European Commission

Space and combination heaters

Ecodesign and Energy Labelling

Review Study

Task 6

Options

<u>FINAL REPORT</u>

Review study of Commission Regulation (EU) No. 813/2013 [Ecodesign] and Commission Delegated Regulation No. (EU) No. 811/2013 (Energy Label)

Prepared by

VHK for the European Commission

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Energy

Prepared by

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Cover: Gas-fired central heating boiler [picture VHK 2016-2017]

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EXECUTIVE SUMMARY

The aim of Task 6 is to make an inventory and analysis of policy- and design options for review of the space/combination heater regulations 811/2013 (Energy Label) and 813/2013 (Ecodesign).

The report discusses horizontal options (Chapter 2), options for single products as addressed mainly in the Ecodesign regulation (Chapter 3), options for packages of space heating generators (Chapter 4) and other options (Chapter 5). The final chapter contains a first, mainly qualitative analysis of costs and benefits (Chapter 6).

Horizontal options include:

- Green hydrogen (H_2-ready) and biogas: Making combustion-type space heaters ready for a carbon-neutral EU;
- New primary energy factor and other considerations: Consequences for the minimum Ecodesign energy efficiency limits and Energy Label class limits;
- Verification tolerances: Preliminary outcomes of the ECOtest project;
- Third-party conformity assessment: Some heat pump manufacturers now seem in favour of 3rd party conformity assessment, but details are not clear;
- Extension of the product scope to 1 MW: Closing the gap with the new MCP-directive;
- Clearer definition of drinking water and inclusion of carbon-neutral fuels where appropriate;
- Dealing (or not) with the shared chimney problem;
- Proposed new Ecodesign work items: Emitters and their controls.

Options for regulation of single products

- High (65 °C) instead of medium (55 °C) temperatures for heat pumps;
- Dynamic heat pump testing instead of at declared compressor frequencies (speed);
- Energy label: Indicate also the low temperature and high temperature efficiency numbers with heat pumps. Show electric power (kWe) for cogenerators;
- Harmonise boiler and heat pump test conditions;
- Cogeneration: Follow the regulation, but with a fixed (not CC) factor 2.65 for electricity production.

Options for packages

- First proposals for improvement of the general calculation for hybrids, temperature controls, solar thermal devices;
- Include and implement PFHRD-option for combi boilers;
- Proposal for single calculation method for all (single products and packages).

Note that this report contains proposed options and stakeholder-reactions on the proposals, which would then only be a first input for the Commission-led further consultation on revisions.

This report can only present the main stakeholder comments. For a full overview, please consult the comments and papers on the project website: www.ecoboiler-review.eu.

Acronyms and units

3XS / XXS / XS / S / M / L / XL / XXL / 3XL / 4XL	Size classes for water heating tapping patterns, from very small XXS to medium M to very large 4XL
811/2013	Energy Label Commission Delegated Regulation (EU) No. 811/2013 for central heating boilers
813/2013	Ecodesign Commission Regulation (EU) No. 813/2013 for central heating boilers
B1, C4, C8	Boiler classifications on the basis of air input and flue gas handling
CC	Conversion Coefficient (here equal to pef)
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Use
CH	Central Heating
CO	Carbon Monoxide
CO_2	Carbon dioxide (R744 as refrigerant)
(m)CHP	(micro) Combined Heat and Power
EC	European Commission
EED	Energy Efficiency Directive
e-fuels	Electro-fuels (gas/oil produced with carbon-neutral electricity through electrolysis, methanation, etc.)
EHP	Electric heat pump
ENER	EC, Directorate-General Energy
EPBD	Energy Performance of Buildings Directive
GCV	Gross Calorific Value (of a fuel)
GHP	Gas-fired heat pump
H_2	Hydrogen
HC	Hydrocarbons
HT	High Temperature
LCC	Life Cycle Costs
LLCC	Least Life Cycle Costs
LT	Low Temperature
MCP	Medium-Sized Combustion Plants
MSA	Market Surveillance Authority
NBR	Nitril Butadiene Rubber
NCV	Net Calorific Value (of a fuel)
NH_3	Ammonia
NO_x	Nitrogen oxides
PE	Poly-ethylene
pef	primary energy factor
PEM	Proton Exchange Membrane
POM	Polyoxymethylene
PVC	Poly Vinyl Chloride
RRT	Round Robin Test
SCOP	Seasonal Coefficient Of Performance
SEER	Seasonal Energy Efficiency Ratio
SOFC	Solid Oxide Fuel Cell
VHK	Van Holsteijn en Kemna (author)
WP	Working Package
ηs	Seasonal space heating energy efficiency

__Parameters__

P	Power [kW]
E	energy input [kWh]
Q	heat output[kWh]
η	efficiency [-]
h	hours
K	degree Kelvin
kWh	kilo Watt hour
°C	degree Celsius
a	annum (year)
W	Watt

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1 INTRODUCTION

1.1 Scope

The scope of Task 6 is to make an inventory of policy- and design options for review of the boiler regulations 811/2013 (Energy Label) and 813/2013 (Ecodesign). In principle, this includes an assessment of costs and benefits and –where possible— a calculation of Life Cycle Costs and Payback Periods per design option. However, note that this is a review study and the focus is not necessarily on setting new limits at Least Life Cycle Costs (LLCC), but rather on improving the regulations based on experience and new insights.

The overall aim is to make the boiler regulations more effective (more impact) and more efficient (with lower burden/costs) in view of the policy objectives on climate change, energy efficiency, renewables, extra-EU energy dependence, air- and water pollution, internal market, circular economy, etc..

In the 2017 Energy Label Regulation and by way of exception, the current scheme of 10 labelling classes, from A+++ to G, can be maintained for this product group at least until 2025 (instead of the 7 classes A-G).

Task 6 also will address the questions from the review clause of the 813/2013 regulation regarding the appropriateness of Ecodesign requirements for GHG emissions, other emissions (CO, HC, PM), boilers using biomass gas or oil as well as the validity of the conversion coefficient and the appropriateness of third part conformity assessment.

The review clause of 811/2013 labelling regulation says to consider technological progress and in particular changes in market shares of various types of heaters, feasibility and usefulness of indicating heater efficiency based on standardised heating seasons, other than for heat pumps only. Also, it asks to look at the appropriateness of package fiches and labels as well as including passive flue heat recovery devices in the scope of the regulation.

This Task report presents design and policy options for the various issues identified in other Task reports, also taking into account stakeholder reactions on proposals presented at the 2nd stakeholder meeting. To further discuss and investigate issues identified the study team proposes to set up a special consultation initiative with stakeholders.

1.2 Approach

In the comprehensive Task 6 Report of the Preparatory Study of 2007 the main focus was on determining energy efficiency limits at LLCC throughout various size classes (from XXS to 4XL) of various (combinations of) space heating devices for water-based central heating. This was already a considerable effort, where the researchers were treading new grounds.

Climate change, renewables and other objectives were taken into account in the 2007 Preparatory Study evaluation of saving measures, but only to a limited way in shaping the measures. At the moment, in 2019, it seems that climate change objectives, i.e. the transition to a carbon-neutral society in 2050, take highest priority. The latest developments in that field have been documented in Task 3.

The Task 6 report will thus not repeat the exercise of the 2007 Preparatory Study, but – apart from looking for improvements in general— focus on the new objectives.

The basis of the design options will be the issues that have been discussed in the previous Task reports 1 to 5. After completion of Task 6, the impacts of applying (clusters of) design options will be calculated in the scenario analysis in Task 7.

1.3 Report Structure

This Task 6 final report contains, after this introductory Chapter 1, four chapters where the design (and policy) options are discussed:

- Chapter 2. Horizontal (design) options;
- Chapter 3. Options for single heat generators;
- Chapter 4. Options for packages;
- Chapter 5. Other design options (NO_x, noise, etc.);
- Chapter 6. Analysis of Options.

Annex I and II present more detailed information on ECOtest results and the shared chimney problem respectively.

2 HORIZONTAL OPTIONS

2.1 Introduction

Horizontal options are those that apply across various types and space heater technologies. This section will address:

- H_2-ready appliances;
- Appliances suited for biogas;
- Primary energy factor;
- Verification tolerances;
- Third-party conformity assessment;
- Extension of scope to 1 MW;
- Shared chimney problems;
- Important items for the next Ecodesign Working Plan: Emitters and hydraulic controls.

2.2 H_2-ready

The 2018 Vision documents presented by the Commission and discussed in Task 3 present various pathways to an (almost) emission-neutral society, and –depending on the scenario – there is more or less use of carbon-neutral gaseous fuels. In particular in specific scenarios for space heating Power-To-Gas *(P2G)*, where electricity is used to create hydrogen or hydrogen-based synthetic fuel from water, such as ammonia (NH_3)[1], e-methane, e-methanol, etc.[2] play an important role. According to many stakeholders, hydrogen will be the dominant carbon-neutral gaseous fuel.

Carbon-free versus carbon-neutral

Hydrogen has the unique quality, as opposed to other e-fuels or biofuels, that its combustion or other energy conversion is not just 'carbon-neutral' but 'carbon-free'. Other e-fuels or biofuels produce carbon emissions during combustion or other energy conversion but this is assumed to be compensated by the absorption of greenhouse gases during production of the fuel (e.g. photosynthesis) or by the capture and storage of the carbon emissions at/after combustion a.k.a. Carbon Capture and Storage (CCS). But CCS is controversial[3] and biomass is only carbon-neutral when made from waste

[1] Liquid at room temperature and thus easier and safer to store than hydrogen, which requires 200-700 bar tanks. However, combustion of biofuels might not be suitable for space heating purposes. As an example 'combustion' of ammonia is complex, i.e it starts only at high temperature and is currently mainly used in experimental settings for co-firing of power stations. As such it is not deemed suitable for space heating in a relevant setting.

[2] For a recent discussion of technologies and costs see Malins, C., *What role is there for electrofuel technologies in European transport's low carbon future?*, Cerulogy report, November 2017.

[3] Euractiv, 6 Feb. 2019, by Sam Morgan.
https://www.euractiv.com/section/climate-strategy-2050/news/carbon-capture-feasibility-splits-meps-in-2050-planning/
Washington Post, The inconvenient truth about carbon capture, by Jan Christoph Minx and Gregory Nemet, May 31, 2018
https://www.washingtonpost.com/news/theworldpost/wp/2018/05/31/carbon-capture/?noredirect=on&utm_term=.b1e688f41c5a
The Guardian, 16 Feb. 2018

(e.g. biogas from anaerobic fermentation of organic waste; biomass from forest maintenance) or backed by equivalent reforestation. In the latter case there are also controversial issues.[4]

Green, blue and grey hydrogen

'Green' hydrogen comes from the wind and solar driven electrolysis of water. This is the sustainable, carbon-free hydrogen source in the long run that is intended. 'Grey' hydrogen is produced from fossil fuels (typical natural gas) with considerable carbon emissions and would not play any role in a carbon-neutral society in 2050. A unique hydrogen-type is so-called 'Blue' hydrogen that uses the quality that its combustion is absolutely carbon-free. It is made from pyrolysis of natural gas (mainly methane CH4) in an oxygen-free environment. This process does not use CCS (Carbon Capture and Storage) but CCU (Carbon Capture and Utilisation): It decarbonises the methane, i.e. it is split in hydrogen gas H2 and solid carbon[5] [6]. The solid carbon black can be put to various good uses. One-sixth of the hydrogen is used for the pyrolysis-process and 83% can be distributed for carbon-free combustion (in a boiler), other conversion (e.g. in fuel cells, for heat and electricity generation) or storage for power generation on days with low wind and/or sunshine. The R/P ratio (Reserves vs. Production) of natural gas reserves is currently 55 year and likely to be increasing because of newly available shale gas, etc.. And there are strong market forces in the EU's most important suppliers (Norway, NL, UK, Russia[7], Algeria, Qatar) to decarbonise the gas before distributing it in the form of hydrogen. In that way, blue hydrogen could be the solution to reach the 2050 goals, utilizing the full potential of the already existing 2.21 million km of EU gas grid connected to 118 million EU gas customers.

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https://www.theguardian.com/commentisfree/2018/feb/16/itd-be-wonderful-if-the-claims-made-about-carbon-capture-were-true

[4] Like whether it is not better to leave the forest to be a carbon sink and –for certain crops—competition with food crops

[5] Abanades A, et al., Development of methane decarbonisation based on liquid metal technology for CO2-free production of hydrogen, International Journal of Hydrogen Energy (2015), http://dx.doi.org/10.1016/j.ijhydene.2015.11.164

[6] Pyrolysis of methane (CH4) without oxygen gives solid carbon C and hydrogen gas $2H_2$. Around 1/3 molecule of hydrogen can be used for the pyrolysis and 5/3 molecule of H2 is the effective output for further use. The solid carbon could be used e.g. as carbon black. See: Abanades A, et al., 2015. Also (more popular): https://www.advancedsciencenews.com/decarbonizing-natural-gas-methane-fuel-without-carbon-dioxide/

[7] E.g. https://www.bloomberg.com/news/articles/2018-11-08/russia-looks-to-hydrogen-as-way-to-make-gas-greener-for-europe

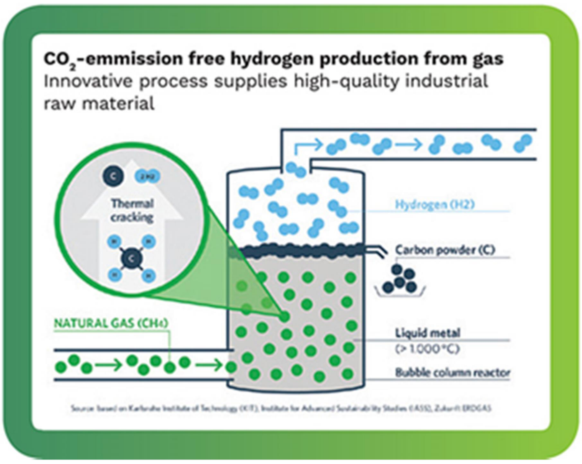

Figure 1. Methane pyrolysis diagram. Based on Karlsruhe Institute of Technology (KIT) and Institute for Advanced Scientific Studies (IASS), Zukunft ERDGAS 2018.

Using carbon-neutral gas is the most economic option in the most recent PRIMES scenarios, saving €335 bn between 2015 and 2050 to reach the Paris goals.[8] Of all the carbon-neutral gas-options, e.g. biogas[9], methanation[10], ammonia, etc., green hydrogen is the only one that does not need CCS to be carbon-neutral.

But there is a problem with the hydrogen scenario and this is where Ecodesign could come in: Below 30% share of hydrogen a normal natural gas boiler could work, but at a higher shares special adaptations are needed –beyond a simple switch of burner bed and a nozzle—to enable safe and optimal hydrogen combustion. This is what is intended by 'hydrogen-ready', which is a boiler that can operate on both natural and a high (>30%) share of hydrogen gas. At some point, i.e. when switching to 100% hydrogen, some further adjustment of the burner bed might be needed. Without the gas boiler being 'hydrogen ready', the whole boiler needs to be replaced. This means a stranded investment of potentially several thousands of euros per household if and when such a switch to hydrogen is needed, e.g.. Socially and politically, even if a sustainable climate of the planet is at stake, this will be a very difficult message to sell to the citizens. To avoid such a situation, and given the product life of heating appliances that is now around 20 years or more, the promotion and –eventually—making it mandatory to require hydrogen-readiness is paramount.

In this context it is important to realize that only 100% (carbon-free) hydrogen gives carbon-neutrality. Mixing in up to 30% hydrogen in the gas grid helps in the transition phase, but if it stops there then the Paris goals will not be achieved.

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[8] https://eurogas.org/website/wp-content/uploads/2018/05/Press-Release_scenario-study-with-PRIMES.pdf

[9] Combustion of biogas produces at least as much CO2 as combustion of fossil gas, but because the organic source material absorbs CO2 during its life through photosynthesis and because it is assumed that the organic material used for combustion will be replanted it is assumed to be low-carbon. In the Energy Label for solid fuel boilers biomass gets a labelling factor 1.45. The assumed conversion efficiencies for biomass (physical energy content and technical conversion) in the Fraunhofer study are 0.3 (compared to 1 or 1.1 for fossil gas). See:
Esser, A., Sensfuss, F., Final report: *Evaluation of primary energy factor calculation options for electricity, Fraunhofer ISI for the EC, 13.5.2016.*

[10] Methanation is the conversion of COx to methane (CH_4) using hydrogen (and a Ni-catalyst). For instance: $CO_2+4H_2 \rightarrow CH_4 + 2H_2O$ +heat. The reaction is exothermic. The methanation is called 'carbon-neutral' because in the production process of the methane CO2 is absorbed (but still some CCS is required to be really 'neutral').

The low efficiency of hydrogen conversion is often mentioned as a negative, but most estimates start from the assumption that the hydrogen from wind- or solar driven electrolysis (efficiency 75%) first needs to be stored (at very high pressure, e.g. 700 bar or thereabouts, to minimise storage volume) and converted again to electricity by a fuel cell (efficiency 50-60%) when there is not enough variable (solar, wind) renewable electricity. In that case, the efficiency of the process may be lower than Joule-heating (40%) and the costs for a single household may be extremely high.

The most advantageous heating appliance would be a hybrid of an electric heat pump and a hydrogen-fired boiler back-up. This gives the required energy flexibility (no actual storage, just a switch), it is cheap for the householder (no fuel cell; basically known technology with some minor adjustments; no stakeholder contended the 200-300 euro extra costs!). With a hybrid you don't need the local storage tank –storage may be at the distributors—and you don't need the fuel cell.

Hydrogen boilers exist, as a redesign of a natural gas boiler, in experimental projects and –as mentioned and confirmed by the comments of BDR Thermea[11].

In that context it is much more likely that hydrogen will be used for space heating and certain industrial applications than for cars[12]. Hydrogen cars require high pressure storage tanks and –because electricity is much more efficient for traction than for combustion— a fuel cell. So, for cars it is much more efficient to directly use the electricity from charging batteries.

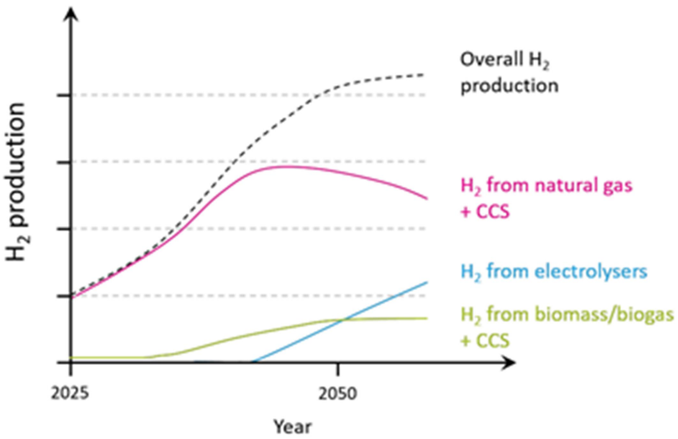

Figure 2. Illustration of a qualitative scenario for future production of hydrogen from natural gas, electricity from renewables and biomass (Reprinted from: SINTEF & IFPEN (forthcoming, 2019). Hydrogen for Europe pre-study report)[13]

[11] BDR THermea made these hydrogen boilers. They do correct the KIWA-report, used as a source in Task 6, that indeed a larger fan would not be required but that it is enough to regulate the air-side of the premix. Most adaptations are in sensors and contrals.

[12] For trucks, trains, planes it might be advantageous to use hydrogen, but that requires a considerably smaller amount of hydrogen.

[13] Source: The potential for CCS and CCU in Europe, REPORT TO THE THIRTY SECOND MEETING OF THE EUROPEAN GAS REGULATORY FORUM 5-6 JUNE 2019, COORDINATED BY IOGP. https://ec.europa.eu/info/sites/info/files/iogp_-_report_-_ccs_ccu.pdf

Smart hybrid

Specifically for space- and water heating, however, there could be a new option for days with insufficient renewable energy supply (wind, solar): A smart hybrid of an electric heat pump, hydrogen gas boiler and possibly solar assistance. Instead of using the stored hydrogen to generate electricity, which is then used in heat pumps, the hybrid space heater just switches to hydrogen combustion instead of the electric heat pump for the heat generation. So there is no need for a large scale power plant or a micro-scale fuel cell to produce electricity at considerable energy loss, but instead the hydrogen is used directly for heating. The heating efficiency of that hydrogen boiler will often be less than that of the electric heat pump (also depending on outdoor temperature, dimensioning of the heat pump, etc.) but overall the efficiency will often be better –without the intermediate electricity generation step— and at a lower capital expenditure, not having to invest in electric power generation and -distribution, using the existing gas grid with modest modifications.

Technology and appliance costs

Task 4 discusses technical and cost aspects of hydrogen boilers and hydrogen distribution. From the viewpoint of all these aspects no particular problems are expected. Hydrogen-fired boilers exist and are currently applied in several field tests. The adaptation of a gas boiler to a 100% hydrogen (-ready) requires technical adaptations beyond the capabilities of installers, but are perfectly feasible for a manufacturer at a mere €200-300 mark-up. Field tests and long-time industrial experience with hydrogen pipelines indicate the feasibility for a safe and low-cost use of the existing gas-grid for hydrogen distribution with minor adaptations.

Timing

There are only 31 years till the 2050 Paris-target and probably the switch from natural gas to a hydrogen gas network will need to be realised well before that (2040?). Depending on type, quality, usage, etc. the average age of the boiler varies between 15 and 30 years. It may take another 2-6 years before the potential revised regulations will start to apply. As an illustration that time is running out for a full conversion of the space and water heating appliances park: In 1981, the first mass-produced condensing heating boiler appeared on the market. Today, almost 40 years later in 2019, after extensive incentive-programs and eventually mandatory Ecodesign legislation, still only 50% of the installed fossil-fuel fired heating boilers in the EU is condensing. A 95% conversion in the installed park to condensing technology[14] cannot be expected before 2035, i.e. 55 years after the first introduction of the technology.

If the Paris goals are to be taken seriously there will be practically no **fossil** gas/oil combustion left in only 30 years (a 'marginal' 3% in 1.5ºC scenarios). Apart from green electrification, green[15] hydrogen and power-to-x technologies can play an important role in reaching the Paris goals and reaching it in an affordable way, if the gas- and oil boiler appliance industry, supported by utilities, is pro-active. This is confirmed, amongst others, in June 2019 study of the IEA for Japan in the context of the G20, which elaborates various future hydrogen options for space heating[16].

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[14] A full conversion is unlikely, because of exeptions in the regulations.

[15] Green in the long term, green and blue in 2050.

[16] IEA, The Future of Hydrogen, prepared for Japan in the context of the G20, June 2019.

The main question, also from some stakeholders, is whether there will be enough green hydrogen production, i.e. from wind- or solar driven electrolysis of water, and whether the probably scarce green hydrogen should be used for space heating and not transport or industrial processes.

There is no convergence in opinion on these issues. The vision documents presented by the Commission and discussed in Task 3 present various pathways to an (almost) emission-neutral society, and –depending on the scenario – there is more or less use of gaseous fuels for (space & water) heating. Given the uncertainty of which scenario will appear more appropriate 30 years from now, the study team is convinced it is best to keep options open and not close doors for certain scenario's to develop.

Thus it is recommended that *'H_2-ready'* will become a mandatory Ecodesign requirement as soon as possible.

To give time for the market actors to prepare, it is proposed to first introduce the 'H_2-ready' concept in the Energy Labelling, i.e. giving a 20% energy efficiency bonus or 1.2 labelling factor leading to an A+ rating for a single boiler, and then after 2 years make 'H_2-ready' mandatory. Using factors to change label ratings rather than basing them on physically measured energy efficiency is not new and applied in other regulations as well. In the case of biomass in the Solid Fuel Boiler regulation there is a BLF, Biomass Labelling Factor, of 1.45 in the rating of boilers intended for biomass (but often also dual fuel and/or suitable for co-firing with coal).

As regards the economic gain of H_2-ready: It is not in the lower energy costs, but it is in avoiding a premature replacement of the boiler, often with product lives over 20 years or more, when the switch from natural gas to carbon-neutral hydrogen(and biogas) has to be made. In that sense, the economics are comparable to buying a 'HD-ready' television set in the period 2005-2009 when there was no public High-Definition (HD) broadcasting. Nonetheless, consumers found it a valid argument to buy these TVs instead of the cheaper classic PAL-resolution TVs.

H_2 Stakeholder comments and study team reactions

Associations of gas utilities (Eurogas, Liquid Gas Europe, Marcogaz), industry of –amongst others— gas-fired equipment (EHI, COGEN, PACE, BDR Thermea, the gas heat pump section of EHPA) and the few Member States reacting at this stage (Denmark, Belgium, UBA-BAM) are cautiously supporting the hydrogen-option, but believe that further investigation is needed before a decision on concrete measures can be made. There appears to be some support for a hydrogen-icon on the energy label (UBA-BAM, ECOS), but not –at this stage— for an outright bonus. The figure of 20%, inspired by neutralising the pef-change from 2.5 to 2.1 which works in favour of the energy label rating of electric appliances, is also considered premature by these stakeholders.

The position of several stakeholder, especially gas utilities, EHI and EHPA/GHP, seems ambiguous in the sense that there is some preliminary support for hydrogen-promotion, but there seems to be a much stronger concern over a negative effect on the rating of 'normal' A-rated condensing gas boilers and misleading the consumers.

EHPA/GHP states that the proposal for 20% bonus for "bio-methane and 20% hydrogen" (Green Gas) products needs to be immediately applicable to TDHPs otherwise it will result in penalization (conversion factor is immediately applicable for electrical products) and they note that the current proposal does not indicate definition of the criteria that would enable the eligibility for the bonus. COGEN and PACE (mCHP project) are in favour of promoting hydrogen, but again would like more study. Regarding the Task 6 proposal to introduce a labelling-factor/ bonus for carbon-neutral '100% *hydrogen-ready'* boilers, the vast majority of stakeholders was not in favour.

Out of the 20 stakeholders reacting, there are 4 stakeholder that find no merit in the proposal whatsoever, i.e. consumer association ANEC/BEUC, the electric heat pump section of EHPA, heat pump manufacturer Daikin and association EPEE (representing mostly heat pump and air conditioning manufacturers with extra-EU HQ).

The most frequent argument by these stakeholders, citing the 2017 Energy Label Regulation[17], is that the energy labelling should be limited to giving information based on energy efficiency, i.e. ratio of energy input versus performance. The measure reportedly creates confusion and misinterpretation of the actual efficiency of the unit and it is not in line with the purpose of Ecodesign. It would be misleading the consumers because the boilers will not use hydrogen, but are just 'ready' to do so and thus there will not be an actual economic advantage. [18]

ANEC/BEUC does not agree that hydrogen (H_2) is good policy solution for (home) heating and does not endorse the notion of H_2 as a 'carbon-free' fuel (i.e. GWP of zero). It would be a while before surplus hydrogen from wind and solar would be available, it would be too expensive[19], etc.. Dutch consumer association *Consumentenbond* believes that the efficiency of using hydrogen will be worse than Joule-heating[20]. Consumer associations, Denmark and ECOS/EEB believe that hydrogen will be used for transport and industry and not for heating. Within the timeframe of the review study hydrogen should not play a role. The electric division of EHPA Study sees a lack of technology neutrality as the proposal awards bonuses on products that are far from reaching the market and are still in the state of R&D.

Eurofuel mentions several publications related to low-carbon or carbon-neutral solutions Biomass-to-Liquid (BtL) and Power-to-Liquid (PtL) solutions based on CCS. The BtL-solutions are believed to be the most relevant and are discussed in the next section.[21]

Conclusion:

The study team proposes to set up a special consultation initiative with the stakeholders to further discuss and investigate the issue.

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[17] Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU (Text with EEA relevance) OJ L 198, 28.7.2017, p. 1–23

[18] ANEC/BEUC, EHPA, Daikin, Denmark, EEB/ECOS are the most outspoken on the issue but others have similar reservations.

[19] Citing economists like prof. Mulder from Groningen University. https://www.energiepodium.nl/artikel/interview-professor-machiel-mulder-groene-waterstof-is-voorlopig-veel-te-duur

[20] See the elaboration by Consumentenbond (through ANEC-BEUC) in the compilation of stakeholder comments received.

[21] Most PtL-solutions are based on calculated carbon-neutrality, i.e. a carbon credit is acquired because of CO2-absorption in production and used to compensate the carbon release during use (e.g. combustion).[21] This is not the same as green hydrogen or pre-conversion decarbonisation of natural gas. Also a switch from fossil gas oil to these solutions does not necessarily require a replacement of the boiler

It is important to state here that the goal of that discussion will certainly NOT be define the full EU strategy to reach the Paris goals. That is not the role of Ecodesign or Energy Labelling. The goal will be to determine, whatever the Paris-strategy will be, what the heating appliance design can contribute to optimise the chances (or reduce the adverse risks) to meet the Paris-objectives.

2.3 Biofuels (gas, liquids)

Apart from hydrogen there are fuels that are not carbon-free during combustion, but carbon-neutral taking into account their credit as carbon-sinks and taking into account that their combustion avoids a much more damaging impact on the climate.

The general idea is that these 'biofuels' originate from plants and during their previous life as plants they will have taken —through photosynthesis under the influence of (sun)light— 'carbon' (CO_2) and water out of the atmosphere, giving sugars to the plant and oxygen back into the ambient. Another concept is the fact that by capturing biogas, i.e. the gas from anaerobic digestion or fermentation of organic waste, one avoids the release of a gas (methane) that is 25 times more powerful greenhouse gas than CO_2. And if that captured gas is then combusted, releasing CO_2, the overall carbon balance is still positive.[22]

Having said that, the balance is fragile. For instance, if the bio-fuel is transported halfway around the world, e.g. from the US or Latin-America to Europe, a considerable part of the positive carbon-balance is destroyed because of the carbon emissions of transport.

There is the issue of energy crops: vegetal oil crops (colza, palm seeds) grown specifically to substitute diesel or sugar cane grown to make methanol replacing petrol. Sometimes valuable rain forests, important carbon-sinks, are destroyed to make way for energy crops. Sometimes (monocultures of) energy crops take the place of food crops in areas where there is food-shortage.

The sustainability and carbon-impact of biodiesel, especially from vegetable oil is fiercely debated. Green group Transport & Environment mentions continues growth of palm oil imports, two-thirds of which goes to non-food applications such as heating oil.[23] [24] The impact is on indirect and direct Land Use Change (ILUC, DLUC), which ultimately translates into greenhouse gas ('carbon') emissions, as is shown in the figure below.

Most of these issues relate to oil-substitutes or solid biofuels. Biogas, usual from fermentation of organic (food-related) waste and/or manure, is typically a local energy source, produced from waste, and there is no substitution of food crops.

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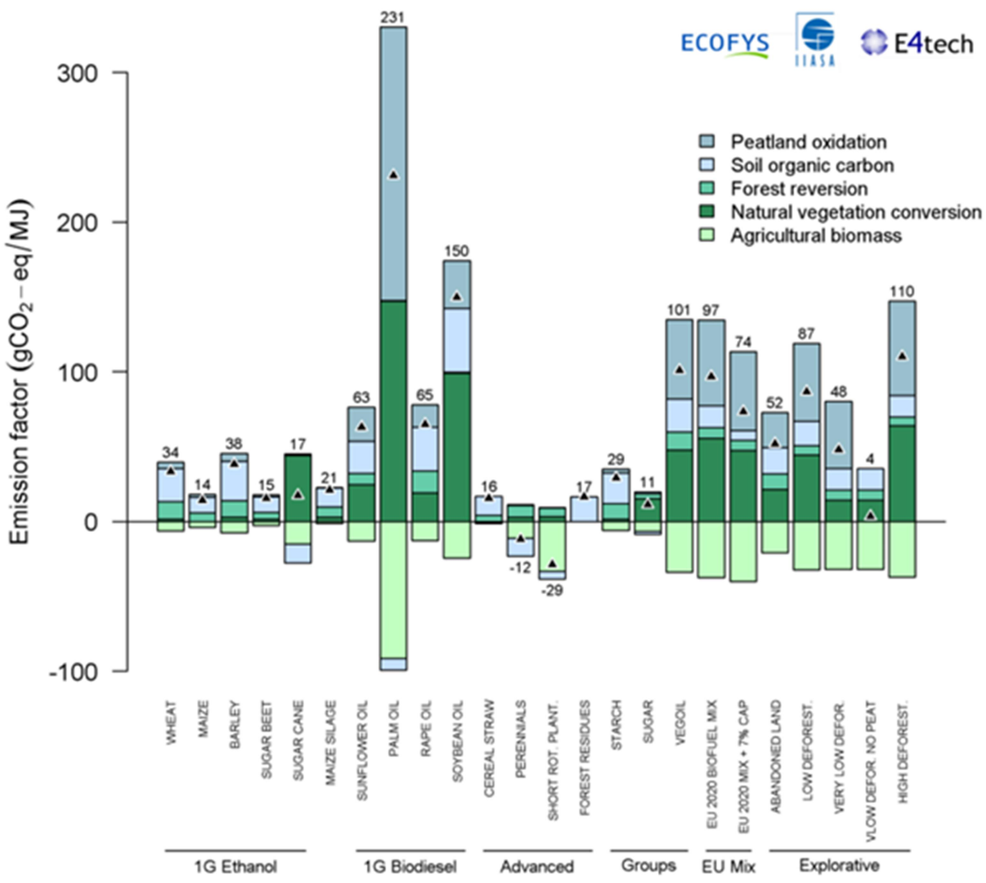
[22] Bio-methane originates from all organic matter in nature like leaves, dead plants and animals, most part of faeces, etc., but if we can capture the part that is anthropogenic (man-made, e.g. originates from elements in the human food-chain) this is already a Good Thing.

[23] Transport & Environment, The trend worsens: More palm oil for energy, less for food. Drivers burn more than half of palm oil imported into the EU, briefing, June 2019.

[24] IIASA, Ecofys et el., The land use change impact of biofuels consumed in the EU, Quantification of area and greenhouse gas impacts, report to the Commission, 27.8.2015.



Source GLOBIOM 2015

Figure 3. Overview of modelling results: LUC emissions per scenario

The European association of gas utilities Eurogas calls the mix of renewable gases 'R-gas' and believes it can make up 76% of the gas used in 2050.[25] Eurogas also asked PRIMES in 2016 to calculate a gas scenario that definitely show large technical and economic advantages vis-à-vis the full electrification scenario.

In the review clauses of the boiler regulations there is the question on the appropriateness to set Ecodesign requirements for biomass-based gas- or liquid fuel fired boilers. To answer that question, it must first be established whether such boilers can technically be distinguished from normal natural gas or oil-fired boilers. This question was put by the study team to the ECO-BEDAC committee with experts from the boiler sector[26]. The answer was that although biogases or bio-oil may contain aggressive substances/pollutants that attack certain seals in the boiler these problems can be solved by using other/improved materials or designs. Boilers suitable for bio-oil (FAME - Fatty Acid Methyl Ester or Biodiesel, usually a 10% share FAME is allowed) or bio-gas can be distinguished from other boilers by a fit-for-purpose indicator (e.g. indicated in technical specifications). What could be more serious is the wide range of calorific values that may occur with bio-gas. The solution may be that, as it is done today, the bio-gas is mixed

[25] Eurogas presentation 2017. https://www.entsog.eu/sites/default/files/entsog-migration/publications/Events/2017/tyndp/EUROGAS%20Renewable%20Gas%20Policy.pdf

[26] ECO-BEDAC meeting in Leuven (BE), 18.10.2017.

with other gas like natural gas to stay within a limited range of calorific values. Or, and in that case an adapted design is necessary, the boiler is equipped to handle a wide range of calorific values, possibly at the expense of a more limited modulation.

A design option is to give a special allowance, e.g. a labelling factor 1.2, for boilers that are placed on the market exclusively to handle biogas[27] but a specific definition is then needed to differentiate them from fossil fuel fired boilers. To (continue to) completely exempt these boilers does not seem advisable, in order not to create a loophole e.g. whereby large quantities of non-compliant natural gas boilers are sold as 'biogas boilers'.

For solid biomass boilers a Biomass Labelling Factor (BLF) of 1.45 applies. It thus stands to reason that also a similar factor would apply to gaseous or liquid biomass. However, with straw-, wood log- or pellets fired boilers the product design is usually evidently different from a fossil solid fuel (coal) fired boiler and thus there is no (or little) danger of creating a loophole when applying the BLF. In the case of boilers for gaseous or liquid biomass such risk could exist. That is why Task 6 is proposing a labelling factor only where the boiler is clearly designed for that purpose. And it is believed that this is the case when the boiler is prepared for 100% biogas or bio-oil, i.e. able to handle a wide range of calorific values and withstand aggressive fractions (such as hydrogen sulphide, siloxanes, moisture) that can be found in 100% biogas or bio-oil (traditional oil carrying seal materials may need to be modified, bio-oil also often has a higher viscosity).

Similar to the pef for electric appliances, the share of carbon-neutral components in the fuel supplied can be expressed in a pef-like factor for fuels (representing the share of primary energy or fossil carbon in the fuel). It is important to realise that it is not within the scope of Ecodesign-legislation to define a pef (primary energy factor) or similar for a situation with a significant mix with biogas (or hydrogen). It is understandable that this is an important subject for gas/oil utilities and gas/oil appliance industry, but the decision on the new pef for electricity was taken at the level of a trialogue between European Commission, Council and Parliament and not put forward by a contractor in a specific Ecodesign review study. The same goes for bio-fuels and liquids in particular, where there is the added dimension –compared to bio-gas from fermentation—of land-use for energy crops (see also Section 2.4 further on).

At the moment biogas/bio-oil boilers are not in the scope of the regulation. This has so far not led to loopholes that the study team is aware of, loopholes could occur in the future because there is no technical definition or test defining a biogas boiler. In other words, it is possible to try to keep an inefficient boiler on the market by claiming it is a biogas boiler. Secondly, keeping a real biogas boiler out of the scope, with a favourable rating, also means a missed opportunity in promoting such a device. It also does not seem consistent vis-à-vis the practice with regulating solid biomass boilers. We would agree that specifying suitable tests to differentiate the biogas boilers from others requires a substantial effort and –later on—surveillance effort. Thus, in the end, the policy makers will have to decide whether it is worth it given the relatively modest contribution that 100%-biogas boilers can make to decarbonisation.

Another issue is the NO_x-emission of biofuel boilers, where currently there is no yardstick for what is feasible.

[27] Only if directly relatable to biogas. If due to ongoing and future gas quality variations because of other reasons (LNG terminals, Russian gas, Groningen field depleted) then no allowance because "business-as-usual".

Stakeholder comments

Marcogaz mentions that the draft report does not acknowledge the development of biomethane in a number of Member states, i.e. biogas upgraded to natural gas quality, able to be injected in natural gas grids or to be used as a fuel for vehicles. In Sweden, Finland, the United Kingdom, the Netherlands, Denmark, the share of biomethane is above 14-15 % of biogas production. Denmark has already reached a level where 10% of the gas in the grid is bio methane (annual average). France has a goal of 10 % biomethane in gas grids by 2030. The future impact of H2 injection in gas grids should also be taken into consideration. The European Commission's involvement in supporting the development of hydrogen on the road to a climate neutral economy can be witnessed through FCH JU (public/private partnership used by the EC for financing R&D and demonstration projects for the development of fuel cells and hydrogen). Among the calls published by FCH JU in 2019 one deals with the impact on gas grids, and another one on the impact on end-use applications (gas appliances).

Eurofuel reminds the study team that liquid biomass ('biodiesel') should not be forgotten and points to various studies that especially highlight the economic potential of biodiesel for Germany. The studies discuss the technologies, the economic potential (e.g. of electrolysers), etc..

Germany (UBA-BAM) mentions that the loophole of biogas boilers should be closed. If space heaters are operable with conventional gas, they should meet the Ecodesign requirements for the operation with conventional gas. The actual use of a product cannot be predicted when placing it on the market. However, UBA-BAM does not think that biogas space heaters should be subject to Ecodesign when operated with biogas. The quality of biogas depends on the raw material (substrate) and the art of processing. Its composition is always different. Testing of biogas combustion at the test stand can only show emissions using a standard fuel composition but not real emissions. Testing of biogas makes only sense in local case by case examination. This cannot be solved by Ecodesign. A 10 percentage efficiency bonus is also not an appropriate solution, according to UBA-BAM.

