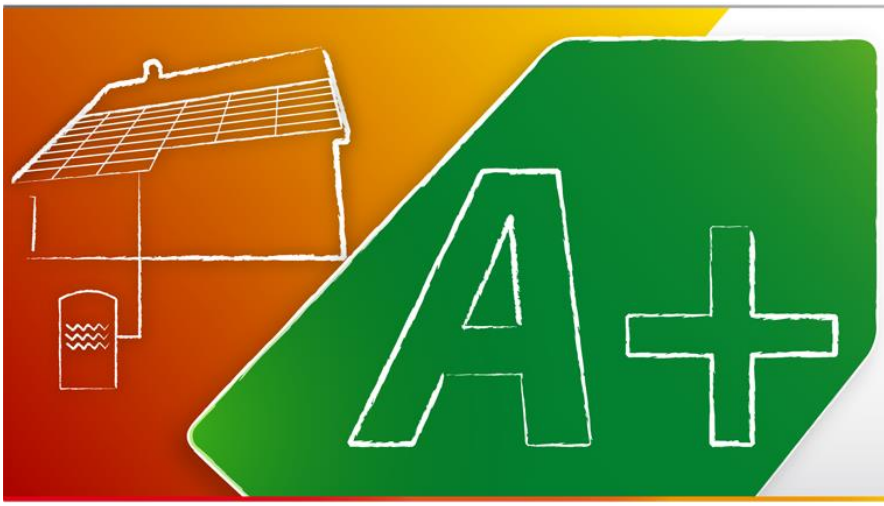
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

LabelPack A+



Sensitivity Analysis

Package Label for

Space and Water Heaters

The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EASME nor the European Commission are responsible for any use that may be made of the information contained therein.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

PUBLICATION DATA

Title: *Label Pack A+ - "Sensitivity Analysis Package Label for Space and Water Heaters"*

Date of publication: *Brussels, July 2018*

Authors: *Dario D'Alessandris – Assolterm; Pedro Dias - Solar Heat Europe/ESTIF*

Available at: *www.label-pack-a-plus.eu/*

Deliverable: *Deliverable D4.7 Sensitivity analysis on the application of the "package label"*

Dissemination level: *PU: Public*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

LabelPack A+

Content

1 Executive Summary 4
2 Introduction 5
3 Energy efficiency classes 6
3.1 Water heating efficiency 6
3.2 Seasonal Space Heating Efficiency 8
4 Calculation process 9
5 Water heating efficiency 10
5.1 Introduction 10
5.1.1 Solar thermal systems 10
5.1.2 Combinations assessed 10
5.1.3 Preferential heaters 11
5.2 Variation on Load profile 11
5.3 Variation on solar device derived from variation on solar field size 12
5.4 Variation on solar device derived from variation on thermal storage size 13
5.5 Variation on solar device derived from variations on the solar field and the thermal storage 14
6 Seasonal Space Heating Efficiency 16
6.1 Introduction 16
6.1.1 Combination heaters 16
6.1.2 Combinations assessed 16
6.2 Variation on temperature control 17
6.3 Variation on primary and secondary heater 19
6.4 Variation on primary, secondary heater and storage 21
6.5 Variation on solar device derived from variations on the solar field size 22
6.6 Variation on solar device derived from variations on the efficiency of the solar collectors 23
6.7 Variation on preferential heater, maintaining the same solar device 26
6.8 Variation on thermal storage size 27
6.9 Variation on thermal storage efficiency 28
7 Conclusion 30
7.1 Energy efficiency classes 30
7.2 Water heating efficiency 30
7.3 Seasonal Space Heating Efficiency 31
Annex I: Combinations used for LPA+ Sensitivity Analysis 33
Annex II: Results for LPA+ Sensitivity Analysis – Water heating 35
Annex III: Results for LPA+ Sensitivity Analysis – Space heating 36

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

1 Executive Summary

This document presents a sensitivity analysis of the package label for space and water heaters. This analysis aims to illustrate the behaviour of the different solutions (packages) regarding their energy efficiency.

This assessment tries to identify the main sensitivity factors affecting the performance of space and water heating systems, in particular their energy efficiency class. The analysis is done based on likely combinations found in the market, varying different elements (components) of a package.

The analysis focused on the distinction between the energy efficiency classes and the simulations of different combinations assessing the Water Heating Efficiency or the Seasonal Space Heating Efficiency.

The **energy efficiency class** of a product or a package is expected to affect the decision of consumers when acquiring a new space and water heating solution. When we address space and water heating systems, the price of a package (space or water heating system) is much higher than for other products also subject to energy labelling and Ecodesign regulations. Therefore, the difference in class, entailing in most cases a considerable additional investment, should reflect a logical choice by the consumer. This might not always be the case, as the energy efficiency classes for space and water heaters are far from being homogeneous.

Regarding the **water heating efficiency**, one of the main factors to consider is the identification of the correct load profile. An incorrect assessment of the load profile or comparing energy efficiency classes for solutions adapted to different load profiles can lead to very different and hardly comparable results. Package solutions are only considered when combining with solar devices. While in practice several factors (storage, efficiency) should have a relevant contribution to the energy efficiency contribution of a solar device, that is not the case and almost only the size of the collector field plays a relevant role. These factors, combined with the low impact of the thermal storage in the calculations, are only some of the examples of mismatches between how solutions would be assessed and designed in the market and the way the estimation of energy efficiency behaves.

Finally, the **seasonal space heating efficiency** shows the caveats of trying to identify a model that simplifies a complex assessment of a myriad of variables. This means that some of the results, namely n different variations in the components result in changes in the energy efficiency results (and classes) are often no in-line with the expected performance of such combinations in the market. While some factors might provide an arbitrary positive contribution, such as the smart controls, other factors have none or limited impact, such as the choice of preferential and secondary heater, thermal storage size and efficiency. Another example refers to the performance of solar devices, where the efficiency of the solar thermal collectors or the thermal storage does not affect the calculations. On top of that, the contribution of solar thermal is considered as an add-on, depending strongly on the power of the preferential heater, while in practice, systems using solar thermal treat this energy, being “free”, as having priority, or being “preferential”.

It is though acknowledged that such models are extremely complex to elaborate and no suggestions for concrete changes in the calculations are put forward, as this was not the aim of this sensitivity analysis.

The results of this report can be used to demonstrate to market players how different combinations can affect the energy efficiency class. It can also be used to understand some positive points or gaps in the current regulations, that can facilitate an understanding of changes to be considered for the upcoming review of Lot1 & Lot2.

2 Introduction

The Ecodesign and Energy Labelling framework application to space and water heaters (Regulated Acts No.811 and 812/2013) brought an innovative aspect with the introduction of a new concept in the energy labelling requirements, the package labelling, meant for the labelling of heating systems composed by more than one appliance, in an overall system evaluation perspective.

This new package label brings some additional complexity in its application, involving an understanding and a commitment with its application by stakeholders such as installers. It can be an important tool to communicate to consumers, by means of the information provided in the package label, namely the energy class but also with additional elements included in the label. Therefore, it is also a tool for installers, manufacturers, distributors or other market players to influence consumers decision.

Taking this into account, it is important to understand how different combinations possible when setting up a space and water heater system perform in terms of the energy efficiency class. Such understanding can be used by different stakeholders in their work designing, manufacturing, commercialising or installing space and water heating systems. And it can also be used for assessing potential improvements for the package label related regulations.

The analysis focuses on factors that have a greater impact in the efficiency of the packages. For instance, it considers the effects that can result from varying one of the components. This leads to an understanding of how packages can be improved to reach a higher class and compare such solutions with the benefits for the consumer.

As an example, one of the options considered is a combination of a primary heater with solar device, varying the space heater rated heat output or the size of the solar device. Another case assesses different primary and secondary heater with a storage tank, varying the energy efficiency class of the storage tank.

The full list of combinations that were chosen for this analysis are presented later in this report.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

3 Energy efficiency classes

Central to the comprehension of this report is understanding the Energy Efficiency Classes for Packages of Space and Water Heaters.

The energy efficiency classes are defined by intervals of the energy efficiency of the system. There are different approaches to these intervals, depending on the type of heating efficiency covered: water heating efficiency or seasonal space heating efficiency.

3.1 Water heating efficiency

The water heating energy efficiency class of a water heater is determined on the basis of the intervals indicated on table 1 of Annex II of Commission Delegated Regulation No. 812/2013[1].

Water heating energy efficiency classes of water heaters, categorised by declared load profiles, η_{wh} in %

