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European Partnership for Energy and the Environment

<u>Boiler testing and calculation method</u>

<u>Tracked changes version of 24 November 2009 with respect to documents presented during the meeting of the Ecodesign Consultation Forum on 24/25 June 2009 – Documents 3, 5 and 6</u>

Document 3
Technical Definitions

RELATING TO GENERAL BOILER DEFINITIONS IN CHAPTER 2 OF DOCUMENT 2

Nominal boiler heating power output [Pmax] in kW is the maximum heating power output of the boiler under design (extreme) conditions, i.e. with no contribution of a possible solar heat generator. For possible air-source heat pump generators the contribution is determined when operating at –10 (Average climate), +2 (Warmer climate) and –22ºC(Colder climate).

Designated Emitters [RH]: Emitter(s) for which the manufacturer declares the product fit for purpose. Options are (Low Temperature) Radiator Heating [RH=1] or Floor Heating [RH=0].

Designated timer regime [TIM]: timer/setback regime for which the manufacturer declares the product fit for purpose. Options are with setback [TIM=1] or without setback [TIM=0]. A regime with setback applies only to radiator heating (RH=1)***Designated climates***: Climates for which the manufacturer declares the product fit for purpose. Options are average, warmer and colder climate, corresponding to the heating season reference climates as described in Tables I.1 and I.2. Declaration of the average climate is mandatory. Declaration of the warmer and/or colder climate is optional only for boilers with SOL or air-source HP. For climates (and emitter types as well as timer regimes) where the manufacturer declares the product not fit for purpose, no efficiency data and specific tests are needed and the manufacturer will declare an "X" in positions where product information according to document 4 is required.

Space heating load profile: Is a set of heating power and energy demands as well as related conditions (outdoor temperature, solar irradiance, CH-water temperatures) that is according to the harmonised standards --for amongst others design heat load calculation-- characteristic for a particular combination of boiler heating power output Pmax, emitters RH, timer regime TIM and one of the three designated climates. Its purpose is to set a standard against which the boiler's performance and seasonal efficiency can be determined.

Specific (seasonal) efficiency etas is specific for one load profile and expressed as

etas=cctrl+ Lh/Qtot

where

- *Lh* is the annual net heat demand in kWh/a, with Lh= hrsmax*Pdesign
- *Qtot* is the annual energy consumption in kWh/a
- *cctrl* is a correction for controls [-]

If SOL or an air-source HP are part of the product configuration the values of etas and Qtot are climate-specific. In that case etas is substituted by *etasA, etasW, etasC* and *Qtot* by *QtotA, QtotW* and *QtotC* indicating that the efficiency value relates to an Average, Warmer or Colder climate respectively.

Hrsmax is defined as follows taking into account the different climates:

	A	***W***	***C***

Total equivalent hours	***1550***	***1400***	***2150***
Equivalent hours including set back	***1100***	***700***	***1400***

Annual energy consumption Qtot is the calculated annual *primary energy* consumed under *normal reference conditions*, expressed as

Qtot= Lh+Lsys+Qgen+Qel

where

- *Lsys* is the annual heat demand caused by system losses, which in part depend on the Boiler
- *Qgen* are the strict heat generator losses per year
- *Qel* are the losses through auxiliary energy consumption minus possible gains of electric power consumption of CHP.

If SOL or an air-source HP are part of the product configuration the values of *Qtot, Lsys, Qgen* and *Qel* are climate-specific and those parameters will be denominated with a postscript A, W or C indicating that the parameters relate to an Average, Warmer or Colder climate respectively.

Extreme reference space heating conditions are defined by the heat load at outdoor temperatures of –10, +2 and –22 °C for the Average, Warmer and Colder climates respectively and average EU building values. ***Normal reference space heating conditions*** *for all heat generators except SOL* are defined by climate profiles for the EU *average* climate (Strassbourg), to be used for heating compliance assessment, and a *warmer* (Athens) and *colder* (Helsinki) climate, to be used for information purposes only, if the manufacturer claims that its device is suitable for either the warmer, the colder or both colder and warmer climates. The climate profiles use the '*bins*' format.

The *number of bin-hours hrdj* stems from representative weather data over the 1982-1999 period. The normal reference situation is based on heat generator operation with night-setback, therefore the hours refer to bin hours between 7:00 an 23:00h. The remainder of the load fractions is given in the first row ('night') of the table below.

The *number of bin-hours hrsj* refers to the number of bin hours without setback (24 h profile..

The *load fractions* $fracdA_j$, $fracdW_j$ *and* $fracdC_j$ for the average, warmer and colder climate respectively indicate the fraction of the total heating demand ('load') occurring in a specific bin for a specific climate. They are determined for the heating season, using the heating reference outdoor *Tdesignh* resulting in the expression of $pl_j = (T_j - 16)/(Tdesignh - 16)$. Values of *Tdesignh* are –10, +2 and –22 for the Average, Warmer and Colder climates respectively.

The expression for $fracdA_j$ is given below:

$$fracdA_j = \frac{hrdA_j * pl_j}{\sum_{j=1}^{46} hrdA_j * pl_j}$$

Expressions for $fracdW_j$ and $fracdC_j$ are as for $fracdA_j$ but substituting nA_j for nW_j and nC_j respectively in the above expression.

For load fractions $fracsA_j$, $fracsW_j$ *and* $fracsC_j$ the same expression applies, but substituting hrd values with hrs values and renaming fracd parameters with the corresponding fracs names.

Note that the 'night' fractions represent the situation with maximum night-setback. Actual fraction will depend on the reheat power of the boiler used at the end of the setback period to return to the normal'comfort temperature (see expressions in footnote, which are part of the mathematical model in document 5).

The outdoor temperatures assumed during night setback are +1, +6 and 0 ºC for the Average, Warmer and Colder climate respectively.

Table I.1. Heating season reference climates, with outdoor temperature T_j, number of hours and load fraction $frac_j$ per bin number j, with and without setback, for the Average(A), Warmer(W) and Colder(C) climate.

		With Setback (TIM=1)						Without Setback (TIM=0)					
		hours(7.00-23.00h)			load frac			hours (24h)			load fractions(24h)		
	climate-->	W	A	C	W	A	C	W	A	C	W	A	C
bin	*Tout*												
j	T_j	$hrdW_j$	$hrdA_j$	$hrdC_j$	$fracdW_j$	$fracdA_j$	$fracdC_j$	$hrsW_j$	$hrsA_j$	$hrsC_j$	$fracsW_j$	$fracsA_j$	$fracsC_j$
#	°C	hrs	hrs	hrs	%	%	%	hrs	hrs	hrs	%	%	%
night[1,2,3]		340	390	445	37,1	31,1	27,7						
9	-22			0			0,0			1			0,0
10	-21			1			0,0			6			0,2
11	-20			4			0,2			13			0,5
12	-19			11			0,5			17			0,6
13	-18			12			0,5			19			0,7
14	-17			15			0,6			26			0,9
15	-16			29			1,1			39			1,3
16	-15			32			1,2			41			1,4
17	-14			24			0,9			35			1,1
18	-13			29			1,0			52			1,6
19	-12			23			0,8			37			1,1
20	-11			27			0,9			41			1,2
21	-10		0	28		0,0	0,9		1	43		0,0	1,2
22	-9		2	28		0,1	0,8		25	54		1,2	1,4
23	-8		13	55		0,7	1,6		23	90		1,0	2,3
24	-7		12	79		0,6	2,2		24	125		1,0	3,1
25	-6		18	118		0,8	3,1		27	169		1,1	4,0
26	-5		35	137		1,5	3,4		68	195		2,7	4,4
27	-4		44	199		1,8	4,7		91	278		3,4	5,9
28	-3		56	195		2,2	4,4		89	306		3,1	6,2
29	-2		101	286		3,8	6,1		165	454		5,5	8,7
30	-1		100	285		3,6	5,7		173	385		5,5	7,0
31	0		121	243		4,0	4,6		240	490		7,2	8,4
32	1		170	364		5,3	6,5		280	533		7,8	8,5
33	2	1	193	247	0,1	5,6	4,1	3	320	380	0,2	8,3	5,7
34	3	2	218	142	0,2	5,9	2,2	22	357	228	1,5	8,6	3,2
35	4	22	210	150	1,6	5,3	2,1	63	356	261	4,0	8,0	3,3
36	5	19	190	182	1,3	4,4	2,4	63	303	279	3,7	6,2	3,3
37	6	71	211	138	4,4	4,4	1,6	175	330	229	9,4	6,1	2,4
38	7	79	213	179	4,4	4,0	1,9	162	326	269	7,8	5,5	2,6
39	8	129	253	174	6,3	4,2	1,6	259	348	233	11,1	5,2	2,0
40	9	181	235	165	7,8	3,4	1,4	360	335	230	13,5	4,4	1,7
41	10	252	236	192	9,2	3,0	1,4	428	315	243	13,7	3,5	1,6
42	11	294	163	156	9,0	1,7	0,9	430	215	191	11,5	2,0	1,0
43	12	330	144	116	8,1	1,2	0,5	503	169	146	10,8	1,3	0,6
44	13	312	123	134	5,7	0,8	0,5	444	151	150	7,1	0,8	0,5
45	14	279	86	93	3,4	0,4	0,2	384	105	97	4,1	0,4	0,2
46	15	238	66	58	1,5	0,1	0,1	294	74	61	1,6	0,1	0,1
subtot		2550	3603	4795	100,0	100	100	3590	4910	6446	100	100	100
'off'		1842	1521	1757				802	214	106			
total		**4392**	**5124**	**6552**	100,0	100,0	100,0	**4392**	**5124**	**6552**			
					+[1]	+[2]	+[2]	**allhrsW**	**allhrsA**	**allhrsC**			

[1]=reheat power 0,83 Pradnom, average reheat time 1h45'; [2]=reheat power 0,83 Pradnom; average reheat time 1h40' – 1h50' per night.

Normal reference heating conditions *for solar heat generators SOL* are defined by climate profiles for the EU *average* climate (Strassbourg), to be used for heating compliance assessment, and a *warmer* (Athens) and *colder* (Helsinki) climate, to be used for information purposes. The climate profiles use the '*monthly*' format.

Table I.2. Heating season reference values for SOL reference climate, with monthly values for load fraction, outdoor temperature and solar irradiance

	Heating Season Month nr.								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Heat load fractions									
LA_tm= (Lh+Lsys)*	0,20	0,20	0,13	0,06	0,06	0,16	0,19		
LW_tm= (Lh+Lsys)*	0,26	0,24	0,18	0,03	0,06	0,23			
LC_tm= (Lh+Lsys)*	0,17	0,17	0,14	0,09	0,04	0,03	0,08	0,12	0,16
Outdoor temperature in oC									
ToutA_tm	2,8	2,6	7,4	12,2	11,9	5,6	3,2		
ToutW_tm	9,5	10,1	11,6	15,3	14,5	10,4			
ToutC_tm	-3,8	-4,1	-0,6	5,2	11	12,8	6,7	1,2	-3,5
Solar irradiance in W/m2									
qsolmA_tm	70	104	149	192	129	80	56		
qsolmW_tm	129	138	182	227	126	110			
qsolmC_tm	22	75	124	192	234	120	64	24	13

Heat input is intended as equivalent gross calorific value (Hs) of the hourly fossil fuel consumption or - in the absence of fossil fuel consumption - the electric power input for heat production.

Primary Energy consumption in kWh is expressed as the quantity of fossil fuel expressed in its equivalent Gross Calorific Value (upper heating value, Hs) and/or the electric energy consumed (or generated in the case of cogeneration) converted to primary energy equivalent using a primary energy conversion factor ***primenergy*** of 2,5. The tables below give the relevant energy parameters and their applicable tolerances.

Table I.3. Electricity and Fossil Fuels

Measured quantity	Unit	Value	Permissible deviation (average over test period)	Uncertainty of measurement (accuracy)	Notes
Electricity					
power	W			± 1 %	
energy	kWh			± 1 %	
voltage, *test-period > 48 h*	V	230/ 400	± 4 %	± 0,5 %	[1]
voltage, *test-period < 48h*	V	230/ 400	± 2 %		
voltage, *test-period < 1 h*	V	230/ 400	± 1 %	± 0,2 %	
electric current	A			± 0,5 %	
frequency	Hz	50	± 1 %		
Gas					
types	-	Test gases GAD			[2]
net calorific value (NCV)	MJ/ m³	Test gases GAD		± 1 %	[3]
temperature	K	288,15		± 0,5	[3]
pressure	mbar	1013,25		± 1 %	[3]
density	dm³/kg			± 0,5 %	
flow rate	m³/s or l/min			± 1 %	
Oil					
Heating gas oil					
composition, *Carbon/ Hydrogen/ Sulfur*	kg/kg	86/13,6/ 0,2 %			
N-fraction	mg/kg	140	± 70		[4]
net calorific value (NCV, Hi)	MJ/kg	42,689			[5]
gross calorific value (GCV, Hs)	MJ/kg	45,55			[6]
density **ρ15** at 15 °C:	kg/dm³	0,85			
Kerosene					
composition, *Carbon/ Hydrogen/ Sulfur*	kg/kg	85/ 14,1/ 0,4 %			
N-fraction	mg/kg	140	± 70		[4]
net calorific value (NCV, Hi)	MJ/kg	43,3			[5]
gross calorific value (CGV, Hs)	MJ/kg	46,2			[6]
density **ρ15** at 15 °C:	kg/dm³	0,79			

Notes:

[1] Test periods >48 h apply to heat pump and/or solar assisted Products. Test periods <48 h apply to conventional Products. Test period <1 h applies to the simplified test procedures for electric instantaneous water heaters

[2] Test gases as in the essential requirements of the Gas Appliances Directive 90/396/EEC with amendments as in 93/68/EC

[3] A factor *K* has to be applied to correct the calorific value for the actual average atmospheric

absolute pressure *pa* and gas gauge pressure *pg* as well as the average gas temperature *Tg* over the test period.

