34. Symposium Solarthermie und Innovative Wärmesysteme

Residential Buildings (One- and Two-Family Houses)

https://doi.org/10.52825/st-symposium.v1i.1345

Published: 26 Nov. 2024

The Simplified Method (TSM)

New Calculation Method for Solar Thermal Systems for Space Heating and Water Heating Based on GTY as Part of the Revision of EU Regulations 811-814 for Ecodesign and Labelling

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Abstract. The EU regulations on Ecodesign and Labelling 811-814 apply to space heaters, water heaters and solar devices. They have been under revision since 2017. The revision should make it easier to calculate the efficiency of solar thermal systems and determine it more correctly. In addition, the improved overall efficiency in connection with the primary energy-consuming heat generators should be made more visible to the consumer. A group of experts under the leadership of the European solar thermal association Solar Heat Europe (SHE/ESTIF) developed a comprehensively valid and simple method for assessing solar thermal systems in accordance with EU regulations. The Gross Thermal Yield (GTY) known from the Solar Keymark certification is used as the sole and standardized solar assessment basis to calculate the new assessment parameter "Solar Device Efficiency". In the system calculation, it is equal to the efficiency of a primary energy consuming heat generator, be it a boiler, a heat pump or an electric heating element, and, simply multiplied by the efficiency of the respective heat generator, gives the resulting efficiency of a solar hybrid or solar assisted package. With the new calculation method, it will be possible to achieve the highest class A for water heating and an improvement of up to 2 classes in combination with a heat generator for space heating with normally dimensioned solar systems within the planned reintroduction of the original label classes A-F. This paper reflects the current status of the drafts [1] and [2] of the regulations. The designations, symbols and indices used below are provisional. They are based on the correction proposals of Solar Heat Europe, as the current draft of the EU Commission is still inconsistent and partly incorrect with regard to the nomenclature.

Keywords: EU Regulations 811+812, SHE, ESTIF, Solar Keymark, GTY, Solar Device Efficiency

1. Introduction

The ErP calculation methods used to date, particularly for solar assisted space heating, suggest that solar thermal has little influence on increasing efficiency and has damaged its reputation not only in day-to-day business, but also at a political level. Even before this, the conventional heating industry's appreciation of completely CO_2-free solar thermal energy was largely limited to the windfall effects of subsidies, which were also happy to subsidize fossil-fuel boilers in the past. In contrast to PV, the quantification of the heat contribution was largely ignored and is therefore not adequately reflected in the EU regulations. The effects can be seen very clearly today when solar energy is understood almost exclusively as solar power and solar thermal energy is seen by some as a life-prolonging measure for the fossil age. However, experts have been aware that solar thermal energy is an independent technology that needs to be evaluated separately not only since the successful projects in heating networks, but also laymen who switch off their boilers in summer and the transitional period and heat exclusively with collector and without additional equipment like a heat pump. A group of experts from SHE therefore set itself the goal of developing a suitable and fair method for calculating the solar device and system efficiency in solar-assisted hybrid solutions for the European climate zones for all common collector technologies and anchoring it in the revised EU regulations, even if a separate collector label can still not be awarded due to the lack of primary energy consumption.

2. Contexts and derivation

The main obstacle to a simple formula-based derivation was identified as the electrical auxiliary energy, i.e. the power requirement for the pump and controller, which must be determined in the current version of the regulation. Since nowadays practically only high-efficiency pumps are used, and no pump is required at all for thermosiphon systems, the use of electricity and thus the primary energy consumption can be neglected. The Commission's technical advisors were also convinced of this fact. This meant that there was no longer any obstacle to simplification and that it was possible to show mathematically that the overall efficiency η_{hyb} of a solar hybrid or solar-assisted package can be described by multiplying the individual efficiencies analogue to typical technical system efficiencies according to formula (1), (5) respectively.