	3XS	XXS	XS	S	M	L	XL	XXL
A^{+++}	$\eta_{wh} \geq 62$	$\eta_{wh} \geq 62$	$\eta_{wh} \geq 69$	$\eta_{wh} \geq 90$	$\eta_{wh} \geq 163$	$\eta_{wh} \geq 188$	$\eta_{wh} \geq 200$	$\eta_{wh} \geq 213$
A^{++}	$53 \leq \eta_{wh} < 62$	$53 \leq \eta_{wh} < 62$	$61 \leq \eta_{wh} < 69$	$72 \leq \eta_{wh} < 90$	$130 \leq \eta_{wh} < 163$	$150 \leq \eta_{wh} < 188$	$160 \leq \eta_{wh} < 200$	$170 \leq \eta_{wh} < 213$
A^{+}	$44 \leq \eta_{wh} < 53$	$44 \leq \eta_{wh} < 53$	$53 \leq \eta_{wh} < 61$	$55 \leq \eta_{wh} < 72$	$100 \leq \eta_{wh} < 130$	$115 \leq \eta_{wh} < 150$	$123 \leq \eta_{wh} < 160$	$131 \leq \eta_{wh} < 170$
A	$35 \leq \eta_{wh} < 44$	$35 \leq \eta_{wh} < 44$	$38 \leq \eta_{wh} < 53$	$38 \leq \eta_{wh} < 55$	$65 \leq \eta_{wh} < 100$	$75 \leq \eta_{wh} < 115$	$80 \leq \eta_{wh} < 123$	$85 \leq \eta_{wh} < 131$
B	$32 \leq \eta_{wh} < 35$	$32 \leq \eta_{wh} < 35$	$35 \leq \eta_{wh} < 38$	$35 \leq \eta_{wh} < 38$	$39 \leq \eta_{wh} < 65$	$50 \leq \eta_{wh} < 75$	$55 \leq \eta_{wh} < 80$	$60 \leq \eta_{wh} < 85$
C	$29 \leq \eta_{wh} < 32$	$29 \leq \eta_{wh} < 32$	$32 \leq \eta_{wh} < 35$	$32 \leq \eta_{wh} < 35$	$36 \leq \eta_{wh} < 39$	$37 \leq \eta_{wh} < 50$	$38 \leq \eta_{wh} < 55$	$40 \leq \eta_{wh} < 60$
D	$26 \leq \eta_{wh} < 29$	$26 \leq \eta_{wh} < 29$	$29 \leq \eta_{wh} < 32$	$29 \leq \eta_{wh} < 32$	$33 \leq \eta_{wh} < 36$	$34 \leq \eta_{wh} < 37$	$35 \leq \eta_{wh} < 38$	$36 \leq \eta_{wh} < 40$
E	$22 \leq \eta_{wh} < 26$	$23 \leq \eta_{wh} < 26$	$26 \leq \eta_{wh} < 29$	$26 \leq \eta_{wh} < 29$	$30 \leq \eta_{wh} < 33$	$30 \leq \eta_{wh} < 34$	$30 \leq \eta_{wh} < 35$	$32 \leq \eta_{wh} < 36$
F	$19 \leq \eta_{wh} < 22$	$20 \leq \eta_{wh} < 23$	$23 \leq \eta_{wh} < 26$	$23 \leq \eta_{wh} < 26$	$27 \leq \eta_{wh} < 30$	$27 \leq \eta_{wh} < 30$	$27 \leq \eta_{wh} < 30$	$28 \leq \eta_{wh} < 32$
G	$\eta_{wh} < 19$	$\eta_{wh} < 20$	$\eta_{wh} < 23$	$\eta_{wh} < 23$	$\eta_{wh} < 27$	$\eta_{wh} < 27$	$\eta_{wh} < 27$	$\eta_{wh} < 28$

Table 1: Table of water heating energy efficiency classes

[1] EU energy labelling regulation for water heaters 812/2013

The energy efficiency classes, evolving from G to A+++, are attributed based on intervals considering the energy efficiency of the system for a given load profile, as explained above.

This means that it is not enough to know the energy efficiency of a product or package, it is also essential to know the applicable load profile. For instance, a product with an efficiency of 60% would be classified as A++ if it was applicable for a load profile of 3XS or 2XS. Though a product or package with a 60% efficiency that would be suitable for an XXL load profile would only get a B energy efficiency class.

Such facts make it harder the assessment of the different options by consumers, though they are required in order to better adequate the assessment of the energy efficiency. This means that a product that can perform well for a low load profile would be ineffective for a higher load profile, meaning that it could happen that it would not provide the required level of comfort (hot water demand) and/or do it with much higher costs.

To facilitate the understanding of the distribution per class, the next graph presents the table above in a more visually clear approach.

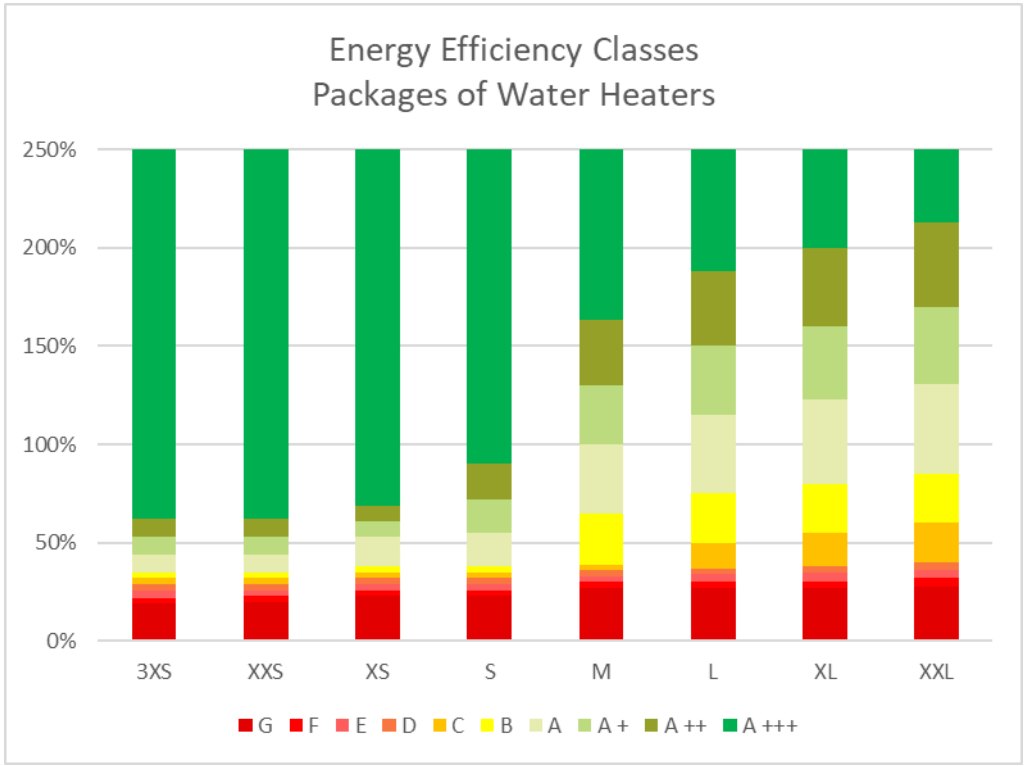


Figure 1: Water heating energy efficiency classes (for water heaters and packages)

The graph is limited to 250% for convenience in terms of presenting visually the different cases. Though there is not an upper limit identified for products falling under the 'A+++' class.

This graph shows well that products covering a low load profile would much easily reach a high energy class that products adequate for higher load profiles. The reasons for this discrepancy are complex and shall not be addressed in this report. Nevertheless, understanding that such differences exist is important for the reading of the present report.

3.2 Seasonal Space Heating Efficiency

The seasonal space heating (SSH) energy efficiency class of a space (or combination) heater is determined on the basis of the tables provided on Annex II of Commission Delegated Regulation No. 811/2013 2.

The different tables indicate the seasonal space heating energy efficiency of heaters (table 1), low-temperature heat pumps and heat pump space heaters for low-temperature application (table 2).

It also indicates the water heating energy efficiency class of a water heater (table 3), same as table 1 of Annex II of Commission Delegated Regulation No. 812/20133. It also includes the energy efficiency classes of solar hot water storage tanks, which will not be addressed in this report.

The efficiency classes for heaters (including low temperature heat pumps), are summarised in the following table:

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%

Table 2: Table of seasonal space heating energy efficiency classes

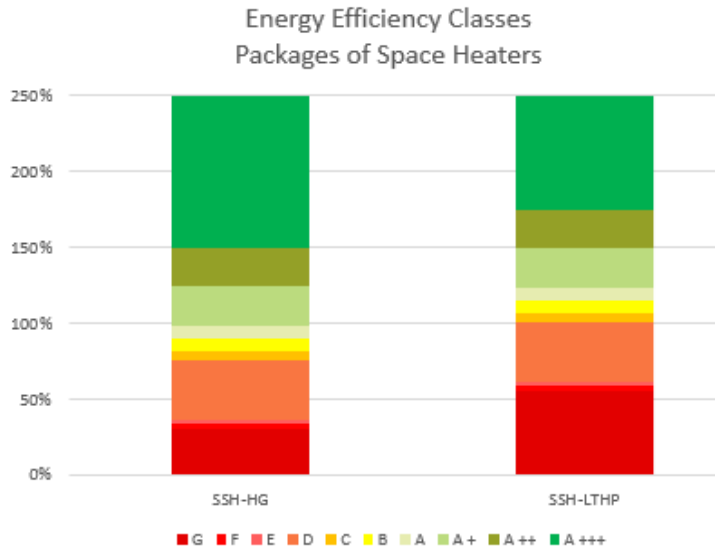


Figure 2: Seasonal space heating energy efficiency classes (for space heaters and packages)

The graph is limited to 250% for convenience in terms of presenting visually the different cases. Though there is not an upper limit identified for products falling under the 'A+++' class.

This graph shows well that the intervals for each SSH efficiency class are quite diverse in range. The reasons for this discrepancy are complex and shall not be addressed in this report. Nevertheless, understanding that such differences exist is important for the reading of the present report.

[2] EU energy labelling regulation for space heaters 811/2013

[3] EU energy labelling regulation for water heaters 812/2013

4 Calculation process

The calculation process was done using the Labelpack A+ package label online calculation tool.

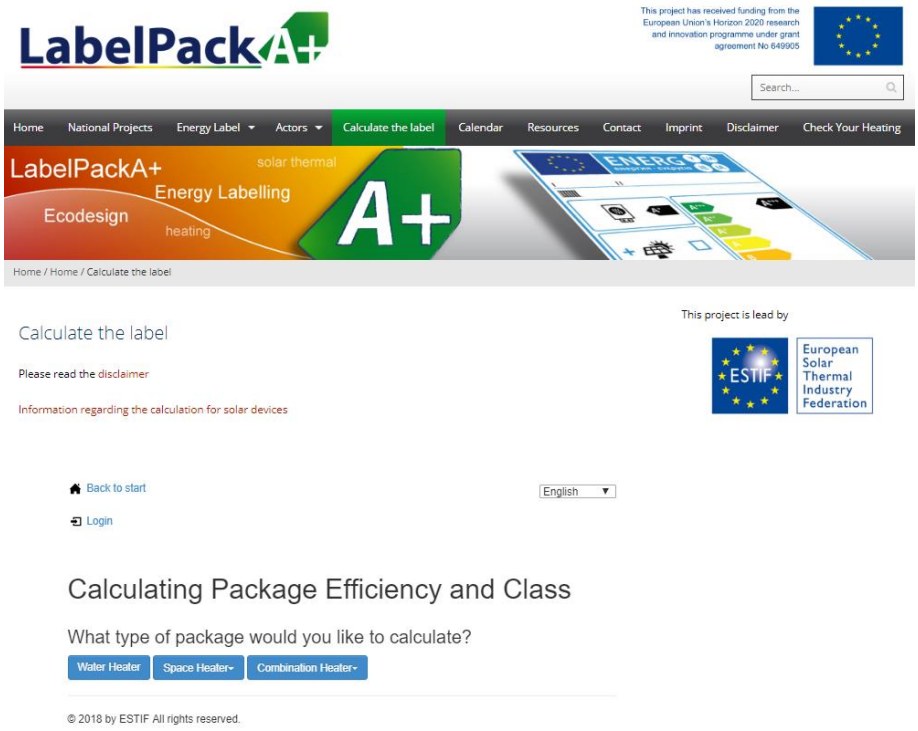


Figure 3: Labelpack A+ package label online calculation tool (screenshot).