K = (*pa* + *pg*)/1013,25 × 288,15/(273,15+*Tg*)

[4] In case of low Sulfur test fuels,N-fractions lower than 70 mg/kg and lower S fractions are allowed

[5] Default value, if value is not determined calorimetrically. Also other values are defaults. Alternatively, if volumetric mass and sulphur content are known (e.g. by basic analysis) the net heating value (*Hi*) may be determined with **Hi = 52,92 - (11,93 × *ρ15*)- (0,3 - *S*)** in MJ/kg

[6] Calculated from net calorific value with multiplier 1,067× GCV=1,067 × NCV

Table I.4. Characteristics of reference test gases, dry gas at 15°C and 1.013,25 mbar (illustrative) [1]

Gas family and group	Desig-nation	Composition by volume %	Net calorific value **Hi** in MJ/m³	Gross calorific value **Hs** in MJ/m³	Wobbe-index net **Wi** in MJ/m³	Wobbe-index gross **Ws** in MJ/m³	density in kg/m³	Test pressure [2] nominal, minimum and maximum in Pa		
								pn	pmin	pmax
1st family										
Group a	**G 110**	CH4 = 26 H2 = 50 N2 = 24	13,95	15,87	21,76	24,75	0,411	8	6	15
2nd family [3]										
Group H and Group E	**G 20**	CH4 = 100	34,02	37,78	45,67	50,72	0,555	20	17	25
Group L	**G 25**	CH4 = 86 N2 = 14	29,25	32,49	37,38	41,52	0,612	25	20	30
3 rd family										
Groups B/P and B [4]	**G 30**	n-C4H10=50 i-C4H10=50	116,09	125,81	80,58	87,33	2,075	29 50	25/ 20 42,5	35 57,5
Group P	**G 31**	C3H8 = 100	88,00	95,65	70,69	76,84	1,550	37 50	25 42,5	45 57,5

Notes:

[1] The definition, preparation and use of test gases is determined by the Essential Requirements of the Gas Appliances Directive. The table above reflects a momentary situation that may be subject to change and is for illustrative purposes only. It does not include limit gases and gases distributed nationally or locally.

[2] Test supply pressures when no test coupling exists. Note that for Groups B/P and P two sets of test pressures are available.

[3] Not shown is Group N (category I2N), which are as appliances using only second family gases at the prescribed supply pressure and that automatically adapt to all gases of the second family. They are tested with both G20 and G25 gases and both sets of pressure specifications.

[4] pmin = 25 Pa applies to group B/P; pmin=20 Pa applies to group B. Note That "LPG" is a mixture of 3rd family gases, usually tested with test gas Group B/P or B.

Solar energy contribution is the global solar irradiance ***G*** in W/m² on an optimally tilted collector surface with South orientation as defined in table II.2 multiplied with the solar heat generator efficiency characteristics as determined in accordance with document 5 and conditions described in Table I.5 below.

Table I.5. Solar energy parameters for solar collector tests. Set values and tolerances

Measured quantity	Unit	Value	Permissible deviation of the arithmetic mean values from set values	Permissible deviations of individual measured values from set values	Uncertainty of measurement (accuracy)	Notes
Solar collector (glazed)--> ***eta0, a1, a2 through least square curve fit for 4 x 4 test results; Asol***						
Test solar irradiance (global G, short wave)	W/m²	>700 W/m²	± 50 W/m² (test)		± 10 W/m² (indoors)	[1]
Diffuse solar irradiance (fraction of total G)	%	<30%				[2]
Thermal irradiance variation (indoors)	W/m²				± 10 W/m²	
Fluid temperature at collector inlet/outlet	°C/ K	range 0-99 ºC	± 0,1 K		± 0,1 K	[3]
Fluid temperature difference inlet/outlet					± 0,05 K	[4]
Incidence angle (to normal)	°	<20°	±2 % (<20°)			[5]
Air speed parallel to collector	m/s	3 ± 1 m/s			0,5 m/s	[6]
Fluid flow rate (also for simulator)	kg/s	0,02 kg/s per m² collector aperture area	± 10 % between tests	± 1 % (max dev in 1 test)		
Tilt angle	°	45°				
Orientation	NESW	S ± 45°				
Collector area A (absorber, gross, aperture)	m²				± 0,3 %	
Pipe heat loss of loop in test	W/K	<0,2 W/K				

Notes:

[1] Measured by pyranometer, equivalent to Class I (ISO 9060) or better. With shading ring or pyrheliometer and provided with a dessicator. Regular inspection of the desiccator shall be observed. Test sample rate 30 s.
Pyranometer stays fixed in one test-point before data recording begins. Sensor shall be co-planar to collector ± 1°, at midheight of collector and receiving the same levels of direct, diffuse and reflected solar radiation as collector. When used with solar irradiance simulator minimize effect of infrared radiation at wavelength > 3µ

[2] If <30% can then be ignored (from EN 12975-2)

[3] Measure within 200 mm of collector connection

[4] Preferable accuracy ± 0,02 K

[5] Measured by simple device: spike normal to collector and reference circles on collector plane to read spike shadow.

[6] Measure 10 to 50 mm above collector, use artifical wind generator if < 2m/s. Check uniform distribution with anemometer. Temperature of artificial wind is ambient ± 1K.

Ambient heat energy contribution is depending on the source of the HP:

- for air-source the outdoor air temperature as defined in the normal reference conditions in table II.1 and represented by test points as defined in document 5;
- for brine-source an average liquid temperature of 0 ºC;
- for water-source an average liquid temperature of 10 ºC;
- for ventilation air source an air temperature of 20 ºC if the flow rate does not exceed values mentioned in the notes to Table I.6 below.

Table I.6. Energy inputs and related parameters ambient heat/ heat pumps

Measured quantity	Unit [climate conditions]	Value	Permissible deviation (average over period	Permissible deviations of individual measured values	Uncertainty of measurement (accuracy)	Notes
Heat pump: Liquid (heat transfer media: brine or water)						
inlet temperature	°C	0 (brine)/10	± 0,2	± 0,5	± 0,1	
outlet temperature	°C		± 0,3	± 0,6		
volume flow	m³/s or l/min		± 2 %	± 5 %	± 1 %	
static pressure difference	Pa		--	± 10 %	± 5 Pa/ 5%	[1]
Heat pump: Air (as heat source)						
outdoor air temperature (dry bulb or dry bulb/wet bulb) (***Tout***)	°C	Table II.1 and document 6	± 0,3	± 1	± 0,2/± 0,3	[2]
vent exhaust air temperature (***Tex***)	°C	20	± 0,3	± 1	± 0,2	
mixed air temperature (***Tmix***)	°C	see note	± 0,3	± 1	± 0,2	[3]
inlet air humidity	g H2O/ m³	5,5			± 5 %	[4]
volume flow	dm³/s		± 5 %	± 10 %	± 5 %	
static pressure difference	Pa		--	± 10 %	± 5 Pa/ 5%	[5]

Comment [r1]: Brought up to date with latest version of EN 14511-3 which specifies also outlet temperature tolerances.

Comment [r2]: Latest version of EN 14511-states 1% (5% in previous version) for volume flow

Notes:

[1] maximum value according to manufacturer instructions shall be set at liquid pump outlet, at nominal flow rate specified. Accuracy of measurement is ± 5 Pa if value < 100 Pa and 5% if value >100 Pa.

[2] Set values apply to electric or fossil fuel fired heat pumps.

[3] In order to avoid over-ventilation a maximum availability of ventilation exhaust air at a temperature of 20 ºC is assumed, depending on the Load Profile. This parameter *ventex* [in m³/h] is given below. If the actual nominal inlet air flow rate *ventreal* [in m³/h] exceeds this value, the heat pump shall use the mixed air temperature *Tmix* [in ºC] for testing. *Tmix* is determined from the relative

proportion of exhaust air temperature *Tex* [in ºC] and exhaust air flow rate *ventex* versus outdoor air temperature *Toutair* and the surplus air flow (*ventreal-ventex*).

In formula: $\mathbf{Tmix = \{Tex \times ventex + Tout \times (ventreal - ventex)\} / ventreal}$

Default value for *ventex* is: ventex (in m³/h)=20*PmaxA (in kW)

Multiplier based 80% on average existing house 0,5 (mechanical ventilation factor)x250m3/ 8 (kW)=ca. 16) and 20% new house of 8 kWpeak power→ 0,5x625/8=39. Total 0,8x16+0,2x39= ca. 20.

If *ventreal* is not known a default value of 300 m³/kW nominal power of heat pump can be used. Note that XXS applies to water heating only.

[4] Note that an absolute humidity of 5,5 g/m³ results in 37% Relative Humidity at 20 ºC dry bulb (12 ºC wet bulb), 65% RH at 10 ºC dry bulb (9 ºC wet bulb), etc.

[5] maximum value according to manufacturer instructions shall be set at duct outlet, with heat pump not operating. Nominal air flow shall be verified. Accuracy of measurement is ± 5 Pa is value is < 100 Pa and 5% if value >100 Pa.

RELATING TO BOILER PRODUCT CONFIGURATION (BOOLEAN AND INTEGERS)

Relating to Data Inputs document 4, Table II.4**.**

SOL, HP, EL, FOS, FOSB, CHP are not only the denominations of the heat generators mentioned in Article 2 but also Boolean parameters (values 'y'=1; 'n'=0) indicating whether (value 'y'=1) or not (value 'n'=0) the heat generators of these types are part of the product configuration.

Timer (TIM): Design option of a heating regime whereby the boiler is shut down during a setback-period of 8 hours minus the time (in h) necessary to reheat the space temperature again from setback level to its normal comfort level. To apply this design option the timer parameter must be declared (TIM=yes=1). Timer is a declared parameter and does not require the physical presence of a timing device in the Product;

System Buffer (BUF, FOSBUF): Primary storage tank. If the configuration includes a primary storage tank the Boolean parameter BUF must be set to BUF=1 (otherwise BUF=0) and the manufacturer shall declare its volume Vbuf in litres and standing losses Psbbuf in W at a temperature difference between store and ambient of 40 K. The manufacturer can add the volume of the boiler to Vbuf if he fills in the option FOSBUF=yes=1, but a conscious use of the boiler as a primary store will result in a higher standby losses in the calculation procedure. Also in case EL is the only heat generator and using a store with volume >4 litres BUF=1 and standing losses will be declared as Psbbuf.

Combi (parameter ***SOLCOMBI, HPCOMBI***) indicates whether the Boiler is also a Combi-boiler, to be declared only in case SOL or HP is part of the product configuration.

Load profile water heating (waterload) is the declared load profile for the Combi-boiler, characterised by the Qref values in Table III.2.

Outdoor (FOSOUT, SOLOUT, BUFOUT)s: Any Boiler or storage tank that is designated by the manufacturer to operate only outdoors. Indoors is defined as the complementary concept of outdoors, i.e. indoors is not outdoors. A designated indoors/ outdoors position shall be declared for the preferential heat generator with the parameter FOSOUT and –if applicable—for the position of the solar storage tank with parameter SOLOUT and/or the position of the system buffer with parameter BUFOUT.

Integrated Collector Storage (ICS): Boolean parameter indicating whether the solar heat generator is of the ICS type; if so, the collector cannot be tested separately form the integrated storage tank.

Heat pump main energy source (HPELEC). Boolean parameter indicating whether the main energy source of the HP is electric ('y'=1) or fossil ('n'=0).

Heat pump ambient heat source (HPSRC). Numerical parameter indicating the ambient heat source, to be chosen from the following options: 1. Outdoor air. 2. Brine; 3. Ventilation air; 4. Water.

Circulator pump options (PMP). Numerical parameter indicating the type of circulator pump and pump configuration, to be chosen from the following options :

1. Variable speed pump & permanent magnet [option **vsd&pm**]
2. Variable speed pump, no permanent magnet type [option **vsd**]
3. Fixed speed pump [option **fixed speed**]
4. No pump, meaning there will be a stand-alone pump in the CH-circuit [option **no pump**]
5. Internal pump only, meaning a configuration with two circulators: one for a small boiler loop and another external pump for the CH-circuit [option **internal only**]

Numbering in excel does not match this numbering ➔ this needs to be aligned.

Note: Circulator efficiency will be regulated through Commission Regulation xx/xx/EC with entry date 1.1.20xx. Until that time default values for the primary energy consumption of the 5 options above are given as a fraction of **Lh** as 2, 2,5, 4, 5 and 6% respectively. After 1.1.20xx the first 3 options are taken as one integrated pump option. The values for the three options integrated pump, no pump, internal only with default values 2, 3 and 5%;

Pump timer (tpmp). Numerical parameter indication for the type of options for circulator pump timer control, to be chosen from the following options:

1. circulator switching off a few minutes after every burner off [option <5min],
2. circulator running all day but (almost) not in the night [option 16h];
3. circulator running 24h/day [option 24h].

Air-fuel mix controls (***AFM, AFMb***) relate to gas- and oil fired CH-boilers and the method of controlling the flow of air (oxygen) and fossil fuel to the combustion process. Four methods are distinguished (values of AFM/AFMb in brackets):

1. ***Atmospheric***: burner regulation through gas-valve. No pre-mix fan present.(0,018)
2. ***Pneumatic***: pre-mix fan present.(0,010)
3. ***Ionisation***: pre-mix fan present plus control of fan and gas-valve through measurement of ionisation from flames.(0,004)
4. ***Next gen O2***: pre-mix fan present plus control of fan and gas-valve through (next generation) measurement of oxygen-content of flue gases.(0,001)

Temperature control options (CTRL). Temperature controls are controls that regulate the boiler temperature on the basis of manual operation (option 1), an on/off signal from a room thermostat (2), an analogue signal of an outdoor temperature sensor (3), an analogue signal of an outdoor temperature sensor in combination with an on-off thermostat (4), a digital signal (‘translated’ analogue signal) of a precision ‘modulating’ room thermostat (5) and an on/off signal from a room thermostat with an imposed specific cycle-time (6).

