Project ECOTEST **Deliverables** **D8.4 Analysis of the results and report** **D8.5 Proposal to CEN and communication**	ECO_WP8_XXX_WP8-RRT3_V2

WP	WP 8 Solar Collector
Type	Annex to WP8 final report
Title	**Annex 1.3** **Extended RRT results and analysis** **RRT3 Combi Store (EN 12977-4)**
Author	A. Bohren
Dissemination	Free

Version	Status	Date	Comments
A	Internal for discussion in the WP	16.12.2018	
B	Version sent as progress report Dec. 2018		
C	Version sent as progress report Feb. 2019	26.02.2019	
D	Final version after steering group meeting for approval by WP8 testing laboratories	09.05.2019	
E	Final	02.06.2019	

Table of contents

1 Introduction

1.1 Context of the test

For the RRT3 one Solar Combi store was sent around to the participating laboratories. This store was sent around independent of all other RRTs as there was no additional testing foreseen as for example with the SWH (RRT2) store or with the collectors (RRT1).
Testing of solar combi store according to EN 12977-4 is a laboratory test which is performed under controlled conditions and using well defined charge and discharge profiles. The testing is therefore independent of ambient conditions such as solar radiation.
The testing procedures and the interpretation of the results is in many points very similar or even identic to the finding of RRT2 (EN 12977-3 for SWH store). For this reason there are many references to the RRT2 report in order not to repeat or copy redundant content.

1.2 Time period

The test have started in December 2017 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 combi store used for this RRT is a standard vertical combi buffer tank of about 800 litres volume made of steel. The store has two internal coil heat exchangers, the DHW heat exchanger and the solar heat exchanger. The store is made in Germany and corresponds very much to an average combi store as it is installed in central Europe for Solar combi systems.

2.2 Picture of the SWH store

Figure 1: The Store installed at the testing laboratory igte, ise and SPF. Depending on test sequence different connectors are connected.

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 12977-4 follows basically the same testing programme as for EN 12977-3. Actually EN 12977-4 is referencing for most test cycles to the EN 12977-3. The store is charged and discharged using (one after the other) the different possible double ports or heat exchangers. 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.

3.2 Test protocol(s) used

The test protocol used by the different test labs is following the standard EN 12977-4.

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 12977-4.

3.4 Test conditions

See RRT2

3.5 Other

None

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

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

1. Deviation from median value (Delta)
   Difference between any value and the median value
2. Arithmetic mean value
   Arithmetic mean of all value (sum of all values divided by the number of values)
3. Deviation from arithmetic mean value
   Difference between any value and the arithmetic mean value
4. 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)
5. 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
6. 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 Solar Combi store performance

Solar combi store data					
LABORATORY		1	2	3	
EN 12977-4					
Gross height of unit incl. insulation		1880.00	1880.00	1880	mm
Gross width incl. insulation		990.00	990.00	990	mm
Gross depth incl. insulation		990.00	990.00	990	mm
Nominal volume- total	V_n	825.00	802.40	825	l
Effective volume- total	V_{eff}	804.00	649.60	794	l
Auxiliary heated volume	V_{Aux}	293.00	352.20	334	l
Solar loop heat exchanger volume		18.90	19.80	16	l
Total effective thermal capacity	C_S	3366.00	2695.39	3285	kJ/K
Thermal capacity of aux. heated part l		808.00	1461.39	1382	kJ/K
Stand-by heat loss rate	$(UA)_{sb,s,a}$	3.44	3.56	3.17	W/K
Effective vertical heat conductivity	λ_{eff}	1.67	1.03	1.51	W/(m*K)
UA-value, solar heat exchanger	$(UA)_{hx,s}$	1972.00	1199.90	986	W/K
UA-value, hot water heat exchanger		1110.00	2082.40	2564	W/K
Cold water inlet (position) - conditioning-direct		17	10	16	%
Hot water outlet (position) - conditioning-direct		100	100	100	%
Cold water inlet (position) - dhw-indirect		19	3	4	%
Hot water outlet (position) - dhw-indirect		99	94	95	%
Collector loop inlet (position)		58	35	60	%
Collector loop outlet (position)		13	11	18	%
Space heating inlet (position)		36	33	40	%
Space heating outlet (position)		53	55	60	%
Auxiliary heating inlet (position)		88	91	90	%
Auxiliary heating outlet (position)		57	55	58	%
Temp. sensor 1, Solar (position)		30	28	30	%
Temp. sensor 2, space heating preheat (position)		53	55	54	%
Temp. sensor 3, Auxiliary heating (position)		66	64	66	%
European regulations					
Standing loss (Tstore = 65 °C, Tambient = 20 °C)		154.9	160.20	143	W
Nominal volume of the store		825	802.40	794	L
Energy Label		D	D	D	

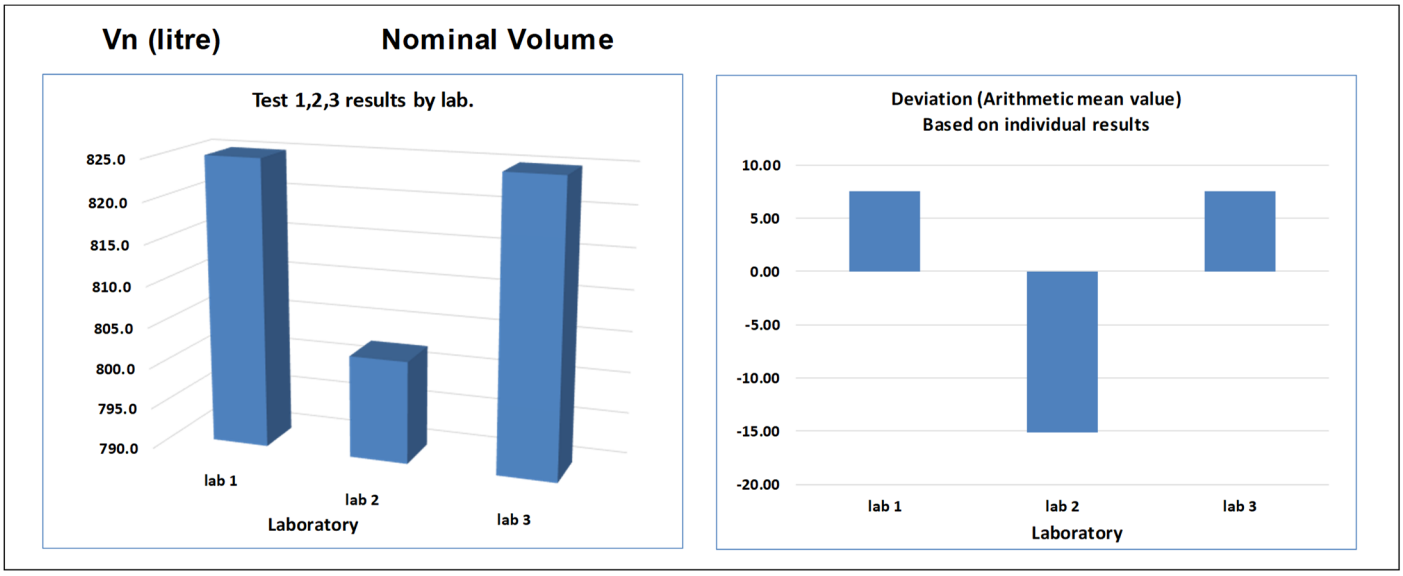
Table 1: Measured parameters submitted by the participating test laboratories (final results)

