BOILeff – Raising the Efficiency of Boiler Installations

Executive Summary

Space heating is the largest component of energy consumption in households in virtually all member states, accounting for 67% at the level of the EU 15, followed by water heating and appliances. Demonstrations based on laboratory analyses show that new condensing boilers achieve efficiencies of more than 100%, both for gas and oil boilers. This contrasts with results of field studies in real conditions which show that the seasonal efficiencies of boilers are up to 15 – 20% lower than under optimal conditions in demonstration cases. While new condensing boilers are already highly efficient with little room for improvement, the installations of heating systems still offer broad opportunities for efficiency improvements. This observation could also be verified by the German research project “Optimus” which dealt with the optimization of installed heating systems.

The general objective in the first project phase was to gather and condense information on existing boiler installations with a focus on the actual quality of these installations resp. on failures and mistakes that are commonly made leading to a decrease of the efficiency of these heating systems. The following tasks were performed:

- Literature analysis of studies and field test reports dealing with boiler efficiencies in practice
- Interviews with market actors
- Analysis of typical weaknesses of boiler installations by performing of 75 audits in Austria, Germany, Hungary, Spain and Greece

The audits revealed the following installation weaknesses:

- Incorrect boiler sizing – no heat load calculation performed (66% of the analysed heating systems)
- Too high exhaust gas losses, surface losses and/or ventilation losses (72%)
- Insufficient insulation of armatures and pipes (93%)
- Missing control systems, e.g. thermostatic valves, etc. (57%)
- No hydraulic balance performed (95%)
- …

In total 27 major weaknesses were identified, summarised, published in a list and communicated to the national stakeholder groups (installers, end-consumers, etc.) in order to raise the awareness concerning energy efficient heating systems. Starting from the observation that there exist serious shortcomings in common heating system installations, the project consortium consisting of the project partners Austrian Energy Agency (Austria), Wuppertal Institute (Germany), Innoterm (Hungary), the Regulatory Authority for Energy RAE (Greece), and the University of Rovira i Virgili (Spain) initiated a project to improve the quality of new boiler installations by developing and testing of two new market approaches.

The first market instrument is called “Declaration of High Quality Installation” (DHQUI). This declaration is included in the contract between installers and end consumers. It provides a checklist of quality criteria for a high quality installation. The second instrument is called “Guaranteed Performance Quality” (GPQU). The installer should be able to pledge a certain seasonal efficiency of his high quality installation.

These two approaches were tested and evaluated by field tests under real conditions in the heating period 2008/2009. For the field tests, typical residential buildings with heat loads up to 20 to 25 kW have been taken into account.

In total, metering results were achieved in 23 gas heating systems, 3 oil heating systems and 3 biomass heating systems in Austria, Germany and Hungary. In average, the gas heating systems achieved a seasonal efficiency of 87.9% (HHV), the two oil heating systems 85.0% (HHV), the pellets system 90.6% (LHV) and the firewood boiler 74.2% (LHV). BOILeff installations outperform standard systems (stock consideration) by 11.9 (gas), 10.0 (oil), 16.6 (pellets) resp. 7.2 (firewood) percentage points. Due to the low number of heating systems with oil and different biomass technologies (and
biomass fuels), for comparison reasons, an in-depth analysis was carried out for gas heating systems (see Table 1).

Table 1 Efficiency of the 14 gas heating systems in comparison to the forecasted values of the GPQU formula. AT stands for Austrian test cases, HU for Hungarian ones. The numbers correspond to the consecutive numbers of the field test objects. (Source: Austrian Energy Agency)

