HARP

Heating Appliances Retrofit Planning

# Deliverable 3.1: Labelling methodologies and validation report October 2020

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## ABBREVIATIONS AND DEFINITIONS

| ABBREVIATION | DESCRIPTION |
|---|---|
| SH | Space heating |
| GB | Gas Boiler |
| WH | Water Heater |
| GIWH | Gas instantaneous water heater |
| GSWH | Gas storage water heater |
| EIWH | Electric instantaneous water heater |
| ESWH | Electric storage water heater |
| $H_i$ (or LHV or NCV) | Lower heat value (or net calorific value) |
| $H_i$ (or HHV or GCV) | Upper heat value (or Higher Heating value, or gross calorific value) |
| $\eta_{son}$ | Seasonal "on" efficiency of SH appliance |
| $\eta_s$ | Seasonal efficiency of SH appliance |
| $\eta_{WH}$ | Water heater efficiency |
| $\eta_{30}$ | Efficiency at 30% part-load, defined at lower heat value |
| $\eta_1$ | Efficiency at 30% part-load, defined at upper heat value |
| $P_1$ | 30% part-load thermal capacity |
| $el_{min}$ | Electrical consumption at part-load |
| $\eta_{100}$ | Efficiency at full load, defined at lower heat value |
| $\eta_4$ | Efficiency at full load, defined at upper heat value |
| $P_4 = P_n$ | Full-load thermal capacity |
| $el_{max}$ | Electrical consumption at full-load |
| $P_{SB}$ | Electrical consumption at stand-by |
| $P_{stby}$ | Stand-by heat losses |

| | |
|---|---|
| $Q_{ref}$ | DHW draw-off energy |
| $Q_{fuel}$ | Fuel consumption of water heater |
| $Q_{el}$ | Electrical consumption of water heater |
| $CC$ | Conversion coefficient to primary energy |
| $SCF$ | Smart control factor |
| $k$ | k-values for the water heater correction factor |
| $Q_{ls}$ | Thermal losses of water heater |

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# 1 PROJECT SUMMARY

The HARP project, Heating Appliances Retrofit Planning, aims at raising consumers awareness to the opportunities underlying the planned replacement of their old and inefficient heating appliance. This will be done by supporting the consumer in the identification of the energy (in)efficiency of their current heating equipment and the saving opportunities deriving from its replacement with a more energy efficient solution. The mission is to accelerate the European replacement rate for heating systems, actively contributing to the reduction of energy demand in buildings, in line with the energy efficiency targets set by the EU.

Now is the time to act and raise consumers' awareness about the opportunities of a planned replacement. Taking advantage of the energy label for space and water heating, we can mainstream the labelling concept to the installed heating stock, allowing to use a well-known support decision tool to communicate and motivate the consumer to replace its heating system with modern high-efficiency and renewable solutions. HARP accompanies the consumer decision process, providing an impartial message, based on the energy label and presenting the market solutions that respond to the consumer's heating needs, providing a quantified approach for economic and non-economic benefits and bridging the gap with the market providers and available national incentives. HARP is promoted by key knowledgeable partners in the fields of consumer behaviour, energy efficiency, heating solutions and business models, working directly with the consumer, or indirectly via professionals who are critical multiplying agents. Promoting dynamic efficient heating communities, where all the agents, from the supply to the demand side are committed to an efficient heating market, supporting the consumer to make smarter choices.

# 2 EXECUTIVE SUMMARY

This document describes the energy labelling methodologies for existing space and water heating appliances.

In order to understand if it is possible to apply the same methodology in the five HARP countries, the work started with the state of the art regarding mandatory maintenance and inspection of heating appliances. This helped understanding which data and information is available for a common and a professional user that can be utilized as an input in the labelling methodology. Then, we analysed labelling schemes for existing appliances already in place, in order to look at what has been implemented in different countries.

From this preliminary activity, we developed a labelling schemes for SH and WH appliances. The description and the validation of SH appliances labelling methodology is presented in chapter 4, while the description and validation of WH is presented in chapter 5.

The guideline for the application of the labelling methodologies is presented in deliverable D3.2.

# 3 STATE OF THE ART

The state of the art has been developed as a prerequisite for the development of the labelling methodology in order to address the possibilities and constraints in each of the HARP countries. The aim is to reach a common approach for every country.

For each country, the state of the art addressed two levels:

1) Rules for mandatory inspection of heating appliances
2) Availability of labelling methodologies of installed appliances.

The first point aims at avoiding that the proposed labelling methodology overlaps with national regulation and is used to understand if there is a common base for the definition in the calculation methodology. In other terms, the idea is to understand the barriers for the application of the methodology and the possibilities to reach the consumers.

With the second point, we investigated the applicability of methods in each country and evaluated the definition of a common methodology. In this way, we understood the advantages, the limits and the constrains of each method in order to define the most appropriate one.

## 3.1 Mandatory maintenance/inspection

The analysis of the rules for heating appliances maintenance and/or inspections has investigated the following aspects:

- If there are mandatory rules or not.
- Which are the appliances included.
- Which are the measures that are taken during the maintenance/inspections.
- If the national regulation is based on a national or European standard.

### 3.1.1 Portugal

At the moment, there are no mandatory inspections to heating appliances. Mandatory requirements will exist for heating appliances above 70kW. The parameters to access and actions to deploy during the inspection activities are still under definition within the EPBD transposition process. The regulation will be compliant with the requirements included in the amended EPBD (directive 844/2018. I).

### 3.1.2 Spain

In Spain, the mandatory inspections are defined for:

- Gas Boilers (above 5 kW)
- Oil / solid fuel boilers (above 5 kW)
- Air conditioners (above 5 kW)
- Water heater (below 24.5 kW)

The frequency depends on the typology of appliance:

- Every year – oil boiler
- Every 2 years – gas boiler
- Every 4 years – air conditioning
- Every 5 years – complete inspection of the whichever kind of boiler (including meter, piping, and keys)
- Every 5 year – water heater below 24.5 kW

For the boiler inspection it is required to check the correct operation of the appliances, the pipes, the seals, and the state of conservation, to ensure its durability and security. In the periodic inspection of efficiency, the nominal useful power performance must be at least 80% of nominal power.

The mandatory inspections are defined in the Royal Decree 1027/2007 [1], which approves the Regulation of Thermal Installations in Buildings and it is based on the UNE-EN 15378 (the actual version in force of this European standard is the EN 15378-1:2017 [2])

### 3.1.3 France

In France, annual maintenance and regular inspections are mandatory for the energy directive performance transposition in the buildings since 2009.

The appliances included are:

- Solid fuel, liquid fuel, and gas boilers for maintenance.
- Liquid fuel and gas boilers for inspection while the solid fuel appliances are not covered by inspection yet.

Different measures should be considered for maintenance or inspection.

Maintenance:

- Verification of the boiler (complete appliance, regulation, chimney, safety, seal)
- Cleaning (heat exchange surface, fan – if present, ash)
- Measurement of CO in the indoor environment, measurement of exhaust smoke temperature and $O_2$/$CO_2$ (for automatic boilers)
- Sharing of necessary advices for the good use of the installed boiler, the possible ameliorations within the overall heat installation and the eventual interest of its replacement.

Inspection:

- Assessment of the efficiency
- Emissions tests on site
- Verification of the good state of the installations

The inspections are made by third part bodies.

The current regulations for heating appliances are:

- Decree N° 2009-649 of the 9th of June 2009 [3] relative to the annual maintenance of the boilers that have nominal heating output between 4 and 400 kW.
- Order of the 15th of September 2009 [4] relative to the annual maintenance of the boilers that have nominal heating output between 4 and 400 kW.
- Decree n° 2009-648 of the 9th of June 2009 [5] relative to the boilers controls that have a nominal heating output higher than 400 kW and lower than 20 MW.
- Order from the October 2nd of October 2009 [6] relative to the boilers controls that have a nominal heating output higher than 400 kW and lower than 20 MW

This regulation is under review.

### 3.1.4 Italy

In Italy, the D.lgs 192/05 [7] defines the “thermal plant” as a technological system for space heating or space cooling with or without domestic hot water, independently from the energy vector (e.g. wood, biomass, natural gas, solar, wind).

The DPR 74/2013 [8] prescribes the periodical maintenance and inspections. The revisions must be recorded in the heating system booklet. The appliances are:

- Gas Boilers (above 10 kW)
- Oil / solid fuel boilers (above 10 kW)
- Air conditioners (above 12 kW)

The law defines maintenance, efficiency check and inspection:

1. The maintenance is mandatory, but the periodicity is defined by the manufacturer (and it should be written in the appliance booklet). The maintenance should include all the actions needed to preserve the normal operation (check the complete appliance, safety, cleaning of surfaces). These actions should be recorded in the appliance booklet, together with the safety usage suggestions for the user and the deadline for the following maintenance.
2. Efficiency check (also referred as combustion smoke check or “green/blue sticker”). The measurement of efficiency from the smoke is mandatory with a periodicity that depends on the appliance (see Table 1). The technician in charge of the efficiency check must write the report and submit it to the competent authority.
3. The inspection is performed by a third body for:

- Heating systems did not submit the report on efficiency check.
- Heating system is older than 15 years.
- Heating systems have a capacity higher than 100 kW.
- Heating systems present an efficiency level below the limit (defined in annex B)

Table 1 – Italian legislation about heating appliances maintenance

| Typology | Fuel | Size [kW] | Frequency [years] | Report |
|---|---|---|---|---|
| System with heat generator and flame | Liquid or solid | 10 < P < 100 | 2 | Type 1 |
| | | P > 100 | 1 | |
| | Gas | 10 < P < 100 | 4 | Type 1 |
| | | P > 100 | 2 | |
| Chiller or Heat pumps | Electrical driven (compressor) or gas fired | 12 < P < 100 | 4 | Type 2 |
| | | P > 100 | 2 | |
| | Compressor with endothermical engine | P > 12 | 4 | Type 2 |
| | Thermal energy | P > 12 | 2 | Type 2 |
| District heating | | P > 10 | 4 | Type 3 |
| Combined heat and power | | W < 50 | 4 | Type 4 |
| | | W > 50 | 2 | Type 4 |

Note1: The Regions are delegated to possible variation of this table.

Note2: The efficiency check should be also performed when there is a modification of the heating appliance or the installation of a new one.

The Regions (or autonomous provinces) are in charge to verify the efficiency check, define how to collect the data and perform the inspections.

The efficiency check is done according to UNI 10389:2019 [9]. The smoke analysis is performed at full load measuring: CO, smoke index (correlated to PM), $O_2$ or $CO_2$, $T_{smoke}$, $T_{air}$, $T_{water}$ delivered, fuel consumption.

From these values the efficiency is calculated according to the national standard.

### 3.1.5 Germany

In Germany, the maintenance is mandatory and must be carried out twice during the 7-year period during the appointment of the competent district chimney sweeper and a fireside notice must be submitted (regarding Chimney Sweeper Craft Law).

The appliances included are hearth, gas and oil fireplaces, solid fuel combustion plants. During the inspections the following activities should be carried out:

- Exhaust systems = chimneys / flue pipes: All chimneys and flues in the house are inspected from outside and inside the building. This means that from the top floor or storage in all floors to the basement these are to be checked.
- Connecting pieces = exhaust pipes / flue pipes: All in-house connectors are inspected from the outside and from the inside (e.g. flue pipes of stoves, open fires, oil or gas firing systems).
- Fireplaces: All in-house fireplaces are to be visually inspected. The distances to combustible components and the proper condition of the fireplaces are checked.
- Combustion system: The combustion air facilities for fireplaces are being tested (openings, supply lines, room volume of the installation rooms, air exhausting devices such as extractor hoods).
- Fuel Storage - Moisture Measurement: Proper storage of solid fuels (e.g. logs, pellets, wood chips) should be considered. A moisture measurement of the fuels used must also be carried out and documented in accordance with the 1st Federal Emission Control Ordinance.

The national implementation of EN 15378 (DIN EN 15378) is used as a base for the regulations. The national bodies that defines the regulations are:

- Chimney Sweeper Craft Law (SchfHwG)
- Federal Sweeping and Checking Order (Bundes-KÜO)
- Federal Emission Control Act (BImSchG)
- Regulation on small and medium-sized combustion plants (BimSchV)

### 3.1.6 Summary

Table 2 presents the summary about the mandatory maintenance/inspections of heating appliances.

Portugal is defining the rules for mandatory maintenance and inspections and cannot be compared to the other countries.

The HARP countries present differences on the threshold of the thermal capacity and the periodicity.

The standard used to perform the emission test is the same in Spain and in Germany, therefore it is the national implementation of EN 15378, while it is different in Italy (a UNI standard) even if all cases the combustion efficiency is calculated.

Table 2– Summary about mandatory maintenance and inspection of heating appliances HARP countries.

| | Portugal | Spain | France | Italy | Germany |
|---|---|---|---|---|---|
| Appliances | Heating systems (above 70 kW) | Gas Boilers (above 5 kW)<br>Water heaters (5 kW)<br>Oil / solid fuel boilers (above 5 kW)<br>Air conditioners (above 5 kW) | Gas Boilers (above 4 kW)<br>Liquid fuel boilers (above 4 kW) | Gas Boilers (above 10 kW)<br>Oil / solid fuel boilers (above 10 kW)<br>Air conditioners (above 12 kW) | Hearth<br>Gas and oil fireplaces<br>Solid fuel combustion plants |
| Periodicity | | 1 year – oil boiler<br>2 years – gas boiler<br>4 years – air conditioning<br>5 years – complete inspection for boilers and water heater (below 24.5 kW) | 1 year | 1 year – solid/liquid fuel boilers with P > 100 kW<br>2 years – solid/liquid fuel boilers with 10 kW< P < 100 kW<br>2 years – gas boilers with P > 100 kW<br>4 years – gas boilers with 10 kW< P < 100 kW | twice during the 7-year period |
| Measurements | To be defined | Energy efficiency according to UNE- EN 15378 (from emission test) | Emission test | Energy efficiency according to UNI 10389 (from emission test) | Energy efficiency according to DIN EN 15378 (from emission test) |
| References | No reference | [1] [2] | [3] [4] | [5] | |

## 3.2 Labelling methodologies

For each country, the analysis of existing labelling schemes for installed appliances has investigated the following aspects:

- Existence of a labelling scheme for old appliances and clarification if it is mandatory or voluntary.
- Included appliances.
- Calculation method considering the simplification and the assumptions.
- Inputs required.
- Outputs given.
- Database availability.

### 3.2.1 Portugal

In Portugal there is not any labelling scheme for installed appliances in force.

### 3.2.2 Spain

The Spanish industry association FEGECA introduced a voluntary scheme for installed appliances [10]. The aim is to replace the old and not-efficient appliances in order to reduce the greenhouse gasses emission and to promote the energy efficiency with the same level of thermal comfort.

This campaign claims to raise awareness of the state of the equipment and to inform about the existence of more efficient alternative technologies.

Figure 1 shows the indication of energy label proposed by FEGECA. The layout recalls the European label of heating appliances [11]. The class is defined as a function of:

- Boiler Age
- Technology

The combination of these two parameters defines the label:

- A+ - condensing boiler with a control
- A – condensing boilers from 2015
- B – condensing boilers before 2015
- C – air-tight boilers with age lower than 15 years
- D – atmospheric boilers with age lower than 15 years
- E – boilers with age between 15 and 20 years
- F – boilers with age between 20 and 25 years
- G – boilers with age higher than 25 years


Figure 1 – Energy label of old boilers. FEGECA.

FEGECA gives the indication of temperature control class depending on the type of control as indicated in the Commission Communication 2014/C 207/02 [12].

| Eficiencia según control de temperatura. | | |
|---|---|---|
| Clase I | 1% | Encendido/apagado |
| Clase II | 2% | Con sonda exterior modulante |
| Clase III | 1,5% | Con sonda exterior apagado/encendido |
| Clase IV | 2% | Encendido/apagado con control TPI (ciclos de encendido y apagado de quemador) |
| Clase V | 3% | Modulante |
| Clase VI | 4% | Modulante con sonda exterior y curva de compensación |
| Clase VII | 3,5% | Encendido/apagado con sonda exterior y curva de compensación |
| Clase VIII | 5% | Modulante multisensor temperatura interior |

Figure 2 – Indication con control class. FEGECA.

### 3.2.3 France

As in Spain, the French national heating association UNICLIMA proposed a voluntary scheme for installed appliances [13]. The labelling scheme is applied to liquid fuel and gas boilers.

The method is defined establishing the seasonal efficiency according to Commission Regulation (EU) No 813/2013 [14], Commission Regulation (EU) No 811/2013 [11] and Commission Communication 2014/C 207/02 [12].

The calculation is based on default values researched in the regulations and norms appliable to gas boilers and fuel boilers:

- The nominal power, the part load power, the ignition power and the stand-by losses are taken from the rules of the calculation method "ThC_Ex" (Table 73 for the gas boilers and 74 for the oil boilers) [15]. These values have been implemented in the national "Arrêté du 17 octobre 2012" [16].
- The auxiliary electrical consumption ($El_{max}$, $El_{min}$ et Psb) has been taken from the table B6 of EN 15316-4-1 (2017).

The default values have been compared to some values measured by the French technical centre "CETIAT".

From the calculation, UNICLIMA decided to propose the simplification of Table 3. The boilers are distinguished according to:

- Fuel: Gas / oil
- Type: standard / low temperature / condensing
- Construction period

Table 3 – French Label

| | GAS | | OIL | |
|---|---|---|---|---|
| | Construction year | Class | Construction year | Class |
| Standard | < 2005 | D | < 2000 | D |
| | > 2005 | C | > 2000 | C |
| Low-temp | All | C | All | C |
| Condensing | < 2005 | B | All | B |
| | > 2005 | A | | |

The input required are:

- Construction year
- Fuel

- Condensing or not
- Department
- Building type
- Period of building construction
- Manufacturer

Figure 3 shows the input window of the Uniclima tool.


Figure 3 – French Label – inputs. Source [13].

As an output it provides the Energy class of the existing boiler (Figure 4) and a comparison with the energy class of a new boiler (Figure 5).

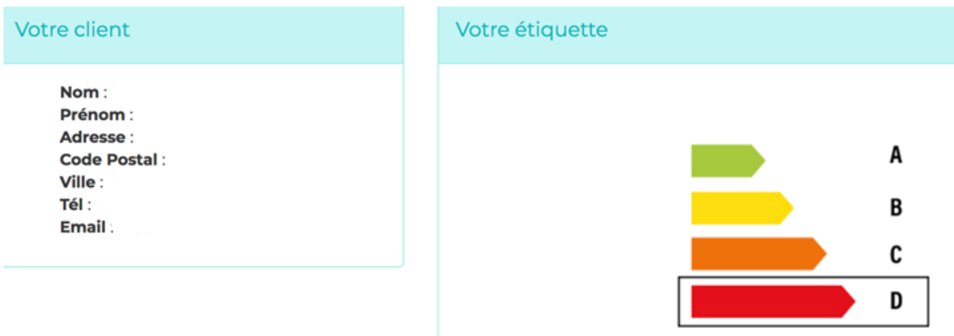



Figure 4 – French Label – output. Source [13].

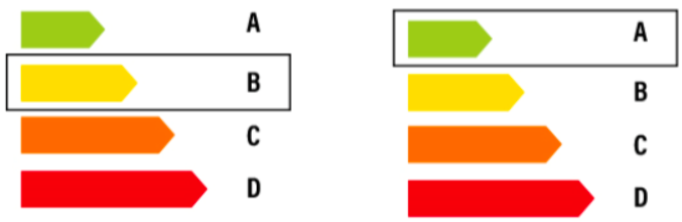
MON ÉTIQUETTE CHAUDIÈRE

Date (10/19)

*Référence : 0062JM-2004-037*

Suite au passage de notre entreprise dans votre logement nous avons établi l'étiquette énergétique de votre équipement :

**Standard* du marché**




Vous disposez d'une chaudière à condensation fioul qui date d'avant 2015 ou d'une chaudière au gaz à condensation de première génération. Ces technologies sont apparues dans les années 2000, elles ne disposent pas des technologies actuelles qui permettent le meilleur niveau de performance. Leur efficacité saisonnière (moyenne annuelle) se situe entre 82 et 90 %. Votre chaudière consomme environ 10 % de plus que si elle était en classe A. Pour aller plus loin : Vous pouvez associer votre chaudière gaz ou fioul à une installation utilisant une énergie renouvelable, par exemple pour produire votre eau chaude grâce à des capteurs solaires thermiques et ainsi optimiser votre consommation énergétique. Vous pouvez améliorer le pilotage de votre installation (régler une température optimale, gérer vos déplacements) avec plus de précisions grâce à une régulation connectée.

**Le changement de votre équipement par une chaudière à haute ou très haute performance énergétique répondant aux standards du marché peut vous apporter des gains importants en terme d'économie d'énergie.**
**N'hésitez pas à demandez conseil à votre professionnel. www.monetiquettechaudiere.fr**

Vous êtes peut-être éligible aux différents soutiens financiers pour le renouvellement de votre équipement. N'hésitez pas à demander conseil à votre professionnel.

*"Mon étiquette chaudière" est une opération gratuite et informative à l'initiative des acteurs membres des associations Energies et Avenir et Coénove. Aucune information personnelle ayant contribué à la génération de cette étiquette ne sera conservée*

Figure 5 – French Label – information sheet. Source [13].

### 3.2.4 Italy

The Italian manufacturer association, ASSOTERMICA has developed a voluntary scheme to label existing gas boiler appliances [17]. The motivation to focus solely on gas appliances is due to the appliances stock where the biggest share are gas boilers (74%) [18].

The calculation method is compliant with the Commission Regulation (EU) No 811/2013 [11] and Commission Communication 2014/C 207/02 [12] since is done according to EN 15502-1:2012+A1:2015 [19].

ASSOTERMICA has implemented the calculation in a web-app where it is possible to perform a simplified calculation or a detailed calculation:

- The simplified calculation is done according to the default values present in the EN 15316-4-1 [20]
- The detailed calculation is done according to the information present in the maintenance book of the appliance (or in the datasheet).

The seasonal efficiency is corrected adding an "aging coefficient".

The inputs are:

- Manufacturer
- Model
- Construction year
- Boiler type
- Rated power
- Full load and part load efficiencies
- Electric consumptions
- Stand-by losses.

For the parameters not known, the user can select the "unknown" flag and the tool will use the default values.

Figure 6 shows the input window of the Assotermica's tool.