This tool was developed in accordance to the instructions to calculate the package label reflected in the regulations 811/2013, 812/2013, 813/2013 and 814/2013. As such, it can be used to calculate the energy labelling of any combination of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device (811/2013 & 813/2013) or water heaters, hot water storage tanks and packages of water heater and solar device (812/2013 & 814/2013).

This online tool includes another tool dedicated to the calculation of the elements relevant for the product fiche of "solar devices", which are necessary to calculate the package label of water heating systems including solar thermal. That specific tool is based on the SOLCAL method. It allows for a calculation using the previous version of the SOLCAL method, as defined in the transitional methods[4] and also for a calculation according to the most recent version of the SOLCAL method, as described in EN 15316-4-3:2017. Nevertheless, as the referred standard is pending harmonisation (EC), for this sensitivity analysis the SOLCAL method used was the previous one, described in the transitional methods.

The data used for the calculation refers to real products in the market. These products were chosen as suitable options with regard to the combinations that were pre-defined for this calculation.

[4] Commission communication in the framework of the implementation of Commission Regulation (EU) No 814/2013 – transitional methods for water heaters.

Further details on the products used as reference and the combinations chosen can be found in Annex I.

5 Water heating efficiency

5.1 Introduction

The first assessment focuses on water heaters, as the packages are simpler in terms of potential combinations than the packages for space heaters. Water heaters are covered in regulations 812/2013 and 814/2013. The applicable intervals for energy classes are indicated in chapter 3.1.

5.1.1 Solar thermal systems

The only water heating packages in the scope of these regulations is the combination of a preferential heater with a solar device. According to the definition, a solar device is "*a solar-only system, a solar collector, a solar hot water storage tank or a pump in the collector loop, which are placed on the market separately*". To complement, it should be clarified that a solar-only system *"means a device that is equipped with one or more solar collectors and solar hot water storage tanks and possibly pumps in the collector loop and other parts, which is placed on the market as one unit and is not equipped with any heat generator except possibly one or more back-up immersion heaters"*.

Therefore, the analysis in what regards water heating system, takes also into account that this is specific to a combination of a preferential heater with a solar device. In order to assess the impact of the component's changes, we shall consider some basic elements, such as the estimated efficiency (in %) and the energy class. Still, considering the specificity regarding solar thermal referred above, it will include also another element: the energy necessary to satisfy the required level of comfort that is not supplied by the solar thermal system (solar device). This is designated as $Q_{nonsol.}$ Its official definition is: " *annual non-solar heat contribution"* expressed *"in kWh in terms of primary energy for electricity and/or in kWh in terms of GCV for fuels, for the load profiles M, L, XL and XXL under average climate conditions".*

Considering that solar thermal systems consume an almost negligible quantity of energy in the form of electricity (Q_{aux}, auxiliary energy to run, for instance, the water pumps and the control), one of the ways to assess the efficiency of a system including solar is, as for other systems, the energy consumption from other sources.

In a simple way, it is logical to assume that the higher the Q_{nonsol} is, the lower will be the estimated efficiency of the system.

5.1.2 Combinations assessed

As referred in the previous point, packages of water heaters are only systems combining a preferential heater with a solar device.

Different preferential heaters can be considered. In this analysis, the simulations took the most common combination in the market, which is with a solar device having as a back-up a condensing boiler.

The additional variations considered for water heating systems were:

- load profile
- solar device, derived from variation on solar field size
- solar device, derived from variation on storage tank size

Taking this basis, the options assessed were:

- Variation on load profile
  - Options: L/XL/XXL
  - No variation on heater & solar device
- Variation on solar device derived from variation on solar field size (and Qnonsol)
  - Options: 2m² / 4m²/ 6m²
  - No variation on preferential heater & load profile
- Variation on solar device derived from variation on thermal storage size (and Qnonsol)
  - Options: 150 L/ 200 L / 300 L
  - No variation on preferential heater & load profile

5.1.3 Preferential heaters

For the following group of simulations, the same combinations will be assessed with one type of preferential heater: Condensing gas boiler (CGB) with an efficiency of 85%

For the load profiles that are most relevant for combinations with solar thermal, L, XL, XXL, the chosen heater is Class A.

The Q_{aux} is constant and the system includes always a storage tank.

5.2 Variation on Load profile

This is the simplest analysis and the results should reflect the variations on energy classes based on load profile explained in chapter 3.1. This analysis focuses on the variation of the load profile.

The calculation done consists of the following elements:

Cases	1a	1b	1c
Variation on load profile	L	XL	XXL
No variation on Qnonsol = collector field (m²)	4,44	4,44	4,44
No variation on Qnonsol = storage tank (L)	200	200	200
Energy class of package: CGB	A+	A+	A
Energy Efficiency of package: CGB	136%	127%	119%

The calculation of the non-solar energy required is similar, as the solar device as the same characteristics.

The result indicated a reduction in the energy efficiency by increasing the load profile with the same solar device, resulted in a reduction of the energy class for the XXL load profile.

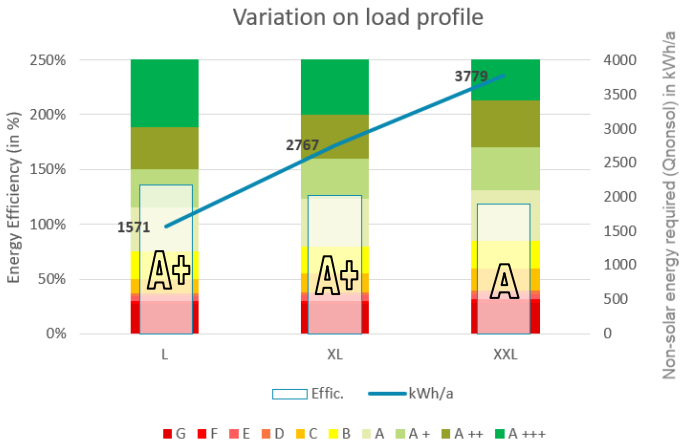


Figure 4: Estimation of energy class considering a variation on the load profile. Efficiency of the water heater (ηWh) is 85% (Class A), the storage tank volume is 200 L and the solar field size is 4.44 m².

Even if the energy generated by the system is higher, there is also an increase of the non-solar energy required, which is higher by 141%. Consequently, the efficiency decreased (by 13% and 11%), reflecting the impact of the variation on the load profile, from L to XXL.

Increasing the load profile with the same solar device, independently from changing preferential heaters, will decrease the energy efficiency and can lead to a reduction of the energy class, depending on the degree of reduction and the proximity to energy class limits.

5.3 Variation on solar device derived from variation on solar field size

For all packages, the calculations depend on the change in components. In the case of water heating systems, there is a "composed" component, which is the solar device. The performance of the solar device depends on its sub-components. In this case, the change will affect the collector size. This will result in changes in the Q_{nonsol} (and Q_{aux}) which will affect the calculation of the package.

The calculation done consists of the following:

Cases	2a	2b=1b	2c
Variation on load profile	XL	XL	XL
Variation on collector field (m²)	2.22	4.44	6.66
No variation of storage tank (L)	200	200	200
Energy Class of package: CGB	A	A+	A+
Energy Efficiency of package: CGB	97%	127%	155%

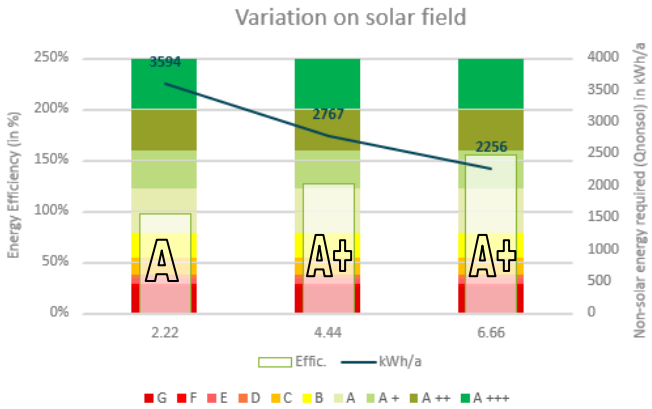


Figure 5: Estimation of energy class considering a variation on the solar device derived from size changes in the solar field. Efficiency of the water heater (ηWh) is 85% (Class A), the storage tank volume is 200 L and the load profile is XL.

The result indicated an increase in the energy efficiency of the solar device, by increasing the size of the solar field. In this case, it resulted in a clear increase of the energy efficiency of the system and the energy class.

An increase in the collector field (threefold) lead to a reduction of the non-solar energy requirements of almost 37%, resulting in a 60% increase in efficiency.

The calculation of the non-solar energy required is similar, as the solar device as the same characteristics.

As the calculation is done assuming the same load profile, the changes in class are more evident and resulted in a jump of one class. The jump would have been of two classes if, in the case of the gas boiler, the starting point was 5 percentual points higher (with final result reaching 160%), allowing a jump from class A to A++.

Increasing the size of the solar field will lead to an increase of energy generation and efficiency of the system. Considering the same load profile, the increase in the collector field is likely to provide an increase in energy class, depending on the proportion of the increase and the proximity to thresholds.

5.4 Variation on solar device derived from variation on thermal storage size

Another important component of the solar device is the thermal storage, usually a hot water storage tank. This component of a solar device can affect how much solar energy can be stored in periods with no or low demand, to be used later. In practical terms, this is an essential component of a water heating system using solar thermal[5].

