Project ECOTEST	ECO_WP8_XXX_WP8-RRT5_V2
Deliverables **D8.4 Analysis of the results and report** **D8.5 Proposal to CEN and communication**	

WP	WP 8 Solar
Type	Annex to WP8 final report
Title	**Annex 1.5** **Extended RRT results and analysis** **RRT5 SWH System** **EN 12977-3 // ISO 9806 // EN 12977-2** **SOLCAL and SOLTHERM methods**
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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 Report	02.06.2019	

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1 Introduction

1.1 Context of the test

For the WP8-RRT5 a solar water heater system is simulated using the results from WP8-RRT1 (collectors) and WP8-RRT2 (SWH store) using the SOLCAL method as defined in the transitional methods (2014/C 207/03). Therefore WP8-RRT5 is a purely computational RRT which is based on components measurements and no additional measurements were required. The system which is simulated in WP8- RRT5 is the same that was tested in WP8-RRT4.

1.2 Time period

See WP8-RRT1, WP8-RRT2 and WP8-RRT4

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.

See Report WP8-RRT4

2.2 Picture of the appliance

See WP8-RRT1, WP8-RRT2 and WP8-RRT4 for pictures of the appliances.
For WP8-RRT5 two software tools were used, screenshots are found below.

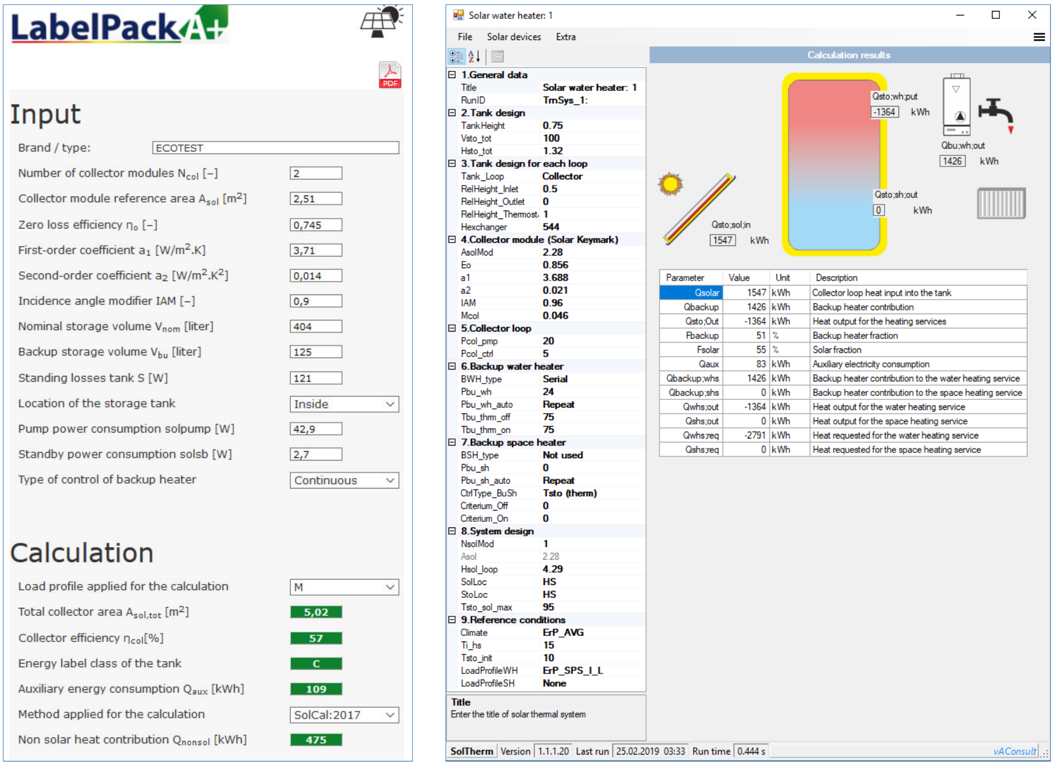


Figure 1: User interface of SOLCAL (left) and SOLTHERM (right)

2.3 Origin of appliances used for the RRT

See WP8-RRT4
The SOLCAL software used to compute the results is publicly available, either described in the transitional methods (2014/C 207/03), or readily implemented under http://www.label-pack-a-plus.eu/solcal-tool/ which has been developed in the framework of the Labelpack A+ project (GA 649905).
The SOLTHERM software is publicly available[1] for the time being as it was developed in a project funded by the SOLAR KEYMARK Certification Fund.

[1] http://www.vaconsult.net/Software/SolTherm/SolTherm_UK.htm

3 Testing programme & testing equipment of labs

3.1 Programme

No physical testing required

3.2 Test protocol(s) used

The WP8-RRT5 consist of applying the SOLCAL method described in the transitional methods (2014/C 207/03) using the data measured in WP8-RRT1 (collector parameters), WP8-RRT2 (store parameters) and WP8-RRT4 (pump and controller power).
There are basically two SOLCAL implementations

- The one which is published in the Official Journal of the European Union, 2014/C 207/3. The method is based on EN 15316-4-3:2007, method B, with some simplifications.
- The one based on EN 15316-4-3:2017, annex F. This is the revised standard EN 15316-4-3:2007. The method 2 is the former method B and has been improved considerably. A description of the main changes is found in chapter 6.1.2 of the Technical Report accompanying the standard (CEN/TR 15316-6-6 of April 2017). The standard has an Annex F, describing how to apply the general method for the SOLCAL method and has the Annex ZA, ZB and ZC for formal linking to the ErP-regulations. This link of the standard to the regulation has been drafted on request of the commission and CEN according to the CEN mandate 534 and 535. However, this standard has not yet been harmonized formally.

For this reason the results are always displayed as SOLCAL:2013 and SOLCAL:2017 results. For the time being the SOLCAL:2013 are the valid results. It must be assumed anyway that the 2017 version will be used in the future.
In addition to the SOLCAL Method(s) the systems were analysed using the new SOTHERM software[2] which is based on the CEN EPBD standards EN 15316-4-3 method 3 and EN 15316-6. In contrast to other software (See WP8-RRT4), this code is open source.
All approaches are assumed fulfilling the requirements of the EN 12977-2:2018

3.3 Overview of the main test equipment used by labs

See WP8-RRT1 and WP8-RRT2

3.4 Test conditions

N/A

3.5 Other

N/A

[2] http://www.vaconsult.net/Software/SolTherm/SolTherm_UK.htm

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 Solar water heater performance

Solar water heater data

LABORATORY		1	2	3	
EN 12975-1 / EN 12977-3 / EN 12976-2 / EN 12977-2 / SOLCAL 2013					
Ann. non-solar heat contribution at av. climate conditions for load profile M	Q_{nonsol}	1042	1149	1086	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile L	Q_{nonsol}	1477	1553	1555	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile XL	Q_{nonsol}	2513	2554	2620	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile XXL	Q_{nonsol}	3449	3472	3569	kWh/a
Power consumption pump	$P_{solpump}$	57	39.3	56.1	W
Standby power consumption controller	P_{solsb}	2.5	2.6	2.6	W
Annual auxiliary heat consumption	Q_{aux}	136	102	135	kWh/a
EN 12975-1 / EN 12977-3 / EN 12976-2 / EN12977-2 / SOLCAL 2017					
Ann. non-solar heat contribution at av. climate conditions for load profile M	Q_{nonsol}	439	458	474	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile L	Q_{nonsol}	1004	1016	1072	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile XL	Q_{nonsol}	2095	2091	2211	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile XXL	Q_{nonsol}	3058	3043	3191	kWh/a
Power consumption pump	$P_{solpump}$	57	39.3	56.1	W
Standby power consumption controller	P_{solsb}	2.5	2.6	2.6	W
Annual auxiliary heat consumption	Q_{aux}	136	102	135	kWh/a
EN 12975-1 / EN 12977-3 / EN 12976-2 / EN12977-2 / SOLTHERM					
Ann. non-solar heat contribution at av. climate conditions for load profile M	Q_{nonsol}	605	606	614	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile L	Q_{nonsol}	1249	1227	1253	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile XL	Q_{nonsol}	2297	2258	2281	kWh/a
Ann. non-solar heat contribution at av. climate conditions for load profile XXL	Q_{nonsol}	3219	3204	3194	kWh/a
Power consumption pump	$P_{solpump}$	57	39.3	56.1	W
Standby power consumption controller	P_{solsb}	2.5	2.6	2.6	W
Annual auxiliary heat consumption for M profile only (SOLTHERM is computing Q_{Aux} depending on the load profile)	Q_{aux}	135	102	134	kWh/a