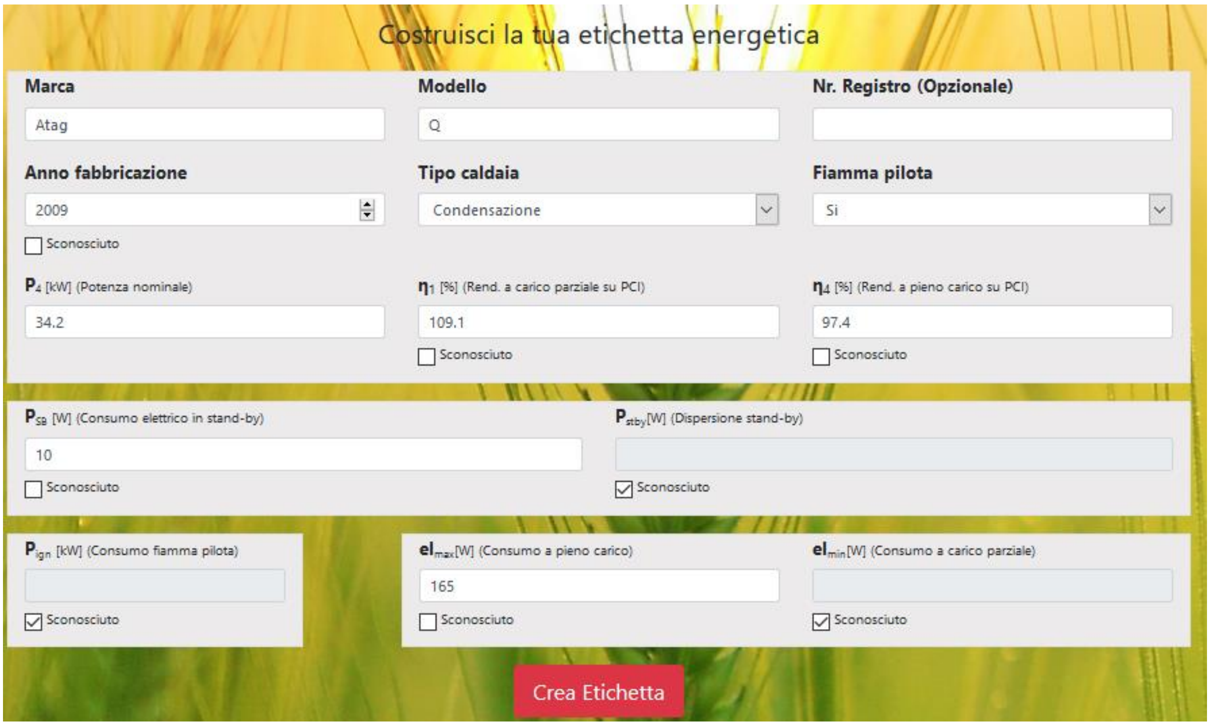


Figure 6 – Italian Label – inputs. Source [17].

As output the tool gives back the inputs used in the calculation (the ones introduced by the user or the default values), and presents the seasonal efficiency and the energy class (Figure 7).

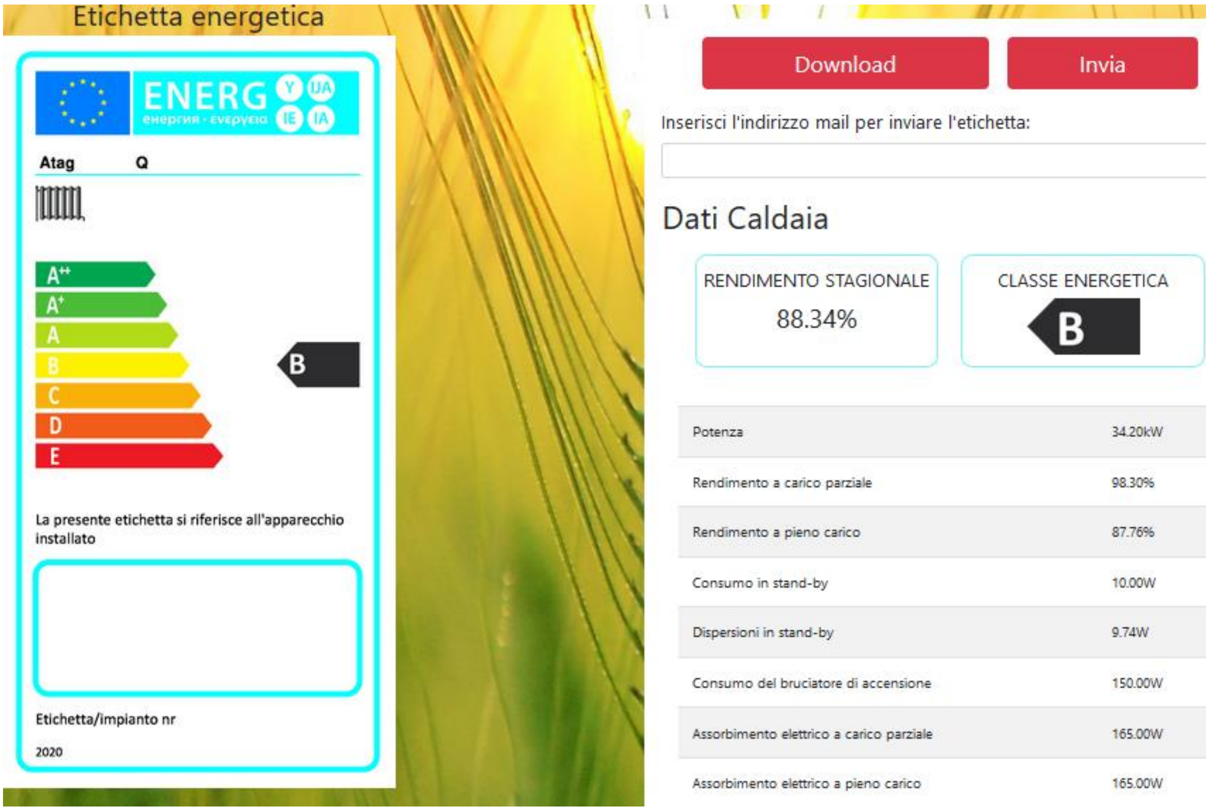



Figure 7 – Italian Label – outputs. Source [17].

### 3.2.5 Germany

Germany is the first country that has implemented a mandatory label for existing boilers. It is applied to:

- Boilers older than 15 years
- Boilers for gaseous and liquid fuels with a nominal capacity of up to 400kW

To determine the energy efficiency class of the boiler, the application provided for this purpose is connected to the website of the Federal Ministry for Economic Affairs and Energy (BMWi) [21]. After entering the required data of the old boiler, the efficiency class is displayed, and the corresponding label can be attached to the heater.

The inputs are:

- Manufacturer
- Model
- Construction year
- Rated power (kW)
- Fuel (gas, oil)
- Boilers Group (standard, low-temperature, condensing)
- Boiler type (atmospheric, forced ventilation, combined, DHW only)

Figure 8 shows the input window of the BMWi database. The user can directly write the model or can perform a research for a defined parameter available as input. In the second option, all the models with those properties will be shown by the database.

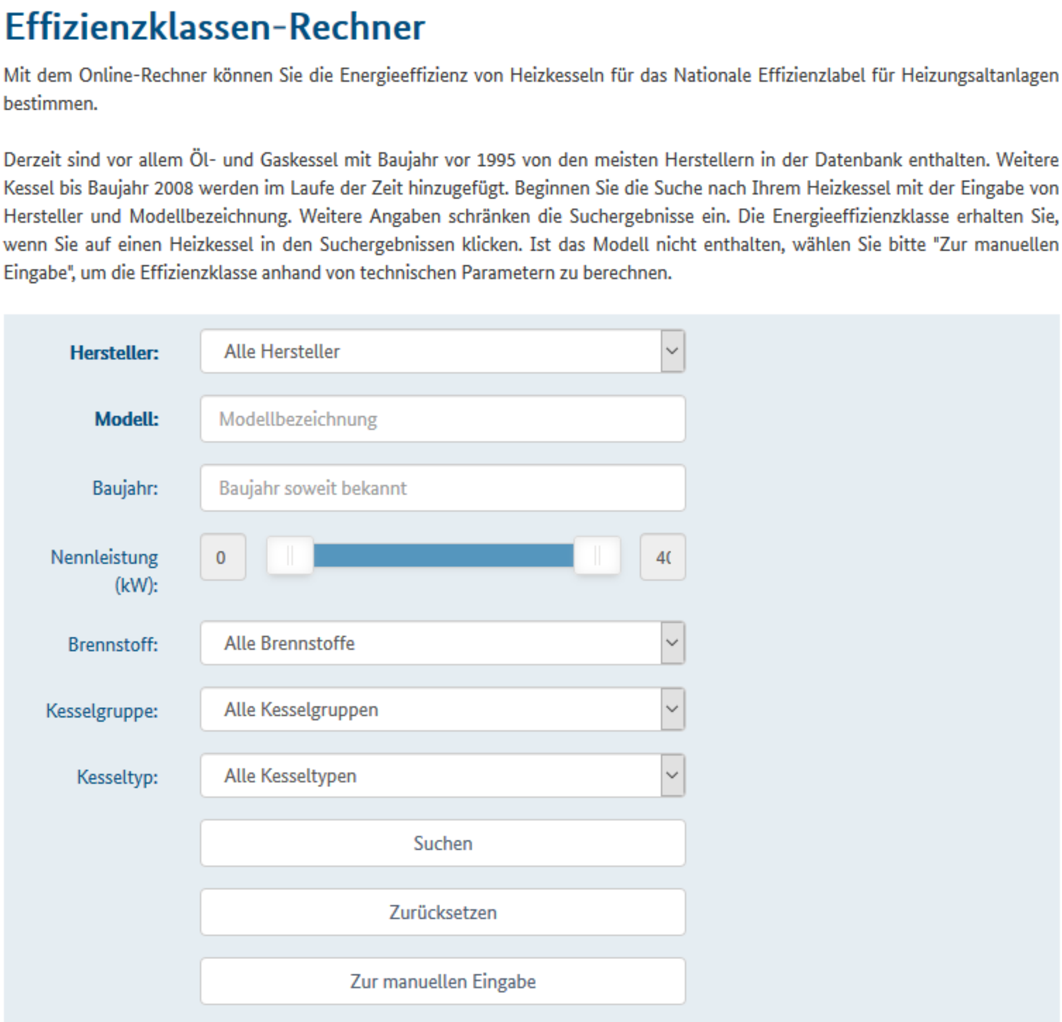


Figure 8 – Germal Label – inputs. Source [21].

The outputs are shown in Figure 9 and are the following ones:

- Manufacturer
- Model
- Construction year
- Rated power (kW)
- Fuel
- Boilers Group
- Boiler type
- Efficiency value
- Efficiency class
- From when to label
- Exchange until


Figure 9 – Germal Label – outputs. Source [21].

The output information is taken from the database working in the background (with 6237 models).

### 3.2.6 Summary

Table 4 presents the summary of the labelling methodologies for installed appliances presented in this chapter.

The German and the Italian labels rate the efficiency and the class while the Spanish and French labels rate only the class. With the efficiency rate it is possible to perform a simple calculation providing the energy and economic benefits of substitution while without this value, an assumption starting from the class should be done to perform the same analysis.

The advantage of the German database is the easy of use while it has a limit that considers only the products that are sold in Germany. It can be possible that a product available in another country' market cannot be found in the database.

None of the methods presented in this chapter foresees any field measurement but the calculations are performed on the boiler classification or on data present in the data-plate or data-sheet.

Table 4 – Labels for existing appliances – summary.

| | Portugal | Spain | France | Italy | Germany |
|---|---|---|---|---|---|
| Method | No | Voluntary scheme | Voluntary scheme | Voluntary scheme | Mandatory for boilers older than 15 years |
| Appliances | N.A. | Gas or liquid fuel boilers | Gas or liquid fuel boilers | Gas or liquid fuel boilers | Gas or liquid fuel boilers with a nominal capacity of up to 400kW |
| Method | N.A. | Function of age and technology | From EN 15316-4-1 definition of class as a function of | EN 15316-4-1 with use of aging coefficients | From database of Federal Ministry for Economic Affairs and Energy (BMWi) |
| Measurements in field | N.A. | No | No | No | No |
| Inputs | N.A. | Age<br>Technology (condensing, standard, low temperature) | Construction year<br>Fuel<br>Condensing or not<br>Department<br>Building type<br>Period of building construction<br>Manufacturer | Construction year<br>Fuel<br>Boiler type<br>Rated power<br>Efficiencies (FL – PL)<br>Electrical consumptions (max, min and stand by)<br>Stand-by losses<br>Pilot flam consumption | Manufacturer<br>Model<br>Construction year<br>Rated power (kW)<br>Fuel<br>Boilers Group<br>Boiler type |
| Output | N.A. | Efficiency class | Efficiency class | Efficiency value<br>Efficiency class | Efficiency value<br>Efficiency class<br>From when must be labelled<br>When must be changed |
| Database | N.A. | No | No | No | Yes |
| Reference | N.A. | [10] | [13] | [17] | [21] |

# 4 LABELLING FOR INSTALLED SPACE HEATING APPLIANCES

This chapter presents the labelling methodologies developed for installed space heating appliances. The work started from the comparison of existing labelling methodologies (3.2) and from that input, we developed the methodology considering the requirements of European regulations [11,12].

## 4.1 Analysis of German database

As indicated in the section 3.2.5, the labelling scheme implemented in Germany for space heating boilers is based on a database of products [21]. The data available online was downloaded and used to elaborate a preliminary analysis of the performance of existing boilers.

The database presents 6237 models of gas and oil boilers up to 400 kW. The construction year varies between 1972 and 2016. Figure 10 and Figure 11 show, respectively, the gas and oil boilers efficiency as a function of construction year, size [kW], and boiler group.

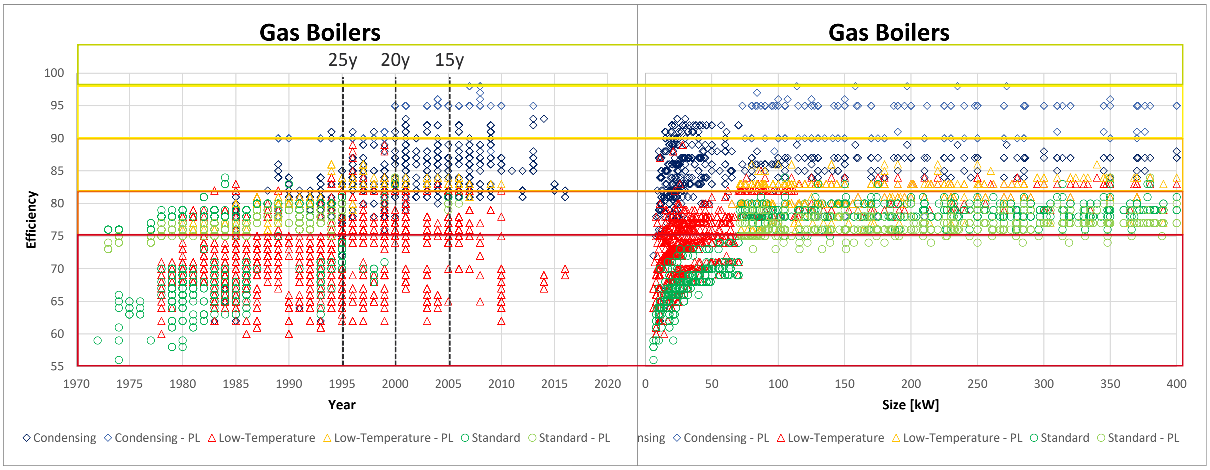



Figure 10 – German database – gas boilers. Elaboration of source [21].

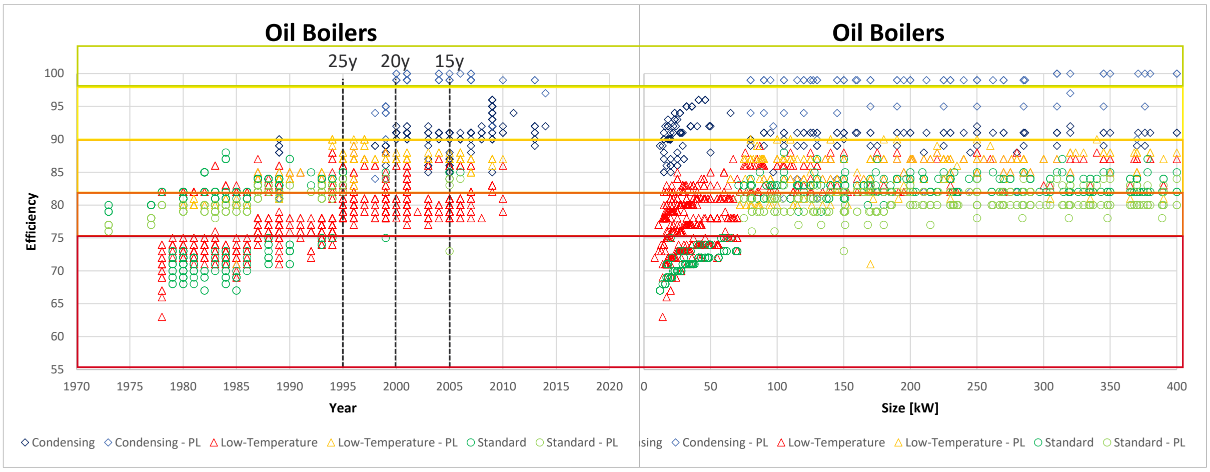



Figure 11 – German database – oil boilers. Elaboration of source [21].

Since the energy labelling is applied up to 70 kW boilers, only the appliances within this limit will be considered in the scope of this work. Considering solely the appliances below 70kW the number of available models decreases to 4449. Therefore, the data of Figure 10 and Figure 11 is re-plotted into Figure 12 and Figure 13. From the figures it is quite clear that the performance improves over the years (thanks to the technological evolution) and the size has a good effect on performance (higher size corresponds to better performance). Given their poor performance, the number of standard boilers is nowadays less present on the German framework, because of their replacement with low-temperature boilers in a first moment and later by condensing boilers.

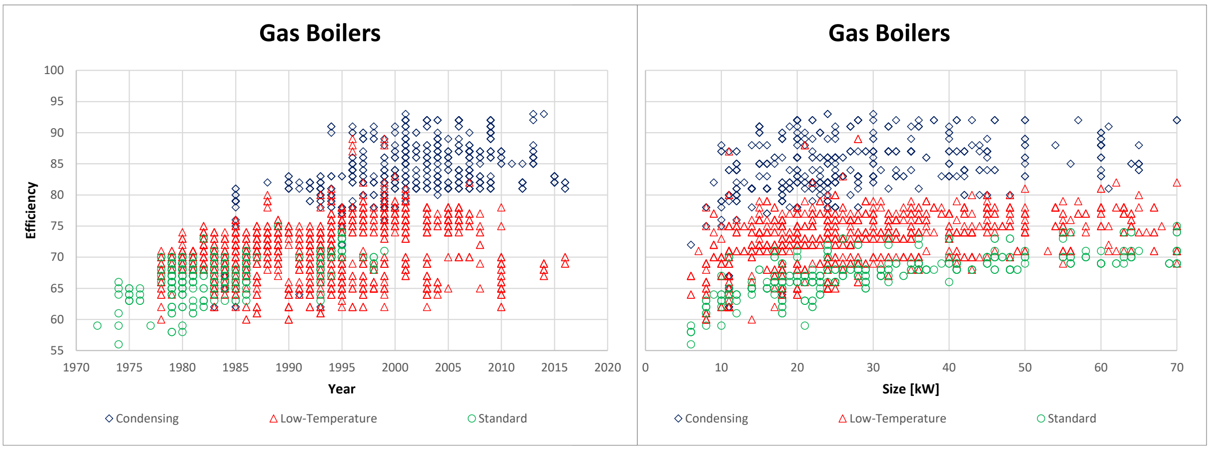



Figure 12 – German database – gas boilers up to 70 kW. Elaboration of source [21].

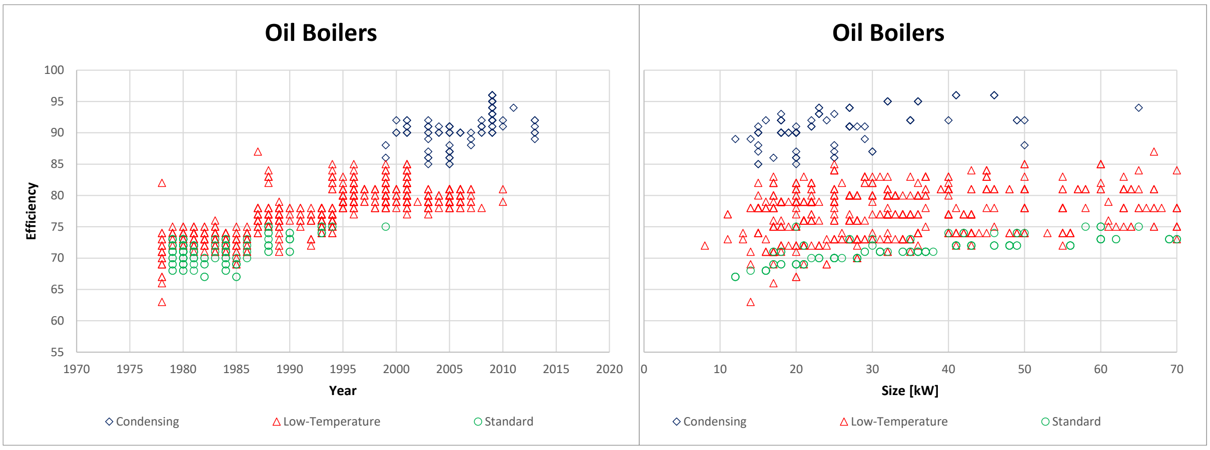



Figure 13 – German database – oil boilers up to 70 kW. Elaboration of source [21].

Figure 14 presents the share of different gas and oil boilers distinguished into "boiler group" and "boiler type". Please note that this is the share of models available in the database, with no relation with the share of installed appliances.

The share of "oil boiler type" presents only the "Combined" and "Forced ventilation" for the different "oil boilers groups". The "forced ventilation" covers about the 80% of the total share. Instead, the share of "gas boiler type" presents also "atmospheric", "central heating" and "domestic hot water" types.