The calculation done consists of the following:

Cases	3a	3b=1b	3c
No variation on load profile	XL	XL	XL
No variation on collector field (m²)	4.44	4.44	4.44
Variation on storage tank (L)	150	200	300
Energy Class of package: CGB	A+	A+	A+
Energy Efficiency of package: GCB	127%	127%	123%

[5] It is also relevant for other products, such as water heating heat pumps, where the water storage is usually integrated by default with the heat pump.

The results indicate that, for the configuration tested, the volume of the hot water storage tank is not influent on the efficiency of the package.

The increase on available storage lead to a reduction of the efficiency, which is also related to the dimensioning of the system, as this proposed configuration (4 m² with a XL load profile) is usually found in the market with a 150 or 200 litres storage tank. The impact of thermal storage should also consider the size of the system, which will be verified in the following analysis (5.5).

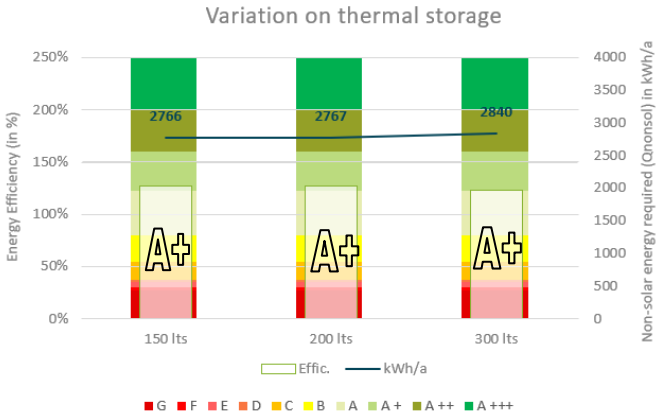


Figure 6: Estimation of energy class considering a variation on the solar device derived from changes of size for the thermal storage. Efficiency of the water heater (ηWh) is 85% (Class A), the load profile is XL and the size of the solar field is 4.4m².

For average size water heating systems using a solar device, the increase of storage capacity has very limited effect on the energy efficiency of the system.

5.5 Variation on solar device derived from variations on the solar field and the thermal storage

This analysis, focused on changes to the solar device, merges the two previous analysis (5.3 and 5.4). It will assess the impact of a combined change, considering a smaller storage tank for a smaller area and a larger storage tank for a larger area. The load profile remains unchanged (XL).

The calculation done consists of the following:

Cases	2d	2e=1b	2f
No variation on load profile	XL	XL	XL
variation on collector field (m²)	2.22	4.44	6.66
Variation on storage tank (L)	150	200	300
Energy Class of package: CGB	A	A+	A+
Energy Efficiency of package: CGB	98%	127%	151%

The results of the variation of the thermal storage in 5.4 demonstrated an almost negligible effect. Hence it is relevant to compare the results of this calculation with the results in 53:

Cases	2a/2d	2b=2e	2c/2f
Energy Efficiency of package: CGB (5.3)	97%	127%	155%
Energy Efficiency of package: CGB (5.5)	98%	127%	151%

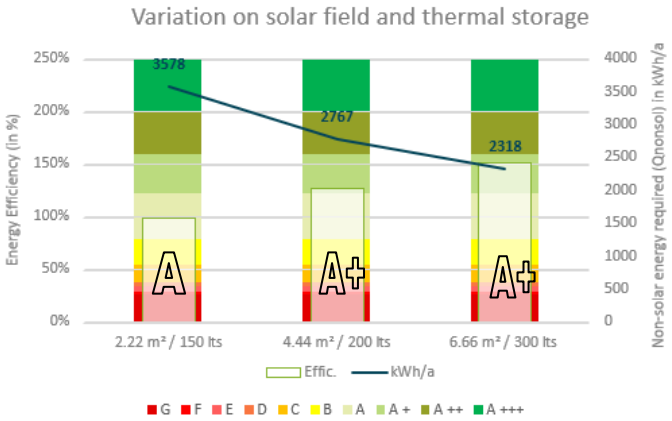


Figure 7: Estimation of energy class considering a variation on the solar device derived from changes on the size of the solar field and thermal storage. Efficiency of the water heater (ηWh) is 85% (Class A) and the load profile is XL.

In the case of the Gas Boiler as preferential heater, the results are slightly better for the smaller solar field, having a smaller storage than in 5.3 (150 L instead of 200 L) and slightly worse for the larger solar field/larger thermal storage combination.

The compared results in 5.3, 5.4, 5.5 indicate that, even if the impact of the size of the thermal storage is rather limited, it seems to have a detrimental impact the larger the hot water tank size.

The impact of the size of the thermal storage, while limited, tends to be positive the smaller the size of the solar storage and to be negative the larger it is.

6 Seasonal Space Heating Efficiency

6.1 Introduction

The following assessment focuses on the space heating function. The water heating efficiency has been analysed in chapter 5. This chapter will focus then only on the seasonal space heating efficiency, even when the solutions proposed can be considered as a package combining both space and water heating capabilities. These are covered in regulations 811/2013 and 813/2013. The applicable intervals for energy classes are indicated in chapter 3.2.

6.1.1 Combination heaters

It should be clarified that combination heaters are assessed separately, in terms of their energy efficiency classes, for their seasonal space heating efficiency and for their water heating efficiency.

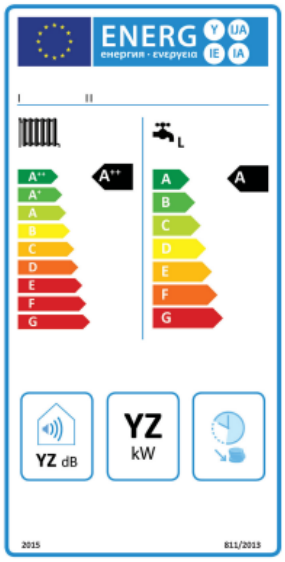


Figure 8: Product label: Boiler combination heaters in seasonal space heating energy efficiency classes A++ to G and in water heating energy efficiency classes A to G

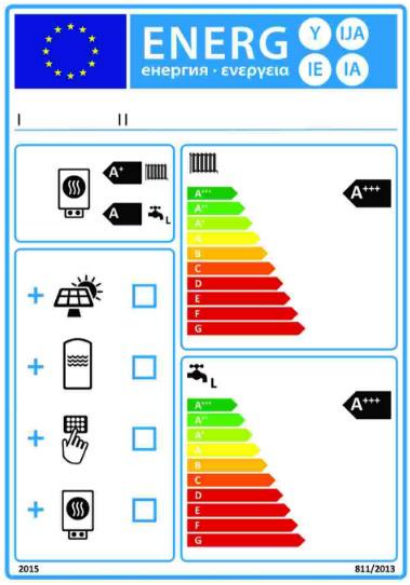


Figure 9: Label for packages of combination heater, temperature control and solar device in seasonal space heating and water heating energy efficiency classes A+++ to G

In what regards packages, the space heating solutions offer a much broader range of options. While for water heaters, the packages where only with solar, in this case the options are more diverse, as they allow to combine besides solar, a secondary heater. For instance, a condensing gas boiler can be combined as preferential heater with a heat pump, being he later the secondary heater, and vice-versa.

Such combinations, preferential heater only or a preferential and a secondary heater can be combined with a solar device. For more information about the concept of solar device, please see chapter 5.1.

6.1.2 Combinations assessed

As referred in the previous point, the possible combinations in this case are much broader.

In terms of heaters, the options to be considered will be limited, as preferential or secondary heaters to the following options:

- Condensing gas boiler: 12 / 18 / 24 kW
- Heat pump: 6 / 9 / 12 kW

Taking this basis, the options assessed were:

- Variation on temperature control
  - Primary heater: CGB (18/24 kW) / HP (9/12 kW)
  - Class I / Class V / Class VIII
  - No solar device
- Variation on primary and secondary heater
  - Primary/secondary heaters: CGB (12/18 kW) / HP (6/9 kW)
  - No variation on thermal storage
- Variation on primary and secondary heater and storage
  - Primary/secondary heaters: CGB (12/18 kW) / HP (6/9 kW)
  - Variation on thermal storage: 500 / 1000 L
- Variation on combinations of gas condensing boiler with solar device
  - Preferential heaters: CGB (12/18/24 kW)
  - Solar field size: 9/18/27 m2
  - Solar collector's efficiency: 59/67/71 %
  - No variation on storage
- Variation on combinations of heat pump with solar device
  - Preferential heaters: HP (6/9/12 kW)
  - Solar field size: 9/18/27 m2
  - Solar collector's efficiency: 59 / 71 %
  - No variation on storage
- Variation on solar device derived from changes on storage
  - Preferential heaters: CGB (24 kW) / HP (12 kW)
  - Storage: 300 /500 /1000 L (energy efficiency C)
  - Energy Efficiency of storage: D, B, A+ (with 500 L)
  - Solar field constant

6.2 Variation on temperature control

One of the combinations that has been seen in the market is a package composed only of a preferential heater and a temperature control. Even if the possibility to compose a package with only these two elements is not clear when consulting the applicable regulations, considering that it is seen in the market, it is interesting to consider the impact of such combination.

