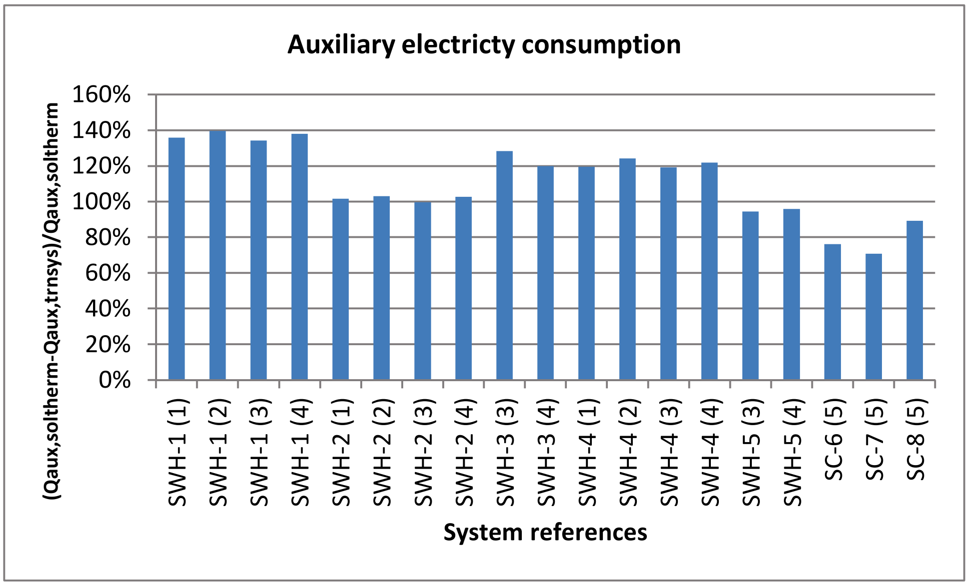


Figure 3 validation results of SolTherm. The results are shown for the prediction of the (auxiliary) electricity consumption (=Q_{aux}).

Notes:

- The electricity consumption (=Q_{aux}) 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 (<±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 (±3%) than the currently available monthly method (assumed: ±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 well-documented, unambiguous and well-referenced (CEN standard) simulation model. The SolTherm 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 SolTherm 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 → 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 *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 *solar plus supplementary* 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 *Wurzburg* hot water sequences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or 600.
SolKey-Stockholm-	EN12976-2 / Solar Keymark reference for *Stockholm* hot water sequences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or

{x}	600.
SolKey-Davos-{x}	EN12976-2 / Solar Keymark reference for *Davos* 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 *Athens* hot water sequences, where {x} is 080, 110, 140, 170, 200, 250, 300, 400 or 600.

Load profiles:	
None	no hot water service
SH_LP	a sequence made available by ITW (DE)

I.4 Program menus

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	Table with monthly calculation results. The button 'Snapshot' loads a 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 executed 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 data-input 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

ANNEX II Validation results

	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

Where:

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

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

ErP-AVG: average climate according to the 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

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

ΣQ_{load} is either the water heating load (water heaters) or the sum of the water and space heating load (combi systems).

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_PH_I_L	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	2.28	*Total collector reference area in m^2*
Eo =	0.856	*Zero loss collector efficiency in -*
a1 =	3.688	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.021	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.96	*Incident angle modifier at 50° in -*
Mcol =	0.046	*Collector flow rate in $kg/(s.m^2)$*

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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	100	*Total tank volume in litres*
Hsto,tot =	1.32	*Total heat loss rate of the tank in W/K*
Htank =	0.75	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat 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*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		75	0	*Thermostat setting on in °C*
Ttherm,off =	95	75	0	*Thermostat setting off in °C*
Design type:		Serial	Not used	*..*
Rated output power:		24	0	*Rated heat output in W*
Control type:		Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °C*
Ti,hs =	15	*Temperature heated space in °C*
tci =	1	*Calculation time step in h*

Results:

	Qirr kWh	Qsolar kWh	ΣQbu kWh	Qhw;out kWh	Qsh;out kWh	ΣQsto;out kWh	ΣQload;req kWh	Qaux kWh
SolTherm	3084	1623	1322	-1475	0	-1475	-2797	85
Validation: TrnSys	3084	1640	1302	-1495	0	-1495	-2797	62
Validation: ΔQ [kWh]	0	-17	19	19	0	19	0	22
Validation: ΔQ [%]	0.0%	0.6%	-0.7%	-0.7%	0.0%	-0.7%	0.0%	-0.8%