$$\eta_{hyb} = \frac{Q_{load,tot}}{E_{nonsol}+E_{sol}} = \frac{Q_{nonsol} + Q_{sol}}{E_{nonsol}} = \frac{Q_{nonsol} + Q_{sol}}{Q_{nonsol}} \cdot \eta_{nonsol} = \left(1 + \frac{Q_{sol}}{Q_{nonsol}}\right) \cdot \eta_{nonsol} \quad (1)$$

with

sol: share of energy provided by solar energy

nonsol: share of primary energy consuming heat generators e.g. gas boiler, heat pump, electric heating rod

total space or water heating load: $Q_{load,tot} = Q_{nonsol} + Q_{sol}$ (2)

primary energy consumption: $E_{nonsol} = \frac{Q_{nonsol}}{\eta_{nonsol}};\ E_{sol} = 0$ (3)

The solar device efficiency is thus defined according to formula (4) as:

$$\eta_{sol} = 1 + \frac{Q_{sol}}{Q_{nonsol}} = \frac{Q_{nonsol} + Q_{sol}}{Q_{nonsol}} = \frac{Q_{load,tot}}{Q_{nonsol}} \quad (4)$$

And thus the overall efficiency η_{hyb} can generally be represented according to formula (5):

$$\eta_{hyb} = \eta_{sol} \cdot \eta_{nonsol} \quad (5)$$

The first step therefore shows that the new solar device efficiency parameter is the corresponding counterpart to the efficiencies of conventional heat generators such as gas boilers or heat pumps, and that solar devices are an equal part of the heat supply. Although solar device efficiency is not yet explicitly known as a parameter in solar thermal energy, it can be very easily converted into a well-known parameter, the solar fraction κ, using formula (6) and (7).

$$\kappa = 1 - \frac{Q_{nonsol}}{Q_{load,tot}} = 1 - \frac{1}{\eta_{sol}} \quad (6)$$

$$\eta_{sol} = \frac{1}{1-\kappa} \qquad (7)$$

The diagram showing the example of a solar thermal system for water heating makes the relationship even clearer.

