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Results of an Interlaboratory Comparison on Four Different Heat Pumps: Standards on the Test Stand

Ivan Malenković[a,*], Urs Gumbel[a], Christoph Thoma[a]

[a] Fraunhofer Institute of Solar Energy Systems ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany

Abstract

As a part of the review process of the EU Ecodesign and Eco Labelling Regulations, project EcoTest was carried out in order to evaluate the standards used for assessing the efficiency of space, combination and sanitary hot water heaters and to issue recommendations to the relevant CEN Technical Committees. Within the project, all technologies with their respective standards covered by the Regulations for the aforementioned products, including some emerging technologies, were assessed in a series of round robin tests performed by accredited laboratories Europe wide. Heat pumps, as one of the acknowledged key technologies in the process of decarbonisation of heat generation in buildings, had a prominent place within the project. Four different electrically driven heat pumps were tested in a series of round robin tests following the latest versions of the relevant standards. In the present paper, selected findings of the project regarding the methodology of the standards, the reproducibility itself and influence of different parameters on the reproducibility of the methods are shown and discussed.

Keywords: Ecodesign; standards; heat pumps; comparison; round robin test

1. Introduction

In order to reduce the greenhouse gas emissions from space, combination and domestic hot water (DHW) heaters, which are responsible for 82 % of the overall final energy consumption in the residential sector within the EU [1], the European Commission introduced requirements for the energy efficiency and labelling of these products with Regulations 813/2013 and 814/2013 and Delegated Regulations 811/2013 and 812/2013 [2-5]. The regulations aim at setting minimum efficiency requirements regarding the seasonal efficiency of the products and obligatory information for the end users on the product efficiency with a labelling system using standardized, reproducible testing and efficiency evaluation methods. The described test and evaluation methods were mostly based on relevant EN standards, with some differences, which were taken into account by issuing mandates to the relevant EN technical committees to harmonise the standards with the regulations [6-7]. The implementation of these regulations started on September 26th, 2015.

Following Article 7 of the aforementioned Commission Regulation and Commission Delegated Regulation, these documents are currently in the process of revision taking into account the advancements in the market products and the applicability of the current testing methodology. In order to evaluate the applicability of the test standards, which are the basis for the performance evaluation of the products covered by the Regulations, the European Commission in cooperation with CEN asked for an action to evaluate and improve, if necessary, the relevant standards.

A group of 22 accredited laboratories gathered in a consortium won an open tender with their proposal for the project EcoTest with the aim to evaluate the standards and formulate recommendation for the CEN TCs regarding possible improvements.

* Corresponding author. Tel.: +49 761 4588-5533; fax: +49 761 4588-9533.
E-mail address: ivan.malenkokvic@ise.fraunhofer.de

2. Project EcoTest

Project EcoTest started in October 2017 and finished in July 2019. It gathered 22 accredited laboratories covering all technologies in the scope of the Ecodesign and Eco Labelling Regulations for space, combination and DHW heaters. The aim was to assess the inter-laboratory reproducibility, intra-laboratory repeatability and variability by evaluating the testing and evaluation methodology used for the implementation of those regulations. The work also aimed at commenting on the applicability and understandability of the relevant standards and their applicability in the light of market surveillance, minimise the room for different interpretations and to suggest improvements to the CEN/TCs. The structure of the project is shown in Figure 1 (left).

The work programme consisted in a series of round robin tests based on the latest versions of the relevant standards that were followed by a detailed analysis of the results for each of the technologies (product groups) in scope, **오류! 참조 원본을 찾을 수 없습니다.** (right).