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Measured efficiency [%] based on HHV</th>
<th>Calculated efficiency by GPQU formula 1 [%]</th>
<th>Calculated efficiency by GPQU formula 2 [%]</th>
<th>Deviation of metered value from GPQU 1 [%]</th>
<th>Deviation of metered value from GPQU 2 [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>HU 1</td>
<td>93,4</td>
<td>90,8</td>
<td>91,1</td>
<td>2,6</td>
<td>2,3</td>
</tr>
<tr>
<td>HU 2</td>
<td>90,1</td>
<td>87,3</td>
<td>87,6</td>
<td>2,8</td>
<td>2,5</td>
</tr>
<tr>
<td>HU 3</td>
<td>88,9</td>
<td>87,3</td>
<td>86,3</td>
<td>1,6</td>
<td>2,6</td>
</tr>
<tr>
<td>HU 5</td>
<td>83,8</td>
<td>87,3</td>
<td>86,3</td>
<td>-3,5</td>
<td>-2,5</td>
</tr>
<tr>
<td>HU 6</td>
<td>80,7</td>
<td>87,3</td>
<td>86,3</td>
<td>-6,6</td>
<td>-5,6</td>
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<tr>
<td>HU 7</td>
<td>80,0</td>
<td>87,3</td>
<td>85,0</td>
<td>-7,3</td>
<td>-5,0</td>
</tr>
<tr>
<td>AT 1</td>
<td>86,7</td>
<td>90,8</td>
<td>88,4</td>
<td>-4,1</td>
<td>-1,7</td>
</tr>
<tr>
<td>AT 2</td>
<td>87,8</td>
<td>90,8</td>
<td>88,4</td>
<td>-3</td>
<td>-0,6</td>
</tr>
<tr>
<td>AT 4</td>
<td>82,4</td>
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<td>85,0</td>
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<tr>
<td>AT 5</td>
<td>94,8</td>
<td>93,6</td>
<td>91,9</td>
<td>1,2</td>
<td>2,9</td>
</tr>
<tr>
<td>AT 6</td>
<td>87,5</td>
<td>87,3</td>
<td>85,0</td>
<td>0,2</td>
<td>2,5</td>
</tr>
<tr>
<td>AT 7</td>
<td>91,3</td>
<td>90,0</td>
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<td>1,3</td>
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</tr>
<tr>
<td>AT 9</td>
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<td>-1,2</td>
<td>-0,2</td>
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<tr>
<td>AT 11</td>
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<td>90,0</td>
<td>90,3</td>
<td>-0,2</td>
<td>-0,5</td>
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</tbody>
</table>

The GPQU formula 1 was created by means of German field test results by FH Wolfenbüttel. It shows a mean deviation of 2,89% from the metered values. The GPQU formula 2 was adapted according to the Austrian field test results. The mean deviation, also after including the Hungarian results, is reduced to 2,38%. The GPQU formula 2 shows deviations of more than 3% in five cases, the GPQU formula 2 in only two cases which also indicates that the GPQU formula 2 is more reasonable. The following graph shows the deviations of the metered values from the two GPQU formulas mentioned in Table 1.
Figure 1 Deviations of the metered seasonal efficiencies from the forecasted value; a positive value indicates that the heating system performed better than forecasted by the GPQU formula (Source: Austrian Energy Agency)

The 8 Austrian test cases show a maximum deviation of 3 percentage points of the determined seasonal efficiency from the calculated value. Due to this fact a security band for the guaranteed seasonal efficiency of 3 percentage points may be considered. Unfortunately two Hungarian test cases show a negative deviation of 5% resp. 5.6%. Accordingly, for Hungarian heating systems a larger security band (up to 6%) must be suggested.

The following parameters contribute positively to the seasonal efficiency: (i) boiler is placed in the heated area, (ii) boiler has no bypass valve, (iii) heat dissipation by floor heating system, and (iv) additional solar thermal system. Positive correlations to the seasonal efficiency were analysed for the following parameters: (i) increasing heat and work load, (ii) low over-dimensioning, (iii) low domestic hot water demand, and (iv) high energy demand. Problems could be identified in test cases with low heat loads. In these cases boilers are often over-dimensioned; sometimes installers did not care to perform heat load calculations or there was no suitable boiler model available.

