Project ECOTEST **Deliverables** **D8.4 Analysis of the results and report** **D8.5 Proposal to CEN and communication**	ECOTEST ECO_WP8_XXX_WP8-RRT2_V2

WP	WP 8 Solar Collector
Type	Annex to WP8 final report
Title	**Annex 1.2** **Extended RRT results and analysis** **RRT2 SWH Store (EN 12977-3)**
Author	A. Bohren
Dissemination	Free

Version	Status	Date	Comments
A	Internal for discussion in the WP	16.12.2018	
B	Version sent as internal draft report Febr. 2019.	20.02.2019	
C	Version sent as progress report Febr. 2019	26.02.2019	
D	Final version after steering group meeting for approval by WP8 testing laboratories	09.05.2019	
E	Final version	02.06.2019	

.

Table of contents

1 Introduction

1.1 Context of the test

For the RRT2 one solar water heater (SWH) store was sent around to the participating laboratories. The same store was used for the RRT4 (EN 12976) solar water heater system testing. RRT2 and RRT4 are therefore done basically at the same time in one laboratory.
Testing of solar water heaters according to EN12977-3 is a laboratory test which is performed under controlled conditions and using well defined test cycles. The testing is therefore independent of ambient conditions such as solar radiation.

1.2 Time period

The tests have started in February 2018 and ended in December 2018

1.3 Laboratories involved

The following labs have been involved in the test of the collector:

ISE
TestLab Solar Thermal Systems
Division Thermal Systems and Building Technologies (TSB)
Fraunhofer-Institut für Solare Energiesysteme ISE
Heidenhofstrasse 2, 79110 Freiburg, Germany

SPF
SPF Institute for Solar Technology
Hochschule für Technik Rapperswil HSR
Oberseestrasse 10, 8640 Rapperswil, Switzerland

IGTE/ITW
Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE)
Former Institute of Thermodynamics and Thermal Engineering (ITW)
Research and Testing Centre for Thermal Solar Systems (TZS)
University of Stuttgart
Pfaffenwaldring 6, 70550 Stuttgart, Germany

2 Appliance tested

2.1 Main features of the appliance tested.

The solar water heater store for the round robin test is a so called bivalent store for solar installations made by a German manufacturer. It is designed to keep drinking water that is heated to a maximum 85 °C ready for use in households and small businesses. The store is designed to be integrated into a central heating installation in combination with an auxiliary heat generator.

The solar water heater store is an indirectly heated hot water storage tank for solar energy supported hot water supply. The storage tank and the pipe coils are enamelled on the drinking water side. As additional corrosion protection, each tank has a magnesium protective anode. The thermal insulation is made of a CFC-free EPS. An electric heating rod can be inserted into the storage tank as an extra accessory (not installed for this Round Robin). Two welded pipe coils are used as Heat exchangers. The storage tank is connected via the cold water connection to the water network and via the hot water connection with the taps. If warm water is drawn from a tap, cold water flows back into the storage tank. The heating takes place in two separate circles: The solar heat exchanger is located in the lower, cold area. The relatively low water temperatures in the lower area ensure even with low solar radiation optimum heat transfer from the solar circuit on the storage water. The auxiliary heating HX is located in the upper, warmer area of the storage tank. The standby volume of the auxiliary heating is about one third of the storage volume.

2.2 Picture of the SWH store

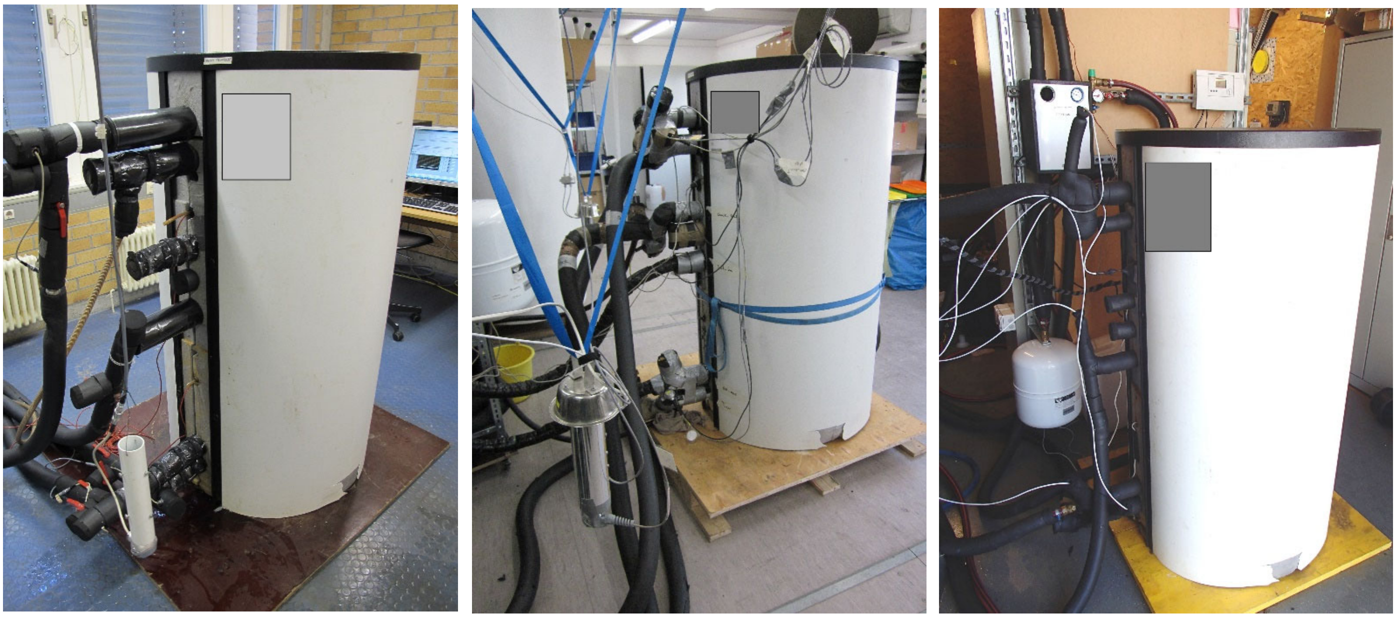


Figure 1: The Store installed at the testing laboratory igte, ise and spf. The grey squares hide the identity of the store. The small insulation damage at the bottom proofs that the same store was used in all labs.

2.3 Origin of appliances used for the RRT

The SWH store was made available by one of the participating test laboratories without addition expectations. After the RRT the store will be returned to its owner.

3 Testing programme & testing equipment of labs

3.1 Programme

The testing of solar water heater stores according to the EN 12977-3 is laboratory testing where the store is charged and discharged according to well-defined charging and discharging profiles. By measuring the in- and outlet temperatures and the flow rates the store can be characterized using a mathematical store model. The test cycles are adapted to the different possible types of store with respect to direct and indirect charging and discharging. The testing consists mainly of the following test sequences.
Sequence C: Determination of the effective store volume and the heat transfer capacity rate of the charge and discharge heat exchangers. For this test the conditioned store is charged with constant power until a temperature of 60° is reached at the charging outlet. The store is then discharged with a constant flow rate and a constant inlet temperature of 20°C until a steady state is reached.
Sequence L: Determination of the stand-by heat loss capacity rate of the entire store. The store is charged similar to the sequence C but not discharged immediately. Instead the store is in standby for approximately 48h before the store is discharged completely.
Sequence NiA: Determination of the heat transfer capacity rate and the position of the auxiliary heat exchanger(s). For this sequence the store is conditioned, then charged with the auxiliary heater and discharged again. If there are more than one auxiliary heaters loops this sequences is performed for every loop individually.
Sequence NiB: Determination of the effective vertical heat conductivity. The store is charged similar to the sequence NiA but not discharged immediately. Instead the store is in standby for approximately 48h before the store is discharged completely.
Sequence S: Determination of the thermal stratification during discharge with a 'high' flow rate. The store is charged similar to the sequence C but discharged with a higher volume flow rate of not less than 600 l/h
Sequence EiA: Determination of the position(s) and length(s) of the electrical heating source(s) (if available). The store is conditioned, then charged using the electric heater, and discharged again. This test sequence was not used due to the missing electrical heating element.

During all these test sequences the external energy flows (i.e. temperatures and flow rates) are measured. With the measured data from the standard test sequences the store is then modelled using a general mathematical model as implemented in the TRNSYS Type 340 "MULTIPORT Store – Model[1]. With this a set of store parameters describing the behaviour of the store is determined using a parameter identification software. The mathematical model is not strictly defined but it has to fulfil the requirements which are defined in the standard Annex D. It is therefore basically possible that different test labs use different models and get different parametrization of the stores.
Most laboratories use the same generic optimization software GenOpt[2], even if any other software can be used for the identification of the store parameters. Basically this should not have an impact on the result as this software is only a mathematical tool. However, as far as we know, all testing laboratories use the model which is implemented in the "TRNSYS Type 340 "MULTIPORT Store – Model" together with a parameter identification tool such as GenOpt or MatLab.

[1] https://www.trnsys.de/download/de/ts_type_340_de.pdf
[2] https://simulationresearch.lbl.gov/GO/

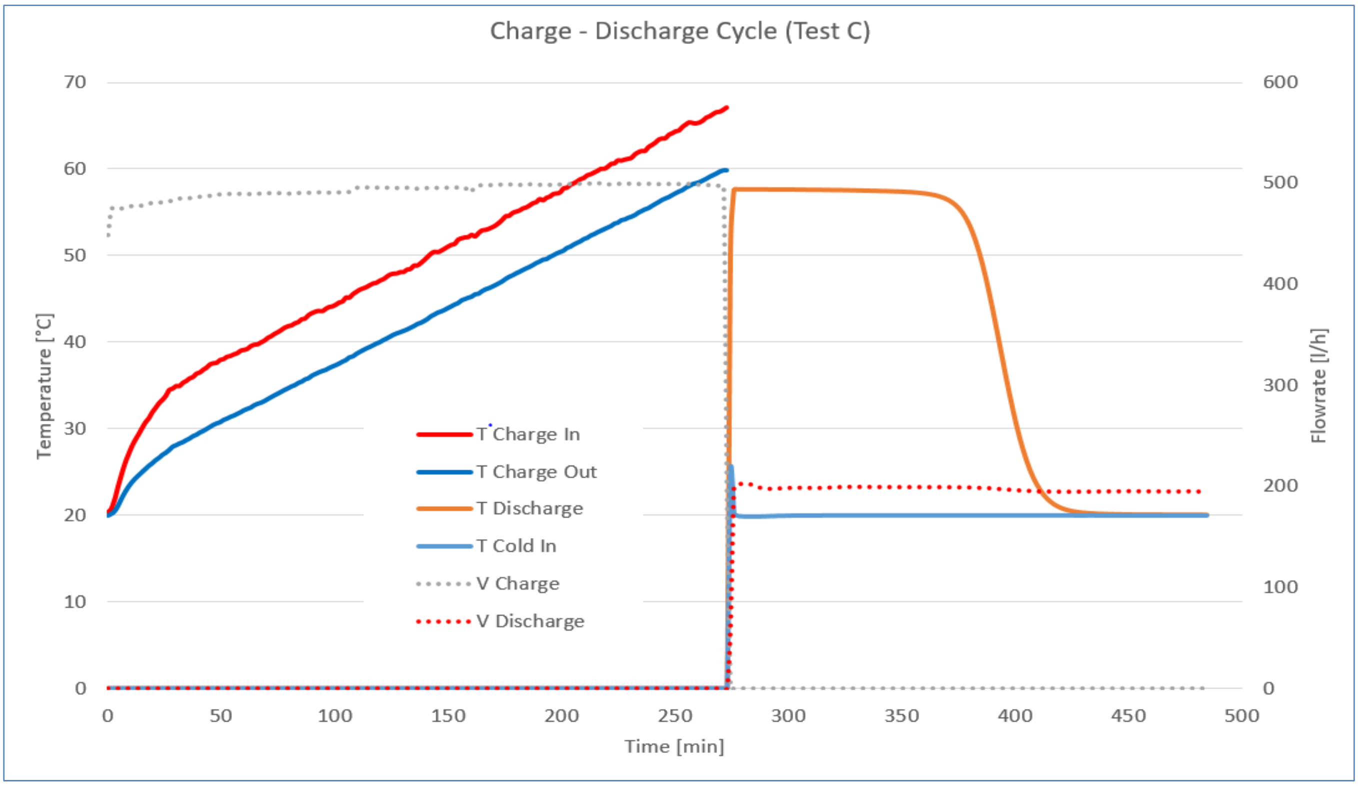


Figure 2: A typical test sequence showing the charging and discharging phases of test cycle C