The analysis considers variations on the primary heater and the temperature control:

- condensing gas boiler
  - different sizes/power (kW): 18 / 24 kW
  - different types/classes of control: Class I / Class V / Class VIII
- heat pump
  - different sizes/power (kW): 9/12 kW
  - different types/classes of control: Class I / Class V / Class VIII

The calculations done were based on the following cases:

Cases with CGB as preferential heater	**4a**	**4b**	**4c**	**5a**	**5b**	**5c**
sizes/power (P_{Boiler}, kW)	18	18	18	24	24	24
types/classes of control	I	V	VIII	I	V	VIII
Energy Class of package	A	A	A+	A	A	A+
Energy Efficiency of package	94%	96%	98%	94%	96%	98%
Cases with HP as preferential heater	**6a**	**6b**	**6c**	**7a**	**7b**	**7c**
sizes/power (P_{HP}, kW)	9	9	9	12	12	12
types/classes of control	I	V	VIII	I	V	VIII
Energy Class of package	A+	A+	A+	A+	A+	A+
Energy Efficiency of package	116%	118%	120%	112%	114%	116%

Regardless of the preferential heater, between the temperature control of class I (the weakest) and class VIII (the best), there is an increment of 4% in the energy efficiency of the combination. It should be noted that; the way the impact of the temperature control is considered, it acts like a bonus to the efficiency of the system, not resulting from any complex calculation. The referred bonus can be observed in the following table, included in the transitional methods[6], point 6.2.:

Class No.	I	II	III	IV	V	VI	VII	VIII
Value in %	1	2	1,5	2	3	4	3,5	5

Table 3: Contribution of temperature controls to seasonal space heating energy efficiency of packages of space heater, temperature control and solar device or of packages of combination heater, temperature control and solar device

[6] Transitional methods for space heaters: Commission communication 2014/C 207/02

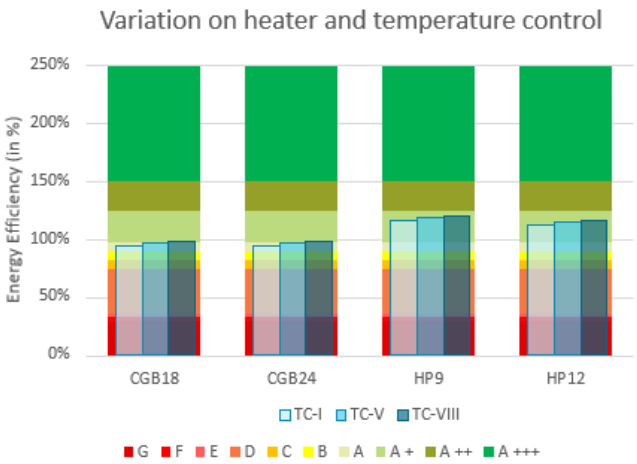


Figure 10: Estimation of energy class of a package consisting of a preferential heater and a temperature control.

Considering the condensing gas boilers, the initial energy efficiency of 93% was boosted to 98% in both cases, with the best control. This increase is exactly what was needed for this CGB to jump one efficiency class, into A+. That's an important consideration, as a condensing boiler on its own can get, in the best cases, a product label with a class A. On the case of the heat pumps, with a product label class A+, there was no improvement in terms of class, as none of the heat pumps considered was close enough (<5%) from the threshold necessary to reach the following class.

The temperature control acts as a bonus factor on the performance of the system, allowing for an increase in efficiency. The increase in efficiency is related to the class of the temperature control.

6.3 Variation on primary and secondary heater

As referred before, the options for packages of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device are substantially more complex than the packages for water heaters, to large extent because they allow a combination of preferential and secondary heaters.

The analysis considers variations on the primary heater and the secondary heater:

- Storage constant: 500 L
- condensing gas boiler and heat pump
  - condensing gas boiler as primary: 12/18 kW
  - heat pump as secondary: 6/9 kW
- heat pump and + condensing gas boiler
  - heat pump as primary: 6/9 kW
  - condensing gas boiler as secondary: 12/18 Kw

The calculations done were based on the following cases:

Cases with CGB as preferential heater	8a	8b	9a	9b
CGB (P_{Boiler}, kW)	12	12	18	18
HP (P_{HP}, kW)	6	9	6	9
Seasonal efficiency Condensing Gas Boiler	93%	93%	93%	93%
Seasonal efficiency Heat Pump	110%	115%	110%	115%
Energy Class of package	A+	A+	A+	A+
Energy Efficiency of package	106%	112%	104%	110%
Cases with HP as preferential heater	**10a**	**10b**	**11a**	**11b**
HP (P_{HP}, kW)	6	6	9	9
CGB (P_{Boiler}, kW)	12	18	12	18
Seasonal efficiency Heat Pump	110%	115%	110%	115%
Seasonal efficiency Condensing Gas Boiler	93%	93%	93%	93%
Energy Class of package	A+	A+	A+	A+
Energy Efficiency of package	106%	104%	112%	110%

It can be observed that when the power of the heat pump (HP) increases, keeping constant the power of the condensing gas boiler (CGB), the efficiency increases. This results from the fact that the improvement in seasonal heating efficiency of the heat pump also increases. On the other hand, when keeping constant the power of the heat pump while increasing the power of the CGB increases the efficiency decreases, even if the efficiency of the gas boilers is the same (93%).

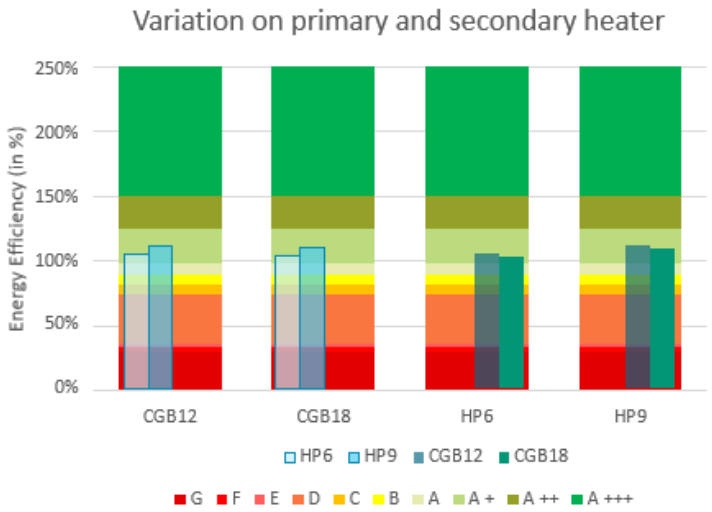


Figure 11: Estimation of energy class considering a variation on the type of primary heater and secondary heater (CGB/HP).

The energy efficiency of the packages having CGB as preferential heater increased by 6%, benefiting from the increase of efficiency of the heat pump from 110% to 115%. This increase was, nevertheless, enough to change the efficiency class.

Another relevant analysis is that changing the preferential heater between HP and CGB does not affect the calculation. So, a conclusion coming from these concrete cases that can be extrapolated is that considering one

space heater as preferential or secondary does not affect the calculation. The calculation will be mainly affected by the efficiency of the heat generator and its power.

When considering the preferential and the secondary heater, the calculation will be positively affected by the efficiency of the heat generators and negatively affected by its power. Switching between preferential and secondary heater does not affect the calculation.

6.4 Variation on primary, secondary heater and storage

The following analysis adds to the variables of the previous case (6.3) the influence of storage. The analysis considers variations on the primary heater, the secondary heater and the size of the thermal storage:

- condensing gas boiler and heat pump
  - condensing gas boiler as primary: 12/18 kW
  - heat pump as secondary: 6/9 kW
  - Storage: 500/1000 L (Energy Class C)
- heat pump and + condensing gas boiler
  - heat pump as primary: 6/9 kW
  - condensing gas boiler as secondary: 12/18 Kw
  - Storage: 500/1000 L (Energy Class C)

The calculation done consists of the following:

Cases with CGB as preferential heater	**12a**	**12b**	**13a**	**13b**	**14a**	**14b**	**15a**	**15b**
CGB (P_{Boiler}, kW)	12	12	12	12	18	18	18	18
HP (P_{HP}, kW)	6	6	9	9	6	6	9	9
Tank (L)	500	1000	500	1000	500	1000	500	1000
Energy Class of package	A+	A+	A+	A+	A+	A+	A+	A+
Energy Efficiency of package	108%	108%	114%	114%	106%	106%	112%	112%
Cases with HP as preferential heater	**16a**	**16b**	**17a**	**17b**	**18a**	**18b**	**19a**	**19b**
HP (P_{HP}, kW)	6	6	9	9	6	6	9	9
CGB (P_{Boiler}, kW)	12	12	12	12	18	18	18	18
Tank (L)	500	1000	500	1000	500	1000	500	1000
Energy Class of package	A+	A+	A+	A+	A+	A+	A+	A+
Energy Efficiency of package	108%	108%	114%	114%	106%	106%	112%	112%

The first fact to consider is that including a thermal storage (hot water storage tank) will have a positive impact on the energy efficiency of the package. For all the cases considered, the increase was 2% (in comparison with results of 6.3). It should be noted that the size of the thermal storage does not affect the energy efficiency of the system.

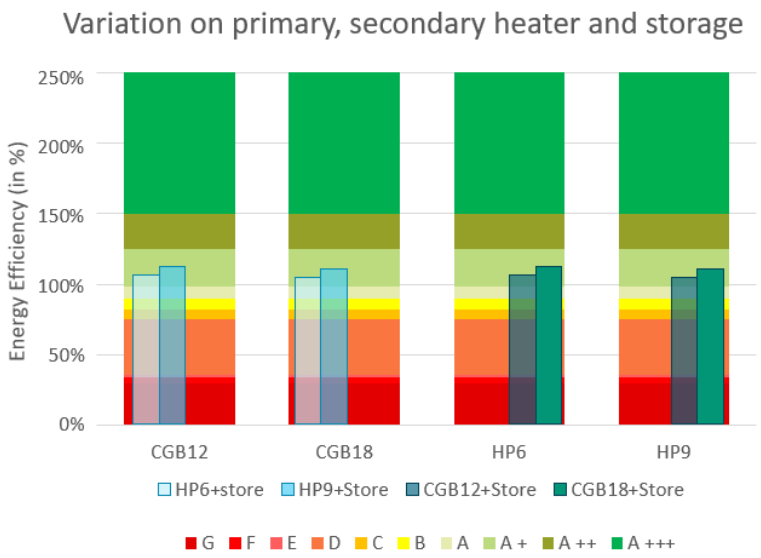


Figure 12: Estimation of energy class considering a variation on the type of primary heater and secondary heater (CGB/HP) and the size of the thermal storage.

The graph above was simplified, considering the irrelevance of the storage size. As such, the results illustrated do not distinguish between size of the thermal stores.

The improvements in energy efficiency observed of 2% (in comparison with constant thermal storage – chapter 6.3) are not enough to make a difference in the case observed and, in practice, will not lead a jump in class in most of the cases.

Including a thermal storage to a system without a solar device will have a small but positive impact on the energy efficiency class. Though, the size of the thermal storage is hardly relevant for the calculation.