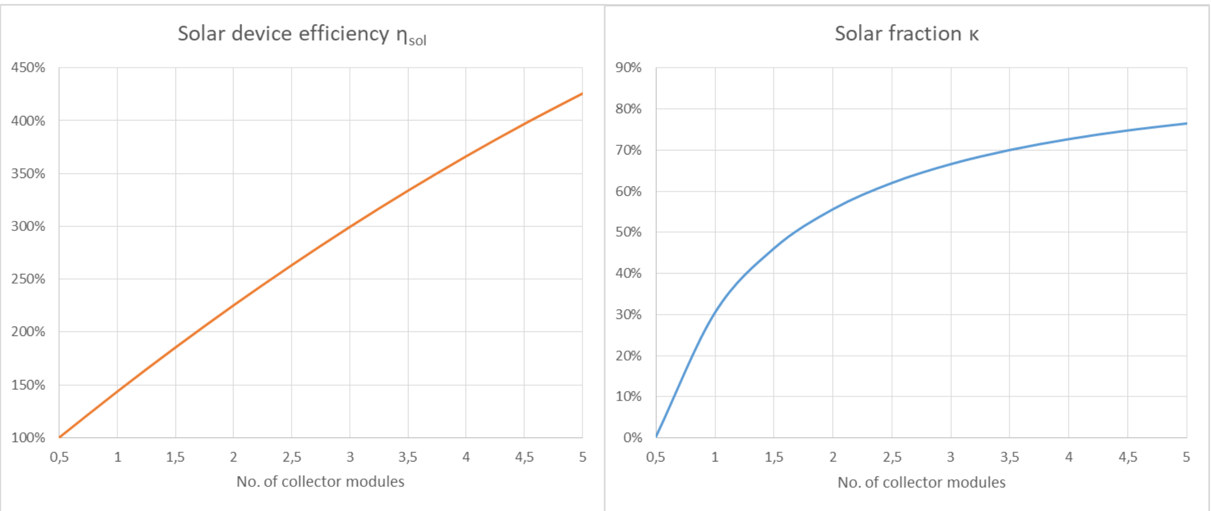

Figure 1. *Comparison solar device efficiency vs. solar fraction*

3. Calculation method TSM (= The Simplified Method)

The second step was to simply determine this solar system efficiency. As is generally known, the correct evaluation of solar systems has always been a point of contention among experts, as the multitude of parameters that together describe the efficiency of the collector led to different and controversial interpretations. The introduction of the gross thermal yield (GTY) in the Solar Keymark certification (SK) was able to untie this Gordian knot and provides a comparable simulated annual yield for 4 locations and 3 operating temperatures for all collectors. Three of the SK reference sites are now also recognized by the EU as reference sites for the 3 EU climate zones, so that no new complex simulations are required and older certificates can also be used. These are Würzburg for average climate (instead of Strasbourg), Stockholm for colder climate (instead of Helsinki) and Athens for warmer climate. As typical solar thermal systems for water heating and space heating operate in the temperature range between 15 and 60°C, it was decided to choose the arithmetic mean of the *GTY* values of 25 and 50°C as the reference value.

$$GTY = \frac{GTY\ (25\ °C) + GTY\ (50\ °C)}{2} \qquad (8)$$

This means that there is only one basic value for each climate zone and each collector. As the actual usability of the gross heat yield depends on the load to be served, calculations and simulations were carried out for the various locations and the load profiles for hot water preparation, taking into account standard storage and pipe losses. The same was done for different heating requirements. In the end, square regressions were determined for all three climate zones, which were then used to determine the so-called "solar device factor" for space heating (*sh*) according to formula (9) as a function of the reference heating demand Q_H.

$$f_{sol,sh} = a \cdot \left(\frac{GTY}{Q_H}\right)^2 + b \cdot \left(\frac{GTY}{Q_H}\right) + c \qquad (9)$$

with

reference annual heating demand: $Q_H = P_{design} \cdot H_{HE}$ (10)

with

design load for heating (boiler): $P_{design} = \frac{800}{H_{HE}} \cdot P_4$ (11)

annual equivalent active mode hours H_{HE}: 2066 h for average, 2465 h for colder, 1336 h for warmer climate

The solar device factor for water heating (*wh*) is calculated according to formula (12) as a function of the hot water demand $Q_{wh,sol}$

$$f_{sol,wh,lp} = a \cdot \left(\frac{GTY}{Q_{wh,sol}}\right)^2 + \left(b + f_{profile}\right) \cdot \left(\frac{GTY}{Q_{wh,sol}}\right) + c \qquad (12)$$

with

annual solar water heating demand: $Q_{wh,sol} = 0{,}6 \cdot 366 \cdot (Q_{ref} + 1{,}09)$ (13)

Table 1. *Annual solar water heating demand*

Load profile	M	L	XL	XXL	3XL	4XL
Q_{ref}: [kWh/d]	5,845	11,655	19,07	24,53	46,76	93,52
$Q_{wh,sol}$: [kWh/a]	1523 kWh/a	2799 kWh/a	4427 kWh/a	5626 kWh/a	10508 kWh/a	20776 kWh/a

The associated climate and load-specific coefficients can be found in Figure 2.

Solar device space heating efficiency coefficients per climate	a	b	c
Average	0.00	0.50	1.00
Colder	0.00	0.61	1.00
Warmer	0.17	0.23	1.00

Solar device water heating efficiency coefficients per climate	a	b	c	d
Average	-0.22	1.93	0.55	0.36
Colder	-0.52	1.94	0.60	0.28
Warmer	1.17	0.59	0.83	0.50

Load profile	M	L	XL	XXL	3XL	4XL
$f_{profile}$ (-)	f_M	f_L	f_{XL}	f_{XXL}	f_{3XL}	f_{4XL}
	0	0.92	1.38	1.64	2.43	3.56

Figure 2. *Climate and load specific coefficients [1] and [2]*

The results are limited upwards and downwards due to the climate and should be given by the manufacturer as a look-up table for the 3 climate zones (see example in table 2. and 3. for collector combinations of the Greek manufacturer Sammler [3], [4] for average climate).