In detail:

1. ***Fixed BT*** (boiler thermostat): Boiler temperature adjusted manually, no room thermostat and no outdoor sensor (weather control).

2. ***On/off RT*** (room thermostat): Room thermostat with sensor, sends 1-way on/off signal to boiler CPU.

3. ***Open protocol***. As option 1, but the CPU uses an open communication protocol, enabling easy transformation to options 5 to 7 below.

4. ***Weather controlled***: Outdoor temperature sensor sends analogue signal to boiler CPU to regulate the boiler temperature along a so-called “heating curve”, which is a concept whereby the boiler temperatures is set against the outdoor temperature. The slope and staring point of the curve are set by the factory and can be adjusted in-situ by installer or consumer. According to standards the heating curve is set at a level that can guarantee a temperature of 25 ° in every room, depending on the setting of the (thermostatic) radiator valve. For the night a setback temperature of 21 °C applies by default. Weather control requires a 24h/day pump operation to check for heat demand at the radiator level. Pump operation hours can be reduced by employing a night-setback for the pump [parameter tpmp; result is an 8h reduction per day].

5. ***Chrono-proportional RT + variable capacity boiler*:** High-quality electronic on/off thermostat with a time-restricted cycle. Settings typically are in the order of 3 to 6 cycles per hour, which means that every on/off cycle lasts 10-20 minutes and the thermostat ‘decides’ on the length of the on-mode. Best performance of this type occurs with fixed capacity boilers with relatively high thermal inertia; the imposed cycle-time restricts room temperature fluctuations. The use with a variable capacity unit might prohibit a better option and is therefore valued lower.

6. ***Chrono-proportional RT + fixed capacity boiler*:** As above, but now in combination with a fixed capacity boiler.

7. ***Modulating RT***: The thermostat continuously communicates the room temperature to the boiler based on a fast-acting and high-precision sensor, allowing the use of advanced logic in the CPU to regulate boiler temperature in function of the temperature of the reference room where the thermostat is positioned. May be equipped with additional ‘satellite’ temperature sensors to capture temperature in more than one room. Best performance of this type occurs in situations where a position for the thermostat can be found that is representative of the heat load of all space served by the CH-boiler.

8. ***Modulating RT + satellites***: As above, but with ‘ satellites’, i.e. temperature sensors in other rooms that make the temperature control independent of the exact position of the thermostat.

9. ***Weather controlled + RT*** (room thermostat): As above, but now the boiler temperature is also controlled by a room thermostat for a part of the boiler temperature range. Best performance of this type occurs in situations where it is difficult, i.e. due

to orientation of the house and/or windows, to find a position for the thermostat that is representative of the heat load of all space served by the CH-boiler.

Applicable values of the derived parameter ***cctrl*** are –3% for options 1 and 2, -1,5% for option 3, -1% for options 4 and 5, 0 for options 6 and 7, +1% for options 8 to 9.

RELATING TO PRODUCT CONFIGURATION (NUMERICAL)

Solar collector aperture area (Asol) in m² is the collector area as established according to Best Testing Practice.

Solar tank volume (Vsol) in ltr. is the volume of the (solar part of) the solar storage tank as established according to Best Testing Practice.

Heat transfer rate of the solar tank heat exchanger (UAsol) in W/K is the maximum heat transfer of the heat exchanger in the solar tank per degree of temperature difference between heat exchanger inlet and outlet temperature as established according to Best Testing Practice. Instead of a test result a default value of 40*Asol may be used.

Tmino in ºC is the declared minimum outdoor temperature in ºC required for heat pump operation.

Comment [r3]: Terminology brought in line with Lot 10

Tminret in ºC is the minimum allowable return water temperature for fossil-fuel fired heat generators, with possible values 30 ºC (gas-fired ‘ condensing’), 50 ºC (‘ standard’ non-condensing) or 40 ºC (other, e.g. ‘ low temperature’).

Turndown ratio (td, tdb, HPtd): declared ratio between the declared minimum and maximum heat input for FOS (*td*) and FOSB (*tdb*) or ratio between declared minimum and maximum heat output for HP (*HPtd*), whereby the latter is determined for a HP tested at +12 ºC outdoor temperature.

Maximum heat input (Pinmax, Pinmaxb) in kW is the declared maximum fossil fuel input in equivalent Gross Calorific Value of the fuel per hour for FOS (*Pinmax*) and FOSB (*Pinmaxb*).

Reheat is the declared ratio between the heating power output for reheating after night setback and the nominal radiator capacity of the specific load profile.

Buffer tank volume (Vbuf) in ltr. is the volume of the primary storage tank as established according to Best Testing Practice.

RELATING TO BOILER MAIN EFFICIENCY TESTS

Test point: Set of test conditions –energy input, ambient, etc.—at which to determine heating power output and energy efficiency of a heat generator through physical tests in accordance with document 5.

Test results are power and/or efficiency values resulting from tests at test points. In Table II.4 the following test values determined in accordance with document 5 are required:

- for HP the heat pump heating power outputs ***Php*** and the Coefficient of Performance ***COP*** (ratio between HP energy output and input; for other types of heat generators generally known as ‘efficiency’);
- for FOS the efficiency values ***_eta***;
- for FOSB the efficiency values ***_etab*** (FOSB efficiency);

- for CHP the ratio of electric power output and FOS heat input Pinmax ***_chp*** ;

Input point: Set of presumed energy input and/or ambient conditions for which a power output or energy efficiency value is used as an input in the mathematical model in document 6. Preliminary calculation methods to convert test point results to input point results are given in document 5.

Input values are power and/or efficiency values for input points obtained directly from test results or indirectly from inter-/extrapolation or other forms of aggregation. In Table II.4 the following values are determined in accordance with document 5:

- for SOL the zero-loss collector efficiency ***eta_0***, first order loss coefficient ***a_1*** and the second order loss coefficient ***a_2*** are parameters used in a second order equation of solare collector efficiency obtained by using the least square method applied to SOL test results..
- for SOL the Incidence Angle Modifier ***IAM*** is a multiplier derived from an extra test at 50 ° incidence angle to the collector.
- for HP the degradation factor ***Cd*** is the ratio derived from the COP from an extra test at 20% cycling (6 minutes on, 24 minutes off) at conditions of ***COP1*** (outdoor temperature +12 ºC). Alternatively a default of *Cd*=0,25 can be used.

RELATING TO BOILER AUXILIARY ENERGY

Collector loop loss (Upipesol) in W/(m.K) is the heating power loss per meter pipe and per degree K temperature difference with the ambient, determined by Best Testing Practice.

Solar tank standing heat loss coëfficient (Psbsol) in W/K is the heating power standing loss of the solar tank, determined as parameter 'S' in accordance with the provisions of document 6, per degree K temperature difference between the hot water and the ambient (usually 40 K)

System buffer tank standing heat loss coëfficient (Psbbuf) in W/K is the heating power standing loss of the system buffer tank, determined as parameter 'S' in accordance with the provisions of document 6, per degree K temperature difference between the hot water and the ambient (usually 40 K).

Auxiliary electric power consumption in kW: The electric power consumption in kW of the heat generator in on-mode, excluding electric power consumption of the main CH-circulator, and denominated depending on the heat generator ***solaux*** (SOL), ***hpaux*** (HP), ***fosaux*** (FOS), ***fosbaux*** (FOSB) and –indicating the electricity consumption of the charge pump— ***bufaux*** (BUF).

Standby electric power consumption in kW: The electric power consumption in kW of the heat generator in off-mode, excluding electric power consumption of the main CH-circulator, and denominated depending on the heat generator ***solsb*** (SOL), ***hpsb*** (HP), ***fossb*** (FOS), and ***fosbsb*** (FOSB).

Standby heat loss *Pstby* in kW is the declared heat loss of the heat generator at an average boiler water temperature of 40 ºC and an ambient temperature *Ta* of 20 ºC. The heat loss is measured in accordance with the applicable harmonised test standards for gas-/oil-fired boilers [1] , using a test rig with external pump and auxiliary electric heater is used. The test measures the average electric power consumption of an auxiliary electric resistance heater while the heat generator (‘ boiler’) in off-mode is mounted in the circuit and the water in the test loop is kept at a constant test temperature *Ttest*. From the result the inherent losses/gains of the test rig and external pump (from tests without heat generator in the loop) are subtracted to find *Ptest*. The test temperature is the average boiler water temperature measured at the system return and –feed side of the boiler. Depending on boiler-type and the harmonised test standard the test temperature *Ttest* should remain at 20±5K or 30±5K above the ambient air temperature (20±2 ºC). Correcting the actual conditions to reference conditions (*Tref*=40 ºC or 40 ºC; ambient 20 ºC), the declared standby heat loss at a reference temperature *Pstby[Tref]* becomes

$$Pstby[Tref] = Ptest * ((Tref - 20)/(Ttest - Ta))^{1,25}$$

Except for gas-fired ‘condensing’ heat generators, the reference temperature for fossil-fuel fired types is set equal to the minimum allowable return water temperature Tminret, i.e. 50 ºC for ‘ standard’ and 40 ºC for other types. Gas-fired ‘ condensing’ heat generators may have been tested at 40 or 50 ºC. In that case Pstby[40 ºC] shall be declared and –following stipulations in the harmonised standards[2]-- assessed with the following reduction formula:

$$Pstby[40\,ºC] = Pstby[50\,ºC] * ((40 - 20)/(50 - Ta))^{1,25}$$

The manufacturer shall declare the values of Pstby for the preferential fossil fuel fired generator FOS (parameter name Pstby) and the non-preferential fossil fuel fired boiler FOSB (parameter Pstbyb) .

Pilot flame power consumption Pign (FOS) or ***Pignb*** (FOSB) in kW is the hourly fossil fuel consumption for the pilot flame in Gross Calorific Value equivalent of the fuel.

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[1] E.g. for gas-fired boilers EN 13836:2006, EN 297:1994/A2:1996, EN 483:1999/A2:2001, EN 303-3:1998/A2:2003; EN 677:1998 (referring to ‘boiler test standards’), EN 625:1995 (referring to 297:1994/A2:1996). For full titles and oil-fired equivalents see WD document 7.

[2] EN 15316-4-1.

OTHER BOILER-RELATED DEFINITIONS

Variable capacity heat generator: heat generator with the capability to vary power output the (fuel burning rate, compressor speed, etc.) whilst maintaining continuous operation. For electric heat pumps also known as 'heat pump with inverter';

Staged capacity heat generator: a heat generator with the capability to vary power output the (fuel burning rate, compressor speed, etc.) between two discrete power levels whilst maintaining continuous operation. This includes boilers with alternative burning rates set once only at the time of installation, referred to as range rating;

Fixed capacity heat generator: a heat generator without the capability to vary power output the (fuel burning rate, compressor speed, etc.) whilst maintaining continuous operation. This includes boilers with alternative burning rates set once only at the time of installation, referred to as range rating;

Recoverable heat loss: part of the heat loss from the space heating system, which may be recovered to lower the heat demand for space heating. Recoverable are for instance certain envelope losses of heat generator, system buffer, solar tank and auxiliary electric devices. Not recoverable are for instance flue gas losses, fuel losses and electricity generation losses;

Recovered heat loss: part of the recoverable heat loss that contributes to meet the heat demand of the space;

Heat recovery rate is the ratio between recoverable and recovered heat loss. The heat recovery rate depends on timing and location of the recoverable heat losses versus timing and location of the heat demand.

<u>Note:</u> The default heat recovery rate for parts placed indoors is 0,55 and 0 when placed outdoors. Internal parameters are *boilrecov, solrecov, bufrecov* and *auxrecov* to indicate the heat recovery rate for fossil fuel fired heat generators, solar tank standing losses, system buffer standing losses and heat from auxiliary electricity consuming devices.

Space heating fraction (usesol, usehp) is the share of the solar and heat pump generator energy output in the heating season partitioned to space heating in case of a combi-boiler, determined by the ratio between the space heating demand Lh and the total heating demand for space and water heating Lh+Lw in the heating season;

Default: Any feature or parameter value of the Product that is used as a basic reference. It does not require verification, i.e. it does not require the feature to be implemented and/or the parameter value to be valid;

Uncertainty of measurement or measurement accuracy is the capacity of the measurement instruments to capture the actual value of the physical parameter, expressed as maximum allowable error.

Permissible deviations of individual measured values is maximum/minimum permissible peak value of the physical parameter measured during the test in order for a test sample to be valid .

Permissible deviations of the <u>average value</u> over the test period (and/or the total of test samples) is the maximum/minimum permissable deviation from the prescribed setpoint of the average measured value of the physical parameter over a single test period.

Note: Usually this is the value intended if harmonised standards refer to a measurement tolerance in generic terms.

EPEE revisions in preparation of 16 December 2009

RELATING TO COMBI-BOILER DEFINITIONS IN CHAPTER 2 OF DOCUMENT 2

Specific efficiency for water heating etawh of combi-boilers is specific for the designated water heating load profile and expressed as

$$etawh = \frac{0{,}6 * 366 * Q_{ref}}{Q_{atotcombi}}$$

where

- Q_{ref} is the reference heat demand (energy content of hot water) in kWh/d for the designated water heating profile (see values in document 4, table II.2);
- $Q_{atotcombi}$ is the annual water heating energy consumption of combi-boiler in kWh/a, with

  $Q_{atotcombi} = Q_{atot} - combicomp - combitrans$

  where

  - Q_{atot} is the annual energy consumption in kWh/a as defined in Commission Regulation XX/XX/EC;
  - *combicomp* in kWh/a is the heat gain for water heating from the net annual boiler envelope losses (discounted for heat recovery) ***Qenvon*** as calculated in document 6;
  - *combitrans* in kWh/a is the heat gain from Passive Flue Heat Recovery Devices, i.e. devices recovering flue gas waste heat in space heating mode for use in water heating mode, determined in accordance with document 5.