3.2 Test protocol(s) used

The test protocol used by the different test labs is following the standard EN 12977-3.

3.3 Overview of the main test equipment used by labs

The participating testing laboratories use tailor-made own test rigs and different sensors which are in full compliance with all the requirements of the EN 12977-3.

3.4 Test conditions

The store is classified as Group 2 store (indirect charging and direct discharging) according to the Table 1 of EN 12977-3. Therefore the test procedures for group 2 stores have been selected by the participating test laboratories. According to the EN 12977-3 the following requirements must be fulfilled during the test:

- The testing stands are located in air-conditioned rooms where the room temperature of 20 °C should not vary more than ± 2 K during the test.

The test circuits fulfil the following requirements:

- the flow rate shall be adjustable and stable within ± 5 %;
- the working temperature range shall be between 10 °C and 90 °C;
- the minimum cooling power in the discharge circuit shall be at least 25 kW at a fluid temperature of 20 °C;
- the minimum heating up rate of the charge circuit with disconnected store shall be 3 K/min;

The heat transfer fluid used for testing was water.

All temperature sensors and flow meters were calibrated as required by the accreditation of the testing laboratories.

3.5 Other

None

4 Definitions used for the statistical analysis (common to ECOTEST)

1. Median value
   The values are ranked from the smallest to the highest or from the highest to the lowest then the value just in the middle is the median value (if the number is odd) and arithmetic average of n/2 and (n/2+1) if n is even
2. Deviation from median value (Delta)
   Difference between any value and the median value
3. Arithmetic mean value
   Arithmetic mean of all value (sum of all values divided by the number of values)
4. Deviation from arithmetic mean value
   Difference between any value and the arithmetic mean value
5. Repeatability standard deviation sr
   The standard deviation of the values measured by each lab (in the column of each lab) and the standard deviation of all the values (in the column "total of all the labs)
6. Reproducibility Standard deviation (*) sR
   The standard deviation of the arithmetic values (if repeatability tests performed) or the value declared by each lab if no repeatability tests
7. Difference between maxi and mini arithmetic mean values.
   The difference between the maximum arithmetic average value and the minimum arithmetic average value (if repeatability test are done) or just the difference between the maximum value and minimum value of the declared values.

5 Measurement results of laboratories, statistics and analyse.

5.1 Overview Table of data measured

In this chapter the test results of the three participating test laboratories are presented as received. The laboratories are name 1, 2, 3 to avoid linking to the M, S, and T that are used in the text.

5.1.1 SWH store performance

SWH efficiency data

LABORATORY		1	2	3	
EN 12977-3					
Gross height of unit incl. Insulation *		1475	1470	1470	mm
Gross width incl. Insulation *		805	800	800	mm
Gross depth incl. Insulation *		805	800	800	mm
Nominal volume- total **	V_n	404	400.00	405.60	L
Effective volume- total **		404	401.00	382.50	L
Auxiliary heated volume		125	136.34	122.40	L
Auxiliary heat exchanger volume		3.7	4.60	4.50	L
Solar loop heat exchanger volume		7.6	10.10	10.40	L
Total effective thermal capacity	C_S	1689	1679	1587.11	kJ/K
Thermal capacity of aux. heated part I (calc)		524	571	507.88	kJ/K
Stand-by heat loss rate	$(UA)_{sb,s,a}$	2.68	2.91	2.57	W/K
Effective vertical heat conductivity	λ_{eff}	1.90	2.01	1.99	W/(m*K)
Stratification number (during discharge)	**N**	174	156.00	145.00	-
UA-value, solar heat exchanger	$(UA)_{hx,s}$	495	444.44	473.62	W/K
UA-value, auxiliary heat exchanger	$(UA)_{hx,aux}$	393	388.88	375.45	W/K
Cold water inlet (position)		0	11	0	%
Hot water outlet (position)		100	93	100	%
Collector loop inlet (position)		52	54	60	%
Collector loop outlet (position)		9	17	0	%
Auxiliary heating inlet (position)		88	89	85	%
Auxiliary heating outlet (position)		69	66	68	%
Temp. sensor 1, Solar (position)		33	36	29	%
Temp. sensor 2, Auxiliary heating (position)		75	76	74	%
European regulations					
Standing loss (Tstore = 65 °C, Tambient = 20 °C)	**S**	120.6	131.25	115.65	W
Nominal volume of the store	V_{nom}	404	400	405.60	L
Energy Label **		D (C.46)	D (C.88)	D (C.26)	

Table 1: Measured parameters submitted by the participating test laboratories (final results)

* Measured values, not fitted values

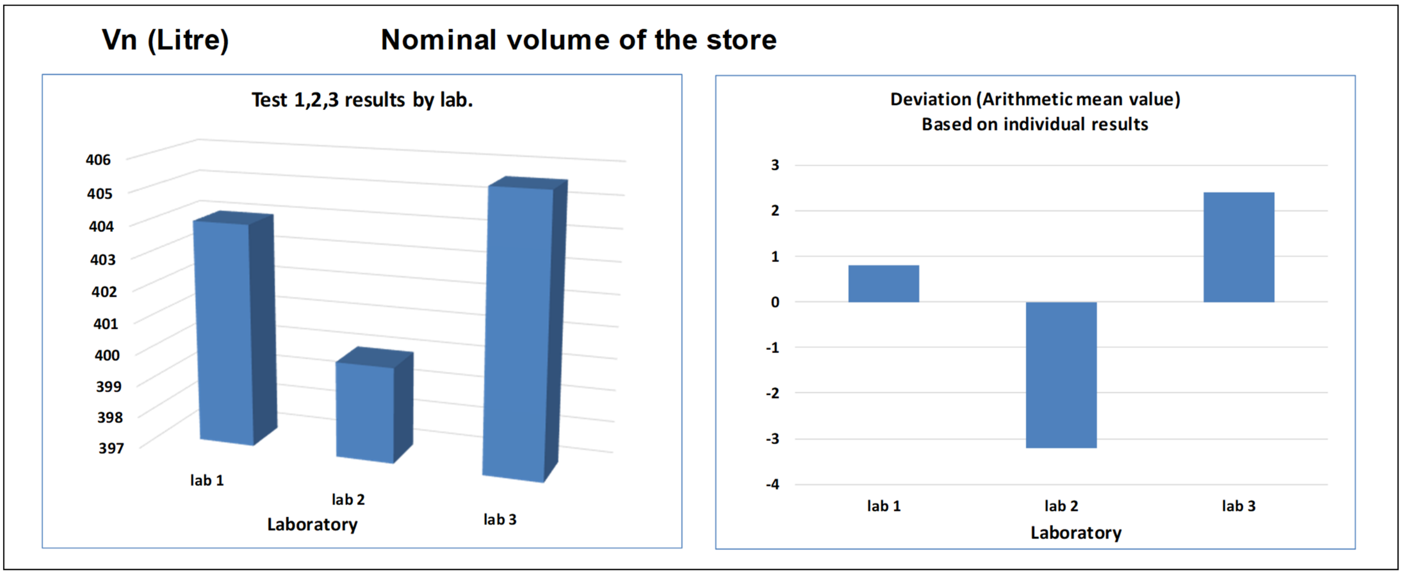
** See remarks in 7.1

5.2 Statistics on the main parameters

In this chapter the relevant parameters as determined by the participating testing laboratories are presented in the standard format required by the ECOTEST project. Comments and explanations in chapter 7. As there were only three testing laboratories the statistical relevance of the presented numbers is limited. Using directly these data for statistical purposes is not appropriate and should be avoided.

5.2.1 Nominal Volume V_n

Parameter	V_n (Litre)	Nominal volume of the store		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	404	400	406
Number of test results		1	1	1
Median value	404	404.0	400.0	405.6
Deviation from median value (Delta)		0.0	-4.0	1.6
Arithmetic mean value	403	404.0	400.0	405.6
Deviation from arithmetic mean value		0.8	-3.2	2.4
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	2.9			
Max - Min (arithmetic mean value)	5.6	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	5.6	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	correct	correct	correct	correct

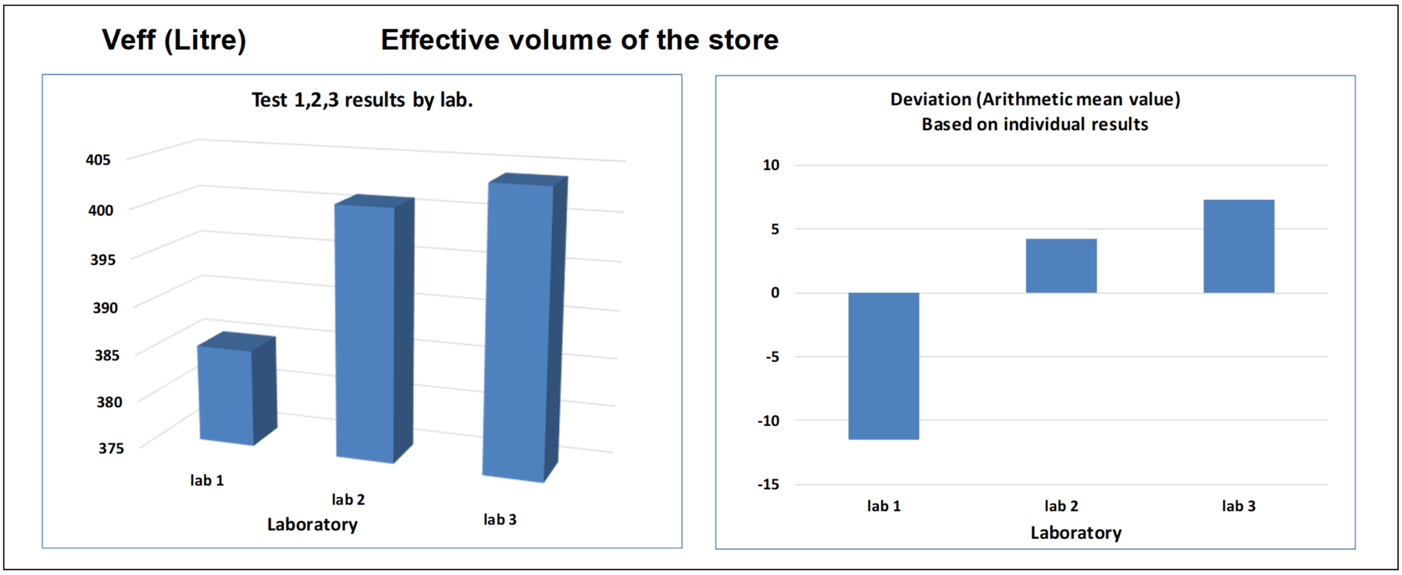


STATISTICS		
Median		404 litre
Arh. mean value		403 litre
R STD		3 litre
r STD	-	
Max - Min (M-m)		6 litre