Table 2. *Example solar device factor for space heating*

		Design values	Solar device efficiency factor average climate $f_{sol,sh}$ – *load-dependent (load exemplary) (min. 100 %, max. 300 %)*					
Package and collector data		P_{design}	**< 2,4 kW**	**< 4,8 kW**	**< 7,3 kW**	**< 9,7 kW**	**< 14,5 kW**	**< 29,0 kW**
		P_4	**< 6,3 kW**	**< 12,5 kW**	**< 18,8 kW**	**< 25,0 kW**	**< 37,5 kW**	**< 75,0 kW**
no. x type	**gross area**	$GTY \mid Q_H$ **[kWh]**	**≤ 5.000**	**≤ 10.000**	**≤ 15.000**	**≤ 20.000**	**≤ 30.000**	**≤ 60.000**
2 x ARIS 2004	4,2 m^2	2190 kWh	122%	111%	107%	105%	104%	102%
3 x ARIS 2004	6,3 m^2	3285 kWh	133%	116%	111%	108%	105%	103%
4 x ARIS 2004	8,4 m^2	4380 kWh	144%	122%	115%	111%	107%	104%
5 x ARIS 2004	10,6 m^2	5475 kWh	155%	127%	118%	114%	109%	105%
6 x ARIS 2004	12,7 m^2	6571 kWh	166%	133%	122%	116%	111%	105%
7 x ARIS 2004	14,8 m^2	7666 kWh	177%	138%	126%	119%	113%	106%
8 x ARIS 2004	16,9 m^2	8761 kWh	188%	144%	129%	122%	115%	107%
9 x ARIS 2004	19,9 m^2	9856 kWh	199%	149%	133%	125%	116%	108%
10 x ARIS 2004	21,1 m^2	10951 kWh	210%	155%	137%	127%	118%	109%

Table 3. *Example solar device factor for water heating*

Pre-designed system or package and collector data				Solar device efficiency factor average climate $f_{sol,wh,lp}$ – *load-dependent (min. 100 %, max. 450 %)*					
name	**no. x type**	**gross area**	***GTY***	**M**	**L**	**XL**	**XXL**	**3XL**	**4XL**
A168	1 x ARIS 2004	2,11 m^2	1095 kWh	182%	140%	114%	103%	-	-
A169	1 x ARIS 2504	2,52 m^2	1308 kWh	205%	156%	125%	112%	-	-
A208	1 x ARIS 2004	2,11 m^2	1095 kWh	182%	140%	114%	103%	-	-
A228	1 x ARIS 2504	2,52 m^2	1308 kWh	205%	156%	125%	112%	-	-
A229	1 x ARIS 2904	2,93 m^2	1667 kWh	240%	182%	143%	128%	-	-
A230	2 x ARIS 2004	4,22 m^2	2190 kWh	287%	218%	170%	150%	113%	-
A308	2 x ARIS 2004	4,22 m^2	2190 kWh	287%	218%	170%	150%	113%	-
A328	2 x ARIS 2504	5,04 m^2	2616 kWh	322%	247%	191%	167%	123%	-
A338	2 x ARIS 2904	5,86 m^2	3334 kWh	372%	293%	225%	197%	142%	106%

Depending on the label class, the hot water storage tank also receives a so-called tank factor between 1,0 and 1,2. When multiplied by the solar device factor, this results in the solar device efficiency for space heating $\eta_{sol,sh}$, formula (14), or water heating $\eta_{sol,wh,lp}$, formula (15) for a specific load profile. The tank factor thus rewards better thermally insulated storage tanks.