Based on this evaluations carried-out, it is concluded that both concepts could be successfully proved by the results of BOILeff project. Taking into account that there was a random choice of condensing boilers on a different price and efficiency level, it may be further concluded that the achieved performances of installations based on certain brands and models (of this brand) will outperform the values of GPQU formula (based on DHQUI installations)!

In-depth analysis of 14 gas heating systems showed annual energy savings of 106.708 kWh (Ø 7.789 kWh per test case in average for Austria, Ø 7.400 kWh per test case in Hungary); including the 2 oil and the 2 biomass systems the savings accumulate to 140.206 kWh. The CO2eq emissions of the Hungarian test cases were reduced by 8.441 kg/a (Ø 1.407 kg/a per test case), in Austria the reduction amounts to 15.765 kg/a (Ø 1.971 kg/a per test case). In total, the CO2eq savings amount to 24.206 kg/a (Ø 1.729 kg/a per test case), which is reduction of almost 30% on average.
In Austria, presently approximately 62,545 GWh/a are required for space heating and domestic hot water. The Austrian Energy Agency assumes final energy savings of up to 13.3% by a total exchange of the heating stock by BOILEff installations. This correlates to a possible reduction of greenhouse gas emissions of up to 4.74 Mio. t per year. Final energy savings of 4,300 GWh/a and a reduction of greenhouse gas emissions of 890,000 kg/a can be achieved. Innoterm expects energy savings of 3,200 MWh/year in Hungary. URV Crever estimates annual energy savings of about 350 MWh/year in Spain.

When assessing the two new proposed market approaches only small differences exist in the participating countries. The customers as well as the installers regard the DHQUI approach as realistic whereas the GPQU is only partly agreed with at the moment. It seems that too many questions are still open (e.g. the open question regarding an independent arbitrator in case the guaranteed efficiency is not achieved).

Generally the agreement in Austria and Germany is higher than in Hungary, Greece and Spain but the customers’ motivation to implement a high quality installation matches the installers’ in all participating countries: Customers want a high quality installation to save greenhouse gas emissions and money, installers see the possibility to extend their business activities via a clear differentiation from cheap installations.

Because of the higher installation quality, both the customers and the installers expect fuel savings between 5 % and 30 %. The customers principally accept additional costs, which will result from DHQUI and GPQU, though there are some differences between countries regarding the amount of the additional costs. It is agreed that additional costs could be reduced partly by the general integration of heat and electricity meters into the heating system.

The following problems have to be overcome for the future implementation: Insufficient transparency of the installation quality for customers, more personal and time efforts for acquisition and higher efforts for the initial setup by installers.

These obstacles can partly be overcome by the installation of an independent arbitrator, who can mediate in case of problems. Nearly all customers and installers in the participating countries agree to such an institution, though big differences and uncertainties exist concerning the question which institution or person could execute such a role.

An important measure to overcome insufficient transparency for the customer and to reduce time efforts for acquisition of the installer could be the invention of a “Guaranteed Installation Quality Label” for installers who are certified to carry out high quality installations. All customers in the participating countries agree, the installers generally agree as well but show a different grade of agreement in the different countries: Austria 50 %, Germany, Hungary, Spain 70 % to 80 % and Greece 100 %.

Recommendations to the boiler manufacturers focussed on the following issues:

Österreichische Energieagentur – Austrian Energy Agency
- Improvement of the hydraulics of small wall-mounted and floor-standing compact boilers
- Installation of measurement devices in heating systems for achieving automated energy balances
- Reduction of the auxiliary electrical energy consumption in small heating systems for detached and semi-detached houses
- Improving the overall efficiency of integrated heating systems, especially heating systems in combination with thermal solar systems and/or other RES systems for hot water generation and space heating

The BOILeff activities could contribute to a new voluntary measure to increase the energy efficiency in heating systems and could build-up on article 8 (inspection of boilers and heating systems) of EPBD and relate to LOT1 & 2 of the Ecodesign Directive.

Further Information:
www.energyagency.at/boileff

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