Figure 3: ECOTEST statistical representation of the results nominal store volume V_n

5.2.2 Effective Volume V_{eff}

Parameter	V_{eff} (Litre)	Effective volume of the store		
universal statistical evaluation v3.4.SLG by ACLi	**Total over all labs**	lab 1	lab 2	lab 3
test result 1	**Test1**	385.2	401.0	404.0
Number of test results		1	1	1
Median value	**401**	385.2	401.0	404.0
Deviation from median value (Delta)		**-15.8**	**0.0**	**3.0**
Arithmetic mean value	**397**	385.2	401.0	404.0
Deviation from arithmetic mean value		**-11.5**	**4.3**	**7.3**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	**10.1**			
Max - Min (arithmetic mean value)	**18.8**	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	**18.8**	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	correct	correct	correct	correct

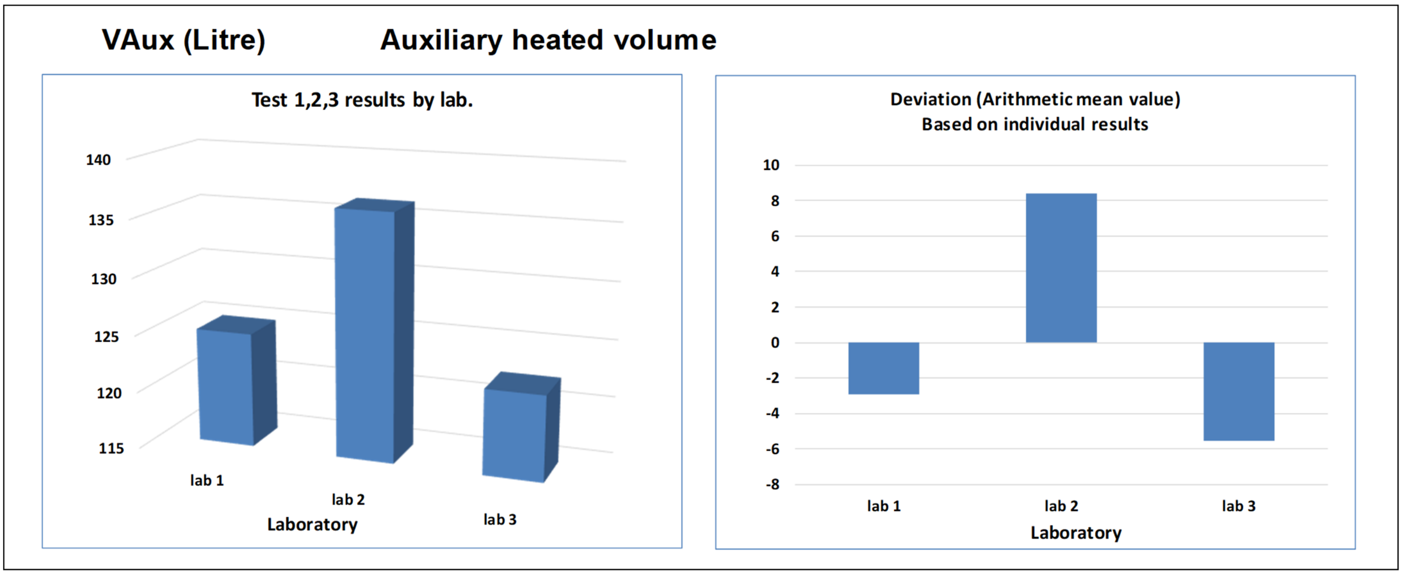


STATISTICS		
Median	401	litre
Arh. mean value	397	litre
R STD	10	litre
r STD	-	
Max - Min (M-m)	19	litre

Figure 4: ECOTEST statistical representation of the results V_{eff}

5.2.3 Auxiliary heated volume V_{Aux}

Parameter	V_{Aux} (Litre)	Auxiliary heated volume		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	125.00	136.34	122.40
Number of test results		1	1	1
Median value	125	125.0	136.3	122.4
Deviation from median value (Delta)		0.0	11.3	-2.6
Arithmetic mean value	128	125.0	136.3	122.4
Deviation from arithmetic mean value		-2.9	8.4	-5.5
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	7.4			
Max - Min (arithmetic mean value)	13.9	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	13.9	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	correct	correct	correct	correct

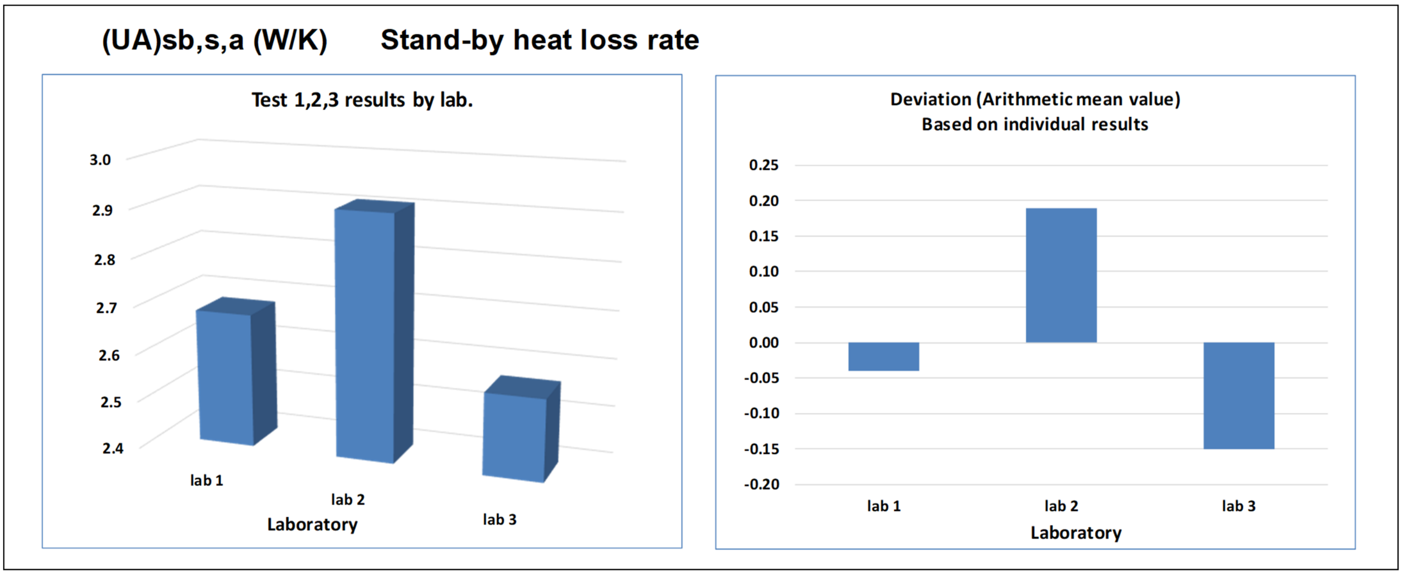


STATISTICS		
Median		125.0 litre
Arh. mean value		127.9 litre
R STD		7.4 litre
r STD	-	
Max - Min (M-m)		13.9 litre

Figure 5: ECOTEST statistical representation of the results Auxiliary heated volume V_{Aux}

5.2.4 Standby Heat Loss $(UA)_{sb,s,a}$

Parameter	$(UA)_{sb,s,a}$ (W/K)	Stand-by heat loss rate		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	2.68	2.91	2.57
Number of test results		1	1	1
Median value	3	2.68	2.91	2.57
Deviation from median value (Delta)		**0.00**	**0.23**	**-0.11**
Arithmetic mean value	3	2.68	2.91	2.57
Deviation from arithmetic mean value		**-0.04**	**0.19**	**-0.15**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	0.173			
Max - Min (arithmetic mean value)	0.340	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	0.340	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	correct	correct	correct	correct

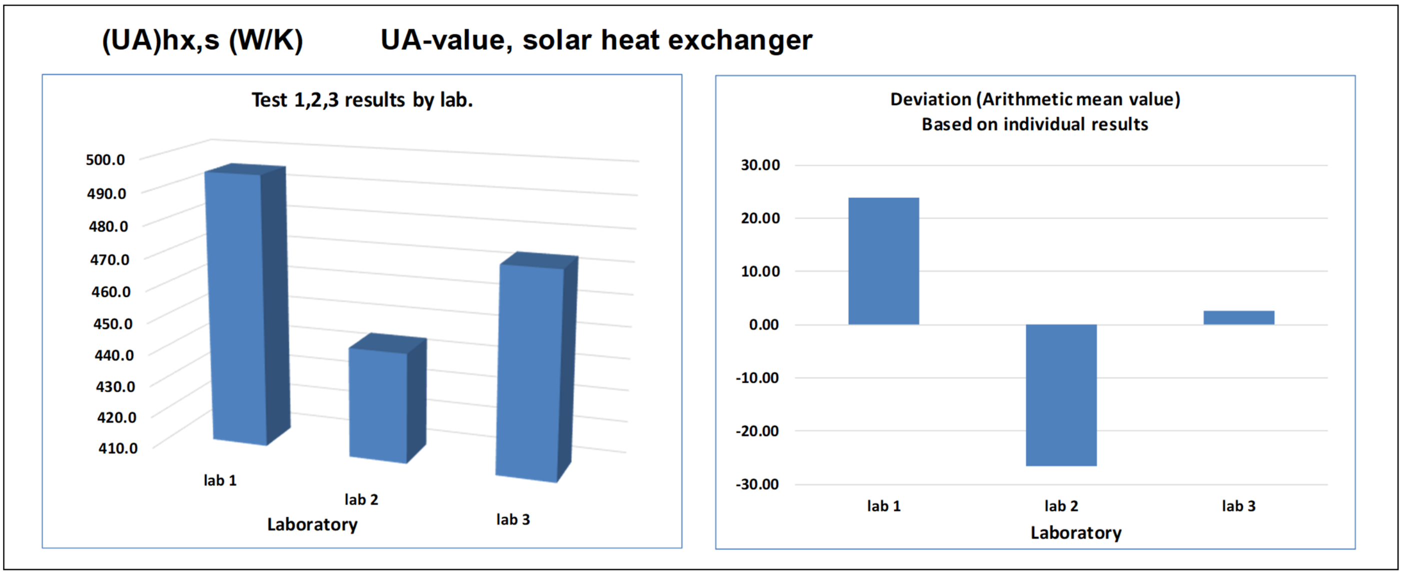


STATISTICS	
Median	2.680 W/K
Arh. mean value	2.720 W/K
R STD	0.173 W/K
r STD	-
Max - Min (M-m)	0.340 W/K

