Project ECOTEST **Deliverables** **D8.4 Analysis of the results and report** **D8.5 Proposal to CEN and communication**	ECOTEST *ECO_WP8_XXX_WP8-RRT1_V2*

WP	WP 8 Solar Collector
Type	Annex to WP8 final report
Title	**Annex 1.1** **Final report WP8/RRT1** **Extended RRT results and analysis** **RRT1 Solar thermal Collector**
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Dissemination	Free

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1 Introduction

1.1 Context of the test

For the RRT1 a number of four collectors was available. All four collectors were pre-aged by the first laboratory before measuring the thermal performance in a comparative measurement in a solar simulator. Based on the measurement, one of the collectors was selected as RRT1 collector. The remaining three collectors were used for other RRTs and for additional measurements. One of the collectors showed a very small technical problem and it was not used for the RRTs.
Several additional tests with varying parameters were made before sending around the collectors. These additional test are considered as iterative tests and are presented in this documents as well

1.2 Time period

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

1.3 Laboratories involved

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

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

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

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 collector is a standard flat plate collector using an aluminium copper absorber. The collector is Solar Keymark certified by a laboratory not participating in this RRT. These results can be used as a reference for comparison; however, it would not be correct to use these data as RRT data as it is not guaranteed that it is exactly the same product.

2.2 Picture of the collector

Figure 1: The four collectors on a solar tracker for pre-ageing.

Figure 2: The collector on the outdoor test rig of one of the labs for thermal performance testing (left). Only the collector on the right side part if the RRT, the second collector is a reference collector.
(right side) The collector installed on a solar simulator for different iterative tests with varying parameters.

2.3 Origin of appliances used for the RRT

The collectors were donated by a German manufacturer without addition expectations.

3 Testing programme & testing equipment of labs

3.1 Programme

Solar thermal testing is usually outdoor testing under natural weather and irradiation conditions. For this reason, the time required for a test is not easily predictable. Furthermore, the testing time depends on the collector itself. For this reason and for financial reasons only three testing laboratories were involved in this RRT. The results shall therefore be analysed cautiously to avoid misinterpretation. The statistical statements are given in chapter 5 using the standard format of the ECOTEST project.
Testing solar thermal collectors requires the operation of the collector under different operating conditions, mainly different temperature levels and different incidence angles. For quasi dynamic testing also varying diffuse radiation contributions and transitional inlet temperatures. For both methods, usable data are selected after the measurements and then analysed using the corresponding mathematical collector models as defined in the standard. The parameters describing the solar collector performance are therefore not static measurements or simple average values measured under static conditions, but parameters of a mathematical model.

3.2 Test protocol(s) used

The test protocol used by the different test labs is following the standard EN ISO 9806:2017. In this standard, it is very clearly declared how to present the results. For solar collectors different test methods are described in the standard (steady state method and quasi-dynamic method). The presentation of the results is however exactly the same for both methods, meaning that the results do not allow to identify which method was used. Furthermore and under well-defined conditions, it is admissible to use the solar simulator for performance testing. In general, outdoor testing is however preferred for several reasons and in this RRT the main results were measured using outdoor testing. The solar simulator was used only for comparative iterative tests.
The parameters as required by the CDR (EU) No 811/2013 and the CDR (EU) No 812/2013 were derived from the measurements according to the EN ISO 9806:2017 and are presented as results of the RRT. The transformation of the results from EN ISO 9806:2017 to the values required in the mentioned European regulation was done on the basis of the EN 12975:2010 and the prEN 12975 which was submitted to CEN in a revised version early 2019. This revision includes all the Z-Annexes as required by the ErP regulations. The publication of this standard is expected later in 2019.

3.3 Overview of the main test equipment used by labs

The participating testing laboratories are all accredited according to ISO 17025 and use tailor-made own test rigs and different sensors which are in full compliance with all the requirements of the EN 12975-1 and the EN ISO 9806.

3.4 Test conditions

The testing of solar thermal collectors is outdoor testing and the test conditions are defined in the EN ISO 9806:2017. The general test conditions and requirements are depending on the test method that is used, i.e. steady state testing or quasi-dynamic testing. Most of the test conditions are defined as stability criteria, such as for example as maximum fluctuation of irradiance during a valid measuring period, or the maximum variation of the flow range over a given period. This is especially true for the ambient temperature where we have no requirements except for some stability criteria: A collector can be tested in winter at T_{amb} = -20°C ambient temperature as well as in a hot summer at T_{amb} =40°C. Compared to other appliance testing which can be done under well-controllable indoor laboratory conditions, the test conditions for collectors are therefore defined in a different manner. The test conditions are defined in EN ISO 9806 and cannot be repeated here for the sake of brevity.
For some parameters, it is even a requirement to cover a certain range of test conditions. As an example, we have different test days including sunny and cloudy weather for the quasi-dynamic testing method.

3.5 Other

The collector used for this RRT is a standard flat plate collector using an aluminium copper absorber. The collector is manufactured by a reliable and well-organised German manufacturer. The scope of the applicable standards EN 12975 and EN ISO 9806 cover however a vast variety of different products such as evacuated tube collectors, wind and infrared sensitive collectors WISCs, large size collectors, custom built collectors, collectors using external power sources, hybrid collectors, etc. All these different types of collectors have their own behaviour and characteristics. The collector that was selected for this RRT is a very typical collector type covering probably 80-90% of the conventional central European solar thermal market. With respect to market surveillance it is however clear, that the variations of the test results as seen in this RRT are probably not met by some other products as they are much more challenging to test correctly. Furthermore, most collector manufacturers are SMEs. Collectors are produced in smaller series and often under semi-industrial conditions. A certain production tolerance should be assumed that going beyond what is seen in this RRT.

The results from this RRT must therefore be considered as indicative. Depending on the collector used for such a RRT, the results could have been rather different.

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. Laboratory T was using the quasi-dynamic test method; S and M were using the steady state method. Laboratory T and M were using water as heat transfer fluid, laboratory S was using a mixture of 33% Ethylene glycol and water. The results are presented as required by the Annex A of the new EN ISO 9806:2017, including the number of digits. According to this standard, some of the parameters are set to zero for this type of collector. The test labs are marked in the tables with the index 1, 2 and 3 to avoid a linking to the indices S, T and M.

5.1.1 Collector performance

Collector efficiency data					
LABORATORY		**1**	**2**	**3**	
EN ISO 9806:2017, EN 12975:2010, prEN12975					
Peak collector efficiency based on hemispherical irradiance	$\eta_{0,hem}$	0.733	0.746	0.745	--
Peak collector efficiency based on beam irradiance	$\eta_{0,b}$	0.737	0.760	0.752	--
Incidence angle modifier for diffuse solar radiation	K_d	0.96	0.88	0.94	--
Heat loss coefficient	a_1	3.84	3.73	3.71	W/m^2K
Temperature dependence of the heat loss coefficient	a_2	0.009	0.011	0.014	W/m^2K^2
Wind speed dependence of the heat loss coefficient	a_3	-	0.00	-	$Ws/(m^3 \cdot K)$
Sky temperature dependence of the heat loss coefficient	a_4	-	0.000	-	—
Effective thermal capacity	a_5	10030	8030	8310	$Ws/(m^2 \cdot K)$
Wind speed dependence of the zero loss efficiency	a_6	-	0.0	-	s/m
Wind speed dependence of IR radiation exchange	a_7	-	0.00	-	s/m
Radiation losses	a_8	-	0.0	-	W/m^2K^4
Thermal capacity	**C/A**	10030	8030	8310	$Ws/(m^2 \cdot K)$
Nominal flowrate	**dm/dt**	181	183	181	kg/h
Gross Area	A_G	2.51	2.51	2.51	m^2
Incidence angle modifier θ_L=0, θ_T=0	K_b(0,0)	1.00	1.00	1.00	--
Incidence angle modifier θ_L=10, θ_T=0	K_b(10,0)	1.00	1.00	1.00	--
Incidence angle modifier θ_L=20, θ_T=0	K_b(20,0)	1.00	1.00	0.99	--
Incidence angle modifier θ_L=30, θ_T=0	K_b(30,0)	1.00	1.00	0.97	--
Incidence angle modifier θ_L=40, θ_T=0	K_b(40,0)	0.99	0.98	0.95	--
Incidence angle modifier θ_L=50, θ_T=0	K_b(50,0)	0.95	0.94	0.90	--
Incidence angle modifier θ_L=60, θ_T=0	K_b(60,0)	0.82	0.84	0.82	--
Incidence angle modifier θ_L=70, θ_T=0	K_b(70,0)	0.65	0.64	0.66	--
Incidence angle modifier θ_L=80, θ_T=0	K_b(80,0)	0.33	0.34	0.16	--
Incidence angle modifier θ_L=90, θ_T=0	K_b(90,0)	0.00	0.00	0.00	--
All incidence angle modifier are considered as symmetric by the test labs, i.e. $K_b(x,0) = K_b(0,x)$. The data are therefore not listed in both directions here.					
European regulations					
Collector Area	A_{sol}	2.51	2.51	2.51	m^2
Collector efficiency	η_{Col}	56	59	57	%
Collector zero loss efficiency	η_0	0.733	0.76	0.745	--
Collector first order coefficient	a_1	3.84	3.73	3.71	$W/(m^2K)$
Second-order coefficient	a_2	0.009	0.011	0.014	$W/(m^2K^2)$
Collector incidence angle modifier	**IAM**	0.98	0.96	0.92	--

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

In addition to the parameters required by the standards, the parameters required by the Eco-design Regulation CDR (EU) No 811/2013 and CDR (EU) No 812/2013 are indicated. The definition of these parameters is partly found in these regulations but not in a sufficiently precise manner. Clear definitions were established in the Solar Keymark Network (www.solarkeymark.org) and in the new prEN 12975, which is currently in ENQ phase. The test laboratories were using these definitions.

5.1.2 Standard performance parameters

The measured thermal performance data are presented in Figure 3 as thermal output per collector under Blues Sky Standard Reporting Conditions (SRC) as defined in EN ISO 9806:2017 Chapter 24.3. In the same graph, the maximum deviations from the average of the measured performance curves are plotted to illustrate the dependency on the temperature difference ΔT. The data are considered as valid up to the maximum measured temperature difference +30K. For simplicity the x-axis was limited to a maximum of ΔT = 100K. The deviation between the three laboratories is in the range of about ±1% up to a ΔT=60K. For higher temperature differences, the deviation is increasing slowly.

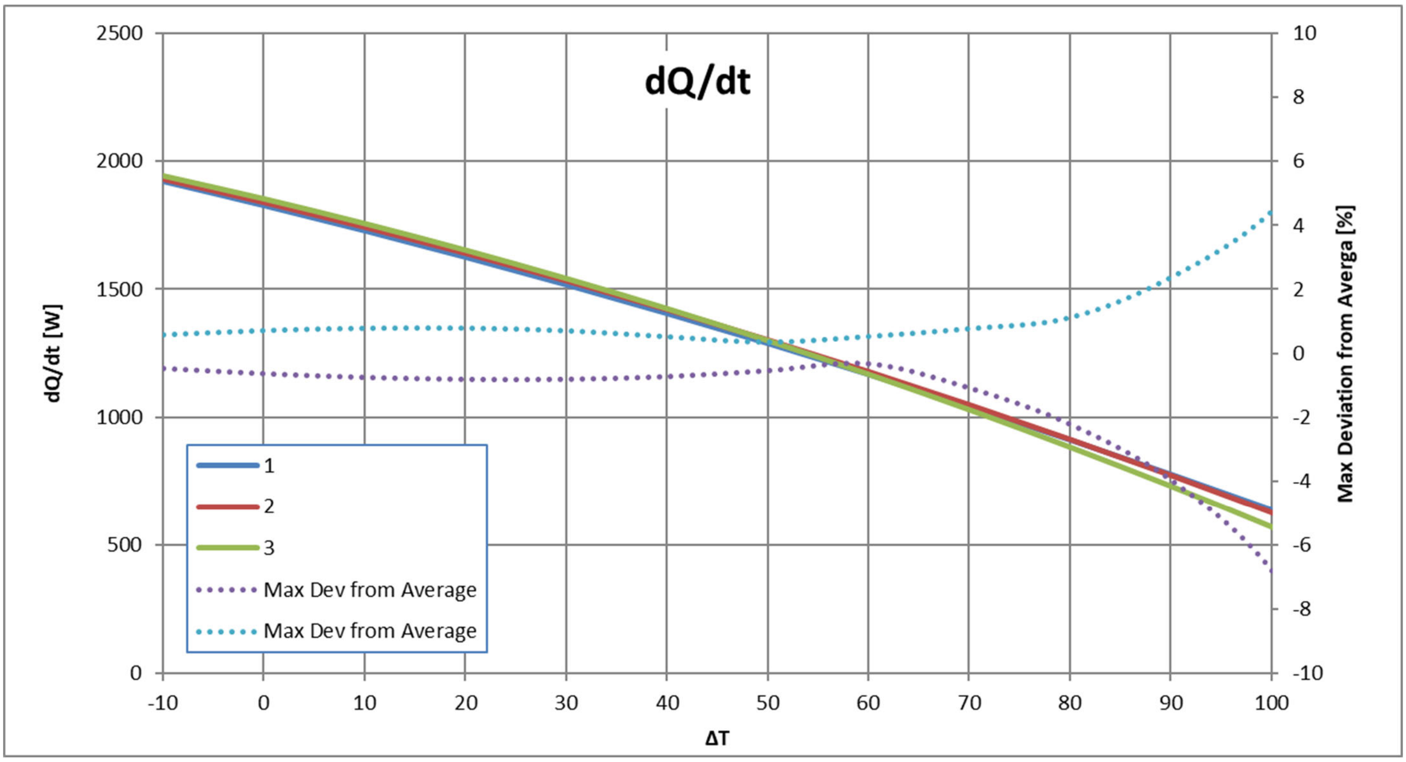


Figure 3: Thermal performance measured by the three laboratories

The second important set of parameters is the incidence angle modifier (Figure 4). The difference between the three laboratories for this measurement is obviously not important. It is however important to understand that the impact of such a deviation on the annual performance of a system is also depending on the geographic location, the system type. In general, the deviations for higher incidence angles do not have a very big impact on these results, as the solar contribution is usually small under high incidence angels anyway. Typical situations with high incidence angels such as morning sun or winter sun do not have an important contribution to the annual yields. It is therefore critical to compare only thermal performance curves or incidence angle curves. Deviations would reveal their effect on annual yields only by simulating real systems.