Fchart:	1176	*EN 15316-4-3, method 2*
ΔQ [%]:	-5.2%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_PH_I_XL	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	2.28	*Total collector reference area in m^2*
Eo =	0.856	*Zero loss collector efficiency in -*
a1 =	3.688	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.021	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.96	*Incident angle modifier at 50° in -*
Mcol =	0.046	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	100	*Total tank volume in litres*
Hsto,tot =	1.32	*Total heat loss rate of the tank in W/K*
Htank =	0.75	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat 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*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		75	0	*Thermostat setting on in °C*
Ttherm,off =	95	75	0	*Thermostat setting off in °C*
Design type:		Serial	Not used	*..*
Rated output power:		24	0	*Rated heat output in W*
Control type:		Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °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	3084	1671	2824	-1586	0	-1586	-4411	87
Validation	TrnSys	3084	1724	2766	-1645	0	-1645	-4411	63
Validation	ΔQ [kWh]	0	-53	58	58	0	58	0	25
Validation	ΔQ [%]	0.0%	1.2%	-1.3%	-1.3%	0.0%	-1.3%	0.0%	-0.6%
			Fchart:	2540	*EN 15316-4-3, method 2*				
			ΔQ [%]:	-6.4%					

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_L	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	2.28	*Total collector reference area in m^2*
Eo =	0.856	*Zero loss collector efficiency in -*
a1 =	3.688	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.021	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.96	*Incident angle modifier at 50^{o} in -*
Mcol =	0.046	*Collector flow rate in $kg/(s.m^2)$*

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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	100	*Total tank volume in litres*
Hsto,tot =	1.32	*Total heat loss rate of the tank in W/K*
Htank =	0.75	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat 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*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		75	0	*Thermostat setting on in ^{o}C*
Ttherm,off =	95	75	0	*Thermostat setting off in ^{o}C*
Design type:		Serial	Not used	..
Rated output power:		24	0	*Rated heat output in W*
Control type:		Repeat	Repeat	..

Tsto,init =	10	*Initial tank temperature in °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	3084	1547	1426	-1364	0	-1364	-2791	83
Validation	TrnSys	3084	1574	1392	-1399	0	-1399	-2791	62
	ΔQ [kWh]	0	-27	35	35	0	35	0	21
	ΔQ [%]	0.0%	1.0%	-1.2%	-1.2%	0.0%	-1.2%	0.0%	-0.8%

Fchart:	1398	*EN 15316-4-3, method 2*
ΔQ [%]:	-1.0%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_XL	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	2.28	*Total collector reference area in m^2*
Eo =	0.856	*Zero loss collector efficiency in -*
a1 =	3.688	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.021	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.96	*Incident angle modifier at 50° in -*
Mcol =	0.046	*Collector flow rate in $kg/(s.m^2)$*

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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	100	*Total tank volume in litres*
Hsto,tot =	1.32	*Total heat loss rate of the tank in W/K*
Htank =	0.75	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat 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*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		75	0	*Thermostat setting on in °C*
Ttherm,off =	95	75	0	*Thermostat setting off in °C*
Design type:		Serial	Not used	*..*
Rated output power:		24	0	*Rated heat output in W*
Control type:		Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °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	3084	1625	2884	-1531	0	-1531	-4415	86
Validation	TrnSys	3084	1671	2836	-1580	0	-1580	-4415	62
	ΔQ [kWh]	0	-46	49	49	0	49	0	24
	ΔQ [%]	0.0%	1.0%	-1.1%	-1.1%	0.0%	-1.1%	0.0%	-0.5%

Fchart:	2742	*EN 15316-4-3, method 2*
ΔQ [%]:	-3.2%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_PH_I_L	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	3.782	*Total collector reference area in m^2*
Eo =	0.791	*Zero loss collector efficiency in -*
a1 =	3.77	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.014	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.92	*Incident angle modifier at 50° in -*
Mcol =	0.023	*Collector flow rate in $kg/(s.m^2)$*

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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	225	*Total tank volume in litres*
Hsto,tot =	1.67	*Total heat loss rate of the tank in W/K*
Htank =	1.7	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	49%	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 =	345	0	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		75	0	*Thermostat setting on in °C*
Ttherm,off =	80	75	0	*Thermostat setting off in °C*
Design type:		Serial	Not used	*..*
Rated output power:		24	0	*Rated heat output in W*
Control type:		Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °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	5116	2262	809	-1988	0	-1988	-2797	82
Validation	TrnSys	5116	2329	763	-2034	0	-2034	-2797	81
	ΔQ [kWh]	0	-67	46	46	0	46	0	1
	ΔQ [%]	0.0%	2.4%	-1.7%	-1.7%	0.0%	-1.7%	0.0%	0.0%
			Fchart:	832	*EN 15316-4-3, method 2*				
			ΔQ [%]:	0.8%					