Figure 6: ECOTEST statistical representation of the results Standby Loss $(UA)_{sb,s,a}$

5.2.5 Heat transfer capacity rate between solar heat exchanger and store $(UA)_{hx,sol,s}$

Parameter	(UA)hx,s (W/K)	UA-value, solar heat exchanger		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	495.00	444.44	473.62
Number of test results		1	1	1
Median value	474	495.00	444.44	473.62
Deviation from median value (Delta)		21.38	-29.18	0.00
Arithmetic mean value	471	495.00	444.44	473.62
Deviation from arithmetic mean value		23.98	-26.58	2.60
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	25.380			
Max - Min (arithmetic mean value)	50.560	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	50.560	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	correct	correct	correct	correct

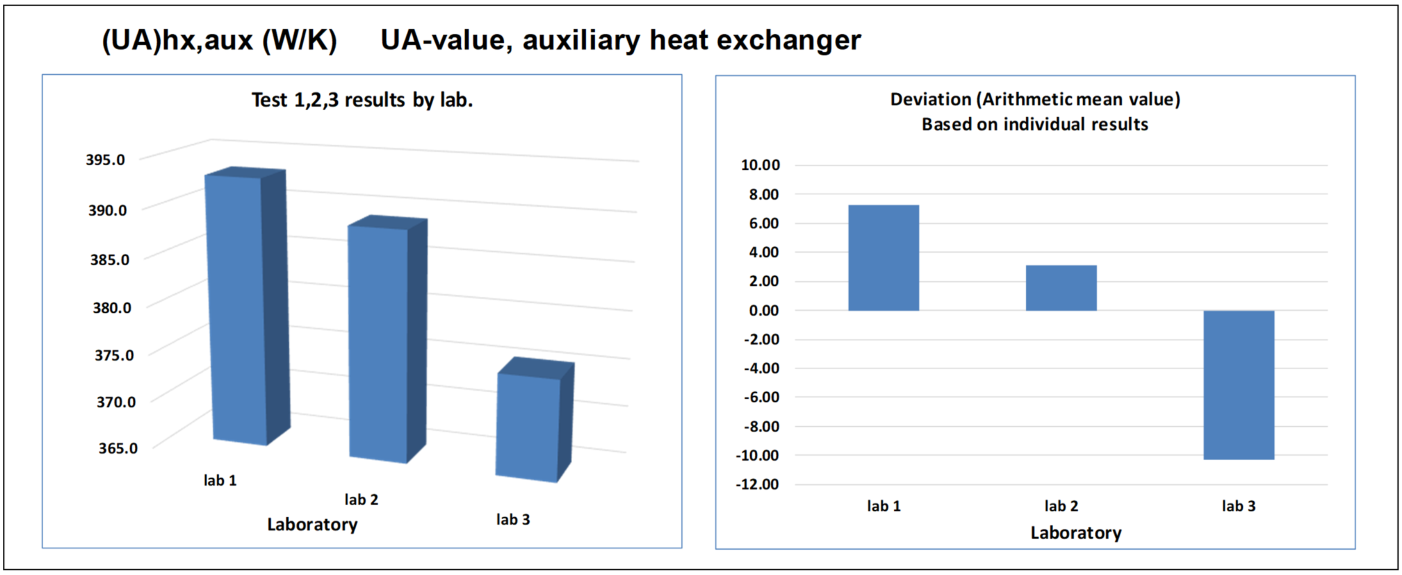


STATISTICS		
Median	473.620	W/K
Arh. mean value	471.020	W/K
R STD	25.380	W/K
r STD	-	
Max - Min (M-m)	50.560	W/K

Figure 7: ECOTEST statistical representation of the results Heat transfer capacity rate between solar heat exchanger and store $(UA)_{hx,sol,s}$

5.2.6 Heat transfer capacity rate between auxiliary heat exchanger and store $(UA)_{hx,aux,s}$

Parameter	(UA)hx,aux (W/K)	UA-value, auxiliary heat exchanger		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	393.00	388.88	375.45
Number of test results		1	1	1
Median value	389	393.00	388.88	375.45
Deviation from median value (Delta)		4.12	0.00	-13.43
Arithmetic mean value	386	393.00	388.88	375.45
Deviation from arithmetic mean value		7.22	3.10	-10.33
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	9.177			
Max - Min (arithmetic mean value)	17.550	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	17.550	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	correct	correct	correct	correct



STATISTICS	
Median	388.880 W/K
Arh. mean value	385.777 W/K
R STD	9.177 W/K
r STD	-
Max - Min (M-m)	17.550 W/K

Figure 8: ECOTEST statistical representation of the results Heat transfer capacity rate between auxiliary heat exchanger and store $(UA)_{hx,aux,s}$

5.2.7 Position of connectors and sensors

The position of the in-/outlets of the double ports and of the temperature sensors which are used as sensors for the controller are considered as fit-parameters in the generalized mathematical store model. Basically these positions could be easily measured from external and even easier the data are usually available in good precision in the user manuals of the stores. In a perfect world the measured and the fitted positions would usually be the same. The differences between the measured and fitted parameters can be caused by the internal design of the store, by dead volumes, irregular heat exchangers, stratification issues, etc., i.e. by factors which are not visible or measurable from outside, but which obviously have an impact on the dynamic behaviour of the store. The positions are therefore considered as virtual positions which describe in the best way the functioning of the store when using the before mentioned mathematical model.

As a consequence it is even not necessarily an issue if there are differences between the parameters measured by the different test laboratories. Much more important is to use the whole set of parameters coming from one test sequence to simulate the store in a system. For sure it would lead to wrong simulation results if only part of the fitted parameters were used and for example the positions of connectors and sensors were replaced by the measured values or by vales form another test sequence.

Nevertheless it is evident that small differences between different test labs and/or between the fitted positions and the positions measured from outside can be considered as positive indicators that the mathematical model is mapping the store in a good way. For this reason the positions indicated by the manufacturer in the user manual area added to the following Figure 9.

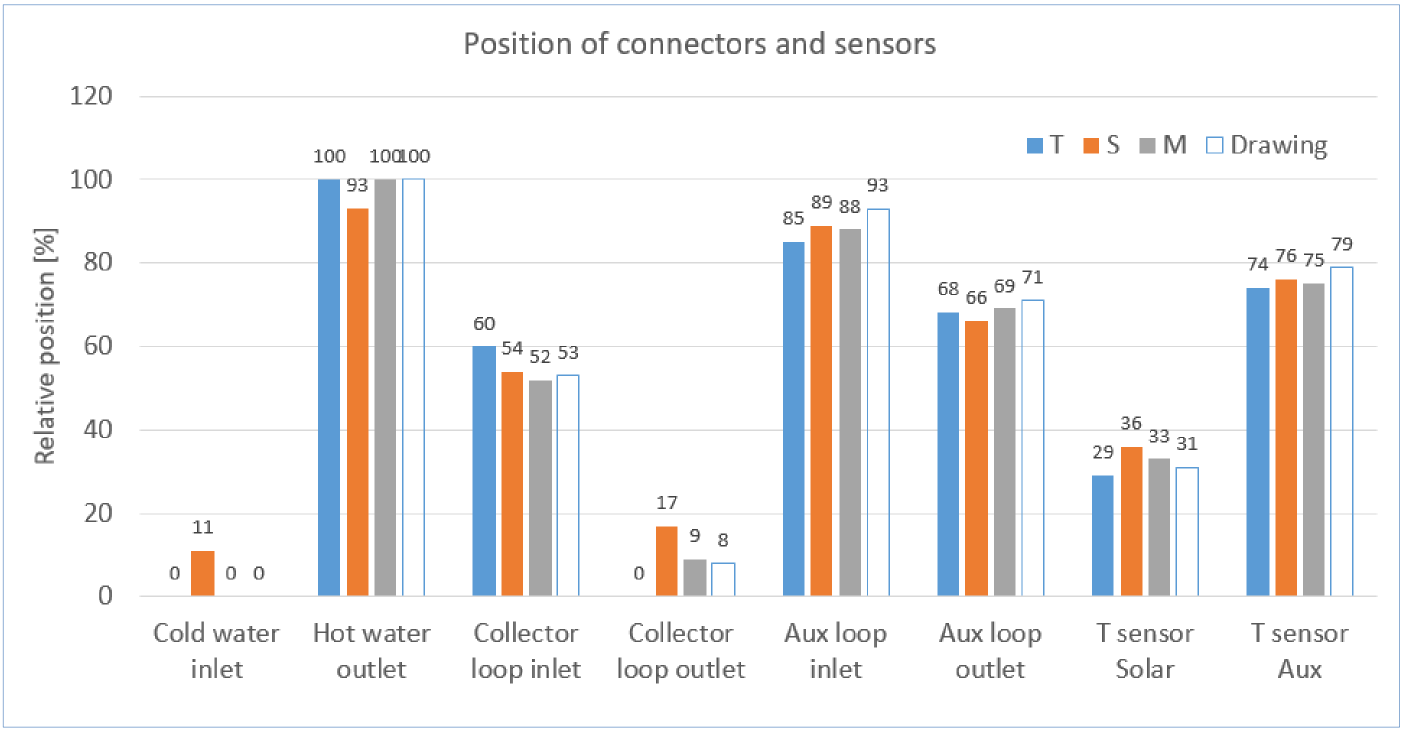


Figure 9: Comparison of the fitted positions of connectors and sensors as submitted by the test labs. Comparison with the positions taken from the drawings found in the user manual of the manufacturer.

It is furthermore evident, that one lab (S) used another scale then the other two labs. Lab S obviously took as reference the overall height of the store (ground = 0% and top of the store is 100%), where the other two labs took the cold water in and outlet as 0% and 100% reference. Figure 10 shows the same data with the recalculated positions for Laboratory S using the same references as T and M.