Conclusion:

The study team proposes to set up a special consultation initiative with the stakeholders to further discuss and investigate the issue.

2.4 Primary energy factor

The review clause requires a check the appropriateness of the Conversion Coefficient (CC), which is made synonymous to the primary energy factor (pef) for electricity generation and – distribution in Directive 2012/27/EU. It has recently been decided at the level of a trialogue between Council, Parliament and Commission to change the pef from 2.5 to 2.1. This reflects the EU policy as described in preamble (40) of the recast of the EED (Directive 2018/2002/EU):

(40) Reflecting technological progress and the growing share of renewable energy sources in the electricity generation sector, the default coefficient for savings in kWh electricity should be reviewed in order to reflect changes in the primary energy factor (PEF) for electricity. Calculations reflecting the energy mix of the PEF for electricity are based on annual average

values. The 'physical energy content' accounting method is used for nuclear electricity and heat generation and the 'technical conversion efficiency' method is used for electricity and heat generation from fossil fuels and biomass. For non-combustible renewable energy, the method is the direct equivalent based on the 'total primary energy' approach. To calculate the primary energy share for electricity in cogeneration, the method set out in Annex II to Directive 2012/27/EU is applied. An average rather than a marginal market position is used. Conversion efficiencies are assumed to be 100 % for non-combustible renewables, 10 % for geothermal power stations and 33 % for nuclear power stations. The calculation of total efficiency for cogeneration is based on the most recent data from Eurostat. As for system boundaries, the PEF is 1 for all energy sources. The PEF value refers to 2018 and is based on data interpolated from the most recent version of the PRIMES Reference Scenario for 2015 and 2020 and adjusted with Eurostat data until 2016. The analysis covers the Member States and Norway. The dataset for Norway is based on the European Network of Transmission System Operators for Electricity data.

The recast EED 2018/2002/EU also draws a direct line between the use of the (revised) PEF and its effect on Ecodesign and energy labelling measures by requesting a revision of this coefficient by December 2022 and every four years after. This revision shall be carried out taking into account its effects on other Union law such as Ecodesign Directive 2009/125/EC and Labelling Regulation (EU) 2017/1369 (Annex IV, footnote 3, as amended by 2018/2002/EU). As such, the effects of a change in pef on ecodesign and labelling is addressed by studies in the context of Directives 2018/2002 and 2012/27.

The change of the pef has consequences for all issues where the pef implicitly or explicitly plays a role in the legislation, i.e. for all conversions from electricity to primary energy in determining the (seasonal) efficiency, e.g. for electric heat pumps, electric resistance heaters and auxiliary components, but also for certain class limits that were set on the assumption that the theoretical maximum primary energy efficiency (from electricity) was 40%. With the new Energy Efficiency Directive 2018/2002 this becomes 47.6%. But also for electric heat pumps it is not intended that the Labelling class limits should become more lenient. In other words, the limits will reflect the same level of electric efficiency/COP where needed.

Note that in the case of mCHP it is proposed to replace the current *pef* ('CC' in the regulation) with a conversion or allocation factor based on Carnot efficiencies and not dependent on the share of low-carbon electricity in the grid (see Task 1 and mCHP option hereafter, section 3.4).

Ecodesign limits

The table shows the current and pef-corrected Ecodesign minimum limits. For appliances where the limits are based on full-electric energy consumption the correction-factor (2.5/2.1=1.19) is applied. For appliances with only auxiliary electricity consumption the limit value is raised with 1 percentage point. The limit for cogeneration space heaters is discussed in the next chapter. Values for heat pumps were rounded (calculated 131% and 149% becomes 130% and 150%).

Table 1. Ecodesign minimum energy efficiency limits, current and pef-corrected

Space heating energy efficiency per type	**now****	**pef-corrected**
Fuel (combi) boiler space heater ≤70 kW, except B1-type	86%	87%
B1 Fuel boiler ≤10 kW & Fuel combi boiler ≤30 kW	75%	76%
Fuel boiler >70 kW, ≤400 kW	86%*	87%*
	94%*	95%*
Electric (combi) boiler	36%	43%
Cogeneration space heaters	100%	See section 3
Heat pump (combi) space heater, except LT-type	110%	130%
LT Low Temperature heat pump	125%	150%

Water heating energy efficiency per tapping profile		
3XS-XXS-XS-S tapping profiles	32%	38%
M tapping profile	36%	43%
L tapping profile	37%	44%
XL tapping profile	38%	45%
XXL tapping profile	60%	61%
3XL-4XL tapping profiles	64%	65%

**=useful energy efficiency at Prated=100% (top value) and Prated =30% (bottom value); all other space heating values relate to seasonal space heating energy efficiency*

***=from 26.9.2017*

For consideration is the relatively small difference between a default space heater and a low-temperature heat pump. There are reasons for a significantly higher limit for low temperature heat pumps, as will be discussed with the energy labelling. An alternative limit could be 170-175%.

In the 2007-2013 period there were good reasons to follow a technology-neutral, strictly functional approach in saving primary energy, using the newly found consensus on tapping patterns after 20 years of preparation. With space heating this was not possible, because of the considerable differences in metrics and testing procedures, e.g. between heat pumps boilers and fossil fuel fired central space heating boilers. At the moment there are still good reasons to follow the strictly functional approach and it is a good thing that the proposal by Sweden and Norway still maintains the energy labelling metrics to show consumers the actual primary energy savings across technologies. On the other hand, there are new policy goals relating to fighting climate change and reducing carbon emissions.

And, while from the primary energy viewpoint it is detrimental to use such a high-exergy energy source as electricity for low-exergy applications as water heating, there is a widespread belief that renewable 'electrification' will be an important part of the answer. In view of this, the study team has prepared a preliminary technology-specific set of Ecodesign efficiency limits for dedicated and combi water heaters, based on what could be estimated –given the limited time— the Least Life Cycle Cost solution with each of the technological categories discussed in Tasks 2 and 4. In the follow-up these new limit values will have to be discussed with stakeholders.

The table below gives the preliminary set of new limit values, with some explanation in the notes.

Table 2. Proposed Ecodesign new minimum energy efficiency limits for water heaters, combi and dedicated (source: preliminary estimate of LLCC by VHK, July 2019)

Water heating energy efficiency per tapping profile [1]	EIWH [2]	ESWH [3]	GIWH [4]	GSWH [5]	Storage-COMBI [6]	Instant-COMBI [7]	HPWH [8]
3XS-XXS-XS-S tapping profiles	42%	38%	55%	45%	45%	72%	60%
M tapping profile	45%	43%	75%	56%	56%	75%	105%
L tapping profile	45%	44%	80%	67%	68%	82%	114%
XL tapping profile	45%	45%	85%	78%	78%	90%	133%
XXL tapping profile	45%	45%	89%	83%	100%	110%	148%
3XL-4XL	45%	45%	92%	88%	105%	115%	157%

Notes:
[1]: For oil-fired versions of the GIWH, GSWH and COMBI, multiply the limit values by 0.95
[2]: Limits are close to maximum for electronic EIWH, at pef=2.1, according to catalogue values.
[3]: Limits for 3XS-XL derived from pef-corrected current regulation. For XXL/3XL/4XL they are close to maximum.
[4]: Own assessment. Limits will eliminate (indirectly) pilot flame use as requested..
[5]: Based on best catalogue data (AO Smith)
[6]: Limits also apply to gas-fired heat pumps (A7/W55) as well as fossil fuel boilers with external indirect cylinder. Limits derived from instant-combi minus storage standing losses
[7]: XL-limit assumes integrated instantaneous PFHRD. XXL/3XL/4XL limits assume integrated storage PFHRD (<3L). Example: Intergas Xtreme 36 (XXL, 115% on GCV)
[8]: Limits based on A7/W55 EN16147. Values derived from catalogue data (mainly Ariston). The S-class value is based on a corrected (downward) value that could be realised by a variation on the Lydos hybrid (currently M with 90% efficiency). Limits also apply to electric heat pumps with indirect cylinder (A7/W55).

Labelling classes

To maintain the same ambition level, the energy labelling classes relating to electric space heaters will have to be adjusted to account for the new conversion coefficient (CC) of 2.1 instead of 2.5 (factor 1.19).

Furthermore, the Ecodesign requirements of 2015 and 2017 have eliminated the worst products in the electric and the fossil-fuel fired categories, whereas at the top end of the market the need for more differentiation has grown. There is no differentiation between good and bad condensing gas- or oil-fired boilers, i.e. they are all "A", so there is no reward for applying best correction factors F(1) to F(4). Also, there are now many technologies that all fall in the very large "A+" category with a class width of 27 percentage points (compared to 8 points for "A" and "B").

At the lower end, the F and G classes should now –since 26.9.2017—be empty. The lowest label class limit should start at seasonal space heating efficiency of 43% (36% x 1.19). Likewise, the current category "C" ($75 \leq \eta s < 82$) should be as good as empty, assuming that the B1-exemptions should at least be able to meet class "B" or anyway there is not much point in differentiating between good and bad exempted boilers.

With most products, for the benefit of market surveillance and in the interest of transparency for customers, the energy label class limits are aligned with minimum Ecodesign requirements. At present this is not the case, i.e. there is a difference of a few percentage points. It is proposed to put the label class boundaries at the newly proposed Ecodesign class limits discussed earlier, i.e. 43% for electric resistance boilers, 76% for B1 boilers, 87% for standard fuel boilers and 130% for heat pump space heaters. This means that an electric boiler should at least be an "F", a standard gas/oil boiler at least a "D" and a heat pump at least an "A+".

Last but not least, the class widths should (preferably) not be wider than the verification tolerances discussed earlier. For example, for gas-/oil fired boilers these tolerances can be tight (4-5%), but for heat pumps the ECOtest project indicates a much wider range in reproducibility.

Based on the above considerations, the table below shows a proposal ('NEW') for a revised labelling classification, comparing it with the current situation ('NOW'). The table also gives an estimate of typical technologies for the various classes.

Table 3. Energy label classes for all central space heaters except low-temperature heat pumps, NOW and NEWly proposed

Label class	Seasonal space heating energy efficiency ηs in %		Class width (in %)		Examples of typical appliances
	NOW	**NEW**	NOW	NEW	NEW
A+++	$\eta s \geq 150$	$\eta s \geq 180$			WHP(+), mCHP(H2), GHP(H_2)
A++	$125 \leq \eta s < 150$	$150 \leq \eta s < 180$	25	30	AHP(+), WHP(0), GHP(+)
A+	$98 \leq \eta s < 125$	$130 \leq \eta s < 150$	27	20	AHP(0), WHP(-), HYB(+), mCHP(+)
A	$90 \leq \eta s < 98$	$110 \leq \eta s < 130$	8	20	SOL(+), HYB(0), mCHP(0),
B	$82 \leq \eta s < 90$	$98 \leq \eta s < 110$	8	12	SOL(0), HYB(-), mCHP(-), Condens(H_2)
C	$75 \leq \eta s < 82$	$93 \leq \eta s < 98$	7	5	Condens(-/0/+)
D	$36 \leq \eta s < 75$	$87 \leq \eta s < 93$	39	6	Condens(-/0/+)
E	$34 \leq \eta s < 36$	$76 \leq \eta s < 87$	2	11	Non-condens(0/+)
F	$30 \leq \eta s < 34$	$43 \leq \eta s < 76$	4	39	EL(+), ATO(+)
G	$\eta s < 30$	$\eta s < 43$			EL(0), ATO(0/-)

*=GSHP=brine/water source heat pump, mCHP=micro-cogeneration, GHP=gas-fired heat pump, ASHP=air-source heat pump, HYB=hybrid ASHP & Condens, SOL=Solar assist & Condens, Condens=condensing gas/oil boiler, Non-condens=non-condensing gas/oil boiler (e.g. B1), EL=Electric resistance boiler, ATO=atmospheric or otherwise non-condensing (banned but e.g. to use for label of existing).
(H_2)=e-hydrogen ready or operating, (+)=good, (0)=average, (-)=bad.

Subsequently, there is the matter of the low-temperature (LT) heat pump and the LT classification of the standard heat pump (where applicable). In the current situation the class limits repeat the label class limits above, increased by 25 percentage points. Correcting for the new CC, the increase would be at least 30 percentage points instead of 25. Furthermore, Task 4 indicates that the difference in SCOP due to the system temperatures is larger than only 25 percentage points. Finally, following studies on current practice discussed in Task 4, it is proposed to increase the system supply temperature of standard heat pumps from 55 °C to 65 °C, which means that the difference in average system temperature with the 35 °C LT heat pumps will grow by 50%. On the basis of these arguments it is proposed to increase the difference with 45 percentage points, to arrive at the table below. An exception is made for the lower limit of the "A" class, which is proposed at the Ecodesign limit value of 150%. In that case the LT heat pump should be at least an "A".

Table 4. Energy label classes for low-temperature heat pumps space heaters (to water), NOW and NEWly proposed

Label class	Seasonal space heating energy efficiency ηs in %	Seasonal space heating energy efficiency ηs in %	Class width (in %)	
	NOW	**NEW**	NOW	NEW
A+++	ηs ≥ 175	ηs ≥ 225		
A++	150 ≤ ηs < 175	195 ≤ ηs < 225	25	30
A+	123 ≤ ηs < 150	170 ≤ ηs < 195	27	25
A	115 ≤ ηs < 123	150 ≤ ηs < 170	8	20
B	107 ≤ ηs < 115	143 ≤ ηs < 150	8	7
C	100 ≤ ηs < 107	139 ≤ ηs < 143	7	4
D	61 ≤ ηs < 100	135 ≤ ηs < 139	39	4
E	59 ≤ ηs < 61	127 ≤ ηs < 135	2	8
F	55 ≤ ηs < 59	88 ≤ ηs < 127	4	39
G	ηs < 55	ηs < 88		

Alternatively, if the stakeholder meeting so indicates, the Ecodesign limit could be at 170% and thus the LT heat pump should be at least an "A+". The "A" class lower limit would then be 155% instead of 150%. This would then be fully consistent with the classification limits for standard heat pumps.

For the water heating efficiency of combi heaters and dedicated water heaters there is the correction for the new CC of 2.1 instead of 2.5 (green cells in the table hereafter). Furthermore, the solar industry signals that in Southern Europe they have competition from low-cost, small gas-fired instantaneous heaters that have an "A+" label without any renewable energy, whereas they struggle to get an "A+" label with a solar installation. In other words, the label values for XS and S gas instantaneous appear to lenient and thus it is proposed to skip an energy class there (pink cells in the table hereafter).

Like with the space heaters, due to Ecodesign measures the lowest energy classes (yellow cells in the table hereafter) are now empty and can be eliminated. However, as opposed to the space heaters, there is no urgent need for extra energy classes. Therefore, there is no need to impact the market and manufacturers with the administrative and commercial burden of a shift in label ratings for the same product (except for the XS and S class).

Table 5. Water heater, lower Energy Label class limits NOW and NEWly proposed

NOW water efficiency (in %) lower limit									**NEW** water efficiency (in %) lower limit								
Class	**3XS**	**XXS**	**XS**	**S**	**M**	**L**	**XL**	**XXL**	**Class**	**3XS**	**XXS**	**XS**	**S**	**M**	**L**	**XL**	**XXL**
A+++	62	62	69	90	163	188	200	213	**A+++**	62	62	75	90	163	188	200	213
A++	53	53	61	72	130	150	160	170	**A++**	53	53	69	80	130	150	160	170
A+	44	44	53	55	100	115	123	131	**A+**	44	44	61	72	100	115	123	131
A	35	35	38	38	65	75	80	85	**A**	42	42	45	45	65	75	80	85
B	32	32	35	35	39	50	55	60	**B**	38	38	42	42	46	50	55	60
C	29	29	32	32	36	37	38	40	**C**	35	35	38	38	43	44	45	48
D	26	26	29	29	33	34	35	36	**D**								
E	22	23	26	26	30	30	30	32	**E**								
F	19	20	23	23	27	27	27	28	**F**								

The study team has the mandate, following the review clauses of the regulations, to look into –amongst others— technological progress and prepare proposals to update the legislation accordingly. The fact that boilers and water heaters were exempted from the obligation for other product groups to eliminate the '+' classes, does not mean that there can be no change and it does not diminish the mandate for the study team. In fact, a member of the Green party in the European Parliament, present at the 2nd stakeholder meeting, reminded the audience of the goal to eliminate the '+' classes if it were possible.

Having said all that, the timing of the measures also plays a role. If the implementation date for a new labelling scheme comes closer to the year 2026, policy makers may decide to prolong the current scheme until that date.

Stakeholder comments

Stakeholders were not in favour of applying a 1.2 labelling factor for H_2-ready, mainly because it would be misleading the consumers that the efficiency of such a space heater would be higher. (see also more extended version of stakeholder comments with paragraphs 2.2 and 2.3). At best, supported by Germany and ECOS-EEB, there could be an icon on the label saying that the appliance would be ready for H_2 or biogas.

Most stakeholders could see the logic of adapting the Ecodesign limits of the space heaters to the new pef. The only exception is that it is no longer fair to the thermally driven (gas/oil) heat pumps (TDHP) to have only one limit for heat pumps, according to EHI, the TDHP-section of EHPA and Eurogas. For electric heat pumps the pef-correction should apply (130% HT and 150% LT) but for TDHP, i.e. heat pumps that did not profit from the pef-corrected CC factor, the current limits should be maintained.

Sweden, without counter-arguments from others at the 2nd stakeholder meeting in May 2019, pleaded again —while maintaining the current energy labelling principle of one scale— to have at least a technology-specific Ecodesign regulation for combination and (dedicated) water heaters. This would enable the policy-makers to raise the overall ambition level by tackling specific types. It would also, according to Sweden, make it superfluous to take certain explicit actions like banning the pilot flame because the more specific limits would do that implicitly. The technology subdivision should be more specific than just between gas- and electric water heaters, as investigated in the 2016 special review study, but at the same level as the technology-specific Ecodesign regulation for space heaters. Norway supported this plea, because the current regulation for XXL, 3XL and 4XL phases out the placing on the market of complete electric storage water heating units (ESWHs) that use the Joule effect (resistance heaters). This is the dominant water heater type in Norway, because of its particular energy mix with hydropower. Furthermore, Norway presented its case that ESWHs can be an effective means of energy storage during the stakeholder meeting (see also the project website).

ANEC/BEUC agrees to align EL classes and ED limits if possible. APPLiA points out undesired rounding effects of changing the pef from 2.5 to 2.1, especially for ESWHs. JRAIA supports the change of pef, asks reasons for the exemptions in Tables 2-3 and asks for a sufficient transition period. ANEC BEUC asks to look into the feasibility to mention (or have a mandatory measure) regarding the minimum heating power of a condensing boiler (lowest modulation). They also welcome to have the SCOP mentioned on the label and would like that aspect included in the consumer survey.

COGEN, BDR Thermea and more cogenerator stakeholders are arguing for a complete review of the PEF towards the marginal PEF. As explained before, it is outside our mandate to 'correct' the trialogue-results of European Commission, Council and Parliament.

EHPA points out that the PEF also applies to (limits for) dedicated heat pump water heaters.

Eurogas mentions that there is now unfair competition for the gas heat pump because only the electric version has a pef-correction.

ECOS-EEB, in a first reaction, would like the energy label for air source heat pump water heaters (also HPWHs) to include efficiencies for all 3 climate zones. Currently only tested at +7 °C outdoor temperature> S should be tested also at -2 (cold) and +20 °C (warm). SPIUG mentions that a product fiche should also be mandatory for LT heat pumps (35 °C). In a more recent reaction ECOS and EEB ('Coolproducts') presented an alternative labelling and Ecodesign proposal for space heating boilers. The proposal takes into account the long product life of the central heating space heaters (15/20 years), making for quick action to be ready to meet the carbon emission policy goals ('Paris') in 2050. Furthermore, it uses only 7 labelling classes (A-G). The fossil fuel non-condensing and electric boilers in class G, being the least efficient, should be phased out in 2025; the condensing fossil-fuel boilers should be phased out in 2030. They recognize the option of hydrogen or other renewable gases but they should be in (gas) heat pump or hybrid format (back-up of electric heat pump).

Table 6. Coolproducts alternative labelling proposal

Existing label, PEF=2.5	**Coolproducts** Proposed label, PEF=2.1	Examples of heaters with proposal **Coolproducts**	Class width
A+++ (Eff >150%)	A (Eff. >190%)	Best ground source heat pumps with good controls, HP + solar hybrids	n.a.
A++ (Eff 125 –150%)	B (Eff. 166 – 190%)	Heat pumps, best boiler + HP hybrids, HP + solar hybrids	14%
A+ (Eff 98 - 125%)	C (Eff. 143 - 165%)	Heat pumps, boiler + HP hybrids, HP + solar hybrids	15%
A (Eff. 90 – 98%)	D (Eff. 123-142%)	CHP + solar hybrids, Heat pumps, boiler+ HP hybrids	15%
B (Eff. 82 - 90%)	E (Eff. 106 - 122%)	Solar+ boiler hybrids, CHP	15%
C (Eff. 75-82%)	F (Eff. 87-105%)	Condensing boilers	21%
D (Eff. 36-75%)	G (Eff < 87%)	Non-condensing B1 boilers Electric boilers	n.a.
E (Eff. 34–36%)			
F (Eff. 30-34%) (Empty class)			
G (Eff. > 30%) (Empty class)			

Sweden welcomes to display the seasonal efficiency on the label (see section 3 hereafter). Stimulates manufacturer to also make small improvements and gives better information to consumers. Same goes for displaying the SCOP of both medium and LT heat pumps, that would clearly show the advantage of LT heat pump.

UBA-BAM (Germany) is in favour of recalculating classes due to changes in the pef and showing the efficiency figure as well as electrical output and efficiency of mCHP units. Sees the need, especially towards installers, for further differentiation in upper energy. classes to promote renewables. Asks the study to elaborate if the impact of the label could be improved, because there is no classic shopping situation, by showing the available class range and the product label in the offer. Sees only 6 labelling classes for water heaters and asks to assess if there is the need for further distinction in 7 classes.

BDR Thermea comments:

- Mentions that the PEF is in NCV and the ED & EL heating efficiency relates to GCV, so the PEF=2.1 should be adapted. [28]
- Mentions that the marginal electricity saving should be applied (2.9) and not the average (2.1).
- BDR Thermea states that using the Carnot efficiency (2.5) is highly debatable/misleading, but the outcome is moving in the right direction (marginal electricity).
- Finally, BDR Thermea is opposed to mentioning the electrical efficiency on the mCHP label, because it is a heating label that should be comparable in that sense.

[28] Clarification of the study team: The new PEF=2.1 and old PEF=2.5 (ESD 2006/32/EC, OJ L 114, 27.4.2006, p. 64–85) both use NCV, so for electricity a correction 2.5/2.1 is correct. For fossil fuel there is no conversion.

As documented in the minutes of the stakeholder meeting, there was a discussion on whether 'rescaling' was allowed for boilers and water heaters under the rules of the new (2017) Energy Labelling Regulation. In particular EHI and some individual manufacturers were under the impression that nothing could be changed about the classes and class limits of the current energy label until 2026. Bosch TT and others brought forward that having no longer an 'A' rating for condensing boilers would be counter-productive because there is still a considerable saving potential in promoting condensing (gas/oil) boiler technology. On the other hand, there were Member States (e.g. Germany) and manufacturers (e.g. Viessmann) that were in favour

Conclusion:

There are several issues with Ecodesign and Energy Labelling to be clarified. The study team proposes to set up a special consultation initiative with the stakeholders to further discuss and investigate the issue.

2.5 Verification tolerances

As mentioned in Task 1, a group of laboratories is currently engaged in a broad Round Robin Test (RRT) project covering repeatability and reproducibility of most types of space heating boilers and water heaters. The final and complete results of this two-year ECOtest project will be published in the early fall of 2019. The ECOtest outcomes relate to

- The results and quantitative evaluation of repeatability and reproducibility of the Round Robin Tests according to the current test standard.
- Following the experience of the RRTs and expert opinion, recommendations for standards, legislators and accreditation entities on how to increase repeatability and reproducibility.

These will be discussed in the following two subsections.

Furthermore, the ECOtest project did not include a new round of testing to find out what verification tolerances could be achieved with improved standards. For that reason the study team requested laboratories –on a personal title— to give their expert opinion of the level of verification tolerances that they believe will achievable with better standards.

ECOtest Round Robin Test results

The tables hereafter give the findings from RRTs in the ECOtest project. The values represent the outcomes of the Round Robin Test per Working Package, corrected for evident errors and without stragglers or outliers.[29]

The columns in the table –from left to right—give the

[29] The number of stragglers and outliers can be derived from the last column, i.e. where the number of test labs for a specific parameter is less than the total number of test labs in the Work Package. Outliers and stragglers are extreme values, evaluated in this case by means of Mandel's statistics, whereby outliers are observations greater than the critical value at 1% confidence level and stragglers are observations greater than the critical value at 5%confidence level and less or equal to the critical value at 1% confidence level.

- *name* of the tested parameter (measurement *unit* in brackets),
- *median* of test results,
- *average* of test results,
- standard deviation of the repeatability *sr* (in %),
- standard deviation of the reproducibility *sR* (in %)
- difference between the lowest and highest average values *minmax* (in %)
- ratio of *minmax* and the average of the test results (in %)
- the number of test results included *N test labs* (#)

In the Annex II extended tables are given, showing an alternative calculation method for the reproducibility by multiplying de standard deviation by 2.83 and 4.00 (R1 and R2 absolute values respectively) and subsequently calculate them as percentage of the average (R1 and R2 averages). It also shows status and data processing by the labs.

The ECOtest team-leaders point out that, while the results in the tables below can be regarded as 'draft final' and can be the quantitative basis for the discussion on verification tolerances,

1. There might be (a few) results with some data that are not yet consolidated. In that case, no definitive conclusions can be drawn.
2. Some of the data would apply in the conditions that the standards are improved according to suggestions made in the project.
3. The relative variation Max-Min and Reproducibility are relevant to compare with the actual tolerance when keeping in mind that the RRT will vary in time with appliances tested, labs involved and possible changes in the test methods.
4. Differences between test results can have several reasons linked to three main sources: the laboratories, the appliance and the test method.

Table 7. ECOtest results Round Robin Tests (RRTs), WP1-WP6, corrected and without outliers and stragglers (source: misc. ECOtest Work Packages, June 2019)

WP1-3 RRT1 (12 labs)	**gas-fired condensing combi-boiler, 20 kW (input in Hi)**					*minmax /avg*	
	median	*average*	*sr*	*sR*	*minmax*		*N-labs*
Seasonal space heating eff on GCV (%)	92.16	92.05	0.31	0.53	1.52	1.65%	10
Full load eta4 on NCV (%)	97.10	97.12	0.39	0.50	1.25	1.29%	11
Part load eta1 on NCV (%)	108.06	107.82	0.33	0.72	1.79	1.66%	10
Hot water efficiency (%, instantaneous)	83.95	84.32	0.41	1.47	4.43	5.25%	11
Standby heat loss (W heat)	49.64	49.55		7.46	27.24	54.98%	12
Standby electricity (W elec)	3.00	3.13	0.08	0.66	2.41	77.00%	10
Qelmax electricity full load (W elec)	25.38	25.60	0.34	2.20	8.90	34.77%	9
NOx weighted part load (mg/kWh)	37.51	38.56		4.43	13.65	35.41%	6
Sound power (dB)	50.3	50.39		0.90	2.19	log-scale	5
WP4 RRT1	**mCHP, Stirling, heat out (CHP+SH) 35 kW**						
	median	*average*	*sr*	*sR*	*minmax*	*minmax/ avg*	*N*
eta seasonal heating GCV(%)	108.09	106.74	0.54	2.82	5.6	5.2%	5
eta seasonal heat on GCV(%)	111.9	110.6	0.54	2.77	5.54	5.0%	5
NOx (during full load test) mg/kWh	41.47	41.71	4.6	7.09	13.9	33.3%	4
P heat capacity CHP+SH Full Load (kW)	35.41	35.11	0.16	0.84	2.02	5.8%	5
Thermal Eff CHP+SH Full Load on NCV(%)	101.18	102.13	0.42	1.95	4.28	4.2%	5
Electr. Eff CHP+SH Full Load on NCV(%)	2.61	2.6	0.03	0.06	0.12	4.6%	4
Equiv. Eff CHP+SH Full Load on NCV(%)	97.53	98.05	0.43	2.13	4.29	4.4%	5
P heat capacity CHP Part Load (kW)	5.83	5.88	0.05	0.13	0.26	4.4%	4
Thermal Eff CHP Part Load on NCV(%)	91.58	91.98	0.46	2.02	4.49	4.9%	5
Electr. Eff CHP Part Load on NCV(%)	14.52	14.64	0.2	0.17	0.16	1.1%	4
Equiv. Eff CHP Part Load on NCV(%)	126.51	124.56	0.94	3.56	7.2	5.8%	5
Auxiliary electr. Cons. (in kW)	0.01	0.02	0	0.01	0.02	100.0%	5
Standby heat loss (kW)	0.07	0.07	0	0.02	0.06	85.7%	5
WP4 RRT2	**mCHP, Fuel Cell, 700W elec (eff>35%), 960W heat (eff 56%)**					*minmax /avg*	
	median	*average*	*sr*	*sR*	*minmax*		*N*
eta seasonal heating GCV(%)	262.55	263.03	6.91	9.77	18.51	7.0%	4
eta seasonal heat on(%)	269.20	269.30	6.88	9.51	17.93	6.7%	4
NOx (during part load test) mg/kWh	9.10	9.75	5.33	5.14	7.18	73.6%	5
Thermal Eff CHP Part Load on NCV(%)	55.12	55.33	1.21	4.41	11.76	21.3%	5
Electr. Eff CHP Part Load on NCV(%)	36.34	36.55	0.26	0.83	1.98	5.4%	5
Equiv. Eff CHP Part Load on NCV(%)	266.38	261.70	6.16	18.96	47.15	18.0%	5
Standby heat loss (kW)	0.02	0.02	0.03	0.02	0.01	50.0%	5
WP3/4 RRT3	**mCHP, Internal combustion engine, heat out 14.7 kW, elec**						
	median	*averag*	*sr*	*sR*	*minma*	*minmax*	*N*
eta seasonal heating GCV(%)	147.04	144.20	0.85	7.79	18.72	13.0%	5
eta seasonal space heat on (%)	150.97	148.04	0.85	7.72	18.40	12.4%	5
Thermal Efficiency CHP nom. Load (%)	66.22	66.76	0.14	1.27	2.68	4.0%	4
Electric efficiency CHP (%)	26.83	26.82	0.06	0.59	1.38	5.1%	5
NOx (during full load test) mg/kWh	424.70	428.44	11.33	121.1	293.53	68.5%	4
eta_wh (%)	125.18	126.31	27.04	30.77	54.20	42.9%	4
AED in kWh	3517.7	3467.4	552.0	919.0	1732.0	50.0%	4
AFC in GJ	40.98	43.11	6.92	9.44	17.84	41.4%	5

WP5 (4 labs)	**Gas heat pump (at nominal load, Tret 42 °C, Tfeed 55 °C)**					*minmax/ avg*	
	median	*average*	*sr*	*sR*	*minmax*		*N*
Nominal load							
heating capacity	38.90	38.89	0.25	0.29	0.11	0.28%	**3**
Cooling capacity	14.18	14.09	0.19	0.04	0.34	2.43%	**3**
AEF	44.45	44.44	1.74	0.64	3.13	7.05%	4
GUE	1.54	1.54	0.01	0.00	0.02	1.12%	4
Part loadA							
heating capacity	34.34	34.38	-	0.07	0.12	0.34%	**3**
Cooling capacity	13.01	13.31	-	1.14	2.63	19.75%	4
AEF	41.16	40.73	-	1.25	2.66	6.53%	4
GUE	1.56	1.56	-	0.01	0.02	1.11%	4
Part load B							
heating capacity	20.73	20.74	-	0.28	0.69	3.31%	4

Cooling capacity	7.36	7.46	-	0.63	1.41	18.85%	4
AEF	26.34	25.89	-	1.08	2.27	8.78%	4
GUE	1.52	1.52	-	0.00	0.00	0.29%	4
Part load C							
Heating capacity	13.50	13.54	-	0.17	0.36	2.64%	4
Cooling capacity	4.02	4.06	-	0.33	0.65	16.12%	4
AEF	17.54	17.53	-	0.02	0.03	0.16%	**3**
GUE	1.43	1.43	-	0.03	0.08	5.31%	4
Part loadD							
Heating capacity	5.99	5.94	-	0.09	0.15	2.56%	3
Cooling capacity	1.07	1.08	-	0.15	0.30	28.01%	**3**
AEF	9.15	9.15	-	0.51	1.26	13.72%	4
GUE	1.23	1.22	-	0.02	0.05	4.34%	4
Seasonal heating							
SAEF	20.73	20.62	-	0.83	1.87	9.07%	4
SGUE	1.48	1.48	-	0.02	0.04	2.49%	4
SPER	1.25	1.25	-	0.01	0.03	2.79%	4
ETASon	125.08	125.07	-	1.42	3.49	2.79%	4
etas	121.08	121.07	-	1.42	3.49	2.88%	4
Domestic hot water							
Qgas	22.70	22.79	1.41	1.49	1.89	8.28%	4
Q elec	1.26	1.28	0.13	0.12	0.09	6.95%	4
etawh	72.87	73.41	5.09	4.78	4.63	6.30%	4

WP6 (9 labs)	**Oil-fired condensing boiler, 20 kW**						
	median	*average*	*sr*	*sR*	*minmax*	*minmax/ avg*	*N*
Full load eta4 on NCV (%) Straggler Removed	96.61	96.74	0.31	0.94	2.7	2.8%	8
Part load eta1 on NCV (%) corrections for	102.73	102.76	0.59	1.08	2.59	2.5%	8
Standby heat loss (W heat) outlier removed	105	103	5.3	13.3	35.7	34.7%	8
Qelmax Electricity Full load (W elec) Outlier	193	195	1.29	4.26	12.85	6.6%	8
Qelmin Electricity Part load (W elec) Outlier	65	64	0.94	3.55	10.3	16.1%	8
Standby electricity (W elec)	1.3	1.7	0	0.7	1.8	105.9%	9
Etas seasonal heating (% GCV)	90	89.9	0	0.88	2.26	2.5%	9
NOx full load test (mg/kWh)	203	202	3.91	11.7	35.9	17.8%	9

Note that the efficiency calculations for the mCHP in WP4 follow the EN 50465 calculation method, which is being debated (see Task 1 and this Task 6 report).