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_PH_I_XL	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	3.782	*Total collector reference area in m^2*
Eo =	0.791	*Zero loss collector efficiency in -*
a1 =	3.77	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.014	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.92	*Incident angle modifier at 50^o in -*
Mcol =	0.023	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	225	*Total tank volume in litres*
Hsto,tot =	1.67	*Total heat loss rate of the tank in W/K*
Htank =	1.7	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	49%	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 =	345	0	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		75	0	*Thermostat setting on in $^o C$*
Ttherm,off =	80	75	0	*Thermostat setting off in $^o C$*
	Design type:	Serial	Not used	*..*
	Rated output power:	24	0	*Rated heat output in W*
	Control type:	Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °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	5116	2631	1914	-2497	0	-2497	-4411	90
Validation	TrnSys	5116	2728	1832	-2578	0	-2578	-4411	87
	ΔQ [kWh]	0	-97	82	82	0	82	0	3
	ΔQ [%]	0.0%	2.2%	-1.9%	-1.9%	0.0%	-1.9%	0.0%	-0.1%

Fchart:	1984	*EN 15316-4-3, method 2*
ΔQ [%]:	1.6%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_L	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	3.782	*Total collector reference area in m^2*
Eo =	0.791	*Zero loss collector efficiency in -*
a1 =	3.77	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.014	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.92	*Incident angle modifier at 50° in -*
Mcol =	0.023	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	225	*Total tank volume in litres*
Hsto,tot =	1.67	*Total heat loss rate of the tank in W/K*
Htank =	1.7	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	49%	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 =	345	0	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		75	0	*Thermostat setting on in °C*
Ttherm,off =	80	75	0	*Thermostat setting off in °C*
	Design type:	Serial	Not used	*..*
	Rated output power:	24	0	*Rated heat output in W*
	Control type:	Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °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	5116	2090	1034	-1756	0	-1756	-2791	78
Validation	TrnSys	5116	2191	948	-1843	0	-1843	-2791	79
	ΔQ [kWh]	0	-101	87	87	0	87	0	0
	ΔQ [%]	0.0%	3.6%	-3.1%	-3.1%	0.0%	-3.1%	0.0%	0.0%

Fchart:	1158	*EN 15316-4-3, method 2*
ΔQ [%]:	4.4%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_XL	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	3.782	*Total collector reference area in m^2*
Eo =	0.791	*Zero loss collector efficiency in -*
a1 =	3.77	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.014	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.92	*Incident angle modifier at 50^o in -*
Mcol =	0.023	*Collector flow rate in $kg/(s.m^2)$*

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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	225	*Total tank volume in litres*
Hsto,tot =	1.67	*Total heat loss rate of the tank in W/K*
Htank =	1.7	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	49%	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 =	345	0	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		75	0	*Thermostat setting on in ^oC*
Ttherm,off =	80	75	0	*Thermostat setting off in ^oC*
Design type:		Serial	Not used	*..*
Rated output power:		24	0	*Rated heat output in W*
Control type:		Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °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	5116	2490	2120	-2295	0	-2295	-4415	88
Validation	TrnSys	5116	2614	2001	-2414	0	-2414	-4415	86
	ΔQ [kWh]	0	-124	119	119	0	119	0	2
	ΔQ [%]	0.0%	2.8%	-2.7%	-2.7%	0.0%	-2.7%	0.0%	-0.1%

Fchart:	2289	*EN 15316-4-3, method 2*
ΔQ [%]:	3.8%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_L	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	4.02	*Total collector reference area in m^2*
Eo =	0.8	*Zero loss collector efficiency in -*
a1 =	3.99	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.0138	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.91	*Incident angle modifier at 50° in -*
Mcol =	0.017	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	250	*Total tank volume in litres*
Hsto,tot =	1.67	*Total heat loss rate of the tank in W/K*
Htank =	1.7	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	6	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	36%	81%	0%	0%	0%	*Height of inlet (%)*
Rh,outlet =	0%	60%	0%	100%	0%	*Height of outlet (%)*
Rh,therm =	50%	60%	50%			*Height of thermostat position (%)*
Hexch =	486	517	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		60	0	*Thermostat setting on in °C*
Ttherm,off =	90	65	0	*Thermostat setting off in °C*
Design type:		Parallel	Not used	*..*
Rated output power:		20	0	*Rated heat output in W*
Control type:		Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °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	5438	2010	1292	-2791	0	-2791	-2791	75
Validation: TrnSys	5438	2108	1192	-2791	0	-2791	-2791	59
ΔQ [kWh]	0	-98	100	0	0	0	0	17
ΔQ [%]	0.0%	3.5%	-3.6%	0.0%	0.0%	0.0%	0.0%	-0.6%

Fchart:	1164	*EN 15316-4-3, method 2*
ΔQ [%]:	-4.6%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_XL	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	4.02	*Total collector reference area in m^2*
Eo =	0.8	*Zero loss collector efficiency in -*
a1 =	3.99	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.0138	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.91	*Incident angle modifier at 50^{o} in -*
Mcol =	0.017	*Collector flow rate in $kg/(s.m^2)$*