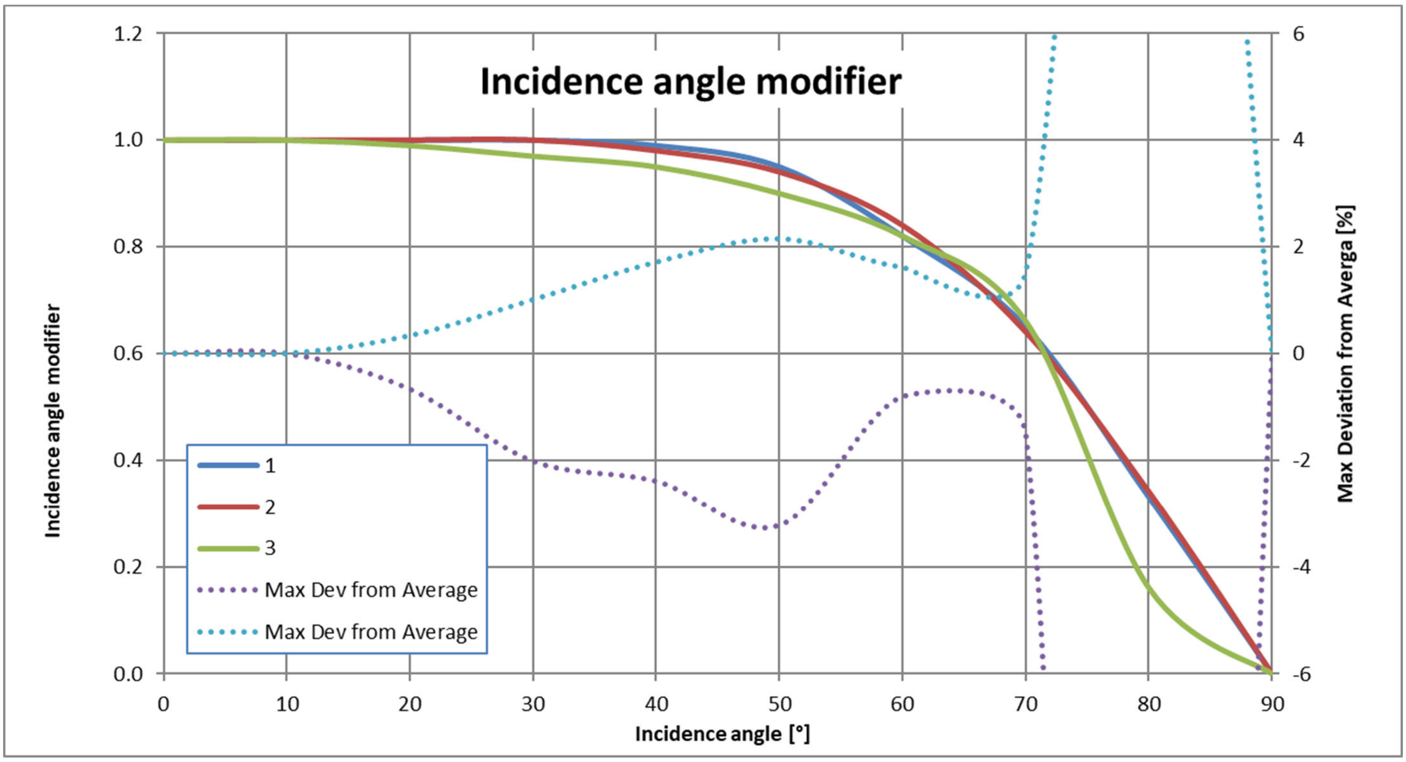


Figure 4: Comparison of measured incidence angle modifier including the maximum deviations from the average of the measured IAMs.

5.1.3 Annual collector output in kWh/collector at mean fluid temperature ϑ_m

In this chapter and in addition to the standard representation, the performance data are presented in a more advanced format considering thermal performance and incidence angle modifier at the same time. The numbers indicated below are computed based on real weather profiles for four different locations: Stockholm, Athens, Davos and Würzburg (see Table 2 below). This is one of the standard representations of the Solar Keymark Certification scheme (http://www.estif.org/solarkeymarknew/solar-keymark-network/calculation-tool). For this calculation, the collector is assumed to be operating at a fixed temperature over the whole year. The standard values are 25°C, 50°C and 75°C. The indicated values are indicating the possible annual yield of a collector when being operated at the given temperature and in a given location. Therefore the annual yields are indicated in kWh/collector/year. This presentation is an approach to simplify the comparison of different collectors as the individual performance parameters given above are considered as not very useful and often lead to misinterpretations.
This first step towards a realistic comparison of collectors can be done with simple office software such as the ScenoCalc tool (which is an Excel sheet) that is available free of charge from the above-mentioned source. This software is using hourly climate data for the indicated locations to compute a gross energy yield per collector and year. This simplified calculation model is not considering any transitional behaviour, no user interaction and assuming a 100% use of the energy provided by the sun.

	Athens			Davos			Stockholm			Würzburg		
Lab	25°C	50°C	75°C	25°C	50°C	75°C	25°C	50°C	75°C	25°C	50°C	75°C
1	2'975	2'078	1'342	2'234	1'522	953	1'640	1'053	632	1'794	1'142	675
2	2'958	2'077	1'342	2'237	1'533	961	1'639	1'060	638	1'783	1'141	677
3	2'956	2'057	1'292	2'217	1'485	886	1'635	1'040	601	1'786	1'125	639

Table 2: ScenoCalc results obtained by the participating test laboratories

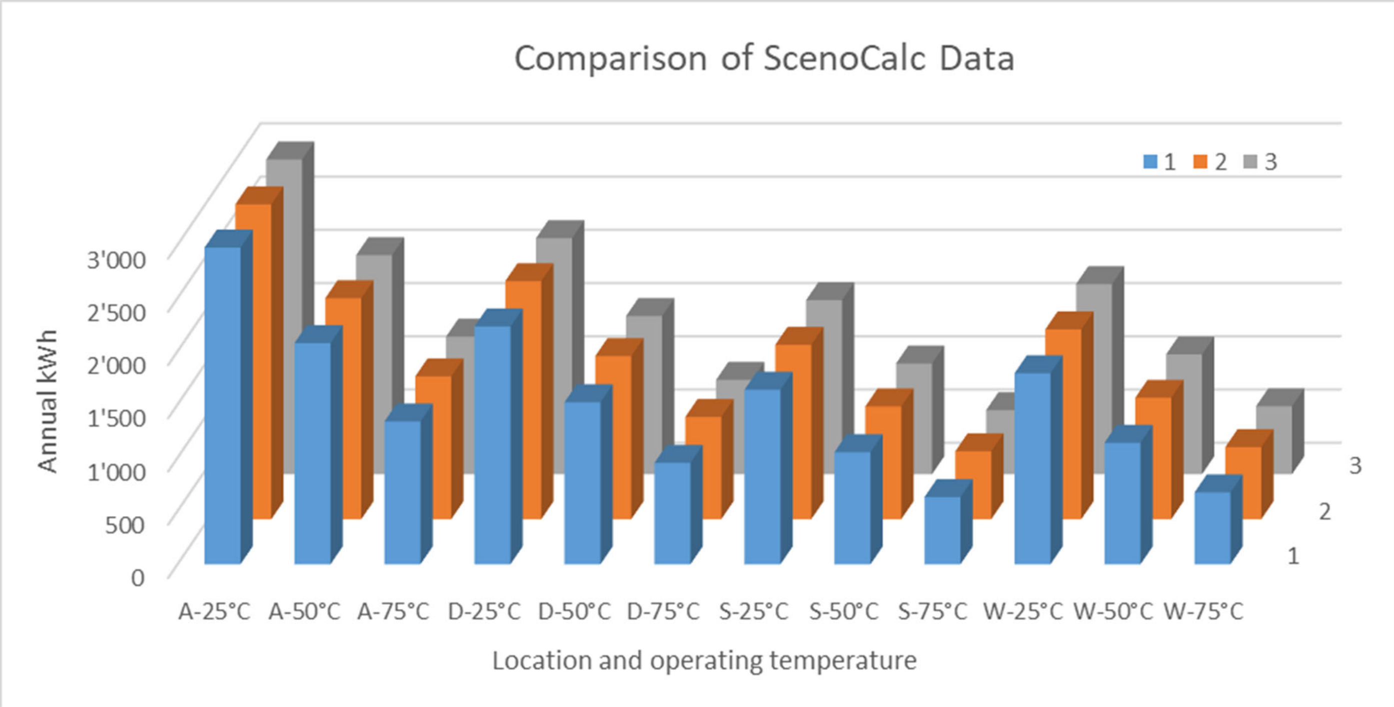


Figure 5: Comparison of the gross energy yield per year for the four standard locations ("A": Athens, "D": Davos, "S": Stockholm, "W": Würzburg") and the three standard operating temperatures 25°C, 50°C and 75°C, computed using the ScenoCalc tool.

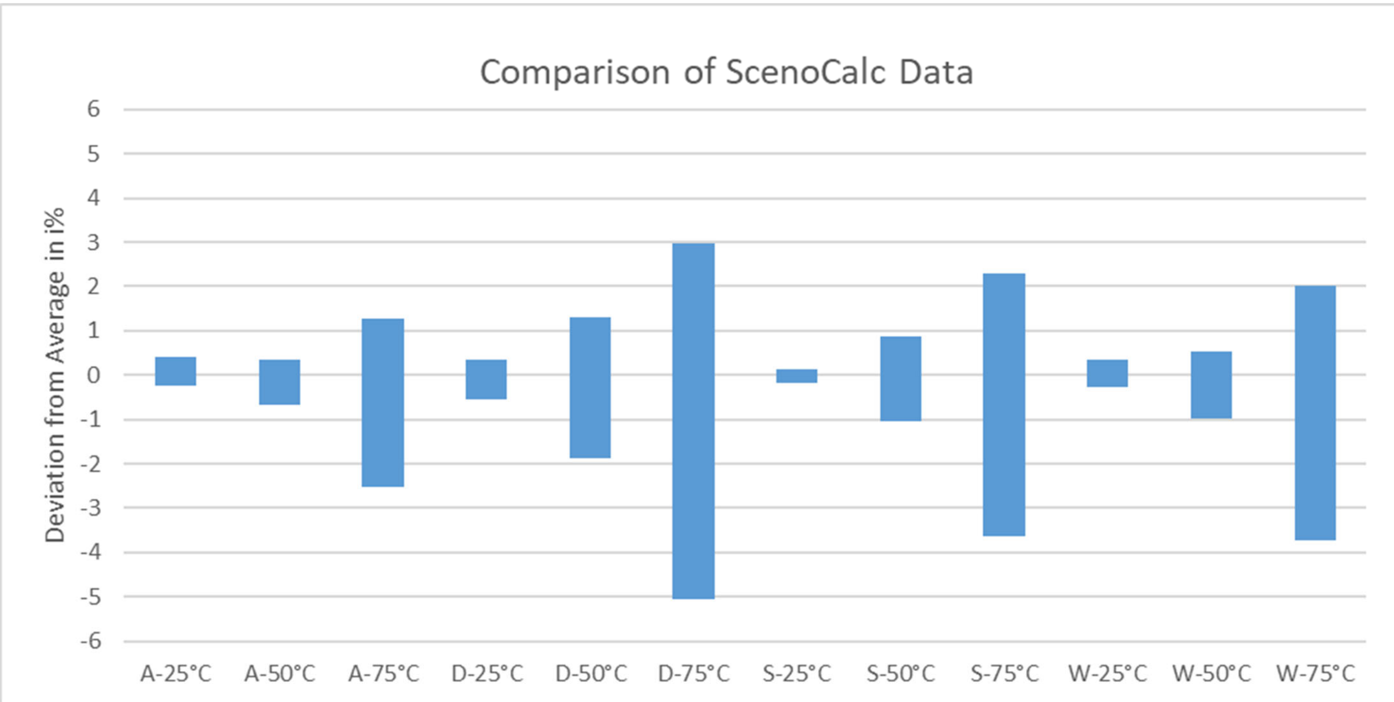


Figure 6: Min-Max deviations of the ScenoCalc results for the participating labs.

Comments:

The comparison of the collector results using the ScenoCalc tool shows a deviation that is strongly temperature depending, i.e. for the 25°C values the results from the different test labs are all easily within less than ±0.5%, where for higher temperatures of 50°C the differences are bigger but still within ±1% except for the values for Davos.

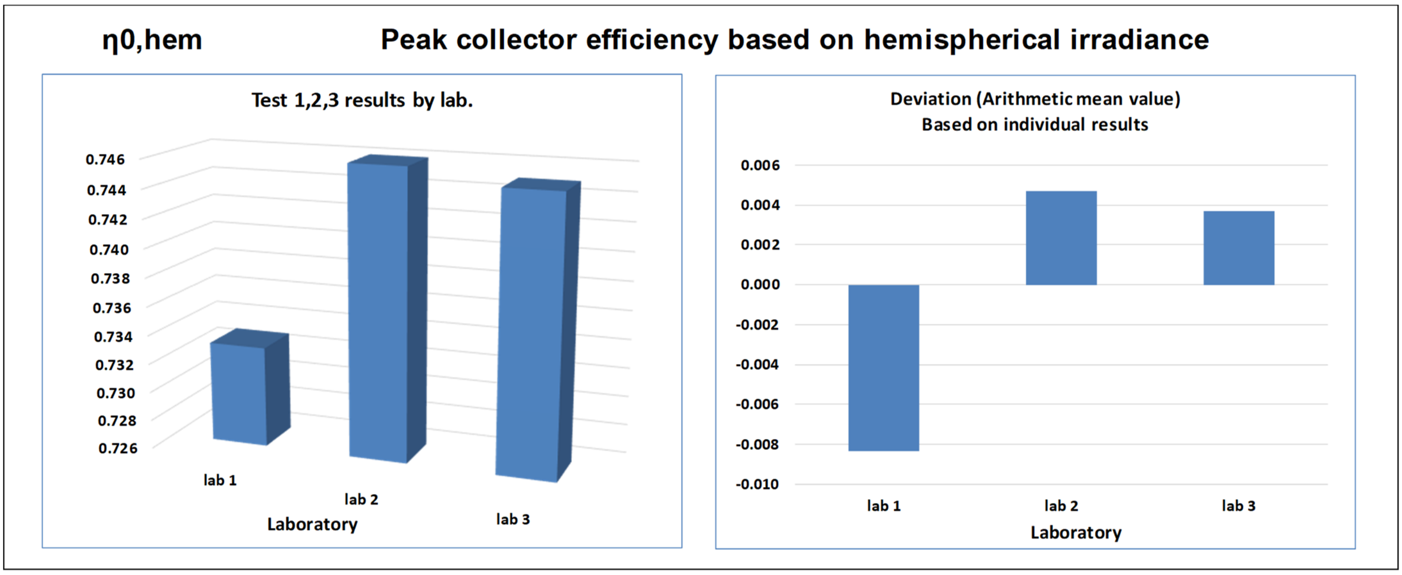
The curves show however that considering such a computed parameter, which is based on all the deduced collector parameters, is much more helpful than comparing thermal performance curves and/or incidence angle modifier curves or even single performance parameters.
To get more meaningful results that also could be linked to CO_2 savings, even more sophisticated computation methods should be applied considering also transient effects and annual cycles for the energy demand and possible solar contribution.

5.2 Statistics on the main parameters

In this chapter, the performance data as measured are presented in the standard format required by the ECOTEST project. 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.