If SOL or an air-source HP are part of the product configuration the values of *etawh*, $Q_{atotcombi}$, Q_{atot} , *combicomp and combitrans*are climate-specific. In that case *etawh* is substituted by *etawhA, etawhW, etawhC* and Q_{atot} by Q_{atotA}, Q_{atotW} and Q_{atotC} , etc. indicating that the efficiency value relates to an Average, Warmer or Colder climate respectively.

Mathematical operators and expressions

+. -, *, /	addition, subtraction, multiplication, division
[X1; X2]	array (one-dimensional, with 2 elements X1 and X2)
MIN (X;Y)	if Y $\leq$ X then Y else X
MAX (X;Y)	if Y $\geq$ X then Y else X
SUM(X;Y)	X+Y
SUM(X)	if X is an array: sum of all elements in the array. If the elements of the array are indexed, e.g. with index **tp** and 7 elements then the classic notation is sigma
MIN(X;MAX(Y;Z))	X$\leq$ Y $\leq$Z
POWER (X;Y) or **X^Y**	X to the power Y (X^Y)
LN (X)	natural logarithm of X
SIN (X)	sinus of X

COS (X)	cosinus of X
TAN (X)	tangent of X
SQRT(SUMX2PY2(X;Y))	square root of the sum of the square of X and the square of Y; $\sqrt{(X^2 + Y^2)}$
IF(A;X;Y)	IF expression A is True THEN X else Y (X and Y can be values or expressions)
IF(A;X;IF(C;Y;Z))	Nested IF..THEN statement: If expression A is True then X else if expression C is True then Y else Z. Represented by a table:
CHOOSE (X;Y)	X is rank number choosing element of array Y with that index
MATCH(X; A1:A3)	Result: Closest lower value matching X in array A1:A3 (cells A1, A2, A3)
INDEX([X1;X2]; X;Y)	Returns a value from a position in an array (X position only) or a table (X and Y positions)

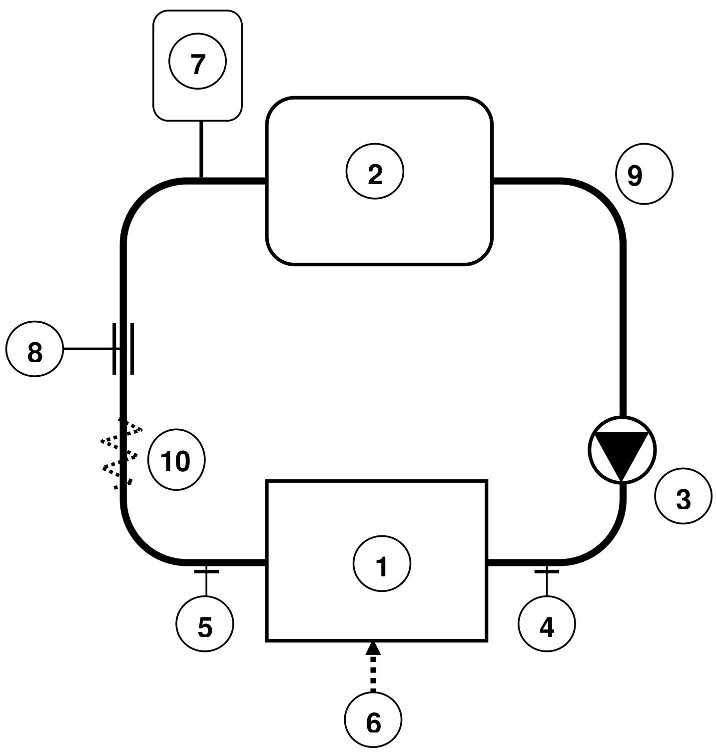
Document 5

Testing Methods

This section deals with the specification of test points and test results defined in document 3 and referenced in the Product Information Requirements in Document 4. Also it specifies preliminary calculation methods to derive input data for input points as required in the energy efficiency calculation in document 6.

GENERAL TEST SET-UP

The diagram below shows the generic test rig for hydronic heat generators, consisting of a circuit with a well-insulated pipe 9, in which water is circulating -driven by a circulator pump 3- between the heat generator 1 and a cooler/heat exchanger 2. The system return temperature *Treturn* is measured just (indicatively 10-20 cm) before the heat generator at point 4 and the system feed temperature *Tfeed* is measured just (indicatively 10-20 cm) after the heat generator at point 5. Rapid-response temperature sensors shall be used. During the test the mass flow rate of the heated water is determined by a high-precision mass (or volume) flow sensor 8. [3]



[3] Flow rate measurement by temporarily tapping water from the loop after the heat generator and letting in water at Treturn before the heat generator is still allowed as an alternative (currently hardly in use).

1. Boiler/ heat generator
2. Cooler/ heat exchanger, typically with large buffer capacity for temperature stabilisation
3. Circulator pump
4. Return temperature (Treturn) sensor
5. Feed temperature (Tfeed) sensor
6. Boiler energy input
7. Expansion vessel to maintain water pressure in the loop
8. Flow sensor
9. Loop
10. Electric resistance heater (for measurement of standby loss)

General ambient conditions are defined by ambient temperature, (local)air speed, heating water temperature and flow rate, as indicated for indoor tests in the table below. For conditions at outdoor tests see section on solar heat generators.

Table IV.1. General test conditions and outputs. Set values and tolerances[4]

Measured quantity	Unit	Value	Permissible deviation (average over test period)	Permissible deviations of individual measured values	Uncertainty of measurement (accuracy)	Notes
Ambient						
ambient temperature indoors *other*	°C/ K	20 ± 2 °C	± 1 K	± 2 K	± 0,1 K	
maximum air speed *HP* (at HP off)	m/s	<1,5 m/s				
maximum air speed *other*	m/s	<0,5 m/s				
Time						
Minimum sample rate SOLAR tests	s	30s			± 0,2 %	
Minimum sample rate HP defrost cycle	s	10s				
system water						
water temperature during test *other*	°C/ K	Tfeed/Treturn	± 0,5 K	± 1 K	± 0,2 K	[1]
volume flowrate *HP*	dm³ /s		± 5 %	± 10%	± 1 %	
volume flowrate *other*	dm³ /s				± 1 %	

Notes:

[1] To be measured by "rapid response thermometer", meaning an instrument that registers within 1 s. at least 90% of the final temperature rise from 15 to 100 °C when the sensor is plunged in still water.

Minimum dimensions of the test room as well as the construction of the platform on which the heat generator is to be mounted to shield it from external influences shall be according to Best Testing Practice.

[4] Compilation of values from harmonised test standards as mentioned in ibid. 8

TEST PROCEDURE EFFICIENCY AND PERFORMANCE TESTS

Tests are performed after thermal equilibrium is reached with the appropriate temperatures, flow rate and energy in- and outputs.

The product of the supplied mass m of water in kg, average temperature difference between *Treturn* and *Tfeed* in K and the specific heat capacity of the heating water set at 0,00116 kWh/kg.K delivered over the test period is defined as the heat output *Qout* in kWh:

Comment [r4]: This paragraph has been expanded, because it was frequently overlooked that e.g. COP was defined here.

$$Qout = \overline{m} * \overline{(Tfeed - Treturn)} * 0,00116$$

The energy input to the heat generator *Qin* in kWh is the total electric energy consumption (in kWh electric) during the testperiod and/or the product of the mass/volume of the fossil fuel delivered at reference conditions[5] and its specific gross calorific value GCV (a.k.a. upper heating value, *Hs*, per unit of mass/volume). The energy inputs, including permissable deviations, measurement accuracy, etc., are defined in Document 3, Table I.3 and are in conformity with current harmonised test standards[6]. Test gases for gas-fired heat generators are defined through the Gas Appliance Directive; an informative table of the current defintions is given in Document 3, Table I.4.

Power input *Pin* is the energy input*Qin* in kWh divided by the duration of the test period t_{test} in h. Power output *Pout* is the energy output *Qout* divided by the duration of the test period t_{test} in h. Test point efficiency *eta* (or *Coefficient of Performance* for heat pumps) is defined as the ratio of power output *Pout* and the power input *Pin* . In case the boiler consumes both fossil fuels and electricity, the test point efficiency is related to the fossil fuel power output and input, while the electric power input is reported separately in kWh electric[7].

Possible renewable heat inputs, i.e. solar irradiation and/or ambient heat, shall be supplied to the heat generator at the required test conditions as stipulated hereafter and in Document 3, specifically tables I.3 (general), I.5.(solar) and I.6 (heat pumps).The definitions in Document 3 are in conformity with current harmonised test standards.[8]

In case the prescribed volume flow rate during the test is small and/or the test is conducted in outdoor conditions, e.g. with solar heat generators, the test rig may not necessarily be a

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[5] See document 3, Table I.3

[6] Table I.3 is a compilation of electricity and fossil fuel (measurement and composition) definitions of --for gas-fired boilers-- EN 297 (no-fan, <70 kW, types B11 and B11BS), EN 303-3 (fan-assisted, <70 kW), EN 656 (type B, 70-300 kW), prEN 303-7 (fan-assisted, type B23, <1000 kW), prEN 13826 (other type B, 300-1000 kW), EN 483 (type C, <70 kW), EN 677 (condensing, <70 kW), EN 625 (combi, <70 kW). and --for oil-fired boilers-- EN 303-6 (combi, <70 kW), EN 304:1998/A1 1998, EN 15035 (Room-sealed, type C13, C33 and C53), EN 15034 (Condensing, <1000 kW), EN 303-2 (fan-assisted, <70 kW) and –for heat pumps— EN 14511-3;2007 and –for solar collectors and solar storage tanks—EN 12975-2, ENV 12977-2 and ENV 12977-3.

[7] To be taken into account in seasonal (primary) energy efficiency through the calculation in Document 6.

[8] Table I.5 is a compilation of EN 14511-2;2007. Table I.6 sources are EN 12975-2; ENV 12977-2 and ENV 12977-3

loop, provided that the water flowing in the heat generator is supplied at the required *Treturn* water temperatures.

The circulator pump used during the test may be a separate pump or an integrated pump delivered with the heat generator.

Accuracy and tolerance levels for the energy inputs as defined in document 3 and the underlying document 5 apply.

In case of an integrated circulator pump, the efficiency and performance test results are corrected for:

- Heat gain by the circulator pump[9], determined through an additional test or from a default deduction of 55% of the average pump electricity consumption during the test. The pump heating power is to be deducted from the measured power output *Pout* before calculation of the energy efficiency of a test point.
- Electric power consumption of the pump, determined through an additional test or separate measurement of pump power consumption during the test.

Comment [r5]: Note that this is necessary because the pump is treated as a separate unit in Document 6 and the pump net primary energy consumption is calculated as a fraction of the annual energy consumption Lh. This provision overrules any prescriptions regarding the exclusion (e.g. EN 14511-3) or inclusion (e.g. standards for gas- and oil-fired boilers in ibid 7) of whole or part of the pump energy in the calculations, thus providing a 'level playing field' and avoiding pump over-sizing for the sake of thermal efficiency improvement.

Furthermore, deviations from reference conditions for the energy inputs and outputs as defined in document 3.

Depending on the type of heat generator, specific test or input point conditions are specified by combinations of

- heat generator power input or –output;
- system feed, return and/or average temperatures;
- flow rates.

For renewable energy sources additional requirements as specified in document 3 and hereafter for ambient or solar energy inputs apply.

The number of tests, i.e. sets of conditions at which testing is required, and the duration of the test periods will be determined either through stipulations hereafter or by the harmonised test standards mentioned in document 7. As a general information it is mentioned that for steady state tests the minimum duration is 10 minutes after reaching thermal equilibrium. For on/off tests the test period will be determined by the duration of the prescribed on/off cycle as well as specific requirements relating to repeatability.

[9] I.e. if the circulator pump is an integrated part of the heat generator and it is not possible to accurately measure the return temperature at a position between pump and entry into the heat generators' heat exchanger.

EPEE revisions in preparation of 16 December 2009

TEST POINTS AND PRELIMINARY CALCULATIONS

SOLAR COLLECTOR TESTS

For solar collectors at least 4 x 4 tests, with 4 different collector inlet temperatures t_{in} evenly spaced over the operating range and 4 test samples per collector inlet temperature are measured to obtain test values for the water outlet temperature t_e, the ambient temperature t_a, the solar irradiance G and the measured efficiency at the test point *eta* [10] . If possible, one inlet temperature shall be selected with $t_m = t_a \pm 3$K to obtain an accurate assessment of the zero-load efficiency eta_0. With fixed collector (no automatic tracking) and test conditions permitting, two test samples should be done before solar noon and 2 after. Maximum temperature of the heat transfer fluid (i.e. the top of the operating range) shall be >80ºC. [11]. The recommended maximum value of the reduced temperature difference T^*_m is >0,09 m^2KW^{-1}.

The flow rate during the tests is a given (70 l/h, see Table I.5).