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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	250	*Total tank volume in litres*
Hsto,tot =	1.67	*Total heat loss rate of the tank in W/K*
Htank =	1.7	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	6	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	36%	81%	0%	0%	0%	*Height of inlet (%)*
Rh,outlet =	0%	60%	0%	100%	0%	*Height of outlet (%)*
Rh,therm =	50%	60%	50%			*Height of thermostat position (%)*
Hexch =	486	517	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		60	0	*Thermostat setting on in ^{o}C*
Ttherm,off =	90	65	0	*Thermostat setting off in ^{o}C*
	Design type:	Parallel	Not used	..
	Rated output power:	20	0	*Rated heat output in W*
	Control type:	Repeat	Repeat	..

Tsto,init =	10	*Initial tank temperature in °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	5438	2381	2452	-4415	0	-4415	-4415	83
Validation	TrnSys	5438	2509	2325	-4415	0	-4415	-4415	69
	ΔQ [kWh]	0	-128	127	0	0	0	0	14
	ΔQ [%]	0.0%	2.9%	-2.9%	0.0%	0.0%	0.0%	0.0%	-0.3%
			Fchart:	2315	*EN 15316-4-3, method 2*				
			ΔQ [%]:	-3.1%					

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_PH_I_L	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	2.37	*Total collector reference area in m^2*
Eo =	0.842	*Zero loss collector efficiency in -*
a1 =	3.62	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.016	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.93	*Incident angle modifier at 50° in -*
Mcol =	0.037	*Collector flow rate in $kg/(s.m^2)$*

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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	123.5	*Total 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	*Method to determine volumes of the tank*
Hsto,automation:	Automation	*Method to distribute heat losses over the volumes*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat 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 thermostat position (%)*
Hexch =	497	517	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		60	0	*Thermostat setting on in °C*
Ttherm,off =	80	65	0	*Thermostat setting off in °C*
Design type:		Serial	Not used	..
Rated output power:		20	0	*Rated heat output in W*
Control type:		Repeat	Repeat	..

Tsto,init =	10	*Initial tank temperature in °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	3206	1703	1244	-1553	0	-1553	-2797	84
Validation	TrnSys	3206	1696	1248	-1549	0	-1549	-2797	70
	ΔQ [kWh]	0	6	-4	-4	0	-4	0	14
	ΔQ [%]	0.0%	-0.2%	0.2%	0.2%	0.0%	0.2%	0.0%	-0.5%

Fchart:	1171	*EN 15316-4-3, method 2*
ΔQ [%]:	-2.6%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_PH_I_XL	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	2.37	*Total collector reference area in m^2*
Eo =	0.842	*Zero loss collector efficiency in -*
a1 =	3.62	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.016	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.93	*Incident angle modifier at 50° in -*
Mcol =	0.037	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	123.5	*Total 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	*Method to determine volumes of the tank*
Hsto,automation:	Automation	*Method to distribute heat losses over the volumes*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat 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 thermostat position (%)*
Hexch =	497	517	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		60	0	*Thermostat setting on in °C*
Ttherm,off =	80	65	0	*Thermostat setting off in °C*
	Design type:	Serial	Not used	*..*
	Rated output power:	20	0	*Rated heat output in W*
	Control type:	Repeat	Repeat	*..*

Tsto,init =	10	*Initial tank temperature in °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	3206	1772	2718	-1693	0	-1693	-4411	86
Validation	TrnSys	3206	1794	2691	-1720	0	-1720	-4411	69
	ΔQ [kWh]	0	-22	27	27	0	27	0	17
	ΔQ [%]	0.0%	0.5%	-0.6%	-0.6%	0.0%	-0.6%	0.0%	-0.4%

Fchart:	2534	*EN 15316-4-3, method 2*
ΔQ [%]:	-4.2%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_L	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	2.37	*Total collector reference area in m^2*
Eo =	0.842	*Zero loss collector efficiency in -*
a1 =	3.62	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.016	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.93	*Incident angle modifier at 50° in -*
Mcol =	0.037	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	123.5	*Total 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	*Method to determine volumes of the tank*
Hsto,automation:	Automation	*Method to distribute heat losses over the volumes*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat 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 thermostat position (%)*
Hexch =	497	517	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		60	0	*Thermostat setting on in °C*
Ttherm,off =	80	65	0	*Thermostat setting off in °C*
Design type:		Serial	Not used	..
Rated output power:		20	0	*Rated heat output in W*
Control type:		Repeat	Repeat	..

