ANNEX V

Draft version 1.1

Revision draft Annex V d.d. 31.1.2008 on Eco-design implementing measures for central-heating boilers and water heaters.

Accompanied by MS-Excel file with identical structure

European Commission

Brussels, 15.4.2008

PREFACE

This is version 1.1 of Annex V of the Working Documents for the Eco-design of Central Heating Boilers and Water Heaters, prepared by the European Commission d.d. 31.1.2008.

Version 1.1 does not contain new items with respect of version 1.Its main merit is that it is now fully synchronised and in line with a spreadsheet-file that has an identical structure and which is distributed simultaneously. The combination of the text and the spreadsheet file allows the policy makers and stakeholders to follow the calculation procedure step-by-step in terms of results and to verify its robustness and applicability in a legal context.

The synchronisation of both the text and spreadsheet file have prompted several improvements terms of accuracy, completeness and readability, which is the main reason for this new Annex V text document.

The underlying document is available in *tracked changes* version (changes with respect of Annex V distributed 31.1.2008) and a clean version.

The latter will be used as a basis for changes following the policy discussion. An overview of the new items currently under consideration is given below.

Under consideration

The following adaptations of Annex V are under consideration and may be implemented in a fully revised version 2 of Annex, depending on political decision making.

[from Commission presentation to Consultation Forum]

Adapted controls paragraph.

- Delete design option hydraulic balancing ('TRV 1 K') à no TRV in EuP (move to EPB)
- Adjust Tcontrol definition to include restricted open protocol →boiler can only work with one Tcontrol type→physical supply of Tcontrol-type not necessary

Revised load profiles:

- Simplification Annex V: remove "optimiser" option (or set to zero)
- Simplification: remove "S" profile (XS→S, XXS→XS; XXS not used here, but could be used later e.g. for local heaters)
- Smoothen sequence: add load profile "XL" in between current L and XL. Current XL→ XXL. This would create a series of load profile series with ca. 50% increment
- Similar for larger profiles, i.e. also extra profiles.
- Result: Sequence that would allow easy implementation "sliding scale" in EPB (e.g. through extrapolation in look-up table)

Including some new technologies

- micro-CHP (heat-demand driven calculation). Would accomodate new option for now. Other options to be added at later date (e.g. electriciy-demand driven).
- CO_2-heat pump. Market-introduction 2008/2009. Current version of the mathematical model uses 70 °C as the maximum sink temperature. With the introduction of new CO_2-based types, higher sink temperatures (e.g. 85°C) are possible. But for the COP there is also a strong dependence on system return temperature, which is to be taken into account. The modality of considering these new types in the model is under consideration (e.g. simple correction factor now, more complete modelling after a few years of practical experience).

Water heaters

- EIWH test proposal should be reviewed [new expert proposal under preparation for Annex F]
- Adapt XXS load profile (25 instead of 40 degrees for one tapping)
- Extra (distribution, pump, etc.) losses centralised systems to be taken into account. In principle all ANNEX J items shall be in EPB (iTG is good basis for proposal), but perhaps could tune the reference distribution losses also in 3XL and 4XL profiles.

[from footnotes of Annex V d.d. 31.1.2008]

- Definitions of Time, Temperature and Hydraulic controls are pragmatic, for lack of harmonised standards. If feasible within the timeframe of measures or at the first revision of measures it is considered to firm up the definitions within the context of harmonised rating/certification of controls.
- Allow definition of Cgrad and Cpar with respect of (the equivalent of) a simple 2-point weather compensated control with setpoints at –10/45 and 20/25 (outdoor temperature/ system feed temperature).
- Instead of using Phpnom, which is –up to a degree—an arbitrary value e.g. typically at 7°C source temperature for an air-based heat pump, to use a specific heat pump output at –10°C. This is especially relevant in case the heat pump has no back-up heater (electric or fossil) to cope with extreme situations.

[Other]

- Default COP values from prEN 15316 should not be allowed (delete option)
- At least 4 test-points required for heat pumps, not only for COP but also for output power
- Boundaries for sink and source temperatures that define nominal output power and COP should be not completely free (e.g. close to 7± 5/ 35 ± 5 for air source).
- Procedure for CH-boiler with primary store to be described.
- Pump test definitions to be clarified. Controls definitions to be updated (if available)
- Annex G (flue gas temperature and combustion efficiency) to be replaced by reference to EN standard.
- Annex I. Extend functionality Excel file (load profiles per Member State and not just EU). Simplify par. I6 and I7 (thermal mass en internal heat transfer) as much as possible, within boundaries of EN standards.
- Default pipe length for solar to be introduced.

Finally

The European Commission and its consultants are well aware of the complexity of this Annex V. Therefore, despite best efforts, errors may still occur and we would be grateful for any error-reports –outside the political context—that would improve the robustness of the underlying document.

Brussels 15.4.2008

Content

ANNEX A: DEFINITIONS

A1. Product

- A *Product* in this document is a boiler for central space heating (*CH-Boiler*), a *Water Heater* or both (*CH-Combi*).
- A *CH-Boiler* is a product that is equipped to generate heat and to transfer this heat to a heat transfer fluid (*CH-water*) circulating in a distribution system (*CH-distribution network*) to which at least one heat exchanging means is connected (*CH-emitter*) that is equipped to transfer the heating energy of the CH-water into space heating of (a part of) buildings.
- A *Water Heater* is a product that is connected to a given external supply of drinking water and is equipped to generate heat and transfer this drinking water to desired temperature levels and at desired quantities, flow rates and intervals.
- The *primary function* of a *CH-boiler* is the capability to reach and maintain the indoor climate of an enclosed space (building, dwelling, room) at a desired level under normal and extreme circumstances, in as much as is possible through heating, using hydronic heat emitters.
- The *primary function* of a *Water Heater* is the capability to reach and maintain the desired temperature levels at desired quantities, flow rates and intervals as mentioned in the product definition.
- A *CH-Combi* is a product with the functionality of both a *CH-Boiler* and a *Water Heater.*
- *CH-distribution networks* and *CH-emitters* are not part of the product definition. For compliance assessment the characteristics of a reference distribution system and reference emitters shall be used, as desribed in Annex C.
- All other means to regulate the heat generation and heat transfer processes *(CH-controls, CH-circulators, flue ducts, combustion air inlets)* may or may not –in whole or in part- be included in the *Product*. If these items, defined hereafter and in Annex B, are not included in the *Product* offered for CE-marking, reference characteristics will be used for compliance assessment as outlined in Annex C.
- The *Product* shall include one or more of the following heat generation processes:
    - combustion of gaseous and/or liquid fossil fuels
    - use of the Joule effect in electric resistance heating elements
    - capturing solar thermal energy
    - capturing ambient heat, including but not limited to transformation processes to bring the heat to a higher exergy level.

  A *heat generator* is the part of the *Product* that accomodates a heat generation process as mentioned above. Multiple heat generators, including cascades of the same type of *heat generators*, are explicitly within the defintion of a *Product*.
- The *minimum output performance* of a *Product* shall meet the requirements of the smallest *load profile* ('XXS') as defined in Annex C for one or both of the *primary functions*. A *CH-Combi* shall comply with both sets of requirements.
- The *energy efficiency performance* of a *Product* is defined in Annexes D23 (CH-Boiler), E6 (conventional Water Heater) and E11 (Water Heater with renewables).
- If the *Product* contains the whole or part of the means required for *space cooling, ventilation, air purification, humidification, de-humidification or any other functionality related to indoor air quality*, this extra functionality will <u>not</u> be part of the compliance assessment.
- If the *Product* contains the whole or part of the means required for *other domestic heating functions, like cooking,* this extra functionality will <u>not</u> be part of the compliance assessment.
- The following *Products* are explicitly <u>not</u> included in the scope:
    - Space- and/or water heating devices that are within the scope of Directive 2001/80/EC on Large Combustion Plants (LCPD).

- Space- and/or water heating devices that produce a surplus of electricity, i.e. beyond what is needed for driving the electrical components within the system (a.k.a. *CHP*, Combined Heat and Power).
- Space- and/or water heating devices using solid fuels, including biomass and bio-oil, as an energy source.
- Space- and/or water heating devices driven by District Heating ("DH"). These are systems fuelled by waste heat from power plants, waste incineration plants, larger industrial installations, etc..
- Centralized and local space heating devices based on air heating (e.g. reversible room- or centralized air conditioners).
- Product components, i.e. devices that are not capable of performing the *primary function*. This includes but is not limited to burners, heat exchangers, storage tanks as well as controls or other provisions for heat generation technologies that are not part of the product offered for CE-marking.

A2. Product features

- ***Conventional*** *Products*: All *Products* that do not (also) use renewable energy sources in the form of solar and/or –through heat pump technology- ambient heat. In the context of this document this comprises electric (Joule effect), gas- and oil-fired CH-boilers.
- *Products* ***with renewables***: All *Products* that (also) use renewable energy sources in the form of solar and/or –through heat pump technology- ambient heat.
- *Products* ***with combustion technology***: *Products* where whole or part of the imposed heat load is fulfilled by capturing and transferring the heat energy from combustion (exothermic reaction with oxygen) of gaseous or liquid fossil fuels to CH-water and/or sanitary hot water.
- ***Electric resistance*** *Products*: *Products* where whole or part of the imposed heat load is fulfilled by capturing and transferring the heat energy from the Joule-effect of inducing an electric current in a heating element to CH-water and/or domestic hot water.
- *Products* ***with solar technology***: Products where whole or part of the imposed heat load is fulfilled by capturing and transferring solar heat energy to CH-water and/or sanitary hot water.
- *Products* ***with heat pump technology***: *Products* where whole or part of the imposed heat load is fulfilled by capturing ambient heat, transforming it to a higher exergy level and transferring this heat to CH-water and/or domestic hot water.
- *Product* ***cascade***: configuration of more than one heat generator, whereby the heat generators are operating consecutively or in parallel to supply heat to the CH-water and/or domestic hot water. A distinction can be made between ***identical cascades***, where all heat generators in the cascade have the same characteristics, and ***non-identical cascades***, where the heat generators do not have the same characteristics. In a non-identical cascade a distinction can be made between ***preferential*** heat generators, i.e. designated by the manufacturer to fulfill the heat demand to the maximum of their capacity, and ***non-preferential*** heat generators, designated by the manufacturer to fulfill the remaining heat demand if it exceeds the maximum capacity of the preferential heat generators.
- ***Back-up*** heating: Any conventional heat generation and heat transfer technology that is used to fulfill the remaining heat demand after the application of the renewable heat (solar and/or heat pumps).
- *Water heating load profile* (***waterload***): For water heating nine load profiles (0=none, 1 to 9) are defined, denominated XXS, XS, S, M, L, XL, XXL, 3XL, 4XL. Each load profile has a predefined 24h water tapping patterns, with per tapping a
  - start-time,
  - minimum flow rate,
  - useful hot water energy to be drawn-off and –for some tappings—
  - minimum peak temperature.

The water heating load is declared by the manufacturer for a *Water Heater* or *CH-combi* and it is used to

- Establish the primary energy efficiency of the product and
- Comply with the minimum performance requirements posed by the selected pattern.

A product can be offered for CE-marking under more than one water heating load profile, but each load profile will result in a different evaluation and technical fiche. Hence a different registration number applies for each load profile and the products shall be brought on the market with a denomination that is specific for the load profile.

Details of the load patterns can be found in Annex C (Reference Conditions).

- Space heating load profile (***heatload***): For space heating nine load profiles (0=none, 1 to 9) are defined, denominated XXS, XS, S, M, L, XL, XXL, 3XL, 4XL. Each load profile has a
  - Minimum output requirement for the product ***MinOutput*** [in kW],
  - Reference load pattern, consisting of a heat load for 9 average days, one for each month in the longest possible heating season (Sept.-May) and with each 24h day made up of 5 net heat load values for specific time-periods [in h]: morn [2h], mid [7h], eve[5h], late [2h] and night[8h]. The annual profile is built by multiplying the load energy values [in kWh] with a factor 30,5 [average days per month dpm].
  - For some classes, maximum output value ***MaxOuput*** [in kWh]

The space heating load is declared by the manufacturer for the *CH-Boiler* or *CH-combi* and it is used to

- Guarantee a minimum space heating performance
- Evaluate the primary energy efficiency of the product
- Limit the applicability of a profile to a reasonable range.

A product can be offered for CE-marking under more than one space heating load profile, but each load profile will result in a different evaluation and technical fiche. Hence a different registration number applies for each load profile and the products shall be brought on the market with a denomination that is specific for the load profile.

Details of the load patterns can be found in Annex C (Reference Conditions).

- ***Outdoors***: Any CH-boiler, water heater or solar 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*.
- ***Smart control*** water heater: Any water heater that complies with the definitions in Annex H of this document.
- ***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.
- ***Twostage***: If a *heat generatore* can assume only two discrete output power levels it is denominated as *twostage*. A heat generator with more than two (up to infinite) discrete output power levels that are evenly spaced is not considered *twostage,* but considered to be fully modulating. *Evenly spaced* is defined as at equidistant intervals (± 15%) between the declared minimum and nominal power output level.
- Combi-compensation (***combicomp***): Situation that may apply to a *CH-combi*, where there is a separate test for measuring space heating energy consumption and a separate test for water heating energy consumption. If the sum of the energy consumption of these separate tests exceeds the energy consumption of a combined (simultaneous) test combi-compensation applies (*combicomp*=yes). Combi-compensation does not apply in case of a solo-CH boiler (waterload= “0”, see Annex B) or a combi-storage boiler where the storage tank is not included in the space heating test (*combicomp*=no.)
- Fuel-dew point (***dpt***): Dry bulb temperature at which the combustion flue gases start condensing. The fuel dew point is given for various types of fuels under reference conditions. The model distinguishes between:

  1. Gas (Natural Gas)

2. Oil
3. LPG (Liquefied Petroleum Gas)

A3. Combustion parameters

- Air-fuel mix controls (parameter ***airfuelmix***) 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:
  1. ***Atmospheric***: burner regulation through gas-valve. No pre-mix fan present.
  2. ***Pneumatic***: pre-mix fan present.
  3. ***Ionisation***: pre-mix fan present plus control of fan and gas-valve through measurement of ionisation from flames.
  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.

Reference conditions are given in Annex C.