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		
universal statistical evaluation v3.4 SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	825.00	802.40	825.00
Number of test results		1	1	1
Median value	825	825.00	802.40	825.00
Deviation from median value (Delta)		0.00	-22.60	0.00
Arithmetic mean value	817	825.00	802.40	825.00
Deviation from arithmetic mean value		7.53	-15.07	7.53
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	13.048			
Max - Min (arithmetic mean value)	22.600	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	22.600	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	outlier	correct	outlier	correct

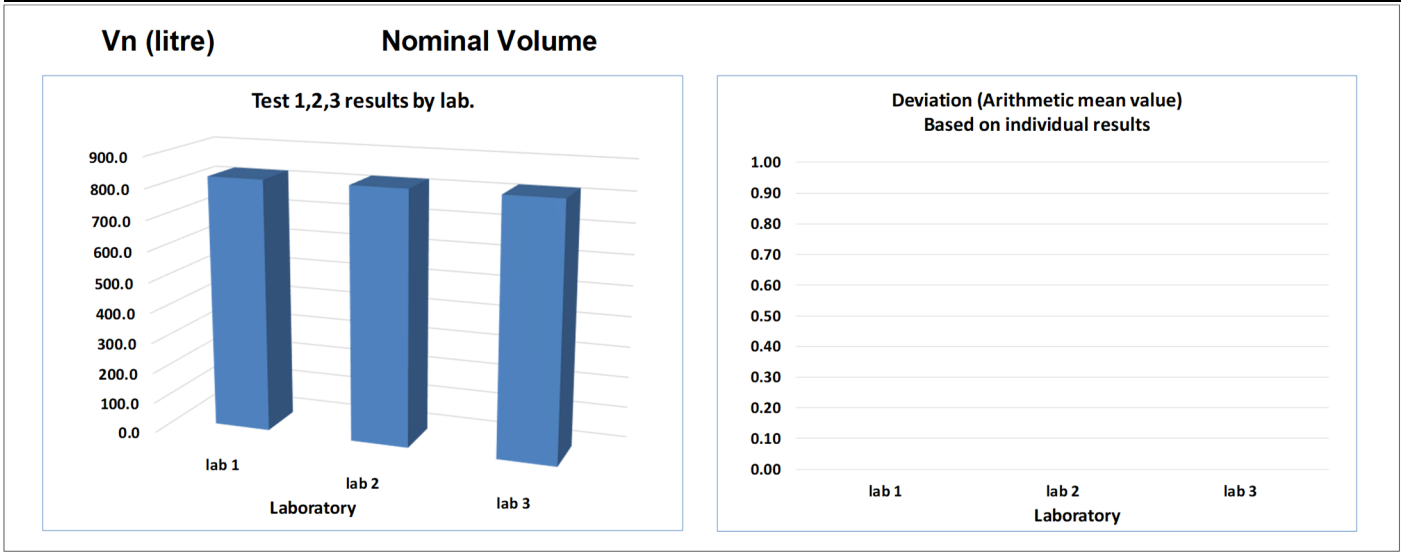


STATISTICS	
Median	825.000 litre
Arh. mean value	817.467 litre
R STD	13.048 litre
r STD	-
Max - Min (M-m)	22.600 litre

Figure 2: ECOTEST statistical representation of the results determined V_n

5.2.2 Nominal Volume V_n (Outlier removed)

Parameter	V_n (litre)	Nominal Volume		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	825.00	825.00	825.00
Number of test results		1	1	1
Median value	825	825.00	825.00	825.00
Deviation from median value (Delta)		0.00	0.00	0.00
Arithmetic mean value	825	825.00	825.00	825.00
Deviation from arithmetic mean value		0.00	0.00	0.00
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	0.000			
Max - Min (arithmetic mean value)	0.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	0.000	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	straggler	-	-	-