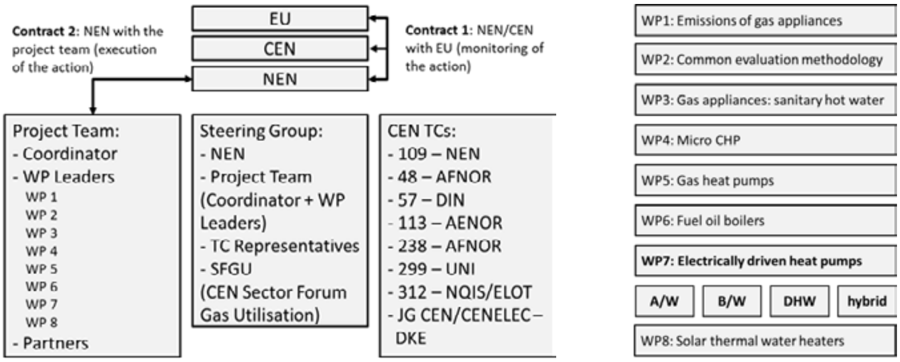

Figure 1: Structure of the EcoTest Project (left) and technologies covered within the Work Packages (right)

Besides the execution of the test and analysis of the results, the participating experts were scrutinising and commenting all applied standards. CEN/TCs were directly involved in the project work through liaisons, which facilitated a first-hand, continuous communication between the project and the CEN experts.

The outcome of the project was put into a series of reports. The main findings were collated in the Project Report. All documents were sent to the EC for approval. The publication is expected by the end of 2019.

3. Execution of the tests on electrically driven heat pumps and methodology evaluation

Within the Work Package 7 for electrically driven heat pumps, four round robin tests (RRTs) on four different appliances were executed. An overview of the main appliance data, applied test conditions and standards used is given in Table 1. A total of 8 laboratories took part in the testing. However, not all laboratories participated in all RRTs which negatively influenced the possibilities for statistical evaluation of the results in some cases.

As three out of four standards were in the process of revision at the beginning of the project, CEN/TC 113 provided the final versions of the revised standards, which had some differences in comparison to the versions in use at the time. This ensured the up-to-dateness of the results and comments, but also imposed a challenge for the participating laboratories, since some of the procedures were new (e.g. for hybrid heat pumps) and executed for the first time by most of the laboratories. This had as a consequence that the focus of RRT4 (hybrid) was rather on providing feedback on the applicability of the newly developed method and the understandability of the method description than on the repeatability or reproducibility.

All laboratories reported their values using templates which were created and distributed for each of the round robin test. A generic template for all appliances within the EcoTest project was common to ensure comparability of the results. However, this document had to be adapted to the specific needs and features of each of the appliances.

Table 1: Overview of the main appliance data, applied test conditions and standards for all four round robin tests

	RRT1	RRT2	RRT3	RRT4
Main appliance data				
HP type (source/sink)	outdoor air / water	water / water	indoor air / DHW	outdoor air / water
Capacity control	inverter	staged (2)	no	only gas burner
Indoor liquid pump	integrated	integrated	-	integrated
Outdoor liquid pump	-	not integrated	-	-
$P_{designh}$ [kW]	12	32.2	-	7 (whole unit)
Installation	outdoor	indoor	indoor	indoor
Water tank capacity [l]	-	-	300	-
DHW set temperature	-	-	55 °C	-
Profile / smart control	-	-	XL / no	-
Acoustic tests	yes	no	no	no
Test conditions and standards used				
Climate	average, “A”	average, “A”	average, “A”	average, “A”
Water flow indoor HX	fixed	fixed	-	fixed
Temperature indoor HX	variable outlet	variable outlet	-	variable outlet
Water flow outdoor HX	-	fixed	-	-
Temperature application	low (35 °C)	medium (55 °C)	-	medium (55 °C)
Liquid pump indoor	integrated	-	-	-
Standards implemented	EN 14511 [8], EN14825 [9], EN 12102-1 [10]	EN 14511, EN14825	EN 16147 [11]	EN 14511, EN14825

After completing a test, a laboratory first sent preliminary data to the work package leader (WPL) who checked them and gave his consent to the reporting lab to send the appliance to the next laboratory. Final results and selected measurement data were reported to the WPL using the templates, as described above. The WPL processed the received data in the following steps:

1. All received data were first checked for plausibility and reporting errors like signs, units, syntax errors etc. Obvious errors were corrected by the WPL.
2. The data sets were compared to each other and outliers and stragglers were detected using a common analysis procedure, as described below.
3. The key performance values were recalculated from the provided data in order to detect inconsistencies and errors in the calculations.
4. A check of the compliance of relevant values with the permissible deviations defined in the standard was carried out.