- ***airintake***: method of combustion air intake of the burners. Affects waste heat recovery. Possible values:
  1. ***room sealed***: Type C appliance, according to `NPR-CEN/TR 1749; 2006
  2. ***open***: Type A or B appliance, according to `NPR-CEN/TR 1749; 2006. For appliances that are classified as both type B and type C airintake shall be given as "open".
  3. ***none*** (electric): no air intake. Appliance uses electric power only.

- Combustion efficiency (***ηcomb***), as defined in Annex C: Affects waste heat recovery of gas- or oil-fired water heaters in the model.

- Flue gas temperature (***Tflue***) as defined in Annex C: Affects waste heat recovery of gas- or oil-fired water heaters in the model.

A4. Geometry and mass

- Boiler volume (***volumeb***, in m³): The envelope of the product (in m³) represented by the smallest cuboid or the smallest cylindrical shape that can contain the product. If the product consists of more than one envelope, then the measurement applies to the largest envelope that is designated for use indoors.
- Boiler mass (***massb***, in kg): Empty mass of a gas- or oil-fired (part of the) CH-boiler.
- Water content (***massw***, in kg): Mass of the water contained in the heat exchanger circuit (from boiler inlet to boiler outlet connection) of a gas- or oil-fired (part of the) CH-boiler.

A5. Electricity consumption and pump parameters

- Pump hours after burner-off (***tpmp***, in h): Factory setting for a gas- or oil-fired (part of the) CH-boiler of the running time of the circulator pump after the burner has been switched off.
- Nominal pump power (***elpmp***, in kWe): Nominal power of the circulation pump of the gas- or oil-fired (part of the) CH-boiler.
- Electricity use at boiler off (***elstby,*** in kWe): Electricity use when both circulation pump and burner of the gas- or oil-fired (part of the) CH-boiler are not operational (see also prEN 15456).
- Electricity consumption at nominal CH-boiler power (***elmaxon***, in kWe): Relates to electricity consumption at nominal heat input for space heating (see also prEN 15456).
- Electricity consumption at minimal CH-boiler power (***elminon***, in kWe): Relates to electricity consumption at minimal heat input for space heating (see also prEN 15456).
- Pump setback (***pmpsb,*** yes/no): control of the circulator pump with a night-setback option that saves 8h on daily pump operation time in the heating season.

- Variable speed (***varsp,*** yes/no): control of pump speed depending on the momentary heat demand.
- The pump configuration for the CH-boiler (***pmpconfig***) is given by 3 possible values:
  1. Integrated pump
  2. Internal pump only (just for the heat exchanger not for network)
  3. No pump
- Pressure drop over the boiler (***pdrop***, in mbar): Pressure drop over the boiler.

A6. Time controls[1]

1. ***Autotimer**:* programmable feature of a *CH-boiler temperature control*, setting the desired room- or boiler-temperature level for at least 4 day-periods per 24h day, to be defined by (at least 4) switching points. Each switching point defines the start-time (on a 24h day) and a desired temperature level. For weekend days (Saturday and Sunday) different switching points can be programmed. High temperature periods are defined as ***comfort-periods***; low temperature periods are defined as ***setback-periods***, with a distinction between ***day-setback*** and ***night-setback***.
   Autotimer is a default feature for XXS to XL load profiles, unless the manufacturer explicitly indicates otherwise, in which case a fixed desired day-temperature setting will be assumed. The latter will e.g. be the case for CH-boilers employing heat pump technology. For XXL, 3XL and 4XL space heating load profiles the feature is not default and has to be actually delivered with the temperature control.
2. ***Optimiser**:* Control feature of a CH-boiler temperature control, that given the optimal operating condition of the CH-boiler –i.e. with the highest energy efficiency— calculates the start-time for the reheating period in order to arrive at the required temperature for the beginning of a comfort-period. *Optimiser* is not a default feature and has to be actually implemented in the CH-boiler product. The *optimiser* option can only be applied when the *autotimer* option applies (*autotimer*=yes)

A7. Temperature controls (Tcontrols)

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

In detail:

1. ***Fixed BT*** (boiler thermostat): Boiler temperature adjusted manually, no room thermostat and no outdoor sensor (weather control). Model assumes the control is not capable of inducing burner modulation. Default for profiles XXL, 3XL and 4XL. For other profiles the manufacturer has to state explicitly that this Tcontrol applies, instead of the default Tcontrol=2.
2. ***On/off RT*** (room thermostat): Room thermostat with sensor, sends 1-way on/off signal to boiler CPU. Model assumes the control is not capable of boiler modulation. Default for profiles XXS-XL. For profiles 3XL and 4XL a programmable (see time control), electronic room thermostat has to be physically part of the product in order to claim Tcontrol=2.
3. ***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 Tout. The slope of this curve can be set by parameter Cgrad [param nr. 10.5b, -]. Also a parallel shift by x K

[1] Under consideration: Definitions of Time, Temperature and Hydraulic controls are pragmatic, for lack of harmonised standards. If feasible within the timeframe of measures or at the first revision of measures it is considered to firm up the definitions within the context of harmonised rating/certification of controls.

can be applied by parameter Cpar [param. nr. 10.5a, K]. The heating curve is set at a level that can guarantee a temperature of 25 °C [internal parameter TW] 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 pmpsb [param. nr. 9.2, values yes/no; result is an 8h reduction per day]. For this Tcontrol a pump with variable speed control varsp [param. nr. 9.8, value yes/no, result in 54% reduction on pump electricity consumption] has the most effect.

Model assumes the control is capable of boiler modulation.

4. ***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. The range is indicated in the model by parameter CL [param. nr. 10c, in K]. This control can run in 24h pump operating mode as a weather control. Through an interlock it can also switch the pump of a few minutes after burner-off. Model parameter tpmp [param. nr. 9.1, in h].

   Model assumes the control is capable of boiler modulation.

5. ***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.

   Model assumes the control is capable of boiler modulation. Works well 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.

6. ***Chrono-proportional RT***: High-quality electronic on/off thermostat with a time-restricted cycle. The model uses a setting of 4 cycles per hour (internal parameter fcyc set at fcyc=4), which means that every on/off cycle lasts 15 minutes and the thermostat 'decides' on the length of the on-mode.

   Control is not capable of boiler modulation, but imposed cycle-time restriction aids in improving room temperature under-/overshoot. Works well as with non-modulating boilers and as a universal retrofit thermostat.

A8. Hydraulic control types (Vcontrol)

Hydraulic controls ('valves') are all components that regulate the heating performance of the CH-boiler by varying the flow rate to the emitter system. Essential distinction is made on the basis of the operating mode: manual (Vcontrol=1), thermo-mechanical "TRV" (Vcontrol= 2 or 3) or electr(on)ic (Vcontrol= 4 or 5). Within the group of TRVs there is a distinction on the basis of the p-band: 2K (Vcontrol=2) or 1K (Vcontrol=3). The hardware between the two may not be different, i.e. if they at least allow pre-adjustment, but the 1K setting is only feasible in terms of comfort if the system is hydraulically balanced. Therefore this option requires the manufacturer to deliver a service contract for balancing the installation and the supply of an introduction-kit of 3 TRVs, of which one TRV with timer. Note that the definition of TRVs also comprises TRVs where the thermo-mechanical action can be restricted by a –usually battery operated— programmable timer device.

The group of electric valves can be highly heterogeneous, comprising e.g. straight emitter valves for (groups of) radiators for e.g. multi-zone control, mixing valves (3-way) that offer a double temperature loop, emitter pump systems, etc.. The only distinction in the methodology is between electric valves that operate only on the basis of a local loop (Vcontrol=4) and those that (also) incorporate CPU and thereby not only control the hydraulics but the boiler temperature as well (Vcontrol=5). To qualify for options Vcontrol=4 or Vcontrol=5 the CH-boiler must contain –apart from electric valves that may be used for the main CH-operation-- two straightforward electric valves (regulate just the flow rate e.g. for multi-zone control) or one hydraulically balanced mixing valve. In this context, 'hydraulically balanced' may be an extra pump for a secondary loop or a mixing valve where temperature and flow rate can be regulated independently.

In detail:

1. ***Manual***: Manually operated valve. Estimated room temperature fluctuation + 1,5 K. Default for load profiles XXL, 3XL and 4XL. For other profiles, the manufacturer has to state explicitly that this Vcontrol applies, instead of the default Vcontrol=2.
2. ***TRV 2K***: (Thermostatic Radiator Valve with p-band 2K). Assumes a non-balanced hydraulic system and a TRV that therefore cannot be pre-adjusted to a range smaller than 2K. Estimated room temperature fluctuation + 1 K. Default for load profiles XXS-XXL. For profiles 3XL and 4XL, TRVs need actually to be installed (compliance check in the context of energy certification or EPB provisions for new buildings). Estimated room temperature fluctuation ± 1 K (at constant CH-water temperature).
3. ***TRV 1K***: (Thermostatic Radiator Valve with p-band <1K). Requires a service-contract for balancing the hydraulic system to be included in the product and guaranteed by the manufacturer. An introduction kit of 3 high-quality pre-adjustable TRVs, of which one with a setback-timer, is part of the product for load profiles, as well as a comprehensive and clear manual on how to install the TRVs. Estimated room temperature fluctuation ± 0,5 K (at constant CH-water temperature).

   Note that for any compliance check –e.g. in the context of regulations or subsidies— on the fact that this option has been acquired; the presence of the 3 TRVs is highly instrumental.
4. ***Motor + PID***: Comprises all other self-contained hydraulic controls –not TRVs or manual valves— that regulate the flow rate on the basis of the input of a local sensor and do not communicate directly or indirectly (through another CPU) with the boiler (burner) control. The sensors are high-precision, fast acting. The control logic is advanced, comprising at least PI or PID logic. The reaction time of local sensors that –through appropriate logic— are able to almost instantly to regulate the flow rate to the CH-emitters. Estimated room temperature fluctuation ± 0,2 K. Examples comprise, but are not limited to, motor valves or single radiator pumps for an emitter or group of emitters, motorized mixing valves for emitters that operate at a different temperature regime, etc.. This option does not apply with Tcontrol=1 and Tcontrol=2. Motor-assisted TRVs (e.g. with timer) are not included in this category 4.
5. ***Motor + CPU***: Comprises all hydraulic controls –not TRVs or manual valves-- that have a direct or indirect communication with the boiler CPU and can thereby directly interact with the power output of the modulating burner(s). Examples comprise, but are not limited to, motor valves or single emitter pumps for an emitter or group of emitters with 2-way communication (sensor signal in, actuator signal out) with a central boiler CPU directly or indirectly. Estimated room temperature fluctuation ± 0,2 K. This option does not apply with Tcontrol=1 and Tcontrol=2.

The definitions in this annex apply to concepts not or only partially defined in harmonized standards. For other parameters and concepts the definitions in the harmonized standards apply.

A9. 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 X is a value SUM(X)=X
MIN(X;MAX(Y;Z))	X$\leq$ Y $\leq$Z
POWER (X;Y)	X to the power Y (X^Y)
LN (X)	natural logarithm of X
SIN (X)	sinus of X
COS (X)	co sinus of X
ATAN (X)	arc 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:

<table>
<tr><td colspan="3">Parameter=</td></tr>
<tr><td colspan="3">condition IF A</td></tr>
<tr><td>YES</td><td colspan="2">NO</td></tr>
<tr><td rowspan="2">X</td><td colspan="2">condition IF B</td></tr>
<tr><td>Y</td><td>Z</td></tr>
</table>

CHOOSE Stacked IF..THEN statement. Example: If X=1 then Y=a else if X=2 then Y=b else if X=3 then Y=c. Represented by a table:

CHOOSE	
X	**Y**
If value	**then equation or value**
1	**=a**
2	**=b**
3	**=c**

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)**

A10. Naming conventions

Q	Energy [kWh]
P	Power [kW]
T	Temperature [ºC or K]
V	Volume [m³]
A or F	Surface [m²]
η or eta	Efficiency
t	Time-period [h] (exception *hd* = length of *d*ayperiod for space *h*eating)
v	Speed [for cooling down or heating up, in K/h]

pre-/postfix (most used only)

b	Gas/oil fired
el or elec	Electric
hp	Heat pump
sol	Solar
h	space heating
w	water heating
a	annual
m	monthly
d	increment

ANNEX B: DATA REPORT

B1. General

Each application for CE-marking shall be accompanied by a *Data Report* on specific performance characteristics of the product, as defined in the table on the following page.

This table is also the general format of the Technical Fiche that manufacturers are to supply with the product (user's manual, installation instruction).

Section 1 (manufacturer, model, date and ID number) is compulsory.

In the also compulsory sections 2 and 11, a CH-boiler is considered 'dedicated' if the water-heating load [param. nr. 11.1] is declared as "0-none". A water heater is considered 'dedicated' if the space-heating load [param. nr. 2.1] is declared as "0-none". A product is a *CH-combi* if none of the above applies.

Depending on the features of the CH-boiler or water heater only a limited part of the other sections has to be filled out:

For conventional CH-boilers or water heaters:

- Electric resistance dedicated water heaters: Param. nr. 7.3, 12.2, 13.1
- Gas- or oil-fired dedicated water heaters: Sections 6, 7, 12, 13 and 14.
- Electric resistance CH-boilers: Sections 10 and 17
- Single conventional gas- or oil-fired CH-boilers: Sections 3 to 10. (*pref* column only)
- Cascades of conventional gas- or oil-fired CH-boilers: Sections 3 to 10. (*pref* and *nopref* column in case of non-identical cascades, *pref* column in case of identical cascades)
- Gas- or oil-fired CH-combi: Sections 3 to 14.

For CH-boilers or water heaters with renewables:

- Solar assisted dedicated water heaters: Sections 15 and 18
- Heat pump (assisted) dedicated water heaters: Sections 16 and 18
- Solar assisted dedicated CH-boilers with gas- or oil-fired back-up: Sections 3 to 10 and 15.
- Solar assisted dedicated CH-boilers with electric resistance back-up: Sections 15 and 17.
- Heat pump (assisted) dedicated CH-boilers with gas- or oil-fired back-up: Sections 3 to 10 and 15.
- Heat pump (assisted) dedicated CH-boilers with electric resistance back-up: Sections 15 and 16
- Solar and heat pump assisted dedicated CH-boilers with gas- or oil-fired back-up: sections 3 to 10, 15 and 16.
- Solar and heat pump assisted dedicated CH-boilers with electric resistance back-up: sections 15 to 17.
- CH-combi: as dedicated CH-boilers, but also with section 18
- Cascades with non-identical CH-boilers: as all dedicated CH-boilers and CH-combi boilers with gas- or oil-fired back-up, but also with 'nopref' column.