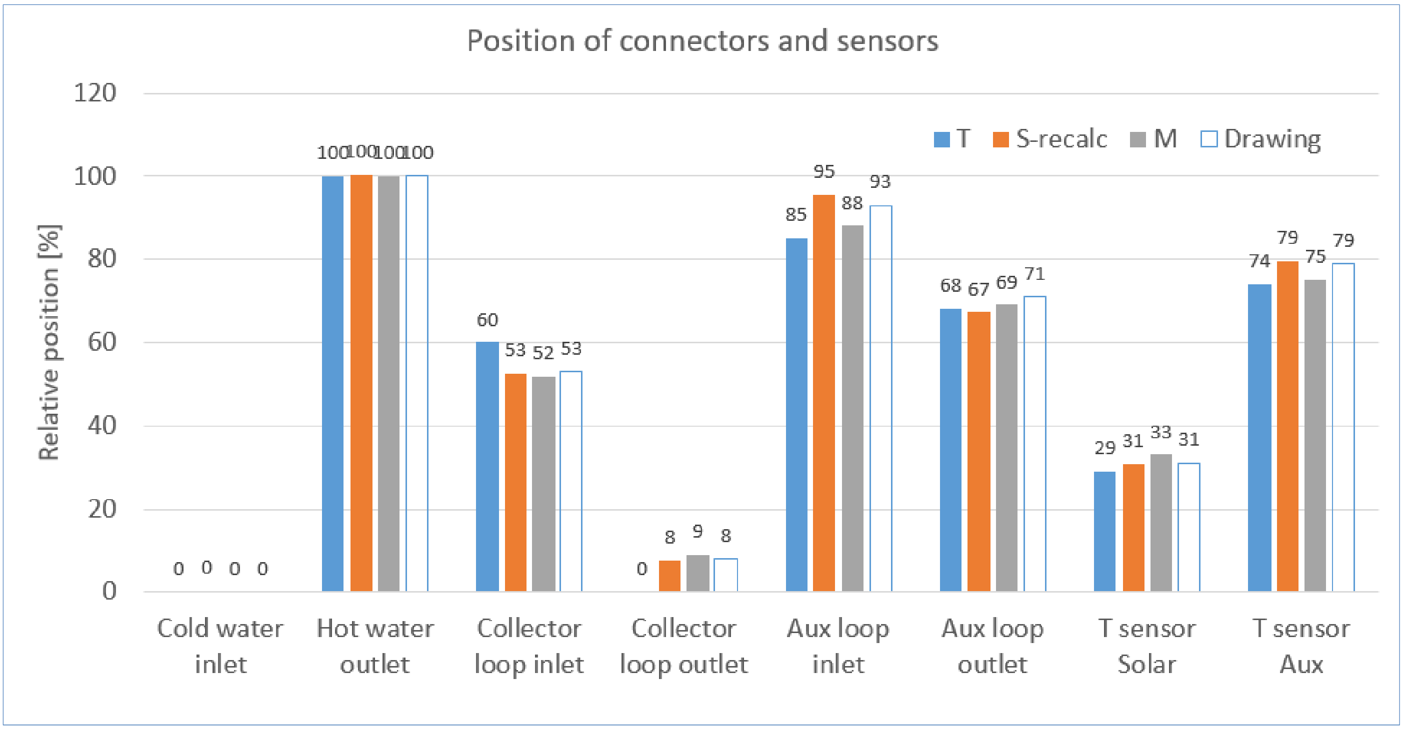
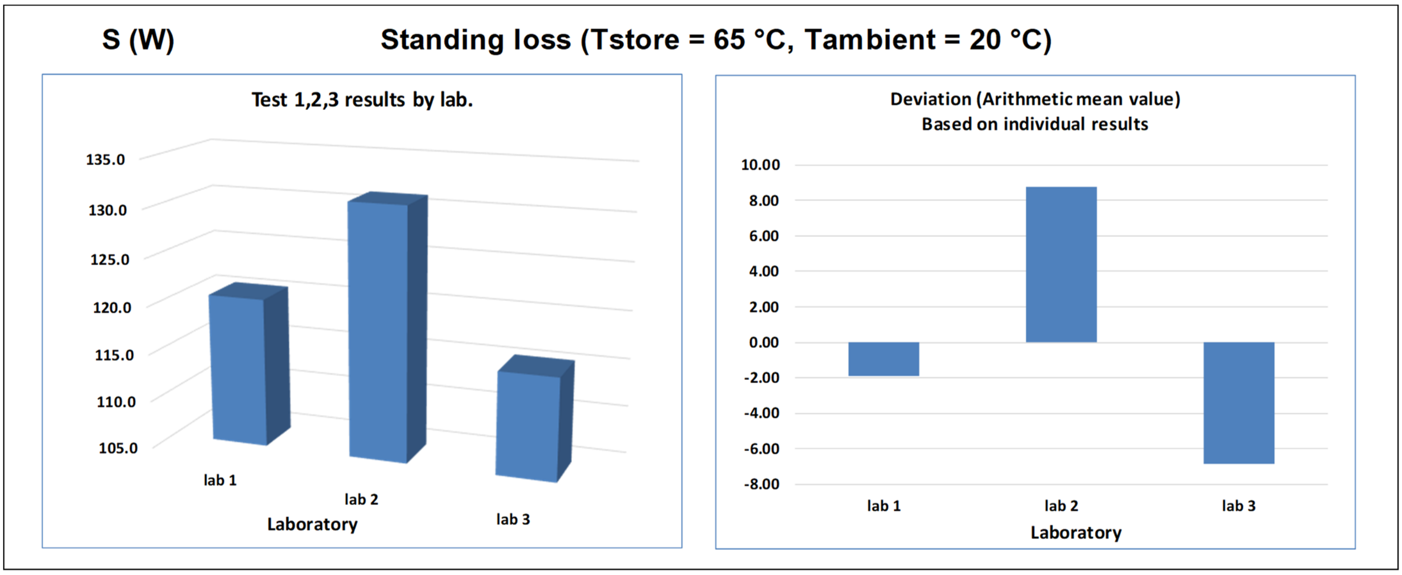


Figure 10: Comparison of the fitted positions of connectors and sensors with the rescaled values from laboratory S

5.2.8 Standing loss S (T_{store} = 65 °C, $T_{ambient}$ = 20 °C)

Parameter	S (W)	Standing loss (Tstore = 65 °C, Tambient = 20 °C)		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	120.6	131.3	115.7
Number of test results		1	1	1
Median value	121	120.60	131.25	115.65
Deviation from median value (Delta)		0.00	10.65	-4.95
Arithmetic mean value	123	120.60	131.25	115.65
Deviation from arithmetic mean value		-1.90	8.75	-6.85
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	7.972			
Max - Min (arithmetic mean value)	15.600	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	15.600	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	correct	correct	correct	correct



STATISTICS		
Median	120.600	W
Arh. mean value	122.500	W
R STD	7.972	W
r STD	-	
Max - Min (M-m)	15.600	W

Figure 11: ECOTEST statistical representation of the results Standing loss S (i.e. a simple multiple of $(UA)_{sb,s,a}$)

6 Comments and explanation on the data tables of this report.

6.1 Introduction

The data from the table in this section are values sent by the laboratories. The data processing has been organised according the following work flow:

a) Labs sending the RRT results (raw data tables) to the WPL- Reports V01
b) WPL Preparing overview table and figures for discussion (not anonymous)
c) WPL Physical WP meeting to discuss results and correct from possible issues
d) Labs sending the RRT results to the WPL- Reports V02
e) WPL organising the statistical analysis & RRT Report (anonymous)

Corrections were classified as in the following table and corrections have been made to correct for:

class	Type	Impact on main results	To be reported in the correction journal	Example
0	editorial	No impact	no	Use of W instead of kW or use of fraction of 1 instead of % but calculate correctly further on
1	Reporting error/ would not happen in normal reporting situation	Maybe	Yes, with explanation why it would not have happened in a normal situation. corrected data is given in the "after discussion" results, the original data given in the "before correction" results	Lab is using other excel evaluation or automated systems normally, error only occurred because labs were asked to use the RRT specific template
2	Misunderstanding of method/ procedure, due mainly to un-clarities in the standard	Maybe	Yes, with explanation how this can be avoided in future by introducing an improvement of the method/ clarification of the standard.	Using the boiler pump during testing. Wrong water temperature regimes etc.
3	Measurement error due to lab hardware.	Probably	Yes, the lab is asked to give more details. Test may be repeated to prove the issue and new data used.	Lab discovers that some hardware used (meter, analyser, sensor, etc.) was defect
4	Mistake made by the laboratory using a wrong method	Probably	Yes, ask lab to give more details If test repetition not possible (e.g. timing issue) and the original values show a "straggler" or "outlier" in the statistical, the after correction evaluation should be done with & without taking into account this lab.	Lab made the test not respecting the protocol.

Table 2: Classification of corrections (common in the whole ECOTEST project)

Any corrections (apart of editorial) is reported (anonymous) in a "journal" based on Laboratory declaration (see next section)
The origin of the issue is analysed and proposals will be made to introduce changes in procedures so to avoid such mistake in the future.

6.2 Journal of corrections made

Here is the list of corrections made to the data following the testing of the boiler and initial reporting:

Laboratory	Classification	Description of issue	For TC
S	2	During the analysis of the test results the fitted value of the connector heights of laboratory S had to be adjusted as there was a fitting mistake. The general description of the test procedure in the standard should be improved to avoid these errors. This error has no impact on the Energy labelling of the store.	Yes

Table 3: List of corrections that were made to obtain the final results as presented in Table 1.

7 Comments and analysis

7.1 Comments and additional information on the table and figure

Compared with other standards for stores, the EN 12977-3 method provides much more information about the store itself. As solar stores falling under this standard are usually used in systems with different heat sources, the main purpose of this standard was never to identify single numbers such as "standby loss under certain conditions" which can be determined probably in a simpler and easier procedure. The standard is much more made to provide a set of parameters characterising the dynamic behaviour of the store when used as a part of a whole system. This includes all the charging and discharging procedures for all double ports and heat exchangers. It is very important to use the set of parameters describing the store always as one complete set of parameters describing the behaviour of the store when using the same mathematical model/software. The effective volume for example cannot be considered as the physical fluid content of the store. It is much more a mathematical parameter which is standing for the volume which is considered as relevant when using a certain store model. It is therefore basically not admissible to replace single parameters by other values, independent on whether measured with other procedures or whether from other store measurements using the same standard. It is imperative to use always the same set and the same mathematical model for predicting/simulating the annual performance of a system.

The set of parameters is then the basis for simulating the performance of a whole system where this store is part of. The European regulation considers only the two parameters "nominal volume" and "standing losses". These parameters are important but are usually not strongly related with the real energy efficiency of a complete system, especially for modern stores with reasonable insulations. The dynamics of charging and discharging (including stratification and thermal mixing) often has a bigger impact on the overall energy efficiency of a store in a system.

According to the current version of the standard (EN 12977-3:2018) which was published in April 2018, i.e. in the duration of this Round Robin, the nominal volume V_n of the store shall be measured using a simple weighing method or according to EN 12897. However, in the previous version EN 12977-3:2012 (which is referenced in the transitional documents), the nominal volume V_n was defined as the manufacturer specification. This may lead to different interpretations and most probably laboratory S did the analysis using the previous definition of the nominal volume. This example is prototypic for several other discrepancies between the regulations, the standards and the transitional documents leading to different possible interpretations.