5.2.1 Peak collector efficiency based on hemispherical irradiance $\eta_{0,hem}$

Parameter	$\eta_{0,hem}$	Peak collector efficiency based on hemispherical irradiar		
universal statistical evaluation v3.4 SLG by ACLi	**Total over all labs**	lab 1	lab 2	lab 3
test result 1	**Test1**	0.733	0.746	0.745
Number of test results		1	1	1
Median value	**0.75**	0.73	0.75	0.75
Deviation from median value (Delta)		**-0.01**	**0.00**	**0.00**
Arithmetic mean value	**0.74**	0.73	0.75	0.75
Deviation from arithmetic mean value		**-0.01**	**0.00**	**0.00**
Repeatability standard deviation s_r	**-**	-	-	-
Reproducibility Standard deviation (*) s_R	**0.01**			
Max - Min (arithmetic mean value)	**0.013**	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	**0.013**	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

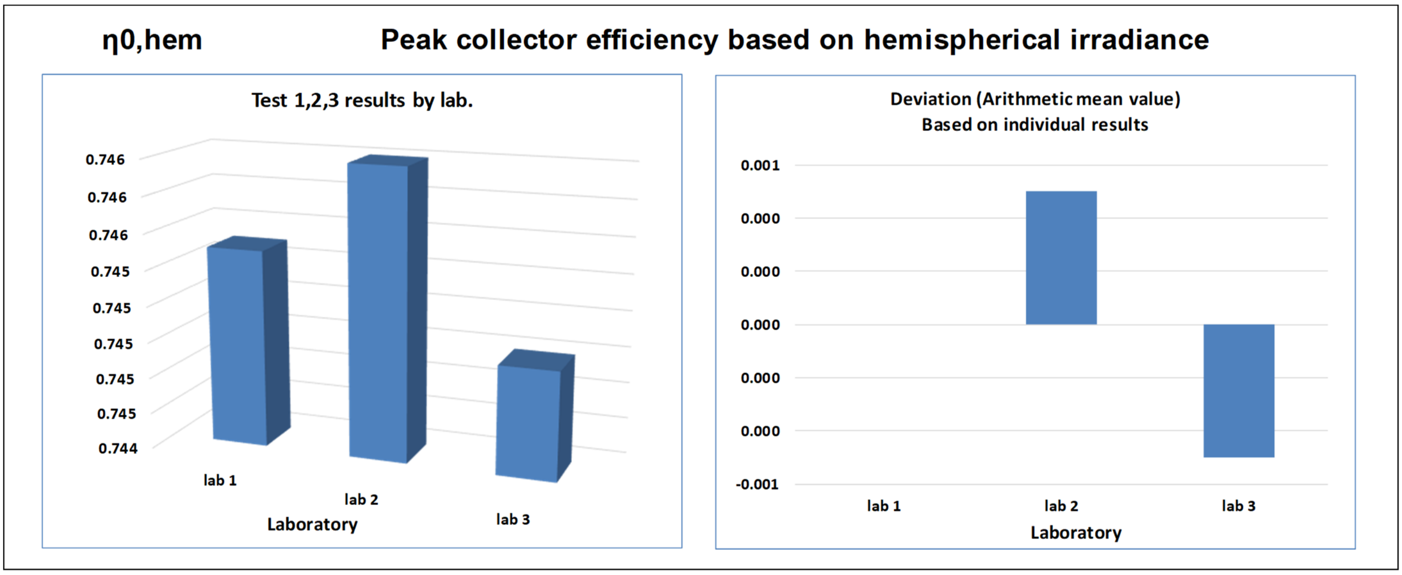


STATISTICS	
Median	0.745
Arh. mean value	0.741
R STD	0.007
r STD	-
Max - Min (M-m)	0.013

Figure 7: ECOTEST statistical representation of the results measured $\eta_{0,hem}$

5.2.2 Peak collector efficiency based on hemispherical irradiance $\eta_{0,hem}$ (Removed Outlier)

Parameter	$\eta_{0,hem}$	Peak collector efficiency based on hemispherical irradiar		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	0.7455	0.746	0.745
Number of test results		1	1	1
Median value	0.75	0.75	0.75	0.75
Deviation from median value (Delta)		0.00	0.00	0.00
Arithmetic mean value	0.75	0.75	0.75	0.75
Deviation from arithmetic mean value		0.00	0.00	0.00
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	0.00			
Max - Min (arithmetic mean value)	0.001	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	0.001	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

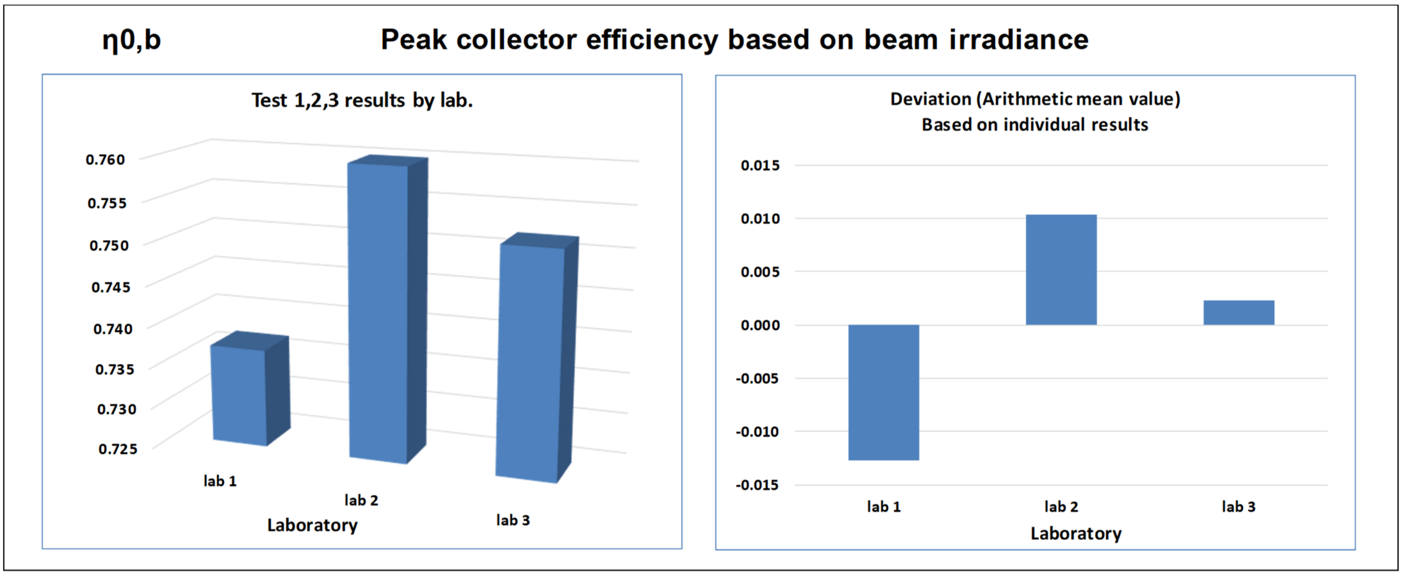


STATISTICS	
Median	0.746
Arh. mean value	0.746
R STD	0.001
r STD	-
Max - Min (M-m)	0.001

Figure 8: ECOTEST statistical representation of the results measured $\eta_{0,hem}$. The outlier (see 5.2.1) was removed and replaced by an average value of the other two parameters (see

5.2.3 Peak collector efficiency based on beam irradiance $\eta_{0,b}$

Parameter	$\eta_{0,b}$	Peak collector efficiency based on beam irradiance		
universal statistical evaluation v3.4.SLG by ACLI	**Total over all labs**	lab 1	lab 2	lab 3
test result 1	**Test1**	0.737	0.760	0.752
Number of test results		1	1	1
Median value	**0.75**	0.74	0.76	0.75
Deviation from median value (Delta)		**-0.02**	**0.01**	**0.00**
Arithmetic mean value	**0.75**	0.74	0.76	0.75
Deviation from arithmetic mean value		**-0.01**	**0.01**	**0.00**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	**0.01**			
Max - Min (arithmetic mean value)	**0.023**	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	**0.023**	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

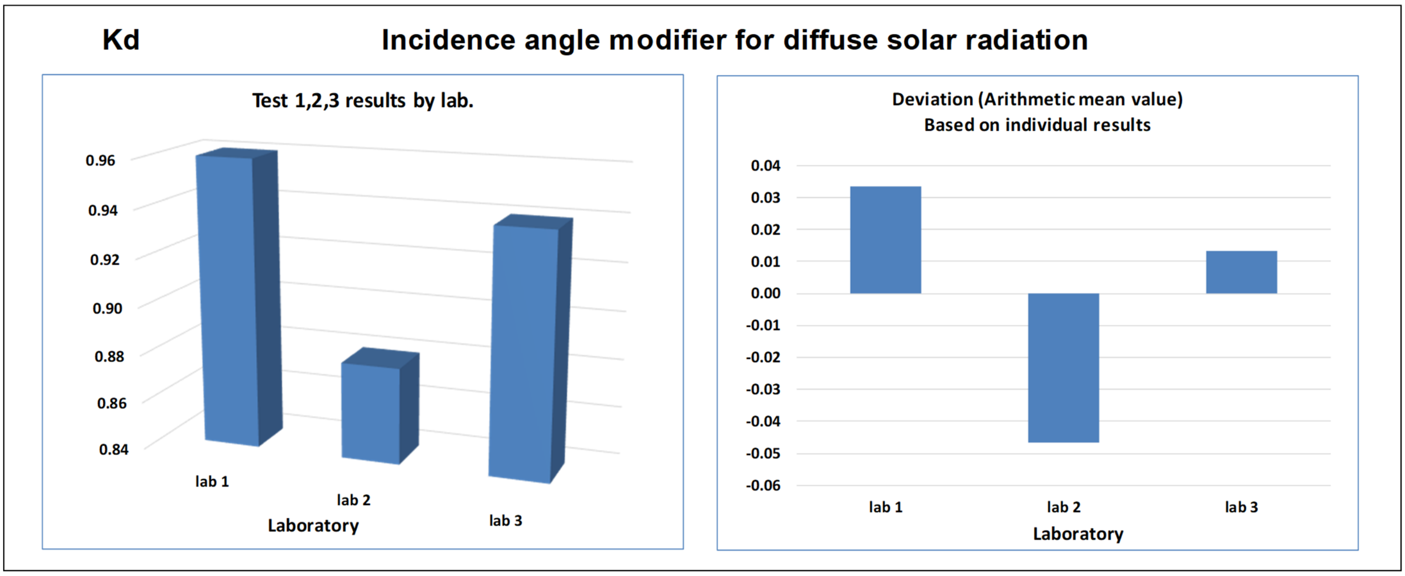


STATISTICS	
Median	0.752
Arh. mean value	0.750
R STD	0.012
r STD	-
Max - Min (M-m)	0.023

Figure 9: ECOTEST statistical representation of the results measured $\eta_{0,b}$

5.2.4 Incidence angle modifier for diffuse solar radiation K_d

Parameter	K_d	Incidence angle modifier for diffuse solar radiation		
Universal statistical evaluation v3.4.SLG by ACLI	**Total over all labs**	lab 1	lab 2	lab 3
test result 1	**Test1**	0.96	0.88	0.94
Number of test results		1	1	1
Median value	**0.94**	0.96	0.88	0.94
Deviation from median value (Delta)		**0.02**	**-0.06**	**0.00**
Arithmetic mean value	**0.93**	0.96	0.88	0.94
Deviation from arithmetic mean value		**0.03**	**-0.05**	**0.01**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	**0.04**			
Max - Min (arithmetic mean value)	**0.080**	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	**0.080**	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

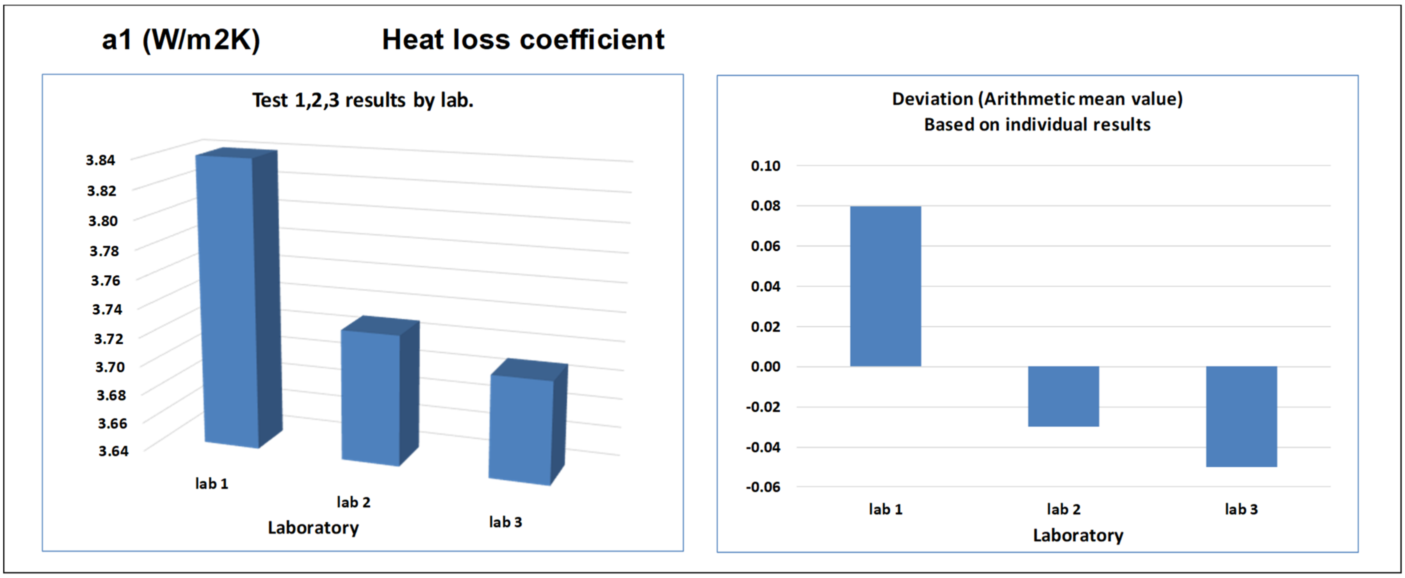


STATISTICS	
Median	0.940
Arh. mean value	0.927
R STD	0.042
r STD	-
Max - Min (M-m)	0.080

Figure 10: ECOTEST statistical representation of the results measured K_d

5.2.5 Heat loss coefficient a_1

Parameter	a_1 (W/m²K)	Heat loss coefficient		
universal statistical evaluation v3.4.SLG by ACLi	**Total over all labs**	lab 1	lab 2	lab 3
test result 1	**Test1**	3.84	3.73	3.71
Number of test results		1	1	1
Median value	**3.73**	3.84	3.73	3.71
Deviation from median value (Delta)		**0.11**	**0.00**	**-0.02**
Arithmetic mean value	**3.76**	3.84	3.73	3.71
Deviation from arithmetic mean value		**0.08**	**-0.03**	**-0.05**
Repeatability standard deviation s_r	**-**	-	-	-
Reproducibility Standard deviation (*) s_R	**0.07**			
Max - Min (arithmetic mean value)	**0.130**	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	**0.130**	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