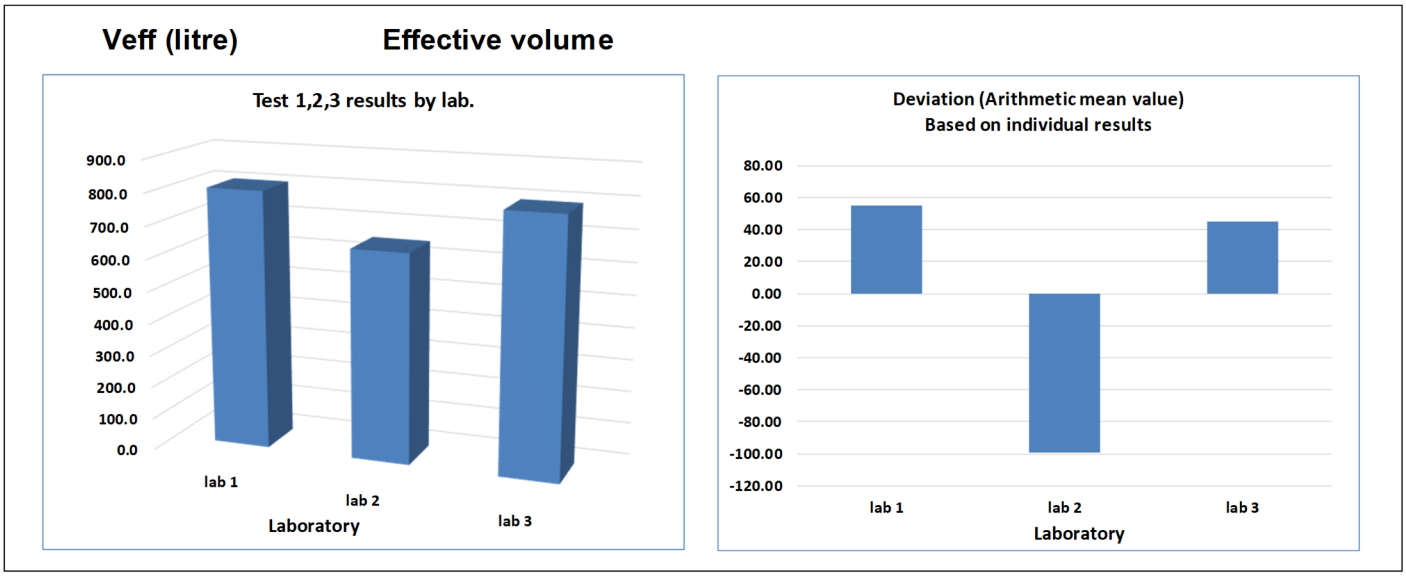


STATISTICS	
Median	825.000 litre
Arh. mean value	825.000 litre
R STD	0.000 litre
r STD	-
Max - Min (M-m)	0.000 litre

Figure 3: ECOTEST statistical representation of the results determined V_n without outlier considered (See 7.1)

5.2.3 Effective Volume V_{eff}

Parameter	V_{eff} (litre)	Effective volume		
universal statistical evaluation v3.4 SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	804.00	649.60	794.00
Number of test results		1	1	1
Median value	794	804.00	649.60	794.00
Deviation from median value (Delta)		10.00	-144.40	0.00
Arithmetic mean value	749	804.00	649.60	794.00
Deviation from arithmetic mean value		54.80	-99.60	44.80
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	86.401			
Max - Min (arithmetic mean value)	154.400	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	154.400	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	outlier	correct	outlier	correct

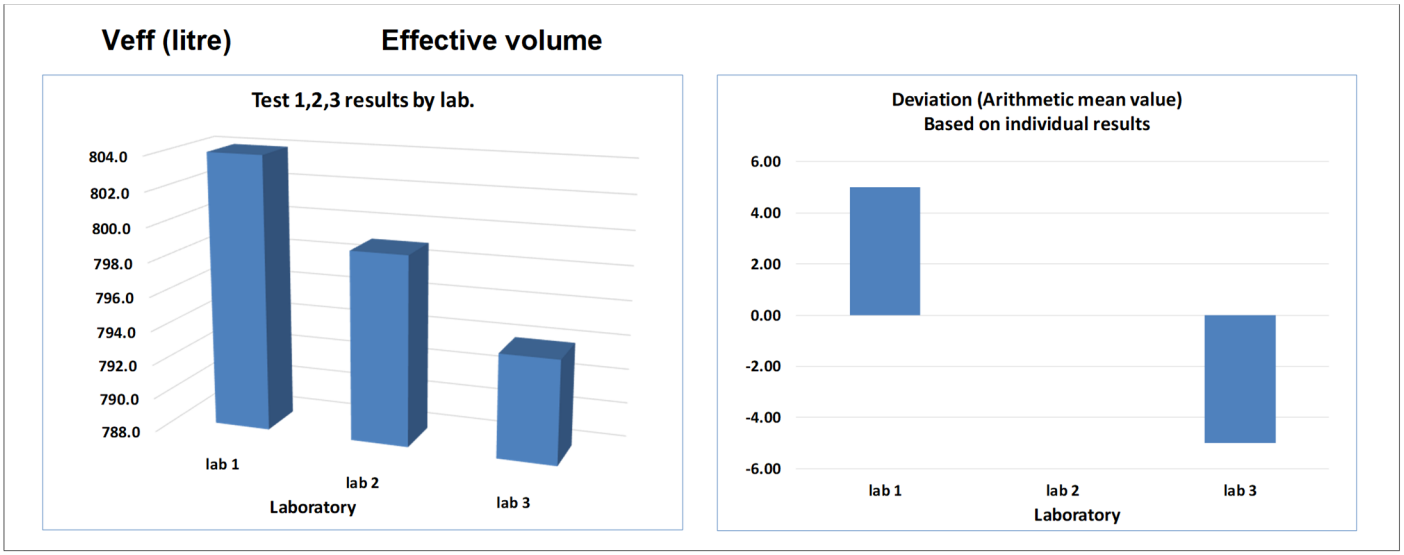


STATISTICS	
Median	794.0 litre
Arh. mean value	749.2 litre
R STD	86.4 litre
r STD	-
Max - Min (M-m)	154.4 litre

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

5.2.4 Effective Volume V_{eff} (Outlier removed)

Parameter	V_{eff} (litre)	Effective volume		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	804.00	799.00	794.00
Number of test results		1	1	1
Median value	799	804.00	799.00	794.00
Deviation from median value (Delta)		**5.00**	**0.00**	**-5.00**
Arithmetic mean value	799	804.00	799.00	794.00
Deviation from arithmetic mean value		**5.00**	**0.00**	**-5.00**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	5.000			
Max - Min (arithmetic mean value)	10.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	10.000	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