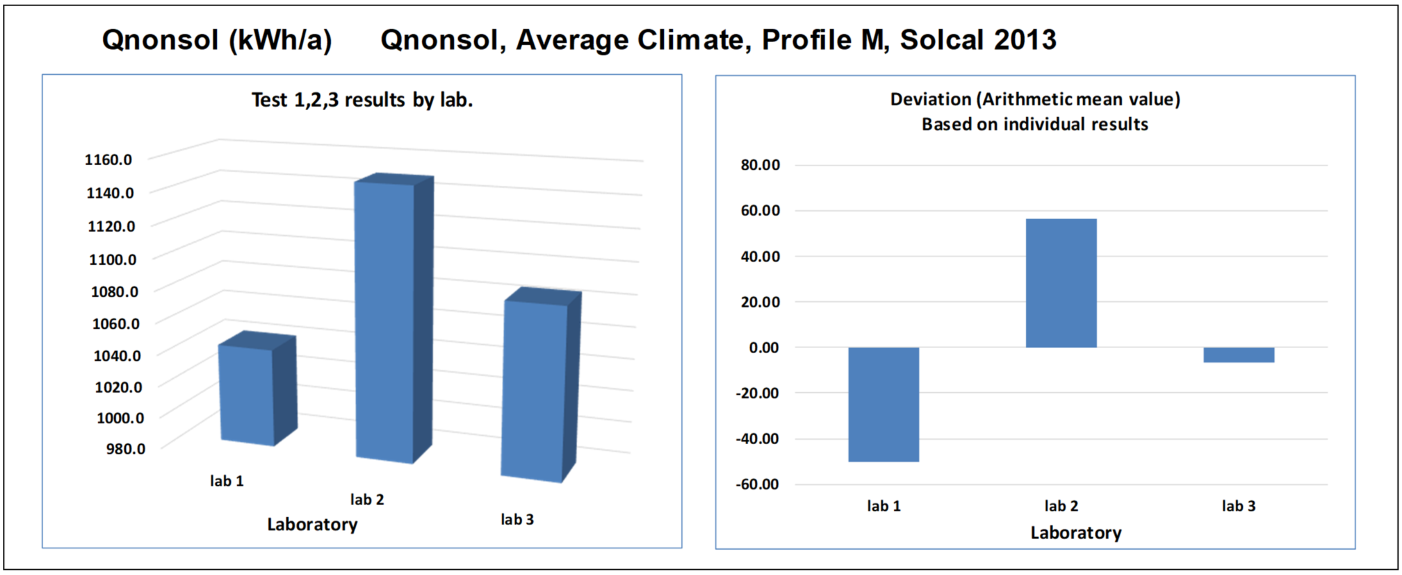
Table 1: Measured parameters submitted by the participating test laboratories (final results)

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 SOLCAL:2013 Annual non-solar heat contribution at av. climate conditions for load profile M

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile M, Solcal 2013		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	1042.00	1149.00	1086.00
Number of test results		1	1	1
Median value	1086	1042.00	1149.00	1086.00
Deviation from median value (Delta)		**-44.00**	**63.00**	**0.00**
Arithmetic mean value	1092	1042.00	1149.00	1086.00
Deviation from arithmetic mean value		**-50.33**	**56.67**	**-6.33**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	53.780			
Max - Min (arithmetic mean value)	107.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	107.000	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

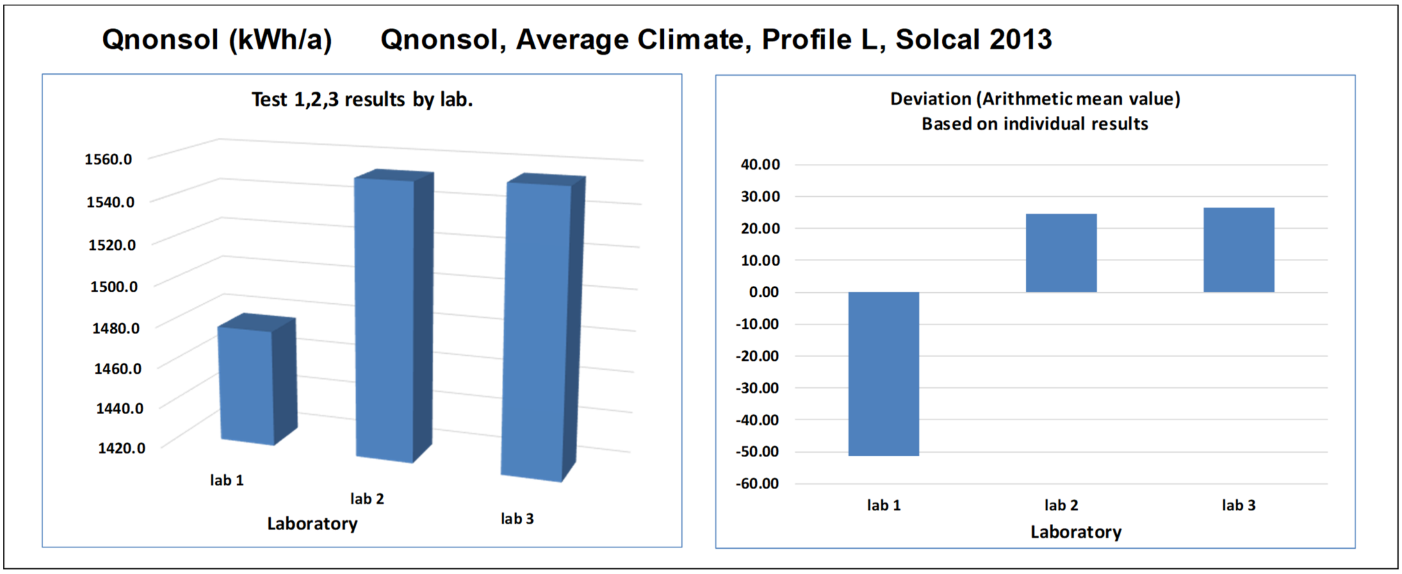


STATISTICS	
Median	1086.0 kWh/a
Arh. mean value	1092.3 kWh/a
R STD	53.8 kWh/a
r STD	-
Max - Min (M-m)	107.0 kWh/a

Figure 2: ECOTEST statistical representation of the results Q_{nonsol} for load profile M computed with SOLCAL:2013

5.2.2 SOLCAL:2013 Annual non-solar heat contribution at av. climate conditions for load profile L

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile L, Solcal 2013		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	1477.00	1553.00	1555.00
Number of test results		1	1	1
Median value	1553	1477.00	1553.00	1555.00
Deviation from median value (Delta)		-76.00	0.00	2.00
Arithmetic mean value	1528	1477.00	1553.00	1555.00
Deviation from arithmetic mean value		-51.33	24.67	26.67
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	44.467			
Max - Min (arithmetic mean value)	78.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	78.000	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	outlier	outlier	correct	correct

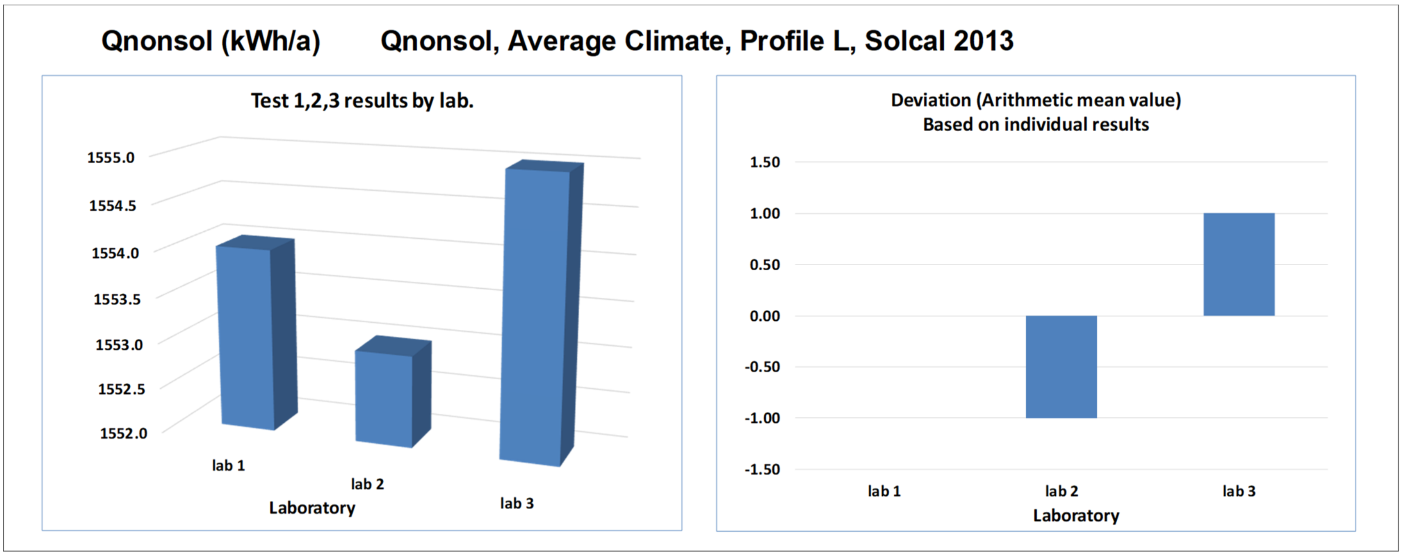


STATISTICS	
Median	1553.0 kWh/a
Arh. mean value	1528.3 kWh/a
R STD	44.5 kWh/a
r STD	-
Max - Min (M-m)	78.0 kWh/a

Figure 3: ECOTEST statistical representation of the results Q_{nonsol} for load profile L computed with SOLCAL:2013

5.2.3 SOLCAL:2013 Annual non-solar heat contribution at av. climate conditions for load profile L (outlier removed)

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile L, Solcal 2013		
universal statistical evaluation v3.4.SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	1554.00	1553.00	1555.00
Number of test results		1	1	1
Median value	1554	1554.00	1553.00	1555.00
Deviation from median value (Delta)		**0.00**	**-1.00**	**1.00**
Arithmetic mean value	1554	1554.00	1553.00	1555.00
Deviation from arithmetic mean value		**0.00**	**-1.00**	**1.00**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	1.000			
Max - Min (arithmetic mean value)	2.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	2.000	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