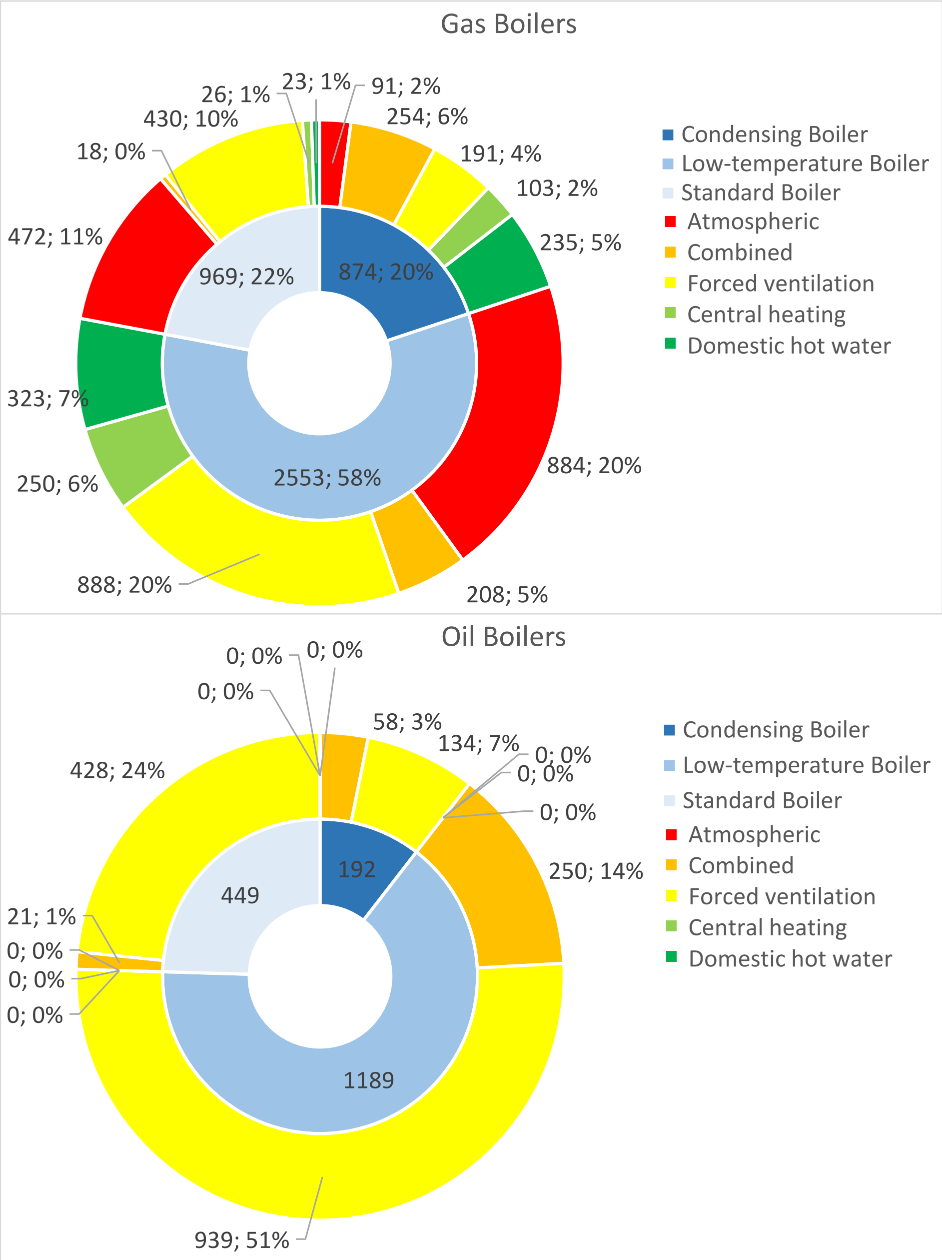



Figure 14 – German database – share of boiler group and type. Elaboration of source [21].

In order to understand how this share can affect the labelling methodology, the efficiency of the three boilers groups is distinguished between the different boiler types in Figure 15. To simplify the visualization of the points in the figure, the efficiency is plotted as the average of all the boiler type and group with the same "year".

Considering the same construction year, the difference between the boiler type is included in a 10% boundary.

The distinction between "Atmospheric" and "Forced ventilation" is small while the biggest difference is represented by the "DHW" that should be considered for the WH methodology and not in this section (the data has been presented as part of this database).

The outcome is that it is not necessary to distinguish between boiler type but only between boiler group.

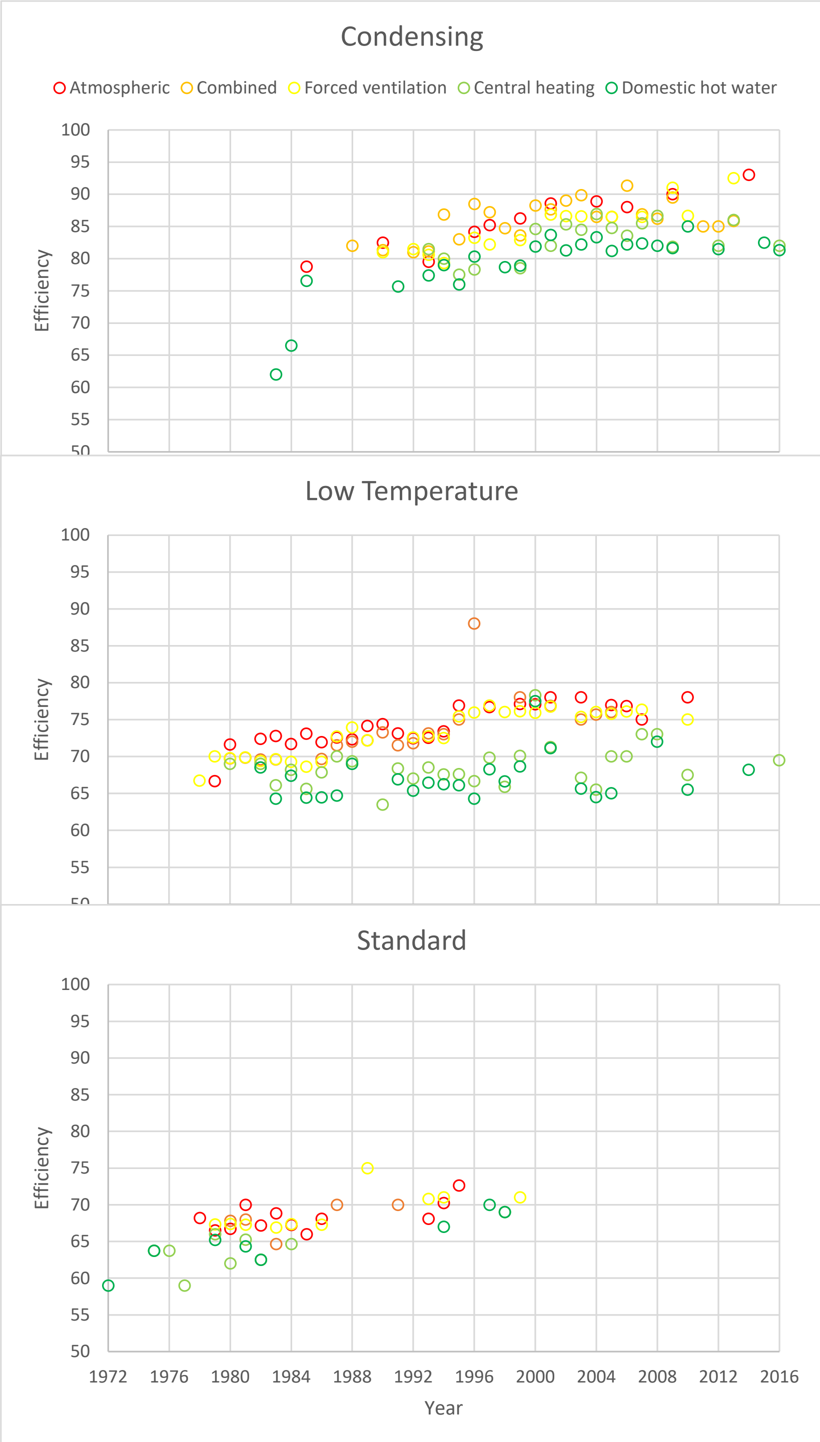



Figure 15 – German database – gas boilers up to 70 kW. Elaboration of source [21].

Table 5 presents the energy class of boilers divided by boiler "group", "type" and "fuel". The gas standard boilers present all the model in the "D" class, while the oil standard boilers present only the 1% in "C" class and the 99% in "D" class. The biggest share of gas low-temperature boilers "D" class with 0.3% in "B" class and 27.5% in "C" class. Instead the oil boilers present an opposite distribution: about 26% of low-temperature boiler is "D" class and 68% is "C" class and 6% in "B" class.

The gas condensing boilers present a wider distribution of classes: 12% is "A" class, 58% is "B" class 29% is "C" class and 1.4% is "D" class. The oil condensing boilers present 75 % of "A" class and 25% of "B" class.

Table 5 – Share of energy class per boiler group and type.

| Group | Type | Gas | | | | Oil | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | A | B | C | D |
| Standard | Atmospheric | 0 | 0 | 0 | 100 | N.A. | N.A. | N.A. | N.A. |
| | Combined | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 |
| | Forced ventilation | 0 | 0 | 0 | 100 | 0 | 0 | 0.8 | 99.2 |
| | central heating | 0 | 0 | 0 | 100 | N.A. | N.A. | N.A. | N.A. |
| | Domestic hot water | 0 | 0 | 0 | 100 | N.A. | N.A. | N.A. | N.A. |
| | **TOT** | **0** | **0** | **0** | **100** | **0** | **0** | **0.7** | **99.3** |
| Low-temperature | Atmospheric | 0 | 0 | 34.9 | 65.1 | N.A. | N.A. | N.A. | N.A. |
| | Combined | 0 | 2.7 | 23.8 | 73.5 | 0 | 16.6 | 60.5 | 22.87 |
| | Forced ventilation | 0 | 0 | 38.2 | 61.8 | 0 | 2.6 | 70.4 | 27.05 |
| | central heating | 0 | 0.8 | 6 | 93.2 | N.A. | N.A. | N.A. | N.A. |
| | Domestic hot water | 0 | 0 | 7.43 | 92.6 | N.A. | N.A. | N.A. | N.A. |
| | **TOT** | **0** | **0.3** | **27.5** | **72.2** | **0** | **5.9** | **68.1** | **26.0** |
| Condensing | Atmospheric | 1.43 | 80 | 18.6 | 0 | N.A. | N.A. | N.A. | N.A. |
| | Combined | 29.9 | 57.1 | 12.9 | 0 | 86.5 | 13.5 | 0 | 0 |
| | Forced ventilation | 11.1 | 68.1 | 20.8 | 0 | 64.9 | 35.1 | 0 | 0 |
| | central heating | 0 | 74.3 | 25.7 | 0 | N.A. | N.A. | N.A. | N.A. |
| | Domestic hot water | 2.21 | 42.5 | 50.9 | 4.4 | N.A. | N.A. | N.A. | N.A. |
| | **TOT** | **11.7** | **58.3** | **28.6** | **1.4** | **75.2** | **24.8** | **0** | **0** |

## 4.2 Comparison of existing methodologies

The different methodologies presented in section 3.2 have been applied to three different boilers in order to understand the differences in the results.

### 4.2.1 Model 1

The first boiler is a "standard" oil boiler installed in the 1989. The nominal power is 28 kW. The result of the application of the different labelling schemes is the following one:

- Spanish label: CLASS G
- French label: CLASS D
- Italian label (with data plate): CLASS D - $\eta_s$=63.2
- Italian label (with default value): CLASS D - $\eta_s$=56.7
- German label: the gas boiler is not in the database

The Spanish and French label do not give any indication about the seasonal efficiency.

This model is not presented in the German database since it has been built by an Italian manufacturer. This means that if the product has not been sold in the German market the appliance is not present in the German database and therefore cannot be labelled. In other terms, the German scheme cannot be extended to other countries.

The Spanish label gives a “G” class that currently is not available anymore, while the French and Italian labels rate the boiler as “D” class.

The labelling of the boiler with the Italian label has been performed with the simplified calculation and the detailed calculation which result in the same class (“D”) and a different seasonal efficiency. In the case of the detailed calculation the seasonal efficiency is 63.2% while with the detailed values is 56.7% (difference of 6.5%).

### 4.2.2 Model 2

The second model considered in the comparison is a condensing gas boiler installed in 2009. The manufacturer is the same of “Model 1” and the nominal power is 28.7 kW.

- Spanish label: CLASS B
- French label: CLASS A
- Italian label (with data plate): CLASS B - $\eta_s$=87.1
- Italian label (with default value): CLASS C - $\eta_s$=81.1
- German label: the gas boiler is not in the database

The label is different for Spanish, French and the two Italian labels. The French label is the most optimistic, with a “A” class rate, while the Spanish label rates the boiler as “B” class. The Italian calculations also provide two different classes, B with the detailed method and C class with the simplified calculation. The difference between the two calculations is 6%, comparable to the difference obtained for the “Model 1” but, in this case, the difference is between the threshold of the B and C classes.

This model is not listed in the German database, and for that reason it was not possible to identify it’s class according to the German labelling scheme.

### 4.2.3 Model 3

The third model is a condensing gas boiler installed 2009 from a German manufacturer that has an Italian branch. The nominal power is 34.2 kW.

- Spanish label: CLASS B
- French label: CLASS A
- Italian label (with data plate): CLASS B - $\eta_s$=88.3
- Italian label (with default value): CLASS B - $\eta_s$=82.5
- German label: the GB is not in the database

The classification of this boiler with the Spanish and French label is the same as for the previous model, B and A. Using the Italian labelling methodologies, the simplified and detailed calculation lead to the same class rate "B" (as for the Spanish label). The difference of the detailed and simplified calculation is 5.8%, similar to the previous ones.

Despite being from a German manufacturer, this model is built only by the Italian branch and therefore, this model cannot be found in the German database.

### 4.2.4 Model 4

The fourth model is a low-temperature atmospheric gas boiler of 1993. The nominal power is 24 kW.

- Spanish label: CLASS D
- French label: CLASS C
- Italian label (with default value): CLASS D - $\eta_s$=65.1
- German label: CLASS D - $\eta$=73

For this model, the Spanish, Italian and German labels agree on the class "D" while the French label rate as class "C".

The data plate and the data sheet of "Model 4" were not provided and therefore the Italian detailed calculation was not possible to be implemented.

For the French label, all the "low-temperature" boilers have the same class while different products of German database classified as "atmospheric low-temperature" are rated differently ("C" or "D" depending on the model).

### 4.2.5 Discussion

As highlighted in section 3.2.6, the Spanish and French labels do not estimate the efficiency but only the energy class. The Italian label calculates the seasonal efficiency and the energy class, and the German label provides the full load efficiency and the energy class.

The German label cannot be applied to products not sold in Germany. Therefore, the methodology cannot be extended to other countries even if it is the most user-friendly (since as input it is needed only the model).

The Italian scheme offers a simplified and a detailed version allowing for different users, common or a professional user. The efficiency differences between the two calculations is about 6%.

## 4.3 Proposed methodology for heating appliances

The main aim of the labelling methodology is to allow the consumer to compare the energy class of old and new heating appliances and therefore it should be compliant to regulation 811/2013 [11,12].

### 4.3.1 Energy Labelling for new SH appliances

For new appliances, the seasonal efficiency is calculated correcting the "seasonal space heating energy efficiency in active mode" (defined with the appliances switched on) with correction factors $F_{(i)}$ to consider the effect of component consumptions when the appliance is not active – see Eq.1.

$$\eta_s = \eta_{son} - \sum F_{(i)}$$

Eq.1

The "seasonal space heating energy efficiency in active mode" is calculated weighting the part load efficiency and the full load efficiency according the Eq.2.

$$\eta_{son} = 0.85 \cdot \eta_1 + 0.15 \cdot \eta_4$$

Eq.2

The correction factors applied to Eq.1 are defined in Table 6 that presents Eq.3 to Eq.6. These are respectively correction for the absence of temperature control, the auxiliary electrical consumption, the standby heat losses, and the pilot light consumption.

Table 6 – Correction factors for new SH appliances

| | | |
|---|---|---|
| no temperature control | $F(1) = 3\%$ | Eq.3 |
| auxiliary electricity consumption | $F(2) = \frac{2.5 \cdot (0.15 \cdot el_{max} + 0.85 \cdot el_{min} + 1.3 \cdot P_{SB})}{0.15 \cdot P_4 + 0.85 \cdot P_1} \cdot 100$ | Eq.4 |
| Standby heat losses | $F(3) = \frac{0.5 \cdot P_{stby}}{P_4} \cdot 100$ | Eq.5 |
| Pilot light | $F(4) = \frac{1.3 \cdot P_{ign}}{P_4} \cdot 100$ | Eq.6 |

Sources: Regulation EU 811/2013 – Annex VIII. Communication 2014/C 207/02 [11,12]. EN 15502-1 c.9.5 [19].

The part load efficiency ($\eta_1$) and the full load efficiency ($\eta_4$) must be referred to the upper heat value. Therefore, if it is presented with the lower heat value it should be corrected according to Eq.7 and Eq.8.

$$\eta_1 = \eta_{30} \cdot \frac{H_i}{H_s}$$

Eq.7

$$\eta_4 = \eta_{100} \cdot \frac{H_i}{H_s}$$

Eq.8

Where $H_i$, $H_s$ represent lower and upper heat values.

In the literature, there are used different nomenclatures. To avoid misunderstanding, the following equations show the different possibilities. The subscript 30 represents the 30% of nominal power while the subscript 100 represents the nominal power. The lower heat value (or net calorific value) is heat produced by combustion of unit quantity of a solid or liquid fuel when burned at a constant volume, under conditions such that all the water in the products remains in the form of vapor. Instead, the higher heat value (or gross calorific value) is the heat produced by combustion of unit quantity of a solid or liquid fuel when burned at constant volume, under specified conditions, with the resulting water condensed to a liquid. The difference between LHV and HHV is the condensation heat.

$$P_1 = P_{30}$$

Eq.9

$$P_4 = P_{100} = P_n$$

Eq.10

$$H_i = LHV = NCV$$

Eq.11

$$H_s = HHV = GCV$$

Eq.12

Table 7 presents the efficiency boundaries that define the energy label for space heating appliances. The class D has a wide range from 36 to 75%.

Table 7 – Energy Label, classes efficiency boundaries. Source Regulation EU 811/2013.

| **A+++** | $\boldsymbol{\eta > 150}$ |
|---|---|
| **A++** | $125 \leq \eta < 150$ |
| **A+** | $98 \leq \eta < 125$ |
| **A** | $90 \leq \eta < 98$ |
| **B** | $82 \leq \eta < 90$ |
| **C** | $75 \leq \eta < 82$ |
| **D** | $36 \leq \eta < 75$ |

Sources: Regulation EU 811/2013 – Annex VIII. Communication 2014/C 207/02 [11,12]. EN 15502-1 c.9.5 [19].

### 4.3.2 Energy Labelling for old SH appliances

In order to reach more users, the method foresees two possibilities: one simplified calculation for a common user and a detailed calculation for a professional user.

Figure 16 shows that the calculation performed is the same. This means that the distinction impacts only the input selection. Specifically, a common user should indicate the fuel, boiler group between "standard", "low temperature" and "condensing", the construction year, and the nominal power. Instead the professional user should also indicate the other parameters.

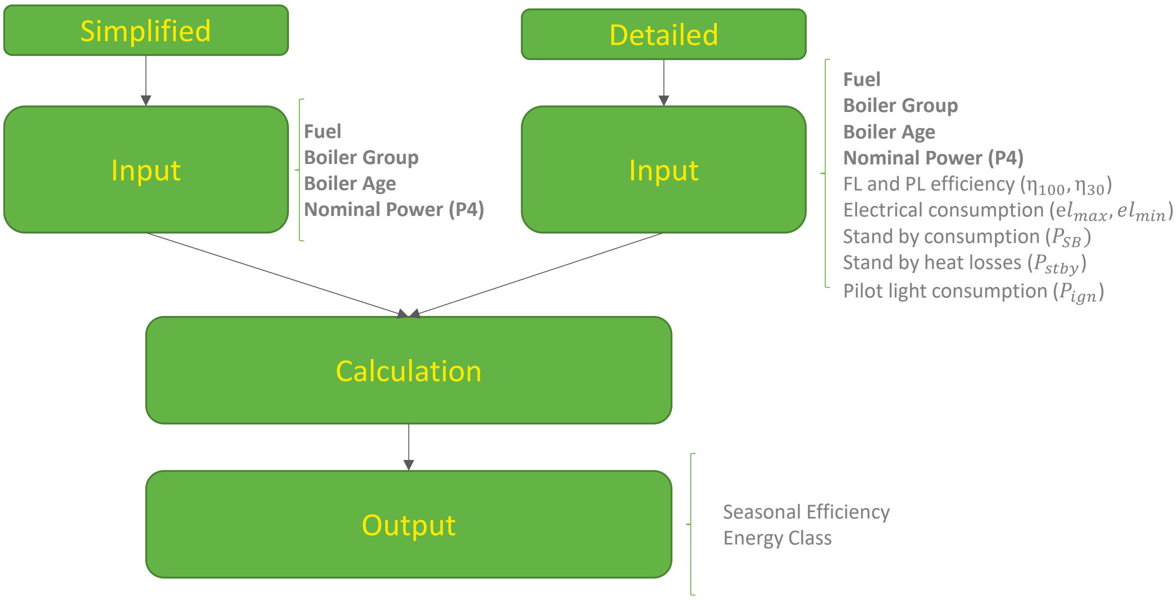



Figure 16 – Flow chart of old SH appliance labelling methodology.

In the Eq.13, the seasonal efficiency is calculated similarly as the Eq.1 with the correction factors presented in Table 8. The only difference is the aging coefficient (Eq.14).

$$\eta_s = (\eta_{son} \cdot \boldsymbol{C_{age}} - \sum F_{(i)})$$

Eq.13

Table 8 – Correction factors for old SH appliances

| | | |
|---|---|---|
| Aging coefficient | $C_{age} = f(age) < 1$ | Eq.14 |
| no temperature control | $F(1) = 3\%$ | Eq.3 |
| auxiliary electricity consumption | $F(2) = \frac{2.5 \cdot (0.15 \cdot el_{max} + 0.85 \cdot el_{min} + 1.3 \cdot P_{SB}) \cdot 100}{0.15 \cdot P_4 + 0.85 \cdot P_1}$ | Eq.4 |
| Standby heat losses | $F(3) = \frac{0.5 \cdot P_{stby} \cdot 100}{P_4}$ | Eq.5 |
| Pilot light | $F(4) = \frac{1.3 \cdot P_{ign} \cdot 100}{P_4}$ | Eq.6 |

To consider the effect of components degradation during the years of working, the aging coefficient is presented in Table 9. Different studies in literature [22–26] have implemented an exponential correlation between the age and the performance degradation.

$$C_{age} = (1 - M)^{age}$$

Eq.15

Where M depends on the appliance and the maintenance level of the appliance. The table presents the values for a "Normal" maintenance (according to the program indicated in chapter 3.1) and the values for a "Bad" maintenance (in the case that the maintenance is not performed or is performed not following the mandatory maintenance program). Specifically, Hendron [22] suggests M = 0.005 for gas boilers with normal maintenance and M = 0.015 for gas boilers without maintenance.

The coefficient defined for a normal maintenance was initially defined in cooperation with manufacturers and the value that was defined is indicated in the first column of Table 9. This value agrees with the relation expressed in the Eq.15. The other values are defined with "M" coefficient indicated in Table 9.