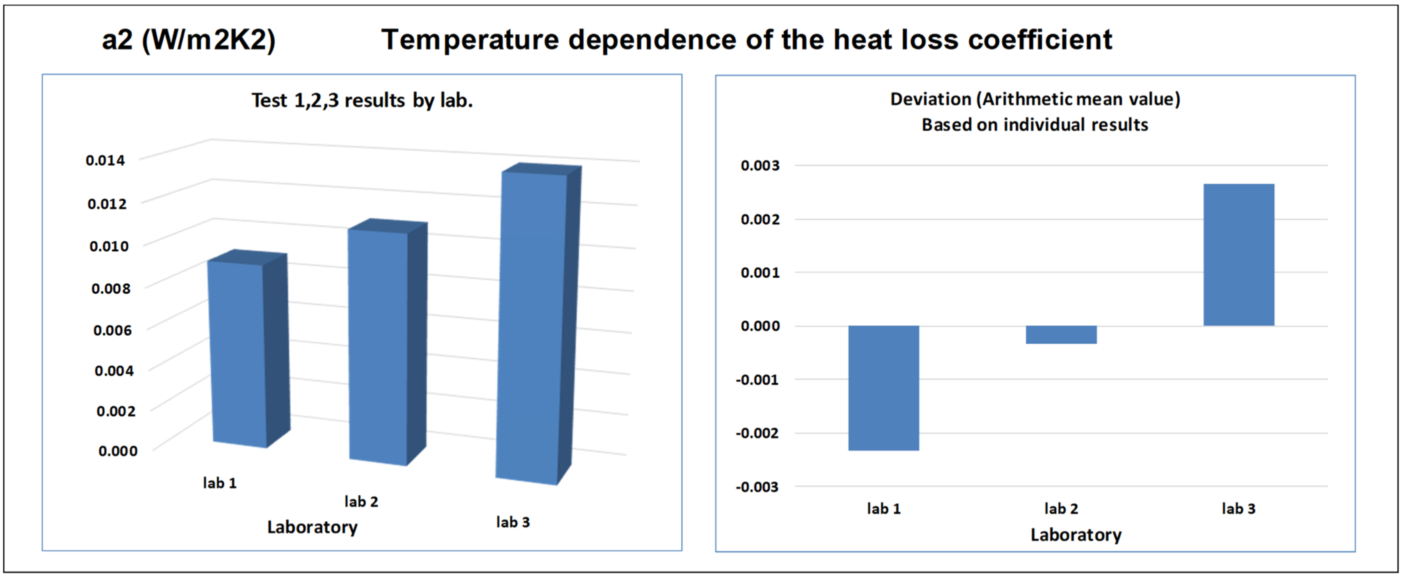


STATISTICS		
Median	**3.73**	**W/m2K**
Arh. mean value	**3.76**	**W/m2K**
R STD	**0.07**	**W/m2K**
r STD	**-**	
Max - Min (M-m)	**0.13**	**W/m2K**

Figure 11: ECOTEST statistical representation of the results measured a_1

5.2.6 Temperature dependence of the heat loss coefficient a_2

Parameter	a_2 (W/m^{2}K^2)	Temperature dependence of the heat loss coefficient		
universal statistical evaluation v3.4.SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	0.009	0.011	0.014
Number of test results		1	1	1
Median value	0.01	0.0090	0.0110	0.0140
Deviation from median value (Delta)		-0.0020	0.0000	0.0030
Arithmetic mean value	0.01	0.0090	0.0110	0.0140
Deviation from arithmetic mean value		-0.0023	-0.0003	0.0027
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	0.00			
Max - Min (arithmetic mean value)	0.005	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	0.005	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

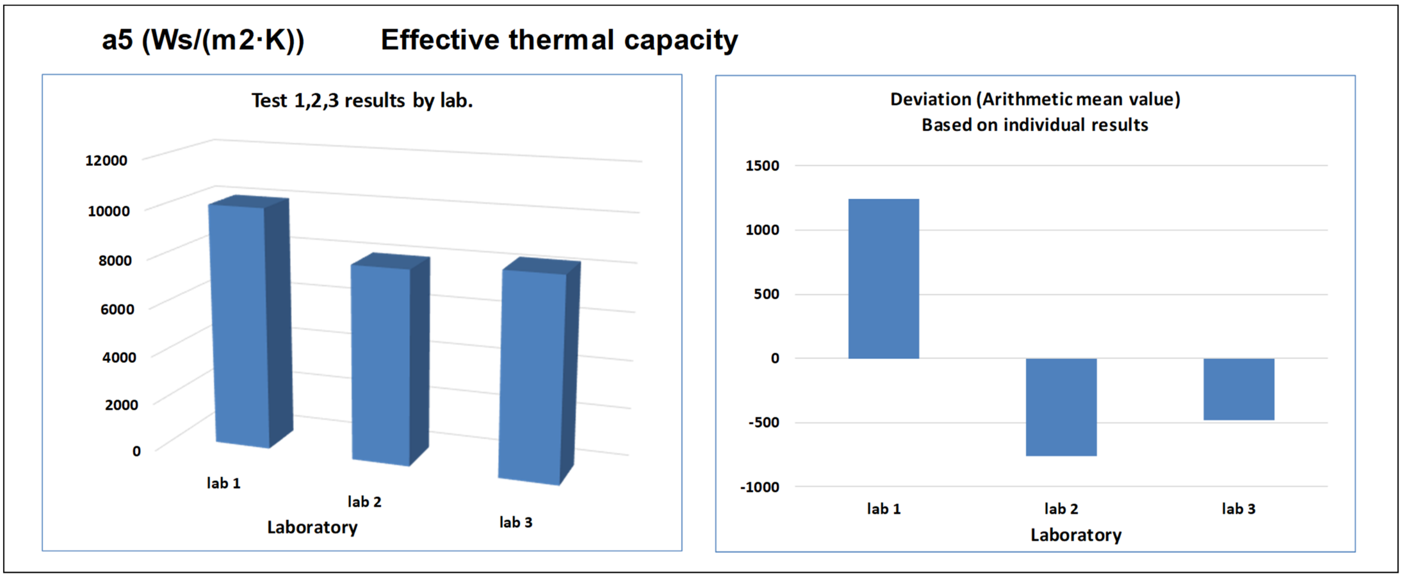


STATISTICS	
Median	0.0110 W/m2K2
Arh. mean value	0.0113 W/m2K2
R STD	0.0025 W/m2K2
r STD	-
Max - Min (M-m)	0.0050 W/m2K2

Figure 12: ECOTEST statistical representation of the results measured a_2

5.2.7 Effective thermal capacity a_5

Parameter	a_5 (Ws/(m^2·K))	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	10030	8030	8310
Number of test results		1	1	1
Median value	8310	10030	8030	8310
Deviation from median value (Delta)		1720	-280	0
Arithmetic mean value	8790	10030	8030	8310
Deviation from arithmetic mean value		1240	-760	-480
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	1083			
Max - Min (arithmetic mean value)	2000	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	2000	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

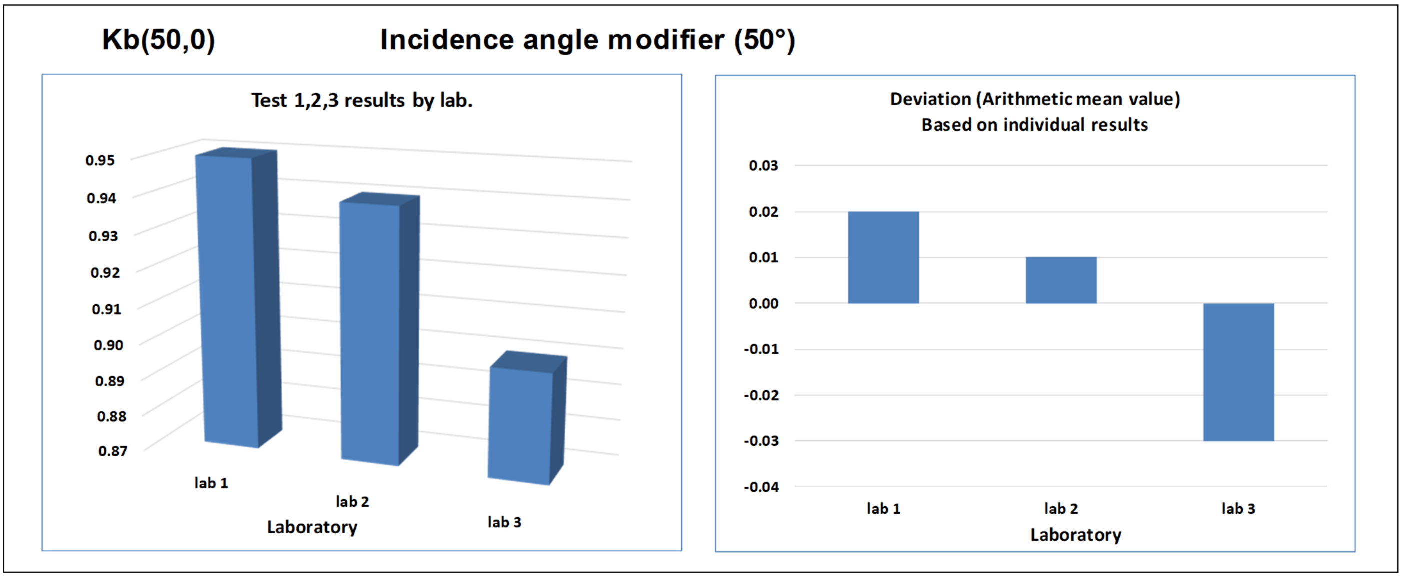


STATISTICS		
Median		8310 Ws/m2K
Arh. mean value		8790 Ws/m2K
R STD		1083 Ws/m2K
r STD	-	
Max - Min (M-m)		2000 Ws/m2K

Figure 13: ECOTEST statistical representation of the results measured a_5

5.2.8 IAM(50°)

Parameter	Kb(50,0)	Incidence angle modifier (50°)		
universal statistical evaluation v3.4.SLG by ACLI	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	0.95	0.94	0.90
Number of test results		1	1	1
Median value	**0.94**	0.95	0.94	0.90
Deviation from median value (Delta)		**0.01**	**0.00**	**-0.04**
Arithmetic mean value	**0.93**	0.95	0.94	0.90
Deviation from arithmetic mean value		**0.02**	**0.01**	**-0.03**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	**0.03**			
Max - Min (arithmetic mean value)	**0.05**	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	**0.05**	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

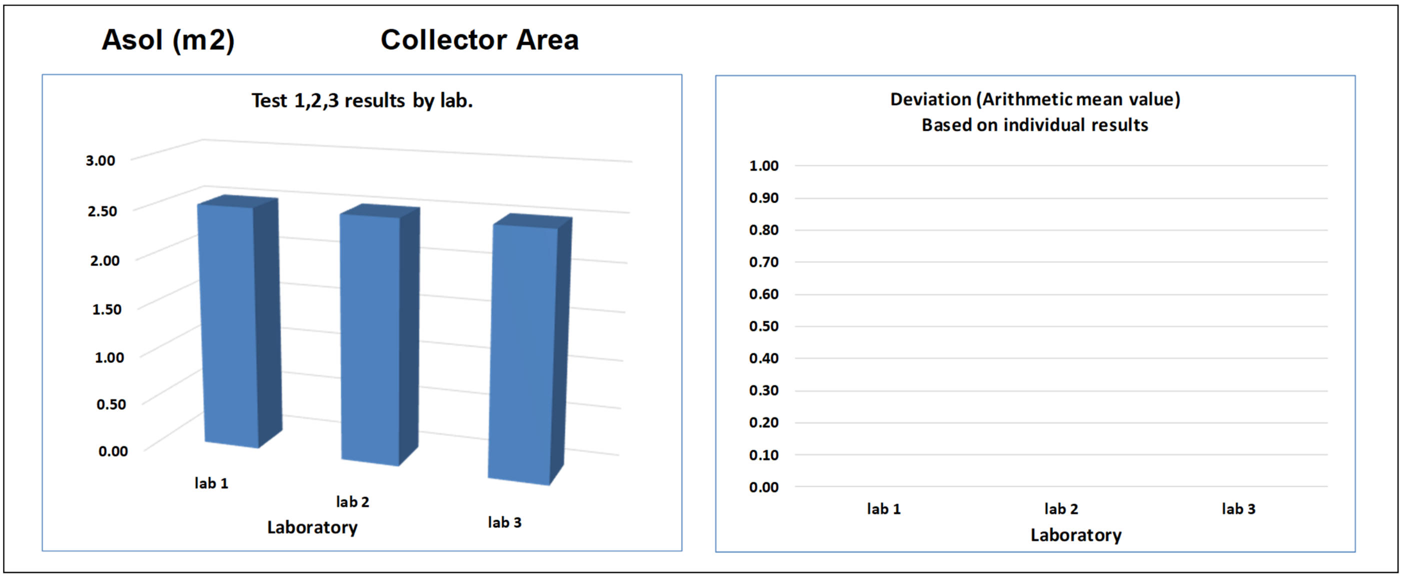


STATISTICS	
Median	0.94
Arh. mean value	0.93
R STD	0.03
r STD	-
Max - Min (M-m)	0.05

Figure 14: ECOTEST statistical representation of the results measured IAM(50°)

5.2.9 Collector area A_{sol}

Parameter	A_{sol} (m^2)	Collector Area		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	2.51	2.51	2.51
Number of test results		1	1	1
Median value	**2.51**	2.51	2.51	2.51
Deviation from median value (Delta)		**0.00**	**0.00**	**0.00**
Arithmetic mean value	**2.51**	2.51	2.51	2.51
Deviation from arithmetic mean value		**0.00**	**0.00**	**0.00**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	**0.00**			
Max - Min (arithmetic mean value)	**0.00**	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	**0.00**	Diff between the max and min of all measured values by all labs		
(*) based on the arithmetic mean values				
Between-lab consistency - assumed classif.	correct	**correct**	**correct**	**correct**

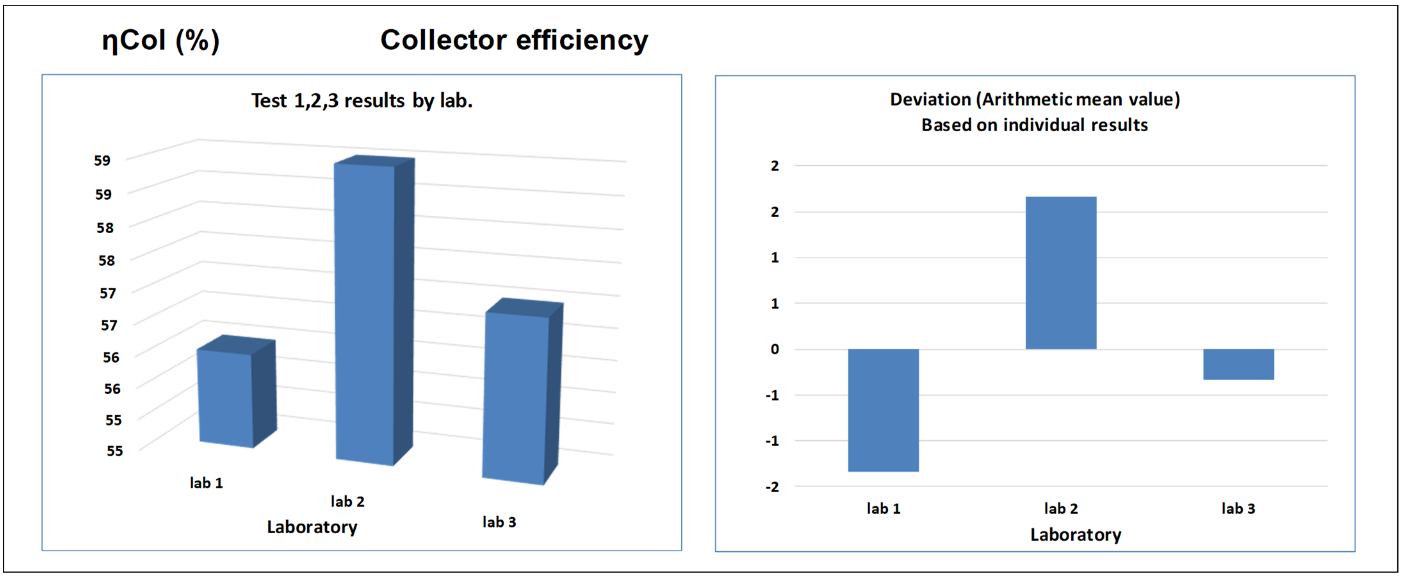


STATISTICS		
Median		2.51 m2
Arh. mean value		2.51 m2
R STD		0.00 m2
r STD	-	
Max - Min (M-m)		0.00 m2