6.5 Variation on solar device derived from variations on the solar field size

The following analysis focuses on changes to the solar device, more specifically the size of the collector field. The analysis considers a system combining a preferential heater with a solar device:

- Thermal storage constant: 500 L
- Preferential heater with solar thermal system
  - Preferential heater: CGB *24kW / HP 12kW*
  - size of solar field (part of solar device): 9/18/27 m^2
  - performance of solar collectors is constant: 59%

The calculation done consists of the following:

Cases with CGB as preferential heater	20a	20b	20c
CGB (P_{Boiler}, kW)	24	24	24
Coll. Area (m^2)	8,88	17,76	26,64
Coll. Perf. (%)	59%	59%	59%

Energy Class of package	A	A+	A+
Energy Efficiency of package	97%	102%	106%
Cases with HP as preferential heater	**23a**	**23b**	**23c**
HP (P_{HP}, kW)	12	12	12
Coll. Area (m²)	8,88	17,76	26,64
Coll. Perf. (%)	59%	59%	59%
Energy Class of package	A+	A+	A+
Energy Efficiency of package	115%	120%	124%

There are two analyses that can be done in this case. One aspect is the impact of including a solar device and the impact of the size of the solar field in the energy efficiency of the package.

The inclusion of a solar device provides an increase in energy efficiency of 4 to 5%, for the smaller size, depending on the primary heater. The increase of the size of the solar field leads to an increase in energy efficiency of the package. The tripling of the size of the solar field provided an increase in efficiency of 9 percentual points.

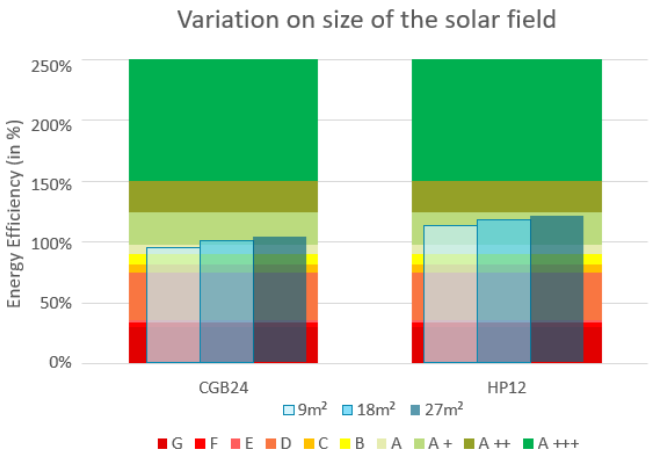


Figure 13: Estimation of energy class considering a variation on the solar device, derived from a change on the size of the solar field.

.

The combined effect of introducing a solar device with the largest size proposed (27 m²), provided an improvement of 13 to 14%. This is a considerable increase in the efficiency of the system, considering that the class A as a range of 8% and the A+ and A++ have a range of 25 to 27%.

Hence, for the condensing boiler it allowed to jump on class, to A+. On the case of the heat pump, it has not changed the class, though only by 1% (it reached 124% efficiency and the class A++ starts at 125%).

The inclusion of a solar device provides a positive impact in the energy efficiency of the package. An increase in the size of the solar device will also result in an increase of the energy efficiency of the system.

6.6 Variation on solar device derived from variations on the efficiency of the solar collectors

The following analysis affects the solar device, as the previous one. Though in this case, the variations on the solar device efficiency are caused by a variation of the performance of the solar collectors.

The analysis considers a system combining a preferential heater with a solar device:

- Thermal storage constant: 500 L
- Preferential heater with solar thermal system
  - Preferential heater: CGB 24kW / HP 12kW
  - performance of solar collectors: 59%/67%/71%
  - size of solar field constant: 18 m^2

The calculations done consist of the following:

Cases with CGB as preferential heater	21a=20b	21b	21c
CGB (P_{Boiler}, kW)	24	24	24
Coll. Area (m²)	17,76	17,76	17,76
Coll. Perf. (%)	59%	67%	71%
Energy Class of package	A+	A+	A+
Energy Efficiency of package	102%	103%	103%
Cases with HP as preferential heater	**24a=23b**	**24b**	**24c**
HP (P_{HP}, kW)	12	12	12
Coll. Area (m²)	17,76	17,76	17,76
Coll. Perf. (%)	59%	67%	71%
Energy Class of package	A+	A+	A+
Energy Efficiency of package	120%	121%	121%

It can be observed that the efficiency of the solar thermal collector has an insignificant impact on the energy efficiency of the package, regardless of the preferential heater. In the cases analysed, an improvement of the collector efficiency of 12% lead to an increase of the overall efficiency of the package of only 1%.

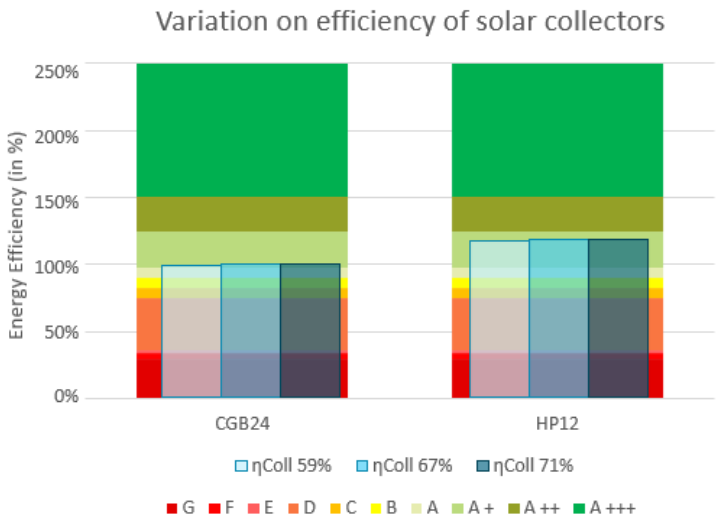


Figure 14: Estimation of energy class considering a variation on the solar device derived from variations on the efficiency of the solar collectors.

As such, the impact in terms of energy efficiency classes is almost imperceptible, as can be noticed in the graph presented above.

Increasing the efficiency of the solar collectors will have a negligible effect on the energy efficiency of the package.

6.7 Variation on preferential heater, maintaining the same solar device

The following analysis how a solar device interacts with different preferential heaters. The analysis considers one single solar device, combined with different types of preferential heaters, with different rated output:

- Thermal storage constant: 500 L
- Preferential heater with solar thermal system
  - Preferential heater:
    - Condensing gas boiler - rated output: 12 kW /18kW /24kW
    - Heat Pump - rated output: 6 kW / 9 kW /12kW
  - Solar device constant: 18 m^2 with 59% efficiency

The calculation done consists of the following cases:

Cases with CGB as preferential heater	**22a**	**22b**	**22c=20b**
CGB (P_{Boiler}, kW)	12	18	24
Energy Efficiency of CGB	93%	93%	93%
Coll. Area (m^2)	17,76	17,76	17,76
Coll. Perf. (%)	59%	59%	59%
Energy Class of package	A+	A+	A+
Energy Efficiency of package	110%	104%	102%
Cases with HP as preferential heater	**25a**	**25b**	**25c**
HP (P_{HP}, kW)	6	9	12
Energy Efficiency of HP	110%	115%	111%
Coll. Area (m^2)	17,76	17,76	17,76
Coll. Perf. (%)	59%	59%	59%
Energy Class of package	A++	A++	A+
Energy Efficiency of package	127%	126%	120%

The solar device considered, increases the energy efficiency of the space heaters with the lowest rated output (12kW for the CGB and 6 kW for the HP) by 17%, which is a considerable improvement.

Though, the increase in the rated output of the preferential heater erodes a part of the positive effect of the solar device. For the preferential heaters with the highest rated output (24kW for the CGB and 12 kW for the HP), the improvement provided by the solar device reduced to 9%.

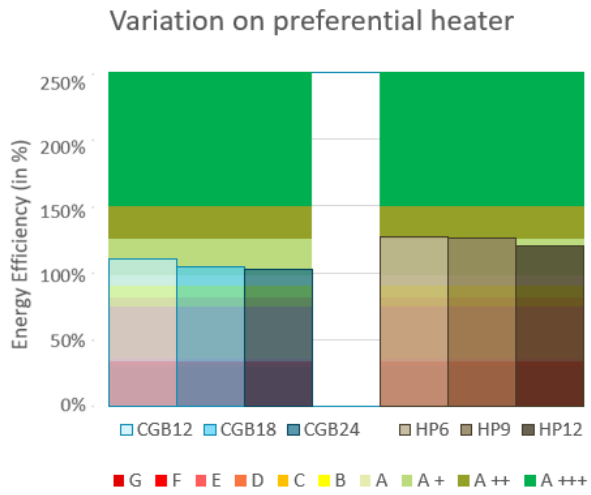


Figure 15: Estimation of energy class considering a variation on the preferential heater, maintaining the same solar device.

The reduction of impact of the solar device is about 7-8%, with the doubling of the rated output of the preferential heaters considered. Such a large different can have an impact on the energy efficiency class, as noted in the graph above. The combination with gas condensing boiler got to the lower threshold of the current class and in the case of the heat pump, the final combination fell in a lower class (120%; A+).

The inclusion of a solar device provides a positive impact in the energy efficiency of the package. That positive effect erodes with the increase of the rated power output of the preferential heater.

6.8 Variation on thermal storage size

The following analysis tackles the variation on the solar storage size.

The analysis considers one solar device combined with different types of preferential heaters and different sizes of thermal storage:

- Preferential heater with solar thermal system
  - Preferential heater:
    - Condensing gas boiler - rated output: 24kW
    - Heat Pump - rated output: 12kW
- Thermal storage tank: 300 / 500 /1000 L
- Solar device constant: 18 m^2 with 59% efficiency

The calculation done consists of the following cases:

Cases	26a/27a	26b/27b	26c/27c
CGB as preferential heater (P_{Boiler}, kW)	24	24	24
CGB as preferential heater (P_{HP}, kW)	12	12	12
Coll. Area (m²)	17,76	17,76	17,76
Coll. Perf. (%)	59%	59%	59%
Storage Tank (L)	300	500	1000
Energy Class of package (both)	A+	A+	A+
Energy Efficiency of package (with CGB)	102%	102%	102%
Energy Efficiency of package (with HP)	120%	120%	120%
Cases with HP as preferential heater	**27a**	**27b**	**27c**

Regardless of the preferential heater used, the variation on the storage size has not affected the energy efficiency of the system. This result is even more relevant considering that the largest thermal storage was three times larger than the smallest one (300 L vs. 1000 L).