In case of a CH-combi and Water Heater with renewables ascertain that the values for param. nr. 12.1 and 12.2 are 0 (zero).

All measured values are subject to Third Party testing. All assessments are subject to verification by notified bodies.

Values in the Data Report on the next page are fictitious and used to indicate the precision (number of decimals) required.

DATA REPORT CH-BOILERS & WATER HEATERS

1.1	Manufacturer		1.3 Date	
1.2	Model		1.4 ID	

2.1	**SPACE HEATING LOAD**	**4 -M**	
	BOILER(S)	*pref*	*nopref*
3.1	**Qb8060** nominal heat input in kW	**9999,99**	**9999,99**
3.2	Turndown ratio **turndown**	**99,9%**	**99,9%**
3.3	Two-stage burner **twostage** ?	**0 -no**	**0 -no**
3.4	Combi compensation **combicomp** ?	**0 -no**	
4.1	**η8060**	**99,9%**	**99,9%**
4.2	**η8060min**	**99,9%**	**99,9%**
4.3	**η5030**	**99,9%**	**99,9%**
4.4	**η5030min**	**99,9%**	**99,9%**
5.1	**p_bstby s**tandby heat loss **% of Qb8060**	**99,90%**	**99,90%**
5.2	**Pign p**ilotflame power in kW	**99,999**	**99,999**
6.1	**airfuemix**	1 -atmospheric	
6.2	**Fueldewpoint dpt**	1-gas	
7.1*	Combustion **airintake**	1 -room sealed	
7.2*	Designated in-/outdoors **boilpos**?	1 -indoors	
7.3*	Env. Volume **volumeb**	m3	**99,99**
7.4	Noise (**noiseh**)	dB-A	**99**
8.1	Boiler (empty) **massb**	kg	**999,9**
8.2	Water content **massw**	kg	**999,9**
9.1	Pump hrs after off **tpmp**	h	**24,00**
9.2	Pmp hr/d setback **pmpsb**	0 -no	
9.3	El. pump Pboff **elpmp**	kW	**99,999**
9.4	El. at Pboff **elstby**	kW	**99,999**
9.5	El. at Pbnom **elmaxon**	kW	**99,999**
9.6	El. at Pbmin **elminon**	kW	**99,999**
9.7	Variable speed pump **varsp**	**0 -no**	
9.8	Pump configuration **pmpconfig**	1 -integrated	
9.9	If no pump: pressure drop boiler **pdrop**	mbar	**9999**
	CONTROLLERS		
10.1	Automatic timer **autotimer**?	**1 -yes**	
10.2	**Optimiser?**	**0 -no**	
10.3	Valve control **Vcontrol**	2 -RTV 2K	
10.4	Temperature control **Tcontrol**	2 -on/off RT	
10.5	Setting **Cgrad** 9,99 **Cpar** 99	**CL**	99

	hp	Pcor			COPcor		
16.13T	oC	99	99	99	99	99	99
16.13a	99	9,99	9,99	9,99	9,99	9,99	9,99
16.13b	99	9,99	9,99	9,99	9,99	9,99	9,99
16.13c	99	9,99	9,99	9,99	9,99	9,99	9,99
16.13d	99	9,99	9,99	9,99	9,99	9,99	9,99
16.13e	99	9,99	9,99	9,99	9,99	9,99	9,99

11.1	**WATER HEATING LOAD**	**4 -M**	
	WATER HEATER (gas/oil/elec)		
12.1	Fuel consumption (in GCV) **Qfuel**	kWh/d	**9999,99**
12.2	Electricity consumption **Qelec**	kWhe/d	**9999,99**
13.1	smart control factor **dhwsmart**	**0 -no**	
13.2	noise (**noisew**)	dB-A	**99**
14.1	combustion efficiency **ηcomb**	%	**99%**
14.2	avg. flue gas temp. at tapping **Tflue**	oC	**999**
	SOLAR ASSIST		
15.1	Collector aperture area **Asol**	m2	**999,9**
15.2	Zero-loss collector efficiency **η0**	-	**0,99**
15.3	First-order loss coefficient **a_1**	$W/(m^2K)$	**9,99**
15.4	Second-order loss coefficient **a_2**	$W/(m^2K^2)$	**9,999**
15.5	Incidence angle modifier **IAM**	-	**9,99**
15.6	**Solar part of** tank volume **vsol**	ltr	**9999**
15.7	UA-value of heatexchanger **UAsol**	W/K	**999**
15.8	Collector loop pipe lenght, **Lpipesol**	m	**999,9**
15.9	Coll. loop loss per m pipe **Upipesol_m**	W/(m.K)	**9,99**
15.10	Tank heat loss coeff **UA**	W/K	**99,9**
15.11	Solar pump power **solaux**	W	**9.999**
15.12	Tank position **solpos**	1 -indoors	
15.13	Usage sol **usesol** (HW, CH or both)	1 -CH	
	BACK-UP HEATER		
17.1	**ELBU** el. back-up space heating?	**0 -no**	
	hot water back-up additional data		
18.1	Waterloadmin	**1 -XXS**	
18.2	**Qfuelmin**	kWh	**999,99**
18.3	**Qelecmin**	kWhel	**999,99**
18.4	Waterloadmax	**4 -M**	
18.5	**Qfuelmax**	kWh	**999,99**
18.6	**Qelecmax**	kWhel	**999,99**
	HEAT PUMP		
16.1	Nominal Power **Phpnom**	kW	**999,99**
16.2	**turndownhp**	%	**99,9%**
16.3	**HPtype** (Tsrc/Tsnk)	3 -El. air/ water 7/45	
16.4	Nominal COP **COPnom**		**9,9**
16.5	50%. load COP correct **COP50**	%	**999,9%**
16.6	Maximum sink temperature **Tsnkmax**	oC	**99**
16.7	Auxiliary el. consumption **hpaux**	W	**9999**
16.8	Tank volume nominal **Vhp**	ltr	**9999**
16.9	Tank ref. heat loss **Pstbyhp**	W	**9999**
16.10	Tank hot water capacity **V40hp**	frac. Vhp	**9,99**
16.11	Use (also) vent. exhaust air **ventmix** ?	**0 -no**	
16.12	Usage hp **usehp** (HW, CH or both)	1 -CH	
16.13	Testpoints (table left)		

	OUTPUT: SPACE HEATING ENERGY		
A.1	Space heat load	kWh/a	**999.999**
A.2	Space heat primary energy use	kWh/a	**999.999**
A.3	Space heat efficiency	99,9%	
A.4	Energy label Space Heat	**A**	

	OUTPUT: WATER HEATING ENERGY		
B.1	Water heat net load	kWh/a	**999.999**
B.2	Water heat primary energy use.	kWh/a	**999.999**
B.3	Water heat energy eff.	99,9%	
B.4	Energy label Water Heating	**A**	

* = mandatory fields also for water heaters

B2. Input parameters based on measurements

B2.1 CH-Boiler

The table below gives input parameters for which definitions and test methods are given in harmonised standards.

Table B1. Input parameters for which definitions and test methods are given in harmonised standards.

Nr.	Parameter	unit	Standards
3.1	**Qb8060** nominal heat input in kW	kW	for gas-fired boilers:
3.2	Turndown ratio **turndown**	%	**EN 297** (no-fan, <70 kW, types B11 and B11BS),
			EN 303-3 (fan-assisted, <70 kW)
4.1	**η8060**	%	**EN 656** (type B, 70-300 kW)
4.2	**η8060min**	%	**prEN 303-7** (fan-assisted, type B23, <1000 kW)
4.3	**η5030**	%	**prEN 13826** (other type B, 300-1000 kW)
4.4	**η5030min**	%	**EN 483** (type C, <70 kW)
			EN 677 (condensing, <70 kW)
5.1	**p_bstby s**tandby heat loss	%	**EN 625** (combi, <70 kW)
5.2	**Pign p**ilotflame power in kW	kW	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)
7.4	Noise (**noiseh**)	dB-A	**EN 15036 (at full load)**
9.3	El. pump **elpmp**	kW	**nominal pump power EN**
9.4	El. at Pboff **elstby**	kW	**prEN 15456**
9.5	El. at Pbnom **elmaxon**	kW	
9.6	El. at Pbmin **elminon**	kW	
9.9	If no pump: pressure drop boiler **pdrop**	mbar	
12.1	Fuel consumption (in GCV) **Qfuel**	kWh/d	**Annex E, with reference to EN 13203-2 prEN 50440**
12.2	Electricity consumption **Qelec**	kWhe/d	
18.2	**Qfuelmin**	kWh	
18.3	**Qelecmin**	kWhel	
18.5	**Qfuelmax**	kWh	
18.6	**Qelecmax**	kWhel	
13.1	smart control factor **dhwsmart**	yes/no	**Annex H**
13.2	noise (**noisew**)	dB-A	**standard to be established (choice)**
14.1	combustion efficiency **ηcomb**	%	**Annex G**
14.2	avg. flue gas temp. at tapping **Tflue**	oC	

Different from what is mentioned in those standards:

- The measurement of the efficiency at nominal and lowest power output [param. nr. 4.3 and 4.4] shall in principle be conducted at a system feed temperature of 50 °C and a system return temperature of 30 °C. In case it is not possible to realize the test at a temperature difference of 20 K, the test shall be conducted at a system feed temperature of 50 °C and the lowest possible return temperature. In case the CH-boiler is technically not equipped to deal with the operating conditions accompanying the test (e.g. condensing), the test shall be conducted at the lowest admissible system return temperature. In case the CH-boiler is not capable of burner-modulation and/or low-temperature operation, the nominal and –if possible—minimal efficiency at 80/60 regime shall be stated for param. 4.3 and 4.4.

- The measurement of the standby heat loss [param. nr. 5.1] all measurements shall always be conducted at a temperature of 50 °C, independent of the boiler-type.

B2.2 Water heater

The manufacturer shall indicate the selected load profile by specifying the ***waterload*** parameter [param. nr. 11.1, values 1 to 9 corresponding to XXS to 4XL] and shall confirm that the product meets the requirements of the selected load profile. The test standard used shall be reported separately (not in the fiche).

For the selected load profile and/or from the tapping pattern test(s) shall be reported as follows:

In case no solar and/or heat pump technology is incorporated in the product:

- the measured fossil-fuel consumption ***Qfuel*** for the *waterload* [param. nr. 12.1, in kWh/d, in Gross Calorific Value GCV]
- the measured electricity consumption ***Qelec*** for the *waterload* [param. nr. 12.2, in kWh/d]

In case solar and/or heat pump technology is incorporated in the product:

- *Qfuel* =0 [param. nr. 12.1] and *Qelec*=0 [param. nr. 12.2]
- for the electric or gas/oil-fired back-up heater a load profile ***waterloadmax*** [param. nr. 18.4] is selected that is equal or one higher than the *waterload*. For the tapping pattern test of *waterloadmax* the following data shall be reported:
  - the measured fossil-fuel consumption ***Qfuelmax*** [param. nr. 18.5, in kWh/d, GCV]
  - the measured electricity consumption ***Qelecmax*** [param. nr. 18.6, in kWh/d]
- for the electric or gas/oil-fired back-up heater a load profile ***waterloadmin*** [param. nr. 18.1] is selected that is at least one lower than the *waterloadmax*. For the tapping pattern test of waterloadmin the following data shall be reported:
  - the measured fossil-fuel consumption ***Qfuelmin*** [param. nr. 18.2, in kWh/d, GCV]
  - the measured electricity consumption ***Qelecmin*** [param. nr. 18.3, in kWh/d]
- For solar assisted products:
  - The collector surface ***Asol*** [param. nr. 15.1, in m²] shall be larger than zero. Other input variables of the solar technology shall be reported as described hereafter.
  - The usage of the solar technology ***usesol*** [param. nr. 15.13] shall be indicated as *usesol*=2 (water heating) or *usesol*=3 (both space and water heating).
- For products with (also) heat pump technology:
  - The heat pump nominal power output ***Phpnom*** shall be larger than zero. Other input variables of the solar technology shall be reported as described hereafter.
  - The usage of the heat pump technology ***usehp*** [param. nr. 16.12] shall be indicated as *usehp*=2 (water heating) or *usehp*=3 (both space and water heating).

The requirements above are based on an approach whereby the single characteristics of solar, heat pump and back-up heater technologies are fed into a mathematical model that evaluates performance and energy efficiency.

Future harmonised standards whereby solar and/or heat pump and back-up heater technologies are tested as a whole, e.g. with an emulation of solar- or heat pump inputs, can be deemed admissible by the notified bodies if:

- the referenced tapping patterns are used, including the requirements for ambient temperature and cold water temperature.
- solar and/or heat pump heat input data are used as given in Annex C. (Reference Conditions)
- If for the other aspects of the test procedure the same or similar accuracy and repeatability is used as in EN 13203-2 and/or prEN 50440.

In case such a new harmonised test standard is used, this shall be explicitly reported and the data that need to be reported are limited to *Qfuel* and *Qelec* [param. nr. 12.1 and 12.2].

B3. Input parameters based on self-declaration

In principle, all data in the data report are numerical. In case of multiple-choice and Boolean variables the numerical value is also accompanied by a denomination. The table below gives input parameters that are multiple choice. Also they have in common that they are all based on self-declaration, taking into account the definitions in Annex A and the reference conditions in Annex C.

Apart from multiple-choice parameters, there are also a limited number of numerical values and defaults for *conventional* CH-boilers and water heaters that do not require any measurements, i.e. are based on self-declaration:

- factory setting ('out-of-the-box') for pump hours after burner-off tpmp [in h]
- In case of Tcontrol=3 or 4, factory settings for ***Cgrad***: [-], ***Cpar***: [in K] and ***CL*** [in K] [2]
- In case of conventional electric water heaters or CH-boilers: default 35 dBA (lowest possible value) for ***noisew*** and/or ***noiseh*** *(does not apply to water heaters with heat pump technology, where actual measurement values shall be used)*

Furthermore, there are a number of relatively easy assessments for which no measurement standard is used:

- 7.3 -Envelope volume ***volumeb*** [in m³]
- 8.1 -Boiler mass (empty) ***massb*** [in kg]
- 8.2 -Water content ***massw*** [in kg]

[2] Cpar (parallel shift, in K) and Cgrad (gradient shift, multiplier of angle) are defined in the mathematical model with respect of an ideal (set of) curve(s) that guarantee a 25°C indoor temperature (21°C at night-period) exactly. This dynamic assessment requires detailed insight in the mathematical model and the control algorhytms, which –e.g. in case of a simple 2-point weather-controiled system—is not readily available. Therefore it is considered to allow definition of Cgrad and Cpar with respect of (the equivalent of) a simple 2-point weather compensated control with setpoints at –10/45 and 20/25 (outdoor temperature/ system feed temperature).