Table 8. ECOtest, Results Round Robin Tests WP7 (electric heat pumps, RRTs corrected for obvious errors and without stragglers and outliers)

WP7 (7 labs) RRT1	**El. heat pump air-to-water, non-ducted, variable speed, 12**						
	median	*average*	*sr*	*sR*	*minmax*	*minmax/av*	*N test-*
eta seasonal space heat	157.60	156.73		7.75	24.09	15%	7
SCOPon	4.12	4.06		0.20	0.61	15%	7
SCOPnet	4.10	4.06		0.20	0.61	15%	7
Thermostat off (kW)	0.03	0.02		0.02	0.04	200%	7
Standby power (kW)	0.01	0.02		0.01	0.03	150%	7
Crankcase heater power	0.00	0.01		0.01	0.03	300%	7
Off-mode (kW)	0.02	0.02		0.01	0.03	150%	7
Rated COP PLR 100%, -10°C	4.54	4.54		0.08	0.24	5%	7
A. COPd PLR 88%, -7°C	2.69	2.69		0.05	0.12	4%	6
B. COPd PLR 54%, 2°C	4.00	4.00		0.07	0.22	6%	6
C. COPd PLR 35%, 7°C	5.43	5.40		0.16	0.45	8%	6
D. COPd PLR 15%, 12°C	7.01	7.01		0.06	0.14	2%	6
Rated Cap. PLR 100%, -10°C	12.47	12.40		0.28	0.81	7%	7
A. Cap. (kW) PLR 88%, -7°C	10.77	10.77		0.17	0.44	4%	6
B. Cap. (kW) PLR 54%, 2°C	7.55	7.53		0.27	0.80	11%	6
C. Cap. (kW) PLR 35%, 7°C	9.29	9.38		0.60	1.66	18%	6
D. Cap. (kW) PLR 15%, 12°C	10.59	10.56		0.16	0.43	4%	6
Sound power (dB) @ 20%	67.02	67.98		2.05	5.10	8%	5

WP7 (5 labs) RRT2	**El. Heat pump water-to-water, Pdesign 32.2 kW, dual compressor, two stage**						
	median	*average*	*sr*	*sR*	*minmax*	*minmax/avg*	*N test-lab*
eta seasonal space heat (%)	184.70	184.18	0.00	12.98	31.70	17%	4
SCOPon	4.93	4.94	0.00	0.11	0.27	5%	4
SCOP	4.75	4.72	0.00	0.26	0.60	13%	4
Thermostat off (kW)	0.12	0.09	0.00	0.09	0.20	220%	5
Standby power (kW)	0.12	0.11	0.00	0.07	0.18	165%	5
Crankcase heater power (kW)	0.05	0.07	0.00	0.08	0.20	299%	5
Off-mode (kW)	0.02	0.07	0.00	0.09	0.20	297%	5
Rated COP@ W10/W55-47	3.65	3.66	0.00	0.04	0.10	3%	5
A. COPbin PLR 88%, -7°C	3.93	3.94	0.00	0.04	0.10	3%	4
B. COPd PLR 54%, 2°C	5.04	5.02	0.00	0.07	0.16	3%	5
C. COPd PLR 35%, 7°C	5.73	5.69	0.00	0.07	0.14	2%	5
D. COPd PLR 15%, 12°C	6.44	6.40	0.00	0.09	0.20	3%	5
Rated Cap. (kW) @	31.14	31.08	0.00	0.18	0.41	1%	5
A. Cap. (kW) PLR 88%, -7°C	28.48	28.51	0.00	0.06	0.10	0%	3
B. Cap. (kW) PLR 54%, 2°C	16.77	16.83	0.00	0.36	0.92	5%	5
C. Cap. (kW) PLR 35%, 7°C	17.17	17.12	0.00	0.19	0.48	3%	5
D. Cap. (kW) PLR 15%, 12°C	17.58	17.61	0.00	0.17	0.43	2%	5
Rated Input (kW) @	8.47	8.50	0.00	0.08	0.21	2%	5
A. Input (kW) PLR 88%, -7°C	7.28	7.28	0.00	0.05	0.10	1%	3
B. Input (kW) PLR 54%, 2°C	3.34	3.33	0.00	0.02	0.04	1%	4
C. Input (kW) PLR 35%, 7°C	3.01	3.01	0.00	0.01	0.03	1%	5
D. Input (kW) PLR 15%, 12°C	2.75	2.75	0.00	0.02	0.04	2%	5

WP7 (5 labs) RRT4	**Hybrid of el. heat pump(2kW at 7A/35W) and 23 kW gas boiler; declared package capacity 7 kW.**						
	median	*average*	*sr*	*sR*	*minmax*	*minmax/avg*	*N test-lab*
Separated method							
eta seasonal space heat (%)	97.60	97.33	0.00	0.80	1.70	1.7%	4
SCOPon	2.48	2.45	0.00	0.08	0.15	6.1%	5
SCOP	2.48	2.44	0.00	0.08	0.17	7.0%	5
Thermostat off (kW)	0.00	0.00	0.00	0.00	0.00	60.5%	5
Standby power (kW)	0.00	0.00	0.00	0.00	0.00	0.0%	4
Crankcase heater power (kW)	0.00	0.00	0.00	0.00	0.00	250.0%	5
Off-mode (kW)	0.00	0.00	0.00	0.00	0.00	56.6%	4
Rated COP 100%, 7°C	2.02	2.02	0.00	0.01	0.01	0.7%	4
C. COPd PLR 35%, 7°C	2.96	2.96	0.00	0.03	0.05	1.7%	4
D. COPd PLR 15%, 12°C	3.47	3.48	0.00	0.09	0.22	6.3%	4
Combined method							
eta seasonal space heat (%)	96.45	96.18	0.00	3.01	5.80	6.0%	4
SCOPon	2.49	2.49	0.00	0.07	0.13	5.1%	4

SCOP	2.49	2.48	0.00	0.08	0.14	5.8%	4
Thermostat off (kW)	0.00	0.00	0.00	0.00	0.00	60.8%	5
Standby power (kW)	0.00	0.00	0.00	0.00	0.00	1.5%	4
Crankcase heater power (kW)	0.00	0.00	0.00	0.00	0.00	250.0%	5
Off-mode (kW)	0.00	0.00	0.00	0.00	0.00	172.1%	5
A. COPd PLR 88%, -7°C	2.39	2.40	0.00	0.11	0.29	12.1%	5
B. COPd PLR 54%, 2°C	2.47	2.48	0.00	0.15	0.40	16.1%	5
C. COPd PLR 35%, 7°C	2.59	2.77	0.00	0.28	0.62	22.4%	5
D. COPd PLR 15%, 12°C	3.52	3.42	0.00	0.20	0.48	14.1%	5
E. COPd PLR XX%, 4°C	2.46	2.50	0.00	0.06	0.11	4.4%	3
F. COPd PLR XX%, 9°C	3.28	3.27	0.00	0.02	0.05	1.5%	4
COPd PLR 100%, -10°C	2.47	2.49	0.00	0.12	0.27	10.8%	4

Table 9. ECOtest Results Round Robin Tests (RRTs), WP8 (solar)

WP8 (3 labs) RRT1 — **Flat plate solar collector (test according to EN 12975 / EN ISO**

	median	*average*	*sr*	*sR*	*minmax*	*minmax/avg*
eta0,hemisphere	0.745	0.741	-	0.007	0.013	1.75%
eta0,beam irradiance	0.752	0.750	-	0.012	0.023	3.07%
Kd diffuse IAM solar	0.94	0.927	-	0.042	0.08	8.63%
IAM (50°)	0.94	0.93	-	0.03	0.05	5.38%
IAM	0.96	0.96	-	0.03	0.06	6.25%
heat loss coefficient a1 (W/m2K)	3.73	3.76	-	0.07	0.13	3.46%
a2=temp. dependence a1	0.011	0.011	-	0.0025	0.005	45.45%
Effective thermal cap. a5 (W/m2K)	8310	8790	-	1083	2000	22.80%
Collector area Asol	2.51	2.51	-	0	0	0.00%
Collector efficiency ηCol	57	57	-	2	3	5.26%
Annual gross yield for Athens 25°	2958	2963	-	10	19	0.64%

WP8 (3 labs) RRT2 — **Solar store, 400 L, bivalent ('hot-top')**

	median	*average*	*sr*	*sR*	*minmax*	*minmax/avg*
Nominal volume (L)	404	403		3	6	1.49%
Effective volume (L)	401	397		10	19	4.79%
Auxiliary heated volume (L)	125	128		7.41	13.94	10.89%
Standby heat loss UA (W/K)	2.68	2.72		0.173	0.34	12.50%
Heat transfer cap solar to store	473.62	471.02		25.38	50.56	10.73%
Heat transfer cap aux to store	388.88	385.77		9.177	17.55	4.55%
Standing loss S @Ts=65, Ta=20°C	120.6	122.5		7.97	15.6	12.73%

WP8 (3 labs) RRT3 — **Solar combi store, 825 L, bivalent (EN 12977-4)**

	median	*average*	*sr*	*sR*	*minmax*	*minmax/avg*
Nominal volume (L)	825	817.47		13.05	22.6	2.76%
Effective volume (L)	794	749.2		86.4	154.4	20.61%
Auxiliary heated volume (L)	334	326.4		30.32	59.2	18.14%
Standby heat loss UA (W/K)	3.44	3.39		0.20	0.39	11.50%
Heat transfer cap solar to store	1199.9	1385.97		518.67	986	71.14%
Heat transfer cap aux to store	2082	1919		741	1454	75.77%
Effective thermal cap (kJ/K)	3285	3115		366.04	670.61	21.53%
Standing loss S @Ts=65, Ta=20°C	154.9	152.7		8.809	17.2	11.26%

WP8 (3 labs) RRT4 — **Solar water heater system, RRT2 store + 2 x RRT1 collector (test EN 12976-1, EN 12976-2, ISO 95459-5)**

	median	*average*	*sr*	*sR*	*minmax*	*minmax/avg*
Effective surface Aeff (m2)	3.395	3.461		0.204	0.391	11.30%
Collector loss coeff. Uc (Wm2/K)	8.087	9.513		3.49	6.528	68.62%
Store heat loss coefficient Us	2.562	3.07		1.234	2.307	75.15%
Heat store capacity Cs (MJ/K)	1.524	1.515		0.077	0.153	10.10%
Aux heat store fraction faux	0.454	0.45		0.052	0.104	23.11%
Mixing constant DI	0.026	0.057		0.056	0.098	172.00%
Auxiliary Electricity QAux	130.9	122.7		17.87	32.8	26.73%
Qnonsol Avg, M	640	568.7		149.3	284	49.90%
Qnonsol Avg, L, XL, XXL	-	-	-	-	-	-

WP8 (3 labs) RRT5 — **Solar water heater calculation according to SOLCAL 2013, SOLCAL 2017 and SOLTHERM**

	median	*average*	*sr*	*sR*	*minmax*	*minmax/avg*
<u>SOLCAL 2013 non-solar</u>						
Tapping pattern M (kWh/a)	1086	1092.33		53.78	107	9.80%
Tapping pattern L (kWh/a)	1553	1528.33		44.46	78	5.10%
Tapping pattern XL (kWh/a)	2554	2562.33		53.98	107	4.18%
Tapping pattern XXL (kWh/a)	3472	3496.67		63.69	120	3.43%
<u>SOLCAL 2017 non-solar</u>						
Tapping pattern M (kWh/a)	458	457		17.52	35	7.66%
Tapping pattern L (kWh/a)	1016	1030.67		36.29	68	6.60%
Tapping pattern XL (kWh/a)	2095	2132.33		68.16	120	5.63%
Tapping pattern XXL (kWh/a)	3058	3097.33		81.46	148	4.78%
<u>SOLTHERM non-solar contribution</u>						
Tapping pattern M (kWh/a)	606	608.33		4.93	9	1.48%
Tapping pattern L (kWh/a)	1249	1243		14	26	2.09%
Tapping pattern XL (kWh/a)	2281	2278.67		19.6	39	1.71%
Tapping pattern XXL (kWh/a)	3204	3205.67		12.58	25	0.78%

WP8 (3 labs) RRT6	**Solar water heater calculation according to SOLCAL 2013, SOLCAL 2017 and SOLTHERM**					
	median	*average*	*sr*	*sR*	*minmax*	*minmax/avg*
SOLCAL 2013 non-solar						
Tapping pattern M (kWh/a)	1278	1273		61.7	123	9.66%
Tapping pattern L (kWh/a)	1487	1505.7		50.6	96	6.38%
Tapping pattern XL (kWh/a)	1858	1841.7		65.1	127	6.90%
Tapping pattern XXL (kWh/a)	2224	2183		110.4	209	9.57%
SOLCAL 2017 non-solar						
Tapping pattern M (kWh/a)	157	154		6.1	11	7.14%
Tapping pattern L (kWh/a)	524	515		38.3	75	14.56%
Tapping pattern XL (kWh/a)	1099	1090		82.9	165	15.14%
Tapping pattern XXL (kWh/a)	1571	1572		127.5	255	16.22%
SOLTHERM non-solar contribution						
Tapping pattern M (kWh/a)	1086	1136.7		149.6	286	25.16%
Tapping pattern L (kWh/a)	1786	1876.7		198.2	364	19.40%
Tapping pattern XL (kWh/a)	2726	2833.7		219.3	397	14.01%
Tapping pattern XXL (kWh/a)	3452	3614.3		315.5	565	15.63%
Auxiliary Electricity QAux pattern M	117	107		19.1	34	31.78%

WP8 RRT5 is strictly computational, based results from RRT1 (collectors) and RRT2 (SWH-store), using SOLCAL method, as described in EN 15316-4-3:2017. The SOLCAL software used to compute the results is publicly available, either described in the transitional methods (2014/C 207/03) as SOLCAL 2013, or —as SOLCAL 2017— readily implemented under http://www.label-pack-a-plus.eu/solcal-tool/ which has been developed in the framework of the Labelpack A+ project (GA 649905). The SOLTHERM software is publicly available for the time being as it was developed in a project funded by the SOLAR KEYMARK Certification Fund[30]. [31]

WP8 RRT6 is similar to RRT5 strictly computational, based on results from RRT1 (collectors) and RRT3 (combi-store). It uses the same calculation methods as WP 8 RRT5. Note that data for the SOLTHERM method have been corrected for obvious reporting errors[32].

The table below gives the results for dedicated water heaters. They are strictly not in the scope of this Task, but the results can be significant for the verification tolerances of certain combi-appliances.

[30] http://www.vaconsult.net/Software/SolTherm/SolTherm_UK.htm

[31] In WP6 RRT5 the data for the SOLTHERM method have been corrected for calculation mistakes.

[32] In WP6 RRT6 the data all three methods have been corrected for calculation mistakes in a second instance.

Table 10. ECOtest preliminary results Round Robin Tests (RRTs), dedicated Water Heaters

RRT2 extension WP3 (11 labs)	Storage water heater, 111 L, gas-fired 8 kW (Hi), L tapping pattern						
	median	*average*	*sr*	*sR*	*minmax*	*minmax /avg*	*N test-lab*
40 °C mix water (L)	216.9	215.84	2.48	14.49	39.13	18.13%	11
Annual Fuel Cons. AFC (GJ GCV)	14.99	14.84	0.12	0.45	1.22	8.22%	10
eta seasonal WH (%)	61.06	61.57	0.5	2.28	8	12.99%	11
Gas cons Qfuel (kWh)	21.21	20.96	0.18	0.76	2.03	9.69%	10

WP7 (8 labs) RRT3	El. Heat pump indoor air (15 °C) water heater, 1.69 kW, 300 L, 55 °C DHW set, source 15/20 °C, no smart control, XL tapping pattern						
	median	*average*	*sr*	*sR*	*minmax*	*minmax /avg*	*N test-lab*
eta water heat (%)	138.70	138.77		1.97	4.97	4%	7
COP DHW	3.38	3.35		0.08	0.22	6%	8
Annual Energy Cons. AEC (kWh/a)	1207.74	1208.24		17.71	43.29	4%	7
V40 litres equivalent at 40 °C (L)	406.23	403.51		7.72	23.20	6%	7
Reference DHW temperature (°C)	53.09	53.15		0.35	1.03	2%	7
Rated power (kW)	1.50	1.50		0.04	0.12	8%	7
Useful energy DHW (kWh/tap pattern)	19.19	19.22		0.16	0.46	2.39%	8
Elec. Cons during tapping (kWh/tap pat)	5.69	5.63		0.32	1.01	17.94%	8
Standby power (W)	26.06	26.15		2.12	6.28	24.02%	8
Elec cons heat up of store (kWh)	4.08	4.1		0.1	0.3	7.32%	8

Last 4 rows are from preliminary results (not consolidated)

ECOtest recommendations for improvement of the standards

During and after the RRTs the laboratories brainstormed about ways to improve repeatability and reproducibility in the standards, the legislation and the accreditation procedure. It would be out of the scope of this preparatory Ecodesign review study to sketch all recommendations in detail, especially because the full ECOtest report is expect to be approved and thus publically available by Sept./Oct. 2019. Therefore, only a summary of one set of recommendations –for the gas boiler (WP3)— is given hereafter as an illustration.

Recommendations for standardisation TCs and WGs of gas boilers (WP3):

- *Defining accurately the thermal stability, possibly introducing (more/better) stability criteria*
- *Better definition of duration and number of tests*
- *Possibly requiring the repetition of the testing (may not be needed if first two points are implemented)*
- *Develop horizontal documents for products with the same functionality*
- *The "corrected heat input", defined in EN 15502-1 section 8.4, shall not be used for the efficiency calculation. It is used to check that the value measured under test conditions differs no more than 5% from the nominal heat input. Give an example to avoid any misunderstanding.*
- *Prescribe a mandatory indirect efficiency control at full load, as this can help avoiding errors due to some measurements.*
- *Differentiate metering uncertainties per type of test, e.g. there can be a difference between safety and efficiency tests in that respect.*

- *Possible, when a standard has requirements on uncertainty, it should also indicate the method to be used to assess this uncertainty.*
- *Uncertainty calculation regarding Individual metering (temperature, flow, etc.) could be included in a shared horizontal document.*
- *range rated boilers were not tested in the framework of this project; it is not clear whether current standards give results that are reproducible enough for application in ErP.*

ECOtest recommendations to the legislator regarding gas boiler legislation (WP3):

- *Harmonise the tolerance of measurement with the TCs. Exclude from legislation the tolerance of indoor temperature for testing or, if it is necessary set the tolerance to ± 5K.*
- *Help in harmonising the approach of each TC to the measurement of ErP parameters*
- *When testing methods are re-considered, include the accuracy of measurement as one aspect to be taken into account. Often simple methods are accurate and reproducible, but not reflecting the reality of the appliance use. More complex methods (e.g. dynamic) may be more realistic, but less accurate due to measurement challenges under dynamic conditions.*
- *Testing 3 additional units when the first unit shows a measured value that is outside the range of the declared value + verification tolerance may indicate a fault in manufacturing (too favourable declaration, too high production tolerances), but also that the lab did not (cannot?) work within the given verification tolerances. Thus the legal implications of not only too lenient but also of too tight verification tolerances may be important. Having said that, three additional test results will certainly reduce statistical uncertainty in any circumstance.*

ECOtest recommendations to Notified Bodies and authorities in charge of market surveillance (WP3):

- *Develop a harmonized procedure of test report control in order to reject test reports that are not respecting tolerance specifications for certain test conditions, especially the load of the boiler for <u>part load testing</u> (various methods possible), <u>water temperature</u>, possible requirements on <u>air excess</u> for the emissions test, scale of <u>analysers and calibration gases.</u>*
- *Discuss if laboratories' accreditation shall be mandatory for ErP test and market surveillance*
- *Discuss if participation in Round Robin Tests shall be mandatory for ErP test and market surveillance*

Also illustrative for the subject matter are the following pictures of the test rigs used within the laboratories.

Figure 4. WP1-3. Left: Water heater D on a test bench. ***Bottles with calibrated gases (CO, NO, NO_2) are sent to laboratories for a blind test (laboratories do not know the composition).***

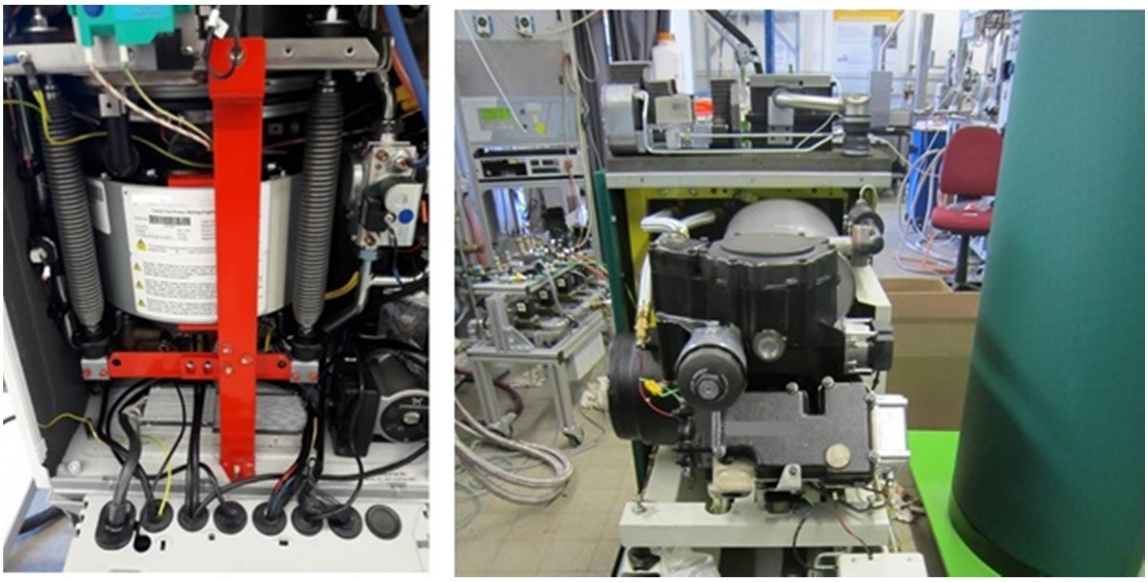


Figure 5. WP4. Left: Stirling system without cover. Right: ICE without cover.

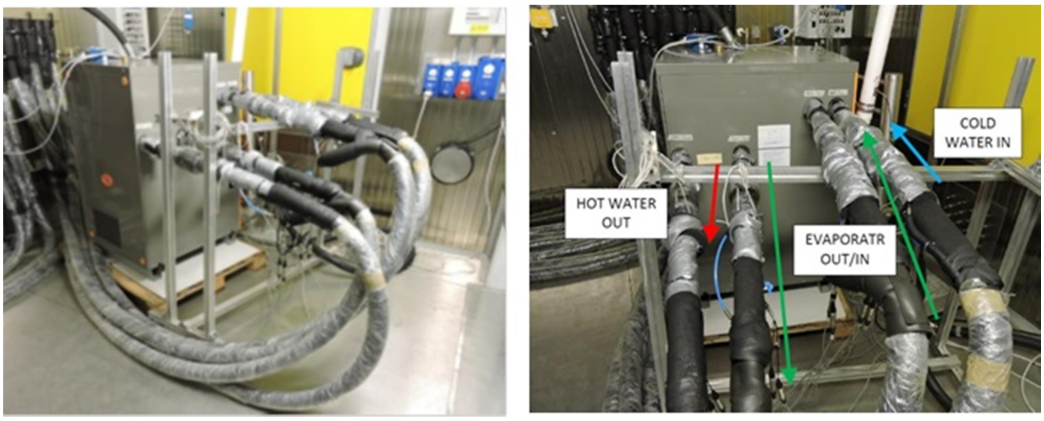


Figure 6. WP5. Gas heat pump under test

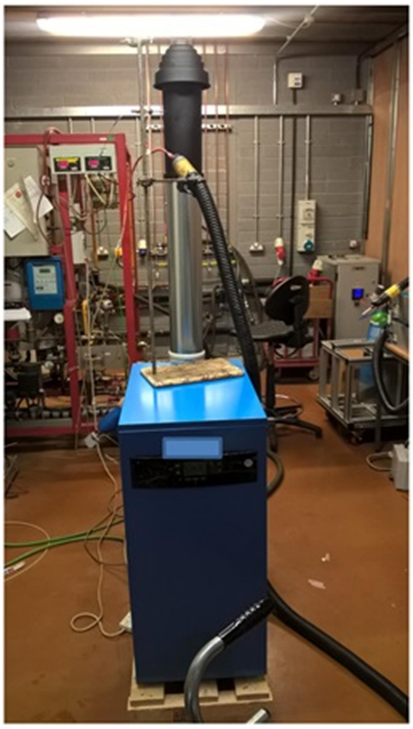


Figure 7. WP6. Oil-fired boiler tested

Figure 8. WP7. Left: Air-to-water heat pump (RRT1). Right: Water to water heat pump.

Figure 9. WP8. Left: Reference measurement and extra tests (iterative tests) in the Solar simulator. Right: Thermal performance test on outdoor tracker (EN 12975 and EN ISO 9806)

Figure 10. WP0. View from the first plenary meeting

Achievable tolerances with improved standards and other measures

As mentioned, the ECOtest project did not foresee re-testing with improved standards and other measures. The study team thus asked for expert estimates from laboratories, on personal title and strictly on a voluntary basis, for an estimate of what verification tolerances would be achievable.

The laboratories that gave their estimates on fossil fuel fired appliances were APPLUS, CATIM, CETIAT, DGC, DGC, DVGW/EBI, GASBE. Fraunhofer ISE, together with CETIAT, were the only ones to comment on the electric heat pumps. A summary, focussing on tolerances that are in the regulation, is given hereafter:

Energy efficiency

Gas-boilers (WP3) and oil-fired boilers (WP6): For the near future a tolerance of 4% (currently 8%) is fine with the proposed improvements; for the future 2.5-3% should be achievable.

For mCHP (WP4), except perhaps Stirling systems, the current tolerance of 8% is still challenging. For Stirling systems 5% tolerance (minmax/avg) was found, for the fuel cell (FC) after correction and without straggler 7% tolerance was established and for internal combustion engines (ICE) the minmax/avg value was 13%.

For the gas-fired heat pump (WP5) a verification tolerance of 5% on space heating efficiency was found. With improvements this could become 3-4%.

For electric heat pumps (WP7), CETIAT and Fraunhofer ISE state that the conducted tests are not representative for assessing the tolerance regarding market surveillance, because the abundance of different appliance types and even differences in controls, component sizing etc. within the same product type is very large. Further, there are more parameters like e.g. production tolerances, which have not been considered in the ECOtest project. This is the fact even when the market products for single family houses are being taken into consideration. The Regulations (as well as the standards), however, apply for appliances up to 400 kW and the variety of systems becomes even larger.

It is recommended that the efficiency class ranges should be matched with the tolerances. Otherwise, there could be room for declaration of values to reach certain efficiency class.

Hybrid heat pumps are currently not covered by the Regulations and the test methods are very new and, partly, incomplete.

Having said all that, the minmax/avg values for air-to-water heat pumps (12 kW, variable speed) was 16%, for water-to-water heat pumps (32 kW) 8% and for hybrids 2% (separate method) and 7% (combined method, without stragglers).

For the tolerance of the solar system contributions to space- or water heating after improvement of the standard there is no input.

For instantaneous and storage gas-fired water heaters the minmax/avg values are 5% and 13% respectively. It is recommended to use 8% and 15% right now. After improvements, i.e. in 2021, 4-5% (instantaneous) and 6-8% (storage type) verification tolerances should be possible.

For the dedicated heat pump water heater (WP7, RRT3), CETIAT and Fraunhofer ISE recommend investigation on a broader basis needed in order to make conclusions. Having said that, the minmax/avg value of the water heating efficiency of the RRT3 is 6% (without straggler).

V40 (equivalent water of 40 °C, in litres)

For V40 the current value of 3% was found to be much too low. For the gas-fired storage water heater (111 L nominal volume) a minmax/avg value of 18% was found. For the dedicated heat pump water heater (300 L nominal volume) a V40 minmax/avg value of 6% was found. Improvements are needed for the storage technology in general. More analysis is needed on the results to give an idea what could be the tolerance.

It is recommended to set tolerances higher or use absolute values for the tolerances.

NO_x emissions

For NOx emissions, the lab experts find that the tolerance in %, currently 20%, is not adapted to low emissions. Currently it is 20% and the minmax/avg value of all gas-fired heaters exceed that value (33%, 35%, 74%, 69%, etc.). They propose a tolerance expressed with an absolute part (e.g. B=15 mg/kWh) and a relative part (e.g. A=15% or similar). The formula would then be TOL=A*Measured value + B. Compared to today, the smaller NOx-limit values would have larger tolerances and the higher NO_x-limit values, e.g. for oil-fired boilers would have smaller tolerances.

Sound power

The current tolerance (2 dB) is almost respected once outliers are removed. For boiler testing sound power is a rather new measurement so the results are encouraging. It is recommended to change tolerance from 2 to 4 dB for gas and fuel oil boilers. Especially on this point differences in technologies can play a role. In the future 2.5 to 3 dB tolerance should be achievable.

Standby heat loss (in W or W/K)

There is no expert estimate on this issue. The minmax/avg values for solar stores (RRT2, RRT3) was in the range of 11.5-12.5%. For the dedicated heat pump water heater a standby electric standby power of 26 W was measured with minmax/avg of 24%, but it is not certain whether this includes the standby heat loss compensation or other issues as well. In any case, the current tolerance of 5% seems low (VHK-opinion).

Electricity consumption of auxiliaries (standby, elmax, elmin)

The tables in par. 2.5 "ECOtest Round Robin Test results" show that minmax/avg values are quite large for these relatively small amounts of measured power. At the moment, with the exception of solar, they are not explicitly subject to verification tolerances.

Conclusion study team

The estimates by the laboratories in this subsection are a valuable input into the decision making process, together with the outcomes of ECOtest project. The experts stress the importance of training, horizontal (GLP, Good Lab Practice) documents, transparent and consistent reporting and test procedures, as well as following up on specific recommendations for improvement per type of appliance. Only with those measures, the estimated tolerance levels can be achieved. The most alarming in terms of tolerances for the legislation are the energy efficiency of air-to-water heat pumps, storage-type products (including their standby heat loss) and the NOx emissions. For the latter, the suggestion to use a fixed and variable part makes sense. It is now up to the Member States and Commission to see how to deal with the follow-up of this work.

2.6 Third-party conformity assessment

Task 1 reports on the appropriateness of third-party 'certification' (meaning 'conformity assessment by a third party i.e. a notified body'). In today's Ecodesign and Energy Label regulations the default situation is a self-declaration by the manufacturers, which can be (spot-)checked by Market Surveillance Authorities (MSAs). The only exception is the efficiency measurement of fossil-fuel fired boilers (space heating efficiency only), where a type-test (Module B) is performed under supervision and responsibility of a Notified Body and the manufacturer declares the final product in conformity with the relevant regulations (Module C). This practice is a legacy of the Gas Appliance Directive under which mandatory third-party conformity assessment was first introduced.

The review article spurred a discussion whether third-party conformity assessment should also become mandatory for the other appliances in the scope of the Ecodesign and Energy Label space heating and water heating appliances (or that it should be removed from energy efficiency testing of space heaters). The main advantages mentioned by stakeholders are a higher credibility, less risk of circumvention (or easier identification of circumvention by MSA), a level playing field especially vis-a-vis extra-EU products. Disadvantages, as mentioned by SME-sized companies, are higher costs and time-to-market for manufacturers and the likely need for an expansion of laboratory capacity plus administrative burdens.

Traditionally, the producers of the gas- and oil-fired heating boilers are in favour of third-party conformity assessment, which is what they are used to. Heat pump manufacturers, in Europe very often with extra-EU origin (Japan, South-Korea, USA), were traditionally against mandatory third-party conformity assessment. However, probably with the increasing competition of lower quality products and the numerous ('voluntary') certifications required for eligibility of national subsidies, certain large heat pump manufacturers have now changed opinion and may accept a system with third-party conformity assessment, provide certain conditions are met (freedom in choice of module, etc.). The Member States that did speak out expressed a clear preference for mandatory 3rd party conformity assessment, but —like most other stakeholders— would like a more thorough assessment of impacts, focusing on lab capacity, testing costs, preferences of Notified Bodies, and a discussion on which modules should be allowed/prescribed, etc. Nonetheless, the discussions provide a basis for a **design option for third-party conformity assessment** to be assessed in more detail in subsequent analysis (as discussed in the 2nd stakeholder meeting).

This is an important step in creating a reliable data foundation, not just for this product group, but also for Ecodesign and Energy Labelling as well as related legislation in the context of EPBD and EED.

Note that according to the framework directive, third-party conformity assessment can be called for if duly justified and proportionate to the risk. Note that currently also third-party conformity assessment is investigated for the Ecodesign of solid fuel boilers.

2.7 Extension of the product scope to 1 MW

The current scope of the Ecodesign boiler regulation extends to capacities up to 400 kW. The reasoning in the past and with other product groups has always been that beyond a certain product size the buyers are professionals that do not need a regulation to tell them how to find the most energy-efficient solution. However, the market situation of especially the large highly inefficient oil-fired jet burners tells a different story. Especially in large multi-family dwellings and in certain, mainly public non-residential buildings the jet-burner boilers (80% oil-fired) are virtually indestructible and there is evidently no commercial or economic mechanism that tells the decision-makers to make the investment to change these old, inefficient and highly polluting boilers.

Several member states, at national or local level, are working with legislation and subsidies to force the (old) oil-boilers out. And indeed, when replacing the existing boiler for a new boiler with a different fuel, the existing boiler is usually oil-fired. But a fuel-switch only happens in 7% of the cases for instance in Germany according to a recent survey. In 93% of cases the replacement is like-for-like. In the case of large floor-standing boilers it is even more tempting not to change, because the heat exchanger almost never breaks down and the jet-burner is designed to be replaced multiple times over the life of the boiler.

The first step to try to change this situation is to extend the scope. Setting the scope to a rated thermal input equal to or smaller than 1 megawatt (1 MWth) also closes the gap in certain emission limits with the new Directive (EU) 2015/2193 of the European Parliament and the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants (Medium Combustion Plant (MCP) Directive). This MCP directive applies to combustion plants (including boilers) between 1 MWth and 50 MWth. Above 50 MWth there are emission limits for large combustion plants (LCPs > 50 MWth)[33], covered under the Industrial Emissions Directive (IED-2010/75/EU).

[33] There are almost 33.000 LCPs in 2015 (source: EEA 2018) https://www.eea.europa.eu/data-and-maps/data/lcp

Ideally there would then be consistency. But there are a few definition problems to take care off. This is explained in Task 1, section 3.2.8. Amongst others the scope of the current Ecodesign regulation is in thermal (heat) **output**, whereas the MCP defines the scope in **Net** Calorific Value NCV of the **fuel input**. The emission limits (not the scope) are expressed in **mg per kWh fuel input** (in Gross Calorific Value GCV) for the Ecodesign regulations and in **mg per Nm³ flue gas output** for the MCP Directive.

These differences, and possible differences in test standards, make it difficult to a make an exact comparison, so the following is only a first impression:

in the Ecodesign boiler regulation 813/2013 the maximum emission limits for NO_x – implementation from 26 Sept. 2018— are 56 mg/kWh GCV for boilers with gaseous fuels and 120 mg/kWh GCV for liquid fuel fired boilers. As an order of magnitude[34] this is more stringent than the 100 mg/Nm³ (natural gas) and 200 mg/Nm³ (gas oil) limits in the MCP Directive. The MCP limits apply –for new combustion plants— from 20 Dec. 2018 onwards.

For cogeneration with internal combustion engines the 813/2013 regulation gives relatively lenient limit values of 240 (gas) and 420 (liquid fuel) mg/kWh GCV, whereas the MCP gives more stringent values of 95 (gas) and 190 (oil) mg/Nm³ for new (and larger) engines (approximately 110 mg/kWh and 220 mg/kWh respectively).

But overall, if the current Ecodesign NO_x limit values were to apply for up to 1 MW boilers the overall ambition level would be coherent.

In Task 3 it is estimated that the extension of the scope from 400 kW to 1 MW will cover an extra 15% in energy consumption.

Note that the cooling performance side (also …-to-water) of reversible heat pumps between 400 kW and 1 MW is regulated in the Ecodesign regulation for central air heating appliances (Lot 21). Already the Ecodesign regulation on space heaters deals with the heating side of that very same reversible product if the heat output is equal to/less than 400 kW.

Stakeholder comments

There are 9 stakeholders reacting specifically on the subject, i.e. COGEN, Daikin, Denmark, ECOS-EEB, Sweden, EHI, UBA-BAM (Germany). Most find the extension of the scope to include 400 kW - 1 MW products useful, at least for space heating. For water heating the highest load profile would not nearly be enough to test these large appliances on that aspect. Only EHI is against the extension, because it finds the periodical on-site testing for compliance assessment under the Medium-sized Combustion Plant Directive (MCPD) more appropriate for these large, tailor-made products. The other stakeholders recognise the problems of size and thus limited laboratory availability, which would probably require on-site testing (not unusual for other large Ecodesign regulated products), and handling specific configurations but obviously do not (yet) find they pose an unsurmountable barrier for inclusion. Germany highlights the different legal context of MCPD vs. Ecodesign and mentions that Ecodesign should be more ambitious than MCPD.

[34] Considering a conversion factor of 1,16 from mg/kWh to mg/Nm³ for Gas H and Heizöl EL in W. Linke, E. Marx, Handbuch Feuerungstechnik 2006, Verlag Gustaf Kopf, 2006. This is for 3% O2.

EHI addresses, as mentioned in the Task Reports, that the relation with the Regulation (EU) 2016/2281 for air heating products, cooling products, high temperature process chillers and fan coil units (lot 21) should be clarified to avoid double regulation of heating energy efficiency and mentions ensuring fair competition between cascading boilers vs. single boilers. Sweden supports to include the regulation of the heating efficiency of reversible heat pumps, air/brine/water-to-water under the boiler regulation, even though the cooling side is regulated under (EU) 2016/2281.

<u>Response:</u> *It is fully recognised that including large, tailor-made products in the scope creates a set of extra problems in terms of testing. On the other hand, covering the emission regulation gap and adding an extra 15% energy consumption to the scope of this important product group of space heating boilers is much more than what can be achieved in any other Ecodesign-regulated product group and thus probably worth the effort. In reaction to EHI it should be mentioned that indeed the compliance assessment in the MCPD is different, aimed at identifying and periodically testing each of the 143.000 individual combustion installations in the EU between 1 and 50 MWth. Extending such a tremendous effort to the more than half a million heating boilers between 400 kW and 1 MWth is probably not worth it, where already the spot-checking Ecodesign market surveillance is a logistic challenge. The amended EPBD also requires periodic checks of heating systems with a capacity equal/larger than 70 kW, and systems exceeding 290 kW have to be equipped with monitoring equipment- see Task 1, Directive 2018/844.*

2.8 Clarification of the product scope

E-fuels and bio-fuels

In Art. 2 (definitions) of the regulations, the options of hydrogen and other electro fuels (e-fuels) should be mentioned with the definition of heat generators, and definitions to differentiate 100% bio-fuel fired equipment (gas and liquid) have to be introduced.

Drinking or sanitary hot water

Manufacturers of pool heaters and industrial process water heaters have asked if and how they should meet certain Ecodesign requirements for (combi) water heaters. This shows that the current definitions just mentioning "drinking or sanitary hot water" and "connected to an external supply" (of drinking or sanitary water) are not clear enough and need to be improved. No suggestions from stakeholders were received. The study team proposes to refer to 'water intended for human consumption' as defined in Art. 2.1(a) and subject to quality standards as referred to in Art. 5 of the Drinking Water Directive 98/83/EC [35] . Art. 2.1(a) defines

1. 'water intended for human consumption' shall mean:

(a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;

[35] COUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption OJ L 330, 5.12.1998, p. 32–54. Latest consolidated version: 27/10/2015.

Addressing circumvention

In line with the regulatory developments[36] in other product groups under Ecodesign and Energy Labelling regulations (and as mentioned in comments by ANEC-BEUC, ECOS-EEB, Denmark and the joint-statement by EHI-EHPA-EPEE-EUROVENT), the product-specific regulations should include requirements to avoid appliances can be tested in a mode that deviates from the normal, regular use (using a device programmed to recognize the test conditions and react specifically to them). This requires the introduction of terms that define (and prohibit) the potential use of such defeat devices, for instance as introduced in the regulation for electronic displays [37].

Said definitions require fine-tuning so that state-of-the-art test methods, with procedures for improving repeatability and reproducibility, are allowed or are given time to be further developed (such as the 'Compensation method' or 'Dynamic testing' as discussed in section 3.2). This refining has to be done together with standardisation committees and working groups, manufacturers, test laboratories, market surveillance authorities and other stakeholders.

2.9 The shared chimney problem (the B1 exception)

In the current regulation there is an exception for B1-type gas boilers up with rated heat output up to 30 kW for combination boilers and 10 kW for (solo-) boilers. This exception, allowing inefficient boilers on the market, was introduced to deal with multi-family buildings with individually-owned boilers per dwelling and a shared flue gas outlet ('chimney') where technical and/or economic problems are reported to install the 86% efficient (and thus usually condensing and positive pressure) boilers.

The market analysis in Task 2 shows that a considerable part of the sales (8% in 2016, i.e. 0.44 million units) relates to these non-condensing B1 boilers. As there are no real restrictions on the sale of B1-boilers (30 kW is big enough for most dwellings), it cannot be excluded that they are also used where they are not required.[38]

In other words, they pose is a considerable loophole. For that reason, it is proposed to **limit the capacity of the B1 exception to 10 kW**. As elaborated in Task 3, 10 kW is more than enough for an apartment and with a 70 L tank it is still a very comfortable hot water solution. The storage combi- boiler, e.g. 100x35x40 cm (h*d*w), would fit in a kitchen cabinet and thus close to the most frequently used tapping point.

A second issue, elaborated in the Task 1 report – section 4.10.2, is that Germany, Austria and several Eastern European Member States report **a problem with C4 and C8 boilers**. The problem is the replacing of (individually owned) non-condensing C4 type boilers (and C8 types) connected to collective flues that operate under negative pressure and are not condensate-resistant (made of brickwork, fire-clay, etc.). Although the issue

[36] See Article 3.4 and 3.5 of the Energy labelling regulation 2017/1369/EU which introduced provisions related to updates and circumvention.

[37] See draft documents Ares(2018)5173952/1-5 here: https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2018-5173952_nl

[38] Recital 12 of Regulation (EU) 813/2013 mentions almost 5 million dwellings using B1 type boilers in shared flue situations; in that light –even at a modest product life of say 15 years—this should give no more than 0.33 million units sales and not 0.44 million units.

is comparable to that of B1 type boilers connected to a shared flue, the present regulation has not introduced lower efficiency limits for such C4/C8 boilers.

The reason these boilers were not given separate requirements may have been that at the time of the introduction of the regulations, both condensing and non-condensing boilers were all categorised as C4/C8 boilers. This could have made a "B1-like' exception for non-condensing boilers based solely on type ("C4, C8") problematic as one doesn't want to cover the condensing boilers. Currently, condensing boilers used in collective chimneys are covered by new categories such as B(11) to B(14) and C4/C8 is only used in reference to the non-condensing types.

Task 1 elaborates various solutions for the C4/C8 problem. It is estimated that at the most 1 million C4/C8 units are installed in the EU. There are several chimney options but a complete chimney renewal (worst case) is estimated to cost €1250 per boiler. This implies in total €1.25 bn, divided over the next 10 years and divided over several Member States.

If governments were to support such a development financially, an exception for C4/C8 boilers would not be needed.

If it is judged that an exception is needed, it is proposed to at least set the 10 kW limit also for combination boilers.

Last but not least, the impact of hydrogen-fired boilers will have an impact on shared chimneys. As mentioned in Task 4, per unit of heat output the amount of condensate will be twice as high as with a natural gas-fired boiler and the flow rate will be three times higher. In other words, if the EU wants to realize a carbon-neutral society with hydrogen, the chimney problem will have to be tackled.

Annex II gives a detailed discussion of the various options.

Stakeholder comments

During the 2nd stakeholder meeting Croatia brought forward concerns regarding the C4/C8 problem for which they want an exception in the regulation, similar to B1 type boilers. The limitation to max 10 kW for both solo or combination heaters was not accepted by them as this could lead to chimney-problems (caused by a low flue gas volume of very moist gases). Other Member States did not take a position on the issue yet, although Germany also raised the general problem. ECOS/EEB ('Coolproducts') was against an exemption for C4/C8 and promoted that instead the countries should take the opportunity to apply a heat pump or other sustainable/carbon-neutral solution. Informally, manufacturers mentioned not to be in favour of a C4/C8 exemption: They have ended production and are reluctant to start up again for what is probably a short-lived future, and expect other stakeholders to bear the costs for the required chimney renewal.

<u>Response</u>*: As the most effective solutions to this problem lie beyond the regulatory scope of ecodesign/labelling it is obvious that Member States must do more in assessing the scale of the problem and the costs involved for mitigation (chimney lining, chimney replacement, other heating systems, etc.). The limitation to 10 kW heat output proposed under ecodesign is a strong signal to the market that misuse of lower efficiency requirements for such boilers should stop, but this cannot solve the problem alone or indefinitely.*

2.10 Monitoring

German representative UBA-BAM mentioned the possible advantages of monitoring product operation and performance (possibly including efficiencies) in a position paper. Monitoring may help to minimise deviation from anticipated efficiencies, by allowing end-users and service personnel to establish inefficient operating conditions (that may be alleviated by better matching product operation to actual demands). This is also mentioned in comments by the Open Therm association.