Table 9 – Degradation coefficient $C_{age}$ as a function of age. SH appliances.

| **Age** | **Gas/Oil Boilers** | | **Heat Pumps** | | **Electric Boilers** | |
|---|---|---|---|---|---|---|
| *Maintenance* | Normal | Bad | Normal | Bad | Normal | Bad |
| *M* | *0.005* | *0.015* | *0.01* | *0.03* | *0.001* | *0.002* |
| <10 | 1.00 | 0.86 | 0.90 | 0.74 | 1.00 | 1.00 |
| 10-15 | 0.98 | 0.80 | 0.86 | 0.63 | 0.99 | 0.97 |
| 16-20 | 0.95 | 0.74 | 0.82 | 0.54 | 0.98 | 0.96 |
| 21-25 | 0.90 | 0.69 | 0.78 | 0.47 | 0.97 | 0.95 |
| 26-30 | 0.88 | 0.64 | 0.74 | 0.40 | 0.96 | 0.94 |
| >30 | 0.87 | 0.59 | 0.70 | 0.34 | 0.95 | 0.93 |

Table 10 presents the input required in the simplified and detailed version of labelling methodology. A professional user should introduce more specific parameters than a common user.

Table 10 – Inputs and output of label of old SH appliances

| | **Simplified** | **Detailed** |
|---|---|---|
| **Input** | Fuel<br>Boiler Group<br>Construction year<br>Nominal Power (P4) | Fuel<br>Boiler Group<br>Construction year<br>Nominal Power (P4)<br>FL and PL efficiency ($\eta_{100}, \eta_{30}$)<br>Electrical consumption ($el_{max}, el_{min}$)<br>Stand by consumption ($P_{SB}$)<br>Stand by heat losses ($P_{stby}$)<br>Pilot light consumption ($P_{ign}$) |
| **Output** | Seasonal Efficiency<br>Energy Class | Seasonal Efficiency<br>Energy Class |

Note: $\eta_{100}$ and $\eta_{30}$ are defined with Hi.

For simplified version, default values are taken from EN 15316-4-1 [20]. The equation used are presented in Table 11.

The standard defines the default values using the lower heat value. Therefore, the corrections of Eq.7 and Eq.8 should be done before using this values in Eq.2 and then in Eq.13.

Table 11 – Default values for old SH appliances

| | | |
|---|---|---|
| Part load efficiency | $\eta_{30} = c_3 + c_4 \cdot \log(P_n)$ | Eq.16 |
| Full load efficiency | $\eta_{100} = c_1 + c_2 \cdot \log(P_n)$ | Eq.17 |
| Thermal losses on stand-by | $P_{stby} = c_5 \cdot (P_n)^{C_6}$ | Eq.18 |
| Stand-by electric consumption | $P_{SB} = c_{7,SB} + c_{8,SB} \cdot (P_n)^{n_{SB}}$ | Eq.19 |
| Part load electric consumption | $el_{min} = c_{7,P1} + c_{8,P1} \cdot (P_n)^{n_{P1}}$ | Eq.20 |
| Full load electric consumption | $el_{max} = c_{7,Pn} + c_{8,Pn} \cdot (P_n)^{n_{Pn}}$ | Eq.21 |
| Pilot light consumption | $P_{ign} = 150\ W$ | Eq.22 |

Where $c_1$, $c_2$, $c_3$, $c_4$, $c_5$, $c_6$, $c_7$, $c_8$, n are defined in the standard as a function of boiler group

The reference value for the Pilot light consumption was assumed considering the values presented by the preparatory study of eco-design directive of VHK (Task 4) [27] and by the TH-C method (table 73 [15]).

For detailed version, the values are read from the appliance datasheet. In some countries these values are recorded in the maintenance book of the appliance. **In case some data is not available, this will be assumed from the default values**. Figure 17 shows an example of a datasheet of an old gas boiler.

| | | [redacted] | |
|---|---|---|---|
| | | Metano | GPL |
| Potenza termica nominale | kW | 22,6 | |
| Portata termica nominale | kW | 26,1 | |
| Potenza termica minima | kW | 7,0 | |
| Portata termica minima | kW | 8,4 | |
| **Valori di allacciamento gas** | | | |
| „23" Gas metano (G 20) | $m^3/h$ | 2,8 | - |
| „31" butano (G 30)/propano (G 31) | kg/h | - | 2,1 |
| Pressione dinamica gas | | | |
| „23" Gas metano (G 20) | mbar | 20 | - |
| „31" butano (G 30)/propano (G 31) | mbar | - | 28-37 |
| **Riscaldamento** | | | |
| Capacità circuito riscaldamento in caldaia | l | 0,17 | |
| Temperatura minima di esercizio | °C | 45 | |
| Temperatura massima di esercizio | °C | 90 | |
| Pressione massima di esercizio | bar | 3 | |
| Pressione minima di esercizio | bar | 1 | |
| **Vaso di espansione** | | | |
| Pressione di precarica | bar | 0,5 | |
| Capacità | l | 7,5 | |
| Capacità utile | l | 4 | |
| **Acqua sanitaria** | | | |
| Intervallo di temperatura impostabile | °C | 40-60 | |
| Pressione massima di esercizio | bar | 12 | |
| Pressione idraulica minima occorrente per portata massima | bar | 1,5 | |
| Pressione minima di esercizio | bar | 0,35 | |
| Minima portata | l/min | 2,5 | |
| Massima portata (con limitatore di portata di serie) | l/min | 10 | |
| **Circolatore** | | | |
| Portata massima (ΔT= 25 °C) | l/h | 600 | |
| Prevalenza residua all'impianto (ΔT = 25 °) | bar | 0,2 | |
| **Parametri di combustione** | | | |
| Portata dei fumi alla portata nominale | g/s | 15,8 | |
| Temperatura fumi pot. nominale | °C | 140 | |
| Tiraggio minimo | mbar | 0,015 | |

| | | Metano | GPL |
|---|---|---|---|
| % $CO_2$ alla potenza termica nominale | % | 4,4 | |
| Emissione di CO alla portata termica nominale | ppm | <67 | |
| Emissione di NOx alla portata termica nominale | mg/kWh | <200 | |
| Connessione in caldaia mm | mm | 60/90 | |
| Classe NOx | | 2 | |
| **Rendimenti** | | | |
| Rendimento PCI al 100% (a potenza termica nominale) | % | 87,9 | |
| Rendimento PCI al 30% (a potenza termica ridotta) | % | 81,6 | |
| **Perdite termiche** | | | |
| Al camino con bruciatore acceso | Pf% | 10,6 | |
| Al camino con bruciatore spento | Pfbs% | 0,4 | |
| Verso l'ambiente tramite l'involucro | Pd% | 1,5 | |
| **Collegamento elettrico** | | | |
| Tensione | V AC | 230 | |
| Frequenza | Hz | 50 | |
| Massima potenza elettrica assorbita | W | 140 | |
| Potenza elettrica assorbita dal circolatore | W | 90 | |
| Grado di protezione | IP | X4D | |
| **Informazioni generali** | | | |
| Peso (senza imballo) | kg | 34 | |
| Altezza | mm | 850 | |
| Larghezza | mm | 400 | |
| Profondità (senza telaio di preinstallazione) | mm | 279 | |

*Tab. 5*

Where find the information - example

Figure 17 – Example of old SH appliance datasheet.

### 4.3.3 Energy labelling for old heat pumps

The labelling methodology presented in the previous section does not cover heat pumps. In this case the labelling has been followed distinguishing three HP types:

- Air to Water
- Water (or Brine) to Water
- Air to Air

The default values was taken from the EN 15316-4-2 [28] that defines the reference performance in terms of COP and heat capacity for the different types with the correction factors to consider different boundary conditions. The calculation of seasonal performance was done following the calculation methodology of EN 14825 [29] for the three reference climates considered in the regulation 811/2013 [11] for the labelling of new heat pumps. The climates are "Average" (corresponding to Strasbourg), "Colder" (Helsinki) and "Warmer" (Athens).

The reference capacity is 12 kW defined at the conditions:

- Air 7°C to Water 45°C – with reference COP = 3.0
- Water (or Brine) 10°C to Water 45°C – with reference COP 3.7

The "performance map" was defined applying the correction factors of Table 12 and Table 13 for A/W heat pumps and Table 14 and Table 15 for W/W heat pumps. The standard EN 15316-4-2 does not provide information about A/A units and therefore the performance of a A/W heat pump with $\vartheta_{out,ref}$ = 25°C was considered.

Table 12 – Default COP for old A/W heat pump.

| | | 0 | 0 | 0 | 0 | 0 | Δϑin,ref |
|---|---|---|---|---|---|---|---|
| **Δϑout,ref** | **ϑout,ref** | **-15** | **-7** | **2** | **7** | **20** | **ϑin** |
| **3** | **25** | 1.06 | 1.32 | 2.64 | 3.30 | 4.13 | 1 |
| **3** | **25** | 1.06 | 1.32 | 2.64 | 3.30 | 4.13 | 1.1 |
| **5** | **35** | 0.96 | 1.20 | 2.40 | 3.00 | 3.75 | 1 |
| **5** | **45** | 0.96 | 1.20 | 2.40 | 3.00 | 3.75 | 0.8 |
| **8** | **55** | 0.77 | 0.96 | 1.92 | 2.40 | 3.00 | 0.8 |
| **10** | **65** | 0.61 | 0.77 | 1.54 | 1.92 | 2.40 | 0.8 |
| | | 0.8 | 0.5 | 0.8 | 1 | 1.25 | |

Table 13 – Default capacity for old A/W heat pump expressed in variation from reference.

| | | 0 | 0 | 0 | 0 | 0 | Δϑin,ref |
|---|---|---|---|---|---|---|---|
| **Δϑout,ref** | **ϑout,ref** | -15 | -7 | 2 | 7 | 20 | ϑin |
| **3** | 25 | 0.82 | 0.89 | 1.04 | 1.09 | 1.23 | 1 |
| **3** | 25 | 0.82 | 0.89 | 1.04 | 1.09 | 1.23 | 1.09 |
| **5** | 35 | 0.75 | 0.82 | 0.95 | 1.00 | 1.13 | 1 |
| **5** | 45 | 0.75 | 0.82 | 0.95 | 1.00 | 1.13 | 0.9 |
| **8** | 55 | 0.69 | 0.75 | 0.87 | 0.92 | 1.03 | 0.915 |
| **10** | 65 | 0.63 | 0.68 | 0.79 | 0.83 | 0.94 | 0.91 |
| | | 0.92 | 0.86 | 0.95 | 1 | 1.13 | |

Table 14 – Default COP for old W/W heat pump.

| | | 3 | 3 | 3 | 3 | Δϑin,ref |
|---|---|---|---|---|---|---|
| **Δϑout,ref** | ϑout,ref | **2** | **10** | **15** | **20** | **ϑin** |
| **3** | 15 | 5.38 | 5.97 | 6.57 | 7.16 | 1.15 |
| **3** | 25 | 4.68 | 5.19 | 5.71 | 6.23 | 1.17 |
| **5** | 35 | 4.00 | 4.44 | 4.88 | 5.32 | 1.2 |
| **5** | 45 | 3.33 | 3.70 | 4.07 | 4.44 | 1 |
| **8** | 55 | 2.66 | 2.96 | 3.26 | 3.55 | 0.8 |
| **10** | 65 | 2.00 | 2.22 | 2.44 | 2.66 | 0.75 |
| | | 0.9 | 1 | 1.1 | 1.09 | |

Table 15 – Default capacity for old W/W heat pump expressed in variation from reference.

| | | 3 | 3 | 3 | 3 | Δϑin,ref |
|---|---|---|---|---|---|---|
| **Δϑout,ref** | ϑout,ref | **2** | **10** | **15** | **20** | **ϑin** |
| **3** | **15** | 1.29 | 1.29 | 1.29 | 1.29 | 1.08 |
| **3** | **25** | 1.20 | 1.20 | 1.20 | 1.20 | 1.09 |
| **5** | **35** | 1.10 | 1.10 | 1.10 | 1.10 | 1.1 |
| **5** | **45** | 1.00 | 1.00 | 1.00 | 1.00 | 1 |
| **8** | **55** | 0.92 | 0.92 | 0.92 | 0.92 | 0.915 |
| **10** | **65** | 0.83 | 0.83 | 0.83 | 0.83 | 0.91 |
| | | 1 | 1 | 1 | 1 | |

The standard EN 14825 defines the seasonal efficiency:

$$\eta_{SH} = \frac{SCOP}{CC} - \sum F_{(i)}$$

**Eq.23**

Where the SCOP is the seasonal COP defined with the bin method, CC is the conversion factor (2.5) and F(i) are the correction factors.

The correction factors are:

- F(1) for the temperature control = 3%
- F(2) for the circulation pumps of the source side – only for water (or brine) source = 5%

Table 16 presents the default values for the seasonal efficiency of old heat pumps according to the three reference climates and the HP type.

Table 16 – Default seasonal efficiencies for old heat pumps.

| | Average | Warmer | Colder |
|---|---|---|---|
| **Air to Air** | 85.2 | 123.3 | 63.8 |
| **Air to Water** | 78.0 | 112.6 | 58.5 |
| **Water to Water** | 108.2 | 132.3 | 99.5 |

## 4.4 Validation and Testing

### 4.4.1 Default values and Validation

The standard EN 15316-4-1 presents the coefficients used in Table 11 in different tables with different classifications (e.g. Table B1, Table, Table B6, and Table B9 – see appendix A). The aim of the validation is to verify the possibility of a simplification of the parameters used.

All the tables present a classification distinguishing the "build year" that can be summarised as follows:

- Construction year before 1978 (included)
- Construction year between 1978 and 1987 (included)
- Construction year between 1987 and 1994 (included)
- Construction year after 1994

Table B1 presents the parameters needed to calculate the full load and part load efficiencies:

- Standard boiler
  - Multi-fuel
  - Atmospheric solid fuel (fossil and biomass)
  - Atmospheric gas boiler
  - Fan-assisted boiler (fossil and biomass)
  - Burner replacement (only for fan-assisted)

- Low-temperature boiler
    - Atmospheric gas boiler
    - Circulation water heater
    - Combination boilers
    - Fan assisted boiler
    - Burner replacement (only for fan-assisted)
- Condensing boiler
    - Condensing boiler
    - Combination
    - Condensing improved

Table B3 presents the parameters needed to calculate the stand-by heat losses with the same classification of table B1.

Table B6 presents the parameters for calculation of power consumption of auxiliary equipment:

- Since 1994
    - Heating boiler with forced draught burner
    - Atmospheric boiler up to 250 kW
    - Atmospheric boiler more than 250 KW
    - Automatically fed pellet central boiler
    - Automatically fed chips central boiler
- Standard boiler
    - Multi fuel boiler
    - Solid fuel boiler
    - Atmospheric gas boiler
    - Heating boiler with forced draught burner
- Low temperature boiler
    - Atmospheric gas boiler
    - Circulation water heater
    - Heating boiler with forced draught burner
- Condensing

The aim is to classify the boiler only as a function of the fuel or group, in order to avoid any misunderstanding of data that should be used as input:

- Standard
- Low Temperature
- Condensing

The boiler's data was analysed considering the different manufactures countries in order to understand if there is a kind of "country bias" due to different testing standards before the EN harmonization.

Another aim of the validation is to reach a good agreement between the simplified and the detailed calculation. Therefore, all the following figures will present a red line (that is the bisector of the graph) that represents the best agreement, two green lines that represents the 5% agreement boundary, two blue lines that represent the 10% agreement.

In order to understand if it is possible to distinguish only into the boiler group, the figures present the results using the coefficient of "Atmospheric", "Fan Assisted" or the average between these two. In the graph we have used the abbreviation "atm" and "fan" indicating the weighting factor. E.g. "Atm 0 – fan 1" corresponds to the use of fan assisted, while "Atm 0.5-fan 0.5" corresponds to the average.

Figure 18 and Figure 19 present the data that comes from Italy respectively for gas and oil boilers. Unfortunately, there is only one oil boiler in this dataset (that is the "Model 1" presented in sections 4.2.1 and 4.4.2). The dataset contains 36 boilers with age included in the range between 1 and 39 years.

The efficiencies calculated in the dataset range between 57% (typical of an old standard boiler) and 93% (typical of a recent condensing boiler). In general, the points in the graphs show a good agreement between the two calculations. The higher deviation is on the condensing boilers.

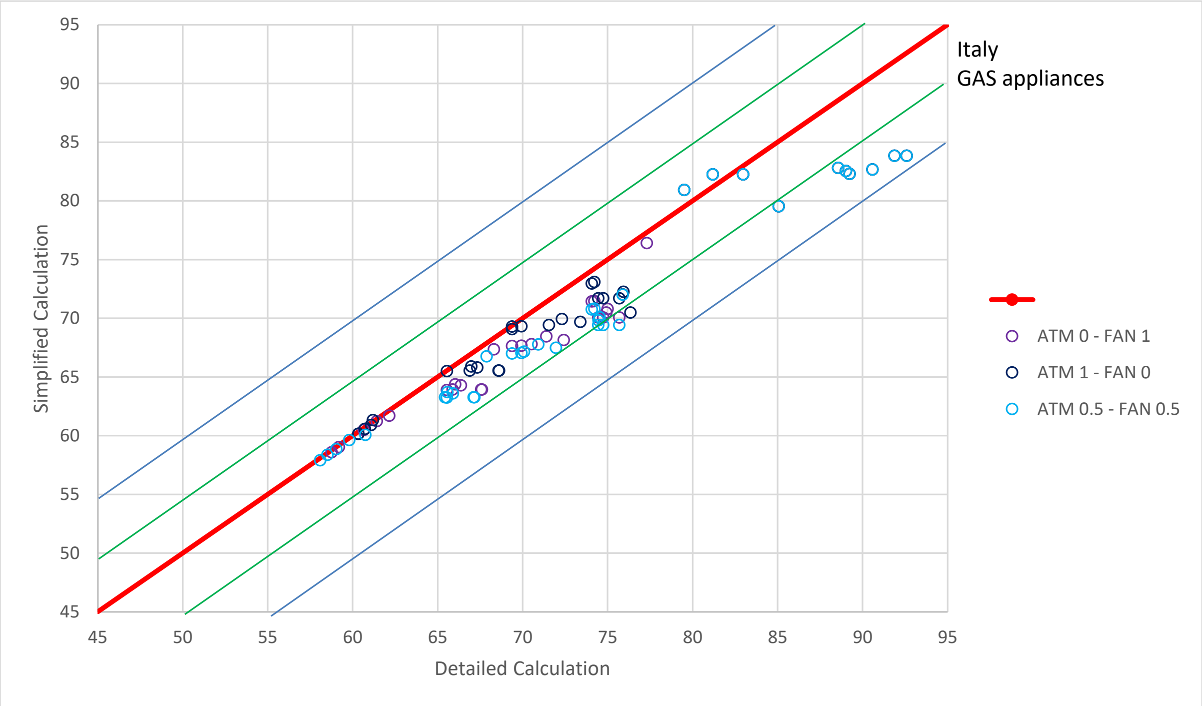



Figure 18 – Validation of SH appliances. Italian gas boilers.

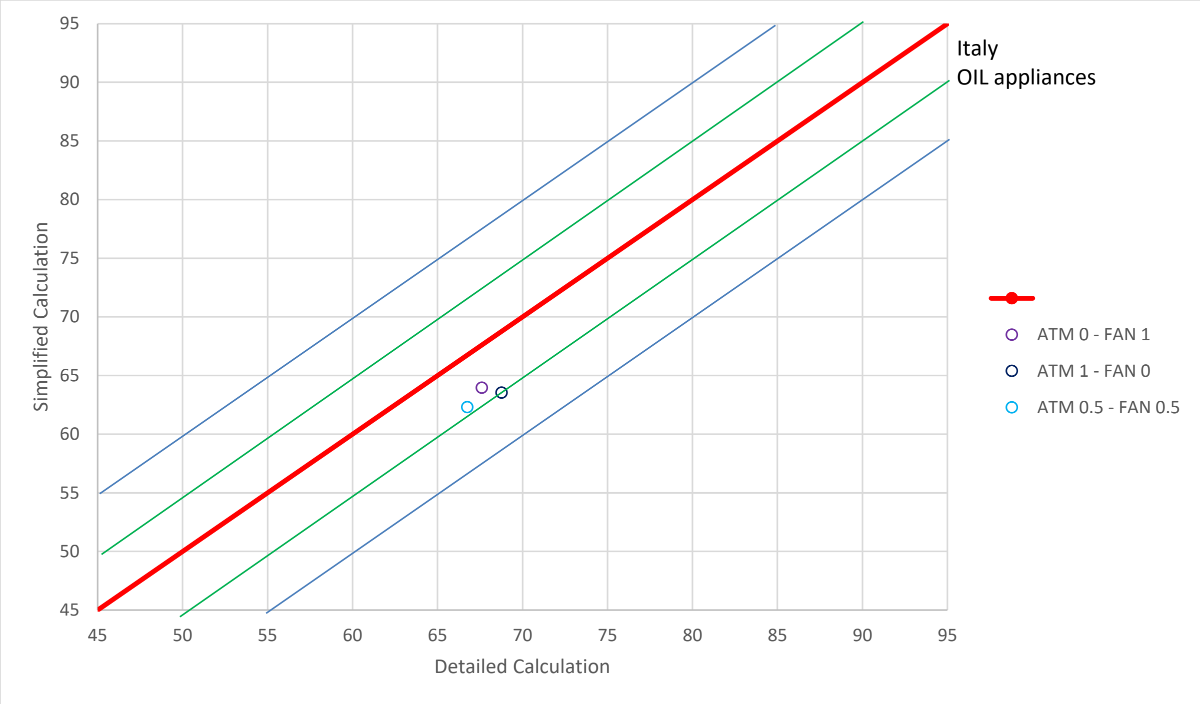



Figure 19 – Validation of SH appliances. Italian oil boilers.

Figure 20 and Figure 21 present the French dataset. This dataset contains 99 gas boilers and 63 oil boilers. The validation with this dataset has a small “weakness” since the boilers are relatively young (age between 1 and 6 years). The data presented in these two figures confirm the validity of the method since all the points are included in the blue boundary. The points of the condensing boilers are presenting the highest deviation.