Tsto,init =	10	*Initial tank temperature in °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	3206	1604	1377	-1414	0	-1414	-2791	81
Validation	TrnSys	3206	1601	1373	-1418	0	-1418	-2791	68
	ΔQ [kWh]	0	3	4	4	0	4	0	13
	ΔQ [%]	0.0%	-0.1%	-0.2%	-0.2%	0.0%	-0.2%	0.0%	-0.5%

Fchart:	1392	*EN 15316-4-3, method 2*
ΔQ [%]:	0.5%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_XL	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	2.37	*Total collector reference area in m^2*
Eo =	0.842	*Zero loss collector efficiency in -*
a1 =	3.62	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.016	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.93	*Incident angle modifier at 50° in -*
Mcol =	0.037	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	123.5	*Total 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	*Method to determine volumes of the tank*
Hsto,automation:	Automation	*Method to distribute heat losses over the volumes*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	4	*Number of tank volumes*

		Backup heater		Heat 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 thermostat position (%)*
Hexch =	497	517	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		60	0	*Thermostat setting on in °C*
Ttherm,off =	80	65	0	*Thermostat setting off in °C*
Design type:		Serial	Not used	..
Rated output power:		20	0	*Rated heat output in W*
Control type:		Repeat	Repeat	..

Tsto,init =	10	*Initial tank temperature in °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	3206	1725	2796	-1619	0	-1619	-4415	85
Validation	TrnSys	3206	1742	2769	-1646	0	-1646	-4415	70
Validation	ΔQ [kWh]	0	-17	26	26	0	26	0	15
Validation	ΔQ [%]	0.0%	0.4%	-0.6%	-0.6%	0.0%	-0.6%	0.0%	-0.3%

Fchart:	2730	*EN 15316-4-3, method 2*
ΔQ [%]:	-1.5%	

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_L	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	7.05	*Total collector reference area in m^2*
Eo =	0.79	*Zero loss collector efficiency in -*
a1 =	3.721	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.016	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.95	*Incident angle modifier at 50° in -*
Mcol =	0.011	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	391	*Total tank volume in litres*
Hsto,tot =	2.5	*Total heat loss rate of the tank in W/K*
Htank =	1.24	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	6	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	62%	76%	0%	0%	0%	*Height of inlet (%)*
Rh,outlet =	0%	68%	0%	100%	0%	*Height of outlet (%)*
Rh,therm =	100%	68%	50%			*Height of thermostat position (%)*
Hexch =	445	354	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		60	0	*Thermostat setting on in °C*
Ttherm,off =	75	65	0	*Thermostat setting off in °C*
	Design type:	Parallel	Serial	..
	Rated output power:	20	0	*Rated heat output in W*
	Control type:	Repeat	Repeat	..

Tsto,init =	10	*Initial tank temperature in °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
Validation	TrnSys	9537	2646	974	-2791	0	-2791	-2791	64
	ΔQ [kWh]	0	29	-4	0	0	0	0	-4
	ΔQ [%]	0.0%	-1.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
			Fchart:	871	*EN 15316-4-3, method 2*				
			ΔQ [%]:	-3.6%					

Climate:	ErP_AVG	*Reference climate region*
Water heating service:	ErP_SPS_I_XL	*Water heating sequence*
Space heating service:	None	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	7.05	*Total collector reference area in m^2*
Eo =	0.79	*Zero loss collector efficiency in -*
a1 =	3.721	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.016	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.95	*Incident angle modifier at 50° in -*
Mcol =	0.011	*Collector flow rate in $kg/(s.m^2)$*
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*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	391	*Total tank volume in litres*
Hsto,tot =	2.5	*Total heat loss rate of the tank in W/K*
Htank =	1.24	*Height of the tank in m*
Sto,loc =	HS	*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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	6	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	62%	76%	0%	0%	0%	*Height of inlet (%)*
Rh,outlet =	0%	68%	0%	100%	0%	*Height of outlet (%)*
Rh,therm =	100%	68%	50%			*Height of thermostat position (%)*
Hexch =	445	354	0	0	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		60	0	*Thermostat setting on in °C*
Ttherm,off =	75	65	0	*Thermostat setting off in °C*
Design type:		Parallel	Serial	..
Rated output power:		20	0	*Rated heat output in W*
Control type:		Repeat	Repeat	..