Now that the revised EPBD does not require inspection of equipment below 70 kW output, there is an increased chance that inefficient behaviour of (smaller) appliances goes unnoticed for a long time. The UBA-BAM document recommends:

- the space/combination heater controls can collect and share data on energy consumption, heat output and actual operating conditions of the products, including calculation of energy efficiency;
- the space/combination heater controls can compare actual performance/efficiency with default values so that deviations from default can be identified;

The above monitoring measures are not so different from what consumers find in cars and which allow consumers to compare actual fuel consumption with the standard fuel consumption. Given that a single typical boiler consumes as much primary energy as a typical car[39], it is surprising that the same feedback mechanism is not present in boilers.

Sharing this information with other devices (smart phones) is an important aspect as space/combination heaters are often installed in spaces that are not frequently visited, nor do many space/combination heaters carry elaborate displays (providing performance/efficiency information would require a more elaborate human interface than currently applied for indicating error controls and supply temperatures). Sharing the monitoring information with a heating control in the living room or through Wi-Fi on a smartphone (app required) could solve this issue, and many heat pumps and PV installations already offer such functionalities.

2.11 New Ecodesign work item: Emitter capacity and control

Task 4 describes extensively the importance of emitter capacity (EC) versus the heat load (HL) of the dwelling/building, i.e. the so-called HL/EC ratio. It estimates that optimising this item, which is the main factor impacting the system temperatures, may bring savings for conventional boilers in the order of 10% and much more —up to 50% or more— for heat pump systems (expressed as seasonal efficiency).

The emitter system is out of the scope of the regulations and thus this study, but it can be recommended to add this subject, including the relevant hydraulic and temperature controls for the emitters, to the future Ecodesign working programme. Also, in a review of circulator regulation and the new subject of building controls the importance of the

[39] The average petrol car consumes 2.4 MJ/km in Europe in 2015. Assuming 15 000 km annually, this represents 36 000 Mj or 10 000 kWh of primary energy. This is close to the expected energy consumption of a typical (gas) boiler in a typical residential dwelling (for petrol car fuel consumption, see: https://www.sciencedirect.com/science/article/pii/S1352231018307295)

system (return) temperature should be scrutinised. Apart from legal measures at EU level, the Member States can of course expand on EPB-measures, installer training and promotion/subsidies to deal with the subject.

3 Options for Single Appliances

3.1 Introduction

Single space heaters are heat pumps, gas/oil boilers and cogeneration (combination) heaters (a.k.a. micro CHP). These are the products that are subject to minimum energy efficiency requirements, noise and maximum emission limits for NO_x under the Ecodesign regulation 813/2013.

This section discusses improvements in test conditions and calculation methods to make the efficiency numbers closer to real life, more efficient, more effective and more up to date with new and imminent innovative technologies.

3.2 Heat pumps

Note: Where this section mentions COP or SCOP, it should be understood that this includes equivalent terms for thermally driven (gas) heat pumps such as GUE, PER and SPER.

System temperatures

In Task 4, sections 2.5 and 2.6, it is found that the test- and calculation methods used in the Regulation are adequate, but that ***the assumptions on the system temperatures on the sink side*** (the emitter system) and related value for the seasonal space heating efficiency in existing dwellings are ***too optimistic***. The actual real-life seasonal ***average supply temperature*** is the ***crucial*** parameter for achieving the projected seasonal space heating efficiency, and is determined by both the heat load/emitter capacity (HL/EC) ratio and the pump- and temperature controls on the sink-side. These parameters can constitute the difference between a seasonal heat pump efficiency of 85% or 174%. Following the findings for existing dwellings, the average supply temperature over the heating season is at least 5K too low (on average over the heating season it should be 43 °C instead of 38 °C), resulting in an average SCOP that is at least 15% too optimistic when based on the current Medium temperature test (55 ºC design supply temperature).

In other words, for a realistic rating the existing buildings the heat pumps should be rated according to the High Temperature (rated T_{supply} 65 °C, ΔT=10K) regime. The same line of reasoning goes for the ground source heat pumps, with the difference that all SCOP values are higher due to different source temperatures (water is 10 ºC and brine is 0 ºC constant[40]).

Part load

According to Task 2 the average heat pump capacity at rated conditions is around 10 kW. This is in line with the average heat load of existing buildings and thus there is no systematic oversizing of heat pump capacity. For new housing the heat load is 5 kW or less. This means that no correction for oversizing is proposed.

[40] See section 3.2 'Brine inlet temperatures' for a discussion of brine temperatures varying per climate zone.

Test conditions

For all the above reasons it is proposed to define new test points for the heat pump at a high temperature, as defined in the new EN 14825 standard. This will set a yard stick for boilers as well so that efficiency of heat pump and boiler can be calculated consistently also for hybrid units.

Note that in the column for exhaust air heat pumps the wet bulb temperature is changed to 15 ºC, instead of the current 12 ºC, to reflect the increased moisture content of ventilation air, following discussions in CEN/TC113 as shown in Task 1, section 5.3.5, second bullet. The dry bulb temperature remains at 20 ºC.

Table 11. Heat pump – Test conditions for Low temperature (35 ºC) applications (source: EN 14825:2018)

Test Condition	**Part Load Ratio** in %			**Outdoor heat exchanger**				**Indoor heat exchanger**			
				Inlet dry (wet) bulb or liquid temperature °C				Fixed outlet °C	Variable outlet**** return/supply temperature °C		
	A	**W**	**C**	**Outdoor air**	**Exhaust air**	**Water* ******	**Brine *******	**All climates**	**A**	**W**	**C**
A	88	n/a	61	−7(−8)	20(15)	10/*	0/*	30/35	29/34	n/a	25/30
B	54	100	37	2(1)	20(15)	10/*	0/*	30/35	25/30	30/35	22/27
C	35	64	24	7(6)	20(15)	10/*	0/*	30/35	22/27	26/31	20/25
D	15	29	11	12(11)	20(15)	10/*	0/*	30/35	19/24	21/26	19/24
E	(TOL - 16) / ($T_{designh}$ - 16)			TOL	20(15)	10/*	0/*	30/35	**	**	**
F	(T_{biv} - 16) / ($T_{designh}$ - 16)			T_{biv}	20(15)	10/*	0/*	30/35	***	***	***
G	n/a	n/a	82	−15	20(15)	10/*	0/*	30/35	n/a	n/a	27/32

The **flow rate** at test condition is determined by part load ratio and supply/return temperatures given.

A/W/C = Average/Warmer/Colder climate

TOL = Temperature operating limit; at bin-temperatures lower than TOL, the load is calculated with electric COP=1 or at efficiency of a back-up heat generator that is part of the package placed on the market

Tbiv = Bivalent temperature, i.e. at bin-temperatures lower than Tbiv, the heat pump cannot deliver the full load of the bin and the remaining load is calculated with electric COP=1 or at efficiency of a back-up heat generator that is part of the package placed on the market

***** = With flow rate as determined at standard rating conditions for a fixed flow rate or a fixed delta T of 3K for a variable flow rate. If for any of the test conditions the resulting flow rate is below the minimum flow rate the latter is used as a fixed flow rate with the inlet temperature for this condition.

****** = for outdoor and exhaust air source the variable outlet supply temperature shall be calculated from interpolation of the supply temperatures between heating design temperature (Tdesignh, is -10, 2, -22 °C for A/W/C) and supply/return temperatures at test condition higher than and closest to TOL. For fixed outlet of air source heat pumps as well as fixed and variable outlets of water- or brine source heat pumps the supply temperature is 35. The return temperature is always 5K less than the supply temperature here.

******* = calculated from interpolation of supply/return temperatures at test conditions higher and lower than and closest to T_{biv}

******** = If the variable outlet temperature is below the minimum of the operation range of the unit, this minimum should be considered.

********* = For climate dependent brine temperatures, see section 3.2. Also covers direct exchange-to-water(brine) heat pumps (DX-to-water(brine)). DX bath temperature is 4 °C.

Table 12. Heat pump-to-water – Test conditions for High temperature (65 ºC) applications (from prEN 14825:2017[41])

Test Condition	Part Load Ratio in %			Outdoor heat exchanger				Indoor heat exchanger return/supply temperatures			
				Inlet dry (wet) bulb or liquid temperature °C				Fixed outlet °C	Variable outlet**** °C		
	A	**W**	**C**	**Outdoor air**	**Exhaust air**	**Water* ******	**Brine *******	**All climates**	**A**	**W**	**C**
A	88	n/a	61	−7(−8)	20(15)	10/7	0/−3	55/65	51/61	n/a	40/50
B	54	100	37	2(1)	20(15)	10/7	0/−3	55/65	39/49	55/65	31/41
C	35	64	24	7(6)	20(15)	10/7	0/−3	55/65	31/41	43/53	26/36
D	15	29	11	12(11)	20(15)	10/7	0/−3	55/65	22/32	29/39	20/30
E	$(TOL - 16) / (T_{designh} - 16)$			*TOL*	20(15)	10/7	0/−3	55/65	**	**	**
F	$(T_{biv} - 16) / (T_{designh} - 16)$			T_{biv}	20(15)	10/7	0/−3	55/65	***	***	***
G	n/a	n/a	82	−15	20(15)	10/7	0/−3	55/65	n/a	n/a	47/57

The **flow rate** at test condition is determined by part load ratio and supply/return temperatures given.

A/W/C = Average/Warmer/Colder climate

TOL = Temperature operating limit; at bin-temperatures lower than TOL, the load is calculated with electric COP=1 or at efficiency of a back-up heat generator that is part of the package placed on the market

Tbiv = Bivalent temperature, i.e. at bin-temperatures lower than T_{biv}, the heat pump cannot deliver the full load of the bin and the remaining load is calculated with electric COP=1 or at efficiency of a back-up heat generator that is part of the package placed on the market

***** = With flow rate as determined at standard rating conditions for a fixed flow rate (10/7 inlet/outlet for water and 0/-3 for brine) or a fixed delta T of 3K for a variable flow rate. If for any of the test conditions the resulting flow rate is below the minimum flow rate the latter is used as a fixed flow rate with the inlet temperature for this condition.

****** = for outdoor and exhaust air source the variable outlet supply temperature shall be calculated from interpolation of the supply temperatures between heating design temperature ($T_{designh}$, is -10, 2, -22 °C for A/W/C) and supply/return temperatures at test condition higher than and closest to TOL. For fixed outlet of air source heat pumps as well as fixed and variable outlets of water- or brine source heat pumps the supply temperature is 65. The return temperature is always 10K less than the supply temperature here. The part load TOL formula applies only to air-source heat pumps; for water- or brine source heat pumps is always 100%.

******* = calculated from interpolation of supply temperatures at test conditions higher and lower than and closest to T_{biv} . The return temperature is always 10K less than the supply temperature here.

******** = If the variable outlet temperature is below the minimum of the operation range of the unit, this minimum should be considered.

********* = For brine temperatures, see section 3.2. Also covers direct exchange-to-water(brine) heat pumps (DX-to-water(brine)). DX bath temperature is 4 °C.

The declared rated heat output power is determined at reference design conditions c.f. following Table 10 of the 813/2013 regulation.

The low temperature (Table 12) and high temperature (Table 13) conditions target respectively the new and existing buildings. In that context it is relevant that the EPBD targets new buildings and large renovations. For these applications the standard emitter

[41] Some parts of this table have been made more explicit than in the standard in order to improve understanding.

system is floor-heating and the standard heat pump should be a low-temperature (35 °C) system, so there is no problem there as the regime for LT heat pumps remains unchanged. The same goes for new or renovated commercial buildings. The main problem is the application of heat pumps in existing housing. With all due respect for the double-digit sales growth rate of heat pumps, it is not going fast enough to reach policy goals. And of course it would be ideal if everyone would adapt their building insulation and emitter systems to suit the heat pump, but the team expects market acceptance could even be higher if the heat pump is more adapted to existing buildings. Apart from that, there is a strange contradiction in the current regulation that requires, in design conditions, an 80 °C feed temperature for a gas/oil boiler and only a 55 °C feed temperature for a heat pump, whereas they should both serve the same market. The current proposal, both for heat pump and boiler is to use, in principle, the same temperature regime, i.e. with a top-feed temperature of 65 °C (61 °C for a variable speed heat pump), because they are made for the same application. Furthermore, 65 °C is the top feed temperature. Most heat pumps have a variable speed and can be just as efficient –or probably more efficient— at 45 °C feed temperature than a heat pump that can only just reach 45 °C feed temperature at full power. Indeed, the chances of needing an electric back-up heater are probably much higher with the 45 °C heat pump than with the 65 °C heat pump. The main difference between a 65 °C and today's 55 °C heat pump is –at the current low production volume— in the performance of the compressor circuit (higher COP of compressor, larger heat exchanger surfaces, more sophisticated controls) and thus in the price. With a level playing field, i.e. 65ºC as test condition for all, the industry should not find a negative impact (on the contrary). The consumer will find a problem-free solution even in a colder winter with LT radiator solutions without the need for floor-heating. And because of that, but also because a 65 °C heat pump is a more efficient heat pump, the consumer will recuperate the investment without any surprises.

Table 13. Reference design conditions for heat pump (combi) heaters (Reg. 813/2013, Table 10)

Reference design conditions for heat pump space heaters and heat pump combination heaters, temperatures in dry bulb air temperature (wet bulb air temperature indicated in brackets)

Climate condition	Reference design temperature	Bivalent temperature	Operation limit temperature
	Tdesignh	T_{biv}	*TOL*
Average	− 10 (− 11) °C	maximum + 2 °C	maximum − 7 °C
Colder	− 22 (− 23) °C	maximum − 7 °C	maximum − 15 °C
Warmer	+ 2 (+ 1) °C	maximum + 7 °C	maximum + 2 °C

Stakeholder comments

In the 2nd stakeholder meeting it was disputed that a high temperature regime (55/65 °C for fixed speed heat pump, lower for variable heat pumps) was actually helpful in promoting the heat pump for existing buildings, given the findings of the Fraunhofer study as discussed in Task 4 (see there).

In a common position paper EHI, EHPA, EPEE and Eurovent[42] expect that following the latest EPBD recast (Directive (EU)2018/844) the thermal insulation of buildings will be significantly improved and a zone/room thermostatic control is applied when replacing the heat generator. According to these stakeholders a move towards a high temperature regime will pre-empt the benefits from the new EPBD. High temperature heat pumps with 65 °C feed temperature can be found, but they are a niche market. In commercial applications many heat pumps are designed for 45 °C and cannot reach 65 °C without supplementary electric heaters, which are very inefficient.

Dynamic testing

Electric heat pumps are tested according the EN 14511 series and EN 14825 to arrive at a seasonal space heating energy efficiency. During the test the product must be in steady-state or transient conditions, and on/off cycling is not permitted (apart from defrosting). This is mainly done to ensure the tolerances of test variables remain within permitted range. The consequence is that compressor frequencies need to be fixed during test, and the unit is not operated using the controls for normal use.

Several stakeholders claim that the current harmonized test standard EN 14825:2016 for testing of heat pumps therefore:

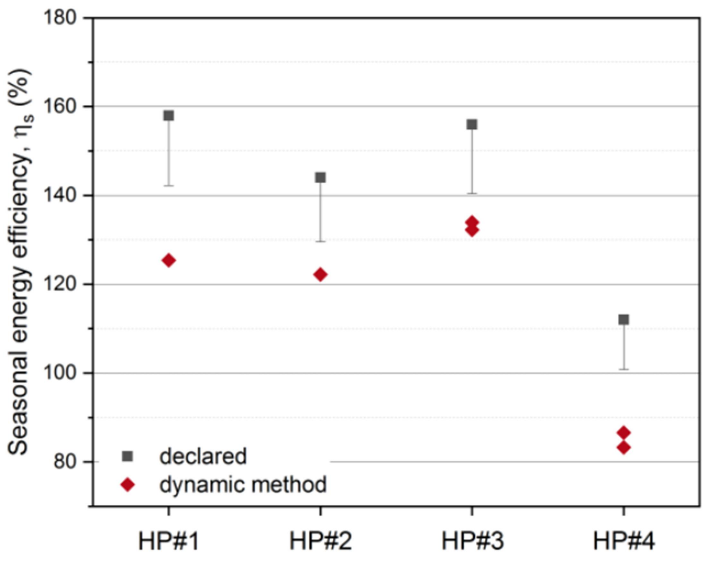
- does not reflect real life operation due to abnormal operation (fixed compressor speed);
- lacks comparability of different appliances, since individual control strategies are not considered (inactive control);
- does not allow for the independent compliance verification by market surveillance authorities (as manufacturers may have to be involved in preparing the product for testing).

Several stakeholders, notably the German, Danish, Swedish and consumer & environmental groups representatives, advocate a different test method (and calculations) for establishing the seasonal space heating efficiency of (electric) heat pumps, referred to as 'compensation method' (no fixed compressor frequencies) and/or 'dynamic method' (no fixed compressor frequencies and using an increased resolution, as inter- and extrapolation is shown to be problematic). UBA-BAM described the methods in more detail and provided initial test results[43] [44].

[42] See compilation of stakeholder comments on the study website.

[43] Anne Simo, Carsten Palkowski, André Wachau, Proposal for the revision of the harmonized test standard EN 14825:2016, for the testing and rating of air conditioners and heat pumps at part load conditions and calculation of seasonal performance, BAM and Umweltbundesamt, 13.12.2018.

[44] See also: https://www.mdpi.com/1996-1073/12/6/1045/htm



(source: BAM/BMWi, 2018)

Figure 11. Difference in seasonal energy efficiency between declared (with fixed speed) and dynamic test method. HP#1 and HP#2 are brine-to-water heat pumps, HP#3 and HP#4 are air-to-water heat pumps

UBA-BAM expects the 'dynamic test' to be less time consuming than EN 14825 and can therefore be cheaper as the setup is the same for both methods. Members of EHPA have a different experience and found the measurement to be very time consuming (thus cost-intensive) due to the difficult adjustment of the measured parameters within allowable deviations under steady state conditions. Also, they state it is yet uncertain whether the dynamic compensation test method makes it possible to fully avoid circumvention. Other technical issues like the reconditioning of the climate chambers are also mentioned.

Most experts agree that the proposal needs further development regarding the following aspects, among others (based on comments by Sweden):

- the stability of the test conditions, e.g. the inlet temperatures into the heat pump and the ambient conditions;
- the assessment of the costs related to the use of the dynamic test method;
- the comparisons with test results from the current version of EN 14825.

Manufacturers have added concerns regarding the scope of products that can be tested using these methods, especially if the scope is extended to 1 MW. They also point that experience needs to be gained and results need to become available so that efficiency requirements for the new methods can be compared to current requirements and methods. They mention that testing costs and repeatability/reproducibility need to be assessed and the development of the test method should be performed by standardisation organisations.

Maximum ventilation air available for exhaust air heat pumps

For exhaust air heat pumps the issue of setting maximum ventilation rates is important to avoid over-ventilation just for the sake of heat recovery from the exhaust air, which is clearly an inefficient practice. For water heating (incl. combination heaters) there is a maximum to available air flow to avoid inefficient practice, but for space heating and/or a mix of space- and water heating (multifunctional appliances) there isn't. Furthermore, the current maximum ventilation rates are considered already very generous by certain stakeholders.

The subject is currently (July 2019) investigated in the preparatory Ecodesign study on ventilation units, which looks at optimal ventilation practice for air quality. In that study, the stakeholders also expressed an opinion on whether ventilation products where the waste air is re-used should be in the scope of the ventilation unit regulation or in the scope of the regulated product that uses the waste air. The current consensus seems to be that heat recovery in balanced (bi-directional) ventilation units should be part of the ventilation unit regulation, whereas recovery of heat from uni-directional ventilation units should be part of the scope of the product re-using the heat from the waste air (the present situation).

The study team proposes to set up a special consultation initiative with the stakeholders to further discuss and investigate the issue..

Brine inlet temperatures

Brine temperatures can be set according the proposed climate dependent brine temperatures as discussed in TC113 WGs. For direct-exchange (DX) type evaporators the bath temperature is set at 4 ºC.

Table 14. Suggested brine temperatures for three climate conditions

Climate Zone	Average brine temperature	Proposed brine inlet temperature (rounded and/or harmonised with current conditions)
Average	6.19 ºC	5 ºC
Warmer	8.97 ºC	10 ºC
Colder	1.88 ºC	0 ºC (present standard rating condition)

ECOS-EEB does not support the increase in brine temperatures as they fear it leads to overestimation of (brine) heat pump efficiencies. Stakeholders like EGEC (European Geothermal Energy Council) welcome the possible introduction of climate dependent brine temperatures and refer to results of the GEOTRAINET project that concluded that average brine temperatures in warmer climates (Iberian peninsula, Italy, Greece, south of France, etc.) are comprised between 10 °C and 20 °C, in milder areas between 8 °C to 15 °C, and in Northern Europe at ground temperatures between 10 and 150 meters deep typically as low as 5 °C. Although these typical values lie above the proposed climate dependent brine inlet temperatures, experts from the shallow geothermal sector argue that:

1. Considering a conservative figure for a standard testing condition is legitimate as regards the technical dynamic of shallow geothermal systems where calories are extracted from the underground, therefore tending to cool it down;
2. From a consumer perspective, a conservative and robust figure for a standard temperature testing is a better guarantee that the testing conditions approach the real-world value of the system once in operation.

In addition, RISE (Swedish research institute) refers to results from the Fraunhofer study "WP Monitor" which show that the average mean brine temperature ((tsupply+treturn)/2)) was 4.2 °C (see Task 4, figure 15). Assuming the same temperature difference of 3K as in EN14825, the mean temperature of 4.2 °C would correspond to a supply temperature of 5.7 °C. RISE has performed complementary measurements at two different sites in Sweden, i.e. a Colder climate, and results show that the supply brine temperature was never lower than 0 °C.

Together with the survey that preceded the proposed climate dependent brine temperatures as performed in CEN/TC113/WG10, there appears to be sufficient evidence that the proposed temperatures are not overly optimistic.

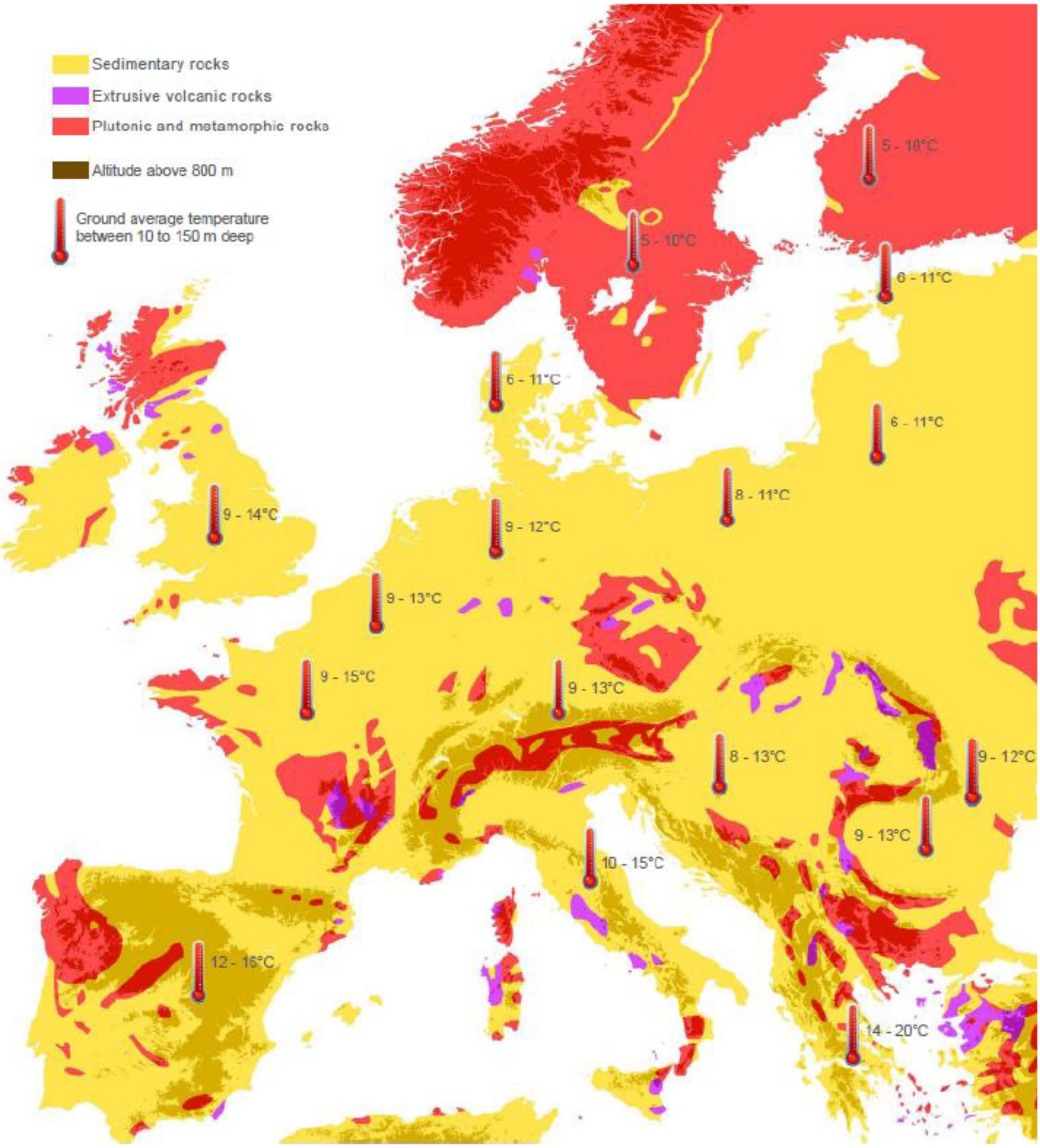


Figure 12. Ground temperature range for shallow geothermal systems in Europe (source: GEOTRAINET)

Mention SCOP (SPER) on the energy label

The current regulation shows the high dependence of the COP for heat pumps on the system temperature by presenting a *Low Temperature* (LT '35 °C') and a *Medium Temperature* (MT '55 °C') performance of the heat pump space heater. The former is based on 30/35 and the latter uses 47/55 °C at -10 °C bin temperature in Average climate. They have different label class ratings, with the LT classes being 25 percentage points higher.

As mentioned in Task 4, the 25 percentage point difference is more than justified (actually too low). But because of the correction of the labelling class limits, the energy label does not emphasize the large difference in energy saving between an LT and MT regime.

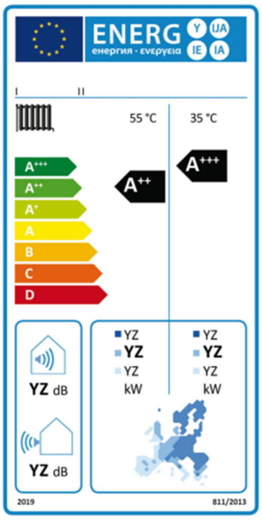


Figure 13. Current heat pump space heater label according to Energy Label delegated regulation 811/2013

For both heat pumps and fossil fuel fired boilers it is recommended to show the **seasonal efficiency or SCOP value on the energy label**. Especially given the corrected scale for heat pumps and the wide class-widths for fuel boilers, efficiency number will help installers and consumers to know how large the efficiency difference between the temperature regimes really is and how much they would be saving by e.g. changing emitters and/or system controls (TRVs, dynamic balancing, etc.).

Product setting

Another issue that is linked to 'test conditions' is which product setting applies. Heat pumps, including gas-electric hybrids, can be controlled in various manners, either optimising energy efficiency, reducing operating costs, minimising noise, enhancing comfort, etc. As the setting applied can have significant influence on the energy efficiency established it is necessary to define the product settings (as test conditions) to be used for testing.

Normally products are tested in "out-of-the-box" mode (no changes to product settings prior to testing). ECOS warns that "out-of-the-box' settings can still be misused in tests and notes that in the test for electronic displays the out-of-the-box setting for display luminance is prescribed (a minimum performance is required "out-of-the-box"). ANEC-BEUC have indicated that they test the energy efficiency of heating products while set in 'comfort mode', and product comfort in 'eco-modes' so that the efficiency or performance realised in real-life will not be less than tested.

Which condition should be used, and how it should be defined, is subject to discussion in the context of the proposed follow-up consultation round.

3.3 Boilers

System temperatures

In Task 4, section 2.4, it is found that the test- and calculation methods used in the Regulation are overrating the share of the time that the boiler is operating with return temperatures of 30 °C. The assumption on the seasonal average return temperature (34.5 °C) is too optimistic.

The actual *real-life* seasonal average return temperature is the crucial parameter for achieving the projected seasonal space heating efficiency, and is determined by both the emitter capacity and the pump- and temperature controls. These parameters constitute the difference between a seasonal efficiency of 85% or 97%.

Part load

The fact that most boilers are oversized with at least a factor 2.5 is not new and has also been discussed extensively in the 2007 Ecodesign preparatory study. But there has been no improvement and, whereas the heat pump is sized at 10 kW, the average boiler capacity for a house is 24 kW. The driver of the oversizing for space heating is the capacity required for instantaneous water heating by a combi boiler. But, as the capacity (kW) is perceived as a quality mark and the price difference between a small and big boiler is small, also the solo boilers and the storage combi boilers now typically have a 24 kW or more output.[45] Thus it is proposed to use the same test conditions as the heat pump but at a part load that is 10/24 of the nominal capacity. This is called an Osize factor in the table below.

[45] Note that there is some movement in the market: At the latest ISH 2019 trade fair many manufacturers introduced 15 kW boilers , there were many more new large storage combi boiler models (>100L) but also several manufacturers offering compact combi boilers (40-50L) with high stratification (44L with a 80L virtual capacity) and thus enough comfort for e.g. apartments.

Test conditions

The proposed test conditions for gas/oil boilers are given in the tables below.

Table 15. Fossil fuel fired boiler – Test conditions for Low temperature applications

Test Condition	**Part Load Ratio** in % of nominal capacity P1 (in kW on GCV @60/80 °C return/supply temperature)			**Indoor heat exchanger** return/supply temperatures			
				Fixed outlet °C	Variable outlet**** °C		
	A	**W**	**C**	**All climates**	**A**	**W**	**C**
A	Osize*88	n/a	Osize*61	30/35	29/34	n/a	25/30
B	Osize*54	Osize*100	Osize*37	30/35	25/30	30/35	22/27
C	Osize*35	Osize*64	Osize*24	30/35	22/27	26/31	20/25
D	Osize*15	Osize*29	Osize*11	30/35	19/24	21/26	19/24
G	n/a	n/a	Osize*82	30/35	n/a	n/a	27/32

Osize is Oversize factor where Osize=1 for boilers with P1≤10 kW or Osize=1/2.4 for boilers with P1>24 kW or Osize=1/[1+(P1−10)/14] for boilers with 10 kW>P1≤24 kW
Values for Average climate shall be determined by tests. Values for Warm and Cold climate may be determined by calculation.

Table 16. Fossil fuel fired boiler – Test conditions for High temperature applications

Test Condition	**Part Load Ratio** in % of nominal capacity P1 (in kW on GCV @60/80 °C return/supply temperature)			**Indoor heat exchanger** return/supply temperatures			
				Fixed outlet °C	Variable outlet**** °C		
	A	**W**	**C**	**All climates**	**A**	**W**	**C**
A	Osize*88	n/a	Osize*61	55/65	51/61	n/a	40/50
B	Osize*54	Osize*100	Osize*37	55/65	39/49	55/65	31/41
C	Osize*35	Osize*64	Osize*24	55/65	31/41	43/53	26/36
D	Osize*15	Osize*29	Osize*11	55/65	22/32	29/39	20/30
G	n/a	n/a	Osize*82	55/65	n/a	n/a	47/57

Osize is Oversize factor where Osize=1 for boilers with P1≤10 kW or Osize=1/2.4 for boilers with P1>24 kW or Osize=10/P1 for 10 kW<P1≤24 kW for boilers with 10 kW>P1≤24 kW [46]
Values for Average climate shall be determined by tests. Values for Warm and Cold climate may be determined by calculation.

Product setting or test configuration

Similar to heat pumps, fuel boilers may require a certain setting to be applied or configuration to be established. The ANTICCS project[47] presents the example of a

[46] Correction courtesy Edward Harris, pers. comm. May 2019.

[47] https://www.anti-circumvention.eu/about-project/project-introduction

condensing boiler which comes with a bypass to raise return temperatures so that condensation does not occur (and the end-user does not have to make provisions for the discharge of condensate). The regulations should be unambiguous as regards the configuration to be used for conformity assessment or verification of performance and how this is reflected in installation manuals or in optional configurations.

For the water heating efficiency of combination boilers, it is advised the regulation specifies the setting (often labelled 'eco' and 'comfort' whereby the latter periodically heats up the heat exchanger of instantaneous combis) used for testing. ANEC-BEUC has already indicated that in their tests for energy efficiency the 'comfort' setting is used and for water heating performance the 'eco' setting, so that the real-life results are usually not worse than expected from their tests.

3.4 Cogeneration heaters

In the Ecodesign boiler regulation 2013/813, Annex III, point 3, it is mentioned that the mCHP-efficiency is *"the seasonal space heating energy efficiency in active mode… corrected by adding the electrical efficiency multiplied by a conversion coefficient CC of 2,5)"*.

> 3. Seasonal space heating energy efficiency of boiler space heaters, boiler combination heaters and cogeneration space heaters
>
> The seasonal space heating energy efficiency η_s shall be calculated as the seasonal space heating energy efficiency in active mode η_{son}, corrected by contributions accounting for temperature controls, auxiliary electricity consumption, standby heat loss, ignition burner power consumption (if applicable) and, for cogeneration space heaters, corrected by adding the electrical efficiency multiplied by a conversion coefficient CC of 2,5.

So, for instance, taking the example of the fuel cell (RRT2) in Working Package 4, mentioned in Table 2. This fuel cell has a thermal efficiency of 55% and an electrical efficiency of 36%. Disregarding the relatively minor corrections for temperature control, etc., the seasonal space heating efficiency thus becomes $55\%+2.5*36\%=\mathbf{145\%}$ according the approach in the 2014 Transitional Method.

The 2018 recast of the Energy Efficiency Directive confirms that the method in Annex II of the 2012 EED (Directive 2012/27/EU) ought to be used for calculation of CHP savings.[48] This method uses the CHPs measured useful space heating efficiency $\boldsymbol{CHPH\eta}$ and electric efficiency $\boldsymbol{CHPE\eta}$ and compares them with respectively a reference separate space heating efficiency ($\boldsymbol{RefH\eta}$, 92% in this case[49]) and separate electricity generation efficiency ($\boldsymbol{RefE\eta}$, 53% in this case) – see also Delegated Regulation 2015/2402 in Task 1 under Directive 2012/27. If the sum of the ratios is larger than 1 (100%) then the difference is called the primary energy saving $\boldsymbol{PES}$.

[48] Also see the pre-amble in paragraph 2.4. DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. OJ L315/1, 14.11.2012

[49] Determined in COMMISSION DELEGATED REGULATION (EU) 2015/2402 of 12 October 2015 reviewing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2012/27/EU of the European Parliament and of the Council and repealing THE EUROPEAN COMMISSION, Commission Implementing Decision 2011/877/EU. OJ L 333/54, 19.12.2015
Note that this regulation expresses useful boiler energy efficiency in NCV at 100% Prated. The reference values depend on the fuel used for the CHP, and the year of installation.

In formula: $\text{PES} = 1 - 1/(\text{CHPH}\eta/\text{RefH}\eta + \text{CHPH}\eta/\text{RefH}\eta)$

In the example: $\boldsymbol{PES} = 1\text{-}1/(55/92 + 36/53) \approx 1\text{-}1/(1.4) \approx 0.29$ (**29%**)

As discussed extensively in Task 1, the EN 40465:2015 mCHP standard follows a different calculation method whereby it arrives at an efficiency of **257%** (A+++) for the same CHP as the electric power output avoids the use of primary fuels by a reference power production system. This 'avoided fuel' is deducted from the fuel used by the CHP for producing power and heat, leaving the remaining fuel as energy input for that heat output.

Over the last two years there has been a change in the political agenda with the aim for a carbon-neutral society in 2050. That change may well alter the considerations for mCHP. The EN 40465 rating is not accepted by Commission Services for harmonisation, but the mCHP does deserve credits as a key tool for distributed (local) power generation, especially from hydrogen, also because fuel cells can also be used the other way around, i.e. to convert power to hydrogen.

According to experts[50] the PEM[51] fuel cells and possibly Solid Oxide cells[52] might be the main technology to be used for hydrogen electrolysis in 2030, because they are more flexible than the currently more popular alkaline electrolysis process. Also in terms of investment, the 2030-costs for PEM cells is expected to drop to €1300-1400/kWel (average estimate, range €800-€2200/kWel) at a system lifetime of 60,000 to 90,000 hours. These values come closer to the alkaline process (around €1000/kWel, same lifetimes).

In terms of distributed hydrogen production also the solar hydrogen panels should be mentioned. They use solar electricity directly to convert water vapour in the air into hydrogen. Universities in –amongst others— Belgium (Leuven) are working on it, with Leuven testing prototypes that produce 250 litres of hydrogen per panel per day at a conversion efficiency over 15%. With 20 panels (m^2) a household could take care of its electricity need (including electric heat pump for space heating) also in winter (with a 4 m^3 storage tank) and with another 20 panels it could power a car all year around.

Still, in terms of converting hydrogen to power, the mCHP are unique. In that context one should not only think of single family appliances and not only of fuel cells. There are internal combustion engines on the market that reach electric efficiencies of up to 27%.

In that light, the study team makes a proposal that is simple and reflects the new political agenda:

Detach the efficiency calculation for mCHP from the primary energy factor, because with more renewables this will only have a negative impact on CHP-efficiency. Instead, introduce a constant e.g. based on the (performance corrected) Carnot efficiency of 2.5 to give credit to the electricity generation.

Take into account that with local electricity generation there are much less distribution losses. At the moment, the distribution losses in the public centralised electricity plants

[50] Schmidt, O., Future cost and performance of water electrolysis: An expert elicitation study international journal of hydrogen energy 42 (2017) 30470-30492

[51] proton exchange membrane

[52] solid oxide electrolysis cell

amount to 6.7%. With local CHP this will be less. Therefore, it is proposed to raise the credit for electricity **to a factor 2.65**.

In short, the extra measures to be taken could be:

- To use a fixed primary energy compensation (e.g. corrected Carnot factor 2.5 as mentioned in Task 1) instead of the ever diminishing pef.
- To give a 6% bonus for avoiding spending energy and material resources to build a power plant.

Supplementary heater

There is an accounting inconsistency with the cogeneration supplementary heater between the transitional method and the regulations. The Ecodesign regulation implies, as discussed above, that seasonal space heating energy efficiency –apart from the correction for electrical efficiency— should be handled the same as that of boiler space heaters and boiler combination heaters (Annex III, point 3). It asks for the same minimum seasonal space heating efficiency of 86% in Tier I (to become 100% in Tier II, Annex II, section 1). In the product information requirements (II, section 5) it asks for the thermal and electrical efficiency of a cogeneration heater with and without a supplementary heater if incorporated.

The 2014 transitional method defined the cogenerator seasonal space heating energy efficiency in active mode ηson, different from that of a boiler (not using part and full load), as

(c) for cogeneration space heaters not equipped with supplementary heaters:

$$\eta_{son} = \eta_{CHP100+Sup0}$$

(d) for cogeneration space heaters equipped with supplementary heaters:

$$\eta_{son} = 0{,}85 \times \eta_{CHP100+Sup0} + 0{,}15 \times \eta_{CHP100+Sup100}$$

Given the typical electrical and thermal capacities of a cogeneration unit this is a very debatable definition. The thermal capacity of a single-dwelling mCHP is usually determined by its electrical capacity which is usually a base-load of 1 kWe. For a typical internal combustion engine (20-28% electric efficiency) this means a thermal output of 3-4 kWth. In an external (e.g. Stirling) engine with 15% electric efficiency this means a thermal output of 5-6 kWth. And in a fuel cell (35-60% electric efficiency) the thermal output is around 1 (±0.2) kWth.

In the latter case the seasonal space heating energy efficiency in active mode ηson of a unit comprising a supplementary heater is weighted for 85% using the efficiency of 1 kWth mCHP heater and 15% of weight for the much larger supplementary space heater. This does not make much sense and —given such low thermal outputs— the contribution of the CHP to meeting space heating demands is likely much less than 85%.