All deviations, inconsistencies – obvious or assumed – were protocolled for all round robin tests. The reported data and the found inconsistencies were discussed within the group or in telephone calls or emails between the WPL and the respective laboratory in order to find the cause and to decide whether the whole test or a part of it needed to be repeated or a calculation procedure used revised.

A number of corrections were made in the course of the data evaluation. All corrections have been added to the protocols and the most important ones – influencing the final result – were reported in the Final Report which gives a detailed analysis of the specific results from each of the round robin tests.

4. Main results for electrically driven heat pumps

4.1. Compliance with the procedures

In general, all the laboratories showed a very high level of knowledge regarding the implementation of standardised test methods to different kinds off appliances. Some deviations from the described methodology or the common practice in some laboratories were detected but they could be attributed mostly to the imprecise formulation within the standards and also to translation issues. In this respect, a number of comments to the TC113 consider clarification in the methodology description.

Most issues regarding the compliance with the procedures were observed during the testing of the hybrid appliance since the methods were used for the first time by all laboratories except one. Discussions prior to, during and after the measurements delivered valuable input to the TC 113 and ad hoc JWG TC 113/WG7 – TC 109/WG1 which has the mandate to develop testing procedures for this type of appliances.

4.2. Compliance with the requirements regarding permissible deviations

The laboratories showed a very high level of maintaining the operating conditions within the permissible deviation ranges throughout the measurements. However, some laboratories did exceed the limits in a small number of cases, both for mean as well as for single measured values.

Table 2 shows the deviations of measured values to the operation conditions' target values for RRT1 and Table 3 the same quantities for RRT2. The biggest problem for the laboratories, as expected, was to reach and maintain the relative humidity of the outdoor air within the required tolerances (RRT1, Table 2). Interestingly, all laboratories managed to keep the single measured vales within the tolerance band of ± 1 K. However, the maximum allowed deviation of the mean from the target value was in one case (one laboratory, one operating condition) outside the tolerance band of ± 0.4 K.

Table 2: Deviations of measured to the operation conditions' target values for RRT1 (impermissible deviations marked in bold)

RRT1: A/W Heat Pump					
		deviation of mean values		*deviation of single measured values*	
		permissible deviation	*max*	*permissible deviation*	*max*
Outdoor heat exchanger					
Inlet air temperature (dry bulb)	*°C*	±0.3	0.19	±1.0	0.71
Inlet air temperature (wet bulb)	*°C*	±0.4	**-0.43**	±1.0	-0.83
Temperature difference (db-wb), deviation from 1 K	*K*	±0.3	**-0.41**	-	0.49
Indoor heat exchanger					
Outlet temperature	*°C*	±0.3	0.11	±0.6	0.40
Inlet temperature	*°C*	±0.2	-0.12	±0.5	-0.37
Mass flow	*%*	±1.0	**-1.03**	±2.5	-1.53
Voltage	*%*	±4.0	2.34	±4.0	3.49

All water temperatures, both at the inlet and at the outlet of the appliances, could be kept well within the respective permissible deviation bands, as well as the voltage. Keeping the mass flow rate constant seems to be a challenge for some laboratories. In RRT2, one laboratory exceeded permissible deviation for the mass flow rate mean value by far in case of one operating condition, which, however, did not significantly influence the final result of the measurement.

Table 3: Deviations of measured to the operation conditions' target values for RRT2 (impermissible deviations marked in bold)

RRT2: W/W Heat Pump				
	deviation of mean values		*deviation of single measured values*	
	permissible deviation	*max*	*permissible deviation*	*max*

Outdoor heat exchanger					
Outdoor HX inlet temperature	*°C*	±0.2	0.1	±0.5	-0.3
Outdoor HX outlet temperature	*°C*	±0.3	0.09	±0.6	0.21
Indoor heat exchanger					
Indoor HX inlet temperature	*°C*	±0.2	0.1	±0.5	0.35
Indoor HX outlet temperature	*°C*	±0.3	0.15	±0.6	0.39
Mass flow rate indoor HX	*%*	±1.0	**-1.08**	±2.5	1.99
Mass flow rate outdoor HX	*%*	±1.0	**1.99**	±2.5	**-4.21**
Voltage	*%*	±4.0	2.24	±4.0	2.79

In Table 4, the deviations of measured to the operation conditions' target values for the indoor-air DHW heat pump during the draw-off test are shown. The provided values are considering only the periods with draw-offs and not the entire 24 h test. Even though the arithmetic mean values were very well within the permissible deviation range, the single measured values of the indoor air were well outside the range at one laboratory. The temperature of the cold water at the inlet was not always within the permissible ±1 K at two laboratories.