Tsto,init =	10	*Initial tank temperature in °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	3353	1799	-4415	0	-4415	-4415	71
Validation	TrnSys	9537	3373	1765	-4415	0	-4415	-4415	74
Validation	ΔQ [kWh]	0	-21	34	0	0	0	0	-3
Validation	ΔQ [%]	0.0%	0.5%	-0.8%	0.0%	0.0%	0.0%	0.0%	0.1%

Fchart:	1659	*EN 15316-4-3, method 2*
ΔQ [%]:	-3.2%	

Climate:	WB_S_45	*Reference climate region*
Water heating service:	ITW_Preheat_Combi	*Water heating sequence*
Space heating service:	ITW_NE50	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	13.98	*Total collector reference area in m^2*
Eo =	0.777	*Zero loss collector efficiency in -*
a1 =	4.026	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.01	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.988	*Incident angle modifier at 50° in -*
Mcol =	0.011	*Collector flow rate in $kg/(s.m^2)$*

Hsol,loop =	4.84	*Heat losses collector loop piping in W/K*
Sol,loc =	NHS	*Location of the collector loop piping*
Pcol,pmp =	20	*Nominal electricyt consumption collector pump in W*
Pcol,ctrl =	4	*Standby electricity consumption of controller in W*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	956.3	*Total tank volume in litres*
Hsto,tot =	3.4	*Total heat loss rate of the tank in W/K*
Htank =	1.72	*Height of the tank in m*
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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	6	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	45%	100%	50%	0%	26%	*Height of inlet (%)*
Rh,outlet =	0%	50%	30%	95%	50%	*Height of outlet (%)*
Rh,therm =	40%	50%	30%			*Height of thermostat position (%)*
Hexch =	1444	0	0	1019	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Tthern,on =		48	37	*Thermostat setting on in °C*
Ttherm,off =	85	55	40	*Thermostat setting off in °C*
Design type:		Parallel	Parallel	*..*
Rated output power:		15	15	*Rated heat output in W*
Control type:		Repeat	Repeat	*..*

Tsto,init =	35	*Initial tank temperature in °C*
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	Qaux
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
	SolTherm	17190	3866	9519	-2771	-9079	-11850	-11853	41
Validation	TrnSys	17193	3736	9405	-2797	-9088	-11885	-11853	53
Validation	ΔQ [kWh]	-3	131	114	26	9	35	0	-13
Validation	ΔQ [%]	0.0%	-1.1%	-1.0%	-0.2%	-0.1%	-0.3%	0.0%	0.1%

Fchart:	8198	*EN 15316-4-3, method 2*
ΔQ [%]:	-11.2%	

Climate:	WB_S_45	*Reference climate region*
Water heating service:	ITW_Preheat_Combi	*Water heating sequence*
Space heating service:	ITW_NE50	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	14.04	*Total collector reference area in m^2*
Eo =	0.845	*Zero loss collector efficiency in -*
a1 =	4.341	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.016	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.985	*Incident angle modifier at 50° in -*
Mcol =	0.011	*Collector flow rate in $kg/(s.m^2)$*
Hsol,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 collector pump in W*
Pcol,ctrl =	4	*Standby electricity consumption of controller in W*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	889	*Total tank volume in litres*
Hsto,tot =	2.92	*Total heat loss rate of the tank in W/K*
Htank =	1.844	*Height of the tank in m*
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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	10	*Number of tank volumes*

		Backup heater		Heat output		
	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 outlet (%)*
Rh,therm =	50%	50%	50%			*Height of thermostat position (%)*
Hexch =	1444	0	0	2989	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		50	50	*Thermostat setting on in °C*
Ttherm,off =	90	55	55	*Thermostat setting off in °C*
Design type:		Parallel	Serial	..
Rated output power:		15	15	*Rated heat output in W*
Control type:		Repeat	Repeat	..

Tsto,init =	35	*Initial tank temperature in °C*
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	Qaux
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
	SolTherm	17263	3905	9275	-2774	-1507	-4281	-11853	39
Validation	TrnSys	17266	3997	9326	-2797	-1512	-4309	-11853	55
	ΔQ [kWh]	-3	-92	-50	23	5	28	0	-16
	ΔQ [%]	0.0%	0.8%	0.4%	-0.2%	0.0%	-0.2%	0.0%	0.1%
			Fchart:	7868	*EN 15316-4-3, method 2*				
			ΔQ [%]:	-11.9%					

Climate:	WB_S_45	*Reference climate region*
Water heating service:	ITW_Preheat_Combi	*Water heating sequence*
Space heating service:	ITW_NE50	*Space heating sequence*

EN ISO 9808 (SK datasheet)

Asol =	10.06	*Total collector reference area in m^2*
Eo =	0.831	*Zero loss collector efficiency in -*
a1 =	3.44	*First order collector heat loss coefficient in $W/(K.m^2)$*
a2 =	0.0176	*Second order collector heat loss coefficient in $W/(K2.m^2)$*
IAM =	0.84	*Incident angle modifier at 50° in -*
Mcol =	0.02	*Collector flow rate in $kg/(s.m^2)$*

Hsol,loop =	4.84	*Heat losses collector loop piping in W/K*
Sol,loc =	NHS	*Location of the collector loop piping*
Pcol,pmp =	20	*Nominal electricyt consumption collector pump in W*
Pcol,ctrl =	4	*Standby electricity consumption of controller in W*