In case of a Stirling engine, the output of 5-6 kW will also not be enough for the space heating design load (maximum load) of an average existing dwelling. In that case, a 5-10 kW supplementary boiler heater would be plausible and the proportion may well be the 85/15 that is in the definition if that supplementary heater would be integrated. And it makes sense that the back-up boiler efficiency is determined at its maximum capacity and thus at the least favourable efficiency $\eta 4$. But if there is also a water heating function then the supplementary heater may easily be 25-30 kW and then –as a back-up space heater—it will work at 30% (or much less) of its capacity and thus achieve a higher rated efficiency $\eta 1$ (if indeed lower heating system temperatures can apply). Overall, one may wonder why the efficiency of a fuel boiler is rated at $0.85\ \eta 1+0.15\eta 4$ while the efficiency of a supplementary fuel boiler heater for a cogeneration heater is calculated only at $\eta 4$.

The boiler Energy Labelling regulation introduces a different way of calculating the supplementary heater of a cogeneration space heater (definition in Annex I, def. (13)):

— for cogeneration space heaters not equipped with supplementary heaters, the useful efficiency at rated heat output, expressed in %;

— for cogeneration space heaters equipped with supplementary heaters, a weighted average of the useful efficiency at rated heat output with supplementary heater disabled, and the useful efficiency at rated heat output with supplementary heater enabled, expressed in %;

The definition of a 'weighted average' indicates a choice, but the 2014 transitional method is to be used for both Ecodesign and Energy Label and thus the 85/15 ratio applies. But in Annex IV of 811/2013 there is a methodology for calculation of efficiency of packages.

More importantly, this package method finds the relative share, characterised by parameter 'II' in Figure 2 of the Label regulation, from Table 6 of that regulation. The size of the relative share is determined by the relative ratio of the rated capacity of the cogeneration space heater (in kW) $Prated/(Prated + Psup)$.

'Rated heat output' ($Prated$) means the declared heat output of a heater when providing space heating and, if applicable, water heating at standard rating conditions, expressed in kW (cit. Article 2, (6)). Also, $Psup$ is a declared capacity but then for the supplementary heater (Annex I, def. 6). $Prated$ relates to the 'preferential heater', in this case the cogeneration space heater in Figure 2.

For instance, if the $Prated$ of the mCHP is 10% of the total, then –according to Table 6— the supplementary heater ($Psup$) contributes 70% (without buffer) or 63% (with buffer) to the space heating efficiency of the package (if there is no solar contribution). But if $Prated$ is 50% or more of the total then the contribution of the supplementary heater is 5% or less.

The package approach is more flexible and better characterizes the real-life performance. It is thus proposed to abandon the fixed 85/15 ratio as calculation basis for 'single products' (even if comprising a supplementary heater) and use the package approach. But instead of Table 6 it is proposed to use the bin-method to determine the relative share of the heaters.

This will be further elaborated in the next chapter.

Energy Label

The current energy label for cogeneration space heaters gives very little information. It only shows the seasonal space heating energy class, the rated heating capacity in kW, sound power in dB and an icon with a lightning bolt to show that it also produces electricity. It does not show the electrical capacity (kWe), thermal efficiency and electrical efficiency. Also, there are no label designs for cogeneration combi heaters or packages with cogeneration heaters. It is proposed to correct this, i.e. show the efficiencies (or similar) and electric output, as well as give guidance on the energy label options for space heaters with cogenerators.

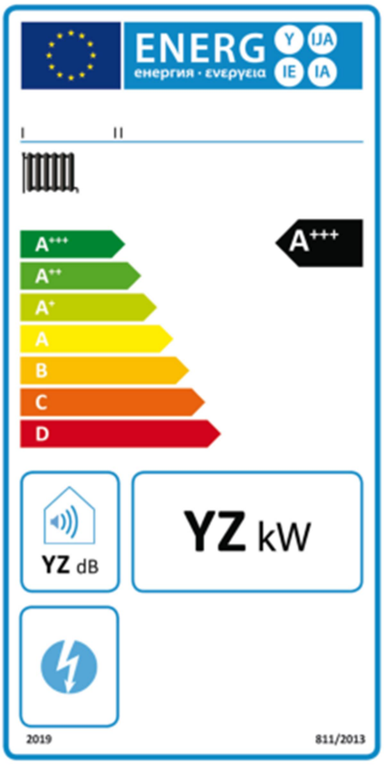


Figure 14. Current cogeneration space heater Energy Label (Regulation 811/2013)

Stakeholder comments

BDR Thermea, PACE and COGEN Europe all indicate preference for using the EN 50465 method for establishing seasonal space heating energy efficiency of cogeneration heaters. BDR Thermea does acknowledge that the higher correction value for electricity production proposed above is "a step in a good direction" as all these stakeholders favour a pef (as used in EN 50465) that is based on marginal electricity production and preferably also takes into account seasonal variations.

4 OPTIONS FOR PACKAGES

4.1 Introduction

Regulation 811/2013 on energy labelling introduces energy labels and calculation methods for packages of space or combination heaters, temperature control and solar devices. Possibly, as it is one of the questions in the review clause, it could also include passive flue heat recovery devices (PFHRDs).

Furthermore, mainly through the transitional method and referenced standards it sets test standards for the various components, apart from the single heating appliances discussed in the previous chapter, of such a packages.

This section describes the

1. General calculation method and first remarks on improvement;
2. Heat pump in the package;
3. Hybrids with heat pump and boiler;
4. Solar thermal;
5. Temperature controls;
6. PFHRDs;
7. Full revisit of the calculation method.

For each item there is a critical discussion of the current regulation, followed by a proposal for one or more options.

4.2 General calculation method

Approach of the review

The boiler Energy Label Regulation 811/2013, Annex IV, sections 5 and 6 prescribe the efficiency calculation for packages of space or combination heaters, temperature control and solar device.

Figures 1 to 4 of Annex IV show four calculation methods for space heating efficiency of packages. Figure 5 gives a method for calculating water heating efficiency of packages.

Starting point in Figures 1 to 4 is always the seasonal space heating efficiency (ηsH) of the preferential heater, defined as in the Ecodesign regulation[53], with symbol 'I'. Then there are supplementary heaters with their own space heating efficiency and relative or absolute share in the overall efficiency.

The most important question in the review study is whether the regulation, in this case the package calculation method, works as effectively and efficiently as intended. The answers differ per stakeholder:

- The method may have been acceptable for industry in the past, but current discussions on e.g. hybrids (heat pump & gas boiler) show this no longer to be the

[53] In regulation 811/2013 the seasonal space heating efficiency for heat pump space heaters, heat pump combination heaters and low-temperature heat pumps under average climate conditions is given in Annex VII, points 3 and 4

case. In general, stakeholders find the method ill-documented, non-transparent and for some aspects too simple and biased.

- The package label may have been perceived so that installers can make a package from components of different brands, but apart from perhaps one or two simple exceptions[54] this does not happen. So even the current highly simplified method is too difficult and/or too much administrative burden; installers prefer the package-options from a single manufacturer.
- The method is apparently not acceptable or at least not recognised by the EPB specialists of the Member States. Although probably based on the same principles, the calculation method is not transparent vis-à-vis the European (and national) standards that are used for EPB calculations of design load and calculations. The result is that –although it would have been a simple regulatory solution for a complex subject in many national EPB standards—there is no instance where the Energy Label methodology was (fully) used for that purpose, as far as the study team is aware.

Having said that, the package method is the very first of its kind, trying to derive a single efficiency number for a multitude of possible combinations of heat generators. In that sense it is an achievement that it has been voted positively as law, worked in practice (for manufacturer-suppliers) and allowed the changing of the market towards optimal, innovative solutions, and it is only logical that there is a serious potential for improvement after the first years of experience.

In this Task 6 report, two routes for improvements are proposed. The first option is an attempt to improve the current, simple method as much as possible, section by section. This will be discussed in this paragraph 4.2 and —for PFHRD as new element— paragraph 4.3.

The second option, discussed in paragraphs 4.4 and 4.5 is to split the package calculation in:

- a state-of-the-art energy balance method that is intended for industry-experts and is –as much as possible— in line with EPB-standards (par. 4.4);
- a basic method for an installer to give an energy label to an add-on solar thermal solution, also for an existing installation (par. 4.5).

The state-of-the-art energy balance method will require more work, but it can build on the work of the 2009-2010 technical expert working group, with experts from industry, NGOs and Commission[55], that already prepared a model that met with considerable consensus at the time. This model and its documentation are given on the project website as a background document to Task 6.

[54] E.g. adding a solar thermal panel and/or storage tank, from a different supplier than the boiler

[55] The group consisted amongst others of Messrs. Pittner (BTT), Backhaus (Vailant), Hormel (Viessmann), Gelderloos (Remeha), Antoine (Ariston), Kool (Intergas), Olesen (ECOS), Kemna (VHK), Kolb (COM).

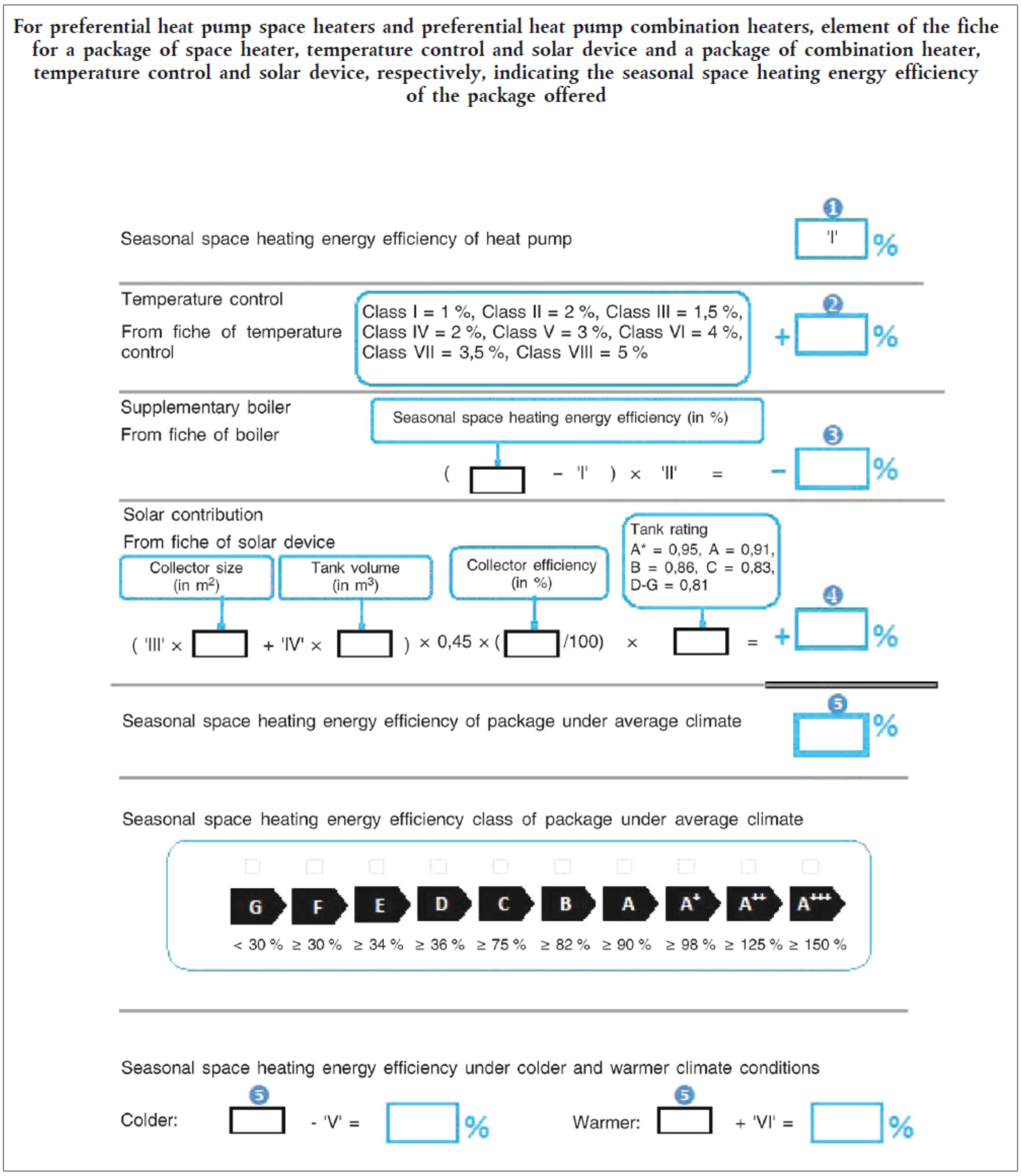


Figure 15. Calculation method for determining the seasonal space heating efficiency hybrid heat generators (Annex IV, Figure 3)

Improving the current method

The first question is why there is a need for the concept of 'preferential heater', leading to 4 methods? Is there not an obvious order for the deployment of the heat generators in terms of efficiency and thus only the need for one method?

In the current method, the choice of the preferential heater makes a considerable difference only in one specific case: in a hybrid with heat pump and fuel boiler there is the choice between

- Figure 1 with a preferential fuel boiler and a supplementary heat pump and;
- Figure 3 with a preferential heat pump and a supplementary boiler.

Two look-up tables appear to be instrumental in calculating the relative share of the heat generators, indicated by the parameter "II":

- Table 5 that takes *Psup* / (Psup + Prated) as an input and gives then the choice of two outputs, one without and one with the presence of a storage tank.
- Table 6 that takes Prated / (Psup + Prated) as an input and also gives two possible outputs depending on whether or not there is a storage tank present.

The graph below gives the input and output values and in fact shows that the output values in the Tables 5 and 6 are complementary, i.e. for the same input the Table 5 output is the Table 6 output minus 1.

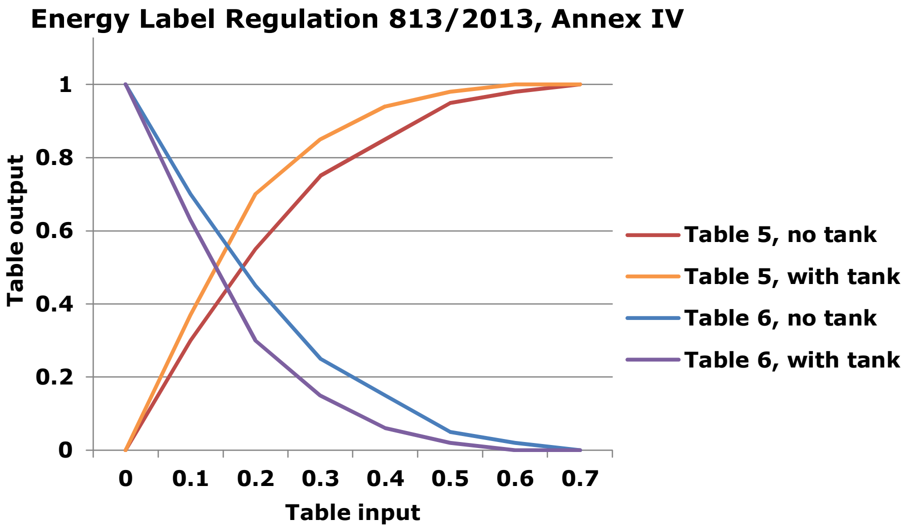


Figure 16. Graph of Table 5 and 6 in Regulation 813/2013

Also considering that the tables use a complementary ratio, they are in fact the same. Just one table, e.g. Table 6 with input *Prated / (Psup + Prated)*, would have been enough.

Heat pump in the package

Apparently, the main reason for making the distinction between preferential heat pump and a supplementary heat pump in a package is that their rated capacities, respectively the heat pump's *Prated* and *Psup*, are defined differently. For *Prated* there are strict rules: It should be based on an outdoor temperature of *Tdesign* = -10 °C, *Treturn*/*Tsupply* of currently 47/55 °C, the Temperature Operating Limit (*TOL*) should be ≤-7 °C, the bivalent temperature *Tbiv* should be ≤+2 °C. If *Tdesign* cannot be reached a real or virtual back-up heater should be taken into account, etc..

In contrast, for *Psup* of a heat pump, the regulation makes its own definition

(5) 'supplementary heater' means a non-preferential heater that generates heat in cases where the heat demand is greater than the rated heat output of the preferential heater;

(6) 'rated heat output of supplementary heater' (*Psup*) means the declared heat output of the supplementary heater when providing space heating and, if applicable, water heating at standard rating conditions, expressed in kW; if the supplementary heater is a heat pump space heater or heat pump combination heater, the standard rating condition for establishing the rated heat output of supplementary heater is the outdoor temperature *Tj* = + 7 °C;

The only rule is that $Psup$ should be determined at a bin-temperature Tj =+7 °C. The fact that "Tj" is mentioned probably refers to the bin-method and thus a part load ratio of 35% and thus probably test conditions C with 30/35 °C $Treturn/Tsupply$. Other than that, the definition does not imply rules for a maximum $Tbiv$ or TOL or the possibility of having a back-up. Probably the intention is to have an add-on small heat pump that stays clear of any danger of frosting/defrosting and that works e.g. at outdoor temperature of say +4 °C till +16 °C.

It is a valid solution, but it seems not realistic to give the efficiency of such a heat pump the same weight as a heat pump, here called 'preferential', that covers the whole load till Tj =−7 °C.

Instead, in line with some proposals in standardisation working groups (TC 113 and TC109), it is more coherent to follow the bin method to determine the relative contribution of the supplementary heat pump to the heat load, based on the test COP data as far as they are available. For instance, if the $TOL = Tbiv$ is indeed ≥3 °C then there should be COP- and capacity data at +12 °C (Test condition D), +7 °C (Test condition C) and $TOL = Tbiv$ (at least for capacity). From these data, using the bin method, the manufacturer can already calculate the percentage contribution that this heat pump can deliver to a bin-profile in Average, Warmer and Colder climate and at what average "partSCOP". The partSCOP is a term conceived here to distinguish in a hybrid between the seasonal efficiency of the heat demand ('load') provided by the electric heat pump part and the seasonal efficiency of the heat demand provided by the back-up boiler part.

The equation becomes

$$\eta\text{s H package} = 1/[\text{HPshare/partSCOP} - (1\text{-HPshare})/\eta\text{s H boiler}]$$

The boundary condition is that, in order for this equation to work, the capacity of the heat pump at a known test point should determine the overall rated capacity of the package at design conditions. The heat pump parameters are climate specific.

The calculations that the manufacturer of the heat pump has to make are:[56]

Total bin-load for Average climate: $L_A = \sum_{j=46}^{46-2} \text{PLR}_j \times \text{h}_j$

Share of the Average Climate load for the heat pump:

$$HPshare_A = \frac{1}{L_A} \cdot \left\{ \sum_{j=46}^{46-15+Tbiv} \text{PLR}_j \cdot \text{h}_j + \sum_{j=46-16+Tbiv}^{46-15+TOL} 0.5 \cdot \text{PLR}_j \cdot \text{h}_j \right\}$$

SCOP for the part of the Average Climate load covered by the heat pump:

[56] note that bin number 46 has T_j of 15°C. Also note that the equations would look simpler if the bin number j was equal to the outdoor temperature Tj.

$$SCOP_A = \frac{1}{HPshare_A \cdot L_A} \cdot \left\{ \sum_{j=46}^{46-15+Tbi} \mathrm{COP}_j \cdot \mathrm{PLR}_j \cdot \mathrm{h}_j + \sum_{j=46-16+Tbiv}^{46-15+TOL} 0.5 \cdot \mathrm{COP}_j \cdot \mathrm{PLR}_j \cdot \mathrm{h}_j \right\}$$

The look-up table below is perhaps easier. Columns A/B/C are bin values copied from the regulation. The part-load is also calculated as prescribed in the regulation with Tdesignh = -10 °C for the Average climate. Column E is necessary to make the conversion to columns F and G. For instance, for a heat pump with Tbiv = 6 °C the part-load up to and including Tbiv is 29.31%. If TOL = 4 °C, then for the section from >Tbiv to TOL the part loads in column F have to be summed, here 6.21% and 7.95%, and divided by 2 . This gives 7.08% that needs to be added to the previous 29.31% and results in a total of 36.39% that this heat pump can contribute to the total design load in an Average Climate.

Table 17. Part Load Ratio (PLR) look-up table for Average Climate with bin-method

A	B	C	D	E	F	G	H
bin j	*tempe-rature Tj*	*hours hj*	*Plj=* (16-*Tj*)/ (16-*Tdesignh*)	*Plj * hj* absolute	*Plj * hj* relative (%)	*Plj * hj* accumu-lative (%)	*COPj* (at Tbiv=-10 °C)
1to20	-30 to -11	0					
21	-10	1	100%	1.00	0.05%	100.00%	1.33A-0.33B
22	-9	25	96%	24.04	1.16%	99.95%	1.22A-0.22B
23	-8	23	92%	21.23	1.03%	98.79%	1.11A-0.11B
24	**-7**	24	88%	21.23	1.03%	97.76%	**A**
25	-6	27	85%	22.85	1.11%	96.73%	0.11B+0.89A
26	-5	68	81%	54.92	2.66%	95.63%	0.22B+0.78A
27	-4	91	77%	70.00	3.39%	92.97%	0.33B+0.67A
28	-3	89	73%	65.04	3.15%	89.58%	0.44B+0.56A
29	-2	165	69%	114.23	5.53%	86.43%	0.56B+0.44A
30	-1	173	65%	113.12	5.48%	80.90%	0.67B+0.33A
31	0	240	62%	147.69	7.15%	75.42%	0.78B+0.22A
32	1	280	58%	161.54	7.82%	68.27%	0.89B+0.11A
33	**2**	320	54%	172.31	8.34%	60.45%	**B**
34	3	357	50%	178.50	8.64%	52.11%	0.2C+0.8B
35	4	356	46%	164.31	7.95%	43.47%	0.4C+0.6B
36	5	303	42%	128.19	6.21%	35.52%	0.6C+0.4B
37	6	330	38%	126.92	6.14%	29.31%	0.8C+0.2B
38	**7**	326	35%	112.85	5.46%	23.17%	**C**
39	8	348	31%	107.08	5.18%	17.70%	0.2D+0.8C
40	9	335	27%	90.19	4.37%	12.52%	0.4D+0.6C
41	10	315	23%	72.69	3.52%	8.15%	0.6D+0.4C
42	11	215	19%	41.35	2.00%	4.63%	0.8D+0.2C
43	**12**	169	15%	26.00	1.26%	2.63%	**D**
44	13	151	12%	17.42	0.84%	1.37%	1.2D-0.2C
45	14	105	8%	8.08	0.39%	0.53%	1.4D-0.4C
46	15	74	4%	2.85	0.14%	0.14%	1.6D-0.6C
Total:		**4910**	**62%**	**2 065.62**	**100%**		

The look-up table for the $partSCOP$ is based on the average COP per bin over the relevant range, weighted for the part load values per bin in column F above and taking into account the range above Tbiv (multiplier 1) and the range between Tbiv and TOL. The COP-values per bin will be derived, as it is done today, from interpolating and extrapolating the measured COP-values at the 4 standard test conditions A/B/C/D at -7/2/7/12 °C for the Average climate. For the Warmer and Colder climate (the latter with an extra test point G at −15 °C) the values and calculations are different. The *COPj* values are illustrative for the interpolation and extrapolation for a heat pump in an average climate that can cover the full range till *Tj* = *Tbiv* = -10 °C. If *Tbiv* and/or *TOL*<-10 °C then the *COP(TOL)* and *COP(Tbiv)* are used for the interpolation/extrapolation below the lowest achievable standard test condition.

The return/supply temperatures at these test conditions will be as defined in the previous chapter for a low temperature or a standard heat pump. Where cycling applies — with fixed capacity units— it will be dealt with as today, i.e. with degradation coefficient *Cd*.

For water/brine heat pumps the method will be similar but simpler because there is only one source temperature.[57]

In the example, the rounded value $HPshare_A$ = 36%, and values for Warmer and Colder climate, needs to be given in the product fiche for the heat pump, as well as the capacity P_C (in kW) at test condition C (*Tj* = +7 °C). The latter implies that:

1. any heat pump should have a Tbiv ≤ +7 °C, and;
2. for the total rated capacity of the package at design conditions (*Tj* =−10 °C) the condition is *Prated* ≤ P_C / 0.35\.

At $HPshare_A$ ≈36% a COP_{36}=0.6C+0.4B applies in the table. Assuming C=4 (COP at+7 °C) and B=3 (COP at +2 °C) the average COP of the heat pump will be 3.6.

Hybrid with a back-up boiler

If an electric resistance boiler is the back-up —or also for a stand-alone application of such a heater— its primary energy efficiency is a constant 47.6% (new CC value). The part load per bin for a back-up heater, i.e. fuel boiler or electric resistance heater, is the remainder after the heat pump contribution. This means[58]

$$\eta_{s\,H\,\text{package}}=1/[\text{HPshare}/\text{partSCOP} + (1-\text{HPshare})/\eta_{s\,H\,\text{backup}}]$$

In the example

$$\eta_{s\,H\,\text{package}} = 1/[0.36/3.6 + (1-0.36)/\,0.476]=1/[0.1+1.34]=69\%$$

For a fuel boiler, as proposed in the previous chapter, the test conditions A/B/C/D would also apply and thus the average efficiency can be calculated in the same way as for the heat pump, weighted for the relative part load per bin. Because of the oversize factor

[57] Although some standardisation working groups suggest to at least differentiate brine temperatures per climate, i.e. -5 (Colder), 0 (Average) and +5 °C (Warmer).

[58] As pointed out by BDR Thermea subtractions/additions of efficiency numbers, including COP, should be implemented with their inverted values, i.e. de specific energy consumption SEC.

introduced for boilers in the previous chapter, the supply and return temperatures for the boiler should now be more in line with those of the heat pump and thus give a realistic outcome.

Possibly the calculation or look-up table can be simplified because there are no restrictions like *TOL* and *Tbiv.* This means the interpolation and extrapolation in column H of the previous table always applies for an Average climate. Thus, if the boiler efficiency at test conditions A/B/C/D is known, the (part load weighted) boiler efficiency at any bin-temperature $\eta(Tj)$ can be found. The average seasonal space heating fuel boiler-efficiency η_{sHrest} at a given *Tbiv* and *TOL* of the heat pump is then:

$$\eta_{rest} = \sum_{j=Tbi}^{Tdesignh} \eta(T_j) - 0.5 \left\{ \sum_{j=Tbi}^{Tdesignh} \eta(T_j) - \sum_{j=TOL}^{Tdesignh} \eta(T_j) \right\}$$

$$\eta_{sHrest} = \eta_{rest}(T_{biv}) - 0.5 \cdot [\eta_{rest}(T_{biv}) - \eta_{rest}(T_{OL})]$$

An example of a look-up table (only columns B and J needed) is given below for the situation where the boiler efficiency at conditions A/B/C/D is 86/88/90/92%.

Table 18. Example of Part Load boiler efficiency (eta) look-up table for Average Climate and efficiencies 86/88/90/92% for test-points A/B/C/D

A	B	C	F	G	H	I	J
bin j	*temperature Tj*	*hours hj*	*PLRj * hj* relative (%)	*PLRj * hj* accumulative (%)	*η(Tj) calc*	*η(Tj) result*	*η rest (Tj)* (average *Tdesignh* to *Tbiv*)
1to20	-30 to -11	0					
21	-10	1	0.05%	100.00%	1.33A-0.33B	85.3%	85.3%
22	-9	25	1.16%	99.95%	1.22A-0.22B	85.6%	85.6%
23	-8	23	1.03%	98.79%	1.11A-0.11B	85.8%	85.7%
24	**-7**	24	1.03%	97.76%	**A=86%**	86.0%	85.8%
25	-6	27	1.11%	96.73%	0.11B+0.89A	86.2%	85.9%
26	-5	68	2.66%	95.63%	0.22B+0.78A	86.4%	86.1%
27	-4	91	3.39%	92.97%	0.33B+0.67A	86.7%	86.3%
28	-3	89	3.15%	89.58%	0.44B+0.56A	86.9%	86.4%
29	-2	165	5.53%	86.43%	0.56B+0.44A	87.1%	86.6%
30	-1	173	5.48%	80.90%	0.67B+0.33A	87.3%	86.8%
31	0	240	7.15%	75.42%	0.78B+0.22A	87.6%	87.0%
32	1	280	7.82%	68.27%	0.89B+0.11A	87.8%	87.1%
33	**2**	320	8.34%	60.45%	**B=88%**	88.0%	87.3%
34	3	357	8.64%	52.11%	0.2C+0.8B	88.4%	87.4%
35	4	356	7.95%	43.47%	0.4C+0.6B	88.8%	87.6%
36	5	303	6.21%	35.52%	0.6C+0.4B	89.2%	87.8%
37	6	330	6.14%	29.31%	0.8C+0.2B	89.6%	87.9%
38	**7**	326	5.46%	23.17%	**C=90%**	90.0%	88.0%
39	8	348	5.18%	17.70%	0.2D+0.8C	90.4%	88.2%
40	9	335	4.37%	12.52%	0.4D+0.6C	90.8%	88.3%

41	10	315	3.52%	8.15%	0.6D+0.4C	91.2%	88.4%
42	11	215	2.00%	4.63%	0.8D+0.2C	91.6%	88.5%
43	**12**	169	1.26%	2.63%	**D=92%**	92.0%	88.5%
44	13	151	0.84%	1.37%	1.2D-0.2C	92.4%	88.6%
45	14	105	0.39%	0.53%	1.4D-0.4C	92.8%	88.6%
46	15	74	0.14%	0.14%	1.6D-0.6C	93.2%	88.6%
Total:		4910	**100%**				

In the example, where *Tbiv* is 6 °C the *ηj rest* is 87.9%. For TOL at 4 °C the *ηj rest* is 87.6%. Thus:

$$\eta_{sHboiler} = 87.9\% - 0.5(87.9\% - 87.6\%) = 87.75\%$$

and:

$$\eta_{s\,H\,\mathrm{package}} = 1/[\mathrm{HPshare/partSCOP} - (1\text{-}\mathrm{HPshare})/\ \eta_{s\,H\,\mathrm{boiler}}]$$
$$= 1/[0.36/\ \mathrm{partSCOP} - (1\text{-}0.36)/\ 0.8775]$$

Solar contribution

For the solar contribution to efficiency of a package the expression is

$$\text{Solar efficiency contribution (in \%)} = (\text{'III' x Asol} + \text{'IV' x Vsol}) \text{ x fsol x } (\eta\text{col}/100) \text{ x S}$$

Where

- 'III' is 294/(11 x Prated), where Prated (presumably in kW) relates to the preferential heater;
- Asol is solar collector surface in m²;
- 'IV' is 115/(11 x Prated), where Prated relates to the preferential heater;
- Vsol is the solar tank volume in m³;
- fsol is a factor that depends on the preferential heater (0.9 if fuel boiler, 0.7 if mCHP, 0.45 if heat pump);
- ηcol is the collector efficiency at a temperature difference between the solar
- collector and the surrounding air of 40 K and a global solar irradiance of 1 000 W/m²;
- S is tank (standby loss) Energy Label rating, with A^+=0.95; A=0.91; B=0.86; C=0.83; D-G=0.81.

At a preferential combi-boiler of Prated=11.6 kW (fsol=0.9), Vsol=Asol*0.05 m³, ηcol =0.55 [59] and a 'B' tank-rating (S=0.86) the solar contribution to the space heating efficiency is exactly 1% per kW Prated. The 11.6 kW value is fairly close to the design heat load for an average house in the Average climate (see Task 3). Task 2 mentioned an average collector surface for (also) space heating of 16 m², so this means a solar

[59] See Fig. 34 Task 1 report, typical value for glazed flat panel at 40K and 1000 W/m². For evacuated tube —at this high influx— the efficiency is worse (around 0.4)

contribution of 16%. At double Prated (23.2 kW) the solar contribution would be half (8%). The calculation is simple but plausible.

For the solar contribution to space heating efficiency there is no simple correction in the regulation for the climate. For the water heating efficiency the solar contribution is 40% more in a Warmer climate and 20% less in a Colder climate with respect of the Average climate. It would be plausible to also apply these corrections for the solar space heating efficiency contribution.

If the solar device is combined with a heat pump, they are both '*fishing in the same pond*' of the heat load at warmer outdoor temperatures and thus the positive impact on the efficiency is cut in half. In Figure 1 of regulation 811/2013 this is done by subtracting half of the solar or heat pump contribution, whichever is smallest, in a separate expression at the end. In Figure 3 and 4 this is done by using a factor fsol = 0.45 instead of fsol = 0.9 for the fuel boiler. In case of a combination of mCHP and solar is somewhere in the middle with a factor fsol = 0.7.

It should be mentioned that Solar Heat Europe, together with Solar Heating Initiative are developing a simple method for consideration of solar contribution to a product/package efficiency. This method is however not yet finalised – see section 4.5.

Cogeneration

Figure 2 of regulation 811/2013 gives the calculation method for the case where a cogeneration space heater is the preferential space heater in a package. In the previous chapter it was discussed that in principle the Figure 2 approach is preferable over the fixed 0.85/0.15 ratio between preferential and supplementary heater, also because the different types of cogeneration heaters have very different proportions between electric and thermal output.

The most remarkable feature of this Figure 2 and also the energy label for cogeneration heaters is the fact that there is no explicit role for the electricity production and efficiency of electricity production. Only the seasonal space heating energy efficiency is taken into account which should, according to the regulation, include the electrical efficiency added to the space heating efficiency (and other corrections).

It would be more transparent –in the fiche— to single out the electricity production and add it at the end of the calculation.

Temperature controls

Within the scope of this study, the role of temperature controls is underestimated and should have more impact e.g. in the factor F(1).

In the current regulation there is a general malus of 3% in the seasonal efficiency calculation of space heaters and a specific bonus for packages of space heaters plus heating controls belonging to 8 categories of heating controls, ranging from 1 to 5%.

As mentioned in Task 4, the influence of the various heating controls is more important than that limited range.

Topics for discussion regarding the existing control-classes (Class I to VIII) are:

- Feed temperature controls have a larger effect on the operating efficiency than the currently assumed default of 3%, especially in combination with heat pumps.

- Flow rate control is not incorporated in the various control classes, although it has significant influence on the operating efficiency of the heat generator. At the moment the calculation model in the regulation obviously already assumes optimal hydraulic control, whereas for gas/oil boiler driven systems the flowrate and feed temperature control can make up 5-10% of performance. For heat pumps it is even more. The factor F(1) should reflect this, in order to give a realistic impression of the energy efficiency of space heating, even if those controls are not in the scope of the regulation. A new Ecodesign regulation can introduce a revised (enlarged) control malus. The bonuses can be introduced through revised labelling regulations or alternatively (insofar not included in space heating labelling regulations) in a building control Ecodesign regulation currently prepared, EPB-regulations, etc. but the Lot 1 regulation should leave room for that. Thus it is proposed to change F(1) to a default of -8%, following Task 4.
- Weather compensation controls (Classes II, III, VI, VII, values 2-4%) generally result in higher average system temperatures than room thermostat controlled systems (provided the reference room has correctly sized emitter capacity) and are thus less energy efficient. This may lead to a **small negative correction of -0.5% for the control classes with weather compensators**.

Manufacturers of building controls, represented by EUBac, believe that current 8 classes should be retained but with some changes in the wording:

- Class IV should be a generic load compensating control using proportional on/off control. This would include TPI controls that currently fall under class IV but not exclude other similar control devices that use different algorithms.
- Class VIII should be extended to include proportional on/off control as well as modulating the burner. Again, this would include products currently in Class VIII but not exclude other similar devices.
- Any classes that reference the boiler (e.g. "for use with on/off output heaters") should be changed to refer to the form of control (e.g. "weather compensating control, on/off"). This would be more appropriate as restricting the application should be done through technical guidance to the installer. This would then be better able to reflect Member State variations in application given that the classes cover a wide range of fossil fuelled boilers and heat pumps etc. Hybrid with a cogeneration heater.

4.3 PFHRD

The review articles of the current boilers regulations requires to investigate the appropriateness of including Passive Flue Heat Recovery Devices PFHRDs. Task 4, section 4.1 reports that the saving potential of storage-type Passive Flue Heat Recovery Devices PFHRDs is significant[60], i.e. around 25 – 30% of dhw-production of all condensing combination boilers. And also for flow-through PFHRDs the impact is not negligible (around 8-9%). It is therefore advised to consider the uptake of PFHRDs into the

[60] Passive Flue Heat Recovery Devices are *flue gas* to *domestic cold water* heat exchangers that are used together with combination boilers and have the purpose to further cool down the flue gas temperatures in order to facilitate condensation by using the cold water inlet and improve generator efficiency. PFHRDs can both be integrated in the boiler design and be added as a separate product, in which case the boiler manufacturer must confirm that the add-on PFHRD can be combined with the condensing boiler (PFHRD may influence the resistance on flue gas side and water side of the boiler).

Regulations for combination boilers. A test method (PrEN 13207) is already in place and —although proposed system temperatures and boiler loads are low with respect to the real-life operating modes— the standard could be used for assessing the improvements on the annual tapping efficiency. Reservations regarding the hygienic aspects of PFHRDs must be handled according to existing national legislation and guidelines concerning legionella prevention (storage tanks already have to comply). They may or may not lead to a reduction of the saving potential, as legionella prevention measures in some countries are not considered critical or depend on the storage volume (see Task 1).

Combination heaters with an integrated instantaneous PFHRD the Energy Label efficiency can include the measured energy efficiency improvement in annual water heating efficiency numbers for the Energy Label. This value does not take into account any potential benefits from transfer of heat from space heating operation to DHW. The Transitional Method explicitly forbids such an allocation, even if it can be quantified using (draft) EN 13203-7 and this should thus be changed to realise greater savings from this technology.

To promote the recovery of such (space heating) losses, it is proposed that manufacturers with an integrated storage PFHRD or where the addition of a storage PFHRD is offered as an option can use the increased water heating efficiency number measured with the appropriate tapping pattern and space heating operation according to prEN 13203-7 as one part, proportionate to the length of the heating season (e.g. 7/12 in the Average climate), together with the measured water heating efficiency without boiler operation, proportionate to the length of the non-heating season (e.g. 5/12 in the Average climate).

Task 4 expects a 30% increase in water heating efficiency, corresponding to savings of around 3 to 4 kWh for tapping pattern L (around 800 kWh per dwelling per annum). Task 2 reports on prices for PFHRDs and indicates the product could be economical at mass production.

4.4 Calculation method revisited

Introduction

The analysis of the heat generators in the previous section shows that improving every single problem is complex, because every type of heat generator has its own history in terms of definitions, test- and calculation methods. The 2013 boiler regulation clearly shows this legacy of treating every type of space heater on its own, very often inconsistently with the other types. If there were one single calculation method for all, single products and packages of all types, it would be much easier to be consistent and fair.

Also not helpful is the fact that the calculation method is treated in different places, i.e. the regulations, transitional method, guidelines and EN standards (harmonised or not), also each with a different legal status. This has led to much confusion and discussions that could have been avoided, at least now that there is a 5 year experience with the regulations, if the more robust details were to be incorporated in the legislation, i.e. the regulations.

The boiler regulations are laid out with a strict divide between a definitions annex at the beginning and a calculation methods annex almost at the end. This makes it very difficult to comprehend. But there are many examples of regulations where definitions/descriptions of calculated parameters and their inputs are put together and thus it is proposed to do the same, i.e. follow a classic technical lay-out of the calculation method.

Last but not least, many of the proposals for single heat generators that are discussed in the previous paragraphs could be substituted by and integrated in a single calculation method.

The history of the boiler regulations took 7 years of preparation, and shows that it is challenging to create such a method, both technically and politically. Yet, such a holistic approach has many benefits and thus it is proposed here.

The basis of the proposed method hereafter is the current regulation, modified on aspects discussed earlier.

There are two possibilities: A separate method and a combined method (different from prEN 14825), both using the bin-method as the basis and the test methods proposed in the relevant standards, modified as in Chapter 3.

Starting point for both methods is the declared capacity of the heat generator P_{rated} (kW)[61] . This can be readily translated in a part load in kW per bin (see Table A, row *plj* in %). The boundary condition is that the heat generator(s) should be able to meet the part load per bin and ultimately the bin where the bin-temperature *Tj* is *Tdesignh*.

$$P_h(j) \geq P_{chp} + P_{el} + \sum_{j=46}^{j=46-Tdesignh} P_{hp}(j) + P_{fuel}(j) + P_{fuelb}(j) \qquad [1]$$

where

- P_h = space heating capacity of space heat generator in bin *j* (kW);
- P_{chp} = space heating capacity of co-generator (kW);
- P_{hp} = space heating capacity of heat pump in bin *j* (kW);
- P_{fos} = space heating capacity of fossil fuel boiler in bin *j* (kW);
- P_{fosb} = space heating capacity of back-up fossil fuel boiler in bin *j* (kW);
- P_{el} = space heating capacity of electric resistance boiler (kW).