Table 4: Deviations of measured to the operation conditions' target values for RRT3 during Stage E (EN 16147). Impermissible deviations marked in bold

RRT3: DHW Heat Pump (draw-offs)						
			arithmetic mean values for the entire tapping cycle		*individually measured values*	
			deviation of mean values		*deviation from target*	
		target value	*permissible deviation*	*max*	*permissible deviation*	*max*
$T_{air,dry\ bulb}$	*°C*	20	±0.6	0.27	max. ±1.5	**2.49**
$T_{air,wet\ bulb}$	*°C*	15	±0.4	0.18	max. ±1.0	**3.45**
$T_{cold\ water,inlet}$	*°C*	10	±1.0	-0.72	±1.0	**1.74**

4.3. Reproducibility of the methods

One of the key aims of the project was to evaluate the reproducibility of the standardised test methods and to investigate possible improvements, especially regarding the key performance factors such as seasonal efficiency $\eta_{s,h}$ for heating appliances and η_{wh} for DHW appliances.

After the initial inspection of the data received from the participating laboratories, a number of errors was discovered. In order to evaluate their influence on the final result ($\eta_{s,h}$ or η_{wh}), all errors were divided into five categories:

1. Syntax error or wrong units, no influence on the final result;
2. Problem with the measurement or data acquisition / post processing, no correction possible but no influence on the final result;
3. Problem with the measurement / data post processing, influence on the final result. Corrected by the laboratory;
4. Problem with the measurement or data acquisition / post processing, no correction possible, influence on the final result;
5. Procedure not followed, influence on the final result.

Many small errors occurred in the course of transferring data into the provided templates. These errors were mostly corrected by the work package leader and were not further considered since they are not likely to happen in circumstances outside of this project (category 1). Some errors were attributed to e.g. the wrong setting of the measurement equipment, but did not influence the result such as setting of the voltmeter for one instead of three phase measurement (category 2). In quite a number of cases, the laboratory reported a wrong value or made a mistake in the calculation. These values were then corrected by the laboratory itself and put into protocol (category 3). In a small number of cases, the laboratories did not comply with the procedures or acquired wrong measurement values which did influence the final result (categories 4 and 5). These errors were, however, rather isolated and could be attributed to the novelty of the method (as for hybrid units) or alternative understanding of the procedure. In cases where errors of categories 4 or 5 happened and the measurement could not be repeated, the results were mostly not taken into account for statistical evaluation (if very obvious) or detected as outliers / stragglers during the statistical analysis.

Table 5: Analysis of the error types encountered in the analysis of the reported data

	RRT1	RRT2	RRT3	RRT4
Category 1	47%	31%	60%	48%
Category 2	0%	0%	0%	14%
Category 3	51%	29%	40%	21%
Category 4	1%	0%	0%	4%
Category 5	0%	40%	0%	12%
# Errors	78	48	10	188

Table 5 shows the number of different error types found in the reported data from the four RRTs. The number of errors is taking into account each single value that was affected, including error propagation up to the final figure. It can be seen that most errors were found in RRT4 for the test on the hybrid appliance. That was expected, since the test methods applied were new and the staff performing the tests had no previous experience. Also interesting, that quite a number of errors of category 5 (procedure not followed) were found in RRT2 for the test of a staged water-to-water heat pump. The reason was the same as for RRT4 – these appliances are not so commonly tested in most laboratories.

Quite a large absolute number of errors of category 3 found, especially in RRT1 and RRT2, could be attributed to the issues connected to the measurement of the electricity consumption in non-active operation modes and calculation errors in the data post-processing. These issues were specifically addressed in the recommendations to the TC 113.