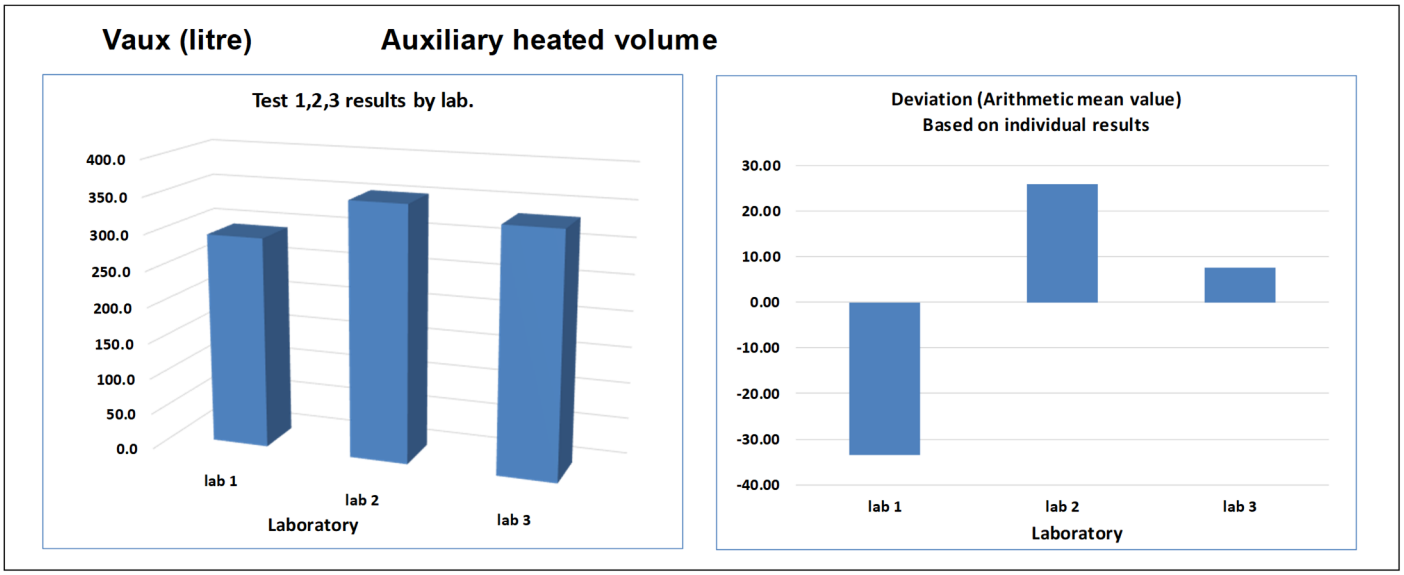


STATISTICS	
Median	799.0 litre
Arh. mean value	799.0 litre
R STD	5.0 litre
r STD	-
Max - Min (M-m)	10.0 litre

Figure 5: ECOTEST statistical representation of the results measured V_{eff} without outliers (see clause 7.1)

5.2.5 Auxiliary heated Volume V_{Aux}

Parameter	V_{aux} (litre)	Auxiliary heated volume		
universal statistical evaluation v3.4 SLG by ACEA	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	293.00	352.20	334.00
Number of test results		1	1	1
Median value	334	293.00	352.20	334.00
Deviation from median value (Delta)		-41.00	18.20	0.00
Arithmetic mean value	326	293.00	352.20	334.00
Deviation from arithmetic mean value		-33.40	25.80	7.60
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	30.323			
Max - Min (arithmetic mean value)	59.200	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	59.200	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

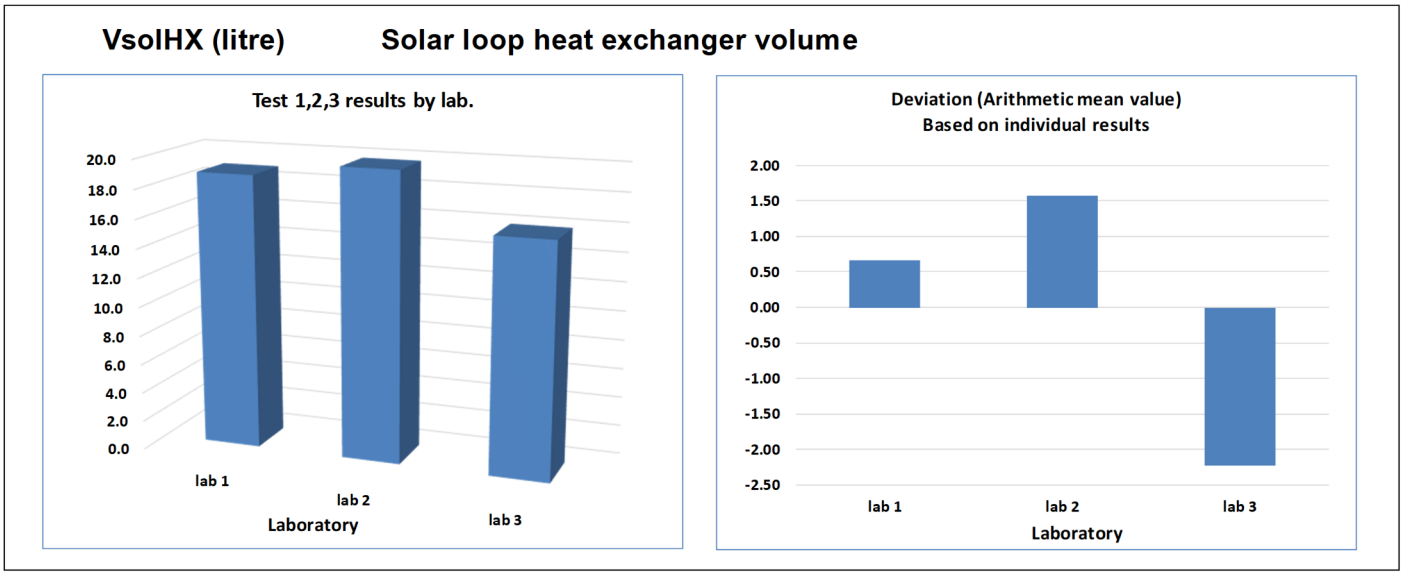


STATISTICS	
Median	334.0 litre
Arh. mean value	326.4 litre
R STD	30.3 litre
r STD	-
Max - Min (M-m)	59.2 litre

Figure 6: ECOTEST statistical representation of the results measured V_{Aux}

5.2.6 Solar Loop HX Volume

Parameter	V_{solHX} (litre)	Solar loop heat exchanger volume		
universal statistical evaluation v3.4 SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	18.90	19.80	16.00
Number of test results		1	1	1
Median value	19	18.90	19.80	16.00
Deviation from median value (Delta)		**0.00**	**0.90**	**-2.90**
Arithmetic mean value	18	18.90	19.80	16.00
Deviation from arithmetic mean value		**0.67**	**1.57**	**-2.23**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	1.986			
Max - Min (arithmetic mean value)	3.800	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	3.800	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