Note: All power output is determined at standard rating conditions, i.e. average climate conditions. P_{chp} only relates to rated thermal output (kW) at full load and relates only to the cogenerator; not the supplementary heat generator. Solar heat output does not contribute to peak demand. Fuel boiler comprises not only natural gas and oil but also (green) hydrogen and biogas.

[61] Following regulation 811/2013, Art 2, definition (6). Usually most critical at design conditions. At the moment, the method is only complete for the Average climate, i.e. with Tdesign at -10°C. Note that for the combi fossil fuel boiler the Osize factor shall be taken into account for *Prated* (tbd).

Table 19. Table A

j	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21
Tj (°C)	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**-1**	**-2**	**-3**	**-4**	**-5**	**-6**	**-7**	**-8**	**-9**	**-10**
plrj(%)	0.1	0.4	0.8	1.3	2.0	3.5	4.4	5.2	5.5	6.1	6.2	8	8.6	8.3	7.8	7.2	5.5	5.5	3.1	3.4	2.7	1.1	1.0	1.0	1.2	0
Plj (%)	4	8	12	15	19	23	27	31	35	38	42	46	50	54	58	62	65	69	73	77	81	85	88	92	96	100
hj (h)	74	105	151	169	215	315	335	348	326	330	303	356	357	320	280	240	173	165	89	91	68	27	24	23	25	1
qj (%)	0	1	1	3	5	8	13	18	23	29	36	43	52	60	68	75	81	86	90	93	96	97	98	99	99	100
Dj	0.2	0.7	1.8	3.0	4.6	6.7	8.5	**9.5**	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Cj	-0.1	-0.2	-0.4	-0.4	0.0	1.4	4.0	8.2	13.6	18.5	22.3	25.4	**27.2**	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2
Bj										1.2	3.7	8.5	15.4	23.7	30.7	36.2	39.9	43.0	44.4	45.5	46.1	46.2	46.2	46.1	45.9	**45.8**
Aj															0.9	2.4	4.2	6.7	8.4	10.7	12.8	13.8	14.8	15.9	17.4	**17.5**
COP(Tj)	=(Aj+Bj+Cj+Dj)/(Aj/COPA+Bj/COPB+Cj/COPC+Dj/COPD)																									
eta(Tj)	= (Aj+Bj+Cj+Dj) /(Aj/etaA+Bj/etaB+Cj/etaC+Dj/etaD)																									

Note: Rows plrj(part load ratio in bin j, in %), Plj (Part load accumulative up to and including bin j, in %) and hj (hours in operation in bin j) are shown to show the origin of the accumulative load qj (in % of total load) up to and including bin j, but they are strictly no longer necessary for the calculation and could be deleted in the legislation. Rows Dj, Cj, Bj, Aj (fraction of the load partitioned to the 12, 7, 2, −7 °C test result in bin j of the Average climate) are relevant in any case for the outside air heat pump and possibly –to be elaborated in a later stage—for fossil fuel boilers.

Combined method

In a combined method, the whole configuration is tested at test conditions A, B, C, D, using the controls of the configuration, as a 'black-box'. Subsequently, the space heating energy efficiency in active mode eta_{on} is calculated using the equation in the last row of Table A,

Where for

- *etaA, etaB, etaC, etaD* are the declared eta_{bin}-values for test conditions *A, B, C, D (Tj=−7/2/7/12 °C),*
- *Aj, Bj, Cj, Dj* are weighting factors for *eta(j)*-values using *eta(j)* at test conditions A, B, C, D (Table A for average climate);

There is no correction for cycling (assuming part loads C and D are realistically low) but it is proposed to perform testing long enough to include one or more on/off cycles as appropriate.

The next step is to include the impact of temperature controls, auxiliary electricity, standby heat loss as well as, where appropriate electricity production of cogeneration and contribution of the solar device.

$$eta_s = eta_{on} - 0.08 + cctrl + \eta_{sol} + E_{aux\_chp}/(P_{rated} \cdot hrsmax) \quad [2]$$

where

- eta_s = seasonal space heating efficiency
- *hrsmax*=equivalent hours at design load per year in h/a (2066 average, 1336 warmer, 2465 colder climate);
- *cctrl=* temperature control, with values according to control classes I to VIII with changes in the wording of the control classes as suggested earlier.

Class no.	I	II	III	IV	V	VI	VII	VIII
Value in %	1	1.5	1	2	3	3.5	3	5

– $E_{aux\_chp} = E_{aux} + E_{hpaux} - Q_{el\_chp}$ [3]

where

– E_{aux} = auxiliary energy consumption for heat generators other than heat pumps, in kWh/a, with

– $E_{aux} = hrsmax \cdot \{ CC \cdot (0.15 \cdot elmax + 0.85 \cdot elmin + 1.3 \cdot P_{SB}) + 0.5 \cdot P_{stby} \}$ [4]

where

- $elmax, elmin, PSB$ = auxiliary electricity consumption in respectively full load, part load and standby (in kW_e)
- P_{stby}= heat loss in standby mode (in kW)
- E_{hpaux} = auxiliary energy consumption for heat pump space heaters in kWh/a, with

$E_{hpaux} = CC \cdot \{ H_{TO} \cdot P_{TO} + H_{OFF} \cdot P_{OFF} + H_{CK} \cdot P_{CK} \}$ [5]

- with parameters depending on climate (Average/Warmer/Colder) and reversibility:
  - H_{TO} = hours in thermostat-off mode (179/755/131);
  - H_{OFF} = hours in off mode (reversible 0/0/0, default 3672/4416/2208);
  - H_{CK} = hours in crankcase heater mode (reversible 179/755/131, default 3851/4476/2944);
  - P_{TO}, P_{SB}, P_{OFF}, P_{CK} are electric power consumption (kW) values in respectively thermostat-off, off and crankcase heater mode.

– $\eta_{sol} = \{1/(11 \cdot P_{rated})\} \cdot (294 \cdot A_{sol} + 115 \cdot V_{sol}) \cdot f_{sol} \cdot \eta_{col} \cdot S$; [7]

with

- η_{sol} is solar contribution as percentage of the heat load;
- A_{sol} is solar collector surface in m²;
- V_{sol} is the solar tank volume in m³;
- f_{sol} is a factor that depends on the preferential heater: 0.9 if there is a fuel boiler, 0.7 if there is a cogenerator, 0.45 if there is a heat pump in the configuration;
- η_{col} is the collector efficiency at a temperature difference between the solar collector and the surrounding air of 40 K and a global solar irradiance of 1000 W/m²;
- S is tank (standby loss) Energy Label rating, with A^+=0.95; A=0.91; B=0.86; C=0.83; D-G=0.81.

– E_{el_chp} = electricity production co-generator, corrected, in kWh/a (primary energy) with

$E_{el\_chp} = 2.65 \cdot \eta_{el\_chp}$ [6]

where

- η_{el_chp} = electric efficiency of cogenerator (kW_e/kW)

  Note: The electric power output on the Energy Label is $P_{chp} \cdot \eta_{el\_chp}$

Note 1: 0.08 is currently called F(1)=3%. It was changed to accommodate extra (also hydraulically induced) control losses identified in Task 4.

Note 2: There are different versions of *hrsmax (or H_{HE})*. In the latest EN14825:2018, the proposal is to have 1400/1400/2100 hours for the heat pump 'active mode' H_{HE} in Average/Warmer/Colder climate. In the transitional method the values for heat pumps are 2066/1336/2465 hours. The latter corresponds to the outcome of the bin-method.

Note 3: Values for classes II, III, VI and VII were lowered by -0.5 because the beneficial impacts of weather compensators are currently overrated according to the findings in Task 4.

Stakeholder comments

Many stakeholder comments at and after the 2nd stakeholder meeting related to the fact that time had been too short for a proper evaluation. BDR Thermea pointed out that the formulas for COP(j) and eta(j) needed to be corrected to use inverse values for a proper efficiency calculation. Some stakeholders wondered how this new combined calculation method works with the Ecodesign limits proposed in paragraph 2.4.

Response: The study team acknowledges that, although within the limits of what is customary for a stakeholder meeting, time was short to find convergence on such a complex subject and will recommend a follow-up discussion/study route to the EC. The formulas for COP(j) and eta(j) were corrected. As regards the Ecodesign limits in the combined method, it is recommended that the limit-values in paragraph 2.4 will be partitioned in accordance with the relative contribution of the heat generators. In other words, there will be no change in limit values due to the method. The relative contribution will be assessed by measuring the main energy parameters of individual heat generators, i.e. the electricity and/or gas consumption of the heat pump compressor or sorption cycle, fan(s), pump(s) and controls; the gas or oil consumption of the co-generator as well as its heat output and net electricity output; the gas or oil consumption, as well as auxiliary electricity use, of fossil fuel boilers. Furthermore, for heat pumps the manufacturer has to declare the bivalent (Tbiv) and operation limit (Tol) temperatures.

Example calculation of Ecodesign minimum efficiency: At the (new pef corrected) Ecodesign limit value for a HT heat pump of 130% (LT 150%), the maximum Tbiv is 2 °C and Tol is -7 °C and thus the heat pump contribution (without backup) to the load looked-up from table A is 60% (from 16 °C to Tbiv) plus 19% (0.5 x Tbiv to Tol), resulting in 79% load-contribution. Hence, with a 100% load contribution (Tbiv≤−10 and Tol≤−10 °C), the HT heat pump efficiency should be (130/79) 160%. With look-up Table A it is now possible to determine the Ecodesign limit for the heat pump at any Tbiv and Tol.

For instance, at Tbiv=+7 °C and Tol=+7 °C, which is the minimum performance level to qualify as a heat pump at all[62], the value of q(j) at Tj=+7 °C is 23%. Assuming that the

[62] See the definition of a non-preferential heat pump in the current regulation, which mentions that there should be a COP at test for 7°C outdoors.

remainder of the heat load is filled in with an electric resistance boiler with a (new pef corrected) 43% minimum efficiency, then the minimum Ecodesign efficiency of the package should be 1/[23/160+(100-23)/43]=52%.

If Tol and Tbiv are different, e.g. Tbiv=+7 °C and Tol=+2 °C, the value of q(j) at Tbivalent (Tj=+7 °C) is still 23%. For the contribution between Tbiv and Tol, look-up Tj=+2 °C, which gives 60%. Take half the difference, i.e. 0.5(60%-23%)=18.5% to find contribution to the load between Tbiv and Tol. The total HT heat pump contribution will thus be 23%+18.5%=41.5%. The package limit with e.g. a fossil gas boiler back up (87% limit) will be 1/[41.5/160+(100-41.5)/87]=108%.*

Note that the solar assistance cannot be taken into account, in whatever way[63], in the calculation of the Ecodesign limit, but it can be taken into account in the calculation of the energy label rating.

Separate method

The combined method has the advantage of being universal, i.e. possible for any type of combination of heat generators in the scope, but it requires testing for each specific configuration and thus leads to relatively high testing costs for industry and surveillance. The aim of the separate method is to give an alternative to manufacturers that want to offer their customers optimal flexibility in putting together a package from individually tested components.

In the separate method the seasonal space heating energy efficiency is built from the parameters of the individual heat generators. The control mechanism is not tested but assumed[64]. This means that there is a fixed order in which the heat generators in the configuration contribute to the load.

The order for the heat generator contribution in fulfilling that demand is determined by efficiency logic, i.e. solar heat (fully renewable, carbon free), cogeneration (base-load product, highest capital costs), heat pump (partially renewable, potentially carbon-free with renewable electricity), fuel boiler (gas/oil/hydrogen/biogas, potentially carbon-free with renewable hydrogen etc.), secondary fuel boiler (different boiler in a cascade, back-up for maintenance, etc.), electric resistance boiler (ultimate back-up, lowest efficiency today), auxiliary electricity and CHP-electricity accounting.

For each generator-type, the space heating output (Q in kWh) and the energy input (E in primary energy kWh) is calculated. In the end, the ratio of net heat demand and sum of the energy inputs determines the seasonal space heating energy efficiency of the product or package.

The net space heating load Q_{load} for which the heat generator configuration is designed can be derived from P_{rated} and an equivalent number of hours $hrsmax$ that can be derived from the bin-method for a designated climate.

[63] The formulas show a solar assistance calculation as in the current legislation, but there are various alternative proposals on the table to improve and simplify the calculation. The reason for not including solar assistance is that Ecodesign Prated starts from a worst case scenario, i.e. without significant solar influx.

[64] Possible exception is the testing without the fixed speed; see 'Dynamic testing' elsewhere.

$$Q_{load} = P_{rated} \cdot hrsmax \quad [8]$$

In order to produce the net space heating load, the space heater needs to produce more heat Q_h to compensate for certain losses in the temperature- and hydraulic controls. These are set at a default malus of 8%, as determined in Task 4. In as much as the temperature controls are part of the space heater a certain bonus $cctrl$ will apply. [65]

$$Q_h = (1 - 0.08 + cctrl) \cdot Q_{load} \quad [9]$$

$$Q_{sol} = (Q_H - Q_{chp}) \cdot \eta_{sol} \quad [10]$$

where

- Q_{sol} = annual space heating energy of the solar space heater in kWh/a ;
- η_{sol} = solar contribution as percentage of the heat load (see combined method);

$$Q_{chp} = P_{chp} \cdot \eta_{th\_chp} \cdot h_{chp} \quad [11a]$$

$$E_{chp} = Q_{chp} / \eta_{th\_chp} \quad [11b]$$

where

- Q_{chp}= space heating capacity of the co-generator in kWh/a
- E_{th_chp}= primary energy input of the co-generator in kWh/a
- η_{th_chp}= thermal efficiency cogeneration space heater at declared load;
- h_{chp}= annual hours of cogeneration function in h/a (2066/1336/2465 for Average/Warmer/Colder climates respectively);

$$Q_{hp} = P_{rated} \cdot \{ q(T_{biv}) - q(T_{start}) + 0.5 \cdot [q(T_{TOL}) - q(T_{biv})] \} \quad [12a]$$

$$E_{hp} = G \cdot P_{rated} \cdot \left\{ \frac{q(T_{biv})}{COP(T_{biv})} - \frac{q(T_{start})}{COP(T_{start})} + 0.5 \cdot \left[\frac{q(T_{TOL})}{COP(T_{TOL})} - \frac{q(T_{biv})}{COP(T_{biv})} \right] \right\} \quad [12b]$$

where

- Q_{hp} = space heating output of the heat pump in kWh/a;
- E_{hp} = space heating primary energy input of the heat pump in kWh/a;
- G= 1 for gas-fired heat pumps or CC=2.1 for electric heat pumps;
- $COP(T_j)$ = Coefficient of Performance in kW/kW at bin j with outdoor temperature T_j using the equation in row $COP(T_j)$ with appropriate inputs as indicated in Table A,
  where

[65] Parameters as for combined method

- *COPA, COPB, COPC, COPD are the declared COP_{bin}-values for test conditions A, B, C, D (Tj=−7/2/7/12 °C),*

  with

  $$COP_{bin}=COP_d \cdot CR/[Cd \cdot CR+(1\text{-}Cd)]$$

  where

  - COP_d = declared COP, i.e. declared capacity *Pdh* / (electricity input + fossil fuel input/*CC*);
  - *CR* = capacity ratio, i.e. heating part load or full load divided by the declared heating capacity of the unit at the same temperature conditions;
  - *Cd* = measure of efficiency loss due to the cycling (default when not measured is 0.9).
  - *CC* = conversion coefficient from electricity to primary energy (new default 2.1)
- *Aj, Bj, Cj, Dj* are weighting factors for COP-values at test conditions A, B, C, D;
- $q(T_j)$ = accumulated fraction of the Load at bin with outdoor temperature T_j

where

- T_{start} = Tj in bin j where qj is closest to $(Q_{chp} + Q_{sol})/ Q_H$, in Table A;
- T_{biv} = bivalent temperature, i.e. declared lowest outdoor temperature point at which the unit is declared to have a capacity able to meet 100 % of the heating load without supplementary heater (whether it is integrated in the unit or not);
- T_{TOL} = operation limit temperature, i.e. declared outdoor temperature below which the declared capacity is equal to zero.

$$Q_{fos} = P_{rated} \cdot \{ q(T_{TOL}) - q(T_{fos}) + 0.5 \cdot [q(T_{TOL}) - q(T_{biv})] \} \quad [13a]$$

$$E_{fuel} = P_{rated} \cdot \left\{ \frac{q(T_{fuel})}{eta(T_{fuel})} - \frac{q(T_{TOL})}{eta(T_{TOL})} + 0.5 \cdot \left[\frac{q(T_{TOL})}{eta(T_{TOL})} - \frac{q(T_{biv})}{eta(T_{biv})} \right] \right\} \quad [13b]$$

where

- Q_{fos} = space heating output of the (primary) fuel boiler in kWh/a;
- E_{fos} = space heating primary energy input (kWh GCV) of the (primary) fuel boiler in kWh/a;
- *eta(Tj)* = space heating energy efficiency in kW/kW at bin j with outdoor temperature *Tj* using the equation in row *eta(Tj)* with appropriate inputs as indicated in Table 1*,*
- T_{TOL} and T_{biv} are taken from the heat pump; if there is no heat pump $T_{TOL}=T_{biv}=T_{start}$ and the second term of the equation can be dropped.
- T_{fos} is maximum bin-temperature for the primary fuel boiler at its rated capacity P_{fos} declared by the manufacturer.

$$Q_{fosb} = P_{rated} \cdot \{ q(T_{fos}) - q(T_{fosb}) \} \quad [14a]$$

$$E_{fuelb} = P_{rated} \cdot \left\{\frac{q(T_{fosb})}{eta(T_{fosb})} - \frac{q(T_{fos})}{eta(T_{fos})}\right\} \quad [14b]$$

where

- Q_{fosb} = space heating output of the secondary fuel boiler in kWh/a;
- E_{fosb} = space heating primary energy input (kWh GCV) of the secondary fuel boiler in kWh/a;
- T_{fosb} is maximum bin-temperature for the secondary fuel boiler at its rated capacity P_{fosb} declared by the manufacturer

$$Q_{el} = (Q_H - Q_{chp} - Q_{sol} - Q_{hp} - Q_{fos} - Q_{fosb}) \quad [15a]$$

$$E_{el} = CC \cdot Q_{el} \quad [15b]$$

where

- Q_{el} =space heating output of the electric resistance space heater in kWh/a;
- E_{el} = space heating primary energy input (kWh GCV) of the electric resistance space heater in kWh/a;

$$E_{aux\_chp} = E_{aux} + E_{hpaux} - Q_{el\_chp} \quad [16]$$

(as combined method)

$$\eta_s = (P_{rated} \cdot hrsmax) / (E_{chp} + E_{sol} + E_{hp} + E_{fos} + E_{fosb} + E_{el} + E_{aux\_chp}) \quad [17]$$

where η_s = seasonal space heating energy efficiency

Stakeholder comments

Comments are similar to those of the 'combined method' and more time is needed for stakeholders to study/discuss the proposals. Also the question is how to calculate Ecodesign limits with this 'separate method'. BDR Thermea would have preferred a more flexible approach as regards the order of the heat generators, i.e. not fixed, and their capacity, i.e. to be set according to manufacturer's declaration (energy-optimised, but also cost-optimised, night setback option, etc.). Furthermore, BDR Thermea thinks the symbols and definitions need to be optimised.

<u>Response:</u> *As mentioned with the separate method, the recommendation for a more extensive study/discussion phase will be recommended to the EC. The calculation of the Ecodesign limits is similar to that of the combined method, but –because each generator is tested separately—it will be simpler to establish the individual contribution and to see if minimum requirements are met. Details are to be elaborated in a follow-up activity. The fixed order and keeping the control's influence in just the 8 control classes help to keep the method simple and robust against circumvention where settings for tests can be very different from settings in reality.*

As regards the optimisation and streamlining of inputs, defaults and calculation procedures there is certainly a need for that. The table on the next page is a first illustration of how the (current) inputs can be presented more user-friendly.

In that context, it will also be considered to cluster the combi-boiler water heating function with the dedicated water heater regulations. Only for a few items (solar, PFHRD) some cross-referencing is needed[66]*, but considerable repetition in the regulations will be avoided.*

[66] Note that in the current regulations this cross-referencing is lacking because there is no explicit link between the solar space heating and water heating; also the PFHRD is not treated because until recently there has been standard for testing storage-type PFHRDs.

Table 20. Inputs: Space heating boiler (illustrative)

1. Heating controls Class no.	**Selected**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Value in %		1	1.5	1	2	3	3.5	3	5
Heat generator	**Unit**								
2. solar assist		**Asol** *(m²)*	**etacol** *(-)*	**Vsol** *(litres)*	**fsol** *(-)*	**S** *(-)*			
3. micro chp heat		**Pchph** *(heat)*					**Pchpe** *(electric)*		
	kW x,x								
		etachph					**etachpe**		
	−(on GCV) x,xxx								
TEST points part load %, HIGH Tret - Tfeed (°C)	*Average*	-	88% 51-61	54% 39-49	35% 31-41	15% 22-32	**when fixed speed apply Cdh and Pcych:** 100% 55-65		
	Warm	-	-	100% 55-65	64% 43-53	29% 29-39			
	Cold	82% 47-57	61% 40-50	37% 31-41	24% 26-36	11% 20-30			
TEST points part load %, LOW Tret - Tfeed (°C)	*Average*	-	88% 29-34	54% 25-30	35% 22-27	15% 19-24	**when fixed speed apply Cdh and Pcych:** 100% 30/35		
	Warm	-	-	100% 30-35	64% 26-31	29% 21-26			
	Cold	82% 27-32	61% 25-30	37% 22-27	24% 20-25	11% 19-24			
TEST source temperatures Outdoor air dry (wet) bulb temperatures Tj	*Tj (bin)*	*−15 °C*	*−7(-8)°C*	*2(1)°C*	*7(6)°C*	*12(1)°C)*	**Other test source temperatures:** Exhaust air 20(12) °C, Water 10/7°C, Brine 0/−3°C		
4. heat pump HIGH or LOW TEST POINTS (as declared LT or HT heat pump) Tret-Tfeed: **LT or HT** Source: **Air (outdoor or exhaust), Water or Brine**							**Tbiv**	**Tol**	**Cdh**
	°C x								
		PhpE	**PhpD**	**PhpC**	**PhpB**	**PhpA**	**Pbiv**	**Pol**	**Pcych**
	kW(heat) x,x								
		COPE	**COPD**	**COPC**	**COPB**	**COPA**	**COPbiv**	**COPol**	
	−(primary) x,xxx								
5. fossil fuel boiler (combi) heater HIGH TEST POINTS			**Pfos4**	(Pfos3)	(Pfos2)	**Pfos1**	**Pstby**	**Pign**	*Pmin(%)*
	kW(heat) x,x								
			etafos4	(etafos3)	(etafos2)	**etafos1**			
	−(on GCV) x,xxx								
6. back-up fossil fuel boiler (combi) heater HIGH or LOW TEST POINTS (low if it is a back-up of an LT heat pump)			**Pfosb4**	(Pfosb3)	(Pfosb2)	**Pfosb1**	**Pstby**	**Pign**	*Pmin(%)*
	kW(heat) x,x								
			etafosb4	(etafosb3)	(etafosb2)	**etafosb1**			
	−(on GCV) x,xxx								
7. electric resistance heater		**Pel**							
	kW(heat) x,x								
		etael							
	−(primary) x,xxx								
8. auxiliary electricity	no heat pump		**elmax**	**elmin**	**PSB**				
	kW(elec) x,xxx								
	heat pump only		**Poff**	**Pto**	**Pck**	**Psb**			
	kW(elec) x,xxx								
Sound power L,WA	dB(A)		Annual Energy Consumption (AEC)		in kWh or GJ				

4.5 Installer label

The Greek Solar Industry Association welcomes the proposed simplification of the energy label, but feels the suggested improvement of 40% still underestimates the real contribution of solar, for instance when combined with an electric immersion heater that —with a favourable climate and a pro-active user— is used only 10-20 times a year. So the solar system covers 80-90% of the need. Hence they propose, while keeping it simple, to show differences between the three climates.

ECOS-EEB is in favour of keeping the solar package label for installers, but warns to use realistic and exaggerated data for solar gain.

According to stakeholders in the solar thermal industry the current energy label, with its single equation and 4 input parameters (Asol, Vsol, fsol, ηcol) is too complicated for the installer. Therefore, in the draft Task 6 report, following early suggestions of stakeholders in solar heating, a very simple alternative method was proposed, giving efficiency improvement per m² of collector surface.

According to experts from Solar Heat Europe[67] and experts from the Solar Heating Initiative [68], the accuracy of this method can be significantly improved, while keeping the simplicity in implementation. The basis is a look-up table of the annual collector output (or the solar enhancement factor), prepared by the manufacturer of the solar heat system.

The inputs for the table are:

- Gross Thermal Yield (GTY) of the solar collector, based on number of modules (or similar)
- Climate (Average, Warmer, Colder)
- Tapping profile (M, L, XL, XXL)

The table would differentiate between water heating and space heating.

The figure and table below illustrate the procedure and the table.

[67] Solar Heat Europe, Proposal for Simplified Method for Solar Thermal, position paper to study team, June 2019.

[68] Solar Heating Initiative, pers. comm. Stefan Abrecht, June 2019.

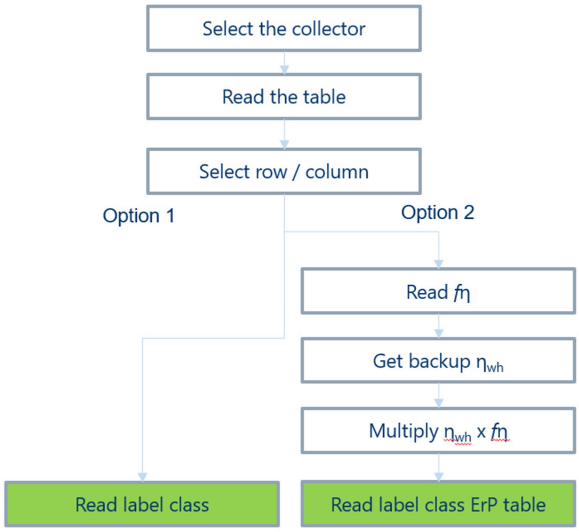


Figure 17. Options regarding label identification process by the installer (source: Solar Heat Europe 2019)

Table 21. Options for table to be provided by the manufacturer summarising the solar thermal impact for a given collector type.

Example of tables:

		Number of collector modules:									
Climate:↓	Profile:↓	1	2	3	4	5	6	7	8	9	10
Average	M	x	x	x	x	x	x	x	x	x	x
	L	x	x	x	x	x	x	x	x	x	x
	XL	x	x	x	x	x	x	x	x	x	x
	XXL	x	x	x	x	x	x	x	x	x	x
Colder	M	x	x	x	x	x	x	x	x	x	x
	L	x	x	x	x	x	x	x	x	x	x
	XL	x	x	x	x	x	x	x	x	x	x
	XXL	x	x	x	x	x	x	x	x	x	x
Warmer	M	x	x	x	x	x	x	x	x	x	x
	L	x	x	x	x	x	x	x	x	x	x
	XL	x	x	x	x	x	x	x	x	x	x
	XXL	x	x	x	x	x	x	x	x	x	x

In the case of option 2, the table can be complemented by a calculation for the package efficiency (see section 4.2) and the reference table from the regulations (space heating or water heating, depending on the case), for installer’s (or other user) convenience.

Table 22. Solar Enhancement Factor

Back-up efficiency	95%	1)
Solar Enhancement Factor	121%	2)
Package efficiency	**115%**	3) = 1)*2)

Device	G		F		E		D		C		B		A		A +		A ++		A +++	
Seasonal Space Heating - Heaters (general)	<	30%	<=	34%	<=	36%	<=	75%	<=	82%	<=	90%	<=	98%	<=	125%	<	150%	=>	150%
Seasonal Space Heating - Low temperature heat pumps	<	55%	<=	59%	<=	61%	<=	100%	<=	107%	<=	115%	<=	123%	<=	150%	<	175%	=>	175%

The Solar Enhancement Factor (or Solar Device Efficiency) should be determined solely with the specifications of the collector, in particular the gross thermal yield in relation to a load and climate. This implies that several assumptions have to be made for other elements, such as the water store, pump or control. Taking the collector as a basis, there are several options in terms of reference methods. These can be grouped into two main streams:

- GTY methods
- EN 15316-4-3, method 2

Solar experts will continue to work on perfecting these two methods. For water heating, as mentioned, the load is the tapping profile selected. For space heating the load comes from the rated power *Prated* multiplied by the default number of hours *hrsmax*.

VHK recommends this work continues and finds a place in (forthcoming) standards, so that (after scrutiny and final checks) it can be referenced in the Official Journal as method endorsed by the Commission.

4.6 Stakeholder comments on packages

There were many stakeholder comments on packages and thus the comments are brought into a separate paragraph. These represent a minor share of all comments received. A full disclosure of comments received after the 2nd stakeholder meeting is available from the study website.

Liquid Gas Europe

Is concerned that the new proposals will lower the relative rating of condensing gas boilers, whereas it is still the LLCC-option (as mentioned in Task 2) and "low-hanging fruit". Later on, with renewable gases blending in, condensing boilers can contribute to decarbonisation.

EHPA/ GHP

Notes that VHK did not find issues with test conditions for GHP (Thermally Driven Heat Pumps TDHP) and concludes that the issues regarding dynamic testing therefore do not apply to TDHP.

UBA-BAM

UBA-BAM writes (also regarding Task 4, the test method for heat pumps):

"We strongly disagree that the current standard for testing heat pumps EN 14825 is "adequate, future proof and representative". In our separate paper on test methods for heat pumps we outline that EN 14825 lacks in representativeness, comparability and independency. In addition, costs are high and ECOtest results cited in the report indicate low reproducibility. Moreover, excluding the control from testing cannot be considered adequate nor future proof in our view, since it has a major influence on energy efficiency.

EN 14825 does not give an incentive to optimise the heat pump's control since it is inactive during the test. However, our investigations have shown very different on/off operation of different units under part load conditions. Therefore, we see a further improvement potential in optimising the control strategies. Please see our proposal for more details."

Denmark

Proposes further technical meetings on the calculation procedure.

Daikin

Daikin writes in relation to the Hybrids & Package approach (Task 6):

"The proposal to include the package label approach into Ecodesign is not clear and needs further investigation. We question how minimum efficiency requirements will be integrated for the package label. To include packages into Ecodesign regulation would also require investigating when a package can be considered to be placed on the market.

Furthermore, the calculation currently proposed [in clause 4.2 in Task report 6] is not mature and does not provide trust in the declaration of products. The calculation does not take into account the combination of electricity and gas and the background of certain factors used is not explained. By doing the calculation ourselves based on our product data, we found big deviations between the results in the report and our results based on the full bin method. We would therefore recommend further investigation before proposing to include this approach in the revision."

ECOS-EEB

ECOS-EEB writes, in relation to Options for Packages

"The preparatory study concluded that package labels are not always correctly used, or used at all, by installers. We propose, however, to keep the package label with some modifications, as it can be an efficient measure to promote, inter alia, solar heating (the heating source with the lowest environmental impact) or the use of heating controls. The proposal should be reviewed 5 years after its introduction."

EHPA

Introductory statement: *"All heat pumps complying with the relevant requirements of the Ecodesign Regulation (e.g. etas, Tbiv, TOL…) and delivered by the manufacturer as a finished product including heat generator, control and backup heater (electric or burner) should be considered as a heat pump and should not fall into the package category.*

VHK is suggesting to introduce the packages in the eco-design regulation and is proposing several methodologies for assessing the performance of the package. The methodologies are based on the bin approach, some consisting of testing the package as a black box, some consisting of testing the products individually within the package. VHK is also introducing a new definition about single products, that didn't exist in the *regulation up to now and that does not fit with some products that are put on the market, such as heat pumps with a fossil backup."*

Note of study team: In the report we are evaluating the current definitions of single products, but in the end we propose to treat all products with the same ('package') approach.

General comments EHPA

Before entering into the details of the proposed test methods and calculations, general issues shall be raised:

- The proposed methods only concern space heating energy efficiency. Test methods would also be needed to assess the domestic hot water energy efficiency of packages encompassing a combination heater, the sound power level for packages encompassing a heat pump and NOx emission for packages encompassing a fuel burning heat generator. Indeed, performance thresholds of the packages for space heating, NOx emissions and sound power level should also be defined.
- The product fiche is defined in both eco-design and labelling regulations; there would be a need to define a package fiche. In particular, when the package is tested as a black box, the product fiche will not be appropriate.
- In case of packages, would that mean that three tests are necessary instead of one? Should single products be tested and compliant to Ecodesign? This is all far more complicated and costly than the current testing procedure.
- In case the separate method is chosen to establish the performance of the package, will the limitations in terms of Tbiv and TOL still be relevant for the heat pump included in the package?
- EPREL: Both products and packages shall be entered in the EPREL. In case the performance of the package is determined according to the combined method, how shall the package be declared in the EPREL database?

- Will the possibility remain for installers to make their own package label, in particular for solar? And how? Will the installers be required to only install "on-site made" packages that fulfil the eco-design requirement on energy efficiency? How to verify? The risk is to have no package but only compliant products put on the market and non-compliant "on-site made" packages installed (risk of no good performance achieved).
- Will heat pumps equipped with a back-up heater be considered as a package of a heat pump + electrical boiler?

Conclusion EHPA

It was not clearly mentioned in the draft VHK reports that it was intended to introduce the package within the eco-design regulation and thus no chance has been given to the stakeholders to react on that issue before the stakeholder meeting. Technical discussions are highly needed as these proposed changes will have huge consequences on many existing products. For EHPA it is of utmost importance that the heat pumps definition remains unchanged, meaning that heat pumps equipped with a backup heater, either electrical or fossil fuel, will be considered a heat pump appliance.

Time is also needed to investigate more thoroughly the proposed methods. Certain coefficients are introduced which need to be explained. A technical meeting would be welcome in order to clarify the points highlighted in this document and to discuss the proposed testing methods. Indeed, manufacturers call for the performance of the hybrid products put on the market to be considered as it is tested and not evaluated in a package.

EPEE

Hybrid boilers: Ecodesign requirements for packages add complexity but no additional value for consumers

- VHK proposed a new calculation method apart from EN 14825. This approach introduces weighing factors and neglects the existing format. In the same context a proposal to include packages of products into the Ecodesign regulation was launched.
- EPEE understands that each product needs to be compliant with the Ecodesign Regulation and a package of products just adds complexity to the regulation without adding value for consumers and is therefore not in favour of this proposal.

UBA-BAM

Package label

"We share the opinion that the package label has just entered into the market to some degree.

The number of package labels could be reduced by shifting controls to the product label. This would relieve installers but put pressure on manufacturers.

When simplifying the package label for solar installations, the ratio of solar size to heat load may be considered (4 m² makes a different contribution to 5 kW or 50 kW heat load). The results of all methods to calculate the package efficiency should be as comparable as possible."

EHI

EHI would like to clarify further test methods for hybrid heat pumps at both standardisation and regulatory levels and proposes to develop a unique test method for hybrid heat pumps at standardisation level.

Since the publication of the Regulation (EU) 811/2013, manufacturers have further developed hybrid space heaters integrating the heat pump, the boiler and a combined control, which help optimise how the two generators work together according to outdoor temperature variations and other parameters.

Further evolution of the test method for hybrid heat pumps is thus welcome in the medium-term as it could reduce testing efforts, improve real-life measurement, etc. It should be defined by the joint CEN TC 113/TC 109 Working Group, not an external consultant. Such calculation method could be adapted to all types of hybrid heat pumps without the need to specify a preferential generator.

This will help calculate the efficiency of hybrid heat pumps, which are delivered by manufacturers as a complete product integrating the heat pump, the boiler and a combined control. Hybrid heat pumps could then be tested in laboratories at various outdoor temperatures with real seasonal energy efficiency values, not virtual ones.

Moreover, the following considerations should be taken into account when applying the method:

- Hybrid heat pumps are sold as one product, as one order/unit, by the manufacturer;

- They should not be limited by geometrical criteria as “in one compact device” or “in one casing”;
- They should be tested according the EN14825:2018 in a "black box" approach;
- They should keep using the current heat pump energy label;
- Assess whether to create a dedicated hybrid heat pump product category in Ecodesign, with dedicated limits, based on the current discussions in the joint CEN TC 113/TC 109 Working Group.

This would contribute to a better recognition of hybrid heat pumps and a better communication of their characteristics to consumers (fit for renovation purposes, grid balancing contribution during winter, etc.).

Conclusion:

The study team proposes to set up a special consultation initiative with the stakeholders to further discuss and investigate the issues.

5 Other Options

5.1 NO_x-emission limits

For 3rd family gases

The current regulation sets one NO_x limit for all gaseous fuels, i.e. natural gas and LPG. However, for third family gases (propane, butane and their blends) these limits are more difficult to achieve than for natural gas. To correct for this, it is proposed to apply for G30 gases a factor 1.30 on the current NO_x-limit (for natural gas) and for G31-gases a factor 1.20. This is in line with the most recent proposal of experts in the relevant EN 15502-1 standard[69].

It is not expected that this increases NO_x emissions of the installed base, as most appliances can be set to use either second or third family gases and have been declared in conformity for use with second family gases. The gas-specific limit values are not expected to change the hardware of products placed on the market. Only tighter ELVs will have this effect.

NO_x-emission limits per combustion technology

Gas / Internal combustion

The current NO_x threshold for gas-fired internal combustion (both cogeneration and heat pump) is set at 240 mg/kWh (GCV). Considering the emissions of a typical cogeneration product described in Task 4, there appears very limited room for improvement (the declared value is some 17% lower than the threshold value) but there is very little data available to show and calculate the impacts of revised thresholds for all products placed on the market. The share of products that would pass/fail a revised threshold is simply not known.

A complicating matter is that the method to establish and calculate NO_x emission levels may vary depending the set-up of the product (is it capable of instantaneous following heat demand, is it equipped with a heat storage and/or supplementary heaters). If data is presented for cogeneration it may not be known which test method (A, B or C) of EN 50465 was applied.

It is concluded that due to lack of information on actual emissions of products the effects of a revised (more stringent) emission limit are not known and changing the limit value is not yet advised (this also applies to gas engine heat pumps, using a similar technology). As the EPREL database does not present Ecodesign-related data, the availability of such data on larger scale is not expected for the near future. A revised energy label, that would include emissions data is an option. Another option opening up the EPREL database to contain Ecodesign-related data.

Gas / fuel cells

Currently, there is no NO_x limit value for fuel cells as none of the combustion principles apply. This is not problematic because fuel cells emit significantly less NO_x per kWh of

[69] EN 15502-1:2012+A1:2015 Gas-fired heating boilers. General requirements and tests

fuel than typical combustion technologies. There is no immediate need for specifying NO_x emission limits for fuel cell heat generators.

NO_x-emission limits based on heat output (not fuel input)

Some stakeholders have argued for NO_x emission limit values (ELV) based on unit of heat output rather than fuel input. This introduces energy efficiency of the product as an aspect that determines the emissions being regulated: More efficient appliances can afford to be relatively more polluting, assuming all else remains the same (for cogeneration devices both heat output and electric power output should be considered).

Changing the calculation basis of the limit value requires a discussion on how the emissions per heat output would be calculated. This could be the ponderation of the emission (currently assessed for different heat inputs or capacities and weighted by a factor) divided by the seasonal efficiency (which often follows a different weighing than for emissions), or the actual emission divided by the efficiency in that same test conditions which are then weighted. The first option allows easier calculation using existing values, the latter better reflects actual 'average' emissions as emissions and efficiencies are established at the same conditions, but no such data is currently available.

Emissions requirements such as for NO_x are currently set per technology (liquid or gaseous fuels, boilers, internal combustion or external combustion) and generally improve the combustion characteristics (low NO_x versus atmospheric combustion etc.). Changing to heat output as denominator will probably still require consideration of combustion technologies as the emissions can vary over a wider range than the (energy) efficiencies (for example: a gas boiler must meet 56 mg/kWh whereas an internal combustion heat pump must meet 240 mg/kWh, a factor 4.3. The seasonal efficiencies however do not differentiate with a factor 4.3 but more like a factor 1.4).

