

Raising the Efficiency of Boiler Installations (BOILeff)

Guenter R. Simader, Franz Zach
Austrian Energy Agency, Austria

Abstract

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 [1].

Demonstrations based on laboratory analyses show that new condensing boilers achieve efficiencies of more than 100 %¹, 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 ([2], [3]). 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.

Starting from the observation that there exist serious shortcomings in common heating system installations, the project BOILeff consisting of the project partners Austrian Energy Agency, Wuppertal Institute (Germany), Innoterm (Hungary), the Regulatory Authority for Energy RAE (Greece), and the University of Rovira i Virgili (Spain) was initialized in order to improve the quality of boiler installations by developing and testing two new market approaches.

The first market instrument is the “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 the “Guaranteed Performance Quality” (GPQU). The installer should be able to pledge a certain seasonal efficiency of his high quality installation. A field test of about 50 installations during the heating period 2008/2009 was performed to evaluate the practicality and effectiveness of both new approaches.

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

Typical weaknesses of boiler installations

In the first project phase 75 audits of typical residential buildings with a nominal power range of up to 20 – 25 kW have been carried out in Austria, Germany, Hungary, Spain, and Greece to identify and to document the major weaknesses of boiler installations in the different countries. The following installation weaknesses were revealed:

- Incorrect boiler sizing – no heat load calculation performed (66 % of the researched 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 relevant stakeholder groups (installers, end-consumers, etc.) in order to raise the awareness concerning energy efficient heating systems. A summary of results both of performed audits and typical weaknesses are available in [5] and [6].

These results were also the basis for developing of the Declaration of High Quality Installation (DHQUI; see following section) and the Performance Guarantee (GPQU; also introduced in the following).

The DHQUI contains a set of quality criteria for a high quality installation. This declaration should become part of the quotation of the installer to the end-consumer. The GPQU includes a guarantee of the installer to achieve a defined “high” seasonal efficiency of the heating system. This second information to the end consumer justifies the “extra” costs – a high quality installation usually costs more than a cheap “standard” one – and indicates the expected seasonal efficiency and(!) the expected future energy savings of the new heating system.

¹ based on the lower heating value (LHV)

These new services are needed to raise the awareness of the end-consumer in order to differ between high and low quality heating installations and to support the installer to sell more expensive but higher quality installations. Both services were tested and evaluated by field tests of heating systems in the heating period 2008/2009.

Declaration of High Quality Installation (DHQUI) and Guaranteed Performance Quality (GPQU)

Due to missing information in the offers of installers, the customer is not able to evaluate the efficiency of a new heating system. The main selection criterion for the system and the installer is the price. Consequently most customers choose the cheapest offer which is usually not the most efficient one. In the frame of the European project "BOILeff" the Austrian Energy Agency developed two instruments in order to visualise how an optimum of efficiency can be achieved. The first one is a **Declaration of High Quality (DHQUI)**; the second one is a **Performance Guarantee (GPQU)** for highly efficient installations. These two services are supposed to help to establish the system efficiency as a second criterion for the customers' choice beside the initial costs.

The DHQUI contains the main quality criteria for an optimal refurbishment or new installation of a heating system. The compliance of these quality criteria should become part of the quotation of the installers to the end-consumers. This is not only beneficial for the customer but also for the installer, who will be able to prove the value of his work which allows differing from cheap "inefficient" quality.

By the use of the GPQU the installer obtains the possibility to guarantee the end-consumer a certain (high) value for the seasonal efficiency of his new efficient heating system.

In principle before the refurbishment or new installation of a heating system a detailed energy consulting of the customer has to take place in order to design a highly efficient heating system which leads to maximum energy and cost savings.

The Austrian Declaration of High Quality is split into a general part and check lists for the heating system. The general part makes the quality criteria easily accessible and comprehensible for the end-consumer and supplies the installer with arguments for high quality installations and against cheap standard offers. The check lists of the DHQUI provide the quality criteria of a high quality installation and should become a part of the offer of installers.

Using the DHQUI and the GPQU leads to advantages for the end-consumer:

- Increased seasonal efficiency → reduction of fuel consumption and operating costs
- Reduction of maintenance and repair services
- Higher comfort by optimal heat distribution

and the installer:

- Clear differentiation from cheap installations
- Higher turnover rates
- Increased customer satisfaction
- Avoiding maintenance and repair services (in the warranty phase)

The most important criteria that were identified to be crucial for the efficiency of a heating system are:

1.) Boiler and regulation system:

- Dimensioning of the boiler and the domestic hot water system according to a heat load calculation and a calculation of the domestic hot water demand using the national standards.
- Implementation of a boiler with low standby losses and a high efficiency (e.g. condensing boiler).