The impact of the detected errors in the initially reported values can be seen from Table 6. It shows the differences between the highest and the lowest reported values by all laboratories for $\eta_{s,h}$ and η_{wh} (RRT3) before and after all corrections have been made. In case of RRT1, the difference slightly increased, in most cases, however, it could be considerably reduced.

Table 6: Difference between the maximum and minimum reported values for $\eta_{s,h}$ or η_{wh} from initially reported values and after corrections

max-min	RRT1	RRT2	RRT3	RRT4 separated	RRT4 combined
initial	24.10	33.30	8.09	51.70	19.27
final, after corrections	25.20	14.10 (2.00)	8.09	2.30	7.20

High difference for RRT1 can be explained with different behavior patterns of the unit in some of the laboratories. In one case, the unit performed a defrost cycle at 7 °C outdoor air temperature, which considerably lowered the calculated seasonal efficiency. If these results are removed from the analysis, the max-min value drops from 25.2 to 16.8. Another factor which had a considerable influence on the results in RRT1 and RRT2 was the measurement of the electricity consumption in non-active operation modes. It was found, that the if the standby mode was reached by lowering the thermostat on one hand or by setting the operation mode to "summer" on the other, substantially different electricity consumptions were measured. This influence can be seen in

Table 6: Difference between the maximum and minimum reported values for $\eta_{s,h}$ or η_{wh} from initially reported values and after corrections

in the RRT2 column. In the first case, the final value for max-min is 14.10, in the second it drops to 2.00.

In Table 7, the statistics on the main parameters from all RRTs are shown. The main quantities shown in the table are the following:

- median: median value from all reported values;
- average: arithmetic mean value from all reported values;
- sR: standard deviation;
- minmax: difference between the highest and the lowest reported value for the parameter;
- **minmax/avg**: difference between the highest and the lowest reported value for the parameter, divided by the arithmetic mean value in %. **This quantity was chosen as the main parameter to conclude on the reproducibility**;
- R1 (abs): reproducibility calculated by multiplying the standard deviation by a factor of 2.83;
- R2 (abs): reproducibility calculated by multiplying the standard deviation by a factor of 4.00;
- R1 (%avg) and R2 (%avg): reproducibility calculated as a percentage of the average;
- N test-lab: the number of reported, valid test results. For each laboratory only one result is considered;
- stragglers and outliers: indication whether there are stragglers (an unusual data point which, when examined using e.g. Grubbs' test, Cochran's test or KSD has the probability between 1 % and 5 % of being valid) and outliers (an unusual data point which, when examined using e.g. Grubbs' test, Cochran's test or KSD has the probability of less than 1 % of being valid) and how many.

However, the number of reported values, i.e. participating laboratories in the RRTs was in the context of statistic evaluation relatively low. Thus, the statistic evaluation of the results can be taken rather as a guide to address some of the issues that were found during the tests than as a hard fact in order to finally conclude on the reproducibility of the methods or to provide recommendations for e.g. adjustment of the market surveillance tolerances.

For a number of parameters taken into account a straggler or an outlier were found. The data were then evaluated again without the straggler or the outlier. These values are indicated with (w/o straggler) or (w/o outlier). In presented data sets, not more than one straggler or one outlier per parameter were found, if any. When excluded, the reproducibility improved significantly. However, in some cases a new straggler or outlier have been detected (indicated with "one new straggler / outlier"). The data were not repeatedly evaluated without the indicated straggler or outlier.

The variation of the reported efficiency figures for the air-to-water capacity controlled heat pump (RRT1) was rather high. The main reason for that was the difference in the appliance behaviour during the testing and presumably influence of the control setting during the measurements of electricity consumption during non-active operation modes as well as different possibilities to account for the efficiency losses during on-off operation of the heat pump (C_d factor). If excluded from the analysis, the reproducibility of the results increases considerably. The same observations were made for the water-to-water two-stage heat pump (RRT2).