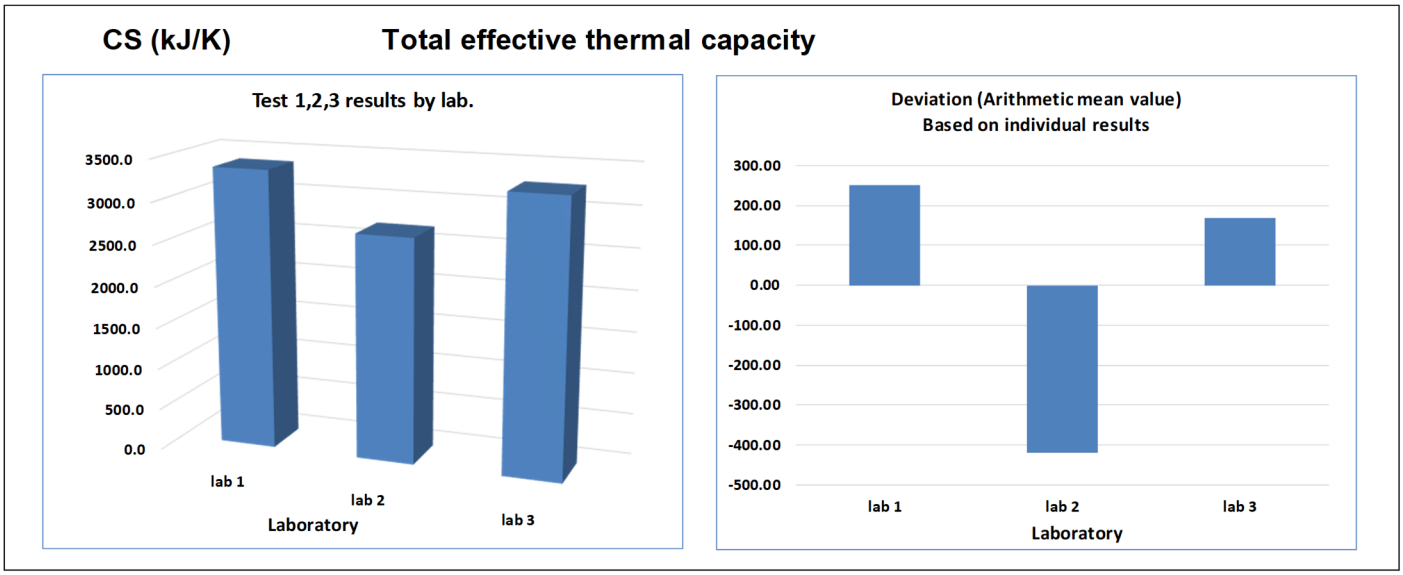


STATISTICS	
Median	18.9 litre
Arh. mean value	18.2 litre
R STD	2.0 litre
r STD	-
Max - Min (M-m)	3.8 litre

Figure 7: ECOTEST statistical representation of the results measured Solar Loop HX Volume

5.2.7 Total effective thermal capacity

Parameter	C_S (kJ/K)	Total effective thermal capacity		
universal statistical evaluation v3.4 SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	3366.00	2695.39	3285.00
Number of test results		1	1	1
Median value	3285	3366.00	2695.39	3285.00
Deviation from median value (Delta)		81.00	-589.61	0.00
Arithmetic mean value	3115	3366.00	2695.39	3285.00
Deviation from arithmetic mean value		250.54	-420.07	169.54
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	366.042			
Max - Min (arithmetic mean value)	670.610	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	670.610	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

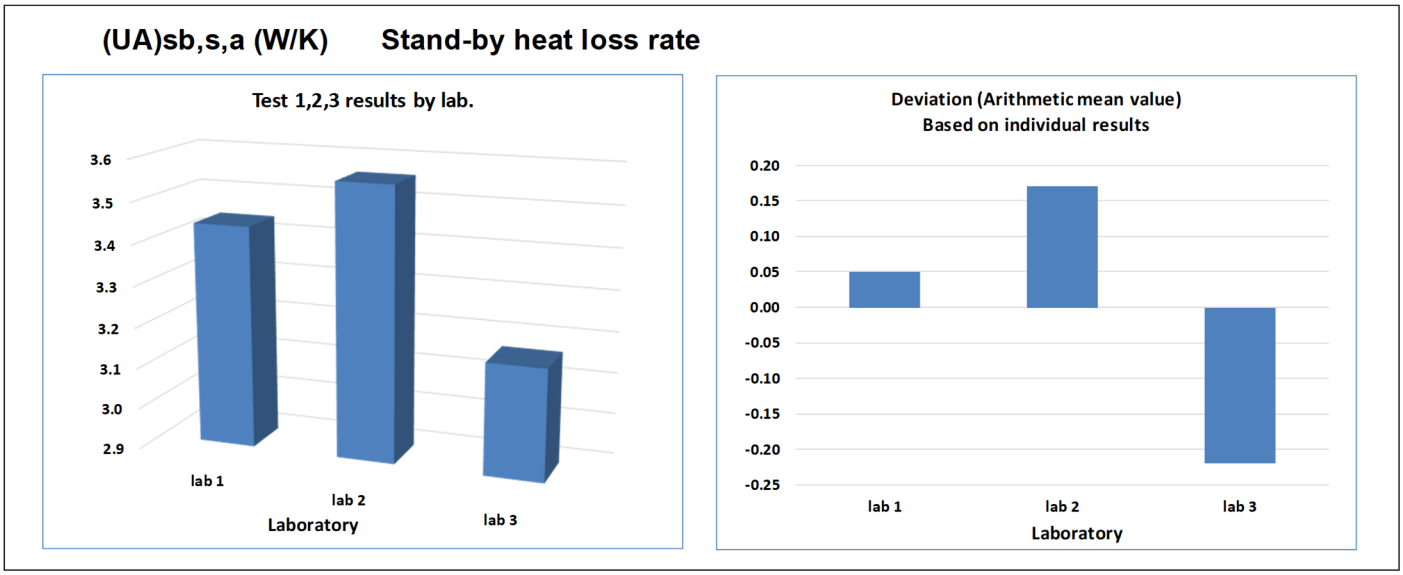


STATISTICS	
Median	3285.0 kJ/K
Arh. mean value	3115.5 kJ/K
R STD	366.0 kJ/K
r STD	-
Max - Min (M-m)	670.6 kJ/K

Figure 8: ECOTEST statistical representation of the results measured effective thermal capacity

5.2.8 Standby heat loss rate

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	3.44	3.56	3.17
Number of test results		1	1	1
Median value	3	3.44	3.56	3.17
Deviation from median value (Delta)		0.00	0.12	-0.27
Arithmetic mean value	3	3.44	3.56	3.17
Deviation from arithmetic mean value		0.05	0.17	-0.22
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	0.200			
Max - Min (arithmetic mean value)	0.390	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	0.390	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