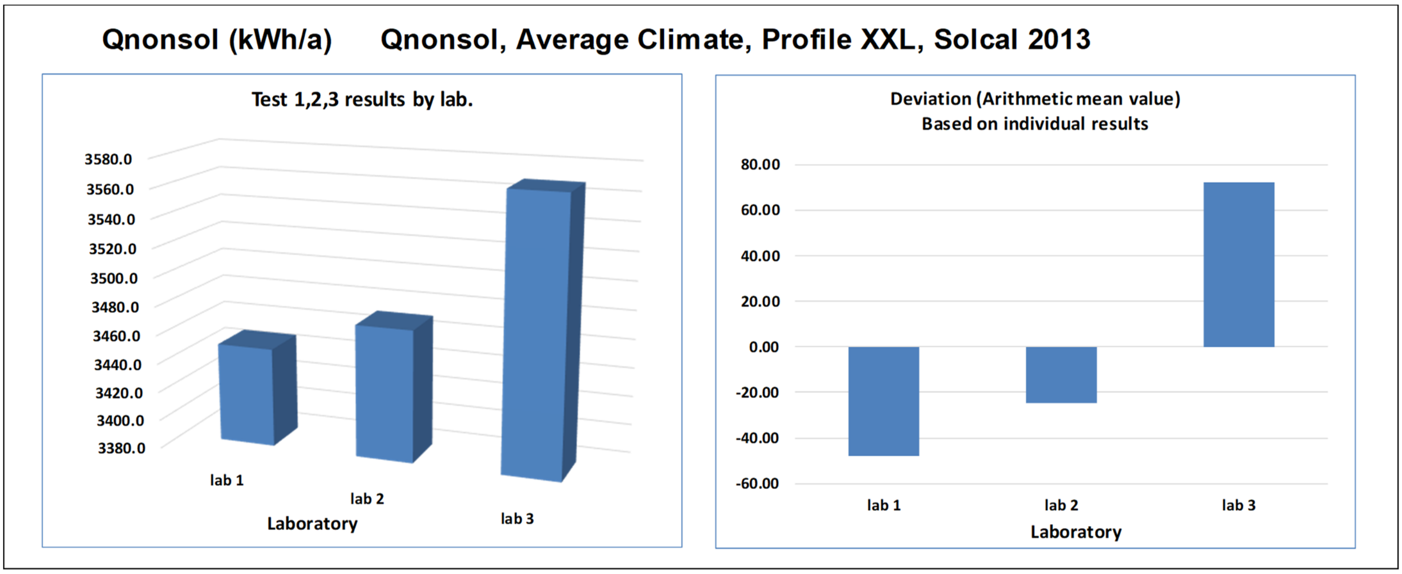


STATISTICS	
Median	1554.0 kWh/a
Arh. mean value	1554.0 kWh/a
R STD	1.0 kWh/a
r STD	-
Max - Min (M-m)	2.0 kWh/a

Figure 4: ECOTEST statistical representation of the results Q_{nonsol} for load profile L computed with SOLCAL:2013, not considering the outlier result.

5.2.4 SOLCAL:2013 Annual non-solar heat contribution at av. climate conditions load profile XL

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile XL, Solcal 2013		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	2513.00	2554.00	2620.00
Number of test results		1	1	1
Median value	2554	2513.00	2554.00	2620.00
Deviation from median value (Delta)		-41.00	0.00	66.00
Arithmetic mean value	2562	2513.00	2554.00	2620.00
Deviation from arithmetic mean value		-49.33	-8.33	57.67
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	53.985			
Max - Min (arithmetic mean value)	107.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	107.000	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

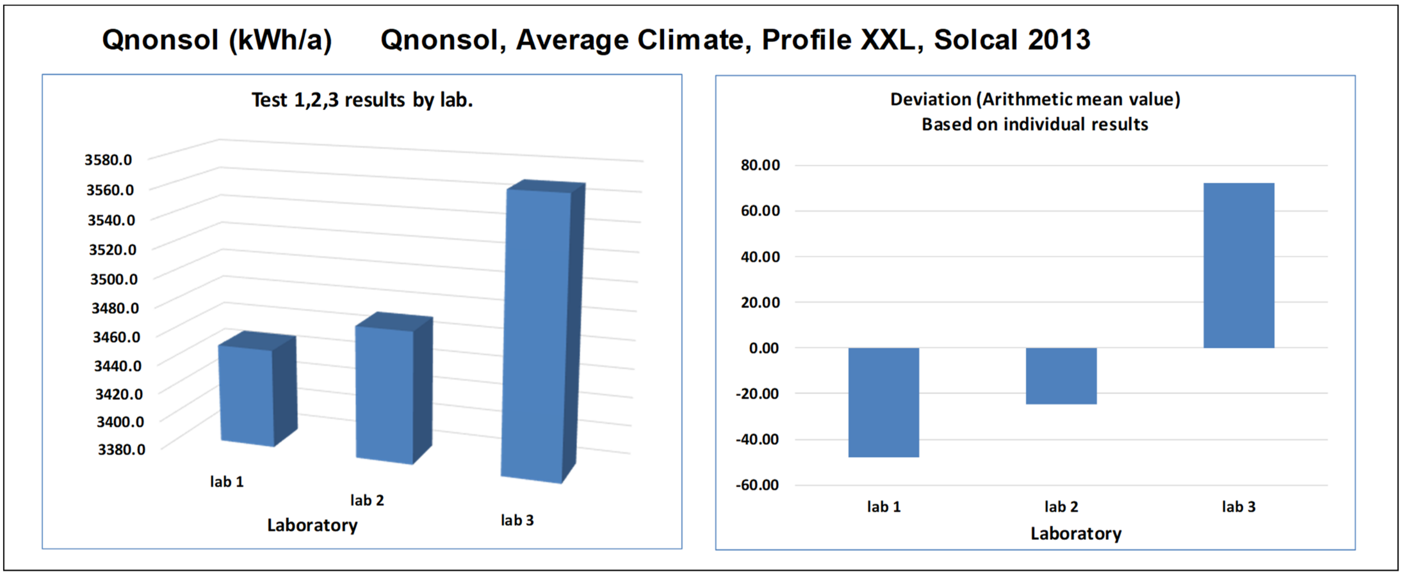


STATISTICS	
Median	2554.0 kWh/a
Arh. mean value	2562.3 kWh/a
R STD	54.0 kWh/a
r STD	-
Max - Min (M-m)	107.0 kWh/a

Figure 5: ECOTEST statistical representation of the results Q_{nonsol} for load profile XL computed with SOLCAL:2013

5.2.5 SOLCAL:2013 Annual non-solar heat contribution at av. climate conditions load profile XXL

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile XXL, Solcal 2013		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	3449.00	3472.00	3569.00
Number of test results		1	1	1
Median value	3472	3449.00	3472.00	3569.00
Deviation from median value (Delta)		**-23.00**	**0.00**	**97.00**
Arithmetic mean value	3497	3449.00	3472.00	3569.00
Deviation from arithmetic mean value		**-47.67**	**-24.67**	**72.33**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	63.689			
Max - Min (arithmetic mean value)	120.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	120.000	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

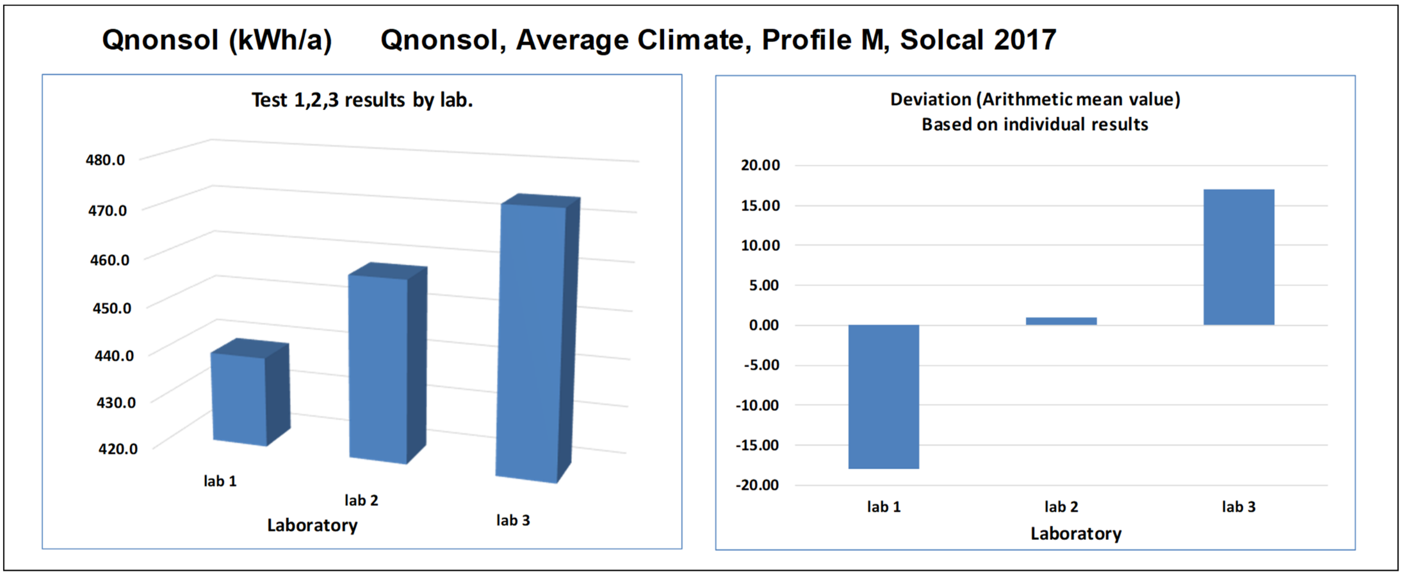


STATISTICS		
Median	3472.0	kWh/a
Arh. mean value	3496.7	kWh/a
R STD	63.7	kWh/a
r STD	-	
Max - Min (M-m)	120.0	kWh/a

Figure 6: ECOTEST statistical representation of the results Q_{nonsol} for load profile XXL computed with SOLCAL:2013