EN 12977 3/4 (SK datasheet)

Vsto,tot =	703	*Total tank volume in litres*
Hsto,tot =	3.87	*Total heat loss rate of the tank in W/K*
Htank =	1.54	*Height of the tank in m*
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*
Csto,automation:	Automation	*Method to distribute the internal convection*
Nvol =	9	*Number of tank volumes*

		Backup heater		Heat output		
	Solar loop	WHS	SHS	WHS	SHS	
Rh,inlet =	49%	100%	60%	11%	0%	*Height of inlet (%)*
Rh,outlet =	3%	56%	28%	99%	55%	*Height of outlet (%)*
Rh,therm =	48%	100%	50%			*Height of thermostat position (%)*
Hexch =	1102	0	0	-3000	0	*Heat exchanger rate in W/K*

EN 12977-5 (SK datasheet)

		Backup heater		
	Solar loop	WHS	SHS	
Ttherm,on =		49	49	*Thermostat setting on in °C*
Ttherm,off =	90	54	54	*Thermostat setting off in °C*
	Design type:	Parallel	Parallel	..
	Rated output power:	15	15	*Rated heat output in W*
	Control type:	Repeat	Repeat	..

Tsto,init =	35	*Initial tank temperature in °C*
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	Qaux
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
	SolTherm	12370	3288	10104	-2774	-9052	-11826	-11853	49
Validation	TrnSys	12372	3436	9723	-2798	-9072	-11870	-11853	55
	ΔQ [kWh]	-2	-147	381	24	20	44	0	-6
	ΔQ [%]	0.0%	1.2%	-3.2%	-0.2%	-0.2%	-0.4%	0.0%	0.1%
			Fchart:	9028	*EN 15316-4-3, method 2*				
			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 °C

P_{exch} 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 [5].

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

$T_{sto(i)}$ is then current and new tank temperature of tank volume I in °C

$V_{sto(i)}$ is the volume of tank volume I in litres

T_{in} is the inlet temperature in °C

Q_{req} is the required heat exchange in kWh

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

ρ is the density of water in kg/litres (=1)

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

t_{ci} 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.

---

[5] 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_{exch} 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.

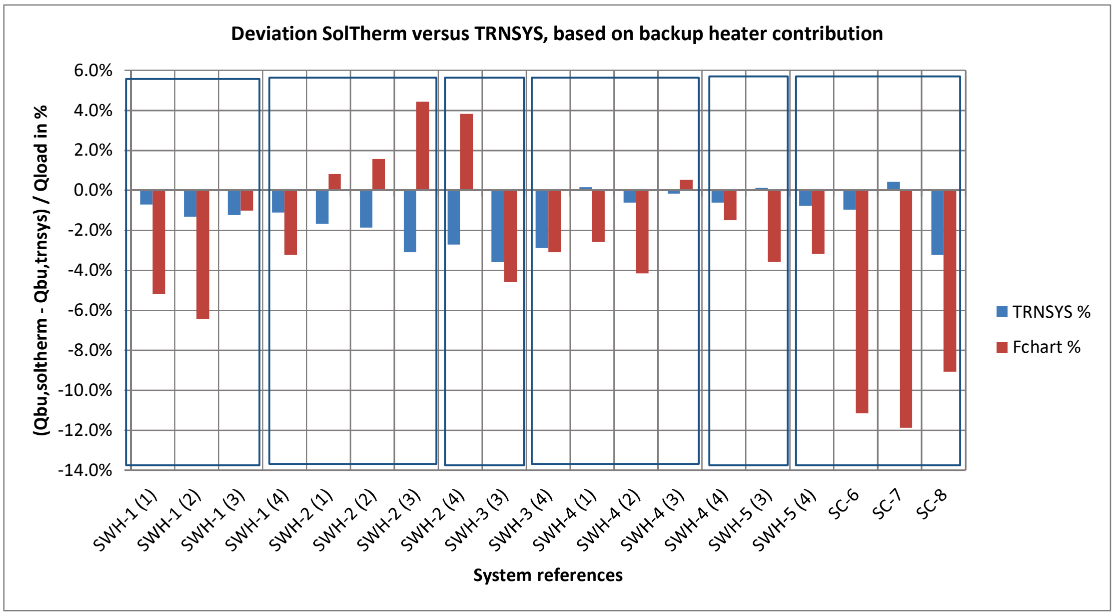


Figure 4 - SolTherm compared to TRNSYS and Fchart.

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.