Table 4. *Tank factor*

Label class tank	**A**	**B**	**C**	**D**	**E**
Tank factor f_{tank}	**1,20**	**1,15**	**1,10**	**1,05**	**1,0**

$$\eta_{sol,sh} = f_{sol,sh} \cdot f_{tank} \qquad (14)$$

$$\eta_{sol,wh,lp} = f_{sol,wh,lp} \cdot f_{tank} \qquad (15)$$

Finally, this solar device efficiency is now specified according to the general formula (5). Formula (16) applies to the space heating efficiency of a solar hybrid, formula (17) applies to the solar assisted package and formula (18) applies to the solar water heating efficiency as a package. In all cases the efficiency is multiplied by the efficiency of the conventional heating appliances - boiler, heat pump, electric immersion heater - or packages resp. hybrid systems. It should be noted that the "add on efficiency“ through improved temperature control (TC) is only used in the package calculation as the influence of the control is already included in the hybrid heater.

Efficiency solar hybrid for space heating:

$$\eta_{s,hyb} = \eta_{sol,sh} \cdot \eta_s \qquad (16)$$

with conventional space heating efficiency: η_s

Efficiency solar assisted package for space heating:

$$\eta_{s,pack} = \eta_{sol,sh} \cdot \frac{Q_{H,pack}}{Q_{HE,pack}} + TC \qquad (17)$$

with

reference annual heating demand of package: $Q_{H,pack}$

annual energy consumption of package: $Q_{HE,pack}$

temperature control benefit: TC

Efficiency solar water heating package:

$$\eta_{wh,pack,lp}\ (or\ \eta_{wh+sol,lp}) = \eta_{sol,wh,lp} \cdot \eta_{wh,lp} \qquad (18)$$

with conventional water heating efficiency: $\eta_{wh,lp}$

4. Application and outlook

The TSM method refers to the gross thermal yield of collectors. The calculation follows a simple procedure (Figure 3. and 4.) and rates solar thermal systems according to their performance. It can be applied to all common solar systems, even thermosiphons and non-separable solar systems like e.g. ICS. In the rare cases that no GTY of the collector is directly available the value can be determined via the Q_{nonsol} [2] derived from the SOLICS method. Then the general calculation can be applied the same way by using a tank factor =1,0.