5.2.6 SOLCAL:2017 Annual non-solar heat contribution at av. climate cond. for load profile M

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile M, Solcal 2017		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	439.00	458.00	474.00
Number of test results		1	1	1
Median value	458	439.00	458.00	474.00
Deviation from median value (Delta)		**-19.00**	**0.00**	**16.00**
Arithmetic mean value	457	439.00	458.00	474.00
Deviation from arithmetic mean value		**-18.00**	**1.00**	**17.00**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	17.521			
Max - Min (arithmetic mean value)	35.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	35.000	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



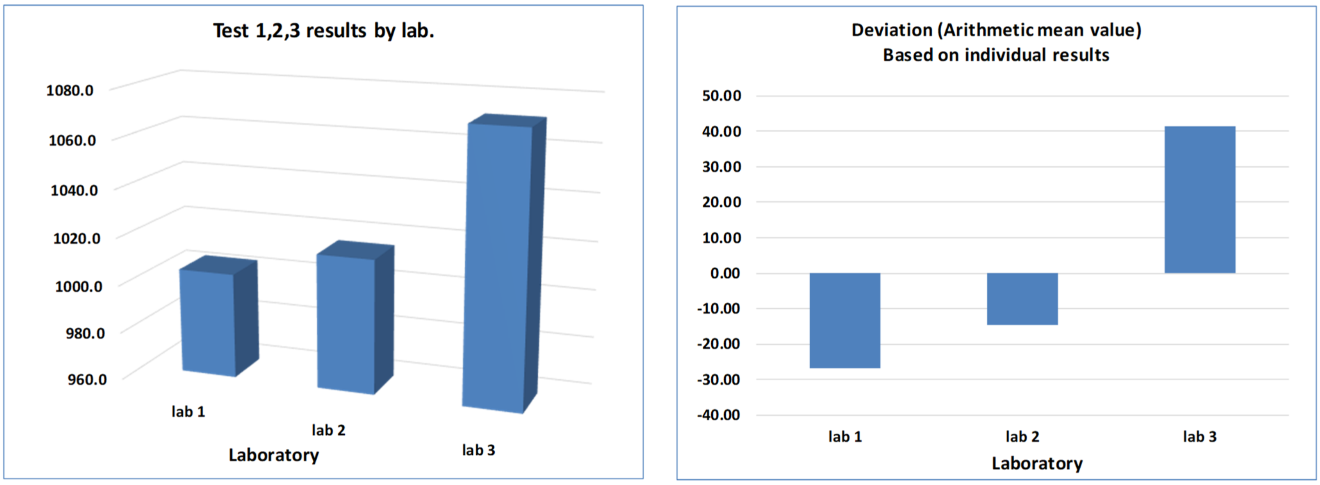
STATISTICS	
Median	458.0 kWh/a
Arh. mean value	457.0 kWh/a
R STD	17.5 kWh/a
r STD	-
Max - Min (M-m)	35.0 kWh/a

Figure 7: ECOTEST statistical representation of the results Q_{nonsol} for load profile M computed with SOLCAL:2017

5.2.7 SOLCAL:2017 Annual non-solar heat contribution at av. climate cond. for load profile L

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile L, Solcal 2017		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	1004.00	1016.00	1072.00
Number of test results		1	1	1
Median value	1016	1004.00	1016.00	1072.00
Deviation from median value (Delta)		-12.00	0.00	56.00
Arithmetic mean value	1031	1004.00	1016.00	1072.00
Deviation from arithmetic mean value		-26.67	-14.67	41.33
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	36.295			
Max - Min (arithmetic mean value)	68.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	68.000	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

Qnonsol (kWh/a) Qnonsol, Average Climate, Profile L, Solcal 2017

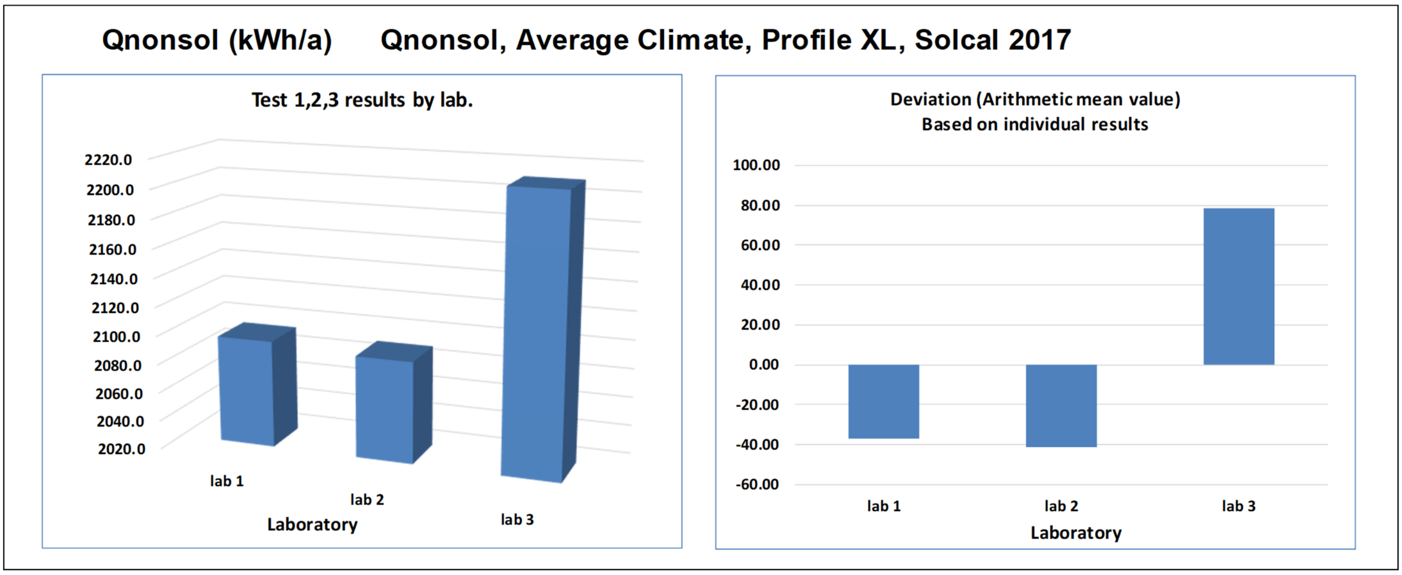


STATISTICS		
Median	1016.0	kWh/a
Arh. mean value	1030.7	kWh/a
R STD	36.3	kWh/a
r STD	-	
Max - Min (M-m)	68.0	kWh/a

Figure 8: ECOTEST statistical representation of the results Q_{nonsol} for load profile L computed with SOLCAL:2017

5.2.8 SOLCAL:2017 Annual non-solar heat contribution at av. climate cond. for load profile XL

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile XL, Solcal 2017		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	2095.00	2091.00	2211.00
Number of test results		1	1	1
Median value	2095	2095.00	2091.00	2211.00
Deviation from median value (Delta)		0.00	-4.00	116.00
Arithmetic mean value	2132	2095.00	2091.00	2211.00
Deviation from arithmetic mean value		-37.33	-41.33	78.67
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	68.157			
Max - Min (arithmetic mean value)	120.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	120.000	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	outlier	correct	correct	outlier

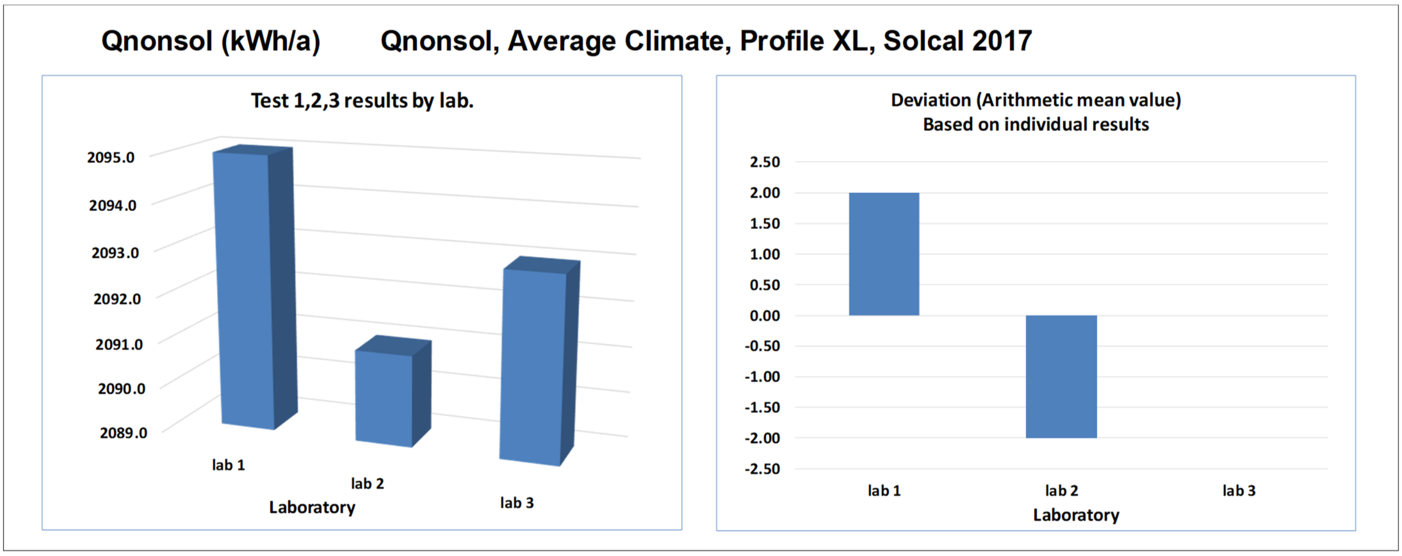


STATISTICS	
Median	2095.0 kWh/a
Arh. mean value	2132.3 kWh/a
R STD	68.2 kWh/a
r STD	-
Max - Min (M-m)	120.0 kWh/a