Table B2. Multiple choice input parameters based on self declaration

Nr.	Parameter	Options
2.1 11.1 18.1 18.4	**SPACE HEATING LOAD** **WATER HEATING LOAD** Waterloadmin Waterloadmax	0 -none 1 -XXS 2 -XS 3 -S 4 -M 5 -L 6 -XL 7 -XXL 8 -3XL 9 -4XL
3.3	Two-stage burner **twostage** ?	0 -no 1 -yes
3.4	Combi compensation **combicomp** ?	0 -no 1 -yes
6.1	**airfuelmix** control	1 -atmospheric 2 -pneumatic 3 -ionisation 4 -next gen. O2
6.2	**fueldewpoint**	1-gas 2 -oil 3 -LPG
7.1*	Combustion **airintake**	1 -room sealed 2 -open 3 -none (electric)
7.2*	Designated in-/outdoors **boilpos**?	0 -outdoors 1 -indoors
9.2	Pmp hr/d setback **pmpsb**	0 -no 1 -yes
9.7	Variable speed pump **varsp**	0 -no 1 -yes
9.8	Pump configuration **pmpconfig**	1 -integrated 2 -internal only 3 -none
10.1	Automatic timer **autotimer**?	0 -no 1 -yes
10.2	**Optimiser?**	0 -no 1 -yes
10.3	Valve control **Vcontrol**	1 - manual 2 -RTV 2K 3 -RTV 1K 4 -Motor + PID-loop 5 -Motor + CPU
10.4	Temperature control **Tcontrol**	1 -fixed BT 2 -on/off RT 3 -weather ctrl BT 4 -weather c. BT+RT 5 -modulating RT 6 -time-prop. RT
15.12	Tank position **solpos**	0 -outdoors 1 -indoors
15.13	Usage sol **usesol**	1 -CH 2 -HW 3 -both HW & CH
17.1	**ELBU** el. back-up space heating?	0 -no 1 -yes
16.3	**HPtype** (Tsrc/Tsnk)	1 -El. brine/ water (0/45) 2 -El. water/ water (10/45) 3 -El. air/ water 7/45 4 -Gas eng.air/water (7/45) 5- Gas abs. NH3/H2O water/water (10/45) 6 -Gas abs. H2O/LiBr water/water (10/45) 7 –Gas/oil brine NO DEFAULTS
16.11	Use (also) vent. exhaust air **ventmix** ?	0 -no 1 -yes
16.12	Usage hp **usehp**	1 -CH 2 -HW 3 -both HW & CH

B4. Solar input parameters

Applicable standards and defaults are given in the tables below

Table B3. Input parameters and measurement standards solar CH-boilers and water heaters

Nr.	Parameter	Name	Unit	Test standard	Parameter	Symbol
15.1	Collector aperture area	Asol	m²	EN 12975-2	aperture area of collector	A_a
15.2	Zero-loss collector efficiency	η0	-	EN 12975-2	zero loss collector efficiency (η at T^*_m = 0), reference to T^*_m	η_0
15.3	First-order loss coefficient.	a_1	-	EN12975-2	heat loss coefficient at (T_m-T_a)=0	a_1
15.4	Second-order loss coefficient	a_2	-	EN12975-2	temperature dependence of the heat loss coefficient	a_2
15.5	Incidence angle modifier.	IAM	-	EN12975-2	collector incidence angle modifier	K_θ
15.6	Solar part of tank volume	vsol	litres	Self-declaration Total tank volume minus supplementary volume; supplementary volume = volume heated by boiler and or electrical heating element; if no supplementary heating	Symbol in EN 15316-4-3:2007	V_{sol}
15.7	UA-value of heat exchanger	UAsol	W/K	ENV 12977-2	Heat transfer rate of heat exchanger Symbol in EN 15316-4-3:2007	$(UA)_{hx}$ $(U_{st})_{hx}$
15.8	Collector loop pipe lenght, total	Lpipesol	m	Self-declaration		
15.9	Collector loop pipe heat loss per m pipe	Upipesol_m	W/mK	Self-declaration		
15.10	Tank heat loss coefficient	UA	W/K	ENV 12977-3	Store heat loss rate Symbol in EN 15316-4-3:2007	$(UA)_s$ U_{st}
15.11	Solar pump power	solaux	W	Self-declaration (ref. EN 15316-4-3)	Total nominal input power of pumps.	$P_{aux,nom}$

Table B4. Solar: Normative values that may be used as Defaults (instead of measurements)

Nr.	Parameter	Name	Unit	Informative value	Normative value
15.2	Zero-loss collector efficiency	η0	-	0.80	0.60
15.3	First-order loss coefficient.	a_1	-	1.8 / 3.5 / 15 (evac / glazed / unglazed)	3 / 6 / 20 (evac / glazed / unglazed)
15.4	Second-order loss coefficient	a_2	-		a2 = 0
15.5	Incidence angle modifier.	IAM	-		0.97 / 1.00 / 0.94 / 1.00 (evac-flat / evac-circ / glazed / unglazed)
15.7	UA-value of heat exchanger	UAsol	W/K	`-	40 * Asol [W/K] *
15.9	Collector loop pipe heat loss per m pipe	Upipesol_m	W/mK		0,3 [W/mK] *
15.10	Tank heat loss coefficient		W/K		$0.16\ vsol^{0.5}$
15.11	Solar pump power	solaux	W	25+2Asol	50+5Asol

Informative and normative values for Parameters nr. 15.2, 15.3, 15.4, 15.5, 15.10 and 15.11 from EN 15316-4-3;2007 and are given as "default" or "penalty" data. Values for 15.7 and 15.9 supplied by ESTIF. Note that for parameters nr. 15.1 and 15.6 and 15.8 measurement values are compulsory.

B5. Heat pump input parameters

Applicable standards and defaults are given in the tables below

Table B4. Reported data and applicable standards for heat pump contribution

	parameter	name	unit	Test standard	Parameter name	symbol
16.1	Nominal heating power heat pump	Phpnom		electric: EN14511-3	heating capacity	P_H
				gas: EN12309-2	heating capacity	Q_H
16.2	Turndown ratio heat pump	turndownhp		stated by manufacturer	% of rated heating capacity at minimum power	%
16.3	Heat pump type	HPtype		stated by manufacturer		-
16.3a	Nominal source temperature	Tsrc		test conditions in: electric: EN14511-2	in heating mode: standard rating conditions for inlet (dry bulb) temperature	-
				gas: EN12309-2	in heating mode: inlet temperature T1	-
16.3b	Nominal sink temperature	Tsnk		test conditions in: electric: EN14511-2	in heating mode: standard rating conditions for outlet temperature	-
				gas: EN12309-2	in heating mode: outlet temperature T1	-
16.4	Nominal COP	COPnom		electric: EN 14511	COP at standard rating conditions	COP
				gas: EN 12309-2	gas utilization efficiency	η_h
16.5	Correction to COP at 50% load	COP50	%	electric: CEN/TS 14825	COP of unit at 50% of rated capacity	$COP_{50\%}$
				gas: equivalent procedure	gas utilization efficiency at 50% of rated capacity	-
16.6	Maximum sink temperature	Tsnkmax	ºC	Self-declaration	measured at outlet [3]	
16.7	Auxiliary electric power consumption (not already included in COP)	hpaux	W	Self-declaration specify the nominal electric power of pumps, controls, etc. not included in determination of COPnom. Examples: - sourcepump (from source to outdoor heat exchanger), - de-freeze control, - sinkpump aka central heating circulator		
16.8	Nominal storage tank volume of heat pump	Vhp	ltr	EN 60379 / prEN50440	actual capacity	C_{act}
				or prEN153322:2005	actual storage capacity	C_A
16.9	Tank reference heat loss	Pstbyhp	W	prEN15332:2005 (at medium storage temp. of 55ºC or higher)	Standby-loss per 24 h (convert kWh/24h to W)	Q_B
				or EN 60379:2004 / prEN50440 (at medium storage temp. of 55ºC or higher)	Standing loss per 24h (convert kWh/24h to W)	Q_{pr}
16.10	Storage tank hot water capacity V40	V40hp	-	prEN50440	Mixed water quantity delivered at 40ºC	V_{40}
				or EN 60379	Mixing factor, mixed water output at 40ºC	C_m
16.11	Use (also) ventilation exhaust air (no=0, yes=1)	ventmix		stated by manufacturer		
16.12	Usage of heat pump	usehp		stated by manufacturer		
16.13	- requirement to fill in test results or default data			see COPnom, Phpnom		

[3] Some heat pump technologies use –for water heating—not a fixed maximum sink temperature Tsnkmax, but a dynamic parameter Tsnkmax depending on outdoor temperature. In such a case, the declared value for Tsnkmax is the weighted average (weighted by Tout in Table C5).

Table B5. Heat pump default test points (from prEN 15316-4-2)

1 -El. brine/ water (0/45)

	Pcor			COPcor		
oC	**35**	**45**		**35**	**45**	
-5	0,92	0,86		1,15	0,88	
0	1,07	1,00		1,32	1,00	
5	1,22	1,14		1,49	1,12	

4 -Gas eng.air/water (7/45)

	Pcor			COPcor		
oC	**35**	**45**	**55**	**35**	**45**	**55**
-7	0,82	0,76	0,69	0,82	0,76	0,69
2	0,95	0,89	0,82	0,95	0,89	0,82
7	1,06	1,00	0,93	1,06	1,00	0,93
20	1,47	1,41	1,35	1,47	1,41	1,35

2 -El. water/ water (10/45)

	Pcor			COPcor		
oC	**35**	**45**		**35**	**45**	
10	1,05	1,00		1,33	1,00	
15	1,11	1,06		1,50	1,15	
20	1,17	1,13		1,67	1,30	

5- Gas abs. NH3/H2O water/water (10/45)

	Pcor			COPcor		
oC	**35**	**45**		**35**	**45**	
10	1,07	1,00		1,07	1,00	
15	1,08	1,03		1,08	1,03	
20	1,10	1,08		1,10	1,08	

3 -El. air/ water (7/45)

	Pcor			COPcor		
oC	**35**	**45**	**55**	**35**	**45**	**55**
-7	0,71	0,68	0,66	0,86	0,71	0,56
2	0,87	0,85	0,83	1,10	0,89	0,67
7	1,03	1,00	0,97	1,23	1,00	0,76
20	1,34	1,29	1,25	1,70	1,28	0,86

6 -Gas abs. H2O/LiBr water/water (10/45)

	Pcor			COPcor		
oC	**35**	**45**		**35**	**45**	
10	1,05	1,00		1,05	1,00	
15	1,11	1,05		1,11	1,05	
20	1,20	1,11		1,20	1,11	

B6. Auxiliary energy consumption heat pump and solar

The self-declaration of auxiliary energy consumption for solar and heat pump technology requires the manufacturer to make an additional technical report specifically on this issue. This report shall cover at least

For solar: operating time and power level(s) of:

- Solar pump (if any)
- Solar controls (if any)
- Defrost installation (if any)
- Circulator pump(s) (if any)

For heat pump technology: operating time and power level(s) of:

- Feeder pump or fan (if any or if not included in COP)
- Heat pump controls (if any)
- Defrost installation (if any)
- Sink pumps, a.k.a. circulator pump(s) (if any)
- Standby heat losses

Note that the indicated operating times shall be consistent with the mathematical model. Furthermore, note that with respect of the circulator pump for the central heating (and also water heating) the model only takes into account pump power for the operating time of the back-up heater. If that same pump is used also for the heat pump or solar technology, the extra running hours of that pump have to be taken into account in ***hpaux*** and ***solaux.***

ANNEX C: REFERENCE CONDITIONS

Reference conditions are lookup values that are used in the mathematical models in Annexes D and E.

C1. Space heating load profile

Within the boundaries set by minimum and maximum output requirements, the producer can select any load profile for the product offered for CE-marking. A load profile consists of a minimum and maximum output requirement, as well as a load pattern for an average EU heating season.

C1.1 Minimum and maximum output

The minimum and maximum output requirements of each load profile are given in Table 1.

Table C1. Minimum (Minout) and maximum (MaxOut) heat outputs of CH-boilers per load profile

Load profile	MinOut	MaxOut
	kW	kW
1 -XXS	3,6	*
2 -XS	5,1	*
3 -S	6,9	*
4 -M	7,7	*
5 -L	10,5	*
6 -XL	30,6	*
7 -XXL	46,4	*
8 -3XL	107,0	*
9 -4XL	350,0	*

*= under consideration

The CH-boiler complies with the minimum output requirement

- If an electric (Joule-effect) back up heater is used : ***ELBU***=yes [param. nr. 17.1] [4] or
- If the sum of the nominal output of heat pump *Phpnom* [param. nr. 16.1] [5], the nominal output of the preferential boiler [***Pb8060***= *Qb8060 * η8060*] and the nominal output of the non-preferential boiler [***Pb8060b***= *Qb8060b * η8060b*] is larger than or equal to Minoutput:

Phpnom +Pb8060 + Pb8060b >= Minoutput C1

The CH-boiler complies with the maximum output requirement if:

Phpnom +Pb8060 + Pb8060b< Maxoutput C2

Please note that the equations above are to be used only in the the context of the energy efficiency assessment. They are not a substitute for capacity assessment of the installation under design conditions.

[4] Note: This doesn't dismiss the manufacturer of delivering an appropriately sized (in kW) electric back-up heater. This simplification is only to be used in the context of the Mathematical Model.

[5] Under consideration: Instead of using Phpnom, which is –up to a degree—an arbitrary value e.g. typically at 7°C source temperature for an air-based heat pump, to use a specific heat pump output at –10°C. This is especially relevant in case the heat pump has no back-up heater (electric or fossil) to cope with extreme situations. It would however add complexity.

C1.2 Load pattern

The load pattern for each load profile is built from average EU climate and building characteristics, following on one hand meteorological and statistical data and on the other hand harmonised standards [EN 832, prEN 13790]. As such they are prepared for incorporation in a holistic evaluation of an energy performance of buildings (EPB). An informative description of data and methodology used is given in Annex H. This description is for informative purposes only. For the underlying document only the results of the method, presented hereafter, shall be taken into account.