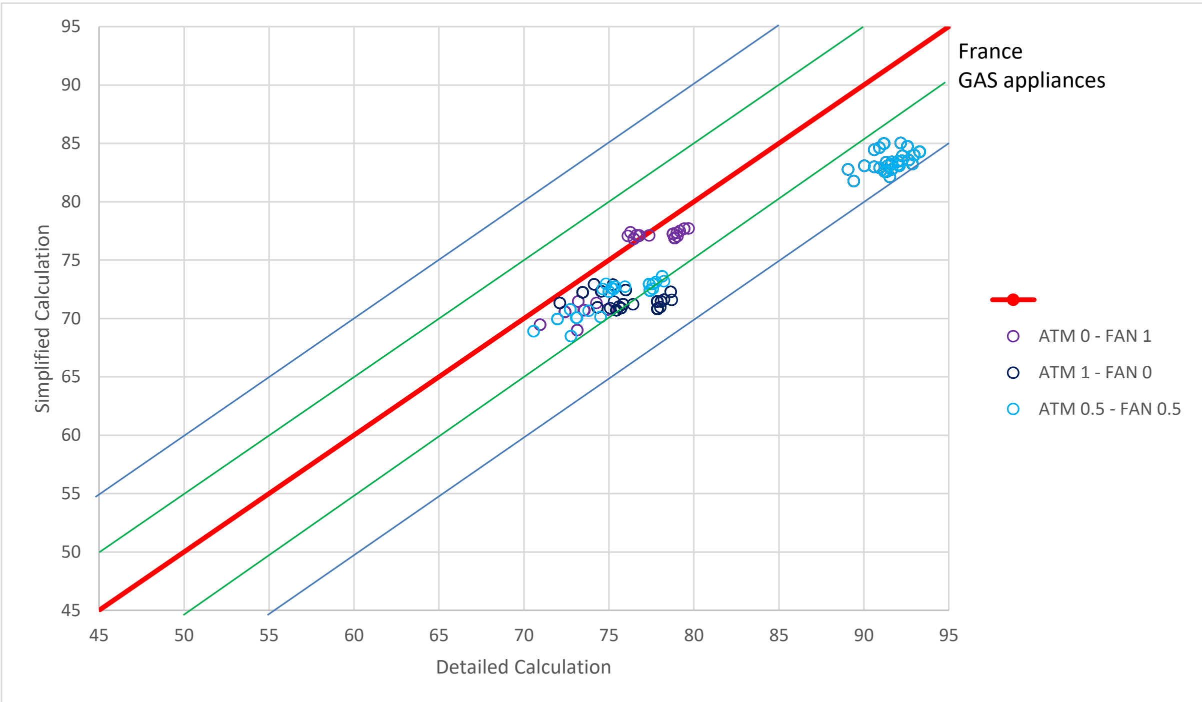



Figure 20 – Validation of SH appliances. French gas boilers.

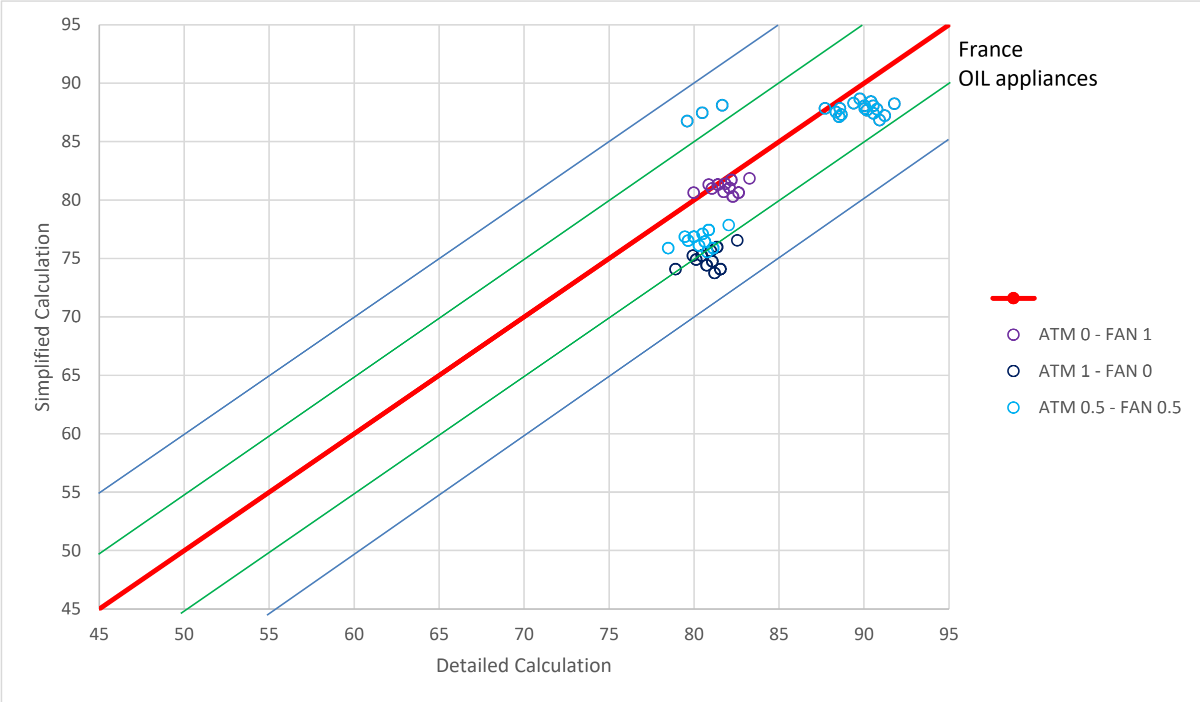



Figure 21 – Validation of SH appliances. French oil boilers.

Figure 22 and Figure 23 present the calculation performed with the German dataset. We need to clarify that for the detailed calculation was possible to use only the full load efficiency since it is the only parameter recorded in the database. Therefore, for the other parameters we used the default values. The agreement between simplified and detailed calculation is excellent for this reason.

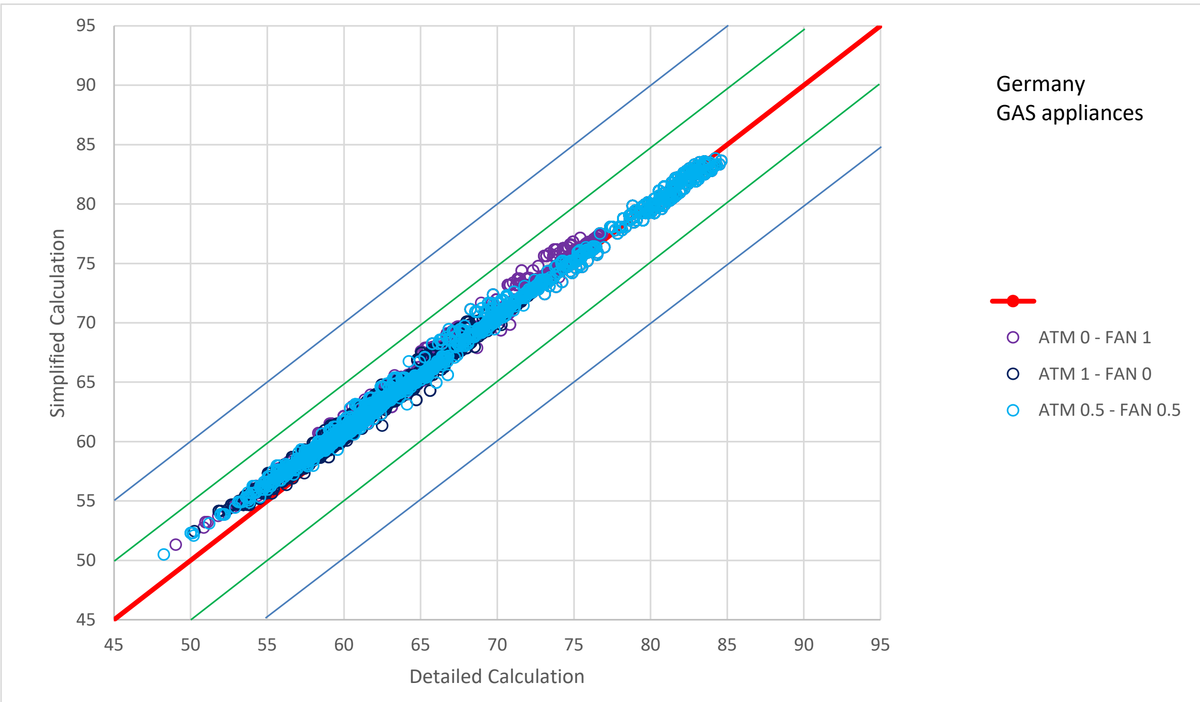



Figure 22 – Validation of SH appliances. German gas boilers.

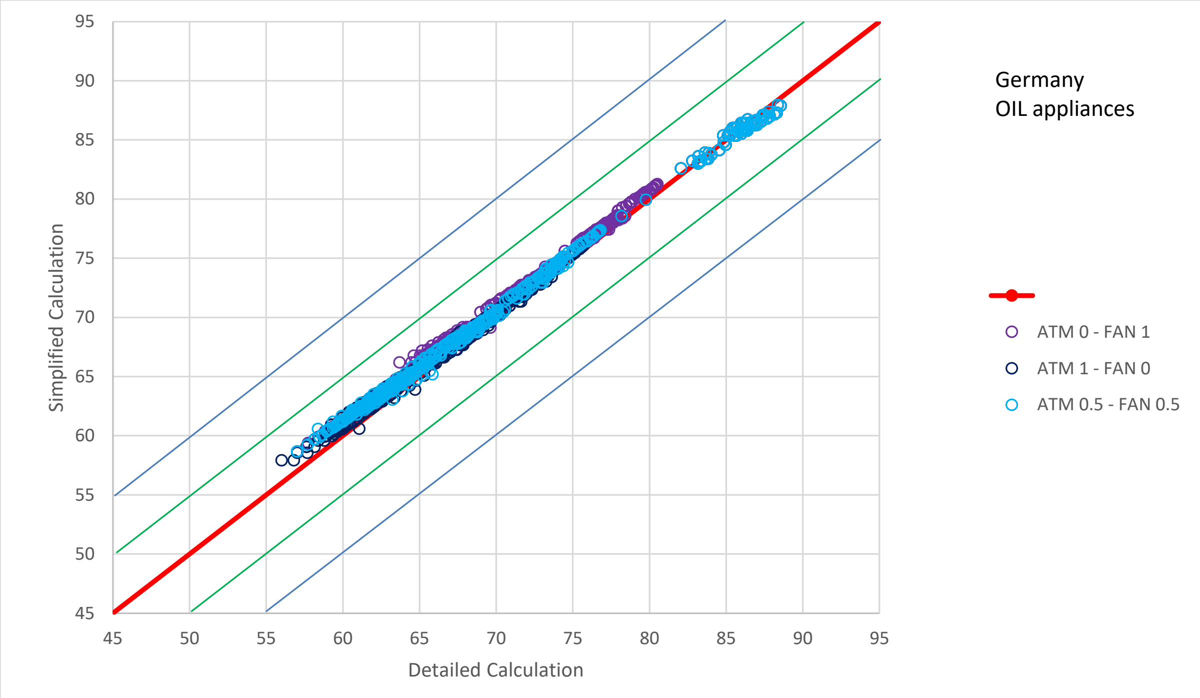



Figure 23 – Validation of SH appliances. German oil boilers.

The results presented graphically from Figure 18 to Figure 23 are summarised in Table 17 and Table 18, respectively for gas and oil boilers. The two tables present the average, the minimum and the maximum deviations distinguished for the three datasets (Italian, French and German), for the coefficients used, and for the boiler group (standard, low-temperature and condensing). The best agreement is obtained when the "fan-assisted boiler" coefficients are used. Only the case of Italian gas boilers performs better with the "atmospheric boiler" coefficient with a very small difference.

Table 17 – Gas SH appliances.

| | **All** | | | **Standard** | | | **Low temperature** | | | **Condensing** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FanA | Atm | Avg | FanA | Atm | Avg | FanA | Atm | Avg | FanA | Atm | Avg |
| Average deviation | | | | | | | | | | | | |
| **IT** | 3.07 | 2.64 | 3.38 | 2.46 | 1.63 | 2.78 | 0.90 | 5.84 | 3.87 | 4.76 | 4.76 | 4.76 |
| **FR** | 5.17 | 6.64 | 6.14 | 2.61 | 1.97 | 2.79 | 1.02 | 6.02 | 4.02 | 8.33 | 8.33 | 8.33 |
| **DE** | -0.89 | -0.70 | -0.80 | -1.23 | -1.26 | -1.24 | -1.09 | -0.80 | -0.95 | -0.08 | -0.08 | -0.08 |
| **ALL** | -0.67 | -0.45 | -0.55 | -1.08 | -1.13 | -1.08 | -1.01 | -0.53 | -0.75 | 0.21 | 0.21 | 0.21 |
| Minimum deviation | | | | | | | | | | | | |
| **IT** | -1.43 | -1.43 | -1.43 | 0.14 | -0.13 | 0.14 | 0.90 | 5.84 | 3.87 | -1.43 | -1.43 | -1.43 |
| **FR** | -1.12 | 0.78 | 1.65 | 1.50 | 0.78 | 1.65 | -1.12 | 3.87 | 1.87 | 6.16 | 6.16 | 6.16 |
| **DE** | -2.88 | -2.88 | -2.88 | -2.28 | -2.31 | -2.28 | -2.81 | -2.42 | -2.62 | -2.88 | -2.88 | -2.88 |
| **ALL** | -2.88 | -2.88 | -2.88 | -2.28 | -2.31 | -2.28 | -2.81 | -2.42 | -2.62 | -2.88 | -2.88 | -2.88 |
| Maximum deviation | | | | | | | | | | | | |
| **IT** | 8.74 | 8.74 | 8.74 | 5.61 | 3.98 | 6.25 | 0.90 | 5.84 | 3.87 | 8.74 | 8.74 | 8.74 |
| **FR** | 9.63 | 9.63 | 9.63 | 4.18 | 3.55 | 4.37 | 2.00 | 7.10 | 5.05 | 9.63 | 9.63 | 9.63 |
| **DE** | 1.18 | 1.33 | 1.18 | -0.45 | -0.35 | -0.43 | 0.99 | 1.33 | 1.16 | 1.18 | 1.18 | 1.18 |
| **ALL** | 9.63 | 9.63 | 9.63 | 5.61 | 3.98 | 6.25 | 2.00 | 7.10 | 5.05 | 9.63 | 9.63 | 9.63 |

Table 18 – Oil SH appliances.

| | All | | | Standard | | | Low temperature | | | Condensing | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FanA | Atm | Avg | FanA | Atm | Avg | FanA | Atm | Avg | FanA | Atm | Avg |
| Average deviation | | | | | | | | | | | | |
| **IT** | 3.64 | 5.22 | 4.43 | 3.64 | 5.22 | 4.43 | N.A | N.A | N.A | N.A | N.A | N.A |
| **FR** | 0.77 | 4.16 | 2.79 | N.A | N.A | N.A | 0.75 | 5.95 | 3.85 | 0.81 | 0.81 | 0.81 |
| **DE** | -0.85 | -0.60 | -0.72 | -1.22 | -1.24 | -1.23 | -0.92 | -0.61 | -0.76 | 0.29 | 0.29 | 0.29 |
| **ALL** | -0.75 | -0.40 | -0.57 | -1.13 | -1.14 | -1.14 | -0.86 | -0.41 | -0.62 | 0.30 | 0.30 | 0.30 |
| Minimum deviation | | | | | | | | | | | | |
| **IT** | 3.64 | 5.22 | 4.43 | 3.64 | 5.22 | 4.43 | N.A | N.A | N.A | N.A | N.A | N.A |
| **FR** | -7.18 | -7.18 | -7.18 | N.A | N.A | N.A | -0.67 | 4.68 | 2.58 | -7.18 | -7.18 | -7.18 |
| **DE** | -2.52 | -1.91 | -2.21 | -1.62 | -1.68 | -1.65 | -2.52 | -1.91 | -2.21 | -0.58 | -0.58 | -0.58 |
| **ALL** | -7.18 | -7.18 | -7.18 | -1.62 | -1.68 | -1.65 | -2.52 | -1.91 | -2.21 | -7.18 | -7.18 | -7.18 |
| Maximum deviation | | | | | | | | | | | | |
| **IT** | 3.64 | 5.22 | 4.43 | 3.64 | 5.22 | 4.43 | N.A | N.A | N.A | N.A | N.A | N.A |
| **FR** | 4.06 | 7.45 | 5.22 | N.A | N.A | N.A | 1.99 | 7.45 | 5.22 | 4.06 | 4.06 | 4.06 |
| **DE** | 0.99 | 0.99 | 0.99 | -0.99 | -0.81 | -0.90 | 0.49 | 0.81 | 0.65 | 0.99 | 0.99 | 0.99 |
| **ALL** | 4.06 | 7.45 | 5.22 | 3.64 | 5.22 | 4.43 | 1.99 | 7.45 | 5.22 | 4.06 | 4.06 | 4.06 |

### 4.4.2 Testing

In order to understand the validity of the data used as input for the method, the three of the four models presented in the comparison of section 4.2 were tested in laboratory. Table 19 presents the comparison of the part load and full load efficiencies between the default values defined after the elaboration of EN 15316-4-1, the values declared in the datasheet, and the measured values.

The difference between the default values and the datasheet values has been analysed in the previous paragraph considering the entire data set. The default value of “model 2” looks the same as of “model 3” but it’s not equal since in the table it was approximated to the first decimal. The $\eta_{30}$ are respectively 99.46 and 99.53, while the $\eta_{100}$ are 94.46 and 94.53. These values are similar since the equation (and the coefficients) is the same but the power is different (and it is an argument of the logarithmic function – see Eq.16 and Eq.17).

The heat calorific values (oil and gas) were assumed by the values declared by the local supplier.

The measured values should be compared with the datasheet values since these are inputs for the detailed method that should give a more accurate energy class.

The difference between the “datasheet” columns and “measured” columns evidence a good correspondence between these values.

Since different test have been repeated (at least three times) the last column presents the repeatability of results.

Table 19 – Laboratory test and field test.

| Model | Type | $P_n$ [kW] | Fuel | Age [y] | Default | | Datasheet | | Measured | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\eta_{30}$ | $\eta_{100}$ | $\eta_{30}$ | $\eta_{100}$ | $\eta_{30}$ | $\eta_{100}$ | Rep |
| 1 | Standard | 24 | Oil | 31 | 84.3 | 86.9 | 89.0 | 90.4 | 88 | 89.3 | ±1.0 |
| 2 | Condensing | 24.7 | Gas | 11 | 99.5 | 94.5 | 107.0 | 97.6 | N.A. | 98.1 | ±1.0 |
| 3 | Condensing | 34.2 | Gas | 11 | 99.5 | 94.5 | 109.1 | 97.4 | 110.1 | 97.8 | ±0.1 |

For “model 3”, the combustion efficiency was measured by a third body that can perform the emission test according to the Italian law. The results are shown in Figure 24 – Emission test performed on “Model 3”.

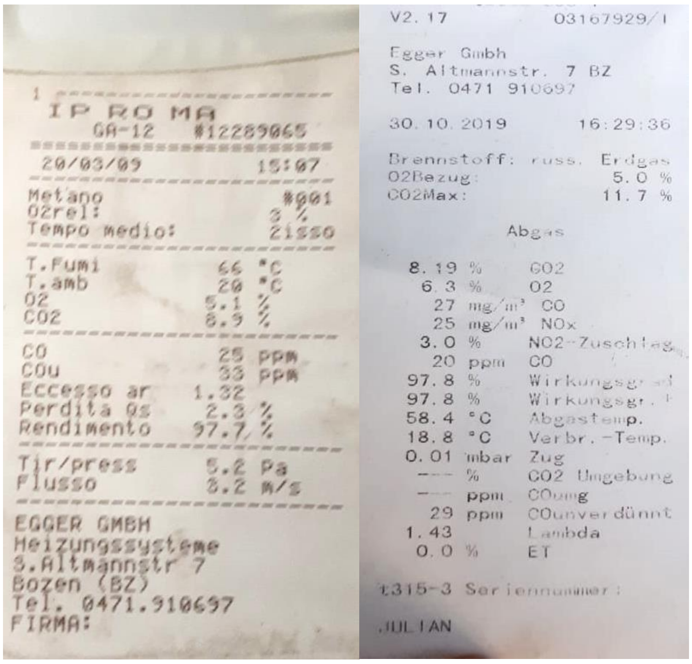



Figure 24 – Emission test performed on “Model 3”.

## 4.5 Conclusions

The method has been validated considering a simplified version of the table of EN15316-4-1.

The validation considered:

- about 4600 models
- with construction year from 1972 to 2019
- gas and oil boilers

During the validation we have found that the differences between the values for fan assisted or naturally ventilated boilers that are negligible (in average these are lower than 3.3%). The representation is done according to the following boiler groups:

- Standard
- Low temperature
- Condensing

Figure 25 and Figure 26 show the results of using the default values coming out from the validation activity. Those coefficients are presented in Table 20. The biggest variations can be identified by "condensing boilers" where the default values are more conservative.

The measurements of the three boilers on field confirmed the results.

To consider the agreement between the detailed and simplified calculation, the seasonal efficiency will be corrected by -3%.

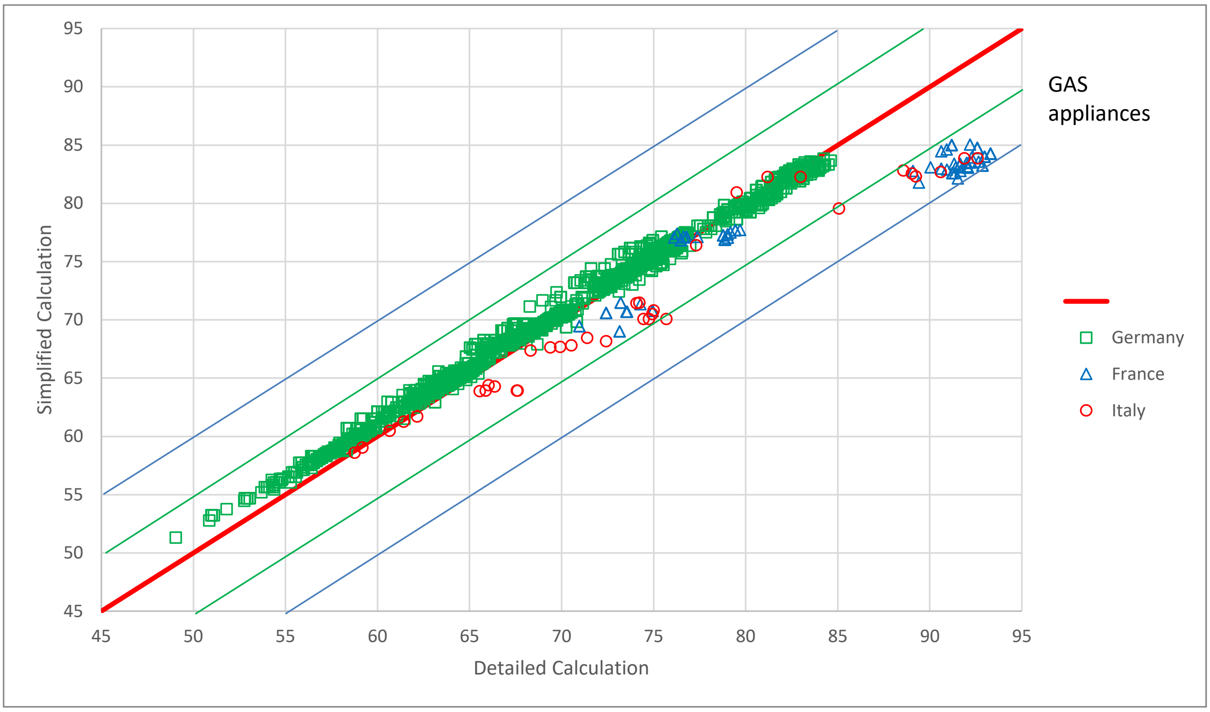



Figure 25 – Gas boilers. Validated dataset.