For the instantaneous collector efficiency eta a continuous efficiency curve of the format as in [Equation 1] below shall be obtained by statistical curve fitting of the test point results, using the least square method.

$$eta = eta_0 - a_1 \times T^*_m - a_2 \times G\,(T^*_m)^2 \qquad \text{[Eq. 1]}$$

where

- eta_0 is the zero-loss collector efficiency (*eta at* T^*_m,=0), reference to T^*_m [-] ;
- a_1 is the heat loss coefficient at $(T_m - T_a) = 0$ (first order coefficient), in $Wm^{-2}K^{-1}$;
- a_2 is the temperature dependence of the heat loss coefficient (second order coefficient) , in $Wm^{-2}K^{-2}$;
- T^*_m is the reduced temperature difference in m^2KW^{-1}

with

$$T^*_m = (t_m - t_a) / G \qquad \text{[Eq. 2]}$$

where

- t_a is the ambient or surrounding air temperature
- t_m is the mean temperature of the heat transfer fluid

with

$$t_m = t_{in} + 0{,}5 \times \Delta T \qquad \text{[Eq. 3]}$$

where

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[10] the instantaneous efficiency *eta* in a test is measured from the product of *flowrate*, temperature increase over the collector and the specific heat of water divided by the solar irradiance input during the test.

[11] For instance, with water filled collectors and a test at Ta = 10 °C appropriate test values of T_{in} could be 10-35-60-85 °C

- t_{in} is the collector inlet temperature
- ΔT is temperature difference between fluid outlet and inlet ($= t_e - t_{in}$)[12].

Unless specified differently, all tests shall be performed according to Best Testing Practice.[13]

INTEGRATED COLLECTOR STORAGE TESTS

In case of an Integrated Collector Storage ICS (e.g. 'heat pipe', vacuum-pipes directly coupled to tank, etc.) an alternative test is used, establishing the overall efficiency *etasol* of the collector+store combination during a 3 day test at maximum heat output, according to Best Testing Practice[14] for this type of heat generator.

AIR SOURCE HEAT PUMPS

The input values required to calculate the seasonal efficiency of heat pumps in Document 6 are and their reference conditions are given in the table below. The manufacturer may declare its product unfit –and thereby not subject to testing-- for either floor heating or radiator heating.

For floor heating only maximum power output data will be used for the seasonal efficiency assessment in document 6. For radiator heating the assessment will use declared data for maximum and minimum steady state operation, as well as an efficiency assessment for cycling.

For the efficiency degradation during cycling a default value Cd=0,25 may be used (no testing required), in which case COP values in the calculation BIN will be degraded as follows

COPdegraded=COPmin1*(1-Cd*(1-Phptp/Phpmin1))

In case the manufacturer decides to test the Cd factor, then the method prescribed in prEN 14825, where the appliance is tested using a cycling interval of 6/24 minutes (6 minutes on, 24 minutes off).

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In Table V.2, power and efficiency values that use the suffix ' f' relate to floor heating. Power and efficiency values with suffix ' min' relate to radiator heating at minimum steady state power output. Parameter names without suffix relate to radiator heating at maximum capacity at the given reference conditions.

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[12] t_e is the collector outlet (exit) temperature. Note: t_{in} and t_e were previously known as $T_{c,in}$ and $T_{c,out}$ in the 2001 Edition of EN 12975-2

[13] This implies following the stipulations of EN 12975-2; 2006, ENV 12977-2 and ENV 12977-3

[14] As described in EN 12976 series for factory made solar systems.

Table IV.2. Reference conditions for input values required in the heat pump seasonal efficiency calculation in document 6

Test	Input values required		Source temperature			Return/feed temperature [1]	
			air-source	water	brine	Floor heating	Radiator
	power output [2]	**COP** [3]	**Tout** dry bulb (wet bulb) [4]	**Tground-water**	**Tbrine**	**Tret/ Tfeed** maxP and Pmin ss [5]	**Tret/ Tfeed** maxP and Pmin ss [6]
	kW		ºC	ºC	ºC	ºC	ºC
A[7]	**Phpf4 Php4 Phpmin4**	**COPf4 COP4 COPmin4**	**-7(-8)**	**10**	**0**	**30/34**	**44/52**
B	**Phpf3 Php3 Phpmin3**	**COPf3 COP3 COPmin3**	**2(1)**	**10**	**0**	**26/29**	**40/43**
C	**Phpf2 Php2 Phpmin2**	**COPf2 COP2 COPmin2**	**7(6)**	**10**	**0**	**25/27**	**36/38**
D	**Phpf1 Php1 Phpmin1**	**COPf1 COP1 COPmin1**	**12(11)**	**10**	**0**	**24/25**	**30/33**
***E** [8]*	***Phpf5 Php5 Phpmin5***	***COPf5 COP5 COPmin5***	***-15(-16)***	***10***	***0***	***32/37***	***46/58***

[1] Note that only the system feed temperatures *Tfeed* are mandatory for testing. The manufacturer may choose to either conduct the tests at a fixed flow rate determined at rating conditions of 40/45 ºC (*Treturn/Tfeed*), in which case—given the specific heating power output-- the return temperature will follow. Alternatively, the manufacturer can choose to use the indicated return temperatures *Tret*, in which case --at a specific power output—the flow rate will be adjusted to arrive at the indicated feed temperatures (±0,5 K). The latter will be closer to real-life, but the former is allowed to accommodate current testing practice. Note that the heating power output of the heat pump should equal –corrected for heat gains and losses in the test rig—the cooling power of the compensator in the test rig.

[2] Declared maximum heat pump power outputs at floor heating are denominated Phpf1, Phpf2, etc., at maximum radiator heating output Php1, Php2, etc. and at minimum steady state radiator heating output they are denominated Php1min, Php2min, etc..

[3] Declared heat pump Coefficients of Performance (COP) at maximum floor heating power are denominated COPf1, COPf2, etc., at maximum radiator heating power COP1, COP2, etc. and at minimum steady radiator heating power denominated COP1min, COP2min, etc..

[4] All source temperatures and sinktemperature according to prEN 14825. The wet bulb temperature –in combination with the dry bulb temperature-- indicates the relative humidity of the air. All values are effectively based on an absolute humidity of 5,5 g/m^3.

[6] For fixed capacity (' on/off') units *Php* values are identical to *Phpmin* values (*Phpmin1=Php1*; *Phpmin2=Php2*; etc). For staged capacity units the part load power output and Coefficient of Performance (COP) are determined at the lowest stage. Subsequently a 2,5% correction (multiplication by factor 0,975) is applied for the fact that the unit is staged and not a variable capacity unit (non-linearity), before the final value COP shall be used as an input in document 4 and document 6. For variable capacity units the input values for power output and COP relate to the condition with minimum steady state operation.

[7] In case the heat pump cannot be tested at –7 ºC (minimum operating outdoor temperature *Tmino* >-7ºC) then the unit will be tested at *Tmino* and projected point D values for COP and power output at –7 ºC will be declared, derived from linear extrapolation between the results of point C and the results at Tmino. In case the heat pump cannot meet the conditions for point C (*Tmino*>+2ºC) then it cannot be declared '*fit for purpose'* to function in an Average climate and if this is true for both radiator and floor heating conditions, it cannot be declared as a useful heat generator at all.

[8] Input point E is only mandatory in case the Colder climate is one of the designated climates. In case the heat pump cannot be tested at –15 ºC (*Tmino*>-15) then the unit will be tested at the minimum operating (outdoor) temperature *Tmino* and for COP and power output at –15 ºC will be declared, derived from linear extrapolation between the results of point A and the results at *Tmino*. In case the heat pump cannot meet the conditions for point A (*Tmino*>-7 ºC) then it cannot be declared '*fit for purpose*' to function in a Colder climate at the indicated (floor- and/or radiator heating) conditions.

The permissible deviations from the set values are given in Tables I.3 and I.6.

For the assessment of the required input values the following options can be used:

Option A.

Testing at the described conditions for each reference point.

Option B.

Testing at the relatively more important[15] mid-range conditions A, B, C and linear extrapolating the results for conditions D and –for colder climates—E.[16]

For each part load test point individually, the manufacturer may choose to employ a default value. For fixed capacity units the default is COPmin= 0,89*COP at power output Phpmin=Php.[17] For staged capacity units the default is COPmin= 0,975*COP at power output Phpmin=0,5*Php. For variable capacity units the default is COPmin= COP at power output Phpmin=0,4*Php.

Option C.

For appliances meeting condition X, the required input values in Table IV.2 may be derived from existing test results at feed and return temperatures according to EN 14511-2;2007 as indicated in the table below.

Option D

The values used for calculation are based on declaration of the manufacturer. The manufacturer shall base this declaration on calculations stemming from tests not necessarily at the same points as the declared value. The calculation should be robust and the detailed data has to be provided in technical information.

Comment [r6]: EPEE suggestion that the tolerance tables 1 and 4 from EN 14511-3, but this is not necessary, as they are already treated (for the referenced values) in Tables I.3 (for elektricity) and I.5 (for other relevant heat pump measurements).

Comment [r7]: This reduces the number of required tests by 25 to 33%. At most 9 tests (at least 3 tests) are required.

Comment [r8]: For fixed capacity units this is an opportunity to save on testing costs for part load, but also for reference points at conditions A (-7 oC outdoor temperature) or E (-15 oC outdoor temperature) where the actual load from the calculation model in document 6 will be close to full load it may be interesting to use the defaults.

Comment [r9]: Scope to be discussed. It may apply to all appliances unconditionally or appliances produced before the publication (or entry into force) of the measure or appliances produced during a transition period of 2 years after entry into force of the measure.

[15] Importance is intended as having more influence on the accuracy of the final rating.

[16] For condition D results can be derived from linear extrapolation weighted for the source temperatures of results for conditions C and B. Similarly results for condition E are derived from results for conditions C and D, provided that the minimum outdoor operating temperature Tmino< -15 oC (otherwise COP=0 and Php=0).

[17] Derived from default values mentioned in EN 15316-4-2, Annex B (informative).

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[In the present calculation methodology, it is not possible to test the prescribed points since it is not known at what demand these should be tested, next to that, testing at minimum and maximum values is neglecting inverter technology benefit;]

Table IV.3. Rating conditions from EN 14511 that can be used as defaults for heat pump reference conditions in Table IV.2

Test	Input values required		Source temperature			Return/feed temperature		
			air-source	water	brine	Floor heating	Radiator heating	
	power output	**COP**	**Tout** dry bulb (wet bulb)	**Tground-water**	**Tbrine**	**Treturn/Tfeed** maxP	**Treturn/Tfeed** maxP	**Treturn/Tfeed** Pmin ss
	kW		ºC	ºC	ºC	ºC	ºC	ºC
A	**Php4**	**COP4**	**-7(-8)**	**10**	**0**	**30/35**	***/55**	*for all points:* **Fixed capacity:** COPmin=0,89 COP at Phpmin=Php. **Staged capacity:** COPmin=0,975 at Phpmin=0,5Php **Variable capacity:** COPmin=COP at Phpmin=0,4Php
B	**Php3**	**COP3**	**2(1)**	**10**	**0**	**30/35**	**40/45**	
C	**Php2**	**COP2**	**7(6)**	**10**	**0**	**30/35**	**30/35**	
D	**Php1**	**COP1**	**12(11)**	**10**	**0**	**30/35**	**extrapolate from B &C**	
E	***Php5***	***COP5***	***-15(-16)***	***10***	***0***	**30/35**	***extrapolate from A&B***	

Note that for the extrapolations and the part load assessments the same rules apply as under option B.

FOSSIL FUEL

The tables below give the ***test points*** for preferential (FOS) and non-preferential (FOSB) fossil fuel fired heat generators

Table IV.4.Reference conditions fossil fuel fired heat generator performance and energy efficiency testing, preferential FOS, non preferential FOSB heat generator (suffix ‘ b’) and cogeneration CHP

Test	Values to report			Test conditions [1] at Tminret		
				30º[2]	**40º**[3]	**50º**[4]
	power output	**efficiency**	**Tsys**	**Treturn/ Tsys/ Tfeed** [5]		
	kW		oC	oC	oC	oC
A	**Pfos4 Pfosb4**	**eta4 etab4 chp4**	**Tfos4**	**60/*/80**	**60/*/80**	**60/*/80**
B	**Pfos3 Pfosb4**	**eta3 etab3 chp3**	**Tfos3**	**60/*/≤80**	**60/*/≤80**	(60/*/≤80)
C	**Pfos2 Pfosb2**	**eta2 etab2 chp2**	**Tfos2**	**30/*/≤50**	**≥35/≥40/***	(*/≥50/*)
D	**Pfos1 Pfosb1**	**eta1 etab1 chp1**	**Tfos1**	**30/*/≤50**	**≥35/≥40/***	(*/≥50/*)
E	***Pcyc= 50% Pfos1***	***eta0 etab0 default Cd=0,1 chp0 measured***	***Tfoscyc=ca. 0,5*(Tfos1+20)***			

[1] = all boilers are to be tested with integrated pump (if present) or a test rig pump that mimicks the behaviour of the integrated pump. The latter may be advantageous to meet conditions described earlier. If the circulator pump has a fixed flow rate then the circulator settings at 'A' test condition will be maintained throughout all tests and the resulting feed (and thus system-) temperature will follow.

If the boiler is supplied without pump then tests will be conducted with a fixed flow rate until Commission Regulation 641/2009 on circulator pumps will enter into force; after that date those tests will be conducted with a variable speed pump with settings as indicated by the boiler manufacturer.

If the boiler is equipped with an integrated variable speed pump then the flow rate for test condition 'A' will be tuned to arrive at an 60/80 (*Treturn/Tfeed*) regime at the appropriate compensator load. For the test conditions 'B' to 'C' flow rate can be set according to manufacturer's instructions within the physical boundaries given by the circulator pump and the minimum and/or maximum values as indicated in the table.