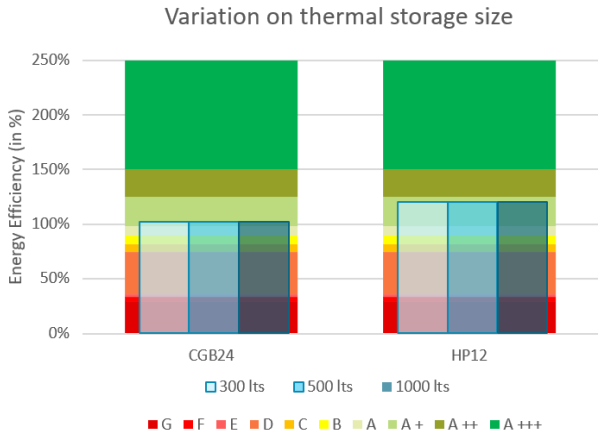


Figure 16: Estimation of energy class considering a variation on the thermal storage.

The variation on the storage size has a negligible effect on the energy efficiency of the system.

6.9 Variation on thermal storage efficiency

The following analysis tackles the variation on the efficiency of the thermal store.

The analysis considers one solar device combined with a heat pump as preferential heater and thermal storages with different energy efficiency class:

- Preferential heater with solar thermal system
  - Preferential heater constant:
    - Heat Pump - rated output: 12kW
- Thermal storage tank:
  - Size constant: 500 L

- Energy Class: D, C, B, A+
- Solar device constant: 18 m^2 with 59% efficiency

The calculation done consists of the following cases:

Cases with HP as preferential heater	28a	27b	28b	28c
HP (P_{HP}, kW)	12	12	12	12
Coll. Area (m^2)	17,76	17,76	17,76	17,76
Coll. Perf. (%)	59%	59%	59%	59%
Storage Tank (L)	500	500	500	500
Energy efficiency Class of Hot Water Tank	D	C	B	A+
Energy Class of package	A+	A+	A+	A+
Energy Efficiency of package	120%	120%	120%	121%

The variation of the energy efficiency of the thermal storage (hot water storage tank), ranging from a class D to a class A+ (best available), has a negligible effect on the performance of the system, with the result (rounded) not changing more than one percentage point.

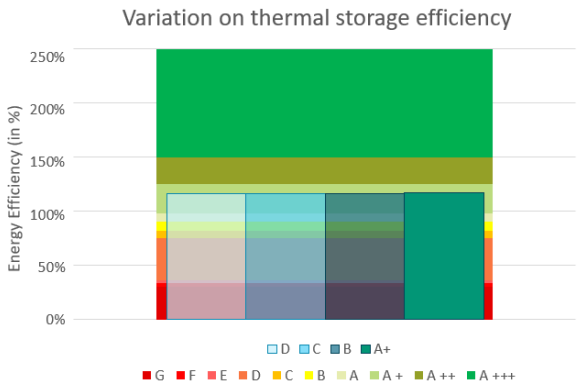


Figure 17: Estimation of energy class considering a variation on the thermal storage.

The variation on the thermal storage efficiency has a negligible effect on the overall energy efficiency of the system.

7 Conclusion

The results of this sensitivity analysis have to be considered separately in what regards 'Water heating efficiency' and 'Seasonal Space Heating Efficiency'. The different methods for calculation, the different ranges and groups of classes (depending also on load profile in the case of water heating) mean also that the results are affected differently depending on different possible combinations.

7.1 Energy efficiency classes

The energy efficiency class of a product or a package is expected to affect the decision of consumers when acquiring a new space and water heating solution. Space and water heating systems are significant investments with a considerable impact on the total energy consumption (and energy bills) of households.

Upper or lower classes are not equal

The difference in energy efficiency class, entailing in most cases a considerable additional investment, should reflect a logical choice by the consumer. That is not the case, due to considerable differences on the intervals of each class. For instance, for water heating (load profile XL), an increase of performance of 20% is enough to go from a class G to B, while the same increase might not be enough to jump one single class when the starting point is a class A, A+ or A++. For space heaters, a similar increase of 20% could make the difference between G and D, or C and A. Though it might not be enough to jump class C (39% interval) or classes A+ or A++.

7.2 Water heating efficiency

The sensitivity analysis of water heating systems focuses only on solutions integrating solar thermal systems, as the only packages that can be considered are those combining a preferential heater with a solar device.

Summary of findings:

- Increasing the load profile with the same solar device, independently from changing preferential heaters, will decrease the energy efficiency and can lead to a reduction of the energy class, depending on the degree of reduction and the proximity to energy class limits.
- Increasing the size of the solar field will lead to an increase of energy generation and efficiency of the system. Considering the same load profile, the increase in the collector field is likely to provide an increase in energy class, depending on the proportion of the increase and the proximity to thresholds.
- For average size water heating systems using a solar device, the increase of storage capacity has very limited effect on the energy efficiency of the system.
- The impact of the size of the thermal storage, while limited, tends to be positive the smaller the size of the solar storage and to be negative the larger it is.

Identifying the right load profile is paramount

The load profile is an essential component on the calculation of the water heating efficiency. One solution may have different results and might even change class just by considering it for a higher or lower load profile. It is important that for the calculation of the energy efficiency of such systems, the load profile requirements are well explained to the consumers. Installers or system designers should take this point in attention, to avoid misleading consumers on their choices. This applies as well for products as for packages.

For solar devices, size matters

The impact of the size of the solar field in the impact the solar device can have in the energy efficiency of the package is evident. Increasing the size of the solar field, i.e., the area of solar thermal collectors, as a positive effect. This effect can be stronger with back-up water heaters with a lower efficiency. A large solar field increases the solar fraction (proportion of the solar contribution to the total demand), reducing the need for auxiliary energy supply. And the auxiliary energy required to satisfy the comfort levels required (load profile) is the main factor for defining the energy efficiency of such solutions.

Thermal storage underestimated

The design of a solar device needs to take into consideration the adequate load profile and adjust the size of the solar field and the thermal storage to it. Though in the calculations, the impact of thermal storage is very limited. On top of that, the increase of the size of the thermal store affects negatively the efficiency. That can indeed happen when the storage size is over-dimensioned., nevertheless that was not the case in the simulations carried out in this report.

Needs for adjustment between market needs and calculated energy efficiency

The results of some calculations lead to a conclusion that the results of the calculations may lead to combinations that would not be considered the most adequate in the market. For instance, reducing the efficiency of the preferential heater and increasing the size of the solar device can lead to relevant gains in terms of energy efficiency calculation, while they are not necessarily the ones giving to the consumer the best performance year-round and the best return on investment.

7.3 Seasonal Space Heating Efficiency

The sensitivity analysis of seasonal space heating is rather complex, considering the number of variations that can be considered. Seventy-two variations were considered and many more could be taken into account. The ones chosen where considered the most adequate, reflecting common and relevant solutions in the market. These allowed to verify the sensitivity to some critical elements when setting up a space heating package.

Summary of findings:

- The temperature control acts as a bonus factor on the performance of the system, allowing for an increase in efficiency. The increase in efficiency is related to the class of the temperature control.
- When considering the preferential and the secondary heater, the calculation will be positively affected by the efficiency of the heat generators and negatively affected by its power. Switching between preferential and secondary heater does not affect the calculation.
- Including a thermal storage to a system without a solar device will have a small but positive impact on the energy efficiency class. Though, the size of the thermal storage is hardly relevant for the calculation.

- The inclusion of a solar device provides a positive impact in the energy efficiency of the package. An increase in the size of the solar device will also result in an increase of the energy efficiency of the system.
- Increasing the efficiency of the solar collectors will have a negligible effect on the energy efficiency of the package.
- The inclusion of a solar device provides a positive impact in the energy efficiency of the package. That positive effect erodes with the increase of the rated power output of the preferential heater.
- The variation on the storage size has a negligible effect on the energy efficiency of the system.
- The variation on the thermal storage efficiency has a negligible effect on the overall energy efficiency of the system.

More is better when adding components to a preferential boiler

The way the calculation is designed, adding components to a preferential boiler will have a positive effect, be it a thermal storage, a control or a solar device, even if with different impact. In the case of the control, this improvement is defined in the calculation, being rather a performance bonus added then a clear result of an efficiency assessment. Solar devices also provide a positive contribution, depending mainly on the size of the solar field. Storage has a more limited effect.

Preferential or secondary, no preference

The preferential and secondary heater, in the simulations done, are interchangeable. This means that in a given combination of a preferential heater A with a secondary heater B, these can switch roles (B as preferential heater) and the energy efficiency calculation will remain the same. Nevertheless, it must be taken into account that the calculation will be positively affected by the increase of efficiency of the heat generators and negatively affected by an increase of power.

For solar devices, size matters

The factor that affects more the performance of the solar device *per se* is the size of the solar field. Surprisingly, the efficiency of the solar thermal collectors, the efficiency of the thermal storage or even the size of the thermal storage have a very limited or even negligible effect. As in the case of solar devices in water heating packages (and in a stronger way in this case), the energy efficiency calculations are not reflecting adequately the factors affecting the performance of a solar thermal system.

Solar devices, preferential or back-up

The calculation considers the solar device as an add-on, complementing the preferential heater. This means that the contribution of the solar device is lower, the higher the power of the preferential heater. In practical terms, in the market, solar thermal systems are in fact preferential systems. As they provide “free energy”, their energy supply has “priority” in the system, being complemented by the “back-up” (or in this context, “preferential”) heater.