If however the request for changing the calculation basis is an attempt to alleviate ELVs for certain product groups, then the actual limit values can be discussed without changing the calculation basis. ECOS-EEB argued that the ELVs for NO_x of internal combustion engines can even be made much stricter.

5.2 No 3XL/4XL tapping pattern for water heating

This issue has been discussed in Task 1, section 5.3.1. Water heaters (and combi heaters) that have a power output ≤70 kW are subject to both Ecodesign and Energy Label regulations. They should be tested at their maximum load profile or the load profile one below the load profile. If they are capable of a tapping pattern 3XL/4XL then that is how they should be tested for the Ecodesign regulation. However, energy labelling regulation only goes up to a tapping pattern 2XL. This implies that

- Manufacturers have to test twice, once 2XL for the label and again at 3XL or 4XL for Ecodesign.
- The 2XL tapping pattern is not representative of the real performance and efficiency (because it is oversized)
- Such water heaters (meeting the 3XL or 4XL profile) are primarily for commercial purposes, for which the energy label is not really intended.

The water heating industry has made a joint request to abolish the need to test the 3XL/4XL water heating appliances that have a power output ≤70 kW for energy labelling. It is proposed to grant this request.

5.3 Sound power limits for heat pump

The sound (or noise) that space heaters and heat pumps in particular produce is a relevant parameter as it influences the options for installation and seasonal efficiency. For these reasons there is a Ecodesign requirement for sound power[70] of heat pumps (and a labelling information requirement for all space heaters, including boilers).

Although the regulation clearly states the outdoor and system temperatures for measurement of noise of heat pumps, the capacity is not clearly defined. At one point, reference is made to the rated heat output but also to "*the same declared capacity... [as used for energy efficiency calculation]*". This is not unambiguous.

It is even more complex if the difference between fixed speed heat pumps and inverter-driven heat pumps is considered: the fixed speed capacity is by definition its full load capacity, for the inverter driven it depends on the part load required and other possible control settings.

To solve this problem, a revised regulation shall clearly state the outdoor and indoor (system) conditions and at minimum require declaring the fan speed and compressor speed that is more representative of conditions when most sound is produced (e.g. by declaring fan speed or flow rate, and compressor speed at bivalent point). The test method and the exact conditions have to be decided with test institutes, industry and other stakeholders together. Stakeholders did indicate that the test should reflect operation in conditions that are expected to be most problematic for sound emissions (more on this in Task 1). In order to properly take into account tonality of the noise (to calculate the emissions on the basis of sound power provided) information per third-octave bands needs to be provided as well.

For space heaters that are known to emit very low noise, stakeholders have suggested a simple approach based on a declaration that the noise emissions (indoor, outdoor whichever are relevant) are below a certain threshold (avoiding the need for testing of these products).

5.4 Pilot flame

As mentioned in Chapter 4, the pilot flame for central space (combi) heaters is extinct and thus can be explicitly phased out to simplify the calculation procedure.

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[70] A stakeholder has suggested "not to differ between sound pressure and power, but between noise emission and noise exposure (or immission). Noise emission is the sound which is emitted by a noise source, often represented by the calculated sound power level (you cannot directly measure it!). Noise exposure (or immission) is the sound which went from the source, through the air or another medium (and could be reflected by walls or attenuated by noise barriers, i.e.) and has an impact on a person, a house or an area, and is often represented by a continuous equivalent sound pressure level. The sound pressure level instead, is only a measurement value which can be used to calculate both, emission and exposure levels". Although this is probably physically correct, the current test standards and regulations refer to 'sound power' and 'sound pressure' and introducing new terms at this stage could be confusing. The use of sound power and sound pressure in their respective legislative contexts has not given rise to any problems so far.

6 ANALYSIS OF OPTIONS

6.1 Introduction

This chapter explores costs and benefits of the options mentioned in the previous sections in as much as possible. Please note that this exploration is bound by the policy objectives and strategies discussed in Task 3. The future role of electric heat pumps, the fuel switch from fossil fuels to carbon-neutral fuels, the role of renewables are considered a given in the context of this review study.

What is important that the cost and benefit aspects of space and combi heating appliances are addressed and as such give a direct input to a review of the regulation and as well contribute to the wider political discussion on the way forward.

Note that this is a first analysis, to be extended after the final stakeholder meeting.

6.2 Horizontal options

H_2-ready

In the recent HyLAW project, the adaptation of end-use gas appliances is mentioned as one of the major barriers for using (carbon-free) hydrogen in the gas grid.[71] This is an aspect where a revised Ecodesign regulation can have a large impact.

According to the H21-report[72], the total H_2-ready saving for a single consumer, or whoever will pay the bill for the switch-over, would be in the order of €213.

Mainly based on the experience with a town gas-to-natural gas conversion kit in 1966-1970, they estimate that the strict boiler-conversion from natural gas to hydrogen would cost £277.80 (€320). Instead, if the boiler were prepared for the conversion (called "HYSWITCH-ready" in the report), then the strict material and labour costs would be £92.60 (€107). These amounts are excluding the replacement of the meters, additional safety features and management mark-up as well as excluding the costs of switching other products such as cookers or dedicated water heaters.

Likewise, another UK source identifies that gas seals, flame detection and the higher flame velocity of hydrogen pose problems for hydrogen combustion. And thus, a grid conversion would reportedly require burner heads and seals to be adjusted/replaced.[73]

However, the study team believes that these sources underestimate the changes in modern boiler technology. More will be needed than a new seal and burner. Atmospheric burners are extinct; almost all burners have (pre-mix) fan-assistance. The higher flame velocity means a (three times) higher flow rate for the fan and —in order to be ready for both natural gas and hydrogen— a continuously variable speed (no single or multi-

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[71] HyLAW, Horizontal Position Paper Gas Grid Issues, Author: Dennis Hayter, January 2019. www.hylaw.eu

[72] The H21 Report - Northern Gas Networks, 2016 (H21 Leeds City Gate Project Concept). https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf

[73] Paul E. Dodds, P.E., Demoullin, S., Conversion of the UK gas system to transport hydrogen, international journal of hydrogen energy 38 (2013).

speed). These specs bring moderate extra costs at the design and production stage, i.e. basically for the higher flow rate because the rest is standard. But changing the fan & drive by the installer gives material and labour cost that easily surpass €300. That is, if it is even possible, because the burner-CPU needs to be prepared in soft- and hardware to regulate the fan. For that, the CPU regulates the fan and gas-valve on the basis of —typically— the input from ionisation. But, as is the case with hydrogen, if the ionisation does not work, then it needs to be replaced by a CO or oxygen sensor. In total, for a new burner, seals, pre-mix fan, CO or oxygen sensor and a new burner-CPU to be installed on-the-spot by a specialised installer, the cost will be higher than buying and installing a new hydrogen-fired boiler, which may cost as little as €1400-1500 (incl. VAT) or only 20% more than a natural gas boiler of the same quality.

The reason is that all these design changes lead to much fewer extra costs when anticipated:

- new software for the burner-CPU costs almost nothing,
- CO- or oxygen sensors will probably become the new standard for flame control for quality boilers anyway74 and their price should drop as production volume grows;
- The high-flow rate variable speed combustion fans will probably be the most expensive item –especially when also a low modulation is required for natural gas operation— but at mass production the prices should become closer to current prices.

As mentioned, the study team estimates these changes to result in €100-150 extra production costs and thus €200-300 extra in consumer price for the average combi boiler.

These are extra acquisition costs for a H_2-ready boiler. The change of burner, seals, etc. could indeed be done at the actual conversion. If the replacement cannot be combined with standard maintenance then a cost of around 100 euro is reasonable (1-2 hours work, modest material costs). Possibly such a —probably not too expensive— conversion kit could be delivered when acquiring the boiler.

Biogas

Whereas for the introduction of hydrogen in the gas grid, instead of natural gas, will be a matter of national/international decision making, for biogas it will be a local decision induced by the availability of larger quantities of biogas in the area.

Biogas typically consists of 60-70% methane (CH_4), 30-35% carbon-dioxide (CO_2) and smaller quantities of hydrogen-sulphide H_2S (0.3%), hydrogen H_2 (3%), etc.[75]. The sulphides will typically be removed as much as possible before biogas is used for heating, because they can cause damage to the appliances.

Biogas can be mixed-in with natural gas (typically up to 10%) and in that case a normal natural gas boiler can be used. For that case no special provisions in the regulation apply.

Alternatively, biogas can be fed directly in a boiler. In that case the boiler should be able to handle the pollutants (H_2S resistant materials in seals etc.) and the lower calorific value (typically 21-27 kJ/m³ NCV) as compared to natural gas (34-38 kJ/m³ NCV). In

[74] Also because of the trend towards the larger variation in gas qualities. E.g. the current transition towards 'rich gas' in Belgium.

[75] Marx, E., Linke, W., Feuerungstechnik 2006, Verlag Gustav Kopf GmbH, Waiblingen, 2006.

many cases a normal natural gas boiler, when equipped with a good combustion control, can handle that situation but there may be in limitations in the degree of burner modulation. In terms of NO_x-emissions there are indications that the presence of CO_2 lowers the emission-level.[76]

Tentatively, it is proposed to allow a 20% efficiency credit if the boiler is placed on the market exclusively for the use with biogas[77] (exact definition to be supplied). A similar rationale can be applied to boilers using bio-liquids.

Primary energy factor

As mentioned in section 2, the change in primary energy factor (conversion coefficient CC in the regulation) from 2.5 to 2.1 should not lead to a lower ambition level for the energy efficiency limits of the appliances in the boiler Ecodesign regulation.

Instead, with the proposal for a revised Energy Labelling, the electric solutions and carbon-neutral fuel solutions will be favoured over the fossil fuel space heating solutions. This is in line with the EU policy objectives. Whether or not it is in the financial interest of the individual consumers is difficult to say. It can be expected that mass production of the carbon neutral solutions will lower acquisition costs, including more efficiency and know-how with installers.

However, the development of energy tariffs is more difficult to predict. The transition to a carbon-free economy in 2050 is likely cause extra societal costs of trillions rather than billions of euros in wind turbines, solar collectors, storage, etc.. Especially given the social unrest (*'gilets jaunes'*, fuel poverty, and social politics in general) it is not clear whether and how Member States will finance such a transition and thus also not who will pay what amount of the bill at what time.

Verification tolerances

The ECOtest-project has made and will be making a vital contribution to responsible regulation, which is utterly impossible without having a clearly defined and realistic repeatability and reproducibility of the rules in legislation. For legal disputes on Ecodesign and Energy Labelling, the funding of this type of large inter-laboratory research is essential for the credibility, efficiency and effectiveness of the Ecodesign and Energy Labelling legislation.

It is difficult to translate credibility into monetary costs. But the wide reproducibility tolerances on certain heat generators are an important signal to all market actors. Markets and decision makers should be aware that there may be differences, even in fully standardised conditions, of up to 10% between the measurements of reputable and fully accredited test laboratories on the exact same product, despite the fact that each test sequence in a lab takes weeks and costs over € 10 000 per product.

In terms of money it means that a consumer may be saving 10% less than what is on the label and that he or she knows that this is the uncertainty margin.

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[76] Yungjin Kim, Nobuyuki Kawahara, Kazuya Tsuboi, Eiji Tomita, *Combustion characteristics and NOX emissions of biogas fuels with various CO2 contents in a micro co-generation spark-ignition engine*, Applied Energy, Volume 182, 15 November 2016, Pages 539-547

[77] Meaning the manufacturer only assumes liability when used with lower calorific gas.

Third-party conformity assessment

What goes for the verification tolerances also goes for third-party conformity assessment. The only difference, and potentially much more damaging for the credibility of minimum requirements and energy label ratings, is circumvention ('cheating') the possibility of which is reduced when tests are performed by accredited laboratories.

This is not to say that there is more circumvention in the boiler- and water heater industry than elsewhere, but the products are usually responsible for the largest part of the energy bill and the purchase decision is very often determined by energy saving and payback criteria where circumvention could have a decisive influence. Furthermore, energy labelling is often the basis for financial incentives by public institutions and must be reliable.

For the producers, third-party conformity assessment creates a more level playing field especially for EU-manufactured vis-á-vis extra-EU products. Disadvantages are higher costs, longer time-to-market for manufacturers and the likely need for an expansion of laboratory capacity.

For the market surveillance authorities it is a considerable advantage to be able to rely on accredited laboratory's reports and cut down on their own spot checks.

Extension of product scope to 1 MW

As mentioned in section 2, the extension of the product scope to fuel boilers up to 1 MW (1000 kW) means adding an extra 15% of energy to the scope and possibly a 15% extra energy saving. The market of boilers between 400 and 1000 kW is not very transparent, but there is anecdotal evidence that many of the >400 kW boilers in the cellar or ground floor of flats, public buildings, etc. are in fact old, atmospheric boilers that are very inefficient. Very often there is a case of split incentives, i.e. where the designated investor is not the one paying the energy bill and not allowed to recuperate the investment in another way (e.g. higher rent). In public buildings (administrative, schools, etc.) there is simply no budget for these large, once-every-25-year-investment sums and it is much easier to keep repairing the old boiler. The EPBD does require periodic control of larger heating systems, but cannot enforce replacement by more efficient alternatives.

Shared chimney problem

Recital 12 of Regulation (EU) 813/2013 mentions almost 5 million dwellings using B1 type boilers in shared flue situations. At a product life of 20-25 years this means that annually 0.2 to 0.25 million units should be sold. In reality, after the implementation of the minimum Ecodesign limit in 2016, at least 0.45 million non-condensing gas-fired boilers were sold. Apart from B1-boilers, this could be sales of non-condensing boilers that were still on stock at the time of the Ecodesign ban. But industry sources confirm that 2017 figures are not very different, meaning that at least 0.2 million non-condensing boilers are sold in situations where they did not replace a B1-boiler. This is around 4% of gas-fired boiler sales in 2016/2017 where the building owners have saved money by not investing in chimney renovation but building inhabitants miss out on around 10% of energy saving.

By restricting the B1-exemption to a maximum capacity to 10 kW also for combi-boilers, i.e. forcing to take a storage combi or separate water heater, it is expected to discourage the misuse of the B1-exemption and keep the misuse below 0.1 million units per year.

This means that non-condensing gas boiler sales should stay below 0.3-0.35 million in the future.

The Task 2 report for space/combination heaters states in section 3.2.1 the price of storage combis is double the price of simpler instantaneous combis (street price, incl. VAT: € 2430/unit). This price increase (above standard combi) is close to the costs of alternative options like chimney renewal (costs per connected boiler: 1250 euro) which can be recuperated in almost half of the boiler life.

Stakeholders expressed mixed opinions. ECO-EEB welcomes the attempt to close the loophole, but most other stakeholders (EHI, ANEC-BEUC, UIPI, Marcogaz, Croatia) expect difficulties for apartment-owners to replace their old boiler by a storage boiler.

Since September 2015 the non-condensing C4/C8 cannot be sold anymore. Stakeholders concerned over replacing C4 (and C8) type boilers mention some 200 000 to 300 000 units in Germany [78], some 100 000 units in Croatia (half of them in Zagreb alone) and possibly similar numbers in countries like Slovenia, Hungary, Bulgaria, Romania and several other former Mid-Eastern European countries. It is estimated that between 0.5 to 1 million C4/C8 boilers are installed in the EU 28.

The boilers are typically installed in multi-family, multi-storey buildings that may not even be that old: comments from the Croatian government suggest that the typical age of buildings in which this system is applied, is 10-15 years. When these dwellings were erected, the closed C4 boiler was preferred over the open B1 type.

As the operating life of non-condensing boilers can be between 15 to 25 years, it is expected that, at least in Croatia, the number of problematic replacements will grow (up to 100 000 units in Croatia) in the coming 5 to 10 years (up to 2025 indicatively).

Not giving an exemption for C4/C8 boilers means that —with an important subsidy from their governments— the 0.5 to 1 million C4/C8 boiler owners have to invest 0.68 to 1.25 billion euros in chimney-renovation over the next 10 years. This means 68 to 125 million euros per year.

The cost of adding C4/C8 boilers to the exemption is zero for administrations. For homeowners, the picture is less clear. Acquisition costs will be somewhat similar (Task 2 explains that costs of condensing and non-condensing boilers are similar), which leaves costs related to missed energy savings and avoided costs for chimney renewal. Missed energy savings are close to 23% according to data presented in Task 5 (based on 7480 kWh/a space heating demand and 88% or 74% annual efficiency) or some 3 000 euro over product life. Chimney renewal costs are an estimated 1250 euro per connected boiler. Chimney renewal can thus be recovered in roughly half the boiler lifetime, but other options may be less expensive.

Improving enforcement (sales of 'B1' boilers beyond intended application in existing collective chimney systems is prohibited) is actually not an Ecodesign/labelling option as it is already required by the existing regulation. The only change would be to award higher budgets to enforcement activities related to sales and commissioning of boilers.

[78] J.Schuberth, Dr.A.Wachau, Gasetagenheizungen der Arten C4, C8 und B3 –Alternativen bei der Erneuerung von mehrfachbelegten Abgasanlagen, energie | wasser-praxis 6/7 2018.

Other options (other than repair and use of 'unapproved' chimney-boiler combinations) focus on chimney renewal or complete replacement of individual boilers by collective systems and/or all-electric systems. Prices range from relatively low (repair) to considerably high (replacement by a more efficient collective heater, combined with a building energy performance upgrade to lower annual heat demand).

As mentioned elsewhere in this report, this is a necessity not just for condensing natural gas-fired boilers but also to make the shared chimneys ready for hydrogen-fired boilers in a carbon-neutral future.

6.3 Options for single appliances

Heat pumps

There are three options proposed for improvement of heat pump regulations:

1. Higher test temperatures for standard heat pumps

It is proposed to conduct the testing for standard (nominal 47/55 °C return/feed temperature) heat pumps at the EN 14825 High Temperature (nominal 55/65 °C) regime, because this is more appropriate for the average situation where these heat pumps are used and results in a more realistic (on average 15% lower) SCOP, according to various surveys.

The most important impact is that people gain more confidence in the energy consumption figures when heat pumps are used, especially in existing buildings. It also puts into evidence that optimising the combination of heat load, emitter capacity and hydraulic controls represents a significant saving potential. If the regulations keep showing unrealistically high SCOP values, this potential will never be tackled and consumers will risk being disappointed on heat pump performance in existing buildings[79] and possibly also in new buildings[80].

An added advantage of testing heat pumps at high temperature is that it can be aligned with the newly proposed boiler testing, i.e. at the same feed/return temperatures for a similar part load. This, in turn, facilitates the testing of hybrid packages (heat pump and boiler) through the separate method.

2. Dynamic testing

Another design option is the German UBA/BAM proposal for dynamic testing, i.e. not at manufacturer-declared (compressor speed) settings per test point but by finding part-load and return/feed temperatures using the product controls.

Reportedly, the time needed for a dynamic test is only 2-3 days compared to 4-6 days for testing according to EN 14825.[81] First feedback from experts seems positive (to be continued). Some appliances are rated lower while others are rated close to the declared value. The differences can be assigned to the individual influence of each unit’s control

[79] Example (in Dutch): https://www.vakbladwarmtepompen.nl/projecten/artikel/2019/03/warmtepompgebruiker-bij-radar-wat-ging-er-mis-1014414\

[80] In the Netherlands it is reported that heat pump sales are stagnating and that 75% of new dwellings choose a gas-fired condensing boiler, i.e. a solution that has been around since 1981 in the Netherlands.

[81] Information André Wachau, BAM. March 2019.

which is active during the alternative test (unfixed compressor, normal operation) but inactive during standard tests (fixed compressor, abnormal operation). Thus, the alternative method allows to distinguish better between efficient and less efficient appliances. It is important to note that a number of appliances does not drop in efficiency when measured with the alternative method, indicating that already today appliances with efficient controls are on the market. Also BAM stresses that enough time should be given in the revised regulation for market actors (industry, MSAs) to get accustomed with the new method. BAM will continue testing and delivering test data to firm up their proposal.

3. Seasonal efficiency on the label

Last but not least, it is proposed —also for boilers— to publish the seasonal efficiency number(s) on the Energy Label to clearly indicate the difference between low and high temperature heat pump applications and not just the (corrected) label rating. This gives the consumer a clearer idea of the efficiency difference they can expect depending on emitter capacity versus heat load.

Conclusion

All of the heat pump design options are proposed to make the outcomes of heat pump efficiency more realistic and the consumer better informed, which initially may mean that the published seasonal efficiency will drop but on the long run also means that the products will be improved as regards the issues mentioned above.

Quantitatively it is aimed that the heat pumps will become 15-20% more efficient in practice, especially in existing housing and also in a hybrid configuration with boilers.

Boiler

The proposal is to test (or at least calculate) the fuel boiler at the same test conditions as the high temperature and low temperature heat pump in terms of return/feed temperatures but with an oversize factor for the part load ratio (PLR).

It is assumed that for a boiler, not being dependent on source temperatures, it is enough to make 4 actual tests at the extremes of PLR and system temperatures for the Average climate:

- 51/61 °C and 29/34 °C at PLR=Osize*88%
- 22/32 °C and 19/24 °C at PLR=Osize*15%

The other test points could be derived from inter-/extrapolation from these points. Also, extra tests at intermediate conditions can be used if the manufacturer desires.

Compared to today, the testing costs will double, i.e. from €2000-2500 to €4000-5000, but will still be half of those of a heat pump and have an insignificant impact on the price of a boiler.

The effect is a more realistic boiler efficiency, i.e. with condensing behaviour that can be expected in real-life.

The objective is more transparency and realistic data for the consumer as well as an extra stimulus to deal efficiently with very low part loads. The latter may give savings in the order of 2-3%.

The added advantage of testing boilers at the same feed/return temperatures for a similar part load is that it facilitates the testing of hybrid packages (heat pump and boiler) through the separate method.

Micro-CHP

It is proposed to use a calculation method that on one hand is consistent with the principles of the CHP-calculation in the Energy Efficiency Directive but on the other hand recognizes some special characteristics of mCHP as a key instrument for distributed (local) electricity generation with waste heat energy use. The first enhances the credibility of the efficiency numbers and facilitates the incorporation of e.g. financial incentives in the National Energy Efficiency Action Plans (NEEAPs). The second ensures that the efficiency accounting for mCHP will not be negatively affected by an increasing share of renewables in electricity generation.

There will be no immediate impact in terms of costs and benefits for the consumer, but overall the measure will increase the effectiveness and efficiency of the regulation.

The main barrier in developing the mCHP market in the EU is not with the efficiency numbers but with the capital costs.

6.4 Options for packages

Temperature controls

Change F(1) to a default of -8%. This takes into account an average suboptimal flowrate control and hydraulic balancing and leaves room for future improvement. There are relative minor improvements as suggested by EUBac.

Overall this may lead to a 2% efficiency improvement, indirectly to new measures outside the scope of the Ecodesign and Energy Label regulations.

Hybrid with preferential heat pump and boiler

A separate method is discussed that builds on the adjustments made in test conditions for heat pumps and boilers and the bin-method. The Tbiv and TOL determine the relative share of both heat generators. This separate method should be a considerable improvement over the current method, leading to a more realistic estimate of the overall efficiency which will probably be significantly —around 10%— higher than the current method, based on look-up tables 5 and 6. The separate method will probably allow lower testing costs if existing components are used.

The same, i.e. the more realistic and higher efficiency, can also be expected for a combined method, where the complete hybrid is tested as a whole. In that case the testing costs will be similar to that of a single heat pump; Preferably dynamic testing applies (once the test method is sufficiently developed).

Hybrid with preferential boiler and heat pump

The situation of a preferential fuel boiler and a supplementary heat pump is rare and only one case was found where it made sense, i.e. where a small heat pump helped the boiler efficiency to a point where a non-condensing fuel boiler could just meet the minimum Ecodesign limit. For this boiler it facilitated the application in a shared chimney to which other non/condensing boilers were connected.

6.5 Combined/separate calculation method

Using one single holistic calculation method for energy efficiency all central space heating generators would increase consistency (level playing field), efficiency, and effectiveness of the measures. It facilitates adoption in national EPB legislation because it will become clear to the local legislators that it is very close to e.g. the EN 15316-4 EPB standards. It promotes future innovation, as all combinations are possible, and facilitates a coherent maintenance of the relevant EN test standards.

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ANNEX I: DETAILED ECOTEST RESULTS

In the Annex II extended tables are given, showing an alternative calculation method for the reproducibility by multiplying de standard deviation by 2.83 and 4.00 (R1 and R2 absolute values respectively) and subsequently calculate them as percentage of the average (R1 and R2 averages). It also shows status and data processing by the labs.

- R1(abs.): The reproducibility from multiplying the standard deviation by (2,83)
- R2(abs.): The reproducibility from multiplying the standard deviation by (4,00)
- R1 (%avg) and R2 (%avg): The above reproducibility calculated as % of the average.
- Status: If the data are final or not.
- Remarks on processing of the raw data sent by the labs, where
  - A=raw data
  - B=corrected for calculation mistakes,
  - C=corrected for potential lab mistakes,
  - D=after retest for one lab,
  - E=assuming suggestions will be implemented in standards,
  - F=same data as above but without outliers/stragglers.
- w/o is without stragglers, w/o* without outliers

Table 23. Extended tables showing an alternative calculation method

	WP1-3 RRT1 (12 labs)	**gas-fired condensing combi-boiler, 20 kW (input in Hi)**						
		R1(abs.)	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*	*Stragglers and outliers*
	Seasonal space heating eff on GCV (%)	0.00	0.00	0.0%	0.0%	Final	C/E	Two stragglers
w/o	Seasonal space heating eff on GCV (%)	0.00	0.00	0.0%	0.0%	Final	F	*One new straggler*
	Full load eta4 on NCV (%)	0.00	0.00	0.0%	0.0%	Final	C/E	One straggler
w/o	Full load eta4 on NCV (%)	0.00	0.00	0.0%	0.0%	Final	F	*One new straggler*
	Part load eta1 on NCV (%)	0.00	0.00	0.0%	0.0%	Final	C/D/E	Two stragglers
	Part load eta1 on NCV (%) (w/o strag)	0.00	0.00	0.0%	0.0%	Final	F	(*)
	Hot water efficiency (%, instantaneous)	0.00	0.00	0.0%	0.0%	Final	C/E	(*)
	Standby heat loss (W heat)	0.00	0.00	0.0%	0.0%	Final	C/E	One straggler
w/o	Standby heat loss (W heat)	0.00	0.00	0.0%	0.0%	Final	F	*One new straggler*
	Standby electricity (W elec)	0.00	0.00	0.0%	0.0%	Final	C/E	Straggler not recalculated (**)
	Qelmin electricity part load (W elec)	0.00	0.00	0.0%	0.0%	Final	C/E	Straggler not recalculated (**)
	Qelmax electricity full load (W elec)	0.00	0.00	0.0%	0.0%	Final	C/E	Straggler not recalculated (**)
	NO_x weighted part load (mg/kWh)	0.00	0.00	0.0%	0.0%	Final	C/E	One straggler
w/o	NOx weighted part load (mg/kWh)	0.00	0.00	0.0%	0.0%	Final	F	*One new straggler*
	Sound power (dB)	0.00	0.00	log-scale	log-scale	Final	C/E	One straggler
w/o	Sound power (dB)	0.00	0.00	log-scale	log-scale	Final	F	(*)

	WP4 RRT1	**mCHP, Stirling, heat out (CHP+SH) 35 kW**						
		R1(abs.)	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*	*Stragglers and outliers*
	eta seasonal heating GCV(%)	7.98	11.28	7.5%	10.6%	Final	C	(*)
	eta seasonal heat on GCV(%)	7.84	11.08	7.1%	10.0%	Final	C	(*)
	NOx (during full load test) mg/kWh	45.53	64.36	94.2%	133.1 %	Final	C	One straggler
w/o	NOx (during full load test) mg/kWh	20.06	28.36	48.1%	68.0%	Final	C/F	(*)
	Pheatcapacity CHP+SH Full Load (kW)	2.38	3.36	6.8%	9.6%	Final	C	(*)
	Thermal Eff CHP+SH Full Load on NCV(%)	5.52	7.8	5.4%	7.6%	Final	C	(*)
	Electr. Eff CHP+SH Full Load on NCV(%)	0.40	0.56	14.9%	21.1%	Final	C	One straggler
w/o	Electr. Eff CHP+SH Full Load on NCV(%)	0.17	0.24	6.5%	9.2%	Final	C/F	(*)
	Equiv. Eff CHP+SH Full Load on NCV(%)	6.03	8.52	6.1%	8.7%	Final	C	(*)
	Pheatcapacity CHP Part Load (kW)	0.65	0.92	10.9%	15.4%	Final	C	One straggler

w/o	Pheatcapacity CHP Part Load (kW)	0.37	0.52	6.3%	8.8%	Final	C/F	(*)
	Thermal Eff CHP Part Load on NCV(%)	5.72	8.08	6.2%	8.8%	Final	C	(*)
	Electr. Eff CHP Part Load on NCV(%)	1.27	1.8	8.6%	12.2%	Final	C	One outlier
w/o	Electr. Eff CHP Part Load on NCV(%)	0.48	0.68	3.3%	4.6%	Final	C/F	(*)
	Equiv. Eff CHP Part Load on NCV(%)	10.07	14.24	8.1%	11.4%	Final	C	(*)
	Auxiliary electr. Cons. (in kW)	0.03	0.04	141.5 %	200.0 %	Final	C	(*)
	Standby heat loss (kW)	0.06	0.08	80.9%	114.3 %	Final	C	(*)

	WP4 RRT2	**mCHP, Fuel Cell, 700W elec (eff>35%), 960W heat (eff 56%)**						
		R1(abs.)	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*	*Stragglers and outliers*
	eta seasonal heating GCV(%)	53.20	75.20	20.8%	29.5%	Final	C	One straggler
w/o	eta seasonal heating GCV(%)	27.65	39.08	10.5%	14.9%	Final	C/F	(*)
	eta seasonal heat on(%)	53.66	75.84	20.5%	29.0%	Final	C	One straggler
w/o	eta seasonal heat on(%)	26.91	38.04	10.0%	14.1%	Final	C/F	(*)
	NOx (during part load test) mg/kWh	14.55	20.56	149.2 %	210.9 %	Final	C	(*)
	Thermal Eff CHP Part Load on NCV(%)	12.48	17.64	22.6%	31.9%	Final	C	(*)
	Electr. Eff CHP Part Load on NCV(%)	2.35	3.32	6.4%	9.1%	Final	C	(*)
	Equiv. Eff CHP Part Load on NCV(%)	53.66	75.84	20.5%	29.0%	Final	C	(*)
	Standby heat loss (kW)	0.06	0.08	283%	400%	Final	C	(*)

	WP3/4 RRT3	**mCHP, Internal combustion engine, heat out 14.7 kW, elec out 5.5 kW, fuel in 20.3 kW**						
		R1(abs.)	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*	*Stragglers and outliers*
	eta seasonal heating GCV(%)	22.05	31.16	15.3%	21.6%	Final	C	(*)
	eta seasonal space heat on (%)	21.85	30.88	14.8%	20.9%	Final	C	(*)
	Thermal Efficiency CHP nom. Load (%)	11.09	15.68	17.0%	24.1%	Final	C	One straggler
w/o	Thermal Efficiency CHP nom. Load (%)	3.59	5.08	5.4%	7.6%	Final	C/F	(*)
	Electric efficiency CHP (%)	1.67	2.36	6.2%	8.8%	Final	C	(*)
	NOx (during full load test) mg/kWh	342.71	484.40	80.0%	113.1 %	Final	C	(*)
w/o	eta_wh (%)	87.08	123.08	68.9%	97.4%	Final	C/F	(*)
w/o	AED in kWh	2601	3676	75.0%	106.0 %	Final	C/F	(*)
	AFC in GJ	26.72	37.76	62.0%	87.6%	Final	C	(*)
	note							*(*) no outliers/ stragglers*

	WP5 (4 labs)	**Gas heat pump (at nominal load, Tret 42°C, Tfeed 55°C)**						
		R1(abs.)	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*	*Stragglers and outliers*
	Nominal load							
	heating capacity	2.34	3.31	6.0%	8.5%	final	C/D/F	one Sraggler
w/o	heating capacity	0.15	0.21	0.4%	0.5%	final	F	(*)
	Cooling capacity	3.78	5.34	25.6%	36.1%	final	C/D	one outlier
w/o	Cooling capacity	3.78	5.34	26.8%	37.9%	final	F	(*)
	AEF	6.85	9.68	15.4%	21.8%	final	C/D	(*)
	GUE	0.05	0.07	3.1%	4.4%	final	C/D	(*)
	Part load A							
	heating capacity	1.66	2.35	4.8%	6.8%	final	C/D	one Straggler
w/o	heating capacity	1.66	2.35	4.8%	6.8%	final	F	(*)
	Cooling capacity	1.66	2.35	12.5%	17.6%	final	C/D	(*)
	AEF	1.66	2.35	4.1%	5.8%	final	C/D	(*)
	GUE	1.66	2.35	106.1 %	149.9 %	final	C/D	(*)
	Part load B							
	heating capacity	1.66	2.35	8.0%	11.3%	final	C/D	(*)
	Cooling capacity	1.63	2.30	21.8%	30.9%	final	C/D	(*)
	AEF	5.30	7.49	20.5%	28.9%	final	C/D	(*)
	GUE	5.30	7.49	347.0 %	490.5 %	final	C/D	one Straggler
w/o	GUE	0.04	0.05	2.4%	3.4%	final	F	(*)
	Part load C							
	Heating capacity	0.63	0.89	4.7%	6.6%	final	C/D	(*)
	Cooling capacity	0.78	1.10	19.1%	27.1%	final	C/D	(*)
	AEF	4.77	6.75	27.5%	38.8%	final	C/D	one outlier
w/o *	AEF	4.77	6.75	27.2%	38.5%	final	C/D	(*)
	GUE	0.09	0.13	6.2%	8.8%	final	F	
	Part load D							
	Heating capacity	0.84	1.18	13.8%	19.5%	final	C/D	one Straggler
w/o	Heating capacity	0.84	1.18	14.1%	19.9%	final	F	(*)
	Cooling capacity	2.09	2.96	144.8 %	204.7 %	final	C/D	one Straggler
w/o	Cooling capacity	2.09	2.96	193.8 %	273.9 %	final	F	(*)

		R1(abs.)	R2(abs.)	R1(%avg)	R2(%avg)	Status	Remarks	Stragglers and outliers
	AEF	2.09	2.96	22.8%	32.3%	final	C/D	(*)
	GUE	2.09	2.96	171.4 %	242.3 %	final	C/D	(*)
	Seasonal heating							
	SAEF	2.66	3.76	12.9%	18.2%	final	C/D	(*)
	SGUE	0.06	0.08	4.0%	5.6%	final	C/D	(*)
	SPER	0.04	0.06	3.2%	4.6%	final	C/D	(*)
	ETASon	4.25	6.01	3.4%	4.8%	final	C/D	(*)
	etas	8.19	11.58	6.8%	9.6%	final	C/D	(*)
	Domestic hot water							
	Qgas	8.20	11.60	38.1%	53.9%	not final		
w/o	Qgas	4.22	5.96	18.5%	26.1%	not final		
	Q elec	8.92	12.61	312.0 %	441.0 %	not final		
w/o	Q elec	0.34	0.48	26.6%	37.6%	not final		
	etawh	32.74	46.28	48.1%	68.0%	not final		
w/o	etawh	13.53	19.12	18.4%	26.0%	not final		

	WP6 (9 labs)	**Oil-fired condensing boiler, 20 kW**						
		R1(abs.)	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*	*Stragglers and outliers*
	Full load eta4 on NCV (%)	3.06	4.32	3.2%	4.5%	Final	A	One straggler
w/o	Full load eta4 on NCV (%) Straggler Removed	2.66	3.76	2.7%	3.9%	Final	A, F	(*)
	Part load eta1 on NCV (%)	3.34	4.72	3.3%	4.6%	Final	D	(*)
	Part load eta1 on NCV (%) corrections for return T and humidity applied	3.06	4.32	3.0%	4.2%	Final	D,B	(*)
	Standby heat loss (W heat)	49.30	69.68	46.1%	65.1%	Final	A	One outlier
w/o	Standby heat loss (W heat) outlier removed	37.64	53.20	36.5%	51.7%	Final	A,F	(*)
	Qelmax Electricity Full load (W elec)	18.00	25.44	9.1%	12.9%	Final	A	One outlier
w/o	Qelmax Electricity Full load (W elec) Outlier removed	12.06	17.04	6.2%	8.7%	Final	A,F	One new straggler
	Qelmin Electricity Part load (W elec)	12.71	17.96	19.5%	27.6%	Final	A	One outlier
w/o	Qelmin Electricity Part load (W elec) Outlier removed	10.05	14.20	15.7%	22.2%	Final	A,F	(*)
	Standby electricity (W elec)	1.98	2.80	116.5 %	164.7 %	Final	A	(*)
	Etas seasonal heating (% GCV)	2.49	3.52	2.8%	3.9%	Final	B	(*)
	NOx full load test (mg/kWh)	33.11	46.80	16.4%	23.2%	Final	A	One outlier

	WP7 (7 labs) RRT1	**Heat pump RRT1**						
		R1(abs.)	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*	*Stragglers and outliers*
	eta seasonal space heat (%)	21.94	31.01	14.0%	19.8%	Not final	B	(*)
	SCOPon	0.57	0.80	13.9%	19.7%	Not final	B	(*)
	SCOPnet	0.57	0.80	14.0%	19.8%	Not final	B	(*)
	Thermostat off (kW)	0.06	0.08	283%	400%	Not final	B	(*)
	Standby power (kW)	0.03	0.04	142%	200%	Final	B	(*)
	Crankcase heater power (kW)	0.03	0.04	283%	400%	Not final	B	(*)
	Off-mode (kW)	0.03	0.04	142%	200%	Final	B	(*)
	Rated COP PLR 100%, -10°C	0.23	0.32	5.0%	7.0%	Final	B	(*)
	A. COPd PLR 88%, -7°C	0.28	0.40	10.6%	15.0%	Final	B	one outlier
w/o *	A. COPd PLR 88%, -7°C	0.13	0.19	4.9%	6.9%	Final	F	(*)
	B. COPd PLR 54%, 2°C	0.34	0.48	8.4%	11.9%	Final	A	one straggler
w/o	B. COPd PLR 54%, 2°C	0.20	0.29	5.1%	7.2%	Final	F	(*)
	C. COPd PLR 35%, 7°C	1.33	1.88	25.4%	35.9%	Final	A	one outlier
w/o *	C. COPd PLR 35%, 7°C	0.46	0.65	8.6%	12.1%	Final	F	one new straggler
	D. COPd PLR 15%, 12°C	0.31	0.44	4.5%	6.3%	Final	A	one straggler
w/o	D. COPd PLR 15%, 12°C	0.16	0.23	2.3%	3.3%	Final	F	(*)
	Rated Cap. PLR 100%, -10°C	0.79	1.12	6.4%	9.0%	Final	B	(*)
	A. Cap. (kW) PLR 88%, -7°C	0.96	1.36	8.8%	12.5%	Final	A	one outlier
w/o *	A. Cap. (kW) PLR 88%, -7°C	0.47	0.66	4.4%	6.2%	Final	F	(*)
	B. Cap. (kW) PLR 54%, 2°C	1.47	2.08	19.1%	27.0%	Final	A	one outlier
w/o *	B. Cap. (kW) PLR 54%, 2°C	0.77	1.08	10.2%	14.4%	Final	F	one new straggler
	C. Cap. (kW) PLR 35%, 7°C	3.08	4.36	34.2%	48.3%	Final	A	one straggler

w/o	C. Cap. (kW) PLR 35%, 7°C	1.71	2.41	18.2%	25.7%	Final	F	one new outlier
	D. Cap. (kW) PLR 15%, 12°C	1.70	2.40	15.8%	22.3%	Final	A	one outlier
w/o *	D. Cap. (kW) PLR 15%, 12°C	0.45	0.64	4.3%	6.0%	Final	F	one new straggler
	Sound power (dB) @ 20%	5.81	8.22	8.6%	12.1%	Not final	A	(*)

Note 1: Why COPd was chosen because it shows the directly measured value without the influence of the degradation factor, which can be seen from e.g. the SCOP value

Note 2: For the statistical evaluation shown here, only the values from the tests which were used for the calculation of the eta_s were used. Repeated tests were omitted.