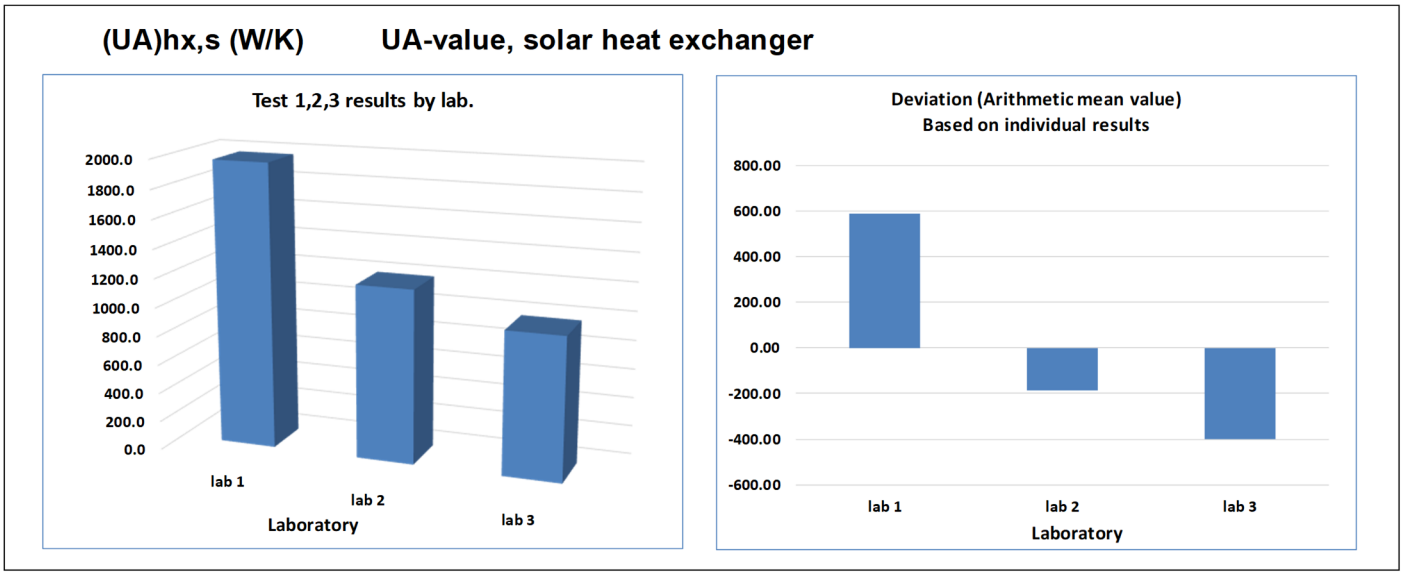


STATISTICS	
Median	3.440 W/K
Arh. mean value	3.390 W/K
R STD	0.200 W/K
r STD	-
Max - Min (M-m)	0.390 W/K

Figure 9: ECOTEST statistical representation of the results measured Standby heat loss rate

5.2.9 UA Solar HX

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	1972.00	1199.90	986.00
Number of test results		1	1	1
Median value	1200	1972.00	1199.90	986.00
Deviation from median value (Delta)		772.10	0.00	-213.90
Arithmetic mean value	1386	1972.00	1199.90	986.00
Deviation from arithmetic mean value		586.03	-186.07	-399.97
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	518.7			
Max - Min (arithmetic mean value)	986.0	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	986.0	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

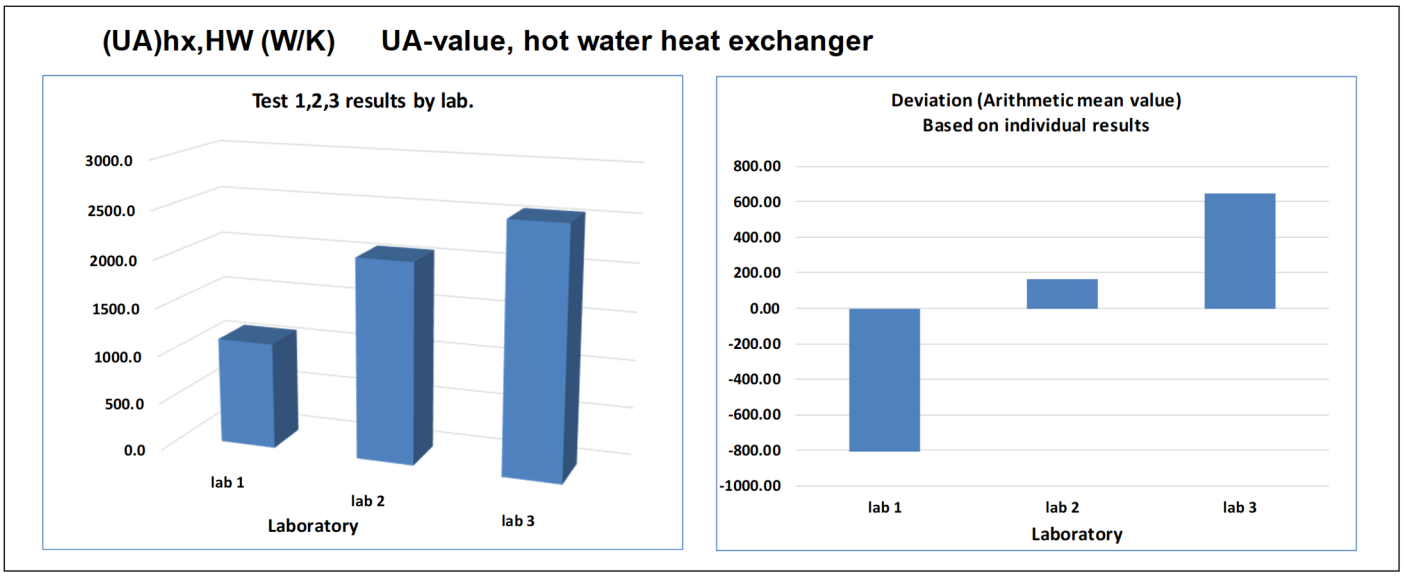


STATISTICS	
Median	1199.900 W/K
Arh. mean value	1385.967 W/K
R STD	518.666 W/K
r STD	-
Max - Min (M-m)	986.000 W/K

Figure 10: ECOTEST statistical representation of the results measured UA Solar HX