The space heating load pattern consists of pre-defined heat loads for 9 average month days in a maximum heating season [Sept.-May]. Each month-day is divided into 5 day-periods with different number of hours: morn [2h], mid [7h], eve[5h], late [2h], night [8h]. The annual profile is built by multiplying the load energy values [in kWh] with a factor 30,5 [average days per month dpm].

For each day-period the heating power load ***PH*** [in kW] is given by

$$PH = 0{,}001 * (qloss * (Tin - Tout) - Qgains) \qquad \text{C3}$$

where

- ***qloss*** is the specific loss factor [in W / K] ,
- ***Tin*** is the indoor temperature [in °C],
- ***Tout*** is the outdoor temperature [in °C],
- ***Qgains*** is the power from solar and internal gains [in W].

The energy load per day-period ***QH*** [in kWh] is defined as

$$QH = PH * hd \qquad \text{C4}$$

where ***hd*** is the length of the day-period [in h]

The parameter *hd* is an array [2;7;5;2;8] corresponding to day-periods [morn;mid;eve;late;night]. Values for *qloss* and *Qgains* are given in Table C2. Values for *Tout* and 4 options for *Tin* are given in Table C3. Note that for the selected load profile *QH, PH, Tin, Tout* and *Qgains* are arrays of 45 elements (5 day-periods and 9 months) and *qloss* is a single fixed value.

The 4 options for Tin are:

Tinx Continuous fixed setting of 19 °C for all day-periods.

Tin30 Multi-zone temperature regime with setback (*autotimer*=yes). Optimiser option is implemented (*optimiser*=yes). This implies that reheating after night-setback takes place at optimal operating condition for the boiler (assumed 30% part load). Background information Zones and temperatures are given in the table below.

Tin00 Multi-zone temperature regime with setback (*autotimer*=yes), as above. Optimiser option is not implemented (optimiser=no). This implies that reheating after night-setback takes place at nominal capacity (assumed 30% part load).

TW Target regime for weather controlled CH-boilers (*Tcontrol*= 3 or *Tcontrol*=4). The given values are room-temperature values that the CH-boiler should be able to achieve at maximum aperture of emitter-valves.

Default values are for load profiles 3XL and 4XL: Tin=*Tinx* with setting of *autotimer*=no. Default values for other load profiles: *Tin=Tin00* with setting *autotimer*=yes.

Also for other load profiles Tin=Tin00 can be applied, in which case the manufacturer should fill in autotimer=no also for these other load profiles.

The equation for the annual load is

$$QH[year] = dpm * SUM(QH) \qquad \text{C5}$$

where ***dpm*** is the average number of days per month [*dpm* = 30,5] .

Table C2. Specific energy loss in Wh/K and Gains in Wh/K

	1 -XXS	2 -XS	3 -S	4 -M	5 -L	6 -XL	7 -XXL	8 -3XL	9 -4XL
qloss in Wh/K	92	132	131	193	262	735	1050	2880	8641

Qgains: Internal and solar gains in Wh/period

		1 -XXS	2 -XS	3 -S	4 -M	5 -L	6 -XL	7 -XXL	8 -3XL	9 -4XL
JAN	morn	705	909	598	775	954	5639	4783	15205	45616
	mid	857	1105	727	942	1160	6856	5815	18486	55457
	eve	480	619	407	527	649	3836	3254	10344	31033
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	388	500	329	426	525	3100	2630	8359	25078
FEB	morn	959	1237	813	1054	1299	7672	6507	20687	62061
	mid	1212	1563	1028	1332	1641	9693	8221	26135	78406
	eve	524	676	444	576	709	4190	3554	11297	33892
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	389	501	330	427	526	3109	2637	8383	25148
MAR	morn	1315	1697	1116	1446	1781	10522	8925	28372	85115
	mid	1615	2083	1369	1775	2186	12917	10955	34827	104482
	eve	627	808	531	689	848	5013	4252	13517	40550
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	410	529	348	451	555	3279	2781	8842	26525
APR	morn	1643	2120	1394	1807	2225	13146	11150	35446	106339
	mid	1942	2505	1647	2135	2630	15540	13180	41900	125699
	eve	770	993	653	847	1043	6162	5226	16614	49841
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	459	592	389	505	621	3672	3114	9900	29701
MAY	morn	1847	2382	1566	2030	2500	14772	12529	39831	119492
	mid	2124	2740	1801	2335	2876	16992	14412	45815	137444
	eve	900	1161	763	989	1218	7199	6105	19410	58229
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	515	664	436	566	697	4116	3491	11099	33297
SEP	morn	1478	1907	1254	1625	2001	11826	10030	31885	95656
	mid	1881	2426	1595	2068	2546	15046	12761	40569	121706
	eve	678	874	575	745	917	5421	4597	14616	43847
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	424	547	360	466	574	3392	2877	9145	27436
OCT	morn	1113	1436	944	1224	1507	8905	7553	24012	72036
	mid	1472	1898	1248	1618	1993	11773	9986	31744	95233
	eve	558	720	474	614	756	4467	3789	12045	36135
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	393	506	333	432	532	3141	2664	8469	25406
NOV	morn	763	984	647	839	1033	6105	5178	16460	49381
	mid	971	1253	824	1068	1315	7769	6589	20947	62842
	eve	488	629	414	536	660	3901	3309	10519	31557
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	388	500	329	426	525	3100	2630	8359	25078
DEC	morn	635	819	539	698	860	5080	4308	13697	41090
	mid	695	897	590	764	942	5563	4718	15000	44999
	eve	474	611	402	521	642	3791	3215	10222	30665
	late	1162	1498	985	1277	1573	9293	7882	25057	75171
	night	388	500	329	426	525	3100	2630	8359	25078

Table C3. Load profiles outdoor temperature and indoor temperature regimes

		Tout	Tinx	Tin30									Tin00									TW
				1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	TWN
				XXS	XS	S	M	L	XL	XXL	3XL	4XL	XXS	XS	S	M	L	XL	XXL	3XL	4XL	
JAN	morn	2,2	19	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	25
	mid	4,4	19	19,1	18,9	18,5	18,4	18,3	19,1	18,5	18,7	18,7	19,0	18,8	18,3	18,2	18,1	19,0	18,3	18,5	18,5	25
	eve	4,5	19	19,1	19,0	18,9	18,9	18,8	19,1	18,9	18,9	18,9	19,0	18,9	18,7	18,7	18,7	19,0	18,7	18,7	18,7	25
	late	3,4	19	19,2	19,2	19,0	18,9	18,9	19,2	19,0	19,1	19,1	19,2	19,2	19,0	18,9	18,9	19,2	19,0	19,1	19,1	25
	night	2,2	19	18,1	18,5	18,0	17,9	17,7	18,1	18,1	18,2	18,3	18,0	18,3	17,7	17,5	17,3	18,0	17,8	18,0	18,1	21
FEB	morn	3,1	19	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	25
	mid	6,4	19	19,0	18,9	18,6	18,4	18,4	19,0	18,6	18,7	18,7	18,9	18,7	18,4	18,3	18,2	18,9	18,4	18,6	18,6	25
	eve	6,4	19	19,1	19,0	18,9	18,8	18,8	19,1	18,9	18,9	18,9	18,9	18,8	18,7	18,7	18,7	18,9	18,7	18,9	18,9	25
	late	4,8	19	19,2	19,1	19,0	19,0	18,9	19,2	19,0	19,1	19,1	19,2	19,1	19,0	19,0	18,9	19,2	19,0	19,1	19,1	25
	night	2,9	19	18,1	18,0	18,1	17,9	17,8	18,1	18,1	18,3	18,3	18,0	17,8	17,8	17,6	17,4	18,0	17,9	18,1	18,2	21
MAR	morn	5,2	19	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	25
	mid	9,2	19	19,0	18,8	18,4	18,3	18,4	19,0	18,4	18,5	18,5	18,9	18,7	18,3	18,2	18,3	18,9	18,3	18,4	18,4	25
	eve	8,8	19	19,0	19,0	18,8	18,8	18,9	19,0	18,8	18,9	18,9	18,9	18,8	18,7	18,7	18,8	18,9	18,7	18,7	18,7	25
	late	6,6	19	19,2	19,1	19,0	19,0	18,9	19,2	19,0	18,9	18,9	19,2	19,1	19,0	19,0	18,9	19,2	19,0	18,9	18,9	25
	night	4,1	19	18,1	18,0	18,1	18,0	17,8	18,1	18,2	17,7	17,8	18,1	17,9	18,0	17,8	17,6	18,1	18,0	17,6	17,7	21
APR	morn	8,7	19	19,2	18,9	18,5	18,3	18,3	19,2	18,5	18,6	18,6	19,2	18,9	18,5	18,3	18,3	19,2	18,5	18,6	18,6	25
	mid	12,9	19	19,0	19,0	18,9	18,7	18,6	19,0	18,9	18,9	18,9	19,0	19,0	18,9	18,7	18,6	19,0	18,9	18,9	18,9	25
	eve	12,3	19	19,0	19,0	18,8	18,8	18,7	19,0	18,8	18,9	18,9	18,8	18,8	18,7	18,7	18,7	18,8	18,7	18,7	18,7	25
	late	9,3	19	19,2	19,1	18,8	18,7	18,7	19,2	18,8	18,9	18,9	19,2	19,1	18,8	18,7	18,7	19,2	18,8	18,9	18,9	25
	night	6,8	19	18,3	18,1	17,6	17,5	17,4	18,3	17,6	17,8	17,9	18,2	18,1	17,6	17,4	17,3	18,2	17,6	17,8	17,8	21
MAY	morn	13,8	19	19,3	19,2	19,1	19,0	18,9	19,3	19,1	19,1	19,1	19,3	19,2	19,1	19,0	18,9	19,3	19,1	19,1	19,1	25
	mid	17,8	19	19,2	19,1	19,0	18,9	18,9	19,2	19,0	19,0	19,0	19,2	19,1	19,0	18,9	18,9	19,2	19,0	19,0	19,0	25
	eve	17,2	19	19,0	18,9	18,8	18,8	18,7	19,0	18,8	18,9	18,9	19,0	18,9	18,8	18,7	18,7	19,0	18,8	18,8	18,8	25
	late	14,3	19	19,3	19,2	19,1	19,0	19,0	19,3	19,1	19,1	19,1	19,3	19,2	19,1	19,0	19,0	19,3	19,1	19,1	19,1	25
	night	10,9	19	17,9	17,7	18,5	18,3	18,1	17,9	18,5	18,8	18,8	17,9	17,7	18,5	18,3	18,1	17,9	18,5	18,8	18,8	21
SEP	morn	14,4	19	19,3	19,2	19,1	19,0	18,9	19,3	19,1	19,1	19,1	19,3	19,2	19,1	19,0	18,9	19,3	19,1	19,1	19,1	25
	mid	18,9	19	19,3	19,2	19,0	19,0	18,9	19,3	19,0	19,1	19,1	19,3	19,2	19,0	19,0	18,9	19,3	19,0	19,1	19,1	25
	eve	17,9	19	19,1	19,0	18,9	18,8	18,8	19,1	18,9	18,9	18,9	19,1	19,0	18,8	18,8	18,8	19,1	18,8	18,9	18,9	25
	late	14,5	19	19,3	19,2	19,1	19,0	19,0	19,3	19,1	19,1	19,1	19,3	19,2	19,1	19,0	19,0	19,3	19,1	19,1	19,1	25
	night	12,1	19	17,9	17,8	18,7	18,5	18,3	17,9	18,7	17,5	17,5	17,9	17,8	18,7	18,5	18,3	17,9	18,7	17,5	17,5	21
OCT	morn	10,5	19	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	25
	mid	14,2	19	19,0	19,0	18,9	18,8	18,7	19,0	18,9	18,9	18,9	19,0	19,0	18,9	18,7	18,6	19,0	18,9	18,9	18,9	25
	eve	13,4	19	19,0	19,0	18,8	18,8	18,7	19,0	18,8	18,8	18,8	18,8	18,8	18,7	18,7	18,7	18,8	18,7	18,7	18,7	25
	late	11,6	19	19,2	19,1	18,8	18,7	18,7	19,2	18,8	18,9	18,9	19,2	19,1	18,8	18,7	18,7	19,2	18,8	18,9	18,9	25
	night	9,8	19	18,7	18,5	17,8	17,7	17,6	18,7	17,8	18,1	18,1	18,7	18,5	17,8	17,7	17,5	18,7	17,8	18,1	18,1	21
NOV	morn	6,2	19	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	25
	mid	8,6	19	19,0	18,8	18,5	18,4	18,3	19,0	18,5	18,8	18,8	18,9	18,7	18,4	18,3	18,2	18,9	18,4	18,6	18,6	25
	eve	8,4	19	19,0	19,0	18,9	18,8	18,8	19,0	18,9	19,0	19,0	18,9	18,8	18,8	18,7	18,7	18,9	18,8	18,9	18,9	25
	late	7,4	19	19,2	19,1	19,0	19,0	19,0	19,2	19,0	18,9	18,9	19,2	19,1	19,0	19,0	19,0	19,2	19,0	18,9	18,9	25
	night	6,1	19	18,2	18,1	18,3	18,2	18,0	18,2	18,3	17,8	17,9	18,2	18,0	18,2	18,0	17,8	18,2	18,2	17,7	17,8	21
DEC	morn	2,8	19	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	19,1	18,9	18,5	18,3	18,3	19,1	18,5	18,6	18,6	25
	mid	4,6	19	19,1	18,9	18,5	18,4	18,3	19,1	18,5	18,7	18,7	19,0	18,8	18,3	18,2	18,1	19,0	18,3	18,5	18,5	25
	eve	4,6	19	19,1	19,0	18,8	18,8	18,8	19,1	18,8	18,9	18,9	19,0	18,8	18,7	18,7	18,7	19,0	18,7	18,7	18,7	25
	late	3,6	19	19,2	19,2	19,0	18,9	18,9	19,2	19,0	19,1	19,1	19,2	19,2	19,0	18,9	18,9	19,2	19,0	19,1	19,1	25
	night	2,8	19	18,1	18,5	18,1	17,9	17,8	18,1	18,1	18,3	18,3	18,0	18,3	17,8	17,6	17,4	18,0	17,8	18,1	18,2	21

C2. Water heater load profile: Tapping patterns

The tapping patterns in the load profiles are based on harmonised European (pre-) standards, but minor adjustments had to be made to harmonise the different standards and to accommodate all appliances within the scope of this measure. Thus the tapping patterns in Table C4 shall be used for testing.