Figure 15: ECOTEST statistical representation of the results measured A_{sol}

5.2.10 Collector efficiency η_{Col}

Parameter	ηCol (%)	Collector efficiency		
universal statistical evaluation v3.4.SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	56	59	57
Number of test results		1	1	1
Median value	57	56.0	59.0	57.0
Deviation from median value (Delta)		-1.0	2.0	0.0
Arithmetic mean value	57	56.0	59.0	57.0
Deviation from arithmetic mean value		-1.3	1.7	-0.3
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	1.5			
Max - Min (arithmetic mean value)	3.0	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	3.0	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

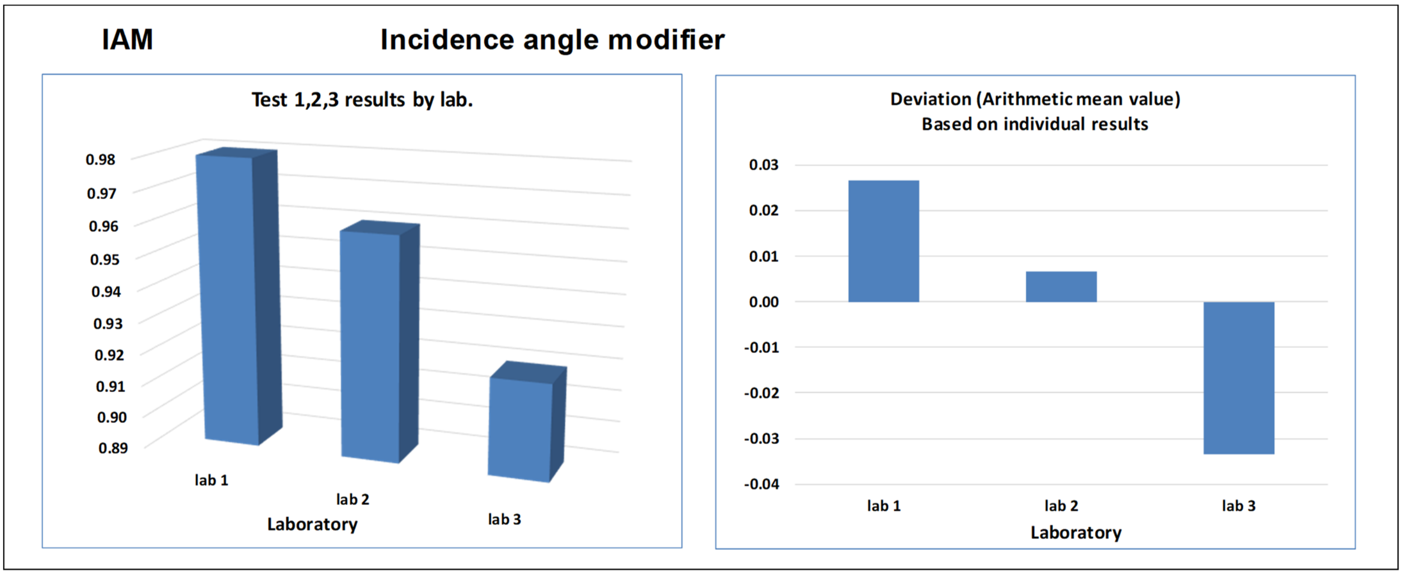


STATISTICS	
Median	57 %
Arh. mean value	57 %
R STD	2 %
r STD	-
Max - Min (M-m)	3 %

Figure 16: ECOTEST statistical representation of the results for η_{Col}

5.2.11 Incidence angle modifier IAM

Parameter	IAM	Incidence angle modifier		
Universal statistical evaluation v3.4.SLG by ACLI	**Total over all labs**	lab 1	lab 2	lab 3
test result 1	**Test1**	0.98	0.96	0.92
Number of test results		1	1	1
Median value	**0.96**	0.98	0.96	0.92
Deviation from median value (Delta)		**0.02**	**0.00**	**-0.04**
Arithmetic mean value	**0.95**	0.98	0.96	0.92
Deviation from arithmetic mean value		**0.03**	**0.01**	**-0.03**
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	**0.03**			
Max - Min (arithmetic mean value)	**0.060**	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	**0.060**	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

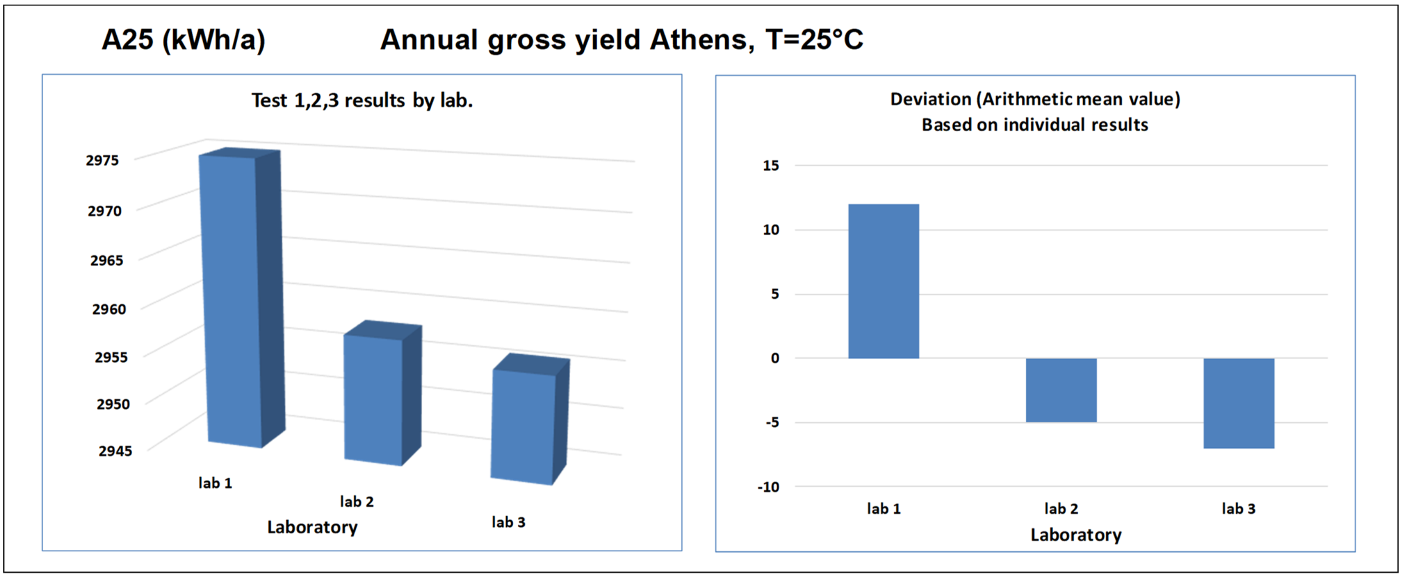


STATISTICS	
Median	**0.960**
Arh. mean value	**0.953**
R STD	**0.031**
r STD	-
Max - Min (M-m)	**0.060**

Figure 17: ECOTEST statistical representation of the results for IAM

5.2.12 ScenoCalc annual gross yield for Athens 25°

Parameter	A25 (kWh/a)	Annual gross yield Athens, T=25°C		
universal statistical evaluation v3.4 SLG by ACLi	Total over all labs	lab 1	lab 2	lab 3
test result 1	Test1	2975	2958	2956
Number of test results		1	1	1
Median value	2958	2975	2958	2956
Deviation from median value (Delta)		17	0	-2
Arithmetic mean value	2963	2975	2958	2956
Deviation from arithmetic mean value		12	-5	-7
Repeatability standard deviation s_r	-	-	-	-
Reproducibility Standard deviation (*) s_R	10.4			
Max - Min (arithmetic mean value)	19.0	Diff between max and min of the arithmetic means measured by all labs		
Max - Min (arithmetic mean value)	19.0	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		2958 kWh/a
Arh. mean value		2963 kWh/a
R STD		10 kWh/a
r STD	-	
Max - Min (M-m)		19 kWh/a

Figure 18: ECOTEST statistical representation of the ScenoCalc gross yield computed for Athens at an operating temperature of 25°C

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 workflow:

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 3: 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
-	0	In the previous version of the report the presentation of the values for the effective thermal capacity in chapter 5.2.7 were wrong due to a copy/paste error. The values reported in 5.1.1 are correct and no other results are affected.	No
None	0	Data presented in Clause 5.2.7 (Effective heat capacity) were wrong in the last version of the report. Most probably copy/paste error: Original data in 5.1.1 were correct.	

Table 4: 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

For most of the parameters, the precision (or digits of precision) is defined in the standard or in the regulations. These indications have been used for the tables if available.

As discussed in the Work package leader consortium, measurements with outlier results were re-analysed without the outlier. As there are only three laboratories involved in WP8 this would reduce the number of results to two. 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 clause 5.2.2.

The parameter "IAM Collector incidence angle modifier" is introduced but not defined in the CDR (EU) No 812/2013. As it also not defined in the relevant existing standards EN 12975 and ISO 9806, it was now defined in the latest version of the EN 12975 that was submitted to CEN in early 2019 for publication. This definition found in Annex A.3.6

$$IAM = 0{,}85 \cdot K_b\left(\theta_L = 40°, \theta_T = 0°\right) \cdot K_b\left(\theta_L = 0°, \theta_T = 40°\right) + 0{,}15 \cdot K_d$$

was used to compute the IAM as indicated in Table 1 and in Clause 5.2.11 of this report.

7.2 Comments on possible discrepancies

No substantial or unexpected discrepancies were found. It is well known that some of the parameters describing the performance of a collector are not completely independent, even if the mathematical representation suggests such independency. The best-known pair of parameters are the collector heat losses a_1 and a_2 which are related such that in some cases a higher a_1 is compensated by a lower a_2 or vice versa. A similar relation is known for Incidence angle modifier and η_0. The reasons for these interrelations are well understood by the experts and are mainly caused by mathematical effects occurring in parameter identification. Comparing collectors should therefore not be based on single parameters, but much more on aggregated parameters as outlined in clause 5.1.3.

7.3 Comments in light of the iterative tests results

None

7.4 Main parameter that influence the measurand

No specific remarks.

7.5 Comments on the results

The variation in the results are very small in the operating range of a collector when used in water heating and space heating systems as specified in the ErP regulations. The results would be even better if more elaborated parameters such as the ScenoCalc parameters would to consider all parameters and balance out some known correlation effects between different collector parameters.

With the given number of test laboratories, it is not possible to establish correlations between labs and test results. The differences are assumed to be mainly due to laboratories uncertainties and to the general uncertainty of the assumed mathematical model. The variations of the measured parameters intended to be used for verification procedures for market surveillance purposes (η_{Col} and A_{sol}) are however far below the values given in the Annex VIII of CDR (EU) No 811/2013 and the Annex IX if the CDR (EU) No 812/2013.

7.6 **Repeatability**

There were only three laboratories involved that all performed one test. The repeatability can therefore not be rated in a statistically correct manner. However, the iterative tests presented below show that for this type of collector the production tolerance of less than +/- 1%. Furthermore, the thermal performance measurement was repeated on the collector after the RRT and this measurement showed no variation beyond the general uncertainties. It is therefore assumed that the repeatability of the thermal performance measurements is better than the uncertainty of measuring at different laboratories.

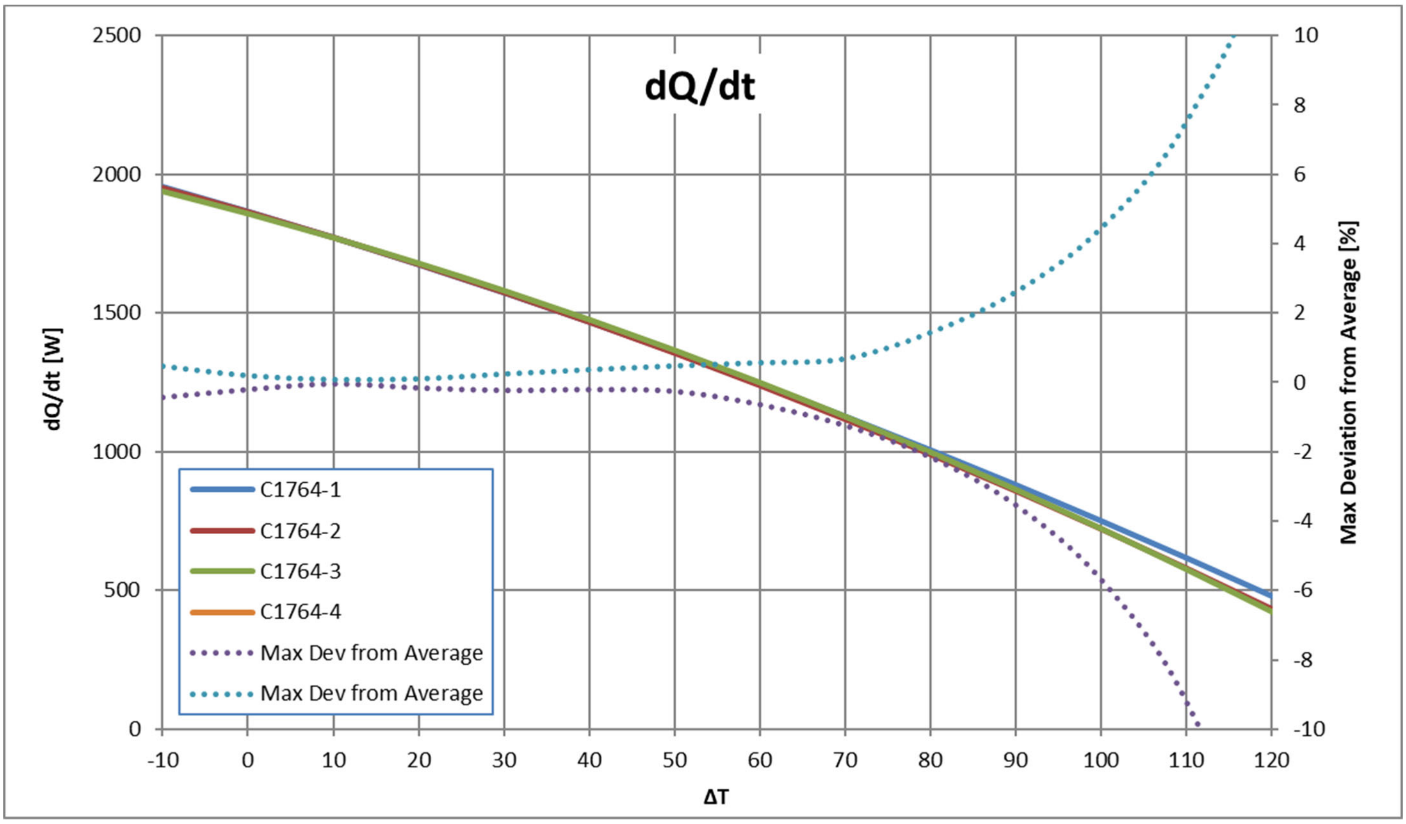
8 Iterative test results

In this chapter, the results of several additional test sequences are reported. Iterative test as with other appliances were not possible due to the short time available. However, several extra test were performed to investigate potential sources of uncertainties that could lead to erroneous assessments of the results of this RRT and even worse in market surveillance activities.