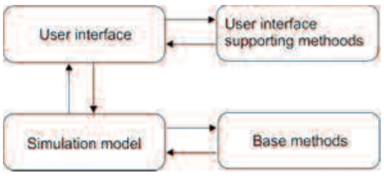


Figure 1- graphical representation of the main structure of the software. The user interface communicates with the simulation model and can make use of the user interface supporting methods. The simulation model communicates with the base methods from the standards

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
…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}

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 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: Tamb	Outside air temperature in oC
- 3th column: Isol	Solar irradiation on the collector plane in W/m^2

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 *solar plus supplementary* 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 *Wurzburg* 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 *Stockholm* 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 *Davos* 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 *Athens* 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 iqnored
- 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;{ΔT_{amplit}};{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 separated 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 l/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 hot 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 following built in sequences, according to

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

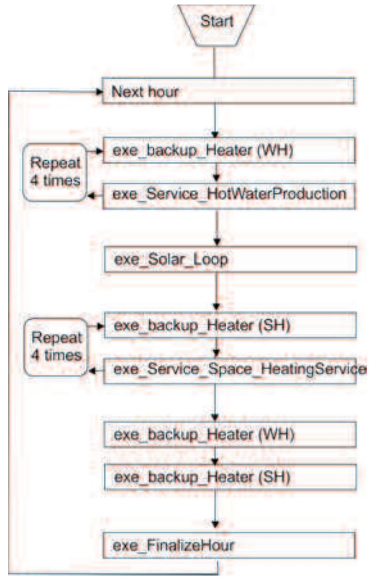
The method is called according to:

…Load the models input parameters

Dim clsSolTherm as new cls_SolTherm.clsSolThermModel002 clsSolTherm.Execute

….Read the calculation results

Soltherm includes one simulation model (Model002) that should fit the requirements of commonly applied solar water heaters, solar space heaters and combi systems.



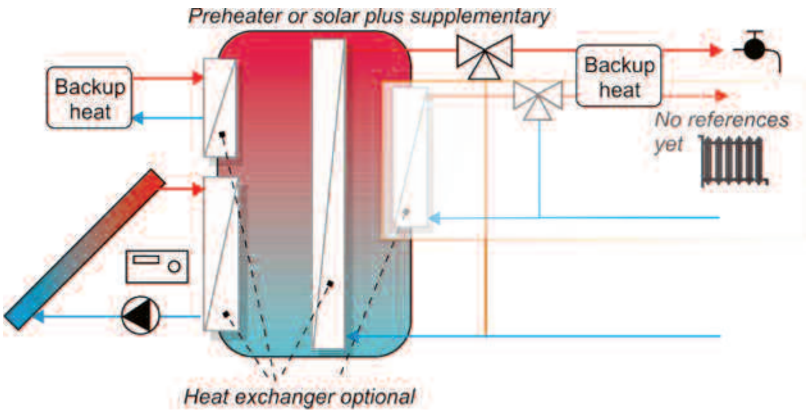


Figure 2 - graphical representation of the solar thermal system that is handled by model 002

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)
```

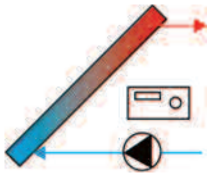
5 Base methods model

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

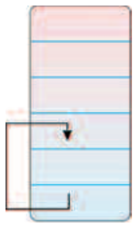
The method describes the function of the collector and collector loop and is intended to be connected to a method for the heat storage tank (EN 15316-5:2017).

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)

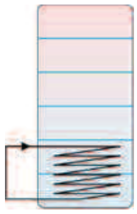
Called from: Simulation model (e.g. hot water withdrawal for hot water service)

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

VariableCollectionOf_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	oC	Thermostat setting solar loop
VariableCollectionOf_BackupHeater			
BacType	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	oC	the lower temperature limit for backup heater on
VariableCollectionOf_Tank			
Nvol	Integer	-	Number of storage volumes (index=0: bottom)
Vsto()	Double	l	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
IposInlet()	Integer		Volume numbersinlet (0:solar loop, 1:backup heater water heating, 2: backup heater space heating, 3: water heating loop, 4: space heating loop
IposOutlet()	Integer		Volume numbers outlet
IposTherm()	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	oC	Storage water temperature for each volume
VariableCollectionOf_Climate			
ClimType	String		
Ti_hs	Double		
Isol()	Double	W/K	Solar irradiation on collector plane
Tair(,)	Double	oC	(0,Hour): Heated space, (1,Hour): not heated space, (2,hour): outside
VariableCollectionOf_HotwaterDemand			
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	oC	Inlet temperature (cold water) per hour
Tsto_out_min()	Double	oC	Minimum outlet temperature per hour
VariableCollectionOf_SpaceHeatingDemand			
ShsType	String		Only for user interface
Qsto_out_req()	Double	kWh	Requested heat output per hour
Tsh_on	Single	oC	On temperature space heating
Tsh_off	Single	oC	Off temperature space heating
Msto()	Double	kg/h	Flowrate
Tsh_high()	Double	K	Inlet temperature (cold water)
Tsh_low()	Double	K	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