For fixed capacity boilers only test condition 'A' is mandatory. Part load and low temperature tests are optional for units with variable or staged capacity, alternatively the manufacturer may use the results from condition 'A' for condition 'C' and the results from condition 'E' for conditions 'B' and 'C' with *Tfos0*=0,5*(60+20)=40 ºC

[2] Condensing, i.e. boiler that can work with a system return temperature *minret/ minretb* of 30°C, permanently condensing a large part of the water vapour contained in the combustion products.

[3] Partly Condensing, i.e. boiler that can work continuously with a system return temperature *minret/ minretb* of 40 °C, possibly producing condensation in certain circumstances.

[4] Non-condensing, i.e. boiler that can only work at a system return temperature above the dewpoint of the air-fuel mixture, not producing condensation under any circumstance. Nominal system return temperature *minret/ minretb* is

then declared as 30°C.

[5] All water temperature values in conditions 'A' to 'D' are derived from existing test methods as in ibid. 7 for gas- and oil-fired central heating boilers. *Treturn* is the system return temperature (in some boiler standards also referred to as the 'water supply temperature'). *Tfeed* is the system feed temperature (in some boiler standards also referred to as the 'flow temperature'). *Tsys* is the system temperature (a.k.a. the 'average emitter temperature') determined as the average of *Treturn* and *Tfeed* for steady state testing.

In case of a staged capacity unit the efficiency values shall be diminished by 0,025.

COGENERATION

In case of CHP being part of the product configuration it shall be tested as a preferential fossil fuel fired heat generator FOS as specified in table IV.4. During the test the electric power output is measured and reported as the ratio of electric power output to 'heat' (fossil fuel GCV) input. These test results are then used to arrive at the values of chp4, chp3, chp2 and chp1 at the points specified in table IV.4. Note that for CHP the cycling test has actually to be performed, because cycling can have a significant effect on the electricity production. The cycle time for 'E' is 60 minutes, i.e. 30 minutes 'on' and 30 minutes 'off'.

COMBI-BOILER

Testing and calculation method for the assessment of ***combitrans***, to be used as an input for combi-boiler water heating efficiency *etawh* defined in document 3:

1. Determine heat capacity in kWh/K of device cdev and hot water content cwater (through calculation)
2. Make sure boiler and device are at ambient temperature Ta.
3. Fill device with cold water *Tcold* of 10 °C, immediately run boiler in space heating mode at part load (can be combined with efficiency test in space heating) for 20 minutes (load weighted average time between draw-offs for most tapping patterns M and higher),
4. Stop the boiler for 20 minutes (burner-off) to account for standing losses.
5. Draw-off water from the device until water temperature is again 10 °C. Measured result: Average water temperature of device *Tavg*, energy content of drawn off water Qtapped in kWh/draw-off
6. If necessary correct result for heat content of the device at start: *Qtappedcor*= *Qtapped*- (*Tambient*-10)**cdev*. *Tavg* is corrected accordingly.
7. Determine maximum annual capacity *Qcapdev* in kWh/a (25 draw-offs per day in heating season) *Qcapdev*= 25**alldays***Qtappedcorr* in kWh/d. where alldays is the number of days in the heating season, i.e. 213, 183, 273 days for Average, Warmer and Colder climate respectively.
8. Calculate the 24h average heat store power capacity *Pstore=Qcapdev/allhrs*
9. From the reference net daily peak energy demand declared water heating load profile *Qref* in kWhd/d (from document 4, table II.2) calculate the average power demand over the 15h tapping period with *Ptap*=0,6**Qref*/15.

10. From the annual flue gas losses in space heating mode *Qflue* in kWh/a for the highest declared space heating load profile as determined in document 6, calculate the average loss over the heating season *Pflue=Qflue/allhrs*.

11. The annual credit for the Passive Flue Heat Recovery Device combitrans in kWh/a is

    combitrans= *allhrs** MIN(*Pstore; Ptap; Pflue*)

NOX EMISSIONS

NOx emissions are to be tested in accordance with best testing practice. Guidance documents are given in document 7.

Document 6
Energy Efficiency Calculation Method

The mathematical model of the space heating boiler in this document (hereafter 'the model') calculates the specific seasonal energy efficiency *etas* from the input data given in document 4, Product Information requirements, Table II.4a in accordance with the definitions in document 3 and the testing methods and preliminary calculations in document 5.

The model is built top-down, with the most aggregated parameters first, followed by the parameters from which the aggregated parameters are built.

The model is divided in three parts:

- a **definition** section (eq. 1-14), giving the general definitions of efficiency, total energy consumption as well as the equations for informative issues as already defined in documents 3 and 4.
- a **heat balance** calculation (eq. 15-81), subdivided in
  - a heat demand section (eq. 15-30), dealing with the net space heating demand Lh (Eq. 15)
  - a heat supply section (Eq. 30-81), calculating the contribution of each of the possible heat generator types SOL (eq. 31-56), HP (eq. 57-71), **EL**(eq. 72), FOS (eq. 74-77) and FOSB (eq. 78-81) in terms of their annual heating energy output 'L' in kWh/a. For FOS and FOSB this entails a simple capacity calculation, but SOL-output depends on the solar irradiance during the heating season –calculated with monthly inputs—and air-source HP outputs depends on the outdoor air (source) temperature, calculated with the bin-method (see document 3).
- a **primary energy loss accounting** (eq. 82-142), subdivided in
  - heat generator losses (eq. 94- 127), usually –except for SOL and **EL** where a simple annual multiplier is sufficient—calculated per outdoor temperature bin, and using the data inputs from tests as defined in document 5;
  - auxiliary energy losses (eq. 128-139), calculated on an annual basis and possible CHP gain from electric power production during the heat generating processes (eq. 140-142).
  - controls forfait (eq. 143-144)

For the most part the model is a simple case of energy accounting. The accounting is comprehensive, also featuring parameters that might be redundant but serve transparency and a future purpose in model maintenance, but uses mostly simple linear equations.

A special feature is the use of the bin-method -as described in document 3- and the fact that the equations for inter- (and extra)polation between data inputs from the tests are explicitly part of the model, e.g. in eq. 86 (HP), eq. 103-109 (FOS) and eq. 121-127 (CHP). This may seem unnecessarily complex, because a simple instruction to interpolate between test point values could fully define any intermediate points. But it allows for more robust modelling -with also a check on the overall contribution of a testing point to the end-result- and it allows the relatively simple incorporation of the modelling of the system buffer BUF with FOS and CHP.

Another feature is the transition of the energy calculation from the monthly method for SOL to the bin-method for HP and any of the following heat generators in eq. 64-71. This conversion entails that the calculated annual heat output from SOL (Lsol) according to the monthly method is redistributed over the temperature bins, starting at the hour-bins with the highest temperature and ending when the accumulated value of Lsol is exhausted. The remaining heat demand profile is then 'offered' to HP and the following heat generators, in the order as described in document 3.

NOMENCLATURE

Parameters are listed as they are used, i.e. in the heat balance (Table V.1) and in the primary energy loss accounting (Table V.2). Table V.3 gives the main test and data input names.

Table V.1. Nomenclature: Heat Balance

HEAT (kWh/a)

	demand total		0
space heating demand	**Lh**		0
	supply total		0
generator useful heat	**Lgen**		0
		of which	
solar heat supply		**Lsol**	0
heat pump heat supply		**Lhp**	0
electric back-up heat supply		**Lel**	0
fossil fuel fired preferential generator heat supply		**Lfos**	0
non-preferential fossil fuel fired generator heat supply		**Lfosb**	0

Balance: Lh+Lsys=Lgen

Table V.2. Nomenclature Primary Energy Loss Accounting

PRIMARY ENERGY LOSSES (kWh/a)

auxiliary primary energy consumption (from electricity) minus primary energy credit from electricity production	**Qel**			0
	of which			
auxiliary primary energy consumption (from electricity)	**Qaux**		0	
	of which in Wh/a electric			
circulator pump electricity consumption	**Qpmp**	0		
solar auxiliary electricity consumption for solar pump, controls, anti-frost device, partitioned to space heating	**Qsolaux**	0		
heat pump electricity consumption for controls, anti-frost device and --if not included in COP-- source fan or source pump, partitioned to space heating	**Qhpaux**	0		
preferential fossil fuel fired generator auxiliary electricity consumption for controls, combustion fan, etc.	**Qfosaux**	0		
non-preferential fossil fuel fired generator auxiliary electricity consumption for controls, combustion fan, etc.	**Qfosbaux**	0		
electric energy production from heat-lid CHP device	**Qchp** (negative)		0	
heat generator losses	**Qgen**			0
	of which			
solar gain (negative) losses	**Qsol**		0	
heat pump gain (usually negative) losses	**Qhp**		0	
electric resistance back-up heater losses from power generation	**Qelbu**		0	
preferential fossil fuel fired generator heat losses	**Qfos**		0	
	of which			
energy consumption pilot flame	**Qign**	0		
envelope losses in off-mode	**Qenvoff**	0		
fuel losses (purge losses, emission of non-combusted fuel)	**Qfuel**	0		
envelope losses in on-mode	**Qenvon**	0		
flue gas losses	**Qflue**	0		
non- preferential fossil fuel fired generator heat losses **(b)**	**Qfosb**		0	
energy consumption pilot flame (b)	*of which*			
envelope losses in off-mode (b)	**Qignb**	0		
fuel losses: purge heat losses, emission of non-combusted fuel) (b)	**Qenvoffb**	0		
envelope losses in on-mode (b)	**Qfuelb**	0		
flue gas losses (b)	**Qenvonb**	0		
	Qflueb	0		
	TOTAL Qel + Qgen			0

Efficiency etag= (Lh)/(Lh +Qgen+Qel)

Table V.3. Nomenclature energy, power, efficiency and time for heat and power generators

heat generator (Boolean)	SOL	HP	EL	FOS	FOSB	CHP
Energy in kWh/a						
primary energy loss/gain total or per period/ bin	Qsol	Qhp	Qel	Qfos	Qfosb	Qchp
Energy loss during on-hrs (heat demand>0) total or per bin				Qfoson	Qfosonb	
useful heat output total or per bin	Lsol	Lhp	Lel	Lfos	Lfosb	
Power in kW						
Standby heat loss	Tank loss part of Qbuf		If storage type than part of Qbuf	Pstby	Pstbyb	
heat demand remaining after SOL; heating power output HP, EL, FOS, FOSB	Prs	Php	Pel	Pfos	Pfosb	
Efficiency test points						
Power in kW (P) and efficiency (COP) HP: cold climate only: Tout=-15 ºC . For floorheating (suffix f), maximum heat output (no suffix) and minimum steady state heat outut		Phpf5/ COPf5 Php5/ COP5 Phpmin5/COPmin5				
Power (P), efficiency (COP, eta) and system test temperature (T).. HP: at Tout= -7ºC. FOS/FOSB/CHP: at max. heating power 80/60ºC	eta_0, a_1, a_2, IAM etasol	Phpf4/ COPf4 Php4/ COP4 Phpmin4/COPmin4	prim-energy	Pfos4 eta4 Tfos4	Pfosb4 etab4 Tfosb4	chp4
efficiency HP: at Tout=+2. FOS/FOS/CHPB at minimum steady state power and 80/60ºC		Phpf3/ COPf3 Php3/ COP3 Phpmin3/COPmin3		Pfos3 Eta3 Tfos3	Pfosb3 Etab3 Tfosb3	chp3
efficiency HP: at Tout=+7ºC. FOS/FOSB/CHP: at max. heating powerminimum allowable return temperature		Phpf2/ COPf2 Php2/ COP2 Phpmin2/COPmin2		Pfos2 Eta2 Tfos2	Pfosb2 Etab2 Tfosb2	chp2
efficiency HP: at Tout=+12ºC. FOS/FOSB/CHP: at minimum steady state power and minimum allowable return temperature		Phpf1/ COPf1 Php1/ COP1 Phpmin1/COPmin1		Pfos1 Eta1 Tfos1	Pfosb1 Etab1 Tfosb1	chp1
extra test point cycling				eta0		chp0
Other						
multipliers interpolation		w		b	bb	b
hours in on mode	solhrs	hphrs		foshrs	fosbhrs	foshrs

hours in heating season	allhrs

PREPARATORY CALCULATIONS

Weighting factors for air-source heat pump

In the assessment of the power output Php and the efficiency COP of the air-source heat pump the calculation procedure determines the values in the intermediate bin through linear inter/-extrapolation with the outdoor temperature. The multipliers w1, w2, etc. that are used can be calculated (see WD June 2009), but effectively they are constants. For the sake of simplicity they are therefore given as tabulated values in Table V.4.