5.2.10 UA-value, hot water heat exchanger

Parameter	$(UA)_{hx,HW}$ (W/K)	UA-value, hot water heat exchanger		
universal statistical evaluation v3.4.SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	1110.00	2082.40	2564.00
Number of test results		1	1	1
Median value	2082	1110.00	2082.40	2564.00
Deviation from median value (Delta)		-972.40	0.00	481.60
Arithmetic mean value	1919	1110.00	2082.40	2564.00
Deviation from arithmetic mean value		-808.80	163.60	645.20
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	740.7			
Max - Min (arithmetic mean value)	1454.0	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	1454.0	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	2082.400 W/K
Arh. mean value	1918.800 W/K
R STD	740.677 W/K
r STD	-
Max - Min (M-m)	1454.000 W/K

Figure 11: ECOTEST statistical representation of the results measured UA Hotwater HX

5.2.11 Position of connectors and sensors

As in the EN12977-3, 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. More details are found in the WP8-RRT2 report. For Combistores there are more positions and sensors and the results of the RRT are summarized in Figure 12. The follwing ports are relevant:

Cond: The direct conditioniing in and outlets (bottom and top)
DHW: Domestic hot water
SH: Space heating
Aux: Auxiliary heating

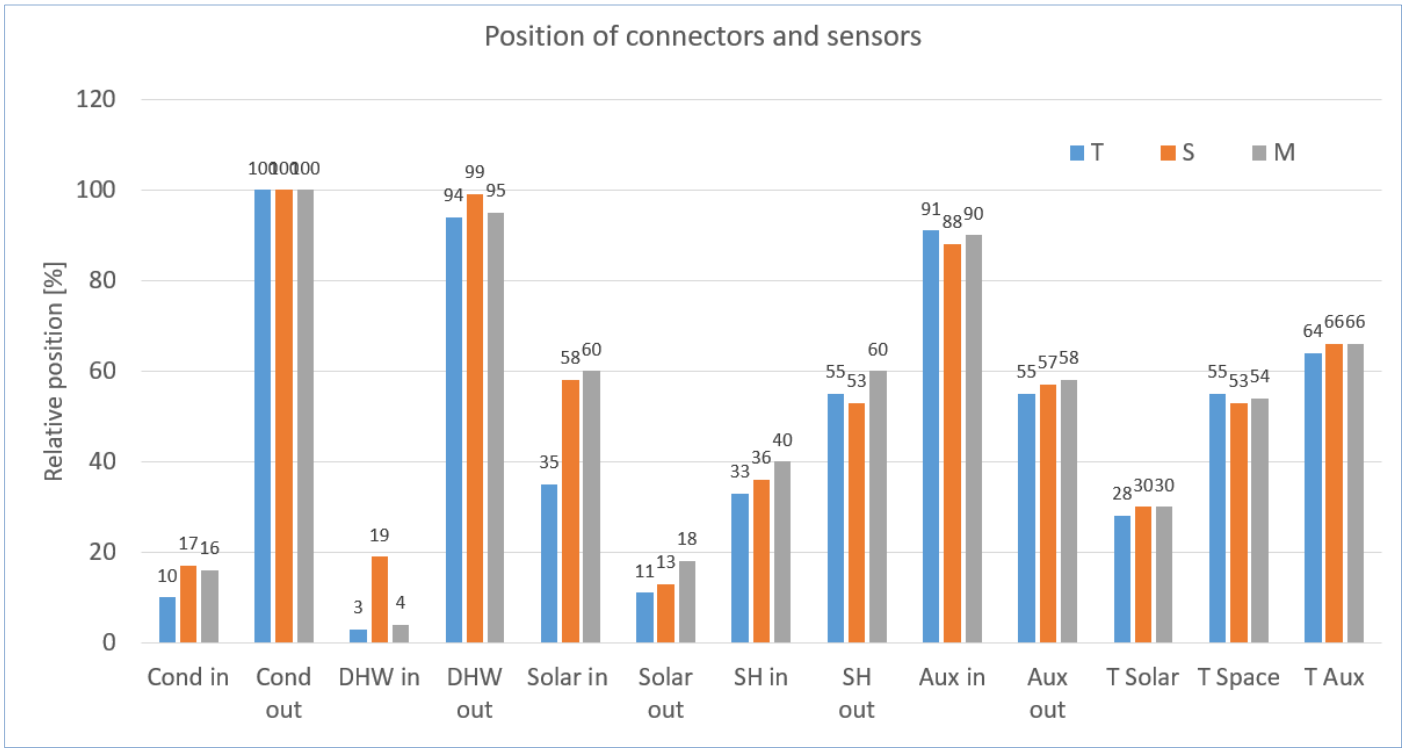
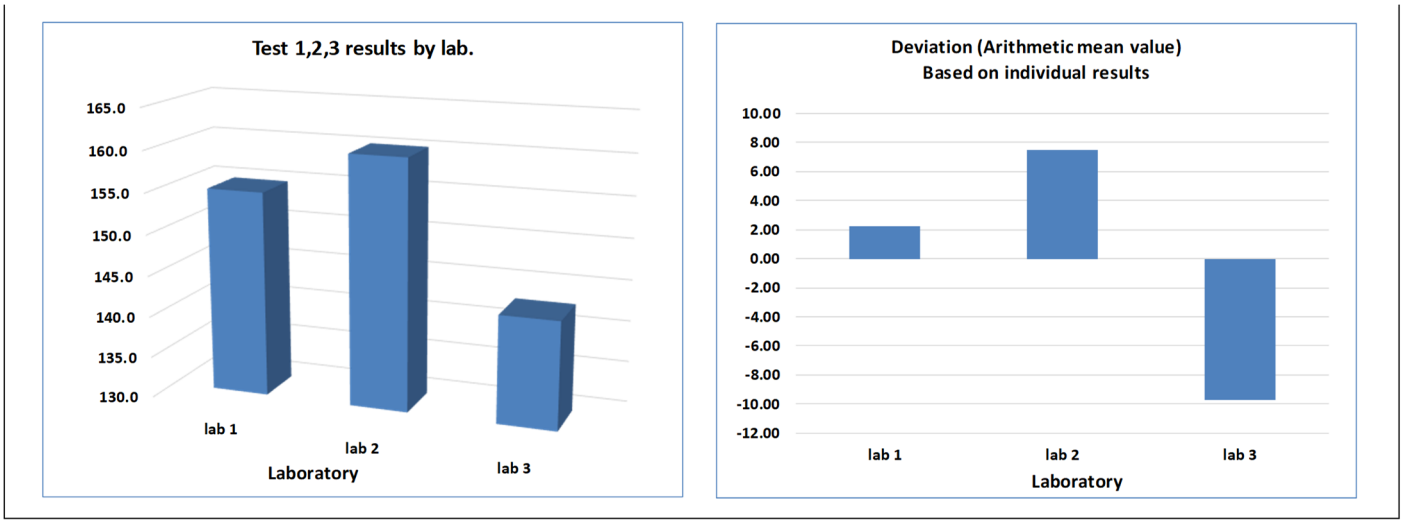


Figure 12: Comparison of the fitted positions of connectors and sensors as submitted by the test labs.