Furthermore in the current version EN 12977-3:2018 the standing losses are defined as $S = 45 \cdot UA_{sb,s,a}$ where the stand-by heat loss capacity rate is defined as $UA_{sb,s,a} = 0.16 \cdot \sqrt{V_n}$, meaning that the standing losses as required by the regulations are a simple multiple of the nominal store volume. It is evident that this definition is wrong and must be replaced. For this round robin the standing losses were computed using the standby heat losses of the measurements as it was for sure the intention of the editors of the standard.

In addition to the standard parameters the Energy efficiency class for the store is determined using the table 2 of the COMMISSION DELEGATED REGULATION (EU) No 812/2013. In the Table 4 below the Standing losses S and the class limits are listed based on the volumes V indicated by the three test labs. From this it is evident that all labs would classify the store as a "D" store. It is however important to note that this unanimous classification must be considered as kind of a lucky punch. In column C.x the relative classification by the test labs between class C and D is indicated based on a linear interpolation. This shows that lab T classified at 26% "above" class C where lab S classified at 88% "above" class C. Meaning that a span of 88%-26%=62% between C and D was already covered. It is evident that in general such a span would cross the class limits, i.e. that different classifications by different test labs will be the general case and not an exception. Furthermore it is important to note that lab T is only 6.4% above the threshold to class C, where lab S is rating only 2.4% below class E. Allowing for an uncertainty of a few percent it is evident that this store could also have been classified by the three labs in class C, D and E.

	S [W]	V [l]	A+	A	B	**C**	**D**	E	F	C.x
T	115.65	405.6	39.75	55.45	77.51	**108.68**	**135.11**	176.90	215.04	C.26
S	131.25	400	39.56	55.19	77.14	**108.17**	**134.48**	176.06	214.02	C.88
M	120.6	404	39.69	55.38	77.40	**108.54**	**134.93**	176.66	214.75	C.46

Table 4: Energy efficiency class limits as obtained by the three laboratories

To define the class limits according to table 2 of the COMMISSION DELEGATED REGULATION (EU) No 812/2013, the storage volume V in litres is needed. According to the regulation, the measured value shall not be more than 2 % lower than the rated value. As mentioned above there are different definitions and ways to determine the nominal store volume according to the EN 12977-3. Based on the philosophy of the EN 12977-3 these "nominal store volumes" or the "Storage Volume" are not appropriate parameters anyway as they cover the total volume of the store and not the "usable" volume of the store. If a store includes dead volumes this could lead to better classification. To illustrate this, it can be assumed that a dead volume of 100 litre is added to the store (i.e. 500 litres instead of 400 litres). If this additional 100 litres are more or less thermally decoupled from the rest of the volume, the limit for class C would be increased to 116.7 W, instead of 108.7 W, and the store would have been rated as class C by laboratory T. Of course this is not a realistic approach and it should not be expected that manufacturers are designing their stores in such a way to get better ratings. It shows however that the store volume is not an appropriate parameter for the classification. In the mathematical model of the EN 12977-3, the effective volume is therefore introduced. This effective volume is again a fitted parameter which cannot be measured by any means as a volume inside the store. It is much more a virtual volume representing the effective volume (i.e. the volume that contributed to the energy exchange) in the test cycles. As such the effective volume would be the correct volume for classification purposes as intended by (EU No 812/2013). In this round robin one test lab indicated the effective volume (EN12977-3) and the other two labs the nominal volume (EN12977-3) as Storage volume (EU No 812/2013).

7.2 Comments on possible discrepancies

To explain the differences between the results of the three test laboratories several web meetings between the test laboratories were held. The main reasons are assumed to be

i) The insulation is not attached firmly to the store. This is often the case for practical reasons so that the insulation can be installed on place only. It is an option that during transport the insulation may have moved a bit and was not exactly the same for all test laboratories.
ii) The test cycles are defined such that after heating up the store has to be kept untouched for about 48 h or until 40-60% of the energy is lost. After all the test labs have not used the same timing for the test and it can be assumed that this has an impact on the results as well (see 8.1).
iii) The whole test procedure is not made to measure the standing losses only. The EN 12977-3 and -4 series were developed with the focus on a full characterisation of the store including the dynamic behaviour. Similar to the collector characterisation it must be assumed that the different parameters listed in 5.1.1 are not completely independent for mathematical reasons.
iv) Unclear definitions of the store volumes and of the heights (see remarks in 5.2.7 and RRT3 clause 7.2)

7.3 Comments in light of the iterative tests results

See Chapter 8

7.4 Main parameter that influence the measurand

No specific remarks.

8 Iterative test results

In the frame of this RRT there were no additional iterative tests foreseen.
Some major topics have been discussed in the duration of the RRT and the participating test labs have worked on these issues already before and independently of this RRT. These results are presented in this chapter even if not part of the RRT, but as a basis for better understanding and interpretation of the results as well as to provide input for improving the testing standards and the European regulations.

8.1 Duration of the test sequence L

The duration of the test sequence L focussing on the stand-by-losses is defined as "*…typically 48 h. The duration of the stand-by period should be chosen in such a way that approximately between 40 % and 60 % of the energy stored initially is lost…*". As modern stores have very small stand-by losses the duration of 48 h is not correlated anymore to a 40-60% loss of the energy. In fact the test labs T and M have already started to investigate this topic. From test laboratory M the following illustrative results (measured on two other stores than this RRT) were made available:

Test 1 (500 litre buffer store, plastic)

standby-time (days/h)	2/48	3/72	7/168
Total energy loaded (kWh)	22.5	22.4	22.5
Energy at discharge (kWh)	20.1	18.3	15.6
Standby losses (%)	10	18	31
$(UA)_{sb,s,a}$ (W/K)	1.322	1.278	1.272
Energy label classification	B	A	A

Table 5: Variation of energy efficiency observed for a 500 l buffer store for different stand-by times

Test 2 (800 litre combi store)

standby-time (days/h)		3/72	7/168
Total energy loaded (kWh)		30.5	30.4
Energy at discharge (kWh)		23.2	16.6
Standby losses (%)		24	45
$(UA)_{sb,s,a}$ (W/K)		3.15	3.26
Energy label classification		D	D

Table 6: Variation of energy efficiency observed for a 800 l combi store for different stand-by times

These results show very clear that for good stores the testing times are becoming extremely long to properly meet the requirements of the standard. In Test 1 even after one week of standby, the losses are still at 31% only, meaning that to reach the required 40% -60%, a testing time in the range of two weeks or even more has to be expected for good stores. Of course the testing situation for low performance stores is much simpler (Test 2 above and store in this RRT) as the losses are big enough to have good results in a short time. From simple mathematical considerations it is evident that extrapolating very small measured standby losses will lead to larger uncertainties of the rated store losses S.
On the other hand testing times of two or more weeks are rather expensive and punishing manufacturers of high performance stores. For this reason the testing laboratories usually stick to the 48h recommendation as the 40-60% conditions is a "should" recommendation and as such not a mandatory condition.
For obvious reasons the scientific work on this matter is very time consuming and therefore very expensive. For this reason this problem could not be investigated further as "iterative test" in the frame of this RRT. It is however important to investigate this matter and to develop faster methods providing sufficiently low uncertainties,

especially also in view of the technical development leading to better stores and also in view of future market surveillance activities.

8.2 Comparability of different test methods

Another main issue which has been discussed and investigated before this RRT are the different possible procedures to determine the standing losses S of a store. Different standards are considered to provide comparable results as stipulated in the transitional documents (even if some standards are not applicable to all stores):

- EN 12977-3:2012 Thermal solar systems and components — Custom built systems — Part 3: Performance test methods for solar water heater stores.
- EN 15332:2007 Heating boilers – Energy assessment of hot water storage tanks
- EN 60379:2004 Methods for measuring the performance of electric storage water-heaters for household purposes
- EN 12897: 2006 Water Supply – Specification for indirectly heated unvented (closed) storage water heaters

The participating test laboratories have performed investigation on this point and publications are available. Details can be found there. To illustrate the main findings the following exemplary results taken from the publication[3] shall be considered. Two different stores with 300 litres and 500 litres volume were tested using three different methods. Based on the measured losses and the rated volumes the energy label was determined:

	300 litre	Label	500 litre	Label
EN 12897	2.44 kWh/d	D	2.53 kWh/d	C
EN 15322	2.25 kWh/d	C	2.71 kWh/d	C
EN 12977-3	2.60 kWh/d	D	2.85 kWh/d	D

Table 7: Comparison of energy efficiency of two stores measured using different EN standards

One of the main findings of this investigation is that EN 12977-3 is indicating higher losses, i.e. lower classification. Several possible reasons for this finding have been identified and are discussed in the publication.
In a very similar project[4], the variation of classification reached even two classes for some stores. In contrast to the previous results, the standing losses were tending to be lower for stores tested according to EN 12977-3.
Without further analysis it is evident that the different possible test procedures do not provide similar results and store classifications. From a simple physical understanding and also based on the definition in the COMMISSION REGULATION (EU) No 813/2013 ('standby heat loss' (Pstby) means the heat loss of a boiler space heater, boiler combination heater or cogeneration space heater in operating modes without heat demand, expressed in kW), the standing loss of a store should however be completely independent of the applied standard.

8.3 Uncertainty assessment

Up to now there is no recognized procedure on how to assess the uncertainty of the parameters deduced from the measurements. It is important to keep in mind that according to the EN 12977-3, the procedure consist of several test sequences which are then analysed using a mathematical model for multiport stores. A set of store parameters is identified using a parameter identification software which is best matching the measured datasets.
The temperatures and flow rates are the only parameters required to make the measurements according to the standard. Up to now there is however no general accepted (or even standardised) procedure to assess the uncertainty of the results which are deduced in such a software-based procedure as defined in the EN 12977-3. Things are even more difficult as the parameters which have to be determined are most probably not completely

[3] Ermittlung der Wärmeverluste von Warmwasserspeichern – Vergleich genormter Prüfverfahren, Stephan Bachmann et al., Universität Stuttgart, Institut für Thermodynamik und Wärmetechnik (ITW) at OTTI - 23. Symposium Thermische Solarenergie 24.-26.04.2013 (in German)

[4] Vergleich der Messmethoden für Solarspeicher, Ozan Türk et al., Institut für Solartechnik SPF, 26. Symposium Thermische Solarenergie, 20.-22. April 2016 (in German)

independent from each other. Such quasi-correlations are very difficult to handle in a purely mathematical way. The most promising approach seems to be some kind of Monte Carlo uncertainty assessment where the measured temperatures and flows are varied randomly according to their uncertainty around the measured values to generate new datasets. Analysing a sufficient number of such randomized datasets will then provide sets of store parameters allowing to deduce the uncertainty of each parameter individually. Such a procedure was proposed for example by the participating laboratory M[5]. This Monte Carlo uncertainty assessment is however very time consuming and with the currently applied fitting procedures almost impossible.
The impact of the measuring uncertainty on the store classification has already been investigated in earlier projects[6]. The uncertainties of the two main measuring parameters (temperature and flow) are for sure well below 1%, hence very small compared to the observed variation of the results as for example found for the standing loss S in this RRT. It is therefore evident, that apart from the uncertainty of the measured parameters, there are methodological uncertainties caused by the testing procedures, the different possible interpretations of the testing procedures or by the parameter identification procedures. This methodological uncertainty of the individual parameters must be investigated further. In this context it is also important to assess the impact of the deduced store parameters on the energy efficiency of a real system, i.e. what is the impact of an uncertainty of x% of the standing loss S on the uncertainty y% of the energy efficiency of a real system. It can be assumed that there is no simple correlation between these two numbers as the efficiency of a solar thermal system is defined not only by the store losses but by many other parameters which are defined by the rest of the system. Just to mention a few: The integration of the solar part in the whole system, controller strategies, user profiles, geographic location, collectors or hydraulic connections.