Table V.4. For inter-/extrapolation: Weighting factors for the air-source heat pump test points against the outdoor temperature for 3 climates: Warmer, Average and Colder

test temperature Tsrc	**12**	**7**	**2**		**-7**	**2**	**-7**	**12**
Colder	w1C_tp	w2C_tp				w3C_tp	w4C_tp	w5C_tp
Average	w1A_tp	w2A_tp		w3A_tp	w4A_tp			
Warmer	w1W_tp	w2W_tp	w3W_tp		w4C_tp			
Tout (in oC)								
nights (TIM=1)	weighting factors							
6 (Warmer)	-	0,80	0,20	-	-	-	-	-
1 (Average)	-	-	-	0,11	0,89	-	-	-
-2 (Colder)	-	-		**-**	**-**	0,56	0,44	-
Tout (in oC)								
-22	-	-	-	-	-	-	-0,88	1,88
-21	-	-	-	-	-	-	-0,75	1,75
-20	-	-	-	-	-	-	-0,63	1,63
-19	-	-	-	-	-	-	-0,50	1,50
-18	-	-	-	-	-	-	-0,38	1,38
-17	-	-	-	-	-	-	-0,25	1,25
-16	-	-	-	-	-	-	-0,13	1,13
-15	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1,00**
-14	-	-	-	-	-	-	0,13	0,88
-13	-	-	-	-	-	-	0,25	0,75
-12	-	-	-	-	-	-	0,38	0,63
-11	-	-	-	-	-	-	0,50	0,50
-10	-	-	-	-0,33	1,33	-	0,63	0,38
-9	-	-	-	-0,22	1,22	-	0,75	0,25
-8	-	-	-	-0,11	1,11	-	0,88	0,13
-7	**-**	**-**	**-**	**-**	**1,00**	**-**	**1,00**	**-**
-6	-	-	-	0,11	0,89	0,11	0,89	-
-5	-	-	-	0,22	0,78	0,22	0,78	-
-4	-	-	-	0,33	0,67	0,33	0,67	-
-3	-	-	-	0,44	0,56	0,44	0,56	-
-2	-	-	-	0,56	0,44	0,56	0,44	-
-1	-	-	-	0,67	0,33	0,67	0,33	-
0	-	-	-	0,78	0,22	0,78	0,22	-
1	-	-	-	0,89	0,11	0,89	0,11	-
2	**-**	**-**	**1,00**	**1,00**	**-**	**1,00**	**-**	**-**
3	-	0,20	0,80	0,80	-	0,80	-	-
4	-	0,40	0,60	0,60	-	0,60	-	-
5	-	0,60	0,40	0,40	-	0,40	-	-
6	-	0,80	0,20	0,20	-	0,20	-	-
7	-	1,00	-	-	-	-	-	-
8	0,20	0,80	-	-	-	-	-	-
9	0,40	0,60	-	-	-	-	-	-
10	0,60	0,40	-	-	-	-	-	-
11	0,80	0,20	-	-	-	-	-	-
12	**1,00**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
13	1,20	-0,20	-	-	-	-	-	-
14	1,40	-0,40	-	-	-	-	-	-
15	1,60	-0,60	-	-	-	-	-	-

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Sink temperature correction of power and efficiency test results.

Especially in Warmer and Colder climate calculations and for radiator heating the applied system temperature deviates significantly from the system temperature used for testing in Document 5. This is a logical consequence of the difference in maximum heat demand. Nevertheless, it leads to efficiency values that are too optimistic for Warmer climates and too pessimistic for Colder climates and is corrected as indicated in Fig. V.1, i.e. on the basis of the temperature difference between source- and (sink)system-temperature. The calculation does not use the system feed temperature –usually seen as the 'sink temperature' —because typically heat pumps are not designed to cover the full heat demand range and the use of the system feed temperature would yield too pessimistic results.

A special correction ' cornight' is required for the reheat bin, where the system temperature that goes with the power output (e.g. 63 oC for the average climate) deviates even more from the test temperature (37 oC). This is also shown in Fig. V.1.

[the fact that the system temperature is 63°C seems to be overestimated. The fact of the matter is that the consumer will install setback, but the temperature of the boiler will not necessarily be adapted. The duration of reheat will increase, but that the set temperature of the boiler will change is a stretch. The assumption is as such degrading the efficiency of heat pumps and is not acceptable. For heat pumps, there will never be an increase to 63°C, this is a technology prescriptive boundary. The reheat temperature will be lower, and at a constant efficiency. Due to the 63°C, the efficiency is dropped and use of backupheater is increased, while the most logic approach would be to apply the efficiency of the heatpump at max sink for radiators, and increase reheat time if necessary.]

The matrix is wrong, and needs to be corrected. Is not possible to convert to the systemtemperatures in this way since there is no correlation between the capacity at the test temperature and the system temperature.

OPTION 1:
prEN 14825 is still in enquiry stage and can be adapted to the system temperatures as indicated in the document for radiator calculation. However, we can not adapt the temperatures for floorheating since at -10°C the temperature exceeds 35°C and this is not acceptable for general health reasons. Common practice is to have less than or equal to 35°C in floorheating application. We believe that the system temperatures need to be adapted taking this 35°C boundary in account.
Then there is no need to include these correction formulas.

OPTION 2

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Linear interpolation between the maximum capacity at the same outdoor temperature for different sink or to calculate based on simulation software the possible change in efficiency and then provide a correction factor.
➔ this option still requires to have reduced systemtemperatures for floorheating not exceeding 35°C in any of the temperature BINS.

Example for linear interpolation:
Phpmax4f @ testtf° 35° = 3
Phpmax4r @ testtr° 52°C = 2
Tsys = 39°C
Php4system = Phpmax4f – Phpmax4f*(Tsys – ttestf)/(Ttestr-ttestr) = Phpmax4f-Phpmax4f(39-35)/(52-35)
NOTE: this interpolation is not taking into account the efficiency evaluation that is to be perceived in partload conditions.
When incorrect points are used, then the efficiency of the heat pump can be affected more severely.

Note: The correction is needed because especially for the Warmer and Colder climate the system temperature is different from the system temperature during the prEN 14825 test conditions. Basis for the correction is the difference between source and system temperature for both the test and the calculated condition

The reheat after night setback represents a special case, because the system temperature is considerably higher than at the test condition. System temperatures pertaining at the reheat power output (now fixed) are 63 (Warmer and Average climate) and 65 oC (Colder climate). However, the outdoor temperatures at night are 6, 1, -2 oC, which implies test temperatures of around 37, 42 and 44 oC and not 63 oC. Therefore, using the weighting factors for the night-bin from table XX the following correction cornight for Php and COP is used in the night bins

Again, is a stretch

cornightW=TIM*(0,80*((Tsystst2-tst2)/(63-tst2) + 0,20*(Tsystst3-tst3)/(63-tst3)))

cornightA=TIM*(0,89*((Tsystst3-tst3)/(63-tst3) + 0,11*(Tsystst4-tst4)/(63-tst4)))

cornightC=TIM*(0,56*((Tsystst3-tst3)/(65-tst3) + 0,44*(Tsystst4-tst4)/(65-tst4)))

Fig. V.1 .Conversion from general input values to climate-corrected input values for air-source heat pump

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MODEL: Energy efficiency calculation procedure

The result of this calculation procedure is specific for one designated emitters/setback combination.
There are 2 possible emitter types : RH=1=radiator; RH=0=floor heating) and --for radiator heating only-- two possible timer regimes: TIM=1=with setback; TIM=0=without setback.

In addition, the procedure is prepared to calculate the efficiency degradation at part peak load 50% (PL=0,5) and 25% (PL=0,25) for the most critical emitter/setback configuration in the average climate.
In every run the efficiency for 3 climates (Average, Warmer, Colder with suffixes A, W, C) is established, but only reported for the designated climate(s). Efficiency assessment for the average climate is always mandatory: The suffixes A, W, C in the parameter names are omitted, unless climate specific equations use different parameters/values.

Overview of efficiency calculations

	A	**W**	**C**	**PL0,5**	**PL0,25**
RH	1	1	1	RH max	RH max
TIM (+RH)	1	1	1	TIM max	TIM max
PL	1	1	1	0,5	0,25

DEFINITION

Peak load assessment (*PmaxA for all) (PmaxW and PmaxC also for air-source heat pumps & solar)*

PmaxA= HP*IF(RH;
IF(Tmino>-10;0;1,33*Php4-0,33*Php3)
+(1-HP*(1-elfrac))*EL*Pel
+(1-HP*(1-fosfrac))*FOS*Pfos4
+FOSB*Pfosb4);
IF(Tmino>-10;0;1,33*Phpf4-0,33*Phpf3)
+(1-HP*(1-elfrac))*EL*Pel
+(1-HP*(1-fosfrac))*FOS*Pfos4
+FOSB*Pfosb4);

Tmino capacity and COP can be used for determining _10°C, it should be possible to use. It is more correct. If data is there for php5, then this can also be used in the interpolation/extrapolation to define Pmax A. 1

(the parameters with suffix W and/or C are only relevant if Warmer and/or Colder=1)

PmaxW=HP*IF(RH;(Tmino>2;0;Php3)+(1-HP*(1-elfrac))*EL*Pel+(1-HP*(1-fosfrac))*FOS*Pfos4 +FOSB*Pfosb4);(Tmino>2;0;Phpf3)+(1-HP*(1-elfrac))*EL*Pel+(1-HP*(1-fosfrac))*FOS*Pfos4 +FOSB*Pfosb4) 2

PmaxC=HP*IF(RH;(Tmino>-22;0;1,88*Php5-0,88*Php4)+(1-HP*(1-elfrac))*EL*Pel+(1-HP*(1-fosfrac))*FOS*Pfos4+FOSB*Pfosb4);(Tmino>-22;0;1,88*Phpf5-0,88*Phpf4)+(1-HP*(1-elfrac))*EL*Pel+(1-HP*(1-fosfrac))*FOS*Pfos4+FOSB*Pfosb4 3

Pradnom=PL*Pmax*IF(RH;1,66;3,3)/IF(TIM;1,38;1) 4

hrsmaxA=IF(TIM;1100; 1550) 5
hrsmaxW=IF(TIM;700; 1400) 6
hrsmaxC=IF(TIM;1400; 2150) 7

Specific seasonal efficiency

etas=Lh/(Lh+Qgen+Qel) + cctrl 8

for SOL=1 and/or HP=1 & air-source only, calculate

etasA=cctrl+Lh/QtotA 9

etasW=cctrl+Lh/QtotA 10

etasC =cctrl+Lh/QtotC 11

QtotA=Lh +QgenA+QelrhA 12

QtotW=Lh +QgenW+QelrhW 13

QtotA=Lh +QgenC+QelrhC 14

HEAT BALANCE

Heat Demand

Lh=PL*hrsmax*Pmax *(climate specific)* 15

16

(climate specific)

17

18

19

20

21

22

Cdistr=5% 23

24

(climate specific)

25

26

(climate specific)

27

28

.

Heat Supply

Lgen= Lsol+Lhp+Lel+Lfos+Lfosb 30

(climate specific)

Lsol= SOL*usesol*CHOOSE(ICS;SUM(Lsol_tm);SUM(Lsolics_tm)) 31

usesol= 1-SOLCOMBI*((1-HPCOMBI)+0,7*HPCOMBI)*Lw/ (Lh+Lsys+Lw) 32

Lw = 213*50%* 33

*CHOOSE [waterload; 2,1; 2,1; 2,1; 5,85; 11,66; 19,07; 24,53; 46,76; 93,52]

ICS=[0;1]=[no;yes] integrated collector storage 34

Lsol_tm =MAX(0; L_tm*(Lh+Lsys)) * 35

* MIN(1;(1,029*Y_tm – 0,065*X_tm – 0,245*Y_tm^2+ 0,0018 * X_tm^2+ 0,0215*Y_tm^3)))

L_tm= CHOOSE(climate; LA_tm; LW_tm; LC_tm) 36

LA_tm= (Lh+Lsys)*	0,20	0,20	0,13	0,06	0,06	0,16	0,19			37
LW_tm= (Lh+Lsys)*	0,26	0,24	0,18	0,03	0,06	0,23				38
LC_tm= (Lh+Lsys)*	0,17	0,17	0,14	0,09	0,04	0,03	0,08	0,12	0,16	39

X_tm= Asol*(a_c+ UL)*etaloop*(Trefh – Tout_tm) * Ccap * 0,732 / (Lh+Lsys) 40

Y_tm = Asol*IAM*eta_0*etaloop*qsolm_tm*0,732 / (Lh+Lsys) 41

a_c = a_1+a_2*40 42

UL = Lpipesol*Upipesol/Asol 43

Lpipesol=6 44

Trefh=100 45

Ccap= (75*Asol/Vsol)^0,25 46

etaloop =1 - (eta_0*Asol*a_c)/Uasol 47

Tout_tm = CHOOSE(climate; ToutA_tm; ToutW_tm; ToutC_tm) 48

ToutA_tm=	2,8	2,6	7,4	12	12	5,6	3,2			49
ToutW_tm=	9,5	10	12	15	15	10				50
ToutC_tm=	-3,8	-4,1	-0,6	5,2	11	13	6,7	1,2	-3,5	51

qsolm_tm= CHOOSE(climate; qsolmA_tm; qsolmW_tm; qsolmC_tm) 52

qsolmA_tm=	70	104	149	192	129	80	56			53
qsolmW_tm=	129	138	182	227	126	110				54
qsolmC_tm=	22	75	124	192	234	120	64	24	13	55

In case of ICS/thermosiphon

Lsolics_tm= MIN(L_tm*(Lh+Lsys); 0,732*Asol*etasol*qsolm_tm) 56

etasol is ICS efficiency (solar input/ useful heat output) from best testing practice

qsoltest per m2 Asol is average global solar irradiation

during full test period (minimum 3 days)

Lhp= HP*usehp*SUM(Lhp_tp) 57

usehp=1- HPCOMBI*((1-SOLCOMBI)+0,3*SOLCOMBI)*Lw/ (Lh+Lsys+Lw) 58

Lhp_tp= HP*Php_tp*hphrs_tp 59

hphrs_tp=HP*IF(Php_tp>0;hr_tp;0) 60

Php_tp=HP*MIN(Pmax_tp; Prs_tp) 61

Pmaxhp_tp= IF(Tout_tp<Tmino;0;IF (RH; 62

Php1A*w1_tp+Php2A*w2_tp+Php3A*w3_tp+Php4A*w4_tp;

Phpf1A*w1_tp+Phpf2A*w2_tp+Phpf3A*w3_tp+Phpf4A*w4_tp))

Tmino or php5 should be used if available.

in case of Cold climate

Pmaxhp_tp=IF (Tout_tp<Tmino;0;IF (RH; 63

Php1A*w1_tp+Php2A*w2_tp+Php3A*w3_tp+Php4A*w4_tp +Php5A*w5_tp;