2.) Heating water pump:

- Performance of a (at least approximate) calculation of the piping network to dimension the heat pump properly.
- Application of continuous RPM-regulated energy efficient EC-pumps for the regulation of the differential pressure, as far as they are external or exchangeable.

3.) Domestic hot water system:

- Application of an optimally insulated storage tank.

4.) Heat distribution and dissipation:

- Insulation of all pipes, armatures, pumps, storage tanks, and of the boiler.
- Implementation of a hydraulic balance of the system.
- Implementation of a room by room temperature regulation (e.g. thermostats).

By the use of the DHQUI and the GPQU the maximum cost-, energy- and CO₂-savings of new highly efficient boilers (e.g. condensing boilers) can be realized.

A detailed discussion showing and explaining the different criteria would be beyond the scope of this paper; the documentation is available in [4]. The different criteria and the implementation possibilities of this declaration by installers were discussed in several stakeholder meetings in the different countries taking into account their perspectives in developing this new service and resulting in updated and country-specific versions of the DHQUI.

In the “Guaranteed Performance Quality” (GPQU) the installer guarantees a certain quality standard of the new heating system to the customer. In principle two issues can be guaranteed: The seasonal efficiency and the annual energy demand resp. the annual savings compared to the old system. Obviously the customer’s behaviour can have a big influence on the energy demand; but also the seasonal efficiency can be influenced by the user. Accordingly at the beginning of the project 3 types of a performance guarantee were suggested:

- (1) Optimal case: The seasonal efficiency *and* the energy savings compared to the old system can be.
- (2) Second case: The energy savings differ fundamentally from the forecasted values due to the individual customer behaviour (rebound effects, changes in use, etc.) which only allows the installer to mention a non-obligatory number; still the seasonal efficiency of the new system can be forecasted in a small security band and therefore be guaranteed.
- (3) Third case (worst case): Neither efficiency values nor energy savings can be forecasted within an acceptable security band due to the customers’ behaviour. The installer can only inform the customer about the energy savings and seasonal efficiencies without obligation.

The results of the field test have shown that methods to forecast the energy consumption or the energy savings are far away from being accurate, but efficiencies can be forecasted very well – in the Austrian field test the deviation did not exceed 3 percentage points in any case. Therefore AEA suggests that method 2.) is the best way for the implementation of a Performance Guarantee. More information about the field test is provided in the following.

The main part of the performance guarantee is an empirical formula to forecast the seasonal efficiency of an optimally installed gas or oil fuelled condensing boiler. This calculation method was developed by the Wuppertal Institute (WI) and was verified and refined by the Austrian Energy Agency (AEA) according to the results of the field test in the frame of the BOILeff project.

The following main criteria of the heating system were identified to be essential for the seasonal efficiency of an optimally installed² boiler:

- Is the boiler located inside or outside the heated area?
- Is the boiler equipped with a bypass valve?
- Are radiators or panel heating systems used?
- Is the boiler fuelled by gas or oil?

By the following formula the installer can forecast the seasonal efficiency of an optimally installed² gas or oil fuelled condensing boiler with a security band of plus/minus three percentage points:

$$\eta_a = 89\% * (1 - 3\%*O) * (1 + 4\%*I) * (1 - 3\%*V) * (1 - 1,5\%*W).$$

The four parameters (O, I, V und W) have to be chosen by the installer according to the specific heating system:

Oil fuelled condensing boiler		O = 1	Gas fuelled condensing boiler		O = 0
Boiler located inside heated area		I = 1	Boiler located outside heated area		I = 0
Boiler equipped with bypass valve		V = 1	Boiler without bypass valve		V = 0
Panel heating	W = -1	Radiators	W = 1	Radiators and panel heating	W = 0

The calculated seasonal efficiency bases on the higher heating value (HHV).

² Optimal installation means that the installation fulfils the high quality level required by the Declaration of High Quality Installation.

Barriers to and expectations of the implementation of highly efficient heating systems

The following informations are based on a survey among 64 customers and 35 installers in the countries participating in the BOILeff project [8].

Nearly all installers in the participating countries agree or partly agree with the following barriers to the success of the DHQUI and the GPQU:

- Insufficient transparency of the installation quality of the heating system: For the customer it is very difficult to differentiate between a good and a suboptimal installation quality (this obstacle can be overcome by DHQUI and GPQU);
- More personnel efforts for the acquisition (advertising and dialogues with customers) and an additional inspection of the heating system;
- More time effort to prepare offers (pre-calculation) for the installation and the controlling of the guaranteed quality;
- Higher efforts for the initial setup of the heating system and the subsequent maintenance are needed.