Figure 9: ECOTEST statistical representation of the results Q_{nonsol} for load profile XL computed with SOLCAL:2017

5.2.9 SOLCAL:2017 Annual non-solar heat contribution at av. climate cond. for load profile XL (removed outliers)

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile XL, Solcal 2017		
universal statistical evaluation v3.4.SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	2095.00	2091.00	2093.00
Number of test results		1	1	1
Median value	2093	2095.00	2091.00	2093.00
Deviation from median value (Delta)		2.00	-2.00	0.00
Arithmetic mean value	2093	2095.00	2091.00	2093.00
Deviation from arithmetic mean value		2.00	-2.00	0.00
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	2.000			
Max - Min (arithmetic mean value)	4.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	4.000	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

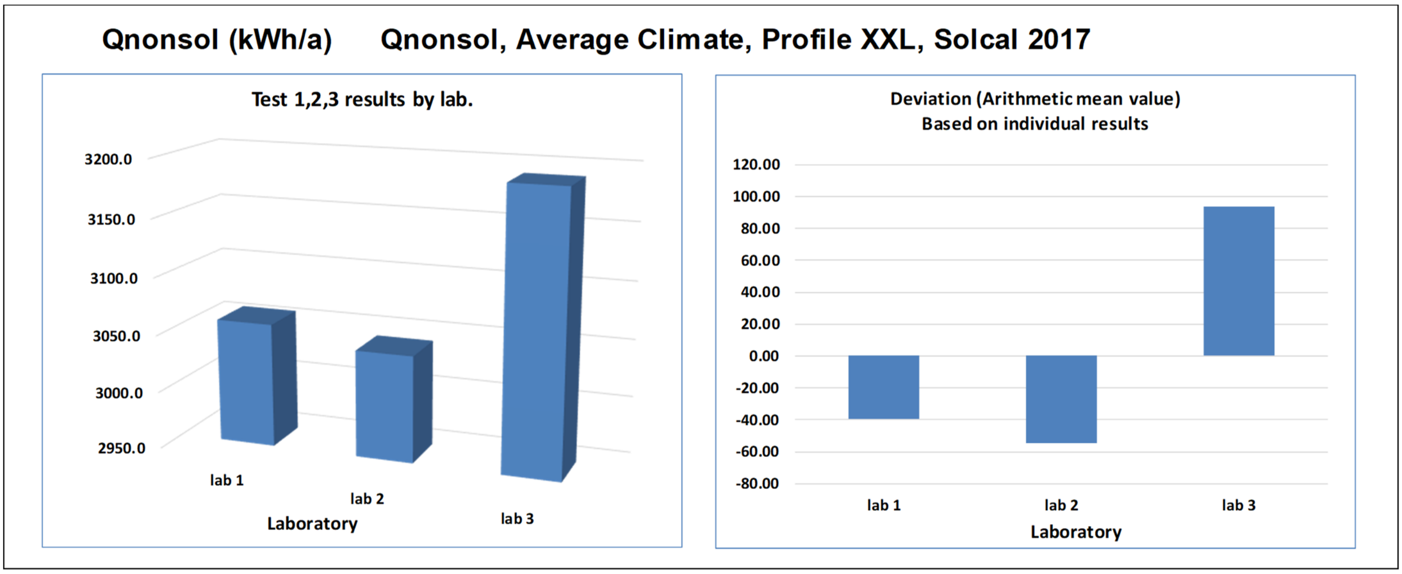


STATISTICS	
Median	2093.0 kWh/a
Arh. mean value	2093.0 kWh/a
R STD	2.0 kWh/a
r STD	-
Max - Min (M-m)	4.0 kWh/a

Figure 10: ECOTEST statistical representation of the results Q_{nonsol} for load profile XL computed with SOLCAL:2017 without considering the outlier result.

5.2.10 SOLCAL:2017 Annual non-solar heat contribution at av. climate cond. for load profile XXL

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile XXL, Solcal 2017		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	3058.00	3043.00	3191.00
Number of test results		1	1	1
Median value	3058	3058.00	3043.00	3191.00
Deviation from median value (Delta)		0.00	-15.00	133.00
Arithmetic mean value	3097	3058.00	3043.00	3191.00
Deviation from arithmetic mean value		-39.33	-54.33	93.67
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	81.464			
Max - Min (arithmetic mean value)	148.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	148.000	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

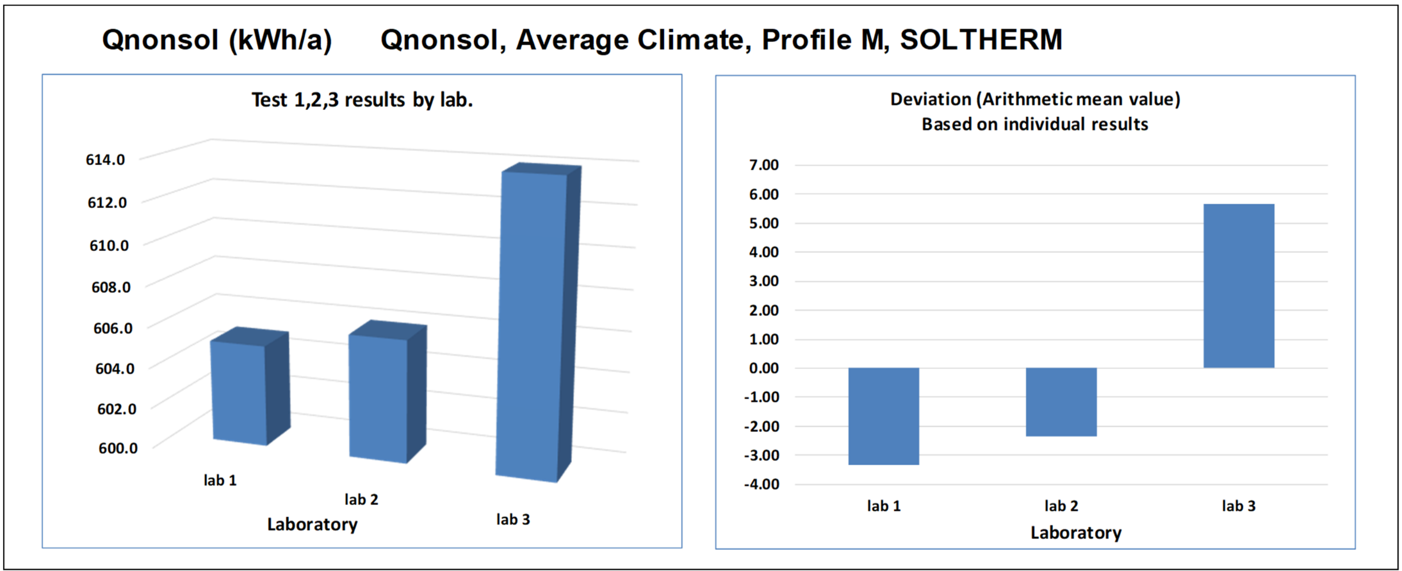


STATISTICS	
Median	3058.0 kWh/a
Arh. mean value	3097.3 kWh/a
R STD	81.5 kWh/a
r STD	-
Max - Min (M-m)	148.0 kWh/a

Figure 11: ECOTEST statistical representation of the results Q_{nonsol} for load profile XXL computed with SOLCAL:2017

5.2.11 SOLTHERM Annual non-solar heat contribution at av. climate conditions for load profile M

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile M, SOLTHERM		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	605.00	606.00	614.00
Number of test results		1	1	1
Median value	606	605.00	606.00	614.00
Deviation from median value (Delta)		-1.00	0.00	8.00
Arithmetic mean value	608	605.00	606.00	614.00
Deviation from arithmetic mean value		-3.33	-2.33	5.67
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	4.933			
Max - Min (arithmetic mean value)	9.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	9.000	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

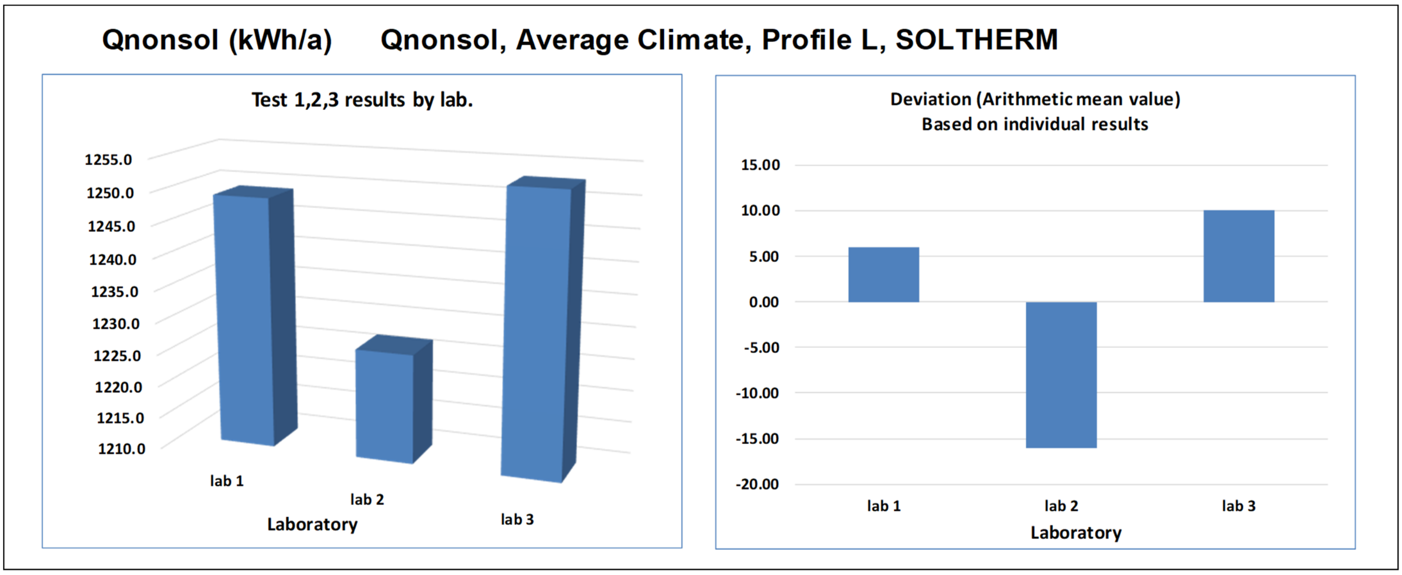


STATISTICS		
Median	606.0	kWh/a
Arh. mean value	608.3	kWh/a
R STD	4.9	kWh/a
r STD	-	
Max - Min (M-m)	9.0	kWh/a