Phpf1A*w1_tp+Phpf2A*w2_tp+Phpf3A*w3_tp+Phpf4A*w4_tp+Phpf5A*w5_tp))

Prs_tp=IF(hr_tp>0;(Lhsys_tp-Lsol_tp)/hr_tp;0) 64

Lhsys_tp= (Lh)*frac_tp 65

frac_tp=0,01*IF(TIM;Table!xx;Table!yy) 66

COPY VALUES FROM TABLE

Lsol_tp=Lhsys_tp*IF(fracac_tp<solfrac;1; 67

IF(fracac_tp-frac_tp<solfrac;(solfrac-fracac_tp-frac_tp)/frac_tp;0) 68

solfrac=Lsol/(Lh) 69

fracac=SUM(fracn_0:fracn_tp) 70

hr_tp= IF(TIM;Table!xx;Table!yy) 71

COPY VALUES FROM TABLE I.1

Psys_tp=Lhsys_tp/hr_tp 71a

Tsys_tp=IF(RH;20+50*(Psys_tp/Pradnom)^(1/1,3);IF((20+50*(Psys_tp/Pradnom)^(1/1,3))<35;
(20+50*(Psys_tp/Pradnom)^(1/1,3));35) 71b

Lelrh=ELrh*SUM(Lelrh_tp) 72

Lelrh_tp=ELrh*IF(PelrhA_tp>0;hrA_tp*PelrhA_tp;0) 72a

Pelrh_tp=ELrh*MIN(Pelrh; Prs_tp-HP*Php_tp) 73

Lfos=(1-EL)*FOS*SUM (Lfos_tp) 74

Lfos_tp= (1-EL)*FOS*Pfos_tp*foshrs_tp 75

Pfos_tp= MIN(Pfos4; Prs_tp-Php_tp) 76

foshrs_tp=IF(Pfos_tp>0;hr_tp;0) 77

Lfosb=(1-EL)*FOSB*(Lh+Lsys-SOL*Lsol-HP*Lhp-FOS*Lfos) 78

Lfosb_tp=Pfosb_tp*fosbhrs_tp 79

Pfosb_tp=(1-EL)*FOSB*Prs_tp -Php_tp-Pfos_tp 80

fosbhrs_tp=IF(Pfosb_tp>0;hr_tp;0) 81

PRIMARY ENERGY LOSS ACCOUNTING

Qgen=Qsol+Qhp+Qelrh+Qfos+Qfosb 82

Qsol= SOL*- Lsol 83

Qhp= HP*SUM (Qhp_tp)- 84

Qhp_tp=primenergyfac*Lhp_tp/COP_tp –Lhp_tp 85

COP_tp= 86
IF(RH;

w1_tp*IF(Php_tp<Phpmin1;COPmin1*(1-Cd*(Phpmin1-Php_tp)/Phpmin1);
IF(Php_tp<Php1;COPmin1+(COP1-COPmin1)*(Php_tp-Phpmin1)/(Php1-Phpmin1); COP1))+
w2_tp*IF(Php_tp<Phpmin2;COPmin2*(1-Cd*(Phpmin2-Php_tp)/Phpmin2);
IF(Php_tp<Php2; COPmin2+(COP2-COPmin2)*(Php_tp-Phpmin2)/(Php2-Phpmin2); COP2))+
w3_tp*IF(Php_tp<Phpmin3;COPmin3*(1-Cd*(Phpmin3-Php_tp)/Phpmin3);
IF(Php_tp<Php3; COPmin3+(COP3-COPmin3)*(Php_tp-Phpmin3)/(Php3-Phpmin3); COP3))+
w4_tp*IF(Php_tp<Phpmin4;COPmin4*(1-Cd*(Phpmin4-Php_tp)/Phpmin4);
IF(Php_tp<Php4; COPmin4+(COP4-COPmin4)*(Php_tp-Phpmin4)/(Php4-Phpmin4); COP4));

[still correct terminology for floorheating needs to be included]

w1_tp*IF(Php_tp<Phpmin1;COPmin1*(1-Cd*(Phpmin1-Php_tp)/Phpmin1);
IF(Php_tp<Php1;COPmin1+(COP1-COPmin1)*(Php_tp-Phpmin1)/(Php1-Phpmin1); COP1))+
w2_tp*IF(Php_tp<Phpmin2;COPmin2*(1-Cd*(Phpmin2-Php_tp)/Phpmin2);
IF(Php_tp<Php2; COPmin2+(COP2-COPmin2)*(Php_tp-Phpmin2)/(Php2-Phpmin2); COP2))+
w3_tp*IF(Php_tp<Phpmin3;COPmin3*(1-Cd*(Phpmin3-Php_tp)/Phpmin3);
IF(Php_tp<Php3; COPmin3+(COP3-COPmin3)*(Php_tp-Phpmin3)/(Php3-Phpmin3); COP3))+
w4_tp*IF(Php_tp<Phpmin4;COPmin4*(1-Cd*(Phpmin4-Php_tp)/Phpmin4);
IF(Php_tp<Php4; COPmin4+(COP4-COPmin4)*(Php_tp-Phpmin4)/(Php4-Phpmin4); COP4));

Note that, except for Cd, all parameters are climate-corrected specific for the designated climate(s) as shown in Fig. VI.1

Cd is the COP degradation per kW output power, derived from COPcyc:

86a

.

Cd =(1-(COPcyc/COPmin1))/((1-(Phpcyc/Phpmin1))

primenergyfac=IF(HPELEC;2,5;1) 87

HPELECis declared input, with HPELEC=1=electric and HPELEC=0=fossil

Qelrh=ELrh*1,5*Lelrh 88

Qfos=FOS*(Qign+Qenvoff+Qfuel+Qenvon+Qflue) 89

Qign= (allhrs-foshrs)*Pign 90

Qenvoff= FOS*(allhrs-foshrs)*(1-boilrecov)*Pstby*((Tsysoff-20)/30)^1,25 91
foshrs= SUM(foshrs_tp) 92

Tsysoff=IF(FOSBUF;60;28) 93
boilrecov=0,55 94

Qfuel=AFM*Qfoson 95
AFM=CHOOSE(airfuelmix;0,018;0,01;0,004;0,001) 96
Qfoson=SUM(Qfoson_tp) 97
Qfoson_tp=(1/eta_tp-1)*Lfos_tp 98
Qenvon= foshrs*(1-boilrecov)*Pstby*((Tsyson-20)/30)^1,25 99
Tsyson= IF(FOSBUF;60;Tminret) 100

Qflue= (1-AFM)*Qfoson-Qenvon 101
void 102

---

eta_tp=((1-BUF)*(eta1/b1A_tp+eta2/b2A_tp)+eta3/b3A_tp+eta4/b4A_tp)/ 103
((1-BUF)*(1/b1A_tp+1/b2A_tp)+1/b3A_tp+1/b4A_tp) - corPcycA_tp - corTcycA_tp
Where

length of each vector (x square)
b1A_tp=SUMSQ(PfosA_tp-Pfos1;IF(TsysA_tp>Tfos1;TsysA_tp-Tfos1;0,001)) 104
b2A_tp=SUMSQ(Pfos2-PfosA_tp;IF(TsysA_tp>Tfos1;TsysA_tp-Tfos2;Tfos1-Tfos2)) 105
b3A_tp=SUMSQ(PfosA_tp-Pfos3;IF(TsysA_tp>Tfos1;Tfos3-TsysA_tp; Tfos3-Tfos1)) 106
b4A_tp=SUMSQ(Pfos4-PfosA_tp;IF(TsysA_tp>Tfos1;Tfos4-TsysA_tp)) 107

correction if cycling because below steady state power range
corPcyc_tp=IF(PfosA_tp<Pfos1; (1-BUF)*(Pfos1/Pfos4)*Cdf*(Pfos1-PfosA_tp)/Pfos1;0) 108

correction if cycling because below admissable temperature range
corTcyc_tp= IF(AND(Tminret>30; TsysA_tp<Tfos1;PfosA_tp>Pfos1); 109
(1-BUF)* ((Tfos1-20)/(Tfos4-20))* IF(TsysA_tp<(Tfos2/Pfos2)*PfosA_tp;2*Cdf; Cdf)
*(Tfos1-TsysA_tp)/(Tfos1-20);0)

Cdf for FOS is default 0,1 (no cycling tests) unless CHP is part of configuration.
Cdf=(1-CHP)*0,1+CHP*(2*Pfos4/Pfos1)*(1-(eta0/eta1))

Qfosb=FOSB*(Qignb+Qenvoffb+Qfuelb+Qenvonb+Qflueb) 110

Qignb= FOSB*(allhrs-onhrsb)*Pignb 111

Qenvoffb=FOSB*(allhrs-fosbhrs)*(1-boilrecov)*Pstbyb*((Tsysoffb-20)/30)^1,25 112

Tsysoffb=IF(FOSBUF;60;28) 113

Qfuelb=FOSB*AFMb*Qfosonb 114
AFMb=CHOOSE(airfuelmix;0,018;0,01;0,004;0,001) 115
Qfosonb=SUM(Qfosonb_tp) 116
Qfosonb_tp=(1/etab_tp-1)*Lfosb_tp 117
Qenvonb=FOSB*fosbhrs*(1-boilrecov)*Pstbyb*((Tsysonb-20)/30)^1,25 118
Tsysonb= IF(FOSBUF;60;Tminretb) 119

Qflueb= (1-AFM)*Qfosonb-Qenvonb 120

etab_tp=((1-BUF)*(etab1/bb1A_tp+etab2/bb2A_tp)+etab3/bb3A_tp+etab4/bb4A_tp)/ 121
((1-BUF)*(1/bb1A_tp+1/bb2A_tp)+1/bb3A_tp+1/bb4A_tp) - corPcybcA_tp - corTcycbA_tp
Where

bb1A_tp=SUMSQ(PfosbA_tp-Pfosb1;IF(TsysA_tp>Tfos1;TsysA_tp-Tfos1;0,001)) 122
bb2A_tp=SUMSQ(Pfosb2-PfosbA_tp;IF(TsysA_tp>Tfos1;TsysA_tp-Tfos2;Tfos1-Tfos2)) 123
bb3A_tp=SUMSQ(PfosbA_tp-Pfosb3;IF(TsysA_tp>Tfos1;Tfos3-TsysA_tp; Tfos3-Tfos1)) 124
bb4A_tp=SUMSQ(Pfosb4-PfosbA_tp;IF(TsysA_tp>Tfos1;Tfos4-TsysA_tp)) 125

corPcycb_tp=IF(PfosbA_tp<Pfosb1;(1-BUF)*(Pfosb1/Pfosb4)*0,1*(Pfosb1-PfosbA_tp)/
Pfosb1;0) 126

corTcycb_tp= IF(AND(Tminret>30; TsysA_tp<Tfos1;PfosbA_tp>Pfosb1); 127
(1-BUF)* ((Tfos1-20)/(Tfos4-20))* IF(TsysA_tp<(Tfos2/Pfosb2)*PfosbA_tp;0,2; 0,1)
*(Tfos1-TsysA_tp)/(Tfos1-20);0)

Qel=Qaux-CHP*Qchp 128

Qaux= Qpmp+(primenergy-auxrecov)*{Qsolaux+Qhpaux+Qfosaux+Qfosbaux} 129

Qpmp= cpmp*tpump*Lh **(1+0,5*(1-RH) 130

tpump=CHOOSE(tpmp;(MAX(hponhrs;onhrs)+200)/allhrs; 131

(allhrs-0,33*(allhrs-MAX(hponhrs;onhrs)))/allhrs; 1)

cpmp=CHOOSE(PMP;0,02; 0,025; 0,04; 0,05; 0,06) 132

auxrecov=IF(OR(AND(FOS;FOSOUT);AND(SOL;SOLBUFOUT));0,275;0,55) 132a

Qsolaux= SOL*0,001*usesol*(solhrs*solaux+(allhrs-solhrs)*solsb) 133

solhrs=0,163*allhrs 134

Qhpaux=HP*0,001*usehp*(onhrshp*hpaux+(allhrs-onhrshp)*hpsb) 135

Qfosaux= FOS*0,001*(foshrs*fosaux+(allhrs-foshrs)*fossb) 136

fosaux=0,5*(elmax+elmin) 137

Qfosbaux= fosbhrs*fosaux+(allhrs-fosbhrs)*fosbsb 138

fosbaux=0,5*(elmaxb+elminb) 139

Qchp= CHP*primenergy*SUM (Qchp_tp) 140

Qchp_tp=foshrs_tp**(chp_tp/eta_tp)*Pfos_tp 141

primenergy=2,5

chp_tp=((1-BUF)*(chp1/b1A_tp+chp2/b2A_tp)+chp3/b3A_tp+chp4/b4A_tp)/ 142

((1-BUF)*(1/b1A_tp+1/b2A_tp)+1/b3A_tp+1/b4A_tp)

- IF(PfosA_tp<Pfos1; (1-BUF)*(Pfos1/Pfos4)*(chp4-chp0)*(Pfos1-PfosA_tp)/Pfos1;0)

-IF(AND(Tminret>30; TsysA_tp<Tfos1;PfosA_tp>Pfos1);

(1-BUF)* ((Tfos1-20)/(Tfos4-20))* IF(TsysA_tp<(Tfos2/Pfos2)*PfosA_tp;2*(chp4-chp0);

(chp4-chp0)) *(Tfos1-TsysA_tp)/(Tfos1-20);0)

CONTROL forfeit

cctrl= CHOOSE(CTRL;-0,03;-0,03;-0,015;-0,01;-0,01;0;0;0,01;0,01) 143

Note: cctrl is included directly in calculation of etas; Qctrl is just for statistics

Qctrl=cctrl*(Lh+Lsys+Qgen+Qel) 144

(climate specific)