Irrespective of specifications in harmonised standards, the measurements shall be performed with

- an ambient temperature of 20 ± 2 ºC and
- a cold water temperature of 10 ± 2 ºC

For all other aspects of the test the manufacturer can choose to apply one of the following standards/ methods:

- EN 13203-2
- prEN 50440
- For electric instantaneous water heaters only: method as described in Annex B.
- For solar water heaters with a gas-fired back-up heater only: prEN 13203-3.

A derived parameter from table C4 is the largest tapping in each tapping pattern. This is used with heat pump water heaters. To accommodate the calculation, this parameter tapmax is expressed not in kWh but in the equivalent litres of 45°C hot water.

tapmax =IF(waterload>0;CHOOSE(waterload; 2; 6; 10; 26,6; 69; 84; 119; 239; 477);0) C6

For the partitioning of solar and heat pump capacity between space- and water heating the water heating energy requirement per day-period is useful:

qtap(morn) = sum(Qtap_07.00:Qtap_08.59)
qtap (mid) = sum(Qtap_09.00:Qtap_15.59)
qtap (eve) = sum(Qtap_16.00:Qtap_20.59)
qtap (late) = sum(Qtap_21.00:Qtap_22.59)
qtap (night) = sum(Qtap_23.00:Qtap_6.59) = 0

Note that the parameters above are specific for each water heating load profile, leading to parameter names composed of the load profile (XXS, XS, etc) and the name of the day-period (morn, mid, etc.). Example: ***qtapxxsmorn*** is the total energy equivalent of the hot water tappings [in kWh] for the morn-period and for the water heating load profile XXS. For a selected load profile, the model uses he array ***qtap,*** containing the 5 relevant values per day-period.

Legend for table C4 (parameters apply only for table next page)

Qref = useful energy content of water withdrawal per 24h
f = flow rate l/min
Tm = temperature from which counting of useful energy content starts
Tp = minimum temperature to be achieved during tapping
Qref = daily water heater load (useful energy)

Table C4: Water heater load patterns (reference test tapping patterns)

	XXS				XS				S			
	Qtap	f	Tm	Tp	**Qtap**	f	Tm	Tp	**Qtap**	f	Tm	Tp
	kWh	l/mn	oC	oC	**kWh**	l/mn	oC	oC	**kWh**	l/mn	oC	oC
07.00	**0,105**	2	25						**0,105**	**3**	**25**	
07.05												
07.15												
07.26												
07.30	**0,105**	2	25		**0,525**	**4**	**35**	**-**	**0,105**	**3**	**25**	
07.45												
08.01												
08.05												
08.15												
08.25												
08.30	**0,105**	2	25						**0,105**	3	25	
08.45												
09.00												
09.30	**0,105**	2	25						**0,105**	3	25	
10.00												
10.30												
11.00												
11.30	**0,105**	2	25						**0,105**	3	25	
11.45	**0,105**	2	25						**0,105**	3	25	
12.00	**0,105**	2	25									
12.30	**0,105**	2	25									
12.45	**0,105**	2	25		**0,525**	4	35	-	**0,315**	4	10	55
14.30												
15.00												
15.30												
16.00												
16.30												
17.00												
18.00	**0,105**	2	25						**0,105**	3	25	
18.15	**0,105**	2	40						**0,105**	3	40	
18.30	**0,105**	2	25									
19.00	**0,105**	2	25									
19.30	**0,105**	2	25									
20.00	**0,105**	2	25									
20.30					**1,050**	4	35	-	**0,420**	4	10	55
20.45	**0,105**	2	25									
20.46												
21.00	**0,105**	2	25									
21.15	**0,105**	2	25									
21.30									**0,525**	6	45	
21.30	**0,105**	2	25									
21.45	**0,105**	2	25									
Qref	**2,100**				**2,100**				**2,100**			

	M				L				XL			
	Qtap	f	Tm	Tp	**Qtap**	f	Tm	Tp	**Qtap**	f	Tm	Tp
	kWh	l/mn	oC	oC	**kWh**	l/mn	oC	oC	**kWh**	l/mn	oC	oC
07.00	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
07.05	**1,400**	6	40		**1,400**	6	40					
07.15									**1,820**	6	40	
07.26									**0,105**	3	25	
07.30	**0,105**	3	25		**0,105**	3	25					
07.45					**0,105**	3	25		**4,420**	10	10	40
08.01	**0,105**	3	25						**0,105**	3	25	
08.05					**3,605**	10	10	40				
08.15	**0,105**	3	25						**0,105**	3	25	
08.25					**0,105**	3	25					
08.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
08.45	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
09.00	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
09.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
10.00									**0,105**	3	25	
10.30	**0,105**	3	10	40	**0,105**	3	10	40	**0,105**	3	10	40
11.00									**0,105**	3	25	
11.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
11.45	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
12.00												
12.30												
12.45	**0,315**	4	10	55	**0,315**	4	10	55	**0,735**	4	10	55
14.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
15.00									**0,105**	3	25	
15.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
16.00									**0,105**	3	25	
16.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
17.00									**0,105**	3	25	
18.00	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
18.15	**0,105**	3	40		**0,105**	3	40		**0,105**	3	40	
18.30	**0,105**	3	40		**0,105**	3	40		**0,105**	3	40	
19.00	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
19.30												
20.00												
20.30	**0,735**	4	10	55	**0,735**	4	10	55	**0,735**	4	10	55
20.45												
20.46									**4,420**	10	10	40
21.00					**3,605**	10	10	40				
21.15	**0,105**	3	25						**0,105**	3	25	
21.30	**1,400**	6	40		**0,105**	3	25		**4,420**	10	10	40
21.30												
21.45												
Qrer	**5,845**				**11,655**				**19,070**			

	XXL				3XL				4XL			
	Qtap	f	Tm	Tp	**Qtap**	f	Tm	Tp	**Qtap**	f	Tm	Tp
	kWh	l/mn	oC	oC	**kWh**	l/mn	oC	oC	**kWh**	l/mn	oC	oC
07.00	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
07.05					**11,20**	48	40		**22,40**	96	40	
07.15	**1,820**	6	40									
07.26	**0,105**	3	25									
07.30					**0,840**	24	25		**1,680**	48	25	
07.45	**6,240**	16	10	40								
08.01	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
08.05												
08.15	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
08.25												
08.30	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
08.45	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
09.00	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
09.30	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
10.00	**0,105**	3	25									
10.30	**0,105**	3	10	40	**0,840**	24	10	40	**1,680**	48	10	40
11.00	**0,105**	3	25									
11.30	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
11.45	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
12.00												
12.30												
12.45	**0,735**	4	10	55	**2,520**	32	10	55	**5,040**	64	10	55
14.30	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
15.00	**0,105**	3	25									
15.30	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
16.00	**0,105**	3	25									
16.30	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
17.00	**0,105**	3	25									
18.00	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
18.15	**0,105**	3	40		**0,840**	24	40		**1,680**	48	40	
18.30	**0,105**	3	40		**0,840**	24	40		**1,680**	48	40	
19.00	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
19.30												
20.00												
20.30	**0,735**	4	10	55	**5,880**	32	10	55	**11,76**	64	10	55
20.45												
20.46	**6,240**	16	10	40								
21.00												
21.15	**0,105**	3	25		**0,840**	24	25		**1,680**	48	25	
21.30	**6,240**	16	10	40	**11,20**	48	40		**22,40**	96	40	
21.30												
21.45												
Qref	**24,530**				**46,760**				**93,520**			

C3. Heat pump and solar technology source parameters

The table below gives the outdoor temperature, solar irradiance, soil temperature ("brine" heat pumps) and groundwater temperature (for "water" heat pump boilers) that are used as default inputs for heat pump technology. (source: JRC Ispra)

Table C5. Heat pump and solar technology source temperatures

		Tout	Toutm	qsol	qsolm	Tsrc brine	Tsrc water	Q_solm
		oC	oC	W/m²	W/m²	oC	oC	kWh/m²
JAN	morn	2,2		62		2,28	10,44	
	mid	4,4		218		2,55	10,88	
	eve	4,5	3,44	4	70	2,57	10,90	51
	late	3,4		0		2,43	10,69	
	night	2,2		0		2,28	10,44	
FEB	morn	3,1		126		2,38	10,61	
	mid	6,4		309		2,80	11,28	
	eve	6,4	4,82	15	104	2,80	11,28	76
	late	4,8		0		2,60	10,97	
	night	2,9		0		2,36	10,58	
MAR	morn	5,2		217		2,65	11,04	
	mid	9,2		411		3,15	11,84	
	eve	8,8	6,88	41	149	3,10	11,76	109
	late	6,6		0		2,82	11,31	
	night	4,1		6		2,51	10,82	
APR	morn	8,7		301		3,09	11,75	
	mid	12,9		495		3,62	12,59	
	eve	12,3	10,09	78	192	3,53	12,45	140
	late	9,3		0		3,17	11,87	
	night	6,8		18		2,84	11,35	
MAY	morn	13,8		353		3,73	12,76	
	mid	17,8		541		4,23	13,57	
	eve	17,2	14,75	111	221	4,15	13,43	162
	late	14,3		0		3,78	12,85	
	night	10,9		32		3,36	12,18	
JUN	morn	17,3		354		4,16	13,46	
	mid	21,2		529		4,65	14,24	
	eve	20,7	18,17	123	222	4,59	14,14	163
	late	17,8		0		4,22	13,56	
	night	14,3		39		3,79	12,86	

		Tout	Toutm	qsol	qsolm	Tsrc brine	Tsrc water	Q_solm
		oC	oC	W/m²	W/m²	oC	oC	kWh/m²
JUL	morn	19,0		366		4,37	13,80	
	mid	23,2		566		4,90	14,63	
	eve	22,8	20,06	119	232	4,85	14,57	170
	late	19,8		0		4,48	13,96	
	night	15,9		35		3,99	13,19	
AUG	morn	18,9		335		4,37	13,79	
	mid	23,8		555		4,98	14,77	
	eve	23,1	20,21	93	217	4,89	14,62	159
	late	19,5		0		4,44	13,90	
	night	15,7		23		3,97	13,15	
SEP	morn	14,4		259		3,80	12,88	
	mid	18,9		479		4,36	13,78	
	eve	17,9	15,67	54	176	4,23	13,57	129
	late	14,5		0		3,82	12,91	
	night	12,1		9		3,51	12,42	
OCT	morn	10,5		166		3,31	12,10	
	mid	14,2		375		3,78	12,85	
	eve	13,4	12,07	24	129	3,68	12,69	94
	late	11,6		0		3,46	12,33	
	night	9,8		1		3,23	11,97	
NOV	morn	6,2		76		2,77	11,23	
	mid	8,6		247		3,07	11,71	
	eve	8,4	7,42	6	80	3,05	11,68	58
	late	7,4		0		2,93	11,49	
	night	6,1		0		2,77	11,23	
DEC	morn	2,8		44		2,35	10,56	
	mid	4,6		177		2,57	10,92	
	eve	4,6	3,77	2	56	2,57	10,91	41
	late	3,6		0		2,45	10,73	
	night	2,8		0		2,35	10,57	

For air-source heat pump technology that uses (also) ventilation exhaust air (***ventmix***=yes) then the model assumes the following default values for the volume of available exhaust air ***ventex*** [in m³/h] that is available.

Table C6. Default values *ventex* per load profile (if *ventmix*=yes)

parameter	unit	1 -XXS	2 -XS	3 -S	4 -M	5 -L	6 -XL	7 -XXL	8 -3XL	9 -4XL
ventex	m³/h	109	136	128	159	190	870	1021	2943	8830

For the partitioning between the volume of exhaust air *ventex* and the outside air, the model assumes that an air-based heat pump technology uses 300 m³/h per kW of nominal input (*Phpnom*). Internal parameter ***hpaf*** = 300 m³/h.kW.

C4. Emitters

The reference is a radiator system with a water content of 20 litres per kW nominal power [EN 442]. The radiator constant ***radc*** is 1,3. The total nominal radiator power ***Pradnomsum*** and the radiator power in each zone of the heated space are given in Table C7.

Table C7. Radiator capacity (EN 442) per load profile

parameter	zone	1 -XXS	2 -XS	3 -S	4 -M	5 -L	6 -XL	7 -XXL	8 -3XL	9 -4XL
Pradnom1	day-zone	2,65	3,94	4,30	6,45	8,88	21,18	34,36	91,7	275,1
Pradnom2	night-zone	1,84	2,76	3,04	4,58	6,32	14,74	24,34	64,7	194,2
Pradnom3	bath-zone	0,60	0,89	0,96	1,44	1,97	4,79	7,66	20,5	61,5
Pradnomsum	total	**5,09**	**7,59**	**8,30**	**12,48**	**17,17**	**40,71**	**66,36**	**176,9**	**530,8**

C5. Distribution system

The reference is a distribution system in existing dwellings and buildings of characteristics matching the load profiles. The table gives

- the total pipe length ***Lpipe*** in meter per m² heated floor area ***F***
- the heat loss factor ***hlf*** that gives the fraction of unrecovered heat
- the heat loss ***Upipe*** in W per metre of pipe and per K temperature difference between pipe and ambient
- the heated floor area ***F*** in m² of the dwelling/building on which the load profile is based
- the specific distribution losses of the dwelling/ building ***pdistr*** per K temperature difference between pipe and ambient. This latter parameter follows from the multiplication of the values in the first 4 columns.

  Pdistr= Lpipe * hlf * Upipe * F (in W/K) **C7**

- The total water volume in the pipes ***Vpipe*** in litres, calculated with an average inner pipe diameter of 18 mm. The factor 10 relates to the fact that Lpipe is given in *m* and not *dm*.