Need for adjustment between market needs and calculated energy efficiency

It is clear that it is extremely complex to calculate the energy efficiency of a heating systems. The variables are countless, depending on local conditions (climate, building), comfort level and energy demand and combined performance of a myriad of potential mixtures of components. The calculation includes some simplifications, as is the case of the increase of performance attributed to smart controls. In other cases, it underestimates the impact of thermal storage or even the combined efficiency of solar devices. While noting in this analysis discrepancies between the results of this model and the expected outcomes, changing the approach is an extremely complex task and was not addressed (as it was not the goal) in this sensitivity analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

Annex I: Combinations used for LPA+ Sensitivity Analysis

COMPONENT	DATA	**CASE A**	**CASE B**	**CASE C**
1	**P_{Boiler} (kW)**	**12**	**18**	**24**
GAS CONDESING BOILER	Model	Victrix 12 kW TT Plus	Duval Themafast 4 Cond. 25	Victrix 24 kW TT Plus
	Ener. Effic. Cl.	A	A	A
	St. Ener. Effic. Cl.	93	93	93
2	**P_{HP} (kW)**	**6**	**9**	**12**
HEAT PUMP	Model	Aermec ANLI 021 H	AUDAX TOP 12 ERP	Aermec ANLI 045 H
	Ener. Effic. Cl.	A+	A+	A+
	Effic. Ener. St.	110	115	111
3	**Cl_{Contr}**	**I=1%**	**V=3%**	**VIII=5%**
TEMPERATURE CONTROL	Model	Exacontrol 7	CAR V2	Evohome
4	**V_{Store} (L)**	**279**	**478**	**946**
TANK	Model	Cordivari Puffer HE 300	Cordivari Puffer HE 500	Cordivari Puffer HE 1000
	Class	C	C	C
5	**η_{Coll}**	**59**	**67**	**71**
SOLAR COLLECTOR	Model	GreenOneTec FK8230 N4a Cu-Al	Kloben SKY PRO 10	GreenOneTec GK 3803 S
	Area Ap.	2.22	1.90	7.41
	η_0	0.759	0.721	0.857
	a1	3.480	1.051	3.083
	a2	0.016	0.004	0.013
	Tipo	Vetrato	sottovuoto	Vetrato big
6	**$A_{Coll.\ Apert.}$ (sm)**	**8.88**	**17.76**	**26.64**
N° COLLECTOR	FK 8230 N4a Cu-Al	4	8	12

COMPONENT	DATA	**CASE A**	**CASE B**	**CASE C**
7.1 Q non sol	**Tank 150 L**	**150 lt 2,22sm**	**150 lt 4,44sm**	**150 lt 6,66sm**
M	kWh/a	1101	897	825
L	kWh/a	2100	1552	1304
XL	kWh/a	3578	2766	2267
XXl	kWh/a	4718	3787	3147
7.2 Q non sol	**Tank 200 lt**	**200 lt 2,22sm**	**200 lt 4,44sm**	**200 lt 6,66sm**
M	kWh/a	1146	957	898
L	kWh/a	2126	1571	1334
XL	kWh/a	3594	2767	2256
XXl	kWh/a	4729	3779	3125
7.3 Q non sol	**Tank 300 lt**	**300 lt 2,22sm**	**300 lt 4,44sm**	**300 lt 6,66sm**
M	kWh/a	1286	1120	1082
L	kWh/a	2231	1679	1455
XL	kWh/a	3679	2840	2318
XXl	kWh/a	4806	3837	3162
8 Q Aux = 0	Efficiency Water Heater	85%	85%	85%
	Vnom / Vbu	150 lt / 75 lt	200 lt / 100 lt	300 lt / 150 lt
	psbsol	1,40 W/K	1,65 W/K	2,10 W/K

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

LabelPack A+

Annex II: Results for LPA+ Sensitivity Analysis – Water heating

WATER		η_{Wh}	Class	Load P.	TANK	Volume	lt	SOL	Aap	sm	Qnonsol		kWh/a					Qaux	Label		Note
Case	Type	%			150	200	300	2.22	4.44	6.66	152	154	202	204	206	304	306	0	Class	Effic.	
1a	CGB in tank	85	A	L		X			X					1571				0	A+	136	increasing the load profile decreases the energy class with the same solar system
1b		85	A	XL		X			X					2767				0	A+	127	
1c		85	A	XXL		X			X					3779				0	A	119	
2a		85	A	XL		X		X					3594					0	A	97	the energy class increases with solar area as expected and allow to skip the class
2b=1b		85	A	XL		X			X					2767				0	A+	127	
2c		85	A	XL		X				X					2256			0	A+	155	
2d		85	A	XL	X			X			3578							0	A	98	the energy class increases with solar area. The volume of tank doesn't change trend
2e=1b		85	A	XL		X			X					2767				0	A+	127	
2f		85	A	XL			X			X							2318	0	A+	151	
3a		85	A	XL	X				X			2766						0	A+	127	the volume of the tank is not influent on the efficiency of the package.
3b=1b		85	A	XL		X			X					2767				0	A+	127	
3c		85	A	XL			X		X							2840		0	A+	123	
3'a		40	B	XL	X				X			2766						0	C	52	the volume of the tank is not influent on the efficiency of the package.
3'b=1'b		40	B	XL		X			X					2767				0	C	52	
3'c		40	B	XL			X		X							2840		0	C	50	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

LabelPack A+

Annex III: Results for LPA+ Sensitivity Analysis – Space heating

HEATING	CGB	Pnom	Kw	HP	Pnom	Kw	TC	Class		TANK	Vol.	lt	SOL	η_{Coll}	%	SOL	Aap	sm	Label		Note
CASE	12	18	24	6	9	12	I	V	VIII	300	500	1000	59	67	71	8.88	17.76	26.64	Class	Effic.	
4a		X					X												A	94	efficiency increases when the class
4b		X						X											A	96	of temper. control increases and it
4c		X							X										A+	98	allows to skip in a better energy class
5a			X				X												A	94	efficiency increases when the class
5b			X					X											A	96	of temper. control increases and it
5c			X						X										A+	98	allows to skip in a better energy class
6a					X		X												A+	116	efficiency increases when the
6b					X			X											A+	118	class of temperature control
6c					X				X										A+	120	but in this case is not sufficient
7a						X	X												A+	112	to skip in a better class
7b						X		X											A+	114	
7c						X			X										A+	116	
8a	1			2															A+	106	when the power of the HP increases
8b	1				2														A+	112	keeping constant the power of CGB,
9a		1		2															A+	104	the efficiency increases and when P. of
9b		1			2														A+	110	CGB increase the efficiency decreases
10a	2			1															A+	106	changing the preferential heater
10b		2		1															A+	104	between HP and CGB nothing changes
11a	2				1														A+	112	So, it is indifferent to consider CGB or
11b		2			1														A+	110	or HP as preferential generator
12a	1			2							X								A+	108	the volume of the tank is not

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

HEATING	CGB	Pnom	Kw	HP	Pnom	Kw	TC	Class		TANK	Vol.	It	SOL	η_{Coll}	%	SOL	Aap	sm	Label		Note
12b	1			2								X							A+	108	influent on the efficiency of package
13a	1				2						X								A+	114	the volume of the tank is not influent
13b	1				2							X							A+	114	regardless of the power of the heaters
14a		1		2							X								A+	106	the volume of the tank is not influent
14b		1		2								X							A+	106	regardless of the power of the heaters
15a		1			2						X								A+	112	the volume of the tank is not influent
15b		1			2							X							A+	112	regardless of the power of the heaters
16a	2			1							X								A+	108	the volume of the tank is not
16b	2			1								X							A+	108	influent on the efficiency of package
17a	2				1						X								A+	114	the volume of the tank is not influent
17b	2				1							X							A+	114	regardless of the power of the heaters
18a		2		1							X								A+	106	the volume of the tank is not influent
18b		2		1								X							A+	106	regardless of the power of the heaters
19a		2			1						X								A+	112	the volume of the tank is not influent
19b		2			1							X							A+	112	regardless of the power of the heaters
20a			X										X			X			A	97	increasing Solar area increases the
20b			X										X				X		A+	102	efficiency of package and with CGB
20c			X										X					X	A+	106	it allows to skip in a better class
21a			X										X				X		A+	102	the efficiency of collector is
21b			X											X			X		A+	103	insignificant for the package efficiency
21c			X												X		X		A+	103	
22a	X												X				X		A+	110	when power of CGB decreases, the
22b		X											X				X		A+	104	solar contribution increases so we can
22c			X										X				X		A+	102	have a better efficiency of package
23a	X												X			X			A+	110	when solar area increases, the package
23b	X												X				X		A+	104	efficiency increases, but it is

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

HEATING	CGB	Pnom	Kw	HP	Pnom	Kw	TC	Class		TANK	Vol.	lt	SOL	η_{Coll}	%	SOL	Aap	sm	Label		Note
23c	X												X					X	A+	102	not enough to skip in a better class
24a	X												X				X		A+	120	the efficiency of collector is
24b	X													X			X		A+	121	insignificant for the package efficiency
24c	X														X		X		A+	121	also when the space heater is an HP
25a				X									X				X		A++	127	when power of HP decreases, the
25b					X								X				X		A++	129	solar contribution increases and with
25c						X							X				X		A+	120	HP it is enough to skip in a better class
26a			X							X			X				X		A+	102	the volume of tank is completely
26b			X								X		X				X		A+	102	not influent when the heater is a CGB
26c			X									X	X				X		A+	102	
27a						X				X			X				X		A+	120	the volume of tank is also completely
27b						X					X		X				X		A+	120	not influent when the heater is a HP
27c						X						X	X				X		A+	120	
28a						X					D		X				X		A+	120	the class energy of tank is completely
28b						X					B		X				X		A+	120	not influent on the package efficiency
28c						X					A+		X				X		A+	121	(regardless if solar is present or not)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649905

LabelPack A+

***

End of Document

***

About the Labelpack A+ Project

The 'Label Pack A+' project aims at supporting the implementation of the energy labelling of heating appliances while boosting its impact, the focus being on the "package label" and its potential to push for the uptake or renewable technologies, in particular solar thermal, in combination with more efficient conventional technologies.

The project addresses one of the main challenges related to this particular energy labelling process in relation to other Energy-related Products : the issuing of the package label by installers. This challenge involves the preparation of the industry, retailers and installers for this process, including the communication to the final consumer.

More information at:
www.label-pack-a-plus.eu