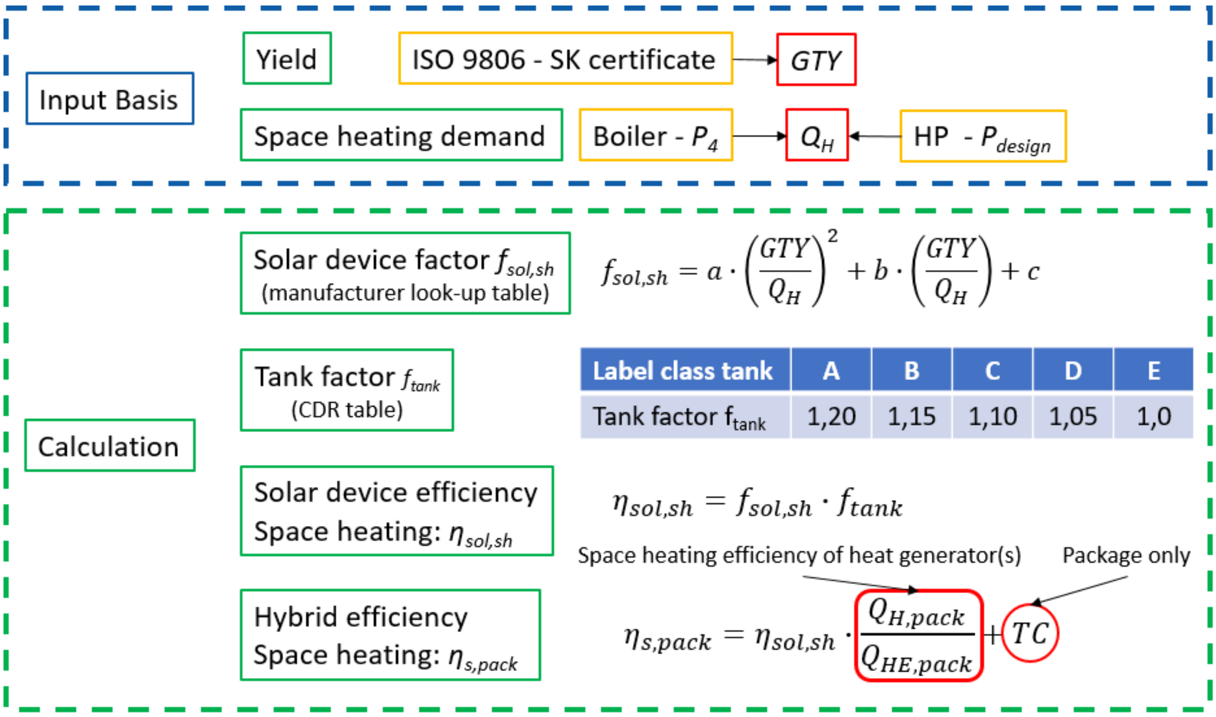

Figure 3. *Flow chart space heating*

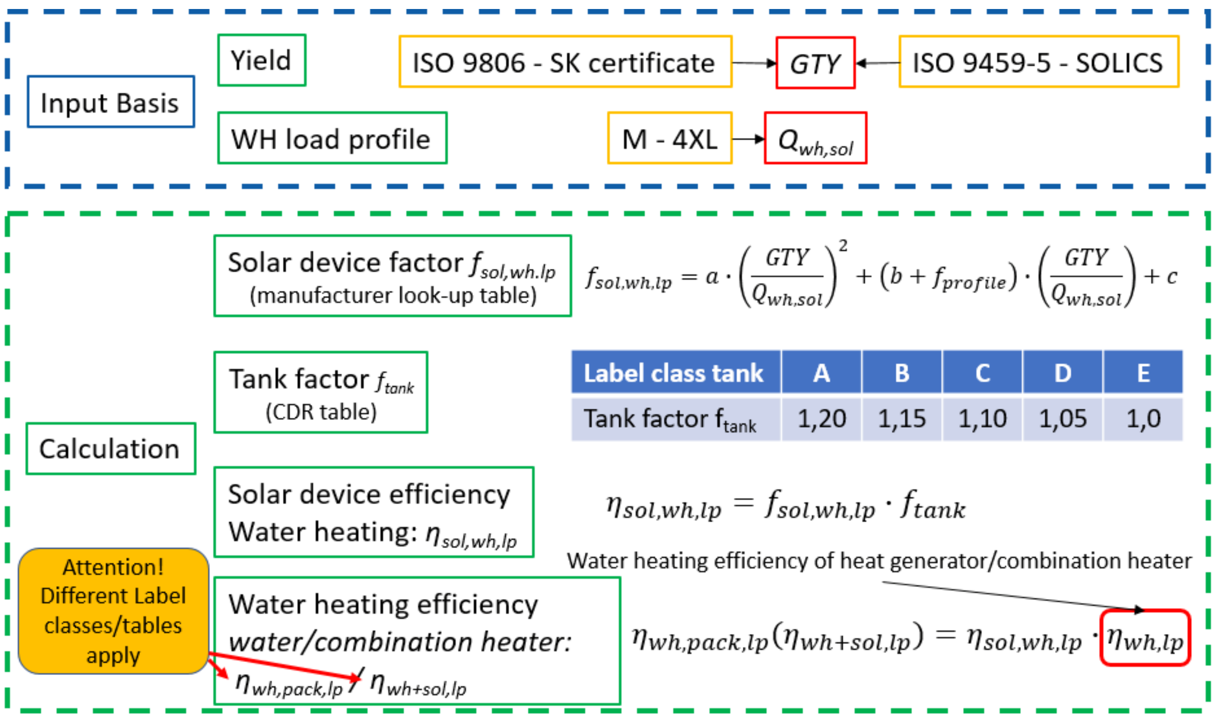

Figure 4. *Flow chart water heating*

This simplicity and generality is a milestone for the entire European solar thermal industry. According to current estimates, the revised regulations should be published in the first half of 2025 and come into force a year later. The label design is still open. It is to be hoped that SHE's extensive proposals on this will be taken into account, which will ensure better understanding through a more customer-friendly design.