Table 7: Statistics on main parameters from all four RRTs

	median	*average*	*sR*	*minmax*	*minmax/avg*	*R1(abs.)*	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*N test-lab*	*stragglers and outliers*
RRT1: A/W Heat Pump											
$\eta_{s,h}$ *(%)*	157.60	157.46	7.84	25.21	**16%**	22.17	31.34	14.10%	19.90%	7	(*)
$SCOP_{on}$	4.12	4.08	0.19	0.61	**15%**	0.55	0.78	13.50%	19.00%	7	one straggler
$SCOP_{on}$ *(w/o straggler)*	4.13	4.14	0.13	0.35	**9%**	0.36	0.51	8.80%	12.40%	6	(*)

Sound power (dB) @ 20%	66.80	66.88	1.20	3.10	log scale	3.38	4.78	log scale	log scale	5	one straggler
Sound power (dB) @ 20% (w/o straggler)	66.45	66.41	0.61	1.32	log scale	1.74	2.45	log scale	log scale	4	(*)
RRT2: W/W Heat Pump											
$\eta_{s,h}$ (%)	185.70	185.50	5.49	14.10	**8%**	15.54	21.96	8.40%	11.80%	5	(*)
$SCOP_{on}$	4.94	4.94	0.10	0.27	**5%**	0.28	0.39	5.60%	8.00%	5	(*)
SCOP	4.84	4.76	0.24	0.60	**13%**	0.69	0.98	14.50%	20.50%	5	(*)
RRT3: DHW Heat Pump											
η_{wh}	138.50	138.07	2.69	8.09	**6%**	7.61	10.75	5.50%	7.80%	8	one straggler
η_{wh} *(w/o straggler)*	138.70	138.77	1.97	4.97	**4%**	5.57	7.88	4.00%	5.70%	7	(*)
θ'_{wh} (°C)	53.05	52.98	0.59	1.97	**4%**	1.66	2.35	3.10%	4.40%	8	one straggler
θ'_{wh}*(w/o straggler)*	53.09	53.15	0.35	1.03	**2%**	1.00	1.42	1.90%	2.70%	7	(*)
V_{40} (l)	405.12	398.32	16.31	47.97	**12%**	46.17	65.25	11.60%	16.40%	8	one outlier
V_{40} *(w/o outlier)*	406.23	403.51	7.72	23.20	**6%**	21.85	30.89	5.40%	7.70%	7	one new outlier
RRT4: Hybrid Heat Pump - separated method											
$\eta_{s,h}$ (%)	97.80	97.54	0.86	2.30	**2.4%**	2.43	3.44	2.50%	3.50%	5	(*)
$SCOP_{on}$	2.52	2.52	0.02	0.06	**2.3%**	0.06	0.08	2.40%	3.30%	5	(*)
SCOP	2.52	2.51	0.02	0.06	**2.3%**	0.06	0.09	2.40%	3.40%	5	(*)
RRT4: Hybrid Heat Pump - combined method											
$\eta_{s,h}$ (%)	98.70	100.80	5.84	15.60	**15.5%**	16.54	23.38	16.40%	23.20%	5	one straggler
$\eta_{s,h}$ (%) *(w/o straggler)*	98.70	98.45	2.95	7.20	**7.3%**	8.36	11.81	8.50%	12.00%	4	(*)
$SCOP_{on}$	2.54	2.61	0.17	0.45	**17.2%**	0.48	0.68	18.50%	26.10%	5	one straggler
$SCOP_{on}$ *(w/o straggler)*	2.54	2.54	0.07	0.18	**7.1%**	0.21	0.30	8.20%	11.60%	4	(*)

The sound power measurements showed relatively good agreement of the results among the laboratories. However, the variability of the results is higher than the market surveillance verification tolerance defined by the European Commission of 2 dB. However, if a straggler is removed, the difference between the highest and the lowest reported values drops down to 1.32 dB. Also here, some differences in the appliance behaviour could be observed regarding the fan speed, which has the largest single influence on the overall sound power level. No direct correlation between the applied measurement methods and the obtained sound power could be observed.