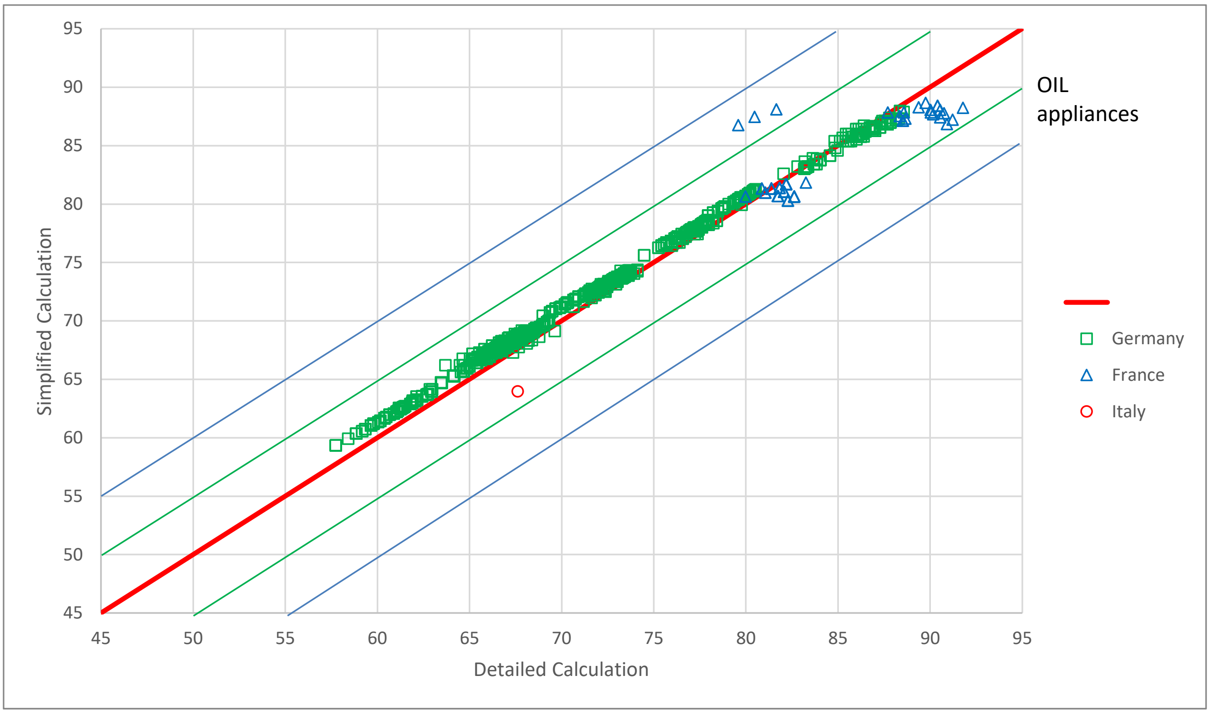



Figure 26 – Oil boilers. Validated dataset.

Table 20 – SH appliances. Coefficients used for the default values.

| | | C1 | C2 | C3 | C4 | C5 | C6 | C7_Pn | C8_Pn | n_Pn | C7_Pi | C8_Pi | n_Pi | C7_P0 | C8_P0 | n_P0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Standard** | y<=1978 | 80.0 | 2.0 | 75.0 | 3.0 | 9.0 | -0.3 | 0.0 | 45.0 | 0.5 | 0.0 | 15.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Standard** | 1978<y<=1987 | 82.0 | 2.0 | 77.5 | 3.0 | 7.5 | -0.3 | 0.0 | 45.0 | 0.5 | 0.0 | 15.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Standard** | 1987<y<=1994 | 84.0 | 2.0 | 80.0 | 3.0 | 7.5 | -0.3 | 0.0 | 45.0 | 0.5 | 0.0 | 15.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Standard** | y>1994 | 85.0 | 2.0 | 81.5 | 3.0 | 8.5 | -0.4 | 0.0 | 45.0 | 0.5 | 0.0 | 15.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Low Temperature** | y<=1978 | 85.5 | 1.5 | 86.0 | 1.5 | 6.0 | -0.3 | 40.0 | 0.1 | 1.0 | 40.0 | 0.1 | 1.0 | 15.0 | 0.0 | 0.0 |
| **Low Temperature** | 1978<y<=1987 | 85.5 | 1.5 | 86.0 | 1.5 | 6.0 | -0.3 | 40.0 | 0.1 | 1.0 | 40.0 | 0.1 | 1.0 | 15.0 | 0.0 | 0.0 |
| **Low Temperature** | 1987<y<=1994 | 85.5 | 1.5 | 86.0 | 1.5 | 6.0 | -0.3 | 40.0 | 0.1 | 1.0 | 40.0 | 0.1 | 1.0 | 15.0 | 0.0 | 0.0 |
| **Low Temperature** | y>1994 | 88.5 | 1.5 | 89.0 | 1.5 | 6.1 | -0.4 | 40.0 | 0.4 | 1.0 | 20.0 | 0.1 | 1.0 | 15.0 | 0.0 | 0.0 |
| **Condensing** | y<=1978 | 89.0 | 1.0 | 95.0 | 1.0 | 7.0 | -0.4 | 0.0 | 45.0 | 0.5 | 0.0 | 15.0 | 0.1 | 15.0 | 0.0 | 0.0 |
| **Condensing** | 1978<y<=1987 | 89.0 | 1.0 | 95.0 | 1.0 | 7.0 | -0.4 | 0.0 | 45.0 | 0.5 | 0.0 | 15.0 | 0.1 | 15.0 | 0.0 | 0.0 |
| **Condensing** | 1987<y<=1994 | 92.0 | 1.0 | 97.5 | 1.0 | 7.0 | -0.4 | 0.0 | 45.0 | 0.5 | 0.0 | 15.0 | 0.1 | 15.0 | 0.0 | 0.0 |
| **Condensing** | y>1994 | 93.0 | 1.0 | 98.0 | 1.0 | 4.0 | -0.4 | 0.0 | 45.0 | 0.5 | 0.0 | 15.0 | 0.1 | 15.0 | 0.0 | 0.0 |
| **Biomass – pellet** | | Note1 | | | | | | 40 | 2 | 1 | 40 | 1.8 | 1 | 15 | 0 | 0 |
| **Biomass – wood chip** | | Note1 | | | | | | 60 | 2.6 | 1 | 70 | 2.2 | 1 | 15 | 0 | 0 |

Note 1: see Standard / low temperature / condensing. It changes only the auxiliar consumption.

# 5 LABELLING FOR INSTALLED WATER HEATERS APPLIANCES

## 5.1 Proposed methodology for water heaters appliances

As the SH appliances, even for the WH methodology, the aim is to compare the label of old appliance with the label of new appliances. Therefore the label should be compliant to regulation 812/2013 [30].

### 5.1.1 Energy Labelling for new WH appliances

The regulation 812/2013 [30] foresees the calculation of water heaters efficiency according to a test profile of one day defined according to the size of the tapping profile. The annual consumption is evaluated considering an equivalent load of 60% of the same profile repeated over the 365 days.

The efficiency is calculated according the Eq.24 where $Q_{ref}$ is defined from the tapping profile and the other parameters are measured during the test of the water heater.

$$\eta_{WH} = \frac{Q_{ref}}{(Q_{fuel} + CC \cdot Q_{el}) \cdot (1 - SCF \cdot smart) + Q_{corr}}$$

Eq.24

Where "SCF" and "smart" are defined for the units with the smart function and the correction "$Q_{corr}$" is done according to the Eq.25 from Eq.28 presented in Table 21.

Table 21 – Correction factors for new WH appliances

| | | | |
|---|---|---|---|
| Qcorr | Electrical | $Q_{corr} = -k \cdot CC \cdot (Q_{el} \cdot (1 - SCF \cdot smart) - Q_{ref})$ | Eq.25 |
| | Conventional | $Q_{corr} = -k \cdot (Q_{fuel} \cdot (1 - SCF \cdot smart) - Q_{ref})$ | Eq.26 |
| | Heat Pumps | $Q_{corr} = -k \cdot 24 \cdot P_{stby}$ | Eq.27 |
| k | From 3XS to XL k=0.23, for XXL k=0 | | Eq.28 |

Source: Regulation EU 812/2013 – Annex VIII [30].

Table 22 presents the tapping profiles from 3XS to S, while Table 23 presents the tapping profiles from M to XXL (the two tables have been separated only for layout purpose). The first column of each profile represents the energy extracted for each draw-off. The last raw presents the sum of "i-th" draw-off that represents the Qref of Eq.24.

Table 22 – Tapping profiles from 3XS to S. Source Regulation EU 812/2013.

| | 3XS | | | XXS | | | XS | | | S | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **h** | Q | f | Tm | Q | f | Tm | Q | f | Tm | Q | f | Tm | Tp |
| **07:00** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | 0.105 | 3 | 25 | |
| **07:05** | 0.015 | 2 | 25 | | | | | | | | | | |
| **07:15** | 0.015 | 2 | 25 | | | | | | | | | | |
| **07:26** | 0.015 | 2 | 25 | | | | | | | | | | |
| **07:30** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | 0.525 | 3 | 35 | 0.105 | 3 | 25 | |
| **07:45** | | | | | | | | | | | | | |
| **08:01** | | | | | | | | | | | | | |
| **08:05** | | | | | | | | | | | | | |
| **08:15** | | | | | | | | | | | | | |
| **08:25** | | | | | | | | | | | | | |
| **08:30** | | | | 0.105 | 2 | 25 | | | | 0.105 | 3 | 25 | |
| **08:45** | | | | | | | | | | | | | |
| **09:00** | 0.015 | 2 | 25 | | | | | | | | | | |
| **09:30** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | 0.105 | 3 | 25 | |
| **10:00** | | | | | | | | | | | | | |
| **10:30** | | | | | | | | | | | | | |
| **11:00** | | | | | | | | | | | | | |
| **11:30** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | 0.105 | 3 | 25 | |
| **11:45** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | 0.105 | 3 | 25 | |
| **12:00** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | | | | |
| **12:30** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | | | | |
| **12:45** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | 0.525 | 3 | 35 | 0.315 | 4 | 10 | 55 |
| **14:30** | 0.015 | 2 | 25 | | | | | | | | | | |
| **15:00** | 0.015 | 2 | 25 | | | | | | | | | | |
| **15:30** | 0.015 | 2 | 25 | | | | | | | | | | |
| **16:00** | 0.015 | 2 | 25 | | | | | | | | | | |
| **16:30** | | | | | | | | | | | | | |
| **17:00** | | | | | | | | | | | | | |
| **18:00** | | | | 0.105 | 2 | 25 | | | | 0.105 | 3 | 25 | |
| **18:15** | | | | 0.105 | 2 | 25 | | | | 0.105 | 3 | 40 | |
| **18:30** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | | | | |
| **19:00** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | | | | |
| **19:30** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | | | | |
| **20:00** | | | | 0.105 | 2 | 25 | | | | | | | |
| **20:30** | | | | | | | 1.05 | 3 | 35 | 0.42 | 4 | 10 | 55 |
| **20:45** | | | | 0.105 | 2 | 25 | | | | | | | |
| **20:46** | | | | | | | | | | | | | |
| **21:00** | | | | 0.105 | 2 | 25 | | | | | | | |
| **21:15** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | | | | |
| **21:30** | 0.015 | 2 | 25 | | | | | | | 0.525 | 5 | 45 | |
| **21:35** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | | | | |
| **21:45** | 0.015 | 2 | 25 | 0.105 | 2 | 25 | | | | | | | |
| **TOT** | **0.345** | | | **2.1** | | | **2.1** | | | **2.1** | | | |

Table 23 – Tapping profiles from M to XXL. Source Regulation EU 812/2013.

| | M | | | | L | | | | XL | | | | XXL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **h** | Q | f | Tm | Tp | Q | f | Tm | Tp | Q | f | Tm | Tp | Q | f | Tm | Tp |
| **07:00** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **07:05** | 1.4 | 6 | 40 | | 1.4 | 6 | 40 | | | | | | | | | |
| **07:15** | | | | | | | | | 1.82 | 6 | 40 | | 1.82 | 6 | 40 | |
| **07:26** | | | | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **07:30** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | | | | | | | | |
| **07:45** | | | | | 0.105 | 3 | 25 | | 4.42 | 10 | 10 | 40 | 6.24 | 10 | 10 | 40 |
| **08:01** | 0.105 | 3 | 25 | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **08:05** | | | | | 3.605 | 10 | 10 | 40 | | | | | | | | |
| **08:15** | 0.105 | 3 | 25 | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **08:25** | | | | | 0.105 | 3 | 25 | | | | | | | | | |
| **08:30** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **08:45** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **09:00** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **09:30** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **10:00** | | | | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **10:30** | 0.105 | 3 | 10 | 40 | 0.105 | 3 | 10 | 40 | 0.105 | 3 | 10 | 40 | 0.105 | 3 | 10 | 40 |
| **11:00** | | | | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **11:30** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **11:45** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **12:00** | | | | | | | | | | | | | | | | |
| **12:30** | | | | | | | | | | | | | | | | |
| **12:45** | 0.315 | 4 | 10 | 55 | 0.315 | 4 | 10 | 55 | 0.735 | 4 | 10 | 55 | 0.735 | 4 | 10 | 55 |
| **14:30** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **15:00** | | | | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **15:30** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **16:00** | | | | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **16:30** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **17:00** | < | | | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **18:00** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **18:15** | 0.105 | 3 | 40 | | 0.105 | 3 | 40 | | 0.105 | 3 | 40 | | 0.105 | 3 | 40 | |
| **18:30** | 0.105 | 3 | 40 | | 0.105 | 3 | 40 | | 0.105 | 3 | 40 | | 0.105 | 3 | 40 | |
| **19:00** | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **19:30** | | | | | | | | | | | | | | | | |
| **20:00** | | | | | | | | | | | | | | | | |
| **20:30** | 0.735 | 4 | 10 | 55 | 0.735 | 4 | 10 | 55 | 0.735 | 4 | 10 | 55 | 0.735 | 4 | 10 | 55 |
| **20:45** | | | | | | | | | | | | | | | | |
| **20:46** | | | | | | | | | 4.42 | 10 | 10 | 40 | 6.24 | 10 | 10 | 40 |
| **21:00** | | | | | 3.605 | 10 | 10 | 40 | | | | | | | | |
| **21:15** | 0.105 | 3 | 25 | | | | | | 0.105 | 3 | 25 | | 0.105 | 3 | 25 | |
| **21:30** | 1.4 | 6 | 40 | | 0.105 | 3 | 25 | | 4.42 | 10 | 10 | 40 | 6.24 | 10 | 10 | 40 |
| **21:35** | | | | | | | | | | | | | | | | |
| **21:45** | | | | | | | | | | | | | | | | |
| **TOT** | **5.845** | | | | **11.655** | | | | **19.07** | | | | **24.53** | | | |

Table 24 presents the lower limit of energy class distinguished between the different tapping profiles. The boundaries are different for each profile. If we look at the same class, the efficiency requirements increase with the Qref.

Table 24 – Energy Label, lower class limit. Efficiency [%]. Source Regulation EU 812/2013.

| | 3XS | XXS | XS | S | M | L | XL | XXL |
|---|---|---|---|---|---|---|---|---|
| **A+++** | 62 | 62 | 69 | 90 | 163 | 188 | 200 | 213 |
| **A++** | 53 | 53 | 61 | 72 | 130 | 150 | 160 | 170 |
| **A+** | 44 | 44 | 53 | 55 | 100 | 115 | 123 | 131 |
| **A** | 35 | 35 | 38 | 38 | 65 | 75 | 80 | 85 |
| **B** | 32 | 32 | 35 | 35 | 39 | 50 | 55 | 60 |
| **C** | 29 | 29 | 32 | 32 | 36 | 37 | 38 | 40 |
| **D** | 26 | 26 | 29 | 29 | 33 | 34 | 35 | 36 |
| **E** | 22 | 23 | 26 | 26 | 30 | 30 | 30 | 32 |
| **F** | 19 | 20 | 23 | 23 | 27 | 27 | 27 | 30 |

### 5.1.2 Energy Labelling for old WH appliances

As the methodology of SH appliances, we have developed two versions for one simplified calculation for a common user and a detailed calculation for a professional user.

Differently from Figure 16, Figure 27 shows that the calculation depends from the WH technology.

A common user should indicate the fuel, WH type between “GSWH”, “GIWH”, “ESWH” and “EIWH”, the construction year and the number of inhabitants. Instead the professional user should also indicate other parameters.

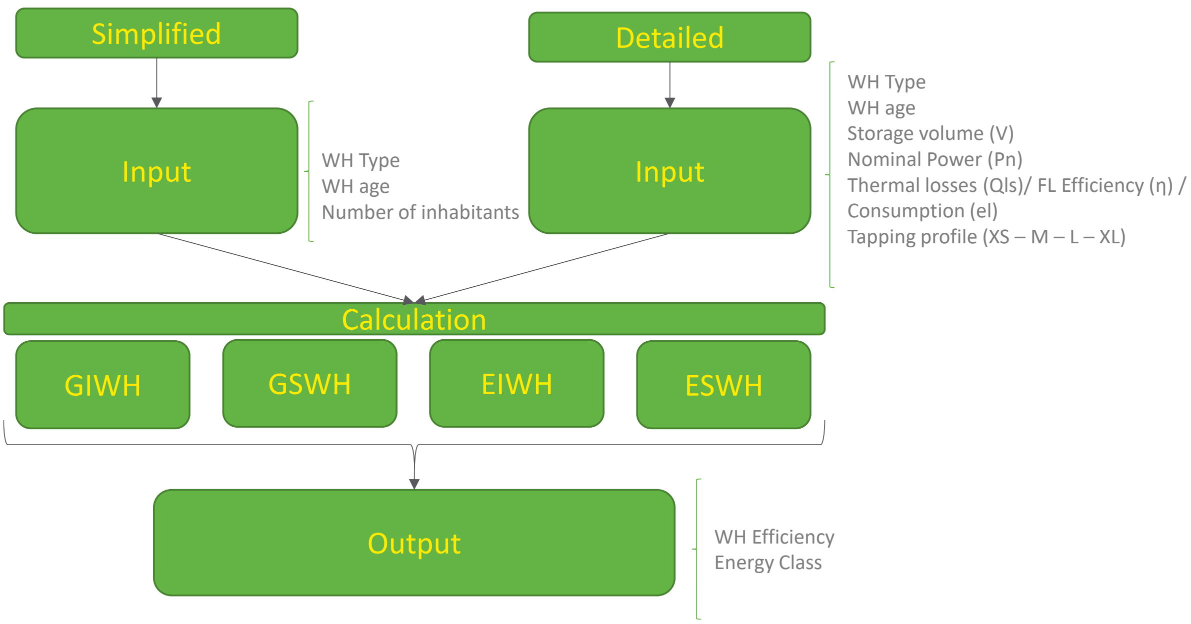



Figure 27 – Flow chart of WH appliances.

The Eq.29 presents the WH efficiency that is calculated similarly as the Eq.24 with two differences:

- as hypothesis we assumed that an old appliance does not have the smart function. Therefore the term "smart" is set to 0 and the correction factors are changed consequently (Table 25).
- We considered the aging coefficient distinguishing into "gas water heaters" and "electric water heater".

$$\eta_{WH} = \frac{Q_{ref}}{(Q_{fuel} + CC \cdot Q_{el}) + Q_{corr}} \cdot \boldsymbol{C_{age}}$$

Eq.29

Table 25 – Correction factors for old WH appliances

| | | | |
|---|---|---|---|
| Qcorr | Electrical | $Q_{corr} = -k \cdot CC \cdot (Q_{el} - Q_{ref})$ | Eq.25 |
| | Conventional | $Q_{corr} = -k \cdot (Q_{fuel} - Q_{ref})$ | Eq.26 |
| | Heat Pumps | $Q_{corr} = -k \cdot 24 \cdot P_{stby}$ | Eq.27 |
| k | From 3XS to XL k=0.23, for XXL k=0 | | Eq.28 |

Table 26 presents the degradation coefficients as a function of age following the approach presented in section 4.3.2.

$$C_{age} = (1 - M)^{age}$$

Eq.15

Table 26 – Degradation coefficient as a function of age. WH appliances.

| **Age** | **Gas/Oil Boilers** | | **Heat Pumps** | | **Electric Boilers** | |
|---|---|---|---|---|---|---|
| *Maintenance* | Normal | Bad | Normal | Bad | Normal | Bad |
| *M* | *0.005* | *0.015* | *0.01* | *0.03* | *0.001* | *0.002* |
| <10 | 1.00 | 0.86 | 0.90 | 0.74 | 1.00 | 1.00 |
| 10-15 | 0.98 | 0.80 | 0.86 | 0.63 | 0.99 | 0.97 |
| 16-20 | 0.95 | 0.74 | 0.82 | 0.54 | 0.98 | 0.96 |
| 21-25 | 0.90 | 0.69 | 0.78 | 0.47 | 0.97 | 0.95 |
| 26-30 | 0.88 | 0.64 | 0.74 | 0.40 | 0.96 | 0.94 |
| >30 | 0.87 | 0.59 | 0.70 | 0.34 | 0.95 | 0.93 |

Table 27 presents the input required in the simplified and detailed version of labelling methodology. A professional user should introduce more specific parameters than a common user.

Table 27 – Input and output of label of WH appliances

| | **Simplified** | **Detailed** |
|---|---|---|
| **Input** | WH Type<br>Construction year<br>Number of inhabitants | WH Type<br>Construction year<br>Storage volume (V)<br>Nominal Power (Pn)<br>Thermal losses (Qls)/ FL Efficiency (η) / Consumption (el)<br>Tapping profile (XS – M – L – XL) |
| **Output** | Efficiency<br>Energy Class | Efficiency<br>Energy Class |

In the simplified version we decided to define the characteristic of a typical appliance starting from the number of inhabitants. This decision was done to avoid misunderstanding of users that can confuse the parameters to use in the calculation.

This will define the correlated tapping profile and to that we associate the parameters needed for the calculation that are the volume and power for a storage WH and the nominal flow and power for an instantaneous WH.

The correlation of the number of inhabitants with the tapping profile has been defined looking at the "Table B.5" of EN 12831-3 and was compared to the experience from the LPA+ project [31]. The column "EN 12831-3" considers the value of a water consumption of 60 l/person/day it comes out an energy consumption of 2.2 kWh/person/day. Dividing the energy of the tapping profile with the daily consumption of one person, we can obtain the correspondence between the tapping profile and number of inhabitants.