5. Exemplary results

Exemplary calculations for water and space heating in combination with condensing boilers and heat pumps were carried out and are presented in tables 5, 6, 7 and 8 under the boundary conditions given in Table 9.

- **Package water heating for average climate:**
  The combination of a class F water heater (gas condensing boiler) with a normal sized solar thermal system can easily achieve class A.

Table 5. *Results water heating – condensing boilers*

TSM - assessment for condensing boiler for heat pump typically better if possible*					
	Hot water tapping profile	**M**	**L**	**XL**	**XXL**
Label classes	Condensing boiler without solar	F	F	F	F
	Condensing boiler, solar assisted space heating 4 m² FPC or 3,2 m² ETC	B	C	D	E
	Condensing boiler, solar assisted space heating 10 m² FPC or 8 m² ETC	A	A	A	B
	Condensing boiler, solar assisted space heating 14 m² FPC or 11,2 m² ETC	A	A	A	A
	Condensing boiler, solar assisted space heating 20 m² FPC or 16 m² ETC	A	A	A	A
Effi-cienciy	Condensing boiler without solar	68%	76%	79%	79%
	Condensing boiler, solar assisted space heating 4 m² FPC or 3,2 m² ETC	202%	172%	139%	123%
	Condensing boiler, solar assisted space heating 10 m² FPC or 8 m² ETC	321%	325%	263%	229%
	Condensing boiler, solar assisted space heating 14 m² FPC or 11,2 m² ETC	321%	359%	335%	292%
	Condensing boiler, solar assisted space heating 20 m² FPC or 16 m² ETC	321%	359%	373%	373%

- **Package space heating for average climate:**
  Reasonable designs can improve the class of a space heater as a package or solar hybrid by 2 levels.

Table 6. *Results space heating – condensing boilers*

TSM - Combination with gas condensing boiler η_s = 92% (Medium temperature - MT label regime, class F)*						
	rated heat output P_{rated}	6,3 kW	9,4 kW	12,5 kW	18,8 kW	25,0 kW
	design load P_{design}	2,4 kW	3,6 kW	4,8 kW	7,3 kW	9,7 kW
	Space heating demand Q_H	5.000 kWh	7.500 kWh	10.000 kWh	15.000 kWh	20.000 kWh
Label classes	Condensing boiler without solar	F	F	F	F	F
	Condensing boiler, solar assisted space heating 10 m² FPC or 8 m² ETC	D	E	E	F	F
	Condensing boiler, solar assisted space heating 14 m² FPC or 11,2 m² ETC	C	D	E	E	E
	Condensing boiler, solar assisted space heating 20 m² FPC or 16 m² ETC	B	C	D	E	E
Effi-ciency	Condensing boiler without solar	92%	92%	92%	92%	92%
	Condensing boiler, solar assisted space heating 10 m² FPC or 8 m² ETC	148%	131%	123%	114%	110%
	Condensing boiler, solar assisted space heating 14 m² FPC or 11,2 m² ETC	169%	145%	133%	121%	115%
	Condensing boiler, solar assisted space heating 20 m² FPC or 16 m² ETC	200%	166%	148%	131%	123%