A considerably lower variability in the reported efficiencies was observed for the DHW heat pump. The minmax/avg value was 4 % after removing a straggler. Also the values for the reference hot water temperature θ'_{wh} showed a very good agreement for all laboratories. The reported volumes of mixed water (V_{40}), however, showed much higher deviations. One laboratory reported a volume smaller by 36 l or around 10 % from the arithmetic mean of the whole measurement series, which was detected as an outlier. The reason for such a measurement outcome could not be found during the discussion of the results with the laboratory. If removed from the statistical evaluation, the minmax/avg value drops to the same level as for other reported parameters.

The two newly developed test methods for hybrid heat pumps (RRT4) showed a very good agreement of calculated efficiencies among themselves. For the separated method, being the simpler one between the two, the difference between the maximum and the minimum reported efficiency figures was very low – around 2 %. Results from the combined method show a much higher variability, at levels comparable to RRT1 and RRT2. These relatively high values could be reduced by half after removing a straggler.

4.4. Brainstorming on standards

The standards used in Work Package 7 have been repeatedly discussed and revised in the past years. At the time when the round robin tests began, all but one standard were under revision and new versions just about to be published. Meanwhile, all versions of the standards used in the project have been published but most of them are already in a new revision process which will consider the outcome of the EcoTest project.

The cause for an almost on-going revision process is that the heat pump market is developing very fast and the emerging products are increasingly complex with more sophisticated controls and rising application diversity. Therefore, many features of the newly published standards were applied by most of the laboratories for the first time and the comments were collected until the end of the testing period. This gave the group less time to discuss the issues reported and search for possible solutions or investigate them within the round robin tests. A considerable number of comments was handed over to TC113 for further discussion.

5. Conclusions and further steps

There are many different types of heat pump appliances on the market win a variety of different configurations using different heat sources. Not all could be covered by the project. Through the choice of the appliances for the round robin tests, an attempt was made to cover as much features of the standards as possible.

From the analysis of the reported data, certain conclusions, some of which can be generally applied to all conducted round robin tests, can be made. In the WP7 Final Report, a more detailed analysis is provided for each of the tested appliances and used test procedures.

- Very good general understanding of the rather complicated test methods by the laboratories, even for appliances which were not easy to test. However, in certain points the reading of the standards differs among the laboratories. As the complexity of the appliances increases, as well as the type of applications covered, it gets harder to follow all the requirements of the standards.
- The specifications for some procedures in certain measurement cases are quite scattered around the standards and can be hard to understand and to follow by laboratories / engineers with less experience. This is especially the case if in a new, revised standard some changes in formulae, coefficients etc. are made.
- All laboratories have shown a high level of accuracy regarding reaching and keeping all test conditions constant throughout the measurements. In just a few cases, minor deviations outside of the permissible range have been found which in most cases did not significantly influence the final result. The parameters, for which outliers could be found, are in areas which are quite well controllable. A better real-time control of these parameters could be implemented to avoid exceeding the permissible deviations.
- In general, the settings on the appliance may quite vary from one laboratory to the other if no or insufficient information from the manufacturer is available. As the controls get more complicated, the variety of possibilities to reach a certain test condition rises. Thus, with current test methods, the support from the manufacturer has an influence on the reproducibility of the results.
- Differences in the measured values for the electricity consumptions in non-active operation modes have been observed. It has not been completely clarified in all cases whether the laboratories used different settings to reach the operation mode or the appliances behaved differently. It was shown that with alternative settings on the controller different values were measured by the same laboratory, which had a considerable influence on the seasonal efficiency (RRT2: 16 % for $\eta_{s,h}$).
- Quite large reported differences between the highest and the lowest values for seasonal efficiencies ($\eta_{s,h}$) for air-to-water capacity controlled (25.2 %) and water-to-water staged (14.1 %) unit. However, the difference could be diminished by:

  a. calculative elimination of the appliance behaviour influence, influence of the freedoms in calculation of seasonal efficiencies;
  b. using an alternative method for the measurement of the electricity consumption in non-active operation mode (influence of the manufacturer's support).

Even though valuable conclusions and recommendations for the improvement of the relevant standards could be made from the project, many issues – some of which were found in the course of testing and discussions – still remain unsolved. In order to solve some of these issues, further experimental investigation on a broader basis is needed. Therefore, a clear commitment regarding the importance of the standardisation work, followed by financial support for similar joint actions, from both the industry and the policy is needed.

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