Some of these obstacles can 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 with such an institution, though big differences and uncertainties exist concerning the question which institution or person could execute such a role.

Installers and consumers expect energy savings of 10 to 30% by the implementation of new heating systems according to the DHQUI.

For the installation of the heating system according to the declaration of high quality the installers in Austria and Germany expect additional costs of 3 to 15% of the total installation costs; 80% of them expect additional costs of around 5%. In Hungary, Spain, and Greece installers expect additional costs of 250 € max. The customers principally accept additional costs as a result from DHQUI and GPQU. It is agreed that additional costs could be reduced by general integration of heat and electricity meters into the heating system.

The probability of realization of the DHQUI appears to be very high to customers as well as to installers whereas for the GPQU major obstacles are seen at the moment. It seems that too many questions are still open (e.g. regarding an independent arbitrator in case the guaranteed efficiency is not achieved).

The customers' motivation to implement a high quality installation matches the installers': Customers want a high quality installation to save greenhouse gas emissions, resources and money, installers expect chances to extend their business activities via a clear differentiation from cheap low quality installations.

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, and most installers agree as well.

For more informations about these issues see [8].

Results of the field test

In the following the results of the Austrian field test are summarised. This field test consisted of 13 heating systems in Austrian households. 9 run with gas, 2 with oil, 1 with pellets and 1 with firewood.

The efficiency values for the oil and gas condensing boilers are related to the higher heating value (HHV), while those of the pellets and the firewood boiler are related to the lower heating value (LHV). This way was chosen, because only the used gas and oil boilers are condensing boilers; accordingly a perfect installation would lead to an efficiency of 100% in all cases. When comparing efficiency values of different energy carriers this fact has to be taken into account and clearly communicated. Furthermore for a meaningful comparison of heating systems with different energy sources the emission factors, specific costs etc. must be added, depending on the purpose of the comparison.

Table 1: Key data and efficiency values of the boilers in the Austrian field test

Nr	Type of building	Fuel	Location	Heat load [kW]	Type of installed boiler	Efficiency [%]	
						GPQU	Measured
1	flat	gas	Vienna	13,1	Wall mounted	88,4	86,7

					condensing boiler		
2	flat	gas	Vienna	4,9	Wall mounted condensing boiler	88,4	87,8
3	single family house	gas	Vienna	11,4	Wall mounted condensing boiler	90,3	N.A.
4	single family house	gas	Maria Enzersdorf (Lower Austria)	4,7	Floor mounted condensing boiler	85,0	82,4
5	small multi family house	gas and solar	Neupurkersdorf (Lower Austria)	22,0	Floor mounted condensing boiler	91,9	94,8
6	single family house	gas	Herzogenburg (Lower Austria)	5,8	Wall mounted condensing boiler	85,0	87,5
7	single family house	gas and solar	Herzogenburg (Lower Austria)	11,2	Wall mounted condensing boiler	89,5	91,3
8	single family house	biomass and solar	Klosterneuburg (Lower Austria)	4,2	Floor mounted wood gas boiler	N.A.	74,2
9	single family house	gas and solar	Linz (Upper Austria)	7,5	Wall mounted condensing boiler	89,0	88,8
10	single family house	oil	Pucking (Upper Austria)	9,8	Floor mounted condensing boiler	85,0	84,2
11	single family house	gas	Pucking (Upper Austria)	12,0	Floor mounted condensing boiler	90,3	89,8
12	single family house	oil	Schwanenstadt (Upper Austria)	8,3	Floor mounted condensing boiler	85,0	85,9
13	single family house	biomass and solar	Seekirchen am Wallersee (Salzburg)	11,0	Floor mounted pellets boiler	N.A.	90,6

The GPQU formula is only valid for gas and oil condensing boilers. Consequently for test cases 8 and 13 there is no forecasted efficiency value. The measurement of test case 3 started too late; therefore no seasonal efficiency could be determined.

In average the gas heating systems performed with a seasonal efficiency of 89,6% (HHV) resp. 99,5% (LHV), the oil systems with 85,0% resp. 90,1%, the pellets system with 90,6% (LHV) and the firewood system with 74,2% (LHV).

Based on [7] the efficiencies for standard systems in Austria were determined to: gas: 76% (HHV), oil: 75% (HHV), pellets: 74% (LHV), firewood: 67% (LHV). Consequently the BOILeff heating systems exceed the efficiency of a standard system by 7,2 (lowest) up to 18,8 percentage points.