Some of the results of the iterative test will be used as input for the standardisation committees where appropriate. Also in this section, it must be very clear that the results must be considered as snapshots taken on one specific standard collector model: The results shall not be generalized in a simplified manner.

8.1 Comparison of 4 collectors (Design Tolerance)

In a first additional measurement, the variation between several products that should be identic was assessed. For this purpose, the four collectors that were delivered by the manufacturer were all pre-aged in the same way and then the thermal performance was measured on the solar simulator under identic conditions and immediately one after the other. The collectors were measured up to a temperature difference of 90°K, meaning that the values are considered valid up to a ΔT of 120°C as defined in the EN ISO 9806:2017.



Collector efficiency data

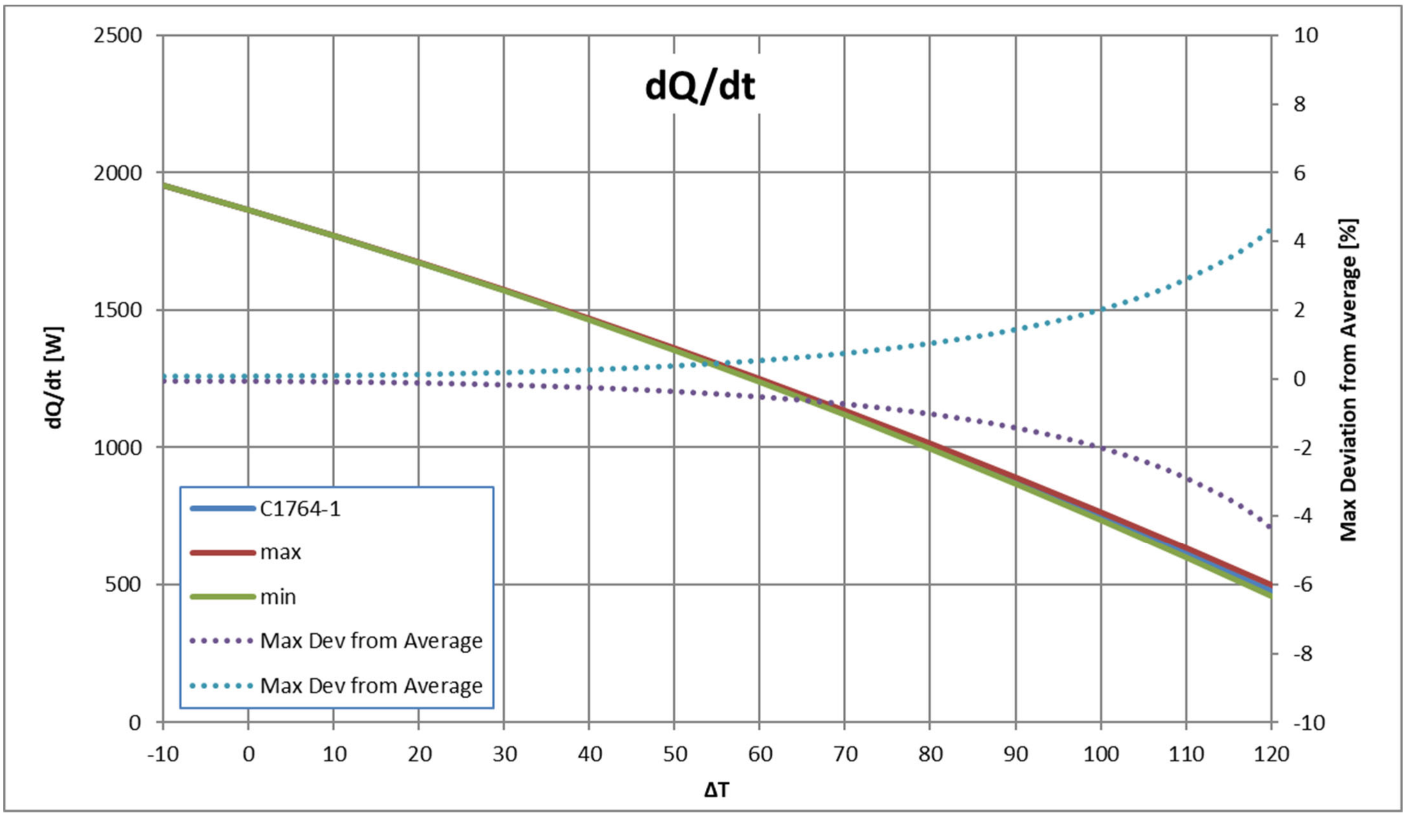
Collector		1764-1	1764-2	1764-3	1764-4	
EN ISO 9806:2017, EN 12975:2010, prEN12975						
Peak collector efficiency based on hemispherical irradiance	$\eta_{0,hem}$	0.743	0.743	0.740	0.740	--
Heat loss coefficient	a_1	3.64	3.55	3.32	3.30	W/m²K
Temperature dependence of the heat loss coefficient	a_2	0.008	0.010	0.012	0.014	W/m²K²

Figure 19: Comparison of the thermal performance of four identical collectors

Conclusion: The measurements indicate that good quality collectors can be manufactured such that the thermal performance is within rather narrow limits. In this case, the deviations are well within ±2% up to a ΔT of 80°C which is covering most application cases. The differences are increasing considerably at higher temperature differences above ΔT=80K. The most reasonable explanation for this observation is that not all collectors are identical. After the pre exposure, some deformations of the absorbers were easily visible, leading to a non-uniform distance between absorber and glazing. This is affecting the thermal losses, as it is visible in the performance curve at higher temperatures.

8.2 Mathematical rounding uncertainty

To assess the uncertainty induced solely by rounding effects, the results of one of the measurements (C1764-1) are provided with the maximum tolerance in the rounded digits, still leading to the same end results. In the example shown here the $\eta_{0,hem}$ = 0.743 is indicated with three digits as defined in the standard. However, the a span of values from 0.7425-0.7435 would result in the same $\eta_{0,hem}$. The same applies for a_1 indicated with two digits as 3.64 covering the range from 3.635 - 3.645 and a_2 indicated as 0.008 covering the range 0.0075-0.0085.
This calculation example shows that the mathematical uncertainty induced only by rounding effects may reach up to ±4% in the range of the valid data up to ΔT = 120°C.
Depending on the measured parameters and the temperature range that is covered by the measurement, this uncertainty can become much higher at elevated temperatures.



Collector efficiency data

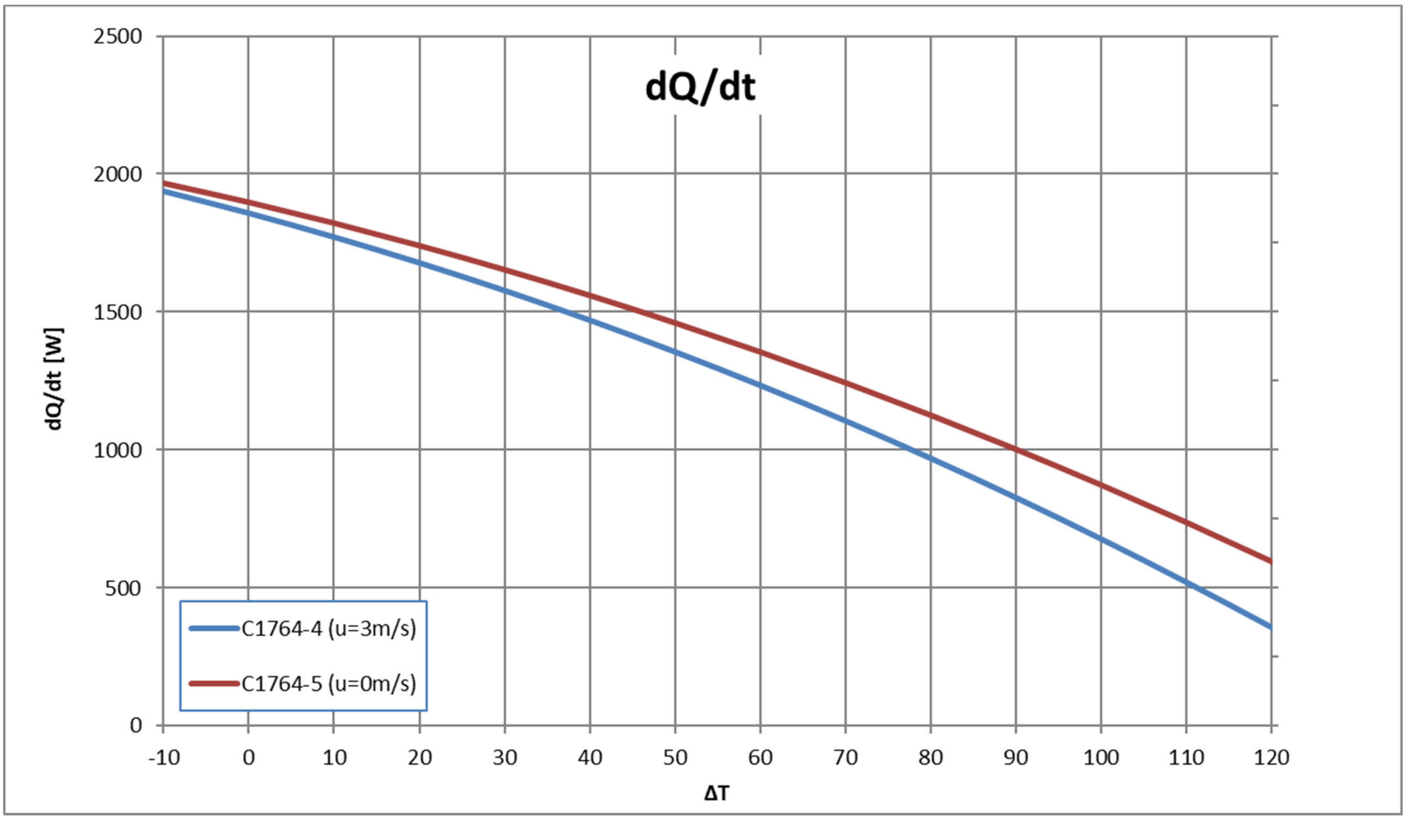
Collector		1764-1	max	min		
EN ISO 9806:2017, EN 12975:2010, prEN12975						
Peak collector efficiency based on hemispherical irradiance	$\eta_{0,hem}$	0.7430	0.7435	0.7425		--
Heat loss coefficient	a_1	3.640	3.645	3.635		W/m²K
Temperature dependence of the heat loss coefficient	a_2	0.0080	0.0075	0.0085		W/m²K²

Figure 20: Effect of mathematical rounding on the thermal performance curve.

Conclusion: Depending on the performance parameters, the number of digits that must be indicated as defined by the standard can already lead to substantial uncertainties especially at higher temperatures. The rounding uncertainty in this case is similar to the deviations found between the four identic collectors (see 8.1).

8.3 Comparison of wind and no-wind condition

It is known, that the thermal performance of collectors is affected by external wind. For this reason, the standard test method requires a 3 m/s wind speed parallel to the surface of the collector, with a tolerance of ±1m/s. The wind dependency is very much depending on the collector type and even with a standard collector as used in this RRT the wind dependency may reach important levels. In this case, the thermal performance of one of the four collectors was measured with 3 m/s wind (standard testing) and without any wind.



Collector efficiency data

Collector		1764-4 3m/s	1764-5 0m/s			
EN ISO 9806:2017, EN 12975:2010, prEN12975						
Peak collector efficiency based on hemispherical irradiance	$\eta_{0,hem}$	0.740	0.756			--
Heat loss coefficient	a_1	3.300	2.880			W/m^2K
Temperature dependence of the heat loss coefficient	a_2	0.0140	0.0120			W/m^2K^2

Figure 21: Comparison of the thermal performance measured with standard wind speed and without wind.

Conclusion: It can be seen that the wind dependency is very much temperature depending which is in line with simple physical considerations. This fact is known and can be considered by the testing laboratories by declaring the collectors as so-called wind and infrared sensitive collectors (WISC).

8.4 Uncertainty induced by wind/no wind tolerance

As shown above, the impact of external wind is measurable for this type of collector. Assuming a linear dependency of the wind on the thermal performance (1st order approximation as assumed in the EN ISO 9806) the uncertainty that must be allowed only due to the tolerance of wind speed given by the standard are considerable. Based on the measure curve with u=3m/s and the curve measured without wind (u=0 m/s) the performance was extrapolated for u = 2 m/s and u = 4 m/s (EN ISO 9806:2017 clause 23.3.3.2). This is covering the permitted variation during the measurement and obviously provides an uncertainty exceeding ±20% at higher temperatures. But already at a rather low temperature difference of ΔT = 80°C the wind uncertainty is at ±5%.