Figure 12: ECOTEST statistical representation of the results Q_{nonsol} for load profile M computed with SOLTHERM

5.2.12 SOLTHERM Annual non-solar heat contribution at av. climate conditions for load profile L

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile L, SOLTHERM		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	1249.00	1227.00	1253.00
Number of test results		1	1	1
Median value	1249	1249.00	1227.00	1253.00
Deviation from median value (Delta)		0.00	-22.00	4.00
Arithmetic mean value	1243	1249.00	1227.00	1253.00
Deviation from arithmetic mean value		6.00	-16.00	10.00
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	14.000			
Max - Min (arithmetic mean value)	26.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	26.000	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

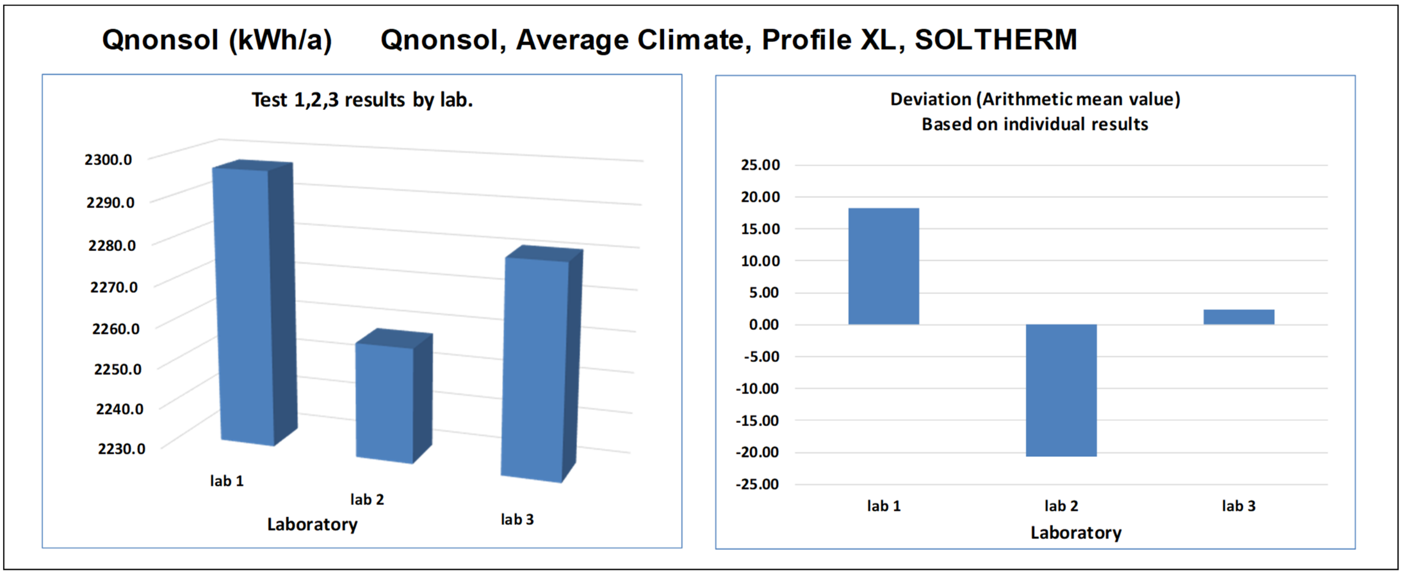


STATISTICS		
Median	1249.0	kWh/a
Arh. mean value	1243.0	kWh/a
R STD	14.0	kWh/a
r STD	-	
Max - Min (M-m)	26.0	kWh/a

Figure 13: ECOTEST statistical representation of the results Q_{nonsol} for load profile L computed with SOLTHERM

5.2.13 SOLTHERM Annual non-solar heat contribution at av. climate conditions for load profile XL

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile XL, SOLTHERM		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	2297.00	2258.00	2281.00
Number of test results		1	1	1
Median value	2281	2297.00	2258.00	2281.00
Deviation from median value (Delta)		16.00	-23.00	0.00
Arithmetic mean value	2279	2297.00	2258.00	2281.00
Deviation from arithmetic mean value		18.33	-20.67	2.33
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	19.604			
Max - Min (arithmetic mean value)	39.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	39.000	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

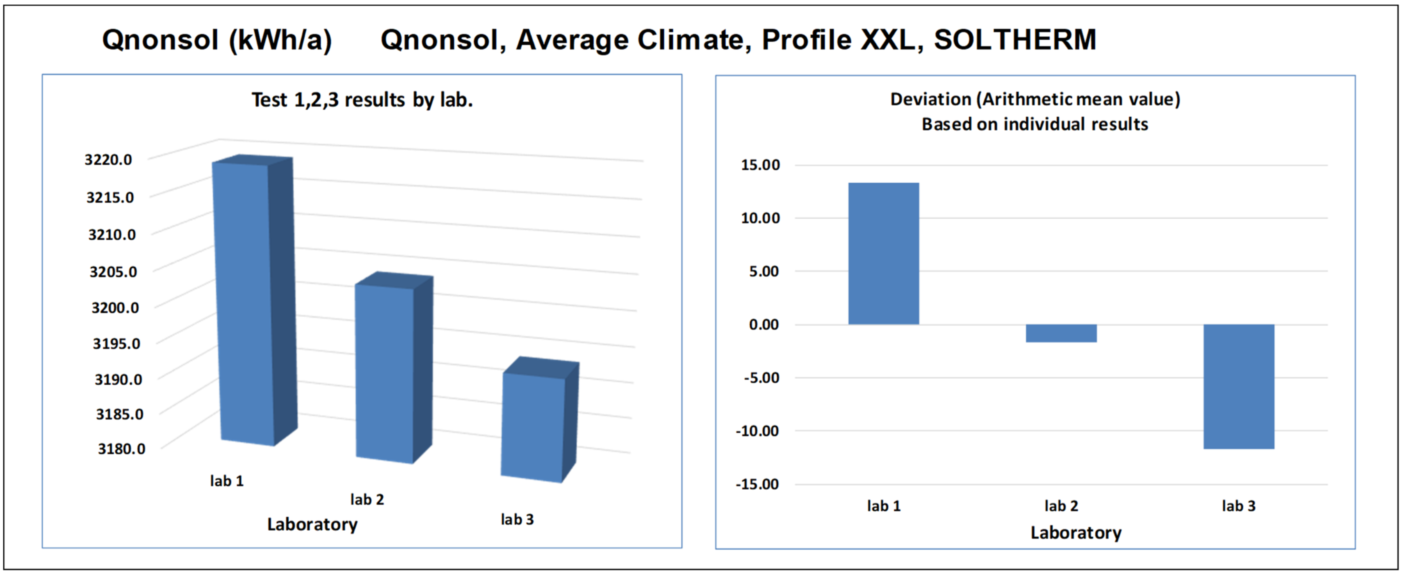


STATISTICS		
Median	2281.0	kWh/a
Arh. mean value	2278.7	kWh/a
R STD	19.6	kWh/a
r STD	-	
Max - Min (M-m)	39.0	kWh/a

Figure 14: ECOTEST statistical representation of the results Q_{nonsol} for load profile XL computed with SOLTHERM

5.2.14 SOLTHERM Annual non-solar heat contribution at av. climate conditions for load profile XXL

Parameter	Qnonsol (kWh/a)	Qnonsol, Average Climate, Profile XXL, SOLTHERM		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	3219.00	3204.00	3194.00
Number of test results		1	1	1
Median value	3204	3219.00	3204.00	3194.00
Deviation from median value (Delta)		15.00	0.00	-10.00
Arithmetic mean value	3206	3219.00	3204.00	3194.00
Deviation from arithmetic mean value		13.33	-1.67	-11.67
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	12.583			
Max - Min (arithmetic mean value)	25.000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	25.000	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	3204.0	kWh/a
Arh. mean value	3205.7	kWh/a
R STD	12.6	kWh/a
r STD	-	
Max - Min (M-m)	25.0	kWh/a

Figure 15: ECOTEST statistical representation of the results Q_{nonsol} for load profile XXL computed with SOLTHERM

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:

- Labs sending the RRT results (raw data tables) to the WPL- Reports V01
- WPL Preparing overview table and figures for discussion (not anonymous)
- WPL Physical WP meeting to discuss results and correct from possible issues
- Labs sending the RRT results to the WPL- Reports V02
- 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

The results were not "corrected" in the above mentioned sense but the results had to be discussed before publications as it was evident that there were some different understandings, especially with the SOLCAL and SOLTHERM methods. These points would have to be considered as class 2 corrections and appropriate cmmenst re made in clause 9 o this report.