By comparing the values of the last two columns it can be stated that the introduced guarantee formula can forecast the seasonal efficiency of a gas or oil condensing heating system within a security band of 3 percentage points. Taking into account that there was a random choice of boilers on a different price and efficiency level basis – although all systems are condensing ones – It may be easily concluded that installers offering a certain brand and certain models (of this brand) the deviation will be even smaller than 3 percentage points when applying GPQU concept (based on DHQUL installations)(!) Moreover the mean deviation between forecast and measurement only amounts to 0,2%.

Apart from the Austrian field test also in Hungary a field test was launched consisting only of gas heating systems due to the predominant role of gas in the Hungarian heat market. The average condensing boiler in Hungarian households performed with a seasonal efficiency of 86,0%.

Combining the results of the 8 Austrian and the 6 Hungarian gas condensing boilers lead to a lot of instructive results regarding the dependency of the seasonal efficiency on different parameters. Among others the seasonal efficiency depends on the heating system's configuration – radiators or floor heating, boiler placed in the heated or in the unheated area, boiler with or without bypass valve, combination with a solar thermal collector (see Figure 1). Positive correlations to the seasonal efficiency were analysed for the following parameters: (i) increasing heat and work load, (ii) low

overdimensioning, (iii) low domestic hot water demand, and (iv) high energy demand. Problems could be identified in test cases with low heat loads.

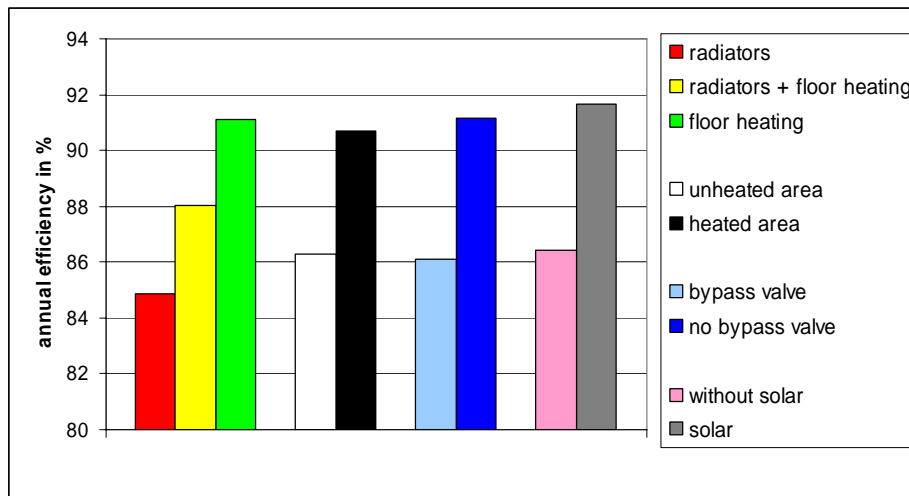


Figure 1: Influence of the heat dissipation system, the position and the type of the gas boiler as well as of a supporting solar thermal system on the seasonal efficiency (Source: Austrian Energy Agency)

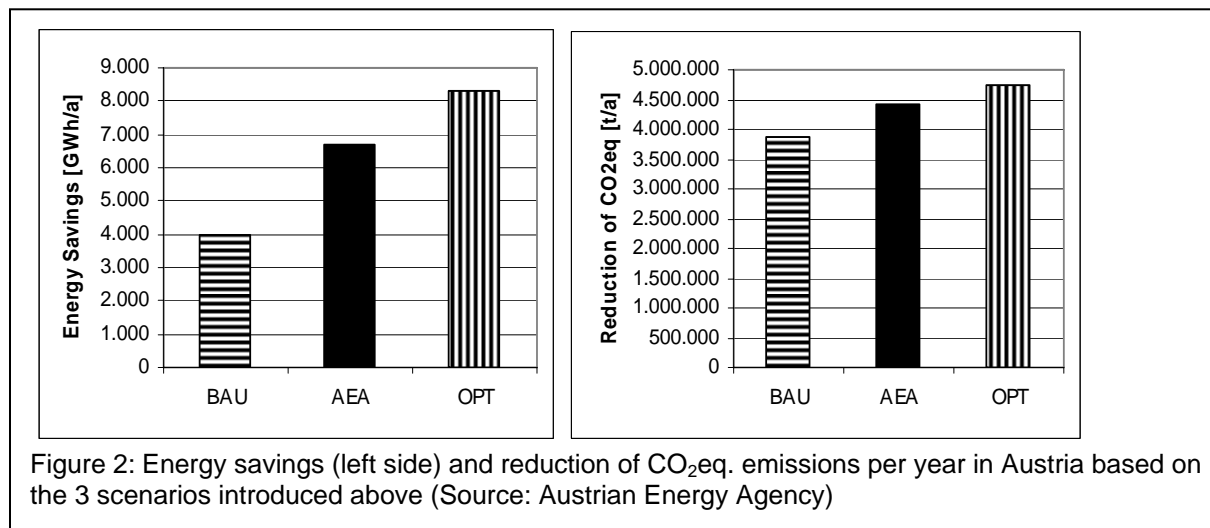
Energy and greenhouse gas savings potential for Austria by highly efficient heating systems