Table 7. *Results space heating – heat pump/medium temperature*

TSM - Combination with air source heat pump ηs = 155% (Medium temperature - MT label regime, class D)*						
	design load P_{design}	2,4 kW	3,6 kW	4,8 kW	7,3 kW	9,7 kW
	Space heating demand Q_H	5.000 kWh	7.500 kWh	10.000 kWh	15.000 kWh	20.000 kWh
Label classes	Heat pump without solar	D	D	D	D	D
	Heat pump, solar assisted space heating 10 m² FPC or 8 m² ETC	B	B	B	C	C
	Heat pump, solar assisted space heating 14 m² FPC or 11,2 m² ETC	A	B	B	C	C
	Heat pump, solar assisted space heating 20 m² FPC or 16 m² ETC	A	A	B	B	B
Effi-ciency	Heat pump without solar	155%	155%	155%	155%	155%
	Heat pump, solar assisted space heating 10 m² FPC or 8 m² ETC	250%	221%	206%	192%	185%
	Heat pump, solar assisted space heating 14 m² FPC or 11,2 m² ETC	285%	244%	224%	204%	193%
	Heat pump, solar assisted space heating 20 m² FPC or 16 m² ETC	338%	279%	250%	221%	206%

Table 8. *Results space heating – heat pump/low temperature*

TSM - Combination with air source heat pump ηs = 220% (Low temperature - LT label regime, class C)*						
	design load P_{design}	**2,4 kW**	**3,6 kW**	**4,8 kW**	**7,3 kW**	**9,7 kW**
	Space heating demand Q_H	**5.000 kWh**	**7.500 kWh**	**10.000 kWh**	**15.000 kWh**	**20.000 kWh**
Label classes	Heat pump without solar	C	C	C	C	C
	Heat pump, solar assisted space heating 10 m² FPC or 8 m² ETC	B	B	B	B	B
	Heat pump, solar assisted space heating 14 m² FPC or 11,2 m² ETC	A	B	B	B	B
	Heat pump, solar assisted space heating 20 m² FPC or 16 m² ETC	A	A	B	B	B
Effi-ciency	Heat pump without solar	220%	220%	220%	220%	220%
	Heat pump, solar assisted space heating 10 m² FPC or 8 m² ETC	355%	314%	293%	272%	262%
	Heat pump, solar assisted space heating 14 m² FPC or 11,2 m² ETC	405%	347%	318%	289%	274%
	Heat pump, solar assisted space heating 20 m² FPC or 16 m² ETC	479%	396%	355%	314%	293%

Table 9. *Boundary conditions **

Condensing boiler: Water heating efficiency η_{wh} according to calculation method and profile (M-68%. L-<76%, XL-79%; XXL-79%)
Condensing boiler: Space heating efficiency ηs=92 %
Medium temperature air source heat pump η_s=155 % (D); Low temperature air source heat pump η_s=220 % (C);
Collector FPC: GTY = 537 kWh/m² (e.g. Viessmann FK Vitosol 100-FM SH1 – SK certificate 011-7S2673F see [4]) Collector ETC: GTY = 670 kWh/m² needs about 20% less gross area for the same results
Storage tank: Label class D (≈ class B in the current regulation) with tank factor f_{tank}= 1,05
Temperature Control benefit (TC): Solar Hybrid not applicable and for package here set to 0%

Data availability statement

Data of GTY used for calculation are accessible via Solar Keymark Database [4].

Author contributions

The method was developed mainly on the author´s findings and includes some aspects of a different proposal of Andreas Bohren, member of the expert group of SHE.

Competing interests

The authors declare that they have no competing interests.

Funding

The work on the method was partially financed by the Solar Keymark Certification Fund.

Acknowledgement

I would like to thank the Solar Heating Initiative for the opportunity to participate in the consultations on the revision of the EU regulations. I would also like to thank the then Secretary General of Solar Heat Europe, Pedro Dias, who managed to unite the interests of the solar thermal industry, as well as the former President Costas Travassaros, who together with me generalized the method to thermosiphons and practically all available collectors and systems. Not forgetting all the members of the expert group from research, industry and test institutes, in particular Andreas Bohren, who has critically and constructively accompanied the development of the method with his expertise and to whom we also owe the name TSM. The partial financing by the Solar Keymark Certification Fund has made it possible for the method to have a solid scientific basis, which has also convinced initially skeptical stakeholders from the heating industry.

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