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 5.2.3 and 5.2.9.

7.2 Comments on possible discrepancies

There are two types of discrepancies to be discussed: i) Discrepancies between the test laboratories and ii) discrepancies between methods.

7.3 Comments in light of the iterative tests results

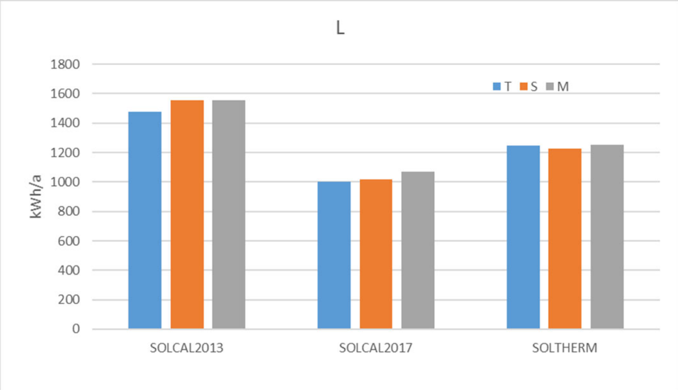
None

8 Iterative test results

No iterative test or additional tests planned. However the use of different methods (SOLCAL 2013, SOLCAL 2017 and SOLTHERM) can be understood as supplementary iterative test. Only the SOLICS 2013 is currently mentioned in eth regulation. The SOLCAL 2017 version would be the logical update as it is using the same basis (see 3.2). To consider the dynamic behaviour of a solar thermal system a more sophisticated software such as SOLTHERM is however recommended which is computing on an hourly basis.
In addition to this comparison, the impact of variations of the measured parameters on the results of the computations is assessed in a sensitivity analysis. This sensitivity analysis is based on a standard system as circulated in the WP8-RRT4. The results must therefore be considered as typical indicative results. Other systems using other collectors may react in a different way on variations. However the general statements can be considered as applicable to most SWH systems.

8.1 Comparison of methodologies

To compare the different methodologies the following graphs summarized again for the four standard load profiles M, L, XL and XXL.



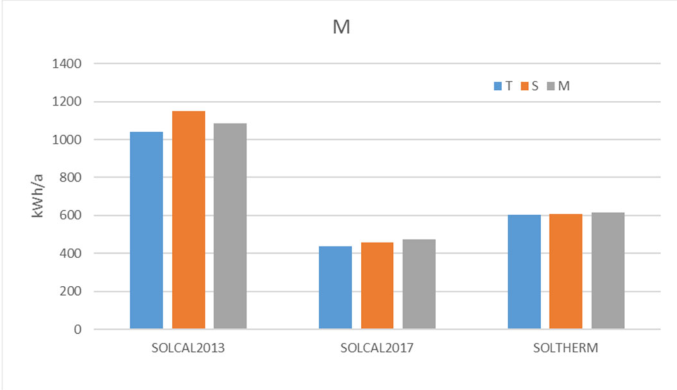


Figure 16: Comparison of Q_{nonsol} for different load profiles computed with different tools and comparison of the participating testing laboratories.

Analysing these results show that

- The Q_{nonsol} of the currently valid method SOLCAL 2013 are the highest for all profiles.
- The difference between the three methods is smaller for the bigger profiles. The variation between the three methods for the XXL profile is always in the range of ±7%, where for the M profile the difference is in a range ±50% and more.
- The differences between the three laboratories are smaller. For SOLCAL:2013 and SOLCAL: 2017 the variations are at a maximum of ±7% for all profiles and for SOLTHERM and all profiles well within ±1% except for one single value which is at 1.3% deviation from average.

8.2 Comparison with RRT4

As in RRT4 the presented methods SOICS 2013, SOLICS 2017 and SOLTHERM are providing a value for the non-solar energy contribution that is required to meet a certain load profile. In a perfect world all the mentioned methods and RRT4 should therefore deliver the same values as it was always exactly the same system. In Figure 17 the Q_{nonsol} derived in RRT4 are added to the graph for comparison. For the other load profiles it is questionable to display such graphs as RRT4 showed that the load profile cannot be met with the tested system. Apart from the variations in RRT4 - which are explained there – the figures shows that the SOLTHERM calculations are closest to the measured system. This result should therefore be interpreted as a hint to use SOLTHERM for ErP purposes if it is the intention to use water heater efficiencies close to reality for energy labelling.

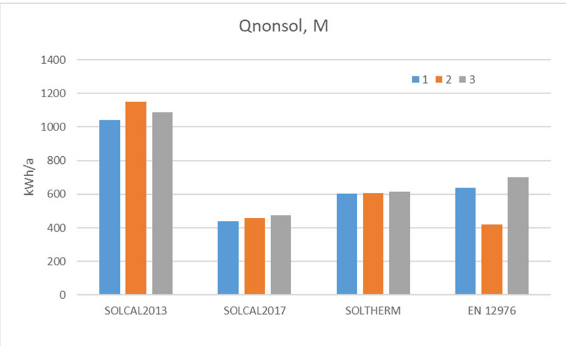


Figure 17:
Comparison of Q_{nonsol} for the profile M using the different methods.

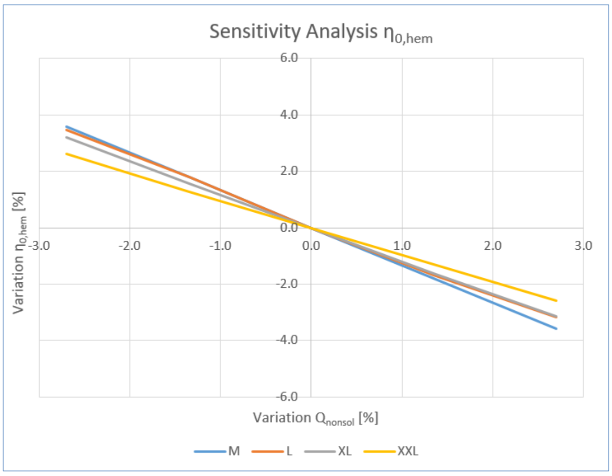
8.3 Sensitivity Analysis

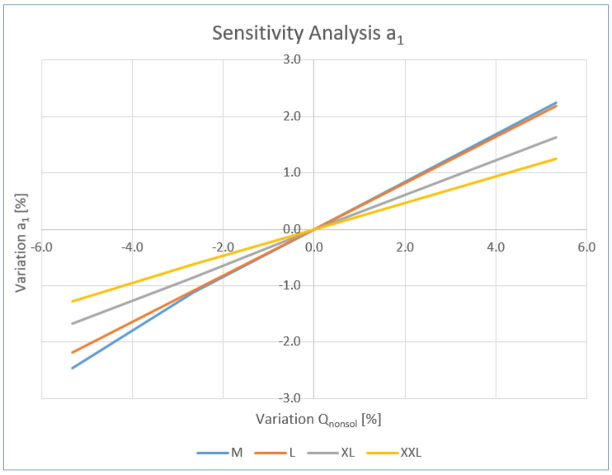
In order to estimate the impact of uncertainties and variations of the measured parameters of the collector and store on the resulting Q_{nonsol} a simplified sensitivity analysis was performed for some parameters. In a first approximation an average system was defined by taking the approximate arithmetic average of the relevant collector parameters as reported in WP8-RR1 and of the store parameters as reported in WP8-RRT2 giving a very typical SWH system with the following parameters:

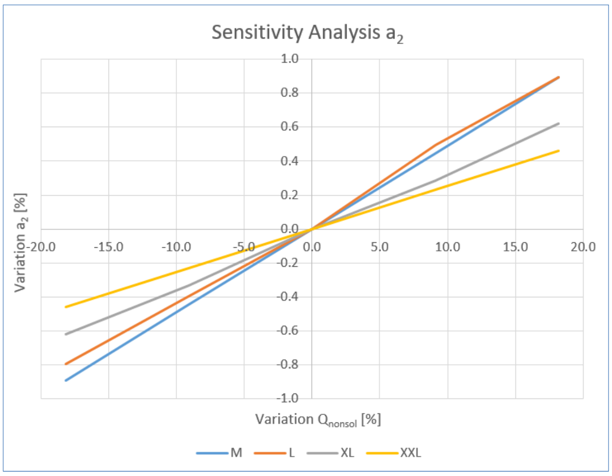
Number of collectors		2	
Collector Area	$\mathbf{A_{sol}}$	2.51	m^2
Collector zero loss efficiency	$\boldsymbol{\eta_0}$	0.741	--
Collector first order coefficient	$\mathbf{a_1}$	3.76	$W/(m^2K)$
Second-order coefficient	$\mathbf{a_2}$	0.011	$W/(m^2K^2)$
Standing loss (Tstore = 65 °C, Tambient = 20 °C)	**S**	122.5	W
Nominal volume of the store	$\mathbf{V_{nom}}$	400	L
Auxiliary heated volume		125	L

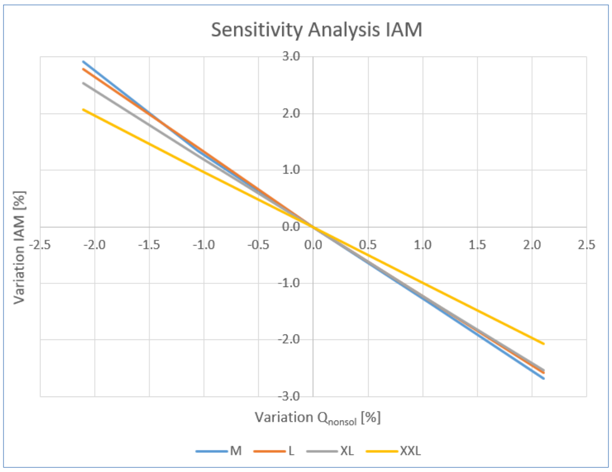
Table 3: Set of standard performance parameters used for a sensitivity analysis.