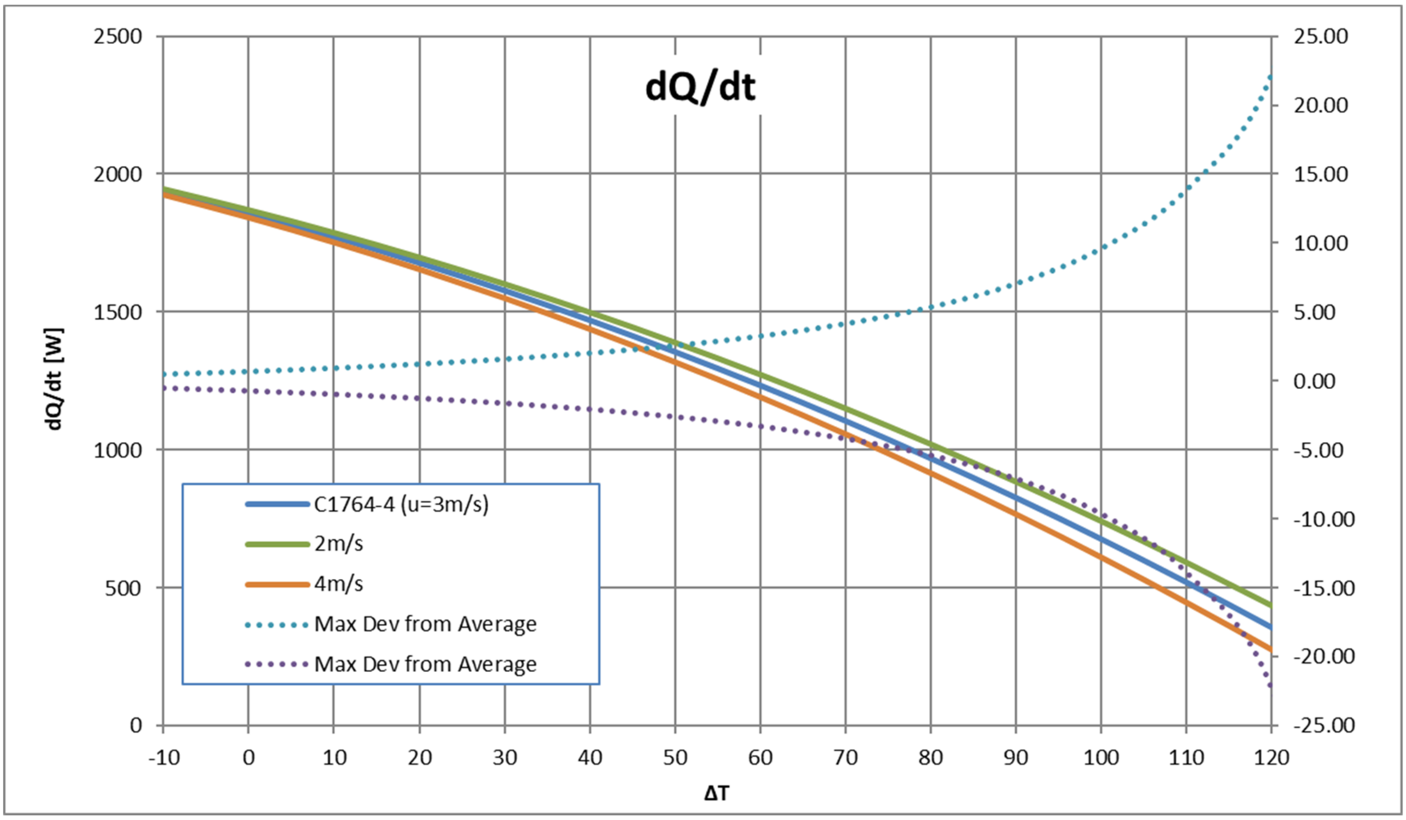
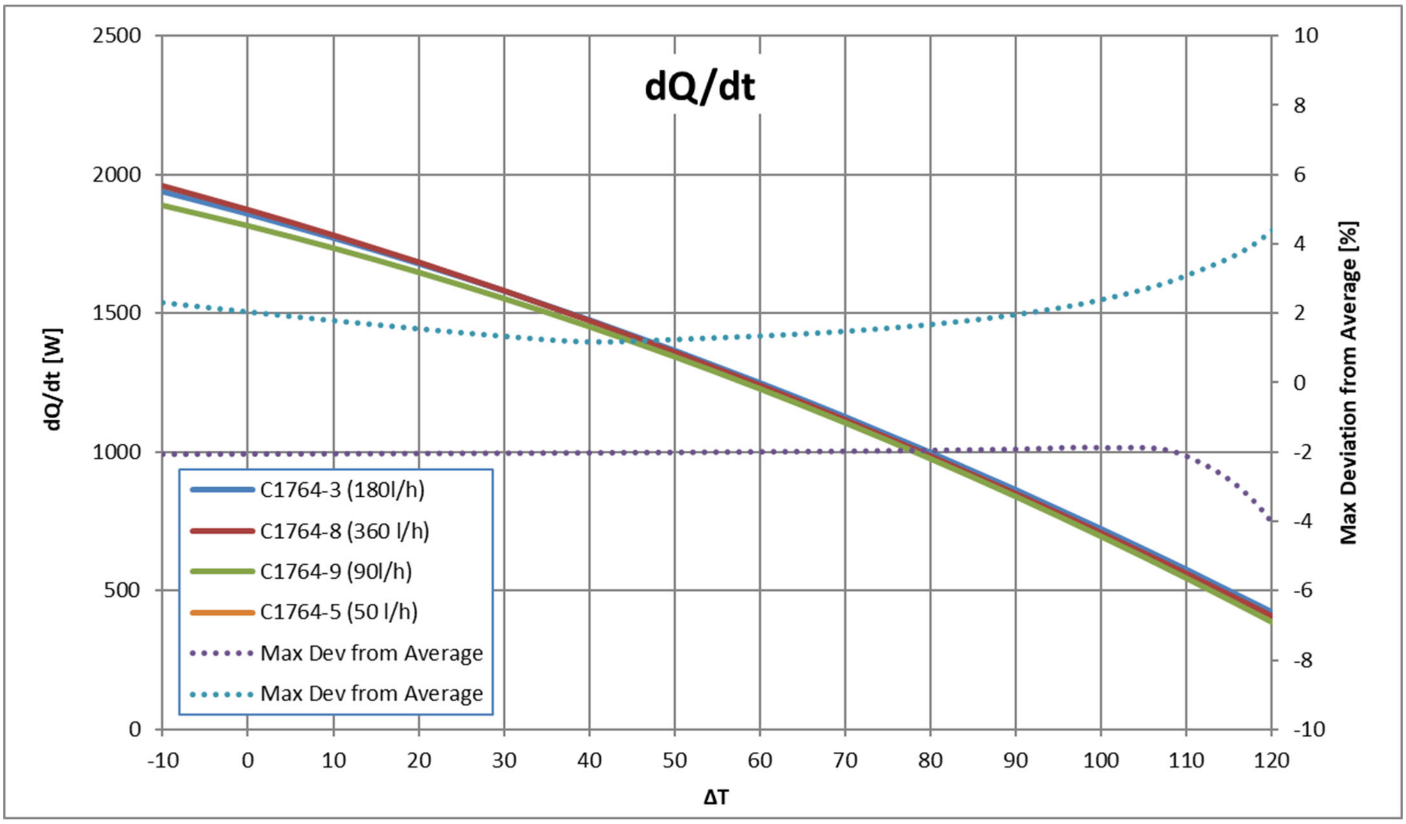


Figure 22: Effect of wind on the thermal performance curve.

8.5 Flow Range variation

The EN ISO 9806:2017 clause 23.3.2.1 recommends using a certain flow rate for testing collectors: "The fluid flow rate shall be set at approximately 0.02 kg/s per square meter of collector gross area. If this is not within the manufacturers' specification, a reasonable flow rate within the specification shall be selected."
Furthermore, there are different theories about flow rate dependencies of the thermal performance. Some manufactures ask for testing at very high flow rates to improve the performance parameters.
To investigate this flow rate dependency, one of the collectors was measured with four different flow rates: Standard flow rate of 180l/h, double flow rate of 360 l/h, half flow rate of 90 l/h and the minimum flow rate which was possible with the current equipment of 50 l/h.



Collector efficiency data

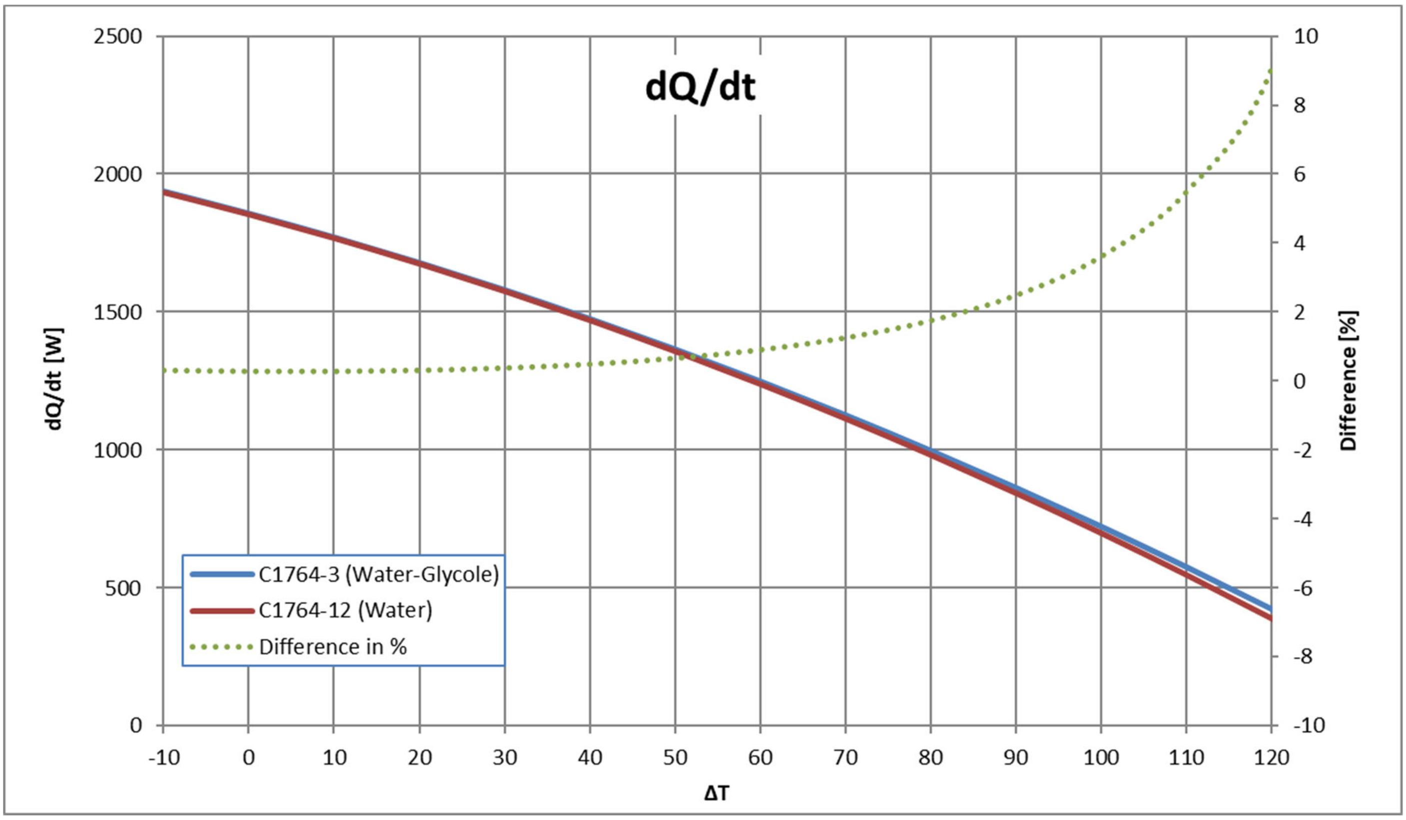
Collector		1764-3 180l/h	1764-8 360 l/h	1764-9 90l/h	1764-10 50 l/h	
EN ISO 9806:2017, EN 12975:2010, prEN12975						
Peak collector efficiency based on hemispherical irradiance	$\eta_{0,hem}$	0.740	0.747	0.724	0.717	--
Heat loss coefficient	a_1	3.32	3.54	3.06	3.21	W/m²K
Temperature dependence of the heat loss coefficient	a_2	0.012	0.011	0.014	0.012	W/m²K²

Figure 23: Effect of flow rate on measured thermal performance

Conclusion: The results are presented in the graph confirm the tendency to lower performance at low flow rate. If the flowrate is doubled, the performance is slightly better at low temperatures (η_0) but not at higher temperatures. The difference is however very small and well within the other uncertainties presented in this section of the report.

8.6 Water / Water-Glycol

According to the EN ISO 9806:2017 any heat transfer fluid can be used for testing. The standard fluid for collector testing is usually water. The laboratories use also water-glycol mixtures or depending on the application high-temperature resistant oils or air. According to the EN ISO 9806 standard, the use of different fluids should not affect the measured thermal performance parameters. To verify this, one of the collectors was measured under identical conditions except for using water and water-glycol using a well-known 33% Ethylene-glycol mixture.



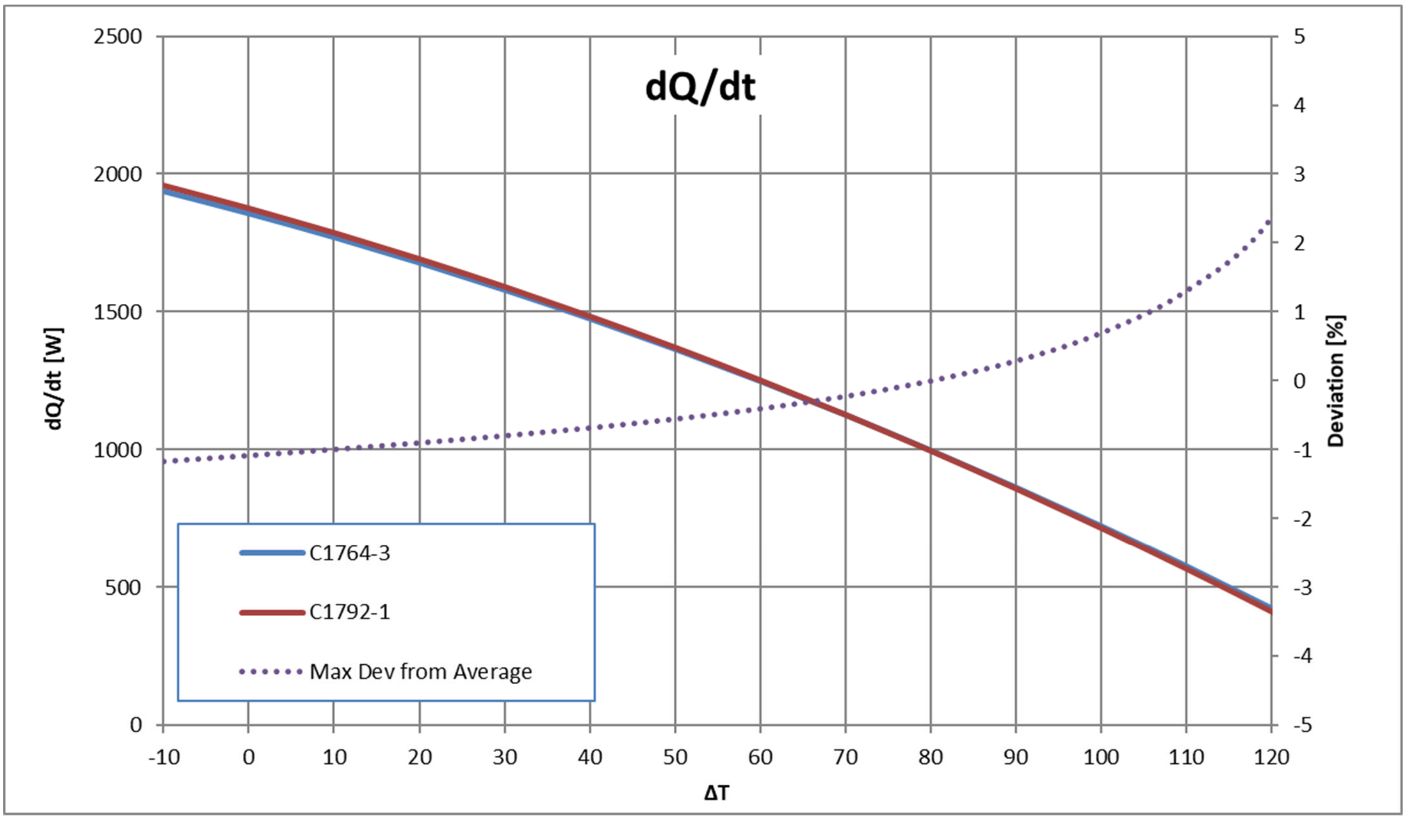
Collector efficiency data				
Collector		1764-3 Water Glycol	1764-12 Water	
EN ISO 9806:2017, EN 12975:2010, prEN12975				
Peak collector efficiency based on hemispherical irradiance	$\eta_{0,hem}$	0.740	0.738	--
Heat loss coefficient	a_1	3.32	3.30	W/m²K
Temperature dependence of the heat loss coefficient	a_2	0.012	0.013	W/m²K²

Figure 24: Effect of heat transfer fluid on measured thermal performance

Conclusion: The difference between the two measurements shows that at lower temperature the difference between the performance curves is very small.

8.7 Time

The collector used for the RRT was measured before and after the RRT under as much as possible identical conditions. This was done to verify that there was no deterioration of the collector during the RRT affecting the results measured by the three labs. The collector was therefore measured at laboratory S in the solar simulator using exactly the same settings before and after the RRT.