  Vpipe= 10 * **POWER*(0,09;2)* * *3,14 * Lpipe * F*** (in ltr.) **C8**

Table C8. Parameters CH-distribution network

Load Profile	Lpipe	hlf	Upipe	F	pdistr	Vpipe
	m/m²F	#	W/K.m	m2	W/K	ltr
XXS	1,00	0,30	0,22	78	5,15	19,81
XS	1,00	0,30	0,22	101	6,67	25,65
S	1,00	0,30	0,44	67	8,84	17,02
M	1,00	0,30	0,44	86	11,35	21,84
L	1,00	0,30	0,44	106	13,99	26,92
XL	0,75	0,37	0,27	628	47,05	119,63
XXL	0,75	0,37	0,50	532	73,82	101,35
3XL	0,55	0,37	0,66	1693	227,39	236,51
4XL	0,55	0,37	0,66	5078	682,03	709,40

C6. Pump

The pump configuration parameter ***pmpconfig*** [param. nr. 9.8] has 3 possible values:

1. Integrated pump
2. Internal pump only (just for the heat exchanger not for network)
3. No pump

For boiler configurations where there is no pump (*pmpconfig*=3) or just an internal pump for the circulation through the heat exchanger (*pmpconfig*=2) the manufacturer fills in the measured values for *elpmp* (0 in case of no pump or just nominal power of internal pump), *elmaxon* and *elminon*. The model then makes a correction for the missing pump values to arrive at the final values for internal parameters ***elpmpz, elmaxonz*** and ***elminonz*** (see Annex D).

For this calculation the model uses a number of look-up values for the following internal parameters:

- Pump power needed for the distribution network ***Ppmploop*** [in kW]
- Reference pressure drop over the boiler ***pdropref*** [in mbar]
- Reference pump power needed for the boiler ***Ppmpboiler*** [in kW]
- Total pump power needed for boiler and network ***Ppmptot*** [in kW]

For a situation where there is no pump (*pmpconfig*=3) the pressure drop over the boiler [param. nr. 9.9] is a mandatory input parameter. The pressure drop over the boiler shall be measured according to harmonised standards.

Table C9. Pump parameters (if no or only internal pump)

Load Profile	Ppmploop	pdropref	Ppmpboil	Ppmptot
	kW	mbar	kW	kW
XXS	0,033	100	0,032	0,065
XS	0,046	100	0,034	0,080
S	0,036	100	0,035	0,071
M	0,051	100	0,039	0,090
L	0,068	120	0,048	0,116
XL	0,250	140	0,053	0,303
XXL	0,291	160	0,073	0,364
3XL	0,775	180	0,090	0,865
4XL	2,403	200	0,104	2,507

Depending on the value of *pmpconfig*, the model uses different equations to arrive at the values of *elpmpz, elmaxonz* and *elminonz* (see equations).

C9

CHOOSE	
pmpconfig=	**elpmpz=**
if value	*then equation*
1	elpmp
2	elpmp + Ppmploop
3	Ppmploop+(pdrop/pdropref)*Ppmpboil

C10

CHOOSE	
pmpconfig=	**elmaxonz=**
if value	*then equation*
1	elmaxon
2	elmaxon+Ppmploop
3	elmaxon+elpmpz

C11

CHOOSE	
pmpconfig=	**elminonz=**
if value	*then equation*
1	elminon
2	elminon+Ppmploop
3	elminon+elpmpz

In case of *pmpconfig*=2 or *pmpconfig*=3 the settings of the pump- and control characteristics shall be filled in as follows:

Table C10. Settings of pump and pump control characteristics in case pmpconfig=2 or pmpconfig=3

param. nr.	parameter	value
9.1	tpmp	24 h
9.2	pmpsb	0- no
9.7	varsp	0- no

The nominal pump flow rate ***fixflow*** [in ltr./h] is a function of the total nominal radiator capacity ***Pradnomsum*** .

fixflow* = 80 * *Pradnomsum **C12**

The average pump flow rate for a variable speed pump ***minflow*** [in ltr./h] is derived from a load profile of 44% at 25% flow, 35% at 50% flow, 15% at 75% flow and 6% at 100% nominal flow rate. On average this amounts to 46%.

minflow* = 46% * *fixflow **C13**

C7. Air fuel mixers

The model distinguishes 4 types of air/fuel mixers with reference conditions (not measured) for each type.[6] For each mixer type the table below gives values for

- fuel loss factor ***flf*** [-]
- air factor ***lambda*** [-]
- purge time ***tpurge*** [in h]

Table C11. Look-up table air/fuel mixers (param. nr. 6.1)

AIR/FUEL MIXERS (param. nr. 6.1)		flf	lambda	tpurge
value	description	fuel loss factor	air factor	purge time
1	1 -atmospheric	3,0%	1,6	0,003
2	2 -pneumatic	1,5%	1,4	0,008
3	3 -ionisation	1,0%	1,2	0,007
4	4 -next gen. O2	0,5%	1,1	0,007

[6] Blue-flame burner and yellow-flame burner are to be added as soon as air-factor and fuel loss measurements of oil-fired burner in practice are available.

C8. Fueldewpoints

For each type of fuel [param nr. 6.2, fueldewpoint] the model gives a reference fueldewpoint:

Table C12. Look-up table fueldewpoint (param. nr. 6.2)

fueldewpoint (param. nr. 6.2)		**dpt**
value	description	dew point
1	1-gas	58
2	2-oil	47
3	3 –LPG	54

Corrected dewpoint dptc is dpt corrected for the air factor lambda (outside air is assumed to be 20°C).

dptc = dpt – (lambda-1)*20

C14

C9. V-control

The p-band (valveband) and time delay (valvedelay) are as follows

Table C13. Look-up table Vcontrol

Vcontrol (param. nr. 10.3)			
		valveband	**valvedelay**
value	description		**h**
1	**1 - manual**	3	0,5
2	**2 -RTV 2K**	2	0,33
3	**3 -RTV 1K**	1	0,25
4	**4 -Motor + PID-loop**	0,5	0,1
5	**5 -Motor + CPU**	0,2	0,05

C10. T-control

The table below shows the control bands for room thermostat (tband), boiler (bband), maximum boiler temperature (Tsysbini) and –only relevant for chrono proportional thermostat—the fixed number of cycles per hour fcyc.

Table C14. Look-up table Tcontrol

Tcontrol (param. nr. 10.4)					
		tband	**bband**	**Tsysbini**	**fcyc**
value	description	**K**	**K**	**oC**	**#**
1	**1 -fixed BT**		10	60	1
2	**2 -on/off RT**	0,5	10	70	1
3	**3 -weather ctrl BT**		5	70	1
4	**4 -weather c. BT+RT**		5	70	1
5	**5 -modulating RT**	0,2	10	70	1
6	**6 -time-prop. RT**		10	70	4

C11. Multiple heat generators: Order and partitioning

The CH-boiler can incorporate multiple heat generators. In the case of a cascade of non-identical fossil-fuel fired boilers a distinction shall be made between "preferential" (abbreviation "pref") and "non-preferential" (abbreviation "non-pref") boilers. Furthermore, the installation may contain heat pump technology and/or a solar collector.

After an assessment of the impact of generic heat generator characteristics, the space heating load is applied in this order: solar collector, heat pump, electric back-up heater, preferential gas/oil-fired boiler, gas/oil-fired non-preferential boiler. After assessing the contribution of a heat generator the remaining load is used as an input for the next heat generator in the order mentioned above.

The model assumes that a solar collector is used for space heating if Asol>0 and usesol=1 (space heating) or usesol=3 (both space and water heating). Likewise, the model assumes that heat pump technology is used in the product if Phpnom>0 and usehp=1 (space heating) or usehp=3 (both space and water heating).

If an electric back-up space heater is used, the remaining energy after the electric space heater is by definition 0 (zero). Manufacturers that indicate that they use an electric space heater (param. nr. 17.1, *ELBU*, yes/no) do not have to submit measured data. The model assumes 40% primary energy efficiency (100% electric efficiency and a primary energy conversion factor 2,5).

C12. Multiple functionality: Order and partitioning

The CH-Combi can incorporate two functions: space heating and sanitary water heating. The manufacturer shall indicate that the product incorporates a water heating function by selecting a waterload pattern (not "0 –none") and by filling in the appropriate parameters:

- For gas/ oil-fired boilers without solar or heat pump: *Qfuel*>0 and/or *Qelec*>0.

  *Please note that the manufacturer **must** fill in Qfuel=0 and Qelec=0 in case there is solar or heat pump technology involved in the water heating and the gas/oil-fired boiler acts as a back-up.*

- For solar assisted products: *Asol*>0 and *usesol*=2 (water heating) or *usesol*=3 (both space and water heating).
- For products with (also) heat pump technology: *Phpnom*>0 and *usehp*=2 (water heating) or *usehp*=3 (both space and water heating)

Note that a gas/oil-fired combi-boiler is the priority setting. Solar and/or heat pump water heating parameters will **not** be taken into account if Qfuel>0 and/or Qelec>0.

In case of solar and/or heat pump (assisted) water heating, the manufacturer shall indicate the energy consumption (*Qfuelmax, Qelecmax, Qfuelmin, Qelecmin*) of the back-up water heater for two different load patterns ***Qloadmax*** and ***Qloadmin***.

The back-up heater can be a (combi-)boiler that is also used for space heating, but the model also accommodates a dedicated electric/ gas or oil-fired water heater to act as a back-up water heater, working alongside e.g. a dedicated gas/oil-fired CH-boiler for space heating.

In case of solar and/or heat pump (assisted) water heating the partitioning of the capacity between the space and water heating functions is as follows:

- For gas-/oil-fired boilers without solar and/or heat pump there are two possible situations:

  - o The test energy consumption can be established independently for each of the two functions. This is the case of combi-boilers with a separate cylinder, where the cylinder and relevant piping can be deactivated (valve) for the space heating test and can be engaged in the water heating test. Here the space and water heating efficiency can be assessed separately.
  - o The test energy consumption for space and water heating cannot be established individually, i.e. it inevitably involves heating of parts that are intended for both functions. This is the case for instantaneous combi-boilers and boilers where the storage facilities are combined (e.g. "tank-in-tank"). This shall be indicated by the manufacturer with the parameter *combicomp* (param. nr. 3.4, yes/no). If combicomp=yes then all calculated envelope losses in the space heating function will be considered as "recovered" (internal parameters Qbenvoff, Qbenvon). This credit will be partitioned between the space and water heating function on the basis of their respective

loads per month. For space heating the load fraction is indicated by the fraction ***CHfrac*** [-]. For water heating the fraction is (1-*CHfrac*).

- For solar collectors: the collector surface *Asol* [in m²] and the solar storage capacity *Vsol* [in ltr.] is partitioned monthly between the two functions on the basis of their respective loads. For space heating the load fraction is indicated by the fraction *CHfrac* [-]. For water heating the fraction is (1-*CHfrac*).
- For generators with heat pump technology: the power output [in kW] is partitioned between the two functions also on the basis of their respective monthly loads, using the parameter *CHfrac* as above. The storage tank relates exclusively to the tank for the sanitary water heating. The model assumes <u>no</u> primary store for the CH-function of the heat pump. The volume indicated in ***Vhp*** [param. nr. 16.8], the standby heat losses ***Pstbyhp*** [param. nr. 16.9] and the hot water capacity [param. nr. 16.10] relate only to hot water.

  In case the CH-function of the heat pump technology does require a tank (with volume >4 litres), the tank standby losses shall be taken into account in the

  - o COP-measurements [param. nr.'s 16.4, 16.5 and 16.14] and/or
  - o The auxiliary energy consumption *hpaux* [param. nr. 16.7]

  The manufacturer shall indicate in a technical report how the extra losses of the primary store were measured and how the measurement results were taken into account in the above parameters.

C13. Efficiency rating (provisional)

Classification and class names are under consideration. The following table is therefore provisional:

Table C15. Efficiency Rating (provisional): Lower class-limit in %

	class (provisional)	**Space heating**	**Water Heating**								
			1	2	3	4	5	6	7	8	9
		all	**XXS**	**XS**	**S**	**M**	**L**	**XL**	**XXL**	**3XL**	**4XL**
1	**A+++**	120	52	62	72	86	98	112	128	140	152
2	**A++**	104	44	52	60	72	82	94	108	118	128
3	**A+**	88	36	42	48	58	66	76	88	96	104
4	**A**	80	32	37	42	51	58	67	78	85	92
5	**B**	76	28	32	36	44	50	58	68	74	80
6	**C**	64	24	27	30	37	42	49	58	63	68
7	**D**	56	20	22	24	30	34	40	48	52	56
8	**E**	48	16	17	18	23	26	31	38	41	44
9	**F**	40	12	12	12	16	18	22	28	30	32
10	**G**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Increment	*8*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*

ANNEX D: SPACE HEATING MODEL

D1. Inputs

On the basis of the inputs from Annex B and C this annex gives the mathematical model used to evaluate the energy efficiency of the space heating function of the CH-boiler.
The diagram below gives an overview of the steps in the mathematical model.

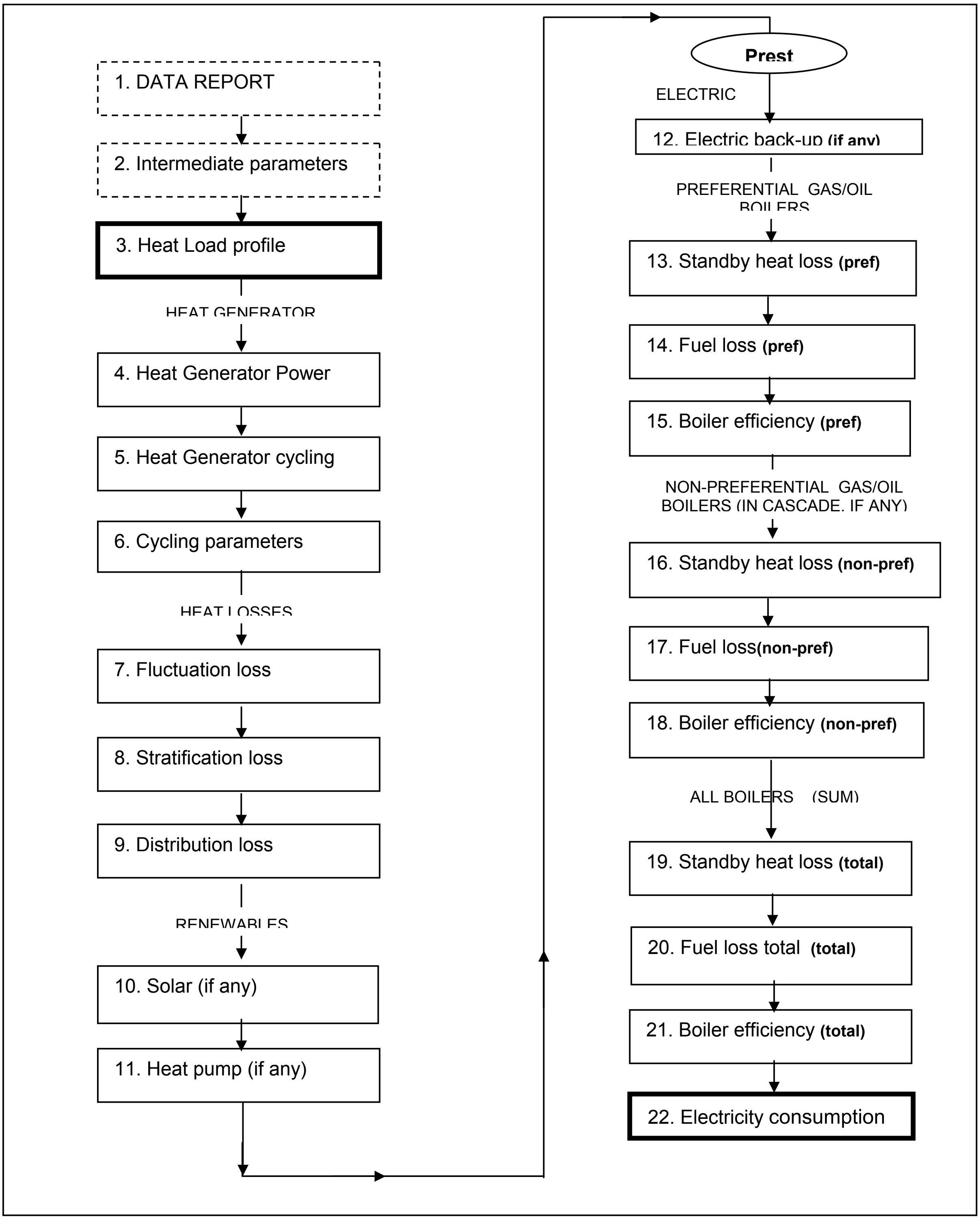


Fig. 1. Space heating mathematical model structure

D2. Intermediate parameters

The input parameters in Annex B represent the minimum number of inputs required to make the calculations. For the mathematical model this section gives a number of derived parameters that facilitate further calculation and data processing.