	WP7 (5 labs) RRT2	**Heat pump RRT2**						
		R1(abs.)	R2(abs.)	R1(%avg)	R2(%avg)	Status	Remarks	Stragglers and outliers
	eta seasonal space heat (%)	36.74	51.93	0.20	0.28	Not final	B	(*)
	SCOPon	0.32	0.46	0.07	0.09	Final	A	(*)
	SCOP	0.73	1.03	0.15	0.22	Final	A	(*)
	Thermostat off (kW)	0.25	0.36	2.75	3.89	Not final	B	(*)
	Standby power (kW)	0.19	0.27	1.72	2.43	Not final	B	(*)
	Crankcase heater power (kW)	0.23	0.33	3.49	4.93	Not final	A	(*)
	Off-mode (kW)	0.25	0.36	3.76	5.31	Not final	A	(*)
	Rated COP@ W10/W55-47	0.11	0.15	0.03	0.04	Final	A	(*)
	A. COPbin PLR 88%, -7°C (interpolation)	0.13	0.18	0.03	0.05	Final	B	(*)
	B. COPd PLR 54%, 2°C	0.19	0.27	0.04	0.05	Final	B	(*)
	C. COPd PLR 35%, 7°C	0.19	0.27	0.03	0.05	Final	A	(*)
	D. COPd PLR 15%, 12°C	0.25	0.35	0.04	0.05	Final	A	(*)
	Rated Cap. (kW) @ W10/W55-47	0.50	0.71	0.02	0.02	Final	A	(*)
	A. Cap. (kW) PLR 88%, -7°C (interpolation)	1.50	2.12	0.05	0.07	Final	A	one outlier
w/o *	A. Cap. (kW) PLR 88%, -7°C	0.17	0.24	0.01	0.01	Final	F	one new outlier
	B. Cap. (kW) PLR 54%, 2°C	1.02	1.44	0.06	0.09	Final	A	(*)
	C. Cap. (kW) PLR 35%, 7°C	0.54	0.77	0.03	0.04	Final	B	(*)
	D. Cap. (kW) PLR 15%, 12°C	0.48	0.67	0.03	0.04	Final	B	(*)
	Rated Input (kW) @ W10/W55-47	0.23	0.33	0.03	0.04	Final	A	(*)
	A. Input (kW) PLR 88%, -7°C (interpolation)	0.55	0.78	0.08	0.11	Final	B	one straggler
w/o	A. Input (kW) PLR 88%, -7°C	0.14	0.20	0.02	0.03	Final	F	(*)
	B. Input (kW) PLR 54%, 2°C	0.16	0.23	0.05	0.07	Final	A	one straggler
w/o	B. Input (kW) PLR 54%, 2°C	0.06	0.09	0.02	0.03	Final	F	one new outlier
	C. Input (kW) PLR 35%, 7°C	0.04	0.05	0.01	0.02	Final	A	(*)
	D. Input (kW) PLR 15%, 12°C	0.05	0.07	0.02	0.02	Final	A	(*)

Note 1: Seasonal efficiency values as well as PLR A were evaluated for 4 laboratories, since one did not follow the exact procedure. However, results for PLR B, C, D and non-active modes were valid and included.
Note 2: For PLR A, an interpolation was needed. Therefore, COPbin is provided instead of COPd as for other PLRs.

	WP7 (5 labs) RRT4	**Hybrid of el. heat pump(2kW at 7A/35W) and 23 kW gas boiler; declared package capacity 7 kW.**						
		R1(abs.)	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*	*Stragglers and outliers*
	Separated method							
	eta seasonal space heat (%)	8.74	12.35	9.1%	12.9%	Not final	B	one outlier
w/o *	eta seasonal space heat (%)	2.27	3.21	2.3%	3.3%	Not final	F	(*)
	SCOPon	0.21	0.30	8.7%	12.4%	Not final	B	(*)
	SCOP	0.23	0.33	9.5%	13.5%	Not final	B	(*)
	Thermostat off (kW)	0.00	0.00	83.1%	117.5%	Not final	B	(*)
	Standby power (kW)	0.00	0.00	119.6%	169.1%	Final	B	one outlier
w/o *	Standby power (kW)	0.00	0.00	0.0%	0.0%	Final	F	(*)
	Crankcase heater power (kW)	0.00	0.00	387.5%	547.7%	Not final	A	(*)
	Off-mode (kW)	0.00	0.00	173.3%	245.0%	Final	B	one straggler
w/o	Off-mode (kW)	0.00	0.00	65.4%	92.5%	Final	F	(*)
	Rated COP 100%, 7°C	0.08	0.11	3.9%	5.5%	Final	A	one outlier
w/o *	Rated COP 100%, 7°C	0.02	0.02	0.9%	1.2%	Final	F	(*)
	C. COPd PLR 35%, 7°C	0.24	0.34	8.1%	11.5%	Final	B	one outlier

w/o *	C. COPd PLR 35%, 7°C	0.07	0.10	2.5%	3.5%	Final	F	(*)
	D. COPd PLR 15%, 12°C	0.52	0.73	15.2%	21.5%	Final	B	one straggler
w/o	D. COPd PLR 15%, 12°C	0.27	0.38	7.6%	10.8%	Final	F	(*)
	Combined method							
	eta seasonal space heat (%)	21.67	30.63	21.8%	30.8%	Not final	B	one straggler
w/o	eta seasonal space heat (%)	8.53	12.05	8.9%	12.5%	Not final	F	one new straggler
	SCOPon	0.54	0.76	21.0%	29.6%	Not final	B	one straggler
w/o	SCOPon	0.20	0.28	7.9%	11.1%	Not final	F	(*)
	SCOP	0.54	0.77	21.2%	29.9%	Not final	A	one straggler
w/o	SCOP	0.21	0.30	8.6%	12.2%	Not final	F	(*)
	Thermostat off (kW)	0.00	0.00	82.5%	116.7%	Not final	B	(*)
	Standby power (kW)	0.00	0.00	119.5%	168.9%	Final	B	one outlier
w/o *	Standby power (kW)	0.00	0.00	2.1%	3.0%	Final	F	one new outlier (negligible)
	Crankcase heater power (kW)	0.00	0.00	387.5%	547.7%	Not final	B	(*)
	Off-mode (kW)	0.00	0.00	182.2%	257.5%	Final	B	(*)
	A. COPd PLR 88%, -7°C	0.30	0.43	12.6%	17.8%	Final	B	(*)
	B. COPd PLR 54%, 2°C	0.43	0.60	17.1%	24.2%	Final	B	(*)
	C. COPd PLR 35%, 7°C	0.79	1.12	28.6%	40.4%	Final	B	(*)
	D. COPd PLR 15%, 12°C	0.56	0.79	16.3%	23.1%	Final	A	(*)
	E. COPd PLR XX%, 4°C	0.46	0.65	18.9%	26.8%	Final	B	one straggler
w/o	E. COPd PLR XX%, 4°C	0.18	0.25	7.2%	10.2%	Final	F	one new outlier
	F. COPd PLR XX%, 9°C	0.19	0.27	6.0%	8.4%	Final	A	one straggler
w/o	F. COPd PLR XX%, 9°C	0.07	0.10	2.1%	2.9%	Final	F	one new straggler (negligible)
	COPd PLR 100%, -10°C	0.33	0.46	13.2%	18.6%	Final	B	(*)

Note 1: Combined method, COP_d for PLR E and at -10°C were measured only by four laboratories.

Note 2: The test procedures were not followed 100% by all labs, especially for the combined method. This has to be taken into account when using the figures.

WP8 (3 labs) RRT1	*R1(abs.)*	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*
eta0,hemisphere	0.08	0.00	11.3%	0.0%	Final	A
eta0,beam irradiance	0.14	0.00	19.2%	0.0%	Final	A
Kd diffuse IAM solar	0.50	0.00	54.4%	0.0%	Final	A
IAM (50 o)	0.36	0.00	38.7%	0.0%	Final	A
IAM	0.36	0.00	37.5%	0.0%	Final	A
heat loss coefficient a1 (W/m2K)	0.84	0.00	22.3%	0.0%	Final	A
a2=temp. dependence a1 (W/m2K2)	0.03	0.00	272.7%	0.0%	Final	A
Effective thermal cap. a5 (W/m2K)	12996.00	0.00	147.8%	0.0%	Final	B
Collector area A_{sol}	0.00	0.00	0.0%	0.0%	Final	A
Collector efficiency ηCol	24.00	0.00	42.1%	0.0%	Final	A
Annual gross yield for Athens 25°	120.00	0.00	4.0%	0.0%	Final	A

WP8 (3 labs) RRT2	*R1(abs.)*	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*
Nominal volume (L)	36.00	0.00	8.9%	0.0%	Final	E
Effective volume (L)	120.00	0.00	30.2%	0.0%	Final	C
Auxiliary heated volume (L)	88.92	0.00	69.5%	0.0%	Final	C
Standby heat loss UA (W/K)	2.08	0.00	76.3%	0.0%	Final	A
Heat transfer cap solar to store (W/K)	304.56	0.00	64.7%	0.0%	Final	A
Heat transfer cap aux to store (W/K)	110.12	0.00	28.5%	0.0%	Final	A
Standing loss S @Ts=65, Ta=20°C (W)	95.64	0.00	78.1%	0.0%	Final	A

WP8 (3 labs) RRT3	*R1(abs.)*	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*
Nominal volume (L)	156.60	0.00	19.2%	0.0%	Final	A
Effective volume (L)	1036.80	0.00	138.4%	0.0%	Final	A
Auxiliary heated volume (L)	363.84	0.00	111.5%	0.0%	Final	A
Standby heat loss UA (W/K)	2.40	0.00	70.8%	0.0%	Final	A
Heat transfer cap solar to store (W/K)	6224.04	0.00	449.1%	0.0%	Final	A

Heat transfer cap aux to store (W/K)	8892.00	0.00	463.4%	0.0%	Final	A
Effective thermal cap (kJ/K)	4392.48	0.00	141.0%	0.0%	Final	A
Standing loss S @Ts=65, Ta=20°C (W)	105.71	0.00	69.2%	0.0%	Final	A

WP8 (3 labs) RRT4	*R1(abs.)*	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*
Effective surface Aeff (m2)	2.45	0.00	70.7%	0.0%	Final	B
Collector loss coeff. Uc (Wm2/K)	41.88	0.00	440.2%	0.0%	Final	B
Store heat loss coefficient Us	14.81	0.00	482.3%	0.0%	Final	B
Heat store capacity Cs (MJ/K)	0.92	0.00	61.0%	0.0%	Final	B
Aux heat store fraction faux	0.62	0.00	138.7%	0.0%	Final	B
Mixing constant Dl	0.67	0.00	1178.9%	0.0%	Final	B
Auxiliary Electricity QAux	214.44	0.00	174.8%	0.0%	Final	B
Qnonsol Avg, M	1791.60	0.00	315.0%	0.0%	Final	B
Qnonsol Avg, L, XL, XXL	-	-				

WP8 (3 labs) RRT5	*R1(abs.)*	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*
SOLCAL 2013 non-solar contribution						
Tapping pattern M (kWh/a)	645.36	0.00	59.1%	0.0%	Final	A
Tapping pattern L (kWh/a)	533.52	0.00	34.9%	0.0%	Final	A
Tapping pattern XL (kWh/a)	647.76	0.00	25.3%	0.0%	Final	A
Tapping pattern XXL (kWh/a)	764.28	0.00	21.9%	0.0%	Final	A
SOLCAL 2017 non-solar contribution						
Tapping pattern M (kWh/a)	210.24	0.00	46.0%	0.0%	Final	A
Tapping pattern L (kWh/a)	435.48	0.00	42.3%	0.0%	Final	A
Tapping pattern XL (kWh/a)	817.92	0.00	38.4%	0.0%	Final	A
Tapping pattern XXL (kWh/a)	977.52	0.00	31.6%	0.0%	Final	A
SOLTHERM non-solar contribution						
Tapping pattern M (kWh/a)	59.16	0.00	9.7%	0.0%	Final	B
Tapping pattern L (kWh/a)	168.00	0.00	13.5%	0.0%	Final	B
Tapping pattern XL (kWh/a)	235.20	0.00	10.3%	0.0%	Final	B
Tapping pattern XXL (kWh/a)	150.96	0.00	4.7%	0.0%	Final	B

WP8 (3 labs) RRT6	*R1(abs.)*	*R2(abs.)*	*R1(%avg)*	*R2(%avg)*	*Status*	*Remarks*
SOLCAL 2013 non-solar contribution						
Tapping pattern M (kWh/a)	740.40	0.00	58.2%	0.0%	Final	B
Tapping pattern L (kWh/a)	607.20	0.00	40.3%	0.0%	Final	B
Tapping pattern XL (kWh/a)	781.20	0.00	42.4%	0.0%	Final	B
Tapping pattern XXL (kWh/a)	1324.80	0.00	60.7%	0.0%	Final	B
SOLCAL 2017 non-solar contribution						
Tapping pattern M (kWh/a)	73.20	0.00	47.5%	0.0%	Final	B
Tapping pattern L (kWh/a)	459.60	0.00	89.2%	0.0%	Final	B
Tapping pattern XL (kWh/a)	994.80	0.00	91.3%	0.0%	Final	B
Tapping pattern XXL (kWh/a)	1530.00	0.00	97.3%	0.0%	Final	B
SOLTHERM non-solar contribution						
Tapping pattern M (kWh/a)	1795.20	0.00	157.9%	0.0%	Final	B
Tapping pattern L (kWh/a)	2378.40	0.00	126.7%	0.0%	Final	B
Tapping pattern XL (kWh/a)	2631.60	0.00	92.9%	0.0%	Final	B
Tapping pattern XXL (kWh/a)	3786.00	0.00	104.8%	0.0%	Final	B
Auxiliary Electricity QAux pattern M (kWh/a)	229.20	0.00	214.2%	0.0%	Final	B

ANNEX II: SHARED CHIMNEY OPTIONS

In the current regulation B1-type gas boilers with a rated heat output up to 30 kW for combination boilers and 10 kW for (solo-) boilers have to meet a less stringent Ecodesign requirement. This exception, allowing inefficient (non-condensing) B1-boilers on the market, was introduced to deal with multi-family buildings with individual boilers per dwelling and a shared flue gas outlet ('chimney') where technical and/or economic problems were reported to install the 86% efficient (and thus usually condensing and positive pressure) boilers. However, the sales of non-condensing boilers appear to outpace the sales that could be expected from the installed base about two to one.

Additionally, Germany and several other Member States, in particular Croatia, report a similar problem with non-condensing boilers of the C4 and C8 category. Similar to type B1 boilers these boilers are connected to collective chimneys that are not condensate-resistant (made of brickwork, fire-clay, etc.) and designed to operate under negative pressure. Although the issue is comparable to that of B1 type boilers the present regulation has not introduced lower efficiency limits for such C4/C8 boilers.

The policy options identified focus on four issues:

1. Whether to allow the same exception to non-condensing C4/C8 boilers;
2. How to discourage or prevent "illegal" sales of non-condensing boilers:
    a. By limiting the attractiveness of B1 (and C4/C8) boilers by limiting their output to 10 kW;
    b. By increasing efforts for enforcement of current rules (includes inspections at building level);
3. How to reduce the overall problem of shared chimneys.

These issues are discussed in more detail below.

Include non-condensing C4/C8 category boilers

Following the rationale set out for B1 category boilers, one could conclude that the lower energy efficiency limit should apply to C4 and C8 boilers as well, as the replacement of C4/C8 boilers is wrought with identical issues of collective chimneys designed to operate under negative pressure, requiring higher flue gas temperatures [82].

There is a risk that broadening exceptions to C4/C8 categories increases the existing loophole of unintended use of non-condensing boilers, which means that the other three recommendations (discouraging & better enforcement, and alternative solutions for

[82] Stakeholder EHI does not agree with laxer requirements for C4/C8 as "there are efficient replacement and renovation solutions available". However, C4/C8 boilers are intended to use chimneys that are part of the building structure and operate under negative pressure. Indeed there have been C4/C8 boilers that use a dedicated (non-structural) chimney but these are now referred to as C10/11/14 and C12/13 respectively (see Task 1, section 4.10.2 on flue gas systems). All these other boiler systems (C10 to C14) operate under positive pressure and are technically different to the functioning of current C4/C8 boilers. It could be that manufacturer manuals have not been updated and still refer to C4/C8 designation, even if the boiler itself operates under positive pressure.

shared chimneys) need follow-up as well. Inclusion of C4/C8 boilers does mean that those seeking replacement do not need to resort to inherently more unsafe B1 boilers.

The exception should relate to the principle for evacuation of flue gases and not whether the chimney is used collectively or not, as there are collective systems that rely on positive pressure (category C10/11/12/13).

Not giving an exemption for C4/C8 boilers means that —with an important subsidy from their governments— the 0.5 to 1 million C4/C8 boiler owners have to invest 0.68 to 1.25 billion euros in chimney-renovation over the next 10 years. This means 68 to 125 million euros per year.

Limited to 10 kW output

Task 2 reports that some 0.45 million non-condensing boilers are still sold after the entry into force of the Ecodesign requirements. This is estimated to be twice the amount of B1 replacement sales expected on the basis of the installed stock, and approximately 1.5 the amount of what could be expected when including replacement sales of non-condensing C4/C8 boilers (not allowed under current rules). As there are no real restrictions on the sale of B1-boilers (30 kW is big enough for most dwellings), it cannot be excluded that they are also used where they are not required.[83] In other words, they pose is a considerable loophole. This view is supported by ECOS-EEB.

For that reason, it is proposed to restrict the B1-exemption to boilers with a maximum capacity of 10 kW, including combi-boilers. As elaborated in Task 3, 10 kW is sufficient for heating an apartment and with a storage tank (70 L or more) it can offer a comfortable DHW solution (10 kW is not sufficient for instantaneous water heaters with load profile S or larger). The storage combi-boiler, e.g. 100x35x40 cm (h*d*w) can fit in a kitchen cabinet and thus close to the most frequently used tapping point.

The limitation to max. 10 kW is expected to discourage the misuse of the B1-exemption and keep sales of non-condensing gas boiler sales below 0.3-0.35 million.

ANEC/BEUC and several other stakeholders have expressed doubts that the loophole (using B1 in non-collective chimney applications) is used this extensively, as the prices of B1 versus modern condensing boilers are very close. As regards the proposal, they find the limitation to 10 kW to be too restrictive, especially as most consumers have few alternative options (confined space, low income). They mention the need for national governments to address the issue.

Croatia mentions that the limitation to 10 kW would introduce problems related to administrative approval of such boilers with the existing chimney as the relevant authorities can only approve the combination of boilers and chimney as prescribed in the design of the collective system, which assumes a certain temperature and volume of flue gases. Croatian experts expect that, over the course of time, the reduced flue gas volumes of the smaller capacity boilers will lead to increased problems related to condensation of flue gases in the chimney.

[83] Recital 12 of Regulation (EU) 813/2013 mentions almost 5 million dwellings using B1 type boilers in shared flue situations; in that light –even at a modest product life of say 15 years—this should give no more than 0.33 million units sales and not 0.44 million units. For a product life of 20-25 years this stock would result in 02 to 0.25 million replacement sales.

Better enforcement

The present regulation requires B1 boilers (max. 30 kW if combi) to be readily identifiable as replacement boiler in collective chimney installations by means of an Ecodesign information requirement. In case these boilers are nonetheless installed in applications for which they were not intended (i.e. new buildings[84]), this is pointing at insufficient market surveillance by building authorities (the breach of law occurs 'when put into practice').

A minor share of non-condensing boilers sold (in 2014) exceed the 30 kW threshold (are sold for commercial or industrial applications?) which is also not allowed under current regulations and requires intervention at the level of 'placing on the market'.

The technical measure of limiting the capacity of B1 (and possibly C4/C8) boilers to 10 kW may reduce the use of this loophole, but better enforcement of current rules – better market surveillance – needs to be considered as well as without this, tightening of rules may not result in the desired effect.

Member States can assess for themselves how many non-condensing boilers have been sold in 2014, in which capacity class (Task 2, Annex I, see Table 39, 40 and 45) and where, and whether this matched the expected demand of replacement sales for boilers in collective chimney systems. Table 40 in Task 2, Annex I indicates that in many countries non-condensing boilers were applied in 'New' installations in 2014. Even in 2014 most of these sales should have been avoided by adequate design of buildings and were not in spirit of the EPBD.

EPBD 2010/31/EC Article 14 introduced mandatory regular inspections of heating systems (and components) with a rated effective output of more than 20 kW. Such a regime could have served to identify inappropriate use of non-condensing boilers. However, with the EPBD recast 2018/844/EU the threshold was raised to 70 kW effective rated output and larger as *"the implementation of regular inspection schemes for heating and air-conditioning systems under Directive 2010/31/EU involved a significant administrative and financial investment by Member States and the private sector, including for the training and accreditation of experts, quality assurance and control, as well as the costs of inspections"*. Member States are allowed to keep in place existing schemes requiring inspections of 20 kW systems and larger.

Options for shared chimneys

The exception for B1 (an possibly C4/C8) boilers would not be needed if shared chimney systems for non-condensing boilers were replaced by systems that allow condensing boilers or other, efficient systems (or prolong the use of the existing chimney-boiler system). Therefore the Commission needs to engage with Member States and other stakeholders (including national chimney approval authorities) to assess technical solutions for boilers connected to collective chimneys. Possible solutions are presented in a publication by BAM and UBA[85]. Some prices were identified by Croatia and other sources. These solutions are (in no particular order):

[84] This includes new housing, 1st time use and non-housing

[85] https://netzwerke.bam.de/Netzwerke/Content/DE/Downloads/Evpg/Heizen-Kuehlen-Lueften/austausch_gasetagenheizungen_2017-01.pdf?__blob=publicationFile

1 - Repair and/or identical replacement (like-for-like)

This first option is actually not intended to remove the shared chimney but to extend its use, together with the original boiler set-up. Repair is a simple way to prolong boiler life. If repair is no option anymore, one can try to replace the defect boiler with a similar (non-condensing) boiler that has already been placed on the market. These could be boilers that have been stocked by suppliers or that have been removed from other buildings (e.g. during building renovation) and stockpiled for later use (second hand). However, in Germany such newly commissioned boilers also have to meet the present emission standards.

The costs for an identical replacement depend on whether it is a new-product (e.g. 1700 euro[86]) or a second-hand product (costs unknown). Costs for repair depend much on actual parts prices and required effort for replacement.

In the meantime preparations will have to be made to replace the non-condensing boilers and/or chimney with more efficient ones.

2 - New boiler with existing chimney

This second option is also not actually describing removal of the existing chimney. The option is in principle only possible if the chimney construction allows the combination of existing non-condensing (negative pressure) and condensing (positive pressure) appliances to the same air/flue duct. This is rarely the case as strict rules apply, and a specific flue assessment will have to be made for each case.

Replacing a non-condensing C4 boiler (not allowed under current rules) with a new non-condensing B1 boiler (allowed under current rules) is technically possible if both the original and replacement product can function with the specific chimney system. A drawback is that the B1 boiler is less safe due to its open combustion chamber, and requires adequate supply of combustion air through the space in which it is installed (with vents to draw in sufficient outside air). If the original C4 boiler was installed in an occupied space, chances are this is no longer allowed for the replacement B1 boiler. Furthermore, the former air supply via the chimney needs to be closed off. This option is not preferable as it reduces the safety of the system.

Anecdotal evidence suggests that parties sometimes use a modern condensing C4/C8 boiler as replacement, but have it running at 80/60 ºC temperature regime constantly. This way, they hope the formation of condensate is minimised (this remains to be seen, as the system temperatures and thus flue gas temperatures are determined by a host of other factors other than the max. temperature limit – see also Task 4). Still, such boilers are still likely to have lower flue gas temperatures than non-condensing boilers and are designed to operate using a positive pressure flue, whereas the existing chimney and connected boilers operate on negative pressure. Whether the addition of a positive pressure boiler can be tolerated and allowed is a matter for boiler manufacturers and chimney specialists and cannot be resolved in this report. This option is certainly <u>not</u> advocated as alternative by the German UBA/BAM without a proper chimney assessment which may prove the combination is allowed or not.

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[86] The Task 2 report mentions 1700 as average for a new condensing boilers, but also states that, given the niche market for non-condensing boilers, the difference in technology is not reflected in the prices and non-condensing boiler are relatively expensive.

The costs are that of a new boiler to which have to be added the costs for a chimney assessment (estimated total 1900 to 2100 euro per connected boiler).

A rather new development is a (closed) non-condensing boiler combined with a heat pump that uses the flue gases as heat source[87]. Although this boiler allegedly meets the efficiency threshold for "C4/C8" boilers (seasonal efficiency 86%) it still has lower flue gas temperatures than the non-condensing boiler it replaces:

- The flue gas temperature of this boiler at max/min flow at 80-60 °C regime is 95 °C/70 °C;
- The non-condensing C4/C8 boiler it replaces has flue gas temperatures of 103 °C/126 °C.

Experts state that also this 'non-condensing' boiler will likely cause condensation in the chimney as flue gases cool down to 55 °C to 65 °C.

3 - New boiler combined with renovation of collective chimney

This option includes chimney renewal, for making it suitable for connecting to condensing, positive pressure boilers. Taking the calculation example provided by Croatian experts (see download section on project website) the costs per connected boiler are estimated at:

1. Project design - 30 €/boiler
2. Renovation or replacement of chimney suitable for positive pressure and condensates - 510 € or 740 €/boiler
3. Pressure test - 40 €/boiler
4. Chimney Attest - 40 €/boiler

This results in total costs of minimum 620 € - 850 € per boiler.

The costs for a new C4/C8 (condensing) boiler plus associated works

1. New boiler with accessories: 1700 €/boiler
2. Construction work in the apartment (opening for repair of chimneys, condensate drainage pipe laying, plastering, tiling - 400 €/boiler

This results in total costs for the boiler plus associated works of 2100 €/boiler

To these are added additional costs for (the renewal of) the gas installation:

3. check of capacity of gas installation - 20 €/boiler
4. renewal of gas valve by an authorized gas installer - 80 €/boiler
5. testing and commissioning of gas installation plus certificate (performed by a gas distributor) - 50 €/boiler
6. Installation and commissioning of the new boiler including a service report- 40 €/boiler

[87] The product referred to is the SIME Uniqa (http://www.sime.it/it/it/prodotti/navmurali/uniqa/)

This results in total costs for works on gas installations of 190 €/boiler[88]

The overall costs is 2910 -3130 € per boiler, of which 1020 – 1250 € or 35-40% is directly related to chimney work and the installation of condensing appliances.

Assuming 5 million B1 boilers plus 1 million C4/C8 boilers in shared flue systems and 1250 € additional 'renovation' costs per connected boiler (the boiler costs themselves are excluded as these costs apply to the reference situation as well) the total costs of chimney renewal in the EU could be 6.2 to 7.5 billion euro, divided over several Member States.

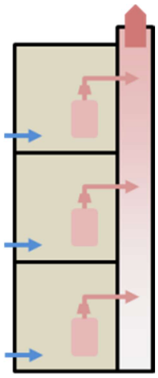
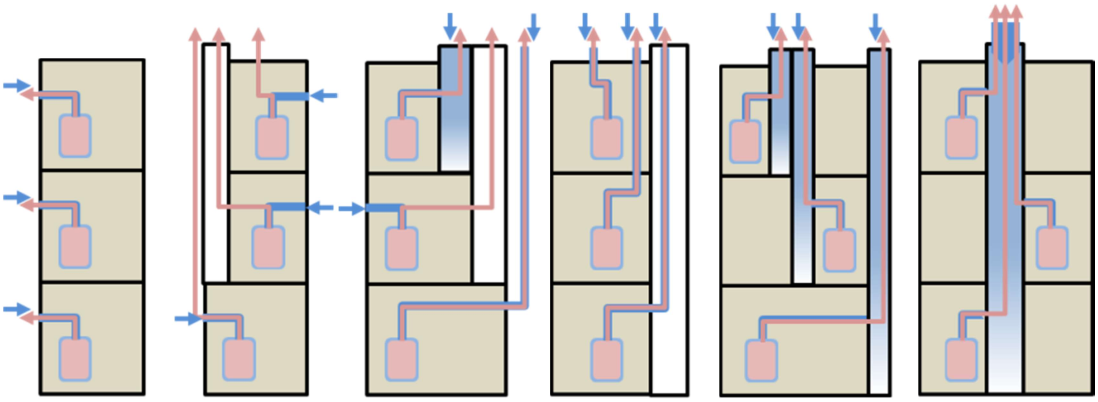
4 - Replacement by other condensing boiler type, using a different flue

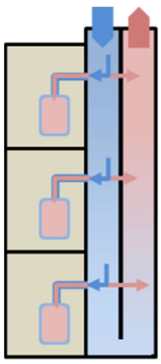
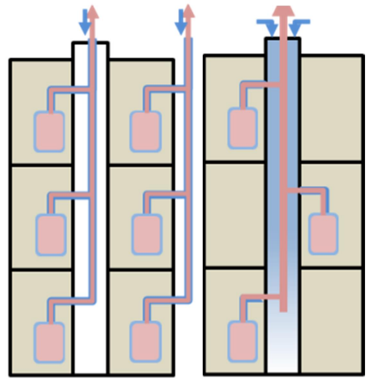
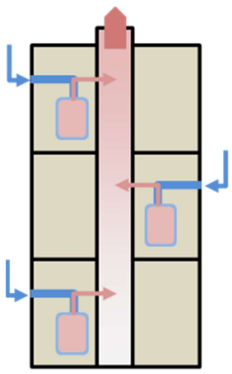
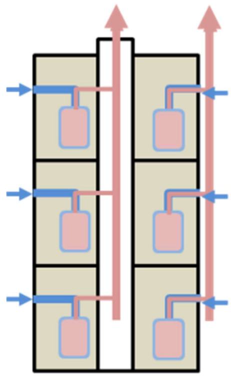
This option also describes the renewal of the flue, by various other flue categories. Depending on the specific circumstances B1, C4 or C8 boilers can be replaced by:

- C1 / C3 / C5 / C6 type boilers, if indeed a separate, individual, flue duct can be arranged;
- C(10)/C(11) and C(14) boilers, and C(12)/C(13) boilers that use a modern collective flue gas duct, that is condensate-proof and positive pressure compatible.
- An alternative to C3 are C9 and C(15) type boilers that use an existing shaft for combustion air and a flue liner (flexible or rigid) for flue gas (C9 – single flue in single shaft, C(15) – multiple flues in single shaft);

The replacement of non-condensing C4/C8 boilers by other types of boilers usually requires a complete renewal of the flue/air system and all boilers connected to it, forcing all homeowners to renew their system as well.

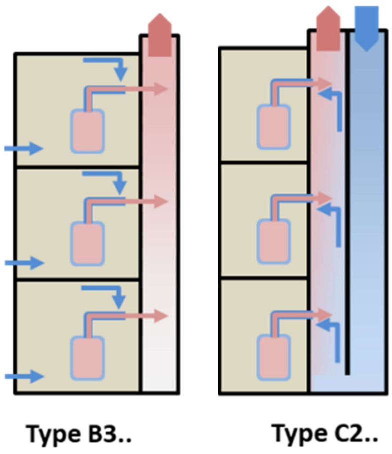
[88] Although the Croatian government mentioned these costs as part of the total costs for chimney renovation because of boiler renewal, it is not clear whether these costs have to be made each time a (gas) boiler is replaced.

	
B1	Alternatives: individual facade solution (C1), roof solution (C3), facade/roof solution (C5), various solutions (C6), using existing shafts (C9) or combing flues in single shaft (C(15))

			
C4	C(10), C(11) and C(14) alternatives	C8	C(12), C(13) alternatives

NOTE: although the figures give the impression of concentric positioning of air/flue ducts, parallel positioning is in most cases also possible.

Figure 18. B1, C4 and C8 boilers and their modern (renovation) alternatives



Technically B3 and C2 boilers also use a collective flue duct, but C2 boilers are considered obsolete and not sold anymore and the B3 boiler could be replaced by a B1, albeit at lower safety levels.

Figure 19. Category B3 and C2

5 – The C15 option (needs further investigation)

This option also includes replacement of the existing flue by types that are moisture-proof and operate under positive pressure.

An increasingly popular renovation measure for multiple boilers connected to a single chimney system is presented as C(15) where multiple flue ducts are routed through the chimney, now functioning as air supply duct. Mostly this is done for all boilers simultaneously, as such liners need careful installation (rigid systems need fixating to wall at regular intervals to avoid creation of leaks, flexible systems -as one continuous tube- may hang from the flue gas terminal).

Replacement of boilers on individual basis, where replaced boilers are disconnected from the collective flue and instead connected to individual liners inserted in the –still operational - 'collective' air or flue duct for existing boilers (see figure below), has not yet been described in TR 1749 nor approved (also not described in the UBA/BAM document). Several options are however described in Cerga News #23[89]. The parallel operation requires careful examination by chimney specialists to ensure the reduced flue area is sufficient to serve the remaining boilers and the terminals allow sufficient flow of combustion air and/or flue gases.

[89] See: www.cerga.be

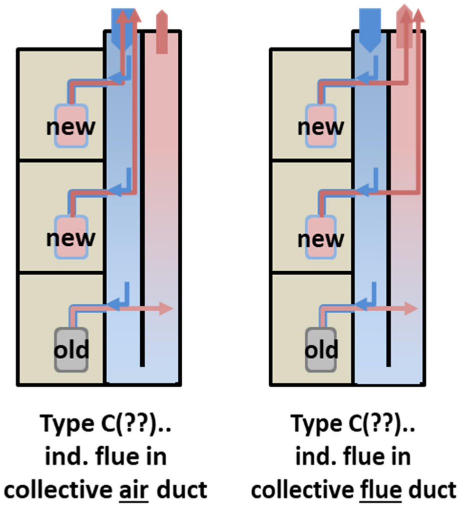


Figure 20. Parallel operation of 'old' non-condensing boiler and new condensing boilers with flue liners in a collective chimney

The costs vary depending on which solution is feasible/preferred. For guidance it is assumed that a boiler costs 1700 euro, and the air/flue duct between 620 – 850 euro, resulting in a total cost of 2320 – 2550 euro.

6 – Chimney lining

Another future-proofing option for the chimney (not described in the UBA/BAM document) is that of coating the flue walls with a condensate resistant lining (spray cast or heat forming process) to solve possible condensate problems. It requires the existing boilers to be disconnected and reconnected after lining.

In the Netherlands several buildings with collective chimney systems have their chimneys renovated using such method (tradename FuranFlex) when upgrading from low temperature boilers to condensing boilers[90]. Whether such a system allows parallel operation of non-condensing and condensing boilers on a single flue is not yet known. It may be that all boilers need to be replaced in one go as well. However, this option is (allegedly) less expensive than chimney replacement. More study is required to investigate the appropriateness of this method for the various types of installations applied in Europe.

7 – Forced extraction by flue gas fan

The low temperature of flue gases of condensing boilers connected to a collective flue system allows the flue gases to condense within the chimney. And if combined with lower capacities (e.g. max. 10 kW as suggested) the flue gas volume is lower as well, also leading to lower speed of flue gas extraction.

Flue gas fans can extract flue gases more rapidly and allow correct operation under more circumstances than chimneys using negative pressure from the stack-effect only. Fanned flues are not a novelty[91] but their application in communal flues however is not documented. Chimney specialists could make an assessment whether the addition of a

[90] See for example: https://www.easy-liner.nl/clv-rookgasafvoersystemen/

[91] See for example: https://www.rockfordchimneysupply.com/draft-and-ventilation-fans/draft-and-vent-fans

flue gas exhaust fans is would allow operation of condensing boilers in collective flue gas systems, also in parallel operation with non-condensing boilers.

8 – Collective boiler

Replacing individual boilers by a collective boiler/system (gas-fired boiler, cogeneration boiler or gas heat pumps, or electric heat pump, possibly combined with solar thermal? district heating?) may be an option if a suitable "boiler room" exists/can be realised. The changes to the building heating system (probably including DHW solution) are profound, but may also bring various benefits such as higher heating efficiencies, use of renewable energy, optional cooling, or even possible integration in district heating, etc.

In case noise or power draw from the electricity grid are problematic, the use of gas heat pumps could be considered. Of course this option requires a complete overhaul of the entire heating system and does not offer a solution for replacement of individual boilers.

9 – Electric heating (heat pumps)

Removing the building from the gas-grid supply entirely (fuel switch towards electric heating e.g. heat pumps) allows ditching the flue gas chimney completely. Many renovation projects have become 'all-electric' by using electric heat pumps, or even electric local space heaters.

In most cases going 'all-electric' is combined with rigorous insulation measures to lower the overall annual heating demand. This aspect should be taken into account as otherwise heating costs may become (remain) unacceptably high.

Overview of alternatives to non-condensing boilers in communal flue systems

As said before, technical solutions that change the original design of the combined boiler-flue system, such as a different capacity of connected boilers, but probably also an additional flue gas ventilator, or other solutions as described above, may not be approved by the authorities for administrative reasons (not in conformity with approved design) and if implemented could be 'illegal' (unless an exhaustive and costly re-calculation and approval procedure is performed).

Last but not least, hydrogen-fired boilers will have an impact on shared chimneys. As mentioned in Task 4, per unit of heat output the amount of condensate will be twice as high as with a natural gas-fired boiler and the combustion air flow rate will be three times higher. In other words, if the EU wants to realize a carbon-neutral society with hydrogen, the chimney problem will have to be tackled.

To relieve the burden of individual home-owners faced with the problem of replacing a non-condensing boiler in a communal flue system local authorities should step-in and provide information (and possibly funding) for alternative solutions. The information could include an assessment of options like collective boilers, chimney lining, flue gas extraction fans, parallel operation of boilers in a C15 system, etc.

An inventory of number of dwellings affected could be started by local authorities to properly assess the size of the problem.

Table 24. Overview of options

Option	Description	Costs	Remarks
Like-for-like repair/replace	Requires 'pool' of C4/C8 boilers for repair or replacement	unknown (demand driven), presumably same as normal replacement	Will result in larger stock of inefficient boilers
New boiler + existing chimney	Replacement by B1 type boiler: need to consider inherently less safe construction and other installation aspects (combustion air supply provisions) Replacement by condensing boiler: need to consider moisture and positive pressure in chimney	indicatively 1.6 times as expensive as normal replacement	Approval by chimney authorities unlikely
New boiler + renovated chimney	Replacement by condensing boiler, combined with renovated chimney. (A cost calculation is provided above)	indicatively 2 times as expensive as direct replacement	
New boiler + new chimney	Replacement by condensing boiler, combined with new chimney (collective outdoor, at facade or individual through roof or facade, etc.) This is only an option if the existing structure and installation location allows such options	unknown (costs will depend on specific installation aspects)	
C(15) option	This options involves adding individual flue gas exhausts (liners) in the existing chimney construction (the original chimney is kept for combustion air supply).	if possible, it can be relatively cheap	Whether this option allows parallel operation of condensing boilers with individual flue exhausts and non-condensing boilers in chimneys with restricted diameter/surface has to be assessed.
Chimney lining	This options differs from option 4, in that the existing chimney remains in use, but is 'renovated' using a glass fibre reinforced thermosetting plastic which makes the chimney moisture resistant and compatible with positive pressure systems.	costs unknown, but probably similar to that of option 4	Whether this option allows parallel operation of non-condensing and condensing boilers has to be assessed
Forced extraction by flue gas ventilators	Forced extraction of flue gases by a fan on top of the collective flue system may alleviate problems related to low temperature and low flue gas volume	Unknown	This option needs further research before it can be presented as realistic alternative

Collective boiler	Replacement of individual boilers by a collective boiler requires profound changes to the heating system (creation of boiler room, supply/return pipes, installing heat delivery units in apartments, or individual heat metering), etc.	Unknown	
Electric heating	Replacing gas-fired heaters by electric ones	Considerable, in particular if this includes building shell renovation to lower heat demand	