Collector efficiency data						
Collector		1764-3 before	1792-1 after			
EN ISO 9806:2017, EN 12975:2010, prEN12975						
Peak collector efficiency based on hemispherical irradiance	$\eta_{0,hem}$	0.740	0.748			--
Heat loss coefficient	a_1	3.32	3.42			W/m^2K
Temperature dependence of the heat loss coefficient	a_2	0.012	0.012			W/m^2K^2

Figure 25: Thermal performance before and after the RRT.

Conclusion: The results is surprising at first sight: The thermal performance after the RTT is slightly better at low ΔT than before. The two measurements are however well within ±1%. Considering the different possible deviations listed in this chapter it is evident that this deviation must be considered as arbitrary which can’t be related to any deterioration or real improvement of the thermal performance of the collector.

8.8 Main conclusion

The iterative tests show that there are several sources of uncertainties not directly linked to “measuring” uncertainties. These additional uncertainties are partly caused by simple physical reasons and by production tolerances that cannot be avoided. Furthermore, the standard allows for some uncertainties that are concessions to industry. Higher precision would be possible but would lead to a disproportional increase of the testing costs and time.

For most of the measurements and considerations it can be seen that the thermal performance curves are not very much affected for temperature differences up to $\Delta T=80K$. For higher temperatures, the deviations are increasing considerably.

All considerations in this chapter are based on measurements of a standard flat plate collector manufactured by a reliable German manufacturer. It is evident, that some of the results would have been different for other collector types and other manufacturers. The deviations and uncertainties presented would most probably be higher for most of the products on the market.

9 Procedures of standards that need to be modified and justification

9.1 Result from the brainstorming on standard

The standard EN ISO 9806:2017 has been published only recently and all the involved testing laboratories were strongly involved in the CEN/TC 312/WG1 which was in charge of this revision. Most of the input of the last years is therefore already incorporated in this standard. The input of the brainstorm on the ISO 9806 is attached as Annex to this report in the appropriate format that must be used for all input to the CEN TCs. All input to the ISO 9806 is currently being collected by the convenor of the WG and is incorporated into a draft preparing the next revision. This input is of course not limited to input from the ECOTEST project. The ISO 9806 is not now managed by the new ISO/TC 180/WG4 which was established in 2018.
The standard EN 12975 is currently in ENQ phase and input to this standard is not possible at this moment. All input of the participating laboratories was already considered in the development of this standard.
As a basis for comparing test results of collector tests as required in several situations such as for market surveillance or in cases of complaints against a product, the net yield calculations (ScenoCalc) could be anchored in the collector standards.

9.2 Procedures of standards that need to be modified and justification

In this RRT no major problems or issues with the procedures were found that would require urgent action for the standards EN 12975 and ISO 9806. The standard has proven to be very robust as the results of the laboratories are found within very narrow limits, even when using different test methods.

9.3 Recommendations to CEN

In view of using net yields (or other methods) which require weather data for their calculation, it is recommended to define appropriate weather data files. The format and content of these data must be agreed on by the relevant TCs and they should be managed by a central entity to make sure that the same they are used for all appliances, similar to the data sets which a managed by ISO. For sure, the availability of reliable weather data is important for the rating of solar thermal appliances but also for heat pumps or for buildings. These data must be adapted from time to time to consider the effects of climate changes appropriately.
The ScenoCalc procedures should be defined in the standards as they are used already now for reliable net yield calculations. These are a good basis for comparing the performance of collectors under different climatic conditions.

10 Conclusion

The result of this RRT show that the standards for solar thermal collectors is very reliable and the uncertainty of the results is very small. The collector standard is therefore a very reliable basis for the ErP. The currently cited standard EN 12975-2 has been replaced by EN ISO 9806:2017. In this standard, all performance rating is based on gross area and aperture area is not used anymore. Much more important is that the whole standard is developed such as to provide a performance rating "per collector" so that collector areas are not necessary anymore for rating purposes. The current standard is furthermore developed such that the indicated performance parameters follow the same format for all solar thermal collectors. Any distinction between different collector types such as flat plate collectors, evacuated tube collectors, swimming pool collectors, glazed and unglazed collectors, etc. is not necessary anymore.

The standard EN 12975-1 will be replaced in 2019 by a standard EN 12975 containing all the ErP relevant Z-Annexes. This standard includes an Annex on how translate and/or recalculate results between the previous standards EN 12985-2, EN ISO 9806:2013, EN ISO 9806:2017 and the current ErP documents 811, 812 and transitional methods.

11 ANNEXES

11.1 ANNEX 1 TEST PROTOCOL

Project ECOTEST / WP8 **RRT1: Collector** **Test protocol**	ECOTEST **ECO_WP8_009**

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 thermal collector for WP8.

This operative instruction gives the general instructions needed for managing all the aspects related to the tasks of receiving the collector, 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 collector RRT1 is performed with **one** reference collector.

Due to the time restrictions (measurements in summer only) the two step approach is not applicable: RRT1 is one step, depending on the weather conditions and lab capacities ambiguities in the standards may be identified.

~~1. Step is to identify ambiguities and to improve the test protocol~~

~~2. Step is to evaluate the inter laboratory reproducibility~~

~~For the 1st step: After first and second laboratory have performed the tests the results are compared by the WPL and discussed with the laboratories concerned. The test protocol is possibly adapted and the respective laboratory (double according the test schedule) repeats some tests to make sure the two reference boilers are equivalent and to possible check the improved test protocol.~~
~~After this the 2nd step is done which is the RRT with the updated test protocol~~
To take into account variations of parameters additional tests are performed by different laboratories (see clause Parameter variation)

3 References

EN 12975-2 (withdrawn but mentioned in the European legal framework)
EN ISO 9806:2013 (to be withdrawn in 2017)
EN ISO 9806:2017 Solar energy — Solar thermal collectors — Test methods. (publication expected 15.11.2017)
Testing according to ISO 9806:2017 is compatible with previous versions. The main document is therefore EN ISO 9806:2017, but references to previous standards are necessary to cope with the regulations requirements.

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 collector marked with "WP8 RRT1".
  Laboratories can add their own tags for identification.
- Installer manual (ECO_WP8_010_RRT1_InstallerManual)
- Test protocol (ECO_WP8_009_RRT1_TestProtocol, this document)
- Test schedule (ECO_WP8_008_ScheduleAndApplianceTracker)
- Template test results (ECO_WP8_011_ RRT1_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 collector is installed according to the installation manual and as prescribed by the ISO 9806:2017.
Hydraulic connectors: Every test labs will receive its own connectors to the collector as an interface to the laboratories hydraulic system. The two unused connectors of the collector are closed by the WPL and shall not be opened by the TLs. Collector in- and outlet for the test will be marked by the WPL.
Pictures of the collector shall be made before / during / after the test.

9 Testing

The following tests are performed

9.1 Thermal performance and incidence angle modifier

The test is carried out according to ISO 9806:2017 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 Annex A of the ISO 9806:2017 and in addition as required for the energy labelling regulations using the template (ECO_WP8_012_RRT1_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
Flow rate		Thermal performance	
Different Flow scheme		Thermal performance	

Other ideas? Indicate who could do which additional tests TO BE DISCUSSED AT WEBMEETING

11 Calculations

In addition to the Standard measurements the parameters used for the ERP shall be calculated and reported: (ECO_WP8_011_RRT1_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_011_RRT1_ResultDataSheet_lab* and replace “lab” by spf, ise or itw.
Do not wait for anything and immediately send the collectors using the box to the next recipient in the list indicated in the *ECO_WP8_008_RRT1_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_RRT1_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_RRT1_ScheduleAndApplianceTracker*
NOTE: Please check on current versions of the schedule on: http://ecotest.dgc.eu/wps/wp8/rrt

14 Task for sender and recipient

<u>Overview: Monitoring of the testing for RRT</u>

All RRTs of the project will be organized according to the following table:

What	Information Action	Who	When (deadlines)
Receipt of the collector	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 collector 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 collector to prevent from damage during the transportation.

- Pack the collector 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 collector is sent, send an e-mail with the expedition sheet to the reference person of the recipient to make him aware of the delivery: 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 collector.
- Make incoming goods control, make photos of the collector 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 collector.
- 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 ISO 9806

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

WPL:
General proposals / questions / errors to be discussed/implemented during the next revision are collected by the convenor in a "ISO_9806_2017(E) – Work Version". These items will be marked with an ** in the WPL column. (see comment 1 for example)

Nr	Line number	Clause/ Subclause	Paragraph/ Figure/ Table	Type of comment	Comments	Influence on Protocol? / To be included as variation of parameter (iterative test)?	Observations of the WPL
1	ise	4 Symbols			a8 is named „radiation loss"	Rename " temperature loss 4th order"	** Not relevant for ECOTEST
2	itw	22.1.2	-	te	The specific heat capacity and density of the fluid used shall be known to within ±1 % over the range of fluid temperatures used during the tests.	Although during testing the specific heat capacity and density of the fluid used shall be known to within ±1 % over the range of fluid temperatures the simulation tool used for the prediction of the yearly yield uses fixed values. It is proposed to evaluate test data using fixed values and compare the results with the ones gained using the temperature depended values	Will be included in the Test protocol. Agree on a fixed value. -------------------- SPF will make a comparison measurement water / water-glycol. ------------------

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
							itw made investigation, probably extract of results
3	ise	22.1.3 Pipe work and fittings		te	Additional connections insulated or not?	Suggestion: yes	ok for ECOTEST **
4	ise	23.2 Preconditioning		te	Preconditioning Cleaning of collector	Only to be performed by first test lab If tested outdoors, collector is to be cleaned every morning	ok for ECOTEST
5	itw	23.3.2.1	-	te	The fluid flow rate shall be set at approximately 0,02 kg/s per square meter of collector gross area. If this is not within the manufacturers' specification, a reasonable flow rate within the specification shall be selected.	To check the impact of the flow rate on the thermal performance of the collector a variation of the flow rate is proposed under eta0 conditions	SPF will make different flow rates. Fan: Different flow rates. Provide paper about flow rate.
6	spf	23.3.2.1	-	te	The fluid flow rate may have an impact on performance, especially at elevated temperatures. Impact is not well known.	Check influence using different flow rates. Scientific basis is poor.	
7	ise	23.3.2		te	Mass flow	Use standard mass flow of 0.02 kg/sm^2	ok for ECOTEST
8	spf	23.3.3.1		te	The collector shall be tested at diffuse irradiance levels of always less than 30 %.	In some regions Gd it is almost never <30%. Can results of testing at higher Gd be used somehow ?	** not relevant for ECOTEST

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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
9	ise	23.3.1		Te	flow pattern	Define exactly which connection is to be used for inlet and outlet	** No dead pipes, SPF will mark
10	itw	23.4.1	-	te	If possible, one inlet temperature shall be selected such that the mean collector temperature is within ±3 K of the ambient air temperature.	To check the influence of the temperature difference between the mean fluid temperature and ambient temperature at the highest performance during the measurement a variation of the temperature difference is proposed	SPF will make a measurement on the Simulator with different delta T
11	spf	23.4.2		te	When testing in a solar simulator, at least two independent data points shall be obtained for each fluid inlet temperature	We have seen sometimes transient effect, i.e. not the same performance for stepping up and stepping down. Check 2 points up and 2 points down?	SPF will do it with longer time steps
12	itw	23.4.5	-	Te	The change in inlet temperature shall be done after each test sequence has been completed. Data recorded during this “step-change” period shall not be included in the test data. The inlet temperature shall be kept stable within ± 1 K during each test sequence.	To check the influence of the step change period on the overall results it is proposed to evaluate test results with and without step change	itw will make different analysis of the measured data.
13	dtu	23.4.5		ge	For the QDT method, the inlet temperature is fixed for each test sequence day.	This requirement might limit full exploitation of the advantages of the QDT method. A variable inlet temperature during a test sequence could be beneficial because it decouples	itw will (try to make – if time is ok) a test in this.

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
						solar radiation with the inlet temperature, thus gives more accurate determination of collector parameters. It is also better to determine Cf. The aim of the comment is not to change the existing method but to bring discussion on the possibilities of a variable inlet temperature.	
14	ise	23.6.1		te	Conditioning and measurement period SST	Use standard conditioning and measurement period (15 min)	Leave it up to the test lab. As required by the standard
15	dtu	23.6.2.2		te	The averaging interval of the measured data could be specified in order to avoid issues of large uncertainty in collector efficiency measurement for some collectors if the averaging interval is too short.	Experience of collector efficiency measurement of PVT collector at DTU shows that there is a large measurement uncertainty of collector efficiency if the averaging interval of the measurement data is too small eg. < the time constant of the collector.	Fan can provide some data to illustrate (Document ECO_WP8_033)
16	ise	24.1.2 Steady-state And 24.1.3 QDT		te	Collector model: For SST the usage of complete model is mandatory while for QDT several exceptions are named → does that make sense?? If a4 is to be determined in SST	Move whole passage with exception to general part 24.1.1	** Exceptions apply also for SS Proposal to introduce a new section in tht standard where the exceptions are defined.

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
					A) Measurement or longwave irrad. is required → contradiction with Table 5 B) Variation of longwave irradiance is required Is determination of a3 / a6 /a7 is mandatory for SST → 3 wind speeds in every measurement?	Suggestion RoundRobin: If SST is used, use reduced model with eta, a1, a2	for ECOTEST RRT: eta, a1, a2
17	spf	24.1.3.		te	Kd is either calculated from IAM i.e. Kd=Kd(Kb(thetas)) or fitted as constant. This is double definition of the same parameter.	Fit the same data using formula (13) with Kd=Kd(Kb(theta)) to see difference to Kd=fitted as constant.	Stephan Fischer can do something on that
18	spf	25		te	Cp Check whether the different methods give the same results		We will compare different Cps
19	itw	25.4	Eq. 19, Table 8	Te	Eq. 19 and the weighting factors in Table 8 are based on the assumption that a very good thermal contact between the different components is given. However they might not be valid in case of collectors using Sydney tubes and/or heat pipes	Redefine eq. and/or weighting factors	Formula works only for Flatplate

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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
20	ise	26.3.1.1 IAM Test procedures General		te	IAM SST always to be measured for 2 angles? Why and which shall than be used for Ambrosetti?		We do it as indicated in the standard. SPF will ask Supplier for glass certificate.
21	itw	26.3.1.2	-	te	The collector shall be operated under stable conditions at different fixed angles for time periods required to reach stable instantaneous efficiencies.	To be comparable to 26.3.1.3 Method 2 and to include the possibility of unsymmetrical IAM from the "left and right" side two 2 measurements (one from "left" one from "right") must be performed for each angle of incidence	If time allows labs using SS will make try.
22	ise			ge	Pictures to be taken	Define exactly which pictures to take. Suggestion: - incoming and outgoing inspection - complete collector installed for testing - close-up of all connections, w/without insulation	AB will propose hat pictures must be taken
23	ise			ge	Handling /storage of collector before / after test	As in Qaist -RR	ECOTest templates have to be used (%)
24	ise			ge	Report sensor types and calibration status?	As in Qaist -RR	ECOTest templates have to be used (%)
25	ise			ge	Report sheet	Use from Qaist -RR	ECOTest templates have to be used (%)

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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
							(%) Comment from WPL: We have to use the protocol as defined in WP2 of ECOTEST.

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