Based on the results of the field tests and data of the heating stock in Austria, the savings potential for end energy and CO₂eq. emissions was calculated. Three scenarios were chosen [9]:

- 1.) BAU – business as usual: The present stock will be replaced by new standard heating systems
- 2.) OPT(imum) scenario: The present stock will be replaced by new highly efficient BOILeff installations
- 3.) AEA scenario: The present stock will only be replaced partly by highly efficient BOILeff systems taking into account appropriate building categories, principal agent problems, fuel switch, etc., the other part will be replaced by new standard heating systems.

Presently, the total energy demand for heating and domestic hot water amounts to 62.545 GWh/a in Austria. Taking into account that new heating systems follow BOILeff quality criteria (DHQUI) energy savings between 2.700 and 4.300 GWh/a can be achieved compared to a business as usual (BAU) scenario; representing a savings potential between 6,4 and 13,3 % (see Figure 4).

The possible annual savings in greenhouse gases are between 3,85 and 4,74 Mio t. Compared to the BAU scenario 0,6 Mio t (AEA scenario) and 0,9 Mio t (OPT scenario) can be realised (see Figure 4). Space heating contributes significantly – with about 14,2 Mio t. CO₂eq. or 15,6 % – to the total annual green house gas emissions of about 91,1 Mio. t. For this reason policy measures aiming to improve heating systems are strongly recommended. These measures will pay-off in significant reductions of green house gases.



Conclusion

The objective of the European project BOILeff was to improve the quality of boiler installations by developing two new services for the heating industry: a “Declaration of High Quality Installation” (DHQUI) and a “Guaranteed Performance Quality” (GPQU).

The DHQUI contains a set of quality criteria for a high quality installation of the heating system. This declaration should become part of installers’ quotations when selling new installations. The second one – the Performance Guarantee – includes a guarantee of the installer to achieve a “high” seasonal efficiency and(!) significant energy savings. This second information to the end consumer justifies the higher investment costs; usually a high quality installation will cost more than a cheap “standard” one.

These new services are needed to raise the awareness of the end-user in order to differ between high and low quality heating installations, creating WIN/WIN/WIN situations for the installers by higher turnover rates, for end-consumers by lower energy consumption in the long run and for the society by increasing the security of supply, by decreasing the import dependency from fossil fuels and by the reduction of greenhouse gases.

In the heating period 2008/2009, both services were tested and evaluated by field tests. In Austria the 8 gas heating systems performed with a mean seasonal efficiency of 89,6% (HHV) resp. 99,5% (LHV) (standard system: 76% (HHV)); the 2 oil system showed an average performance of 85,0% (HHV) resp. 90,1 % (LHV) (standard system: 75% (HHV)); the pellets boiler performed with 90,6% (LHV) (standard: 74%); the firewood boiler with 74,2% (LHV) (standard: 67%). Compared to seasonal efficiencies of standard systems BOILeff installations show improvements of the seasonal efficiency between 7 % and 17 % depending on the fuel used. Taking into account that new heating systems follow BOILeff quality criteria (DHQUI) energy savings between 2.700 and 4.300 GWh/a can be achieved compared to a business as usual (BAU) scenario.

Furthermore, in some countries like Austria it is foreseen that the implementation of the Declaration of High Quality Installation (DHQUI) is also used as additional subsidy criteria when launching boiler exchange programs. Moreover, these new services and quality criteria should build on the activities presently under way concerning the implementation of article 8 (...the inspection of hot water boilers used for heating of buildings) of EPBD (European Energy Performance Directive – 2002/91/EC) and contribute to the discussion when implementing the Ecodesign Directive (Energy using Products – 2005/32/EC) (LOT 1 – Boilers and LOT 2 – Water Heaters).

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