8.4 Stratification rating

The regulations and standards are very much focussed on the rating of the standing losses of the stores. Reducing standing losses is for sure important, as outlined above it is however not evident that a reduction of the standing losses have a corresponding impact on the total system performance. Investigations have shown that especially in combisystems with solar and heat pumps the impact of store stratification can be more relevant than the standing losses with respect to the energy consumption of the heat pump[7]. Stratification is however not yet considered at all in the classification of the stores.

8.5 Main conclusion

To reduce the variations between different test laboratories it is important to clarify the timing of the test cycle L. Much more important is however to harmonise the procedures for standby loss measurements and to clarify the definition of the applicable store volume. Most important is however to make sure that standing loss is the appropriate parameter for the performance rating of a store. In some cases stratification effects are more important with respect to energy savings than standby heat losses. Stratification is however not considered neither in the standards not in the ErP regulations.

[5] Vermessung von thermischen Solarspeichern nach EN 12977 und Parameteridentifikation mit TRNSYS und GenOpt, C. Schmidt et al., Fraunhofer Institut für Solare Energiesysteme ISE, 21. Symposium Thermische Solarenergie, 11.-13. May 2011 (in German)
[6] Prüfkampagne thermischer Speicher und deren Energy Labeling nach ErP Richtlinie, Konstantin Geimer et.al., Fraunhofer-Institut für Solare Energiesysteme ISE, 26. Symposium Thermische Solarenergie, 20.-22. April 2016 (in German)
[7] Die thermische Schichtung von Kombi-Wärmespeichern ist messbar – Ein Weg zur Zertifizierung der Schichtungseffizienz, Robert Haberl et.al., Institut für Solartechnik SPF, 26. OTTI Symposium Thermische Solarenergie, 20.-22. April 2016 (in German)

9 Procedures of standards that need to be modified and justification

9.1 Result from the brainstorming on standard

The input of the brainstorm on the EN12977-3 is attached as annex to this report in the appropriate format that must be used for all input to the CEN TCs. All other findings that were made during the RRT were also added to this report.

9.2 Procedures of standards that need to be modified and justification

The analysis is based on software which is considered as reliable (TRNSYS Type 340 "MULTIPORT Store – Model") and GenOpt (or similar) to identify the parameters. It would be good to describe the mathematical model and the parameter identification procedures in such a detailed way that they can be implemented using other platforms than TRNSYS as well.

In the current standard the thermal stratification is not sufficiently considered. This should be included in a next revision as it is known that stratification can have a considerable impact on the system performance, especially in hybrid systems. There are currently smaller projects ongoing in the frame of the Solar Keymark Certification fund to develop appropriate procedures.

The uncertainty assessment for the results of this standard should be defined in more detail in the standard.

9.3 Recommendations to CEN

It is important to harmonize the rating of the standing loss S which is now possible using at least four different standards using different methods and giving different results. Important is to consider not only a static behaviour but also the dynamic behaviour, such as charge and discharge cycles, but also stratification effects. As the store is a very central unit of every heating system, which is distributing loads between different appliances (heat pumps), it is very important to be able to simulate its dynamic behaviour also in combination with other appliances.
Furthermore it is impotent to harmonize the used of some definitions such as flow rate (l/h or kg/h) and store volumes (nominal, dated, effective, etc.).
As general recommendations to the WG in charge of the standard:

- Too many "should" statements in the standard
- Flow rate not always clear whether mass or volume
- Too much text book. Reduce explanatory text.

10 Conclusion

The variations of the results for the standing loss S between the three testing laboratories which is in the range of ±7% can be partially explained by some unclear definitions and tolerances in the standard. The standard was however not developed to provide such a simplified parameter, but much more to provide a set of parameters allowing to simulate the dynamic behaviour of a store in a system. It is known that some of the parameter in this set of parameters are not completely independent and using single parameters as isolated values is not always appropriate.

The general conclusion from RRT 2 would therefore be that it is important to develop horizontal standards for thermal stores considering that they can be used by different appliances and under varying dynamic operating conditions. The basis for such a general store standard could be a similar dynamic test procedure as used in EN 12977-3.

11 ANNEXES

11.1 ANNEX 1 TEST PROTOCOL

Project ECOTEST / WP8 **RRT2: Solar Water Heater Stores**	ECOTEST **ECO_WP8_024**

Version history

Version	status	date	
A0			To be discussed in WP To be discussed with TC 312 liaison
B			N/A
C0			N/A
C			Final version for second step (final C)

Based on Template B

See clause 1.10 of ECOTEST PART 01

The test protocols will be developed with the following methodology:

A. *First version of the test and measurement protocols based on the CEN standards (version A of the protocol)*
B. *Second version based on an evaluation of the existing CEN standards (desk) (version B of the protocol)*

The following questions will have to be considered:

1. *Are the most critical measurements identified reproducible? If not, which improvement would be suggested?*
2. *Other aspects of the protocol to evaluate:*
   a. *Is the protocol clearly understood by all? If not, define additional explanations.*
   b. *Are there points in the test method that are likely to be open for different interpretations? In this case, define additional descriptions.*
   c. *Are there points in the protocols that are not sufficiently described to guarantee the reproducibility of the testing among labs? In this case, define additional descriptions.*
   d. *Are there missing requirements (e.g. requirements on ambient temperature, etc.) that are likely to bring deviations in the results between labs? In this case, define additional descriptions.*

C. *Third version based on the first tests (version C of the protocol)*

To identify ambiguities in the standard, a preliminary discussion will be organized by each WP leader after the first tests to discuss the existing protocol point by point. Care is taken on how to exchange test results (see section 2.2.3).

The following method will be used.

- *Analysis of the measurements*
- *Have there been deviations?*
- *Can the reasons for discrepancies be identified?*
- *Can the reasons for deviations be removed by improving the test protocol and the descriptions of the tests?*

D. *A final version of the protocol will be proposed after the inter-comparison and in the light of the inter-comparison results and analysis + the results of the iterative tests*

1 Scope

This document is to provide the test protocol for the intercomparison test on a solar water heater stores for WP8.

This operative instruction gives the general instructions needed for managing all the aspects related to the tasks of receiving the store, commissioning and setting it up for testing, carrying out the reference tests, reporting the test results, decommissioning, assessing it for delivering and delivering it at the end.

2 General

The store RRT2 is performed with **one** reference store.

Due to the time restrictions the two step approach is not applicable: RRT2 is one step, depending on the testing conditions and lab capacities ambiguities in the standards may be identified.

To take into account variations of parameters additional tests may be performed by different laboratories (see clause Parameter variation) based on brainstorming on the standards.

3 References

EN 12977-3:2013 Thermal solar systems and components - Custom built systems- Part 3: Performance test methods for solar water heater stores

4 Definitions

For the general technical terms used in this operative instruction see the applicable European standards listed above: chapter References
WPL: work package leader (WPL WP8: Andreas Bohren)
RRT: Round Robin test

5 Test materials and documents

- Reference store marked with “WP8 RRT2”.
  Laboratories can add their own tags for identification.
- Installer manual (ECO_WP8_029_RRT2_InstallerManual)
- Test protocol (ECO_WP8_024_RRT2_TestProtocol, this document)
- Test schedule (ECO_WP8_008_ScheduleAndApplianceTracker)
- Template test results (ECO_WP8_016_ RRT2_ResultDataSheet_lab)
- Reception sheet, (ECO_WP7_007_NoticeOfReception)
- Expedition sheet, (ECO_WP6_008_NoticeOfExpedition)

All documents will be provided on the ECOTEST website: http://ecotest.dgc.eu/wps/wp8/rrt

6 Reference materials

None

7 Ambient conditions

The test conditions as defined in the standard shall be considered.

8 Mounting, Installation and Setting

The store is installed according to the installation manual and as prescribed by the EN 12977-3:2013.
Hydraulic connectors: Every test labs will receive its own connectors to the store as an interface to the laboratories hydraulic system.
Pictures of the store shall be made before / during / after the test.

9 Testing

The following tests are performed

9.1 Determination of the store volume, the heat transfer capacity rate of the lowest heat exchanger and the thermal stratification during discharge

The test is carried out according to EN 12977-3:2013 using the boundary conditions described therein and the preferred methods used by the test lab.
The results obtained from the test shall be reported as required in the EN 12977-3:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_016_RRT2_ResultDataSheet_lab.xlsx).

9.2 Determination of the thermal stratification during discharge with a 'high' flow rate

The test is carried out according to EN 12977-3:2013 using the boundary conditions described therein and the preferred methods used by the test lab.
The results obtained from the test shall be reported as required in the EN 12977-3:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_016_RRT2_ResultDataSheet_lab.xlsx).

9.3 Determination of the stand-by heat loss capacity rate of the entire store

The test is carried out according to EN 12977-3:2013 using the boundary conditions described therein and the preferred methods used by the test lab.
The results obtained from the test shall be reported as required in the EN 12977-3:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_016_RRT2_ResultDataSheet_lab.xlsx).

9.4 Determination of the heat transfer capacity rate and the position of the auxiliary heat exchanger(s)

The test is carried out according to EN 12977-3:2013 using the boundary conditions described therein and the preferred methods used by the test lab.
The results obtained from the test shall be reported as required in the EN 12977-3:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_016_RRT2_ResultDataSheet_lab.xlsx).

9.5 Determination of the position(s) and length(s) of the electrical heating source(s)

The test is carried out according to EN 12977-3:2013 using the boundary conditions described therein and the preferred methods used by the test lab.
The results obtained from the test shall be reported as required in the EN 12977-3:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_016_RRT2_ResultDataSheet_lab.xlsx).

9.6 Determination of the degradation of thermal stratification during stand-by

The test is carried out according to EN 12977-3:2013 using the boundary conditions described therein and the preferred methods used by the test lab.
The results obtained from the test shall be reported as required in the EN 12977-3:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_016_RRT2_ResultDataSheet_lab.xlsx).

10 Parameter variations

The following additional tests are performed to take into account the variations of different parameters
None

Parameter	value	Test to be repeated	laboratory

The main questions are i) Comparability of the different standards and time for standby heat loss testing. Such investigations were already made and it was decided not to repeat measurements that were already done in the participating test labs. Publications form these tests will be added to the RRT report.