It is that some parameters were determined with very good concordance. Some other positions such as "DHW in" or "Solar in" may raise doubts. Basically the positions must be understood as % of the store height. A possible reason for the inconsistencies is a different interpretation of these heights indicted as % values. For sure these parameters must be understood as always as a set of parameters and comparison of individual numbers is not appropriate.

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

Parameter	S (W)	Standing loss		
universal statistical evaluation v3.4.SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	154.90	160.20	143.00
Number of test results		1	1	1
Median value	155	154.90	160.20	143.00
Deviation from median value (Delta)		0.00	5.30	-11.90
Arithmetic mean value	153	154.90	160.20	143.00
Deviation from arithmetic mean value		2.20	7.50	-9.70
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	8.8			
Max - Min (arithmetic mean value)	17.2	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	17.2	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	154.900 W/K
Arh. mean value	152.700 W/K
R STD	8.809 W/K
r STD	-
Max - Min (M-m)	17.200 W/K

Figure 13: 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
-	-	None	-

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

As discussed in the Work package leader consortium, measurements with outlier results were re-analysed without the outlier. As there are only 3 laboratories involved in WP8 this would reduce the number of results to 2. The Excel sheets used to compute and present the results are not available for two laboratories. For this reason the outlier results was replaced as a compromised solution by an average value of the remaining values. This was done in clauses 5.2.2 and 5.2.4.

As the testing procedure is basically the same as in EN 12977-3, all the general remarks of the WP8-RR2 report in clause 7.1 are valid as well for the RRT3 and shall only be summarized here again.

- The testing time with respect to standing losses is becoming too long for good stores if an approximate 50% heat loss must be awaited for this test sequence.
- The definition of "volumes" should be more precise.

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 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. Compared to RRT2 the ratings of the labs are closer together, the variations would however still be relevant if the losses were closer to a classification limit. Still the difference between the rated standing losses is a range of more than ±5%.

	S [W]	V [l]	A+	A	B	C	**D**	E	F	C.x
T	160.2	802.4	50.49	70.18	98.06	137.55	**170.92**	224.25	272.79	C.68
S	154.9	825	50.99	70.87	99.02	138.90	**172.59**	226.46	275.49	C.47
M	143	794	50.30	69.92	97.70	137.05	**170.29**	223.41	271.77	C.18

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

7.2 Comments on possible discrepancies

The definition of V_{eff} is not clear from the standard. Laboratory 2 indicated a lower value in 0 as the dead-volumes above the drinking water HX and below the collector HX were subtracted from the fitted volume. This is neither wrong nor correct as the definition is not clear. For this reason these values are not corrected.

Further comments including the explanation for the outlier of the nominal store volume V_n are found in Clause 7.2 of RRT2

7.3 Comments in light of the iterative tests results

See Report of RRT2

8 Iterative test results

The statements of the report from WP8-RRT2 apply to this RRT without restriction and are therefore not repeated here. No iterative tests were foreseen for RRT3.

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 EN 12977-4 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 comments in ECOTEST Report WP8-RRT2 apply for this RRT and are not repeated here again. In addition to these points, the following points for improvement were identified in RRT3:

- Improve the description of the parameters such volume, positions of the connectors and sensors.
- Investigate the possibility to reduce testing time.
- Improve procedures such that the measured store performance is not influenced by technical issues such as gaps between tank and insulation, by different ways of connecting the store to the test rig, or similar, i.e. to define better the procedure on how to install the store and on how to connect to the test rig.

9.3 Recommendations to CEN

The comments in ECOTEST Report WP8-RRT2 apply for this RRT and are not repeated here again. In addition to these points, the possibility to merge EN 12977-3 and EN 12977-4 in a single standard should be evaluated.

10 Conclusion

As the standards EN 12977-3 and EN 12977-4 follow the same procedures, all the conclusions from ECOTEST report WP8-RRT2 apply and are not repeated here again.

11 ANNEXES

11.1 ANNEX 1 TEST PROTOCOL

Project ECOTEST / WP8 RRT3: Solar Combistores	ECO_WP8_025

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 combistores 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 RRT3 is performed with **one** reference store.

Due to the time restrictions the two step approach is not applicable: RRT3 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 12977-4:2013 Thermal solar systems and components - Custom built systems- Part 3: Performance test methods for solar combistores

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 RRT3”.
  Laboratories can add their own tags for identification.
- Installer manual (ECO_WP8_030_RRT3_InstallerManual)
- Test protocol (ECO_WP8_026_RRT3_TestProtocol, this document)
- Test schedule (ECO_WP8_008_ScheduleAndApplianceTracker)
- Template test results (ECO_WP8_017_ RRT3_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 12977-4:2013.
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 12977-4:2013 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 12977-4:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_017_RRT3_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 12977-4:2013 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 12977-4:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_017_RRT3_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 12977-4:2013 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 12977-4:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_017_RRT3_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 12977-4:2013 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 12977-4:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_017_RRT3_ResultDataSheet_lab.xlsx).

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

The test is carried out according to EN 12977-4:2013 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 12977-4:2013 and in addition as required for the energy labelling regulations using the template (ECO_WP8_017_RRT3_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_017_RRT3_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_017_RRT3_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_RRT3_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_RRT3_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 12977-4**

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 (eg. 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: See also EN12977-3 comments

1	itw	6.1.1	-	ge	Number of charge loops	One instead of two	
2	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	
3	itw	6.2.1	-	te	Insulation of pipes between the store and the temperature sensors	acc. to EN 12897, B1 instead of EN 12828	
4	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.	

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
5	itw	6.3.2.1 6.3.2.3 6.3.2.4	-	te	Duration of stand-by period	For determining the heat loss rate, 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. For determining the effective vertical heat conductivity the duration of the stand-by period should be 48 h.	
6	itw	6.3.2.6	-	te	Number of tests	4 instead of 6 tests: 2 tests with low and high discharge volume flow rate and fully charged store and 2 tests with low and high discharge volume flow rate and auxiliary part charged.	
7	DTU	6.2.2	2nd 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.	

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