Table 28 – Correlation between tapping profiles and number of inhabitants.

| | **Energy** | **EN12831-3** | **LPA+** |
|---|---|---|---|
| S | 2.1 kWh/day | 1 | 0 |
| M | 5.85 kWh/day | 2 – 3 | 1 – 2 |
| L | 11.7 kWh/day | 4 – 5 | 3 – 5 |
| XL | 19.1 kWh/day | 6 – 9 | 6 – 8 |
| XXL | 24.5 kWh/day | 10 – 12 | 9+ |

The “Eco-design and energy label” review study of “Water heaters and Storage Tanks”, in the Market Analysis [32], presents the typical parameters for water heaters under “*Table 16. Typical technical characteristics*”. However, this table combines the EIWH with the GIWH and the ESWH with GSWH as reported in Figure 28. Typically, for storages water heaters, a defined tapping profile corresponds to a nominal power and volume. Instead, for instantaneous water heaters, for a specific power corresponds a tapping profile. However differently from what indicated in Figure 28 there are some differences in the typical characteristics between electric and gas water heaters and in this report we distinguished the four WH typologies.

Table 16. Typical technical characteristics

| Typical parameters | | 3XS | XXS | XS | S | M | L | XL | XXL |
|---|---|---|---|---|---|---|---|---|---|
| Real instant. power (EIWH, GIWH*) | kW (market) | 3.50 | 5.00 | 8.00 | 18.00 | 23.00 | 28.00 | 36.00 | 48.00 |
| Real store (ESWH, GSWH*) | litres | 5.0 | 10.0 | 10.0 | 30.0 | 80.0 | 120.0 | 180.0 | 250.0 |
| Real store reheat power | kW (market) | 2.0 | 2.0 | 2.0 | 2.0 | 2.8 | 2.8 | 8.0 | 12.0 |

Figure 28 – Extract of Table 16 of Task 2 – “Eco-design and energy label” review study of “Water heaters and Storage Tanks”. [32]

Table 29 and Figure 29 were defined with a statistical evaluation of 200 different appliances present in the market of different manufacturers. ESWH appliances with a profile of XS and XXL were not present in the data available. The values associated to those profiles has been extrapolated considering the energy consumption of the tapping.

EIWH presents a small volume and they do not present models with M or higher tapping profiles since the electric power required would be too high for a typical residential use. Table 30 presents the definition of default values for EIWH.

Table 29 – Correspondence between tapping profile with volume and power for an ESWH.

| | Volume [L] | | | | Power [kW] | | | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Average | | Min | Max | Average | |
| **XXS** | 10 | 15 | 12.08 | **12** | 1.2 | 1.2 | 1.2 | **1.2** |
| **XS** | N.A. | N.A. | N.A. | **12** | N.A. | N.A. | N.A. | **1.2** |
| **S** | 30 | 30 | 30 | **30** | 1.2 | 1.5 | 1.39 | **1.4** |
| **M** | 48.5 | 200 | 83.73 | **100** | 1.2 | 2.5 | 1.41 | **1.5** |
| **L** | 78 | 300 | 167.64 | **150** | 1.2 | 3 | 1.875 | **2** |
| **XL** | 500 | 500 | 500 | **500** | 6 | 6 | 6 | **6** |
| **XXL** | N.A. | N.A. | N.A. | **650** | N.A. | N.A. | N.A. | **8** |

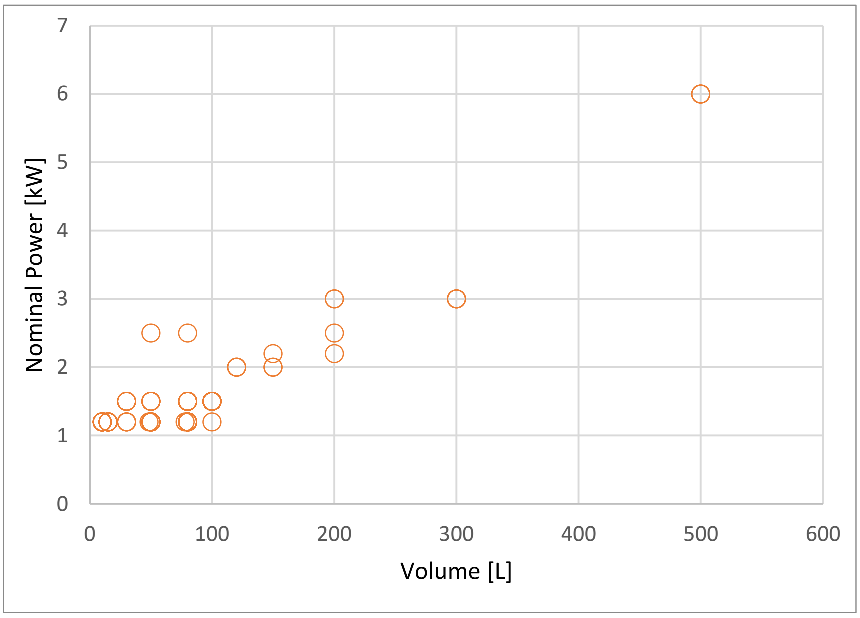


Figure 29 – Correspondence between volume and power for an ESWH.

Table 30 – Correspondence between tapping profile with volume and power for an EIWH.

| | Volume [L] | | | | Power [kW] | | | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Average | | Min | Max | Average | |
| **XXS** | 5 | 15 | 12.2 | **12** | 1.2 | 1.2 | 1.2 | **1.2** |
| **S** | 5 | 30 | 28 | **28** | 1.2 | 2.4 | 1.44 | **1.5** |

Table 31 and Figure 30 were defined with a statistical evaluation of 200 models of different manufacturers where 150 are new models (younger than 10 years old) present in the market and about 50 are old models (older than 10 years old). GIWH appliances with a profile of XXS were not present in the data available. The flow and power associated to the XXS profile is the same of XS appliances since have the same energy extracted by the tapping profile.

Table 31 – Correspondence between tapping profile with nominal flow and power for a GIWH.

| | Flow [l/min] | | | | Power [kW] | | | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Average | | Min | Max | Average | |
| **XS** | 5 | 5 | 5 | **5** | 8.7 | 9.4 | 9.3 | **9** |
| **S** | 11 | 11 | 11 | **11** | 19.2 | 19.3 | 19.3 | **19** |
| **M** | 10 | 13 | 11.1 | **11** | 17.4 | 22.7 | 19.5 | **19.5** |
| **L** | 14 | 16 | 14.1 | **14** | 22 | 30 | 24.5 | **25** |
| **XL** | 14 | 18 | 16.3 | **16** | 23.8 | 35 | 29.5 | **29** |
| **XXL** | 24 | 27 | 25.5 | **26** | 45 | 65 | 55 | **55** |

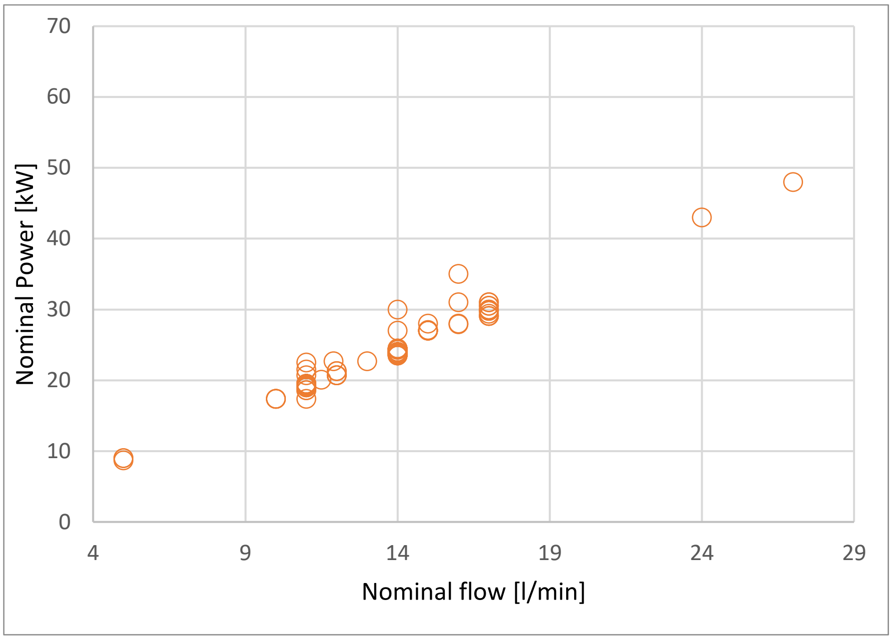



Figure 30 – Correspondence between power and nominal flow for a GIWH.

Table 32 and Figure 31 were defined with a statistical evaluation of 100 models of different manufacturers for the definition of the default values of GSWH. In this case there is not a clear trend of power as a function of volume as the previous figures since different volumes can be combined to different nominal power to fulfil the tapping profile requirements.

Table 32 – Correspondence between tapping profile with volume and power for a GSWH.

| | **Volume [l]** | | | | **Power [kW]** | | | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Average | | Min | Max | Average | |
| **XXS** | N.A. | N.A. | N.A. | **80** | N.A. | N.A. | N.A. | **5** |
| **XS** | N.A. | N.A. | N.A. | **80** | N.A. | N.A. | N.A. | **5** |
| **S** | N.A. | N.A. | N.A. | **80** | N.A. | N.A. | N.A. | **5** |
| **M** | 48 | 115 | 81.4 | **80** | 5 | 5 | 5 | **5** |
| **L** | 115 | 160 | 138.6 | **140** | 4.3 | 16 | 7.4 | **7.5** |
| **XL** | 195 | 200 | 196.3 | **200** | 5.2 | 16 | 9.2 | **10** |
| **XXL** | 190 | 950 | 458 | **450** | 16 | 67 | 33.9 | **34** |

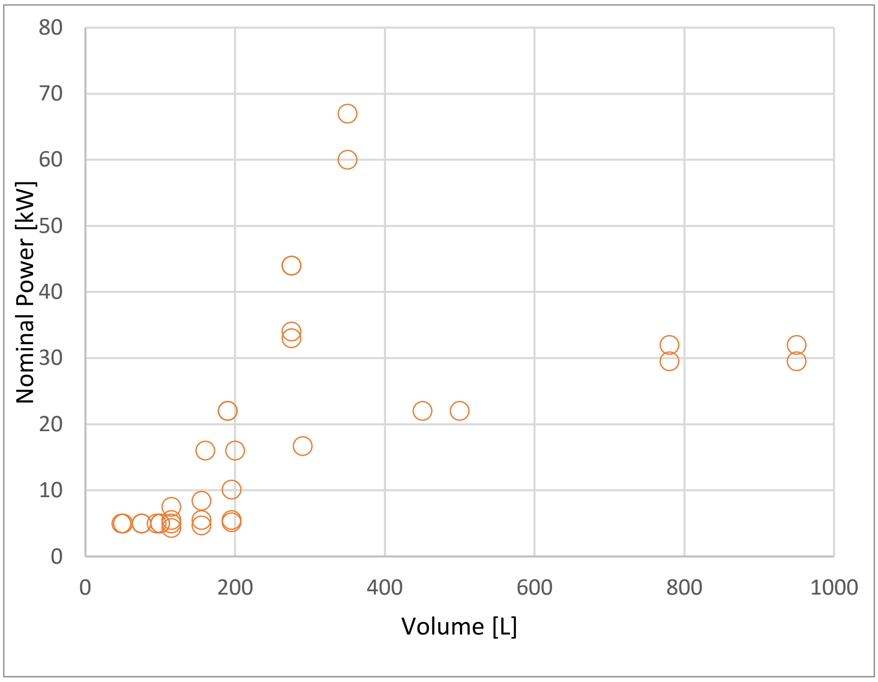



Figure 31 – Correspondence between power and volume for a GSWH.

The calculation of WH efficiency is performed considering the one-day cycle of regulation 812/2013. The Qref came from the tapping profile and the Qfuel and Qel is calculated in different ways depending on the appliances:

- ESWH / GSWH from energy balance with thermal losses (from datasheet or from EN 15316-5)
- GIWH from FL efficiency (from datasheet or from EN 15316-4-1)

To perform an energetic balance on the water heaters, the following parameters should be considered:

- Storage volume - V
- Nominal Power - Pn
- Tapping profile – Qref
- Losses – Qls
- Ambient and storage temperatures - $\vartheta_{amb}, \vartheta_{set}$

Analysing different studies made in literature on the water heaters efficiency present how it changes as a function of the used load [33–39]. Boait et al [35] compare the different technologies available for the WH appliances but the efficiency presented is not compliant to the ERP (therefore is not comparable with our work).

Tajwar et al [36] show how the efficiency of a gas WH can change improving the baffle. The authors start from a 35% and reaches up to 62% or 85% with different combinations. The evolution of the technology is also presented in IEA-Task 45 [39] where they presents that storages built until 2005 have thermal loss 30% to 100% higher than the actual ones.

Two of the cited references [37,38] present the general model of the WH with storage.

$$\sum \dot{Q}_i = M \cdot c \cdot \frac{dT}{dt}$$

Eq.30

Where the $\dot{Q}_i$ represents all the thermal fluxes.

If the calculation is performed over a cycle with the same initial and final temperatures the second term is 0. The equation can be summarized as follows.

$$Q_{in} - Q_{ls} - Q_{ref} = 0$$

Eq.31

Where Qin represents the generation input. The same assumption has been done in [33,34].

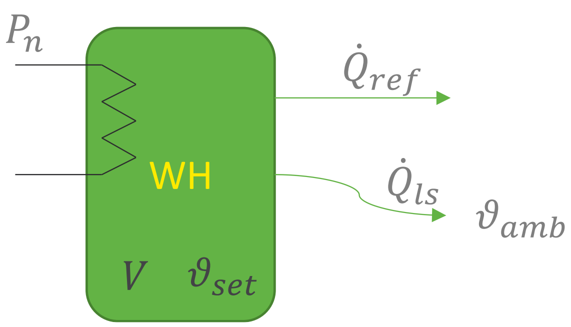



Figure 32 – Simplified model of a WH appliance.

**<u>Consumptions definition:</u>**

From the Eq.31 we can calculate the electric consumption of a ESWH with Eq.32 and the fuel consumption for a GSWH with the Eq.33.

ESWH:

$$Q_{el} = \frac{Q_{ref} + Q_{ls}}{\eta}$$

Eq.32

The efficiency is assumed to be $\eta$ = 100% since the electric resistance is immersed in the storage (all the electricity converted into heat is left to the storage).

GSWH:

$$Q_{fuel} = \frac{Q_{ref} + Q_{ls}}{\eta_{100} \cdot H_i/H_s} = \frac{(Q_{ref} + Q_{ls})}{\eta_{100}} \cdot \frac{H_s}{H_i}$$

Eq.33

$$Q_{el} = \int P \, d\vartheta = el_{max} \cdot \vartheta_{on} + P_{sb} \cdot \vartheta_{off}$$

Eq.34

The efficiency and the electric consumption are read from datasheet (professional user) or taken from the default values of EN 15316-4-1 (common user - Eq.37, $el_{max} = c_{7,Pn} + c_{8,Pn} \cdot (P_n)^{n,Pn}$

Eq.38, and $P_{SB} = c_{7,P0} + c_{8,P0} \cdot (P_n)^{n,P0}$

Eq.39). In the Eq.33 there is implemented the conversion of efficiency defined with lower heat value to the one with higher heat value as indicated in Eq.8.

GIWH – from datasheet or default values from EN 15316-4-1:

$$Q_{fuel} = \frac{Q_{ref}}{\eta_{100} \cdot H_i/H_s} = \frac{Q_{ref}}{\eta_{100}} \cdot \frac{H_s}{H_i}$$

Eq.35

$$Q_{el} = \int P \, d\vartheta = el_{max} \cdot \vartheta_{on} + P_{sb} \cdot \vartheta_{off}$$

Eq.36

As for the Eq.33, the efficiency and electric consumption are read from datasheet (professional user) or taken from the default values of EN 15316-4-1 (common user - Eq.37, $el_{max} = c_{7,Pn} + c_{8,Pn} \cdot (P_n)^{n,Pn}$

Eq.38, and $P_{SB} = c_{7,P0} + c_{8,P0} \cdot (P_n)^{n,P0}$

Eq.39). In the Eq.35 there is implemented the conversion of efficiency defined with lower heat value to the one with higher heat value as indicated in Eq.8.

**Default values:**

$$\eta_{100} = c_1 + c_2 \cdot \log(P_n)$$

Eq.37

$$el_{max} = c_{7,Pn} + c_{8,Pn} \cdot (P_n)^{n,Pn}$$

Eq.38

$$P_{SB} = c_{7,P0} + c_{8,P0} \cdot (P_n)^{n,P0}$$

Eq.39

Where $c_1$, $c_2$, $c_7$, $c_8$ $n$ defined in the EN 15316-4-1 as a function of boiler group. See Table 36.

**Thermal losses for appliances with a storage:**

The energy losses presented in the datasheet are indicated as 24 hours losses with 65°C of storage while the calculation presented in EN 15316-5 is performed with a storage temperature of 55 °C and ambient temperature of 16 °C.

Therefore, to make coherent the simplified calculation with the detailed calculation, the correction on thermal losses should be performed as follows:

$$Q_{ls} = Q_{ls,65} \cdot \frac{\vartheta_{set} - \vartheta_{amb}}{\vartheta_{set,test} - \vartheta_{amb}} \cdot t$$

Eq.40

For the default value, the energy losses are defined from EN 15316-5:

$$Q_{ls} = f_{sto,bac,acc} \cdot f_{sto,dis,ls} \cdot \frac{H}{1000} \cdot (\vartheta_{set} - \vartheta_{amb}) \cdot t$$

Eq.41

Where:

- $f_{sto,bac,acc}$ represents a factor for the adaption for the calculation time step.
- $f_{sto,dis,ls}$ represent a factor that considers thermal bridge.
- H is the heat losses coefficient [W/K].
- $\vartheta_{amb}$, $\vartheta_{set}$ are the ambient and storage temperatures (16 °C and 55 °C).

The standard defines $f_{sto,bac,acc} = 1$ for default, monthly or annual calculation.

The standard defines $f_{sto,dis,ls} = 1$ for installation without thermal bridge while $f_{sto,dis,ls} = 3$ for installations with thermal bridge.

For old appliances we assume that the installation has thermal bridges.

The heat losses coefficient is defined as:

$$H = \frac{1000}{c_4 \cdot c_5} \cdot (c_1 + c_2 \cdot V^{c_3})$$

Eq.42

Where V is the volume [L], $c_1$, $c_2$, $c_3$, $c_4$, $c_5$ are defined as a function of the WH type. See Table 37.

## 5.2 Validation

For the validation about 200 ESWH appliances and about 200 GIWH appliances were analysed.

The tapping profiles associated to the ESWH appliances space between XXS to XL with exclusion of XS while the tapping profiles of the GIWH appliances space between XS to XXL.

The models considered for ESWH are coming from different manufacturers and were produced in the last decade. Data of older products was not possible to be retrieved. Instead, the 26% of the GIWHs have more than 10 years.

Figure 33 present the comparison between the efficiency read from the product fiche and the two values estimated with the simplified and the detailed calculations for the case of ESWH. In this case since there are relatively new models the factor $f_{sto,dis,ls}$ is considerer 1. Those points are represented with the red and blue circles (“Eff_det” and “Eff_sim”). There is a very good agreement between the simplified and detailed calculations with the efficiency of the product fiche.

To simulate an old appliance, the calculation has been repeated considering the factor $f_{sto,dis,ls} = 3$ that represents an appliance with thermal bridges. The WH efficiency decreases about 10% is compared to the new product. In this case there is again a good relation between the detailed and the simplified calculation. To plot the results the “real efficiency” was taken from the new product and decreased by the 10% since there is not available for an old product.

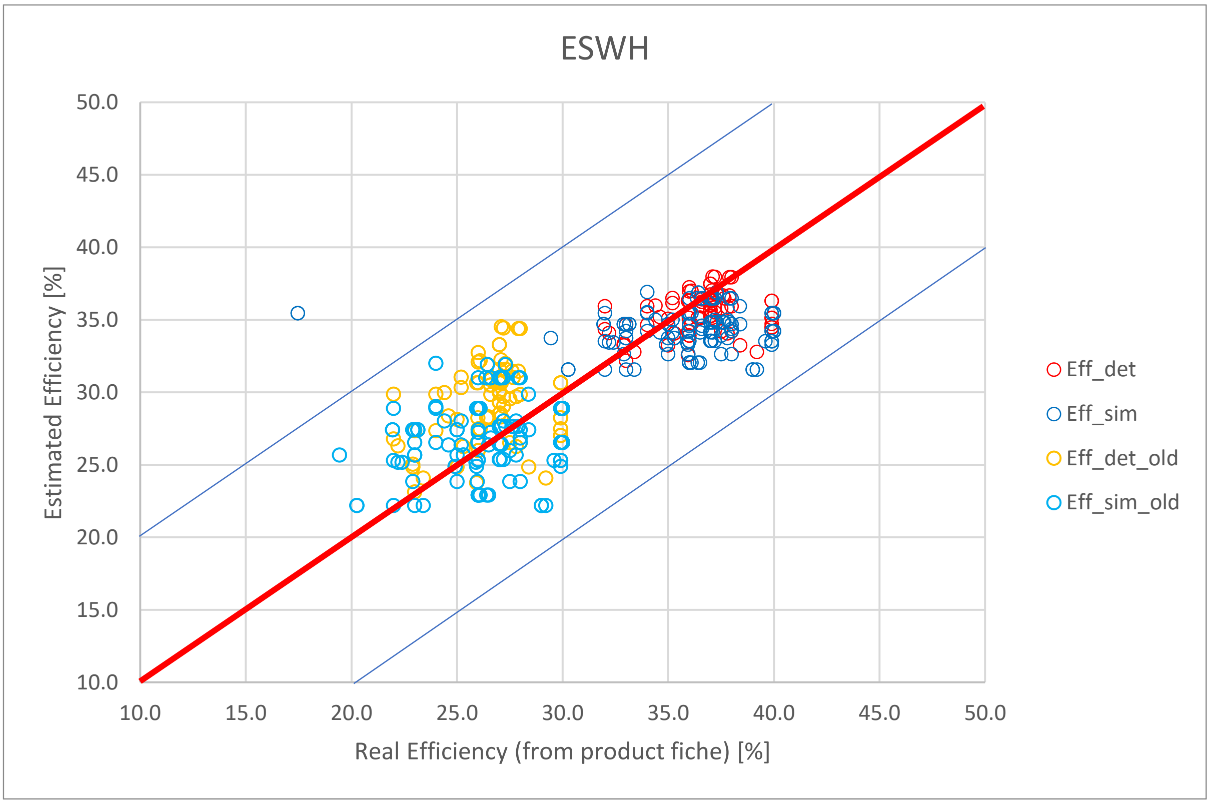



Figure 33 – Validation of ESWH appliances.