These parameters were modified slightly, one-by-one and Q_{nonsol} was determined using the SOLCAL 2017 version to get an idea of the impact of variations of the measurand on the result as displayed in the following graphs.









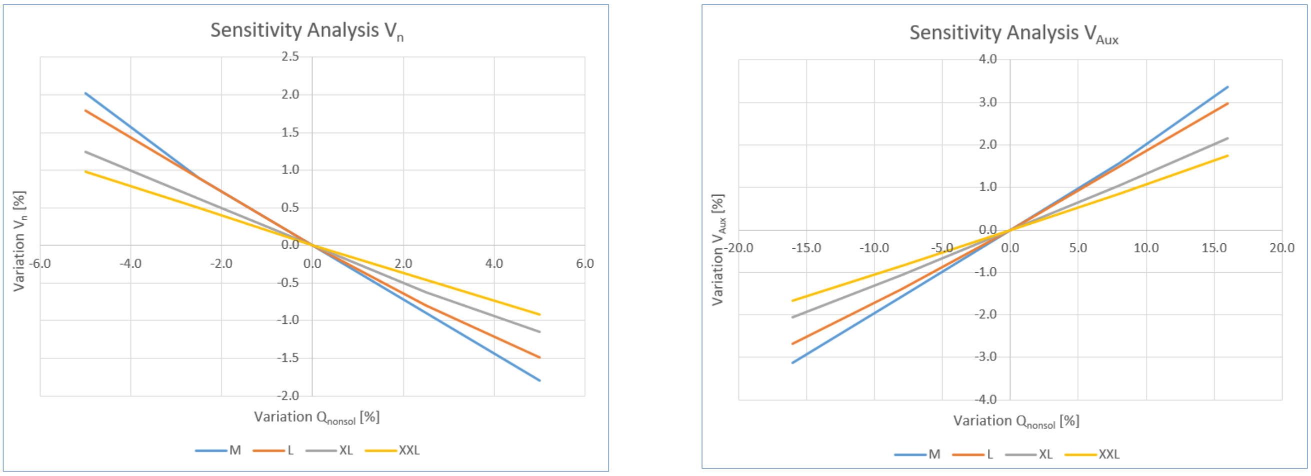


Figure 18: Sensitivity analysis to evaluate the impact of parameter variations on the computed Q_{nonsol}.

The relations show that the XXL load profiles are always less sensitive to changes of the parameters than the smaller profiles. As an approximate rule of thumb:

- variations of 1% the parameters $\eta_{0,hem}$, IAM result in a variation of ≥ 1.0% in Q_{nonsol}
- variations of 1% the parameters a_1 and V_n result in a variation of ≤ 0.5% in Q_{nonsol}
- a_2 and V_{Aux} have almost no impact on Q_{nonsol}

Comparing these numbers with the results of WP8-RRT1 shows that the most critical parameter is the incidence angle modifier IAM where the variation in WP8-RRT1 was in the range of ± 3.5%. For the second critical parameter $\eta_{0,hem}$ the variations in WP8-RRT1 were less pronounced. The other parameters are less critical but are still in a range which could result in additional 1% - 2% uncertainty of Q_{nonsol}.

Using other simulation tools with higher resolution (i.e. TRNSYS) the parameter V_{aux} often has a bigger influence on simulation results than with the simplified tools used here.

9 Procedures of standards that need to be modified and justification

9.1 Result from the brainstorming on standard

The brainstormes of RRT1-RRT4 apply.

9.2 Procedures of standards that need to be modified and justification

The procedures defining SOLCAL should be described in unambiguous manner. There are several unclearly defined parameters and/or parameters which are based on previous versions of the standards. As an example, the nominal volume V_n is not clearly defined and using different definitions in different standards lead to different Q_{nonsol}. The same applies for the IAM which is used in the standard tools as a single value IAM. This value is available in a much better resolution from the Solar collector testing and should therefore not be simplified to a single value. This is not a new finding and was already recommended in the project "Bridging the gap: research and experimental validation on the DST performance test method for solar domestic water heaters Contract No. SMT4-CT96-2067".

Another important point is to define very clearly the required precision for presenting results and for using parameters. As an example: It is not very clear how many digits to use for $\eta_{0,hem}$ or for the standing losses S. On the label S shall be rounded to the nearest integer according to the COMMISSION DELEGATED REGULATION (EU) No 812/2013. It is however not defined whether this rounded values shall be used for further calculations or whether the real value as determined in the measurement can be used. This simple question can result in a 1% difference in Q_{nonsol}. It is recommended to elaborate harmonised rules on when and how to round results.

9.3 Recommendations to CEN

The variations between the different methods providing Q_{nonsol} are substantial. The reason for these discrepancies are manifold, but a major reason seems to be that different standards are using different methods for performance prediction. As an example it is possible to get the Q_{nonsol} for a well-defined product using different paths and methods which are defined in different standards, versions of standards and/or the transitional methods. Physically the parameter Q_{nonsol} should be the same as it is always denoting the auxiliary energy required for a certain system to meet a load profile. The large variations between the different methods should be reduced urgently. As this is an umbrella issue affecting several TCs it should be organised by CEN, best in a coordinated project. Care must be taken to design such methods to be open for future technologies and for combinations of different technologies (i.e. solar and heat pump).

As a first step to reduce misunderstandings and different interpretations it would be advisable to establish an ErP vocabulary (as it is for example available as standard ISO 9488 for solar technologies) to make sure that in the next revision of the standards – and hopefully of the ErP regulations - a harmonised terminology will be used.

10 Conclusion

The procedures for the determination of Q_{nonsol} used for ErP are defined in a rather loose way in the standard EN 12977-2. The reason is that the standard was not developed with the main objective of solely rating a system as intended in the ErP, but much more to have procedures at hand for simulating the dynamic behaviour of a system. For this reason the current version is sometimes referring to TRNSYS, which is one of the most popular scientific simulation tools in this sector, not only for solar thermal system.

In view of a repeatable rating as required by the ErP, the formulations and requirements in the current version of the standard are probably not stringent enough.

The alterative SOLCAL model as defined in the transitional methods, are obviously not inspiring much confidence as can be seen from the results in this RRT. The difference between the results obtained with the two available versions 2013 and 2017 cannot be explained solely by minor improvements of the model.

The newly developed SOLTHERM procedure is much closer to a scientific simulation tool. The results of the SOLTHERM calculations are close to the results from RRT4 (not considering outliers), i.e. where the system was tested as a whole. It can therefore be assumed that a reliable rating of the system is based on either testing the whole system (RRT4) or by using high-level simulation tools. Testing whole systems is of course very expensive and time consuming, especially in view of testing combinations of different products (stores, collectors and controllers) and even more when using hybrid systems interacting with other appliances such as heat pumps. Whole system testing is therefore not a realistic approach for simple economic reasons. It is therefore evident that simulation tools are the best choice. As it was found in the RRT5 and RRT6, such tools exist (SOLTHERM) and deliver good results. However, it was also found that the use of such tools is not easy and requires detailed description of the system and detailed parametrisation of the components (collectors, stores, controllers, user profiles, etc.). For very simple reasons there is a very chance of obtaining wrong results just by entering wrong parameters or by other incorrect operations. Considering combinations with other appliances such simulation tools will get even more complex.

As these problems concern not only RRT5 and RRT6, the general conclusions and proposals are found in the general WP8 report.

11 ANNEXES

11.1 ANNEX 1 Brainstorm on the standard EN 12977-2

The procedures for thermal performance rating are described in a rather open way in the EN 12977-2 standard. Part of the main clause 7.6 is repeated below for illustration in italic:

7.6 System simulation model

The modelling of the system should be carried out using a detailed dynamic simulation programme fitted for the different system and store configurations considered, including their control strategy. The simulation programme should operate on the basis of all parameters determined in the component tests.

NOTE The level of detail needed for most system types is similar to that used in the programmes TRNSYS or equivalent.

The component models for collector and store used in the system simulation shall be respectively the same as for the characterization of the collector according to EN ISO 9806:2013, and for the characterization of the store according to EN 12977-3:2018 or EN 12977-4:2018, whichever applicable.
The behaviour of the control equipment determined according to EN 12977-5:2018 shall be included in the simulation programme.
For other components, e.g. pipework or external heat exchangers, the level of detail in the simulation model shall correspond to the data used for proving the fulfilment of the specific requirements.
The following features shall be implemented in the model:
— a thermostat mixer which reduces the store outlet fluid temperature, ϑS, to the desired hot water temperature, ϑd, during draw-offs. For solar preheat systems and solar-only systems this thermostat mixer shall be located directly at the outlet of the solar part of the system;
— The collector loop operation shall be stopped when the temperature of the storage tank exceeds 95 °C if no other temperature is specified by the manufacturer.
The system simulation model shall have been previously validated.

It is important to note that there are no clear indications about how to make these performance simulations. In EN 12977-2 the performance test is optional and for this reason there are mainly "should" statements which are not clear enough in view of a regulatory rating of the system performance. A brainstorming on the single points of the standards was therefore not considered as meaningful.
The main statement on EN 12977-2 is that in order to be a useful standard for ErP, the procedures and calculations to obtain the thermal performance or a Q_{nonsol} must be defined in a clear and unambiguous way. Probably as an additional amendment to the standard dedicated to the requirements of the ErP. As the main intention of this standard was not the performance rating itself, this should not be considered as an omission of the editors.