11 Calculations

In addition to the Standard measurements the parameters used for the ERP shall be calculated and reported: (ECO_WP8_016_RRT2_ResultDataSheet_lab)

12 Reporting the test results

Once the tests are finished, the results are to be sent to the WPL (andreas.bohren@spf.ch).
For reporting the test results template is used and renamed by using the original document *ECO_WP8_016_RRT2_ResultDataSheet_lab* and replace “lab” by spf, ise or itw.
Do not wait for anything and immediately send the system using the box to the next recipient in the list indicated in the *ECO_WP8_008_ScheduleAndApplianceTracker*.
In case that this is not clear contact the WPL.

The raw data shall be saved properly and each laboratory shall be prepared to send raw data and additional information to the WPL. If required use the file name format
ECO_WP8_012_RRT2_ResultDataSheet_LOG_lab and replace "lab" by spf, ise or itw

13 Sending the test material

The test material is sent using to the address agreed with the reference person of the next destination where the item has to be sent to.
Details on time schedule are available in the document test schedule
ECO_WP8_008_RRT2_ScheduleAndApplianceTracker
NOTE: Please check on current versions of the schedule on: http://ecotest.dgc.eu/wps/wp8/rrt

14 Task for sender and recipient

Overview: Monitoring of the testing for RRT
All RRTs of the project will be organized according to the following table:

What	Information Action	Who	When (deadlines)
Receipt of the store	Send the reception sheet to all TL by email	Lab. X	Immediately upon receipt
Mounting and testing the appliance. Data processing	Send data to the WP leader	Lab. X	Immediately after receipt
Checking the data	If ok, give green light to send the appliance further.	WPL	Immediately after receipt
Sending the appliance to Lab. X+1	Send the expedition sheet to the WP leader and Lab X+1	Lab. X	Immediately after green light
Inform in case the store has not reached the lab within a week	Contact the WPL and Lab. X	Lab. X+1	After one week

14.1 Task for sender

The sender takes care of packaging the store to prevent from damage during the transportation.

- Pack the store using the package that belongs to the device.
- Attach the warning labels that are sent together with the sample
- Check with the next receiver the exact delivery address and delivery time.
- Put in a visible position a big and clear Label with the information of the recipient
- Deliver the crate using a reliable and trusted express courier
- Keep to the planned time schedule as defined in document test schedule.
- When the store is sent, send an e-mail with the expedition sheet to the reference person of the recipient to make him aware of the delivering:
  CC to the TL of WP8.

14.2 Task for recipient

The recipient looks at the crate to see if it have could been damaged during transportation: if it is an annotation is put on the travel documents accompanying the crate;

- Unpack the reference store.
- Make incoming goods control, make photos of the store as delivered.
- Make sure that there are no transport damages. If damages are noticed an e-mail shall be sent to inform the WPL. Check the packing list from the sender and the pictures provided by the sender.
- Inform by email the WG8 about the receipt of the store.
- Carry out the test plan following this operative instruction complying with the time schedule
- Send the test material to the next lab as specified in the time schedule.

11.2 ANNEX 2 Brainstorm on the standard EN 12977-3

Nr	Line number (e.g. 17)	Clause/ Subclause (e.g. 3.1)	Paragraph/ Figure/ Table/ (e.g. Table 1)	Type of comment[1]	Comments	Influence on Protocol? / To be included as variation of parameter (iterative test)?	Observations of the WPL

METHOD FOR THE EVALUATION:

a. Is the method of the standard clearly understood by all? If not, define additional explanations.
b. Are there points in that are likely to be open for different interpretations? In this case, define additional descriptions.
c. Are there points hat are not sufficiently described to guarantee the reproducibility of the testing among labs? In this case, define additional descriptions.
d. Are there missing requirements (e.g. requirements on ambient temperature, etc.) that are likely to bring deviations in the results between labs? In this case, define additional descriptions.
e. Are there requirements that are too weak to guarantee a good Interlaboratory reproducibility (e.g. To high tolerance)
f. Are there not relevant requirements

Standards: (*)

EN 12975_1_2006_A1
EN 12976_1_2017
EN 12976_2_2017
EN 12977_2_2012
EN 12977_3_2012
EN 12977_4_2012
EN ISO 9806_2013
EN 12977_1_2012
ISO_9459_5_2007 (2013)
ISO_9806_2017(E)

Overall comment on this standard:

SPF: General remark –> EN12977-3 and 12977-4 could/should be easily merged into one standard. Reasons: i) Reduce work load for WG ii) Most of the content in -4 is referencing to -3, iii) if content is reduced and available only once there is less risk of having contradictory content.

Nr	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment	Comments	Influence on Protocol? / To be included as variation of parameter (iterative test)?	Observations of the WPL
0	spf	**3**	**3.34**	?	**3.34 reduced charge/discharge volume** integral of a charge/discharge flow rate divided by the store volume	Strange/misleading definition for a "volume". The unit is 1/s (or Hz)	
1	itw	6.1.1	Figure 1	te	position and number of ambient temperature sensor(s) should be stated	2 sensors, height of 1/4 and 3/4 of the storage height at a distance of 0,3 m up to 0,5 m	
2	itw	6.1.1	Figure 2	te	Rename discharge inlet and outlet temperatures in figure 2	Discharge inlet temperature should be renamed to 201 and discharge outlet temperature should be renamed to 202 according to table 2	**

1 **Type of comment:** **ge** = general **te** = technical **ed** = editorial

Nr	Line number (e.g. 17)	Clause/ Subclause (e.g. 3.1)	Paragraph/ Figure/ Table/ (e.g. Table 1)	Type of comment[1]	Comments	Influence on Protocol? / To be included as variation of parameter (iterative test)?	Observations of the WPL
3	itw	6.1.2	Table 2	te	Uncertainty of store temperature sensors should be added: 0,1 K		
4	itw	6.1.2	-	te	Note concerning the check of store temperature sensors should be added	Store temperature sensors can be checked using e. g. a temperature-controlled bath. Temperatures: 20 °C, 40 °C, 60 °C, 80 °C. Max. deviation between the sensors: 0,1 K	
5	itw	6.2.1	-	te	Notes should be added determining the matter in which the store should be mounted	on a palette (height at least 0,05 m), distances to walls (at least 0,7 m), no source of thermal irradiation	
6	itw	6.2.1	-	te	Note concerning the check of volume flow sensors should be added	Connect the sensors FF105 and FF205 in series. Measure some volume flow rates in the range which is expected during testing. The deviation of the measured values from the mean value should be within 1 %	
7	itw	6.2.1	-	te	Insulation of pipes between the store and the temperature sensors	acc. to EN 12897, B1 instead of EN 12828	
8	itw	6.2.2	-	te	Insulation of closed connections	All closed connections shall be insulated acc. to EN 12897, B1 instead of “in the same way as the store”. Exception: special insulation material is delivered by the manufacturer.	
9	itw	-	-	te	Chapter 6.2.3 of ENV 12977-3:2001 (Testing of the storage device in respect of the design of the connections) should be re-included.		
10	itw	6.3.1	NOTE 6	te	Note concerning determination of all store parameters	Change Note: The determination of all the store parameters listed above is possible only according to the method	

1 **Type of comment:** **ge** = general **te** = technical **ed** = editorial

Nr	Line number (e.g. 17)	Clause/ Subclause (e.g. 3.1)	Paragraph/ Figure/ Table/ (e.g. Table 1)	Type of comment[1]	Comments	Influence on Protocol? / To be included as variation of parameter (iterative test)?	Observations of the WPL
						described under 6.3.3. However, some of the parameters may also be determined according to **EN 12897**	
11	itw	6.3.2.1	Passage before NOTE 2	te	Addition	If the heat exchanger is used at different flow rates, the test should be performed four times, using, if possible, the following different charging conditions: constant power Pn at high and low flow rates, as well as constant power 0,5 × Pn at low and high flow rates.	
12	itw	6.3.2.4.1	last passage	te	Change the last sentence	The connections **which are used under common operation** for a complete charge of the store shall be fitted to the charge circuit of the testing stand.	
13	itw	6.3.2.4.2 6.3.2.4.3 6.3.2.4.4 6.3.2.4.5	Test phase L3	te, ed	Change note concerning test phase L3	The duration of the stand-by period should be chosen in such a way, that approximately between **10 %** and 60 % of the energy stored initially is lost during the stand-by period	
14	itw	6.3.2.6	last sentence	te	Insulation of closed connections	Change EN 12828 to EN 12897, B1. Exception: special insulation material is delivered by the manufacturer.	
15	itw	6.3.2.7.4 B.2.2.4	-	te	Insulation of closed connections	The closed connections shall be insulated acc. to EN 12897, B1. Exception: special insulation material is delivered by the manufacturer.	
16	itw	Annex C	-	ge	Contact for set of test and verification sequences	University of Stuttgart	

1 **Type of comment:** **ge** = general **te** = technical **ed** = editorial

Nr	Line number (e.g. 17)	Clause/ Subclause (e.g. 3.1)	Paragraph/ Figure/ Table/ (e.g. Table 1)	Type of comment[1]	Comments	Influence on Protocol? / To be included as variation of parameter (iterative test)?	Observations of the WPL
						Institute of Thermodynamics and Thermal Engineering (ITW) Research and Testing Centre for Thermal Solar Systems (TZS) Pfaffenwaldring 6 70569 Stuttgart, Germany Phone: ++49 (0)711 685-63536 Fax: ++49 (0)711 685-63503 Mail: tzs@itw.uni-stuttgart.de	
17	DTU	6.2.2	4th paragraph	ge	Connections of the store which do not lead to the charge or discharge circuit of the testing stand shall be closed, and not connected heat exchangers shall be filled up with water. All closed connections shall be insulated in the same way as the store.	Not clear. During a test of standby heat loss, shouldn't the connections to the charge/discharge circuit be open? In our opinion they should not be closed. Whether it is open or closed should be the same as when the tank is installed in practice. Connections on the side and the top of the tank will introduce extra heat loss during buoyancy driven flow in the pipe. The heat loss test should be able to measure it.	
18	DTU	6.3.2.4.1	The last 3 paragraphs	ge	The connections which enable a complete discharge of the store shall be fitted to the discharge circuit of the testing stand.	Not clear. The standard should clearly state whether the connections are open. How the connection pipe is placed should also be clarified. For instance an upward or downward connection pipe will bring quite different pipe heat loss.	
	SPF	Annex D		te	The standard does not define the model to be used for the analysis of the measured data. And the parameters to be determined are not well defined as well. Example: Stratification number (terms 3.27). In 6.3.1 General is required "a parameter describing	The mathematical model to be used and the parameters to be determined should be clearly defined in the standard. Reference data are ok but by far not sufficient.	

1 **Type of comment:** **ge** = general **te** = technical **ed** = editorial

Nr	Line number (e.g. 17)	Clause/ Subclause (e.g. 3.1)	Paragraph/ Figure/ Table/ (e.g. Table 1)	Type of comment[1]	Comments	Influence on Protocol? / To be included as variation of parameter (iterative test)?	Observations of the WPL
					the degradation of thermal stratification during stand-by" but this parameter is no defined elsewhere.		
	SPF	Annex D.1		te	Heat capacity is considered as constant for the medium in the store. This should be temperature dependent		

1 **Type of comment:** **ge** = general **te** = technical **ed** = editorial