Figure 34 present the comparison between the efficiency read from the product fiche and the two values estimated with the simplified and the detailed calculations for the case of GIWH. Differently from the ESWH, this figure presents "old" and "new" products. The red circles represent the detailed calculation ("Eff_det") while the blue circles represent the simplified calculation ("Eff_sim").

There are two models that goes out from the boundary with about 15% of deviation from the "real efficiency". All the other points present a very good agreement between the simplified and detailed calculations with the efficiency of the product fiche.


Figure 34 – Validation of GIWH appliances.

## 5.3 Testing

Two GIWH were tested to validate the labelling methodology. The age of the first GIWH is 22 years and the second one is 11 years.

Table 33 – Models tested in the laboratory.

| Model | Type | V [l/min] | Profile | Fuel | Age [y] |
|---|---|---|---|---|---|
| 1 | Standard | 14 | L | Gas | 22 |
| 2 | Standard | 14 | L | Gas | 11 |

The WH has been tested in steady-state condition with an inlet temperature of 10°C ± 2K. The aim was to verify six points in the draw-off diagram of the unit as indicated by Figure 35. In the unit there are two selectors: one for power (curves A and B) and one for the temperature difference (X axe). Those selectors do not present a grade scale and therefore the exact value of temperature difference cannot be selected.

Table 34 presents the tested points of the theoretic diagram of Figure 35.

The “Model 1” reflects coherently the draw-off diagram with exception of point six that presents a higher deviation. Instead, the “Model 2” is not fully coherent with the diagram. The points “2” and “6” present a higher temperature difference and we noticed that there is a kind of hysteresis on the boiler: if the WH starts with the selector in that position or if the selector is changed after that the WH is switched on. The same behaviour is obtained if the flow rate changes during the draw-off or not. We do not investigate deeply this effect since the purpose of the test was to verify the labelling methodology.

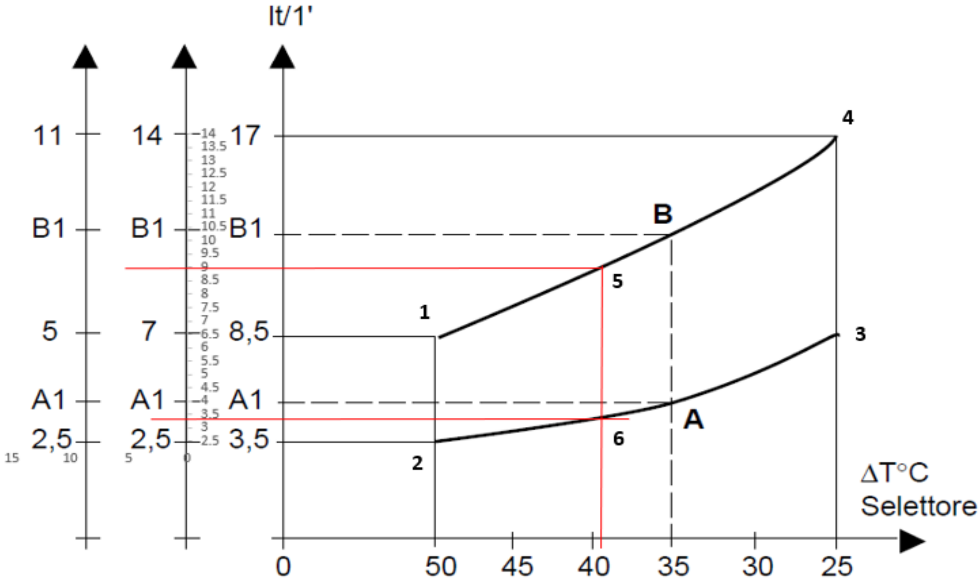



Figure 35 – Logic of control of GIWH.

Table 34 – Laboratory characterization of two GIWH.

| | Point | T_supply | T_return | DT | P_GB | Q_GB | Eff |
|---|---|---|---|---|---|---|---|
| | | [°C] | [°C] | [°C] | [kW] | [kW] | [%] |
| Model 1 | 1 | 61.7 | 10.6 | 51.2 | 23.0 | 28.5 | 80.8 |
| | 2 | 61.6 | 11.2 | 50.5 | 8.5 | 11.1 | 76.7 |
| | 3 | 36.3 | 10.1 | 26.3 | 13.0 | 15.5 | 83.5 |
| | 4 | 34.3 | 9.9 | 24.3 | 23.5 | 27.7 | 85.0 |
| | 5 | 48.7 | 10.9 | 37.9 | 23.4 | 27.6 | 84.8 |
| | 6 | 53.5 | 10.4 | 43.1 | 10.2 | 11.9 | 85.8 |
| | | | | | | | |
| Model 2 | 1 | 62.4 | 10.1 | 52.2 | 24.7 | 30.2 | 81.9 |
| | 2 | 84.3 | 10.9 | 73.5 | 12.4 | 16.1 | 77.1 |
| | 2_bis | 34.1 | 9.6 | 24.6 | 4.3 | 5.1 | 84.1 |
| | 3 | 36.4 | 9.9 | 26.5 | 12.9 | 15.6 | 82.9 |
| | 4 | 35.6 | 10.6 | 25.0 | 24.4 | 28.4 | 85.9 |
| | 5 | 47.7 | 9.6 | 38.1 | 23.6 | 27.9 | 84.7 |
| | 6 | 64.3 | 10.7 | 53.6 | 12.4 | 15.3 | 81.0 |
| | 6_bis | 21.0 | 9.5 | 11.6 | 2.7 | 3.2 | 85.0 |

To verify the labelling methodology, we performed the tapping profile as indicated in the regulation 812/2013 and in the standard EN 13203-2. The temperature difference for the test should be at least 45 K, and the outlet temperature should be lower than 65 °C. The tapping profile foresees a flow rate between 180 l/h and 600 l/h with the possibility to correct according the obtained temperature difference. These WH are not able to satisfy the requirement of the flow rate and therefore it was corrected according to the “Equation 1 of EN 13203-2”. With the DTd = 50 K and DTuseful = 30 we obtain that the minimum flow rate is 360 l/h instead of 180 l/h.

During the test the “Model 1” presented some problems in the starting of the burner. Therefore, we had to by-pass the switch giving an external signal for starting the ignition. This problem was the motivation that motivate the user to replace the WH.

Table 35 presents the comparison between two values that are input for the calculation of the labelling and the efficiency of the WH. The column “Simplified” and “Detailed” present the efficiency calculated with the labelling methodology while the “Measured” column present the efficiency measured in the laboratory. The column “simplified” and “detailed” contains the value of WH efficiency that does not consider the degradation coefficient “$C_{age}$” and are indicated with “$\eta_{WH}*$”. The two models have a different degradation coefficient “$C_{age}$” since the first one is 22 years old ($C_{age}$=0.95) and the second one is 11 years old ($C_{age}$=0.98).

There is a good agreement between the simplified and detailed calculation and the results are also confirmed by the laboratory tests. The efficiency measured in the laboratory is about 5% lower than the calculated one. In any case, the laboratory test highlighted some problems in the running of the two old WH.

Table 35 – Laboratory test results of two GIWH and comparison with labelling methodology.

| Model | Simplified | | | | Detailed | | | | Measured | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_n$ | $\eta_{100}$ | $\eta_{WH}*$ | $\eta_{WH}$ | $P_n$ | $\eta_{100}$ | $\eta_{WH}*$ | $\eta_{WH}$ | $P_n$ | $\eta_{100}$ | $\eta_{WH}$ |
| 1 | 25 | 87.8% | 78.8% | 74.9% | 24.5 | 85.4% | 77.3% | 73.4% | 23.5 | 85.0% | 71.1% |
| 2 | 25 | 87.8% | 78.8% | 77.2% | 24.5 | 86% | 77.8% | 76.2% | 24.4 | 85.9% | 74.5% |

## 5.4 Conclusions

The method was validated considering about 200 ESWH and 200 GIWH with a construction year from 1999 to 2020. The default values were taken from the EN 15316-5 and from the validation made for SH appliances.

The representation of WH is done according to the following types:

- GSWH

- GIWH
- ESWH
- EIWH

The coefficients used to define the default values are presented in Table 36 and Table 37.

The measurements of the two WH in laboratory confirmed the results.

Table 36 – Gas WH appliances. Coefficients used for the default values.

| | | C1 | C2 | C7_Pn | C8_Pn | n_Pn | C7_P0 | C8_P0 | n_P0 |
|---|---|---|---|---|---|---|---|---|---|
| **Standard** | y<=1978 | 80.0 | 2.0 | 0.0 | 45.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Standard** | 1978<y<=1987 | 82.0 | 2.0 | 0.0 | 45.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Standard** | 1987<y<=1994 | 84.0 | 2.0 | 0.0 | 45.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Standard** | y>1994 | 85.0 | 2.0 | 0.0 | 45.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Low Temperature** | y<=1978 | 85.5 | 1.5 | 40.0 | 0.1 | 1.0 | 15.0 | 0.0 | 0.0 |
| **Low Temperature** | 1978<y<=1987 | 85.5 | 1.5 | 40.0 | 0.1 | 1.0 | 15.0 | 0.0 | 0.0 |
| **Low Temperature** | 1987<y<=1994 | 85.5 | 1.5 | 40.0 | 0.1 | 1.0 | 15.0 | 0.0 | 0.0 |
| **Low Temperature** | y>1994 | 88.5 | 1.5 | 40.0 | 0.4 | 1.0 | 15.0 | 0.0 | 0.0 |
| **Condensing** | y<=1978 | 89.0 | 1.0 | 0.0 | 45.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Condensing** | 1978<y<=1987 | 89.0 | 1.0 | 0.0 | 45.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Condensing** | 1987<y<=1994 | 92.0 | 1.0 | 0.0 | 45.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Condensing** | y>1994 | 93.0 | 1.0 | 0.0 | 45.0 | 0.5 | 15.0 | 0.0 | 0.0 |
| **Biomass – pellet** | | Note1 | | 40 | 2 | 1 | 15 | 0 | 0 |
| **Biomass – wood chip** | | Note1 | | 60 | 2.6 | 1 | 15 | 0 | 0 |

Note 1: see Standard / low temperature / condensing. It changes only the auxiliar consumption.

Table 37 – Default values for heat losses depending on the type of storage.

| **EN 15316-5** | **Table B.2 - Default values depending on the type of storage** | | | | | |
|---|---|---|---|---|---|---|
| **Storage Type** | Standard | C1 | C2 | C3 | C4 | C5 |
| **Electric storage heater Horizontal** | EN 60379<br>EN 50440 | 0.939 | 0.0104 | 1 | 45 | 24 |
| **Electric storage heater vertical; V>=75** | EN 60379<br>EN 50440 | 0.224 | 0.0663 | 0.67 | 45 | 24 |
| **Electric storage heater vertical; V<75** | EN 60379<br>EN 50440 | 0.1474 | 0.0719 | 0.67 | 45 | 24 |
| **Solar storage** | EN 12977-3<br>EN 12977-4 | 0 | 0.16 | 0.5 | 1000 | 1 |
| **Electric storage heater with back-up** | EN 60379<br>EN 50440 | 0.1474 | 0.0719 | 0.67 | 45 | 24 |

## 6 CONCLUSIONS

This report has presented the labelling methodology for installed SH and WH appliances.

The methodology presented two levels of detail in the inputs required for the calculation: one for a common user (simplified calculation) and one for a professional user (detailed calculation).

The method for SH appliances has been validated for oil and gas boilers considering about 4600 models built between the 1972 and the 2019. The representation is done according to three boiler groups (Standard, Low-Temperature and Condensing). The laboratory measurements of the three boilers confirmed the results.

To consider the agreement between the detailed and simplified calculation, the seasonal efficiency will be corrected by -3%.

In addition, the reference performance of old heat pumps was calculated.

The method for WH appliances has been validated for electric and gas water heaters considering about 400 models built between the 1999 and the 2020. In this case, the representation is done according to four WH types (ESWH, EIWH, GSWH and GIWH). The laboratory measurement on two GIWH confirmed the results.

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# APPENDIX A - TABLES

Table 38 – EN 15316-4-1. Table B1. Parameters for calculation of generator efficiency and temperature limitation.

| | Type | Year | C1 | C2 | C3 | C4 | $T_{g,t,Pn}$ | $T_{g,t,Pi}$ |
|---|---|---|---|---|---|---|---|---|
| STANDARD BOILERS | Multi Fuel boiler | before 1978 | 77.0 | 2.0 | 70.0 | 3.0 | 70 | 50 |
| | | 1978 to 1987 | 79.0 | 2.0 | 74.0 | 3.0 | 70 | 50 |
| | Atmospheric solid fuel boiler (fossil and biomass fuel) | before 1978 | 78.0 | 2.0 | 72.0 | 3.0 | 70 | 70 |
| | | 1978 to 1994 | 80.0 | 2.0 | 75.0 | 3.0 | 70 | 70 |
| | | after 1994 | 81.0 | 2.0 | 77.0 | 3.0 | 70 | 70 |
| | atmospheric gas boiler | before 1978 | 79.5 | 2.0 | 76.0 | 3.0 | 70 | 50 |
| | | 1978 to 1994 | 82.5 | 2.0 | 78.0 | 3.0 | 70 | 50 |
| | | after 1994 | 85.0 | 2.0 | 81.5 | 3.0 | 70 | 50 |
| | Fan-assisted boiler (fossil and biomass fuel) | before 1978 | 80.0 | 2.0 | 75.0 | 3.0 | 70 | 70 |
| | | 1978 to 1986 | 82.0 | 2.0 | 77.5 | 3.0 | 70 | 70 |
| | | 1987 to 1994 | 84.0 | 2.0 | 80.0 | 3.0 | 70 | 70 |
| | | after 1994 | 85.0 | 2.0 | 81.5 | 3.0 | 70 | 70 |
| | Burner replacement (only fan-assisted boilers) | before 1978 | 82.5 | 2.0 | 78.0 | 3.0 | 70 | 50 |
| | | 1978 to 1986 | 84.0 | 2.0 | 80.0 | 3.0 | 70 | 50 |
| LOW TEMPERATURE BOILERS | atmospheric gas boiler | 1978 to 1994 | 85.5 | 1.5 | 86.0 | 1.5 | 70 | 40 |
| | | after 1994 | 88.5 | 1.5 | 89.0 | 1.5 | 70 | 40 |
| | Circulation water heater (11 kW 18 kW and 24 kW) | before 1987 | 84.0 | 1.5 | 82.0 | 1.5 | 70 | 40 |
| | | 1987 to 1994 | 86.0 | 1.5 | 82.0 | 1.5 | 70 | 40 |
| | | After 1994 | 86.0 | 1.5 | 82.0 | 1.5 | 70 | 40 |
| | Combination boilers KSp[c d] (11 kW 18 kW and 24 kW) | After 1994 | 86.0 | 1.5 | 82.0 | 1.5 | 70 | 40 |
| | Fan-assisted boiler | before 1987 | 84.0 | 1.5 | 82.0 | 1.5 | 70 | 40 |
| | | 1987 to 1994 | 86.0 | 1.5 | 86.0 | 1.5 | 70 | 40 |
| | | After 1994 | 88.5 | 1.5 | 89.0 | 1.5 | 70 | 40 |
| | Burner replacement (only fan-assisted boilers) | before 1987 | 86.0 | 1.5 | 85.0 | 1.5 | 70 | 40 |
| | | 1987 to 1994 | 86.0 | 1.5 | 86.0 | 1.5 | 70 | 40 |
| CONDENSING BOILERS | Condensing boiler | before 1987 | 89.0 | 1.0 | 95.0 | 1.0 | 60 [b] | 30 [b] |
| | | 1987 to 1994 | 91.0 | 1.0 | 97.5 | 1.0 | 60 [b] | 30 [b] |
| | | | 92.0 | 1.0 | | | 30 [b] | |
| | | After 1994 | 92.0 | 1.0 | 98.0 | 1.0 | 60 [b] | 30 [b] |
| | | | 93.0 | 1.0 | | | 30[b] | |
| | Condensing boiler, improved[a] from 1999 | gasolio/gas | 94.0 | 1.0 | 103.0 | 1.0 | 60 [b] | 30 [b] |
| | | oil | 102 | 0.3 | | | 30 [b] | |
| | | gas | 102 | 1 | | | 30 [b] | |

*a If standard values for "condensing boilers improved" are used for the calculation, the product value for the boiler installed must exhibit the above given efficiency.*

*b For condensing boilers testing applies at a return temperature of 60°C respectively to 30 °C.*

*c DL: Boiler with integrated domestic water heating working on the instantaneous principle with heat exchanger (V < 2 l).*

*d KSp: Boiler with integrated domestic water heating working on the istantaneous principle with small storage tank (2 < V < 10 l).*

Table 39 – EN 15316-4-1. Table B3. Parameters for calculation of stand-by heat losses.

| Type | | Year | C5 | C6 | $T_{g,t,P0}$ |
|---|---|---|---|---|---|
| STANDARD BOILERS | Multi Fuel boiler | before 1978 | 12.5 | -0.28 | 70 |
| | Atmospheric solid fuel boiler (fossil and biomass fuel) | before 1978 | 12.5 | -0.28 | 70 |
| | | 1978 to 1994 | 10.5 | -0.28 | 70 |
| | | after 1994 | 8.0 | -0.28 | 70 |
| | atmospheric gas boiler | before 1978 | 8.0 | -0.27 | 70 |
| | | 1978 to 1994 | 7.0 | -0.3 | 70 |
| | | after 1994 | 8.5 | -0.4 | 70 |
| | Fan-assisted boiler (fossil and biomass fuel) | before 1978 | 9.0 | -0.28 | 70 |
| | | 1978 to 1994 | 7.5 | -0.31 | 70 |
| | | after 1994 | 14.0 | -0.28 | 70 |
| LOW TEMPERATURE BOILERS | atmospheric gas boiler | 1978 to 1994 | 6.0 | -0.32 | 70 |
| | | after 1994 | 6.1 | -0.4 | 70 |
| | Circulation water heater (11 kW 18 kW and 24 kW) | before 1994 | 2.2 | 0 | 70 |
| | | After 1994 | 1.2 | 0 | 70 |
| | Combination boilers KSp[e] (11 kW 18 kW and 24 kW) | After 1994 | 2.2 | 0 | 70 |
| | Fan-assisted boiler | before 1987 | 7.0 | -0.37 | 70 |
| | | 1987 to 1994 | 7.0 | -0.37 | 70 |
| | | After 1994 | 4.25 | -0.4 | 70 |
| CONDENSING BOILERS | Condensing boiler | before 1994 | 7.0 | -0.37 | 70 |
| | | After 1994 | 4.0 | -0.4 | 70 |
| | Combination boilers KSp[b] (11 kW 18 kW and 24 kW) | After 1994 | 2.2 | 0 | 70 |
| | Combination boilers DL[a] (11 kW 18 kW and 24 kW) | After 1994 | 1.2 | 0 | 70 |
| *a DL: Boiler with integrated domestic water heating working on the instantaneous principle with heat exchanger (V < 2 l).* | | | | | |
| *b KSp: Boiler with integrated domestic water heating working on the istantaneous principle with small storage tank (2 < V < 10 l).* | | | | | |

Table 40 – EN 15316-4-1 Table B6.

| | $C_{7Pn}$ | $C_{8Pn}$ | $n_{Pn}$ | $C_{7Pi}$ | $C_{8Pi}$ | $n_{Pi}$ | $C_{7P0}$ | $C_{8P0}$ | $n_{P0}$ |
|---|---|---|---|---|---|---|---|---|---|
| since 1994 | | | | | | | | | |
| Heating boiler with forced draught burner a (fossil and biomass fuel) | 0 | 45 | 0.48 | 0 | 15 | 0.48 | 15 | 0 | 0 |
| atmospheric gas boiler and solid fuel boiler (fossil and biomass fuel) up to 250 kW | 40 | 0.35 | 1 | 20 | 0.1 | 1 | 15 | 0 | 0 |
| atmospheric gas boiler with more than 250 kW | 80 | 0.7 | 1 | 40 | 0.2 | 1 | 15 | 0 | 0 |
| automatically fed pellet central boiler, system with buffer tank | 40 | 2 | 1 | 40 | 1.8 | 1 | 15 | 0 | 0 |
| automatically fed wood chips central boiler, system with buffer tank | 60 | 2.6 | 1 | 70 | 2.2 | 1 | 15 | 0 | 0 |
| standard | | | | | | | | | |
| multi fuel boiler | 0 | 45 | 0.48 | 0 | 15 | 0.48 | 20 | 0 | 0 |
| solid fuel boiler (fossil and biomass fuel) | 15 | 0 | 0 | 15 | 0 | 0 | 15 | 0 | 0 |
| atmospheric gas boiler | 40 | 0.148 | 1 | 40 | 0.148 | 1 | 15 | 0 | 0 |
| heating boiler with forced draught burner (oil/gas | 0 | 45 | 0.48 | 0 | 15 | 0.48 | 15 | 0 | 0 |
| low | | | | | | | | | |
| atmospheric gas boiler | 40 | 0.148 | 1 | 40 | 0.148 | 1 | 15 | 0 | 0 |
| circulation water heaters | 0 | 45 | 0.48 | 0 | 15 | 0.148 | 15 | 0 | 0 |
| heating boiler with forced draught burner (oil/gas) | 0 | 45 | 0.48 | 0 | 15 | 0.148 | 15 | 0 | 0 |
| conditioning | 0 | 45 | 0.48 | 0 | 15 | 0.148 | 15 | 0 | 0 |
| *a if there is a forced draught ventilator assisting the burner than the values increse by 40%* | | | | | | | | | |
| *if an electronic controller is used, otherwise Po=0* | | | | | | | | | |

Table 41 – EN 15316-4-1 Table B9.

| Table B.9 Conversion Hs/Hi | |
|---|---|
| Fuel oil | 1.06 |
| Natural gas | 1.11 |
| Liquid petroleum gas | 1.09 |
| Anthrecite coal | 1.04 |
| Lignite coal | 1.07 |
| Wood | 1.08 |
| CHP | 1 |
| Electricity | 1 |

Table 42 – EN 15316-5 Table B.2. Default values depending on the type of storage

| Storage Type | Standard | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|---|
| **Electric storage heater Horizontal** | EN 60379<br>EN 50440 | 0.939 | 0.0104 | 1 | 45 | 24 |
| **Electric storage heater vertical; V>=75** | EN 60379<br>EN 50440 | 0.224 | 0.0663 | 0.67 | 45 | 24 |
| **Electric storage heater vertical; V<75** | EN 60379<br>EN 50440 | 0.1474 | 0.0719 | 0.67 | 45 | 24 |
| **Solar storage** | EN 12977-3<br>EN 12977-4 | 0 | 0.16 | 0.5 | 1000 | 1 |
| **Electric storage heater with back-up** | EN 60379<br>EN 50440 | 0.1474 | 0.0719 | 0.67 | 45 | 24 |