D2.1 Conventional CH-boiler

Table D1. Intermediate energy and power parameters conventional CH-Boiler

GIVEN INPUT PARAMETERS		
name	*description*	*input*
Qb8060	Nominal heat input at 80/60 °C	param. nr. 3.1
turndown	turndown ratio	param. nr. 3.2
η8060	efficiency at nominal power and 80/60 °C	param. nr. 4.1
η8060min	efficiency at minimal power and 80/60 °C	param. nr. 4.2
η5030	efficiency at nominal power and 50/30 °C	param. nr. 4.3
η5030min	efficiency at minimal power and 50/30 °C	param. nr. 4.4
p_bstby	standby heat loss at 50 °C as % of Qb8060	param. nr. 5.1

DERIVED INTERNAL PARAMETERS			
name	*description*	*equation*	
Qbmin8060	Minimal heat input at 80/60 °C	**Qbmin8060** = Qb8060*turndown	D1
Pb8060	Nominal heat output at 80/60 °C	**Pb8060** = η8060*Qb8060	D2
Pbmin8060	Minimal heat output at 80/60 °C	**Pbmin8060** = η8060min*Qbmin8060	D3
Pb5030	Nominal heat output at 50/30 °C	**Pb5030** = η5030*Qb8060	D4
Pbmin5030	Minimal heat output at 50/30 °C	**Pbmin5030** = turndown*Pb5030	D5
Pbstby	Heat loss at burner off	**Pbstby** = p_bstby*Qb8060	D6

D2.2 Waste heat recovery parameters

Table D2 gives heat recovery parameters.

Table D2. Determination of heat recovery parameters

boilpos	**air_intake**	**volumeb**	**noiseh (noisew)**	**qrecovb_winter Oct.-Apr.**	**qrecovb_summer June-Aug.**	**(qrecov) All year**
[-]	[-]	[m³]	[dB(A)]	[%]	[%]	[%]
indoor (= 1)	3 (electric)	≤ 0.5	< 35	85%	-71%	32%
			≥ 35, ≤ 44	55%	-46%	21%
			> 44	25%	-21%	9%
		> 0.5	any value	25%	-21%	9%
	1 or 2 (fossil fuel)	≤ 0.15	≤ 44	85%	-71%	32%
			> 44	25%	-21%	9%
		≤ 0.5, > 0.15	≤ 44	55%	-46%	21%
			> 44	25%	-21%	9%
		> 0.5	any value	25%	-21%	9%
outdoor (= 0)	any value	any value	any value	0%	0%	0%

Note 1: qrecovb_transit (May + Sept.)=0

Note 2: qrecov= (7/12)*qrecovb_winter + (3/13)*qrecovb_summer but with noisew instead of noiseh

Note that *qrecovb_winter*, *qrecovb_transit* (=0) and *qrecovb_summer* are used for the CH-Boiler mathematical model with the noise parameter *noiseh*. The annual recovery factor *qrecov* with the noise parameter *noisew*, is used for the Water Heater mathematical model in Annex E.

The equations indicated by Table D2 are

***qrecovb_winter* = *boilpos**IF(AND(*airintake*=3;*noiseh*<35; *volumeb*<=0,5); 85%;**
IF(*airintake*=2; 25%; IF*(volumeb*<=0,15;
IF(*noiseh*<=44; 85%;25%);IF*(volumeb*<=0,5;IF*(noiseh*<=44;55%;25%);25%)))) **D7**

***qrecovb_transit* = 0** **D8**

***qrecovb_summer* = *boilpos**IF(AND*(airintake*=3;*noiseh*<35; *volumeb*<=0,5);-71%;**
IF(*airintake*=2;-21%;IF*(volumeb*<=0,15;
IF(*noiseh*<=44;-71%;-21%);IF*(volumeb*<=0,5;IF(*noiseh*<=44;-46%;-21%);-21%)))) **D9**

***qrecov* = *boilpos**IF(AND*(airintake*=3;*noiseh*<35; *volumeb*<=0,5);32%;**
IF(*airintake*=2; 9%;IF*(volumeb*<=0,15;
IF(*noisew*<=44; 32%; 9%);IF*(volumeb*<=0,5; IF(*noisew* <=44; 21%;9%);9%)))) **D10**

D2.3 Intermediate parameters CH-Boiler with solar technology

Table D3. Intermediate parameters CH-Boiler with solar technology

name	*description*	*unit*	*equation*	
a_c	Resulting collector heat loss coefficient	W/(m²K)	**a_c** = a_1+a_2*40	**D11**
ηloop	Collector loop efficiency	-	**ηloop** =1 - (η_0*Asol*a_c)/UAsol	**D12**
UL	Collector loop pipe loss **per m² collector**	W/(m².K)	**UL** = Lpipesol*Upipesol_m/Asol	**D13**

D2.4 Exhaust air heat-pump technology

For a ventilation exhaust air heat pump (*ventmix*=yes), the source temperature ***Tsrc_ventmix*** of the mix of outside air (at *Tout*) and the exhaust air (default 20 °C, unless *Tout*>20) can be calculated per day-period using the reference values for hpaf and ventex given in Annex C.

Tsrc_ventmix* = ((*Phpnom**hpaf* - *ventmixventex*)**Tout* + *ventmix***ventex** MAX(20;*Tout*))**
/(*Phpnom*hpaf*)** **D14**

D2.5 Extrapolation of test-points for heat pumps

Input parameter 16.3 in the Annex B Data Report is, apart from the non-numerical headers, a 6x7 table. In The first row (16.13T) two identical sets of a maximum of 3 declared sink temperatures (minimum 2). The first column gives a set of maximum 5 declared source temperatures (minimum 2). What remains are two 5x3 matrices.with each a maximum of 15 declared values for the declared source and sink temperatures. In the lefthand matrix (with header "Pcor") the manufacturer gives correction factors for the heat pump output power Phpnom [param. nr. 16.1]. The correction factor for Phpnom, with its sink and source temperature, must be one point of the matrix and its value is by definition 1. The other points of the matrix follow from the output power values measured at different sink and/or source temperatures.
These test-results are then divided by Phpnom to find the correction factors that should be filled in.
The same procedure applies to the righthand matrix (with header "COPcor") where the correction factors relate to the declared nominal Coefficient of Performance [***COPnom***, param. nr. 16.4].

The purpose of parameter 16.3 is to provide input data for the "seasonal" correction of the output power and the COP, i.e. on the basis of the given values the mathematical model recalculates the output power and COP for each of the relevant day-periods (9 x 5= 45 day-periods for space heating and 12 x 5 = 60 day-periods for water heating).

A two-step approach is followed to facilitate this seasonal correction per day-period. The first step is to expand the matrix of declared values with extrapolated values for source and sink temperatures at the extremes. For the source temperatures the extremes are +30°C and –20°C. For the sink temperatures the extremes are +70 and +20°C. Thus the smallest declared matrix is 2x2 is transformed into an “internal” 4x4 matrix. In general terms, a declared matrix of r x c is transformed into a matrix (r+2) x (c+2).

For the output power, where prEN 15316-4-2 allows only 2 test values, this transformation includes not only extrapolation at the extremes, but also the assessment of the “missing values” in the 2x2 matrix.

After the transformation a matrix of correction factors (at least 4x4) is found for the output power, called _HPPmatrix, and for the COP, called _COPmatrix. The source temperatures at which these values are assessed (declared+ 2 extremes) are listed in an array _Tsrcs, containing 2 or 3 declared values and the the two extremes. Likewise, the relevant sink temperatures are in an array called _Tsnks.

In a second step, the two matrices _HPPmatrix, _COPmatrix and their arrays _Tsrcs, Tsnks are used to find intermediate values. This second step is discussed in paragraph D12 for space heating and in paragraph E9 for water heating.

This section concentrates on the first step, i.e. the extra/interpolation. This extra-/interpolation is less self-evident than it may seem:

In the worst case the matrix may contain as little as 2 diagonally placed test-points, from which 14 unknown values should be derived to arrive at a 4x4 matrix. There is more than one way to do that and therefore the model should specify the extrapolation formula’s to be used.

Table D4. Principle of extrapolation of test-points : from given value11 and value 22

f = Tsnk3-Tsnk1

d =Tsnk3 -Tsnk2

b =Tsnk2 -Tsnk1

a =Tsrc2-Tsrc1

c =Tsrc3-Tsrc2

e =Tsrc3-Tsrc1

	Tsnk1	Tsnk2	Tsnk3
Tsrc1	value11 = given	**value12 = value11 + SIN(ATAN(a/b)) * (value22-value11)**	**value13 = value12 + (d/b) * (value12 - value11)**
Tsrc2	**value21 = value11 + COS(ATAN(a/b)) * (value22-value11)**	value22 = given	**value23 = value13 + (a/f) * (value33 - value13)**
Tsrc3	**value 31 = value 21 + (c/a) * (value21 - value11)**	**value 32 = value31 + (b/f) * (value33 - value31)**	**value33 = value22 + (value22-value11) * SQRT(SUMX2PY2(d;c)) / SQRT(SUMX2PY2(b;a))**

The table shows four types of extra/interpolation employed to find the “missing” test points:

1. **value12** and **value21** follow from the projection of the angle [atan(a/b)]
2. **value 33** follows from a diagonal linear extrapolation of value11 and value22
3. **value31** and **value13** follow from a straight linear extrapolation of the two preceding values (value11 and value21→ value 31; value11 and value12→value13)
4. **value32** and **value23** follow from a linear interpolation from values at the left and right (for value32) and at the top and bottom (for value23) respectively.

With these four methods a matrix of at least 4 x 4 can be extrapolated from 2 given test-points plus conditions at the extremes (-20<Tsrc<30, 20<Tsnk<70 in°C[7]). Or a 5x5 matrix can be created from 3 test points.

[7] Under consideration: Current version of the mathematical model uses 70°C as the maximum sink temperature. With the introduction of new CO2-based types, higher sink temperatures (e.g. 85°C) are possible. But for the COP there is also a strong dependence on system

Table D5. Matrix 4x4 created with 4 methods (1 to 4) from 2 test-points

_Tsrcs \ _Tsnks	20	a	c	70
-20	**2**	**3**	**3**	**3**
b	**3**		**1**	**3**
d	**3**	**1**		**4**
30	**3**	**3**	**4**	**2**

Table D6. Matrix 5x5 created with 4 methods (1 to 4) from 3 test-points

_Tsrcs \ _Tsnks	20	a	c	e	70
-20	**2**	**3**	**3**	**3**	**3**
b	**3**		**1**	**3**	**3**
d	**3**	**1**		**4**	**3**
f	**3**	**3**	**4**		**4**
30	**3**	**3**	**3**	**4**	**2**

D2.6 Accounting parameters

Accounting parameters calculate per consecutive step in the model the power, energy and –for the first steps-- system temperatures. Most of these parameters are not strictly indispensable but they facilitate the understanding and maintenance of the mathematical model. The table D7 contains the parameters and equations.

Table D7. Accounting parameters CH-space heating

Eq. Nr.	Parameter	Equation	Boundary conditions
	fluctuation losses		
D15	PH4	0,001*((Tin+dTfluct−Tout)*qloss− Qgains)	=IF(Pmax>0;PH4;0) =MAX(0;PH4)
D16	QH4	=hd*PH4	=MAX(0;QH4)
D17	dTsysfluct	=20+50*POWER(PH4/Pradnomsum;1/radc))−Tsysini	=IF(Tsysi>22;dTsysfluct;0) =MAX(0;dTsysfluct)
	stratification losses		
D18	PH5	=0,001*((Tin+dTfluct+dTstrat−Tout)*qloss−Qgains)	=IF(Pmax>0;PH5;0) =MAX(0;PH5)
D19	QH5	=hd*PH5	=MAX(0;QH5)
D20	dTsysstrat	= −dTsysfluct+ (20+50*POWER(PH5/Pradnomsum;1/radc))−Tsysini)	=IF(Tsysi>22;dTsysstrat;0) =MAX(0;dTsysstrat)
	distribution losses		
D21	PH6	=PH5 + P_distr	=IF(Pmax>0;PH6;0) =MAX(0;PH6) P_distr=MAX(0;P_distt)
D22	QH6	=hd*PH6	=MAX(0;QH6)
D23	dTsysdistr	=−dTsysfluct – dTsysstrat + +(20+50* POWER(PH6 / Pradnomsum;1/radc)) −Tsysini)	=IF(Tsysi>22;dTsysdistr;0) =MAX(0;dTsysdistr)
	subtotals		
D24	Tsysfeed	=Tsysi+dTsysfluct+dTsysstrat + dTsysdistr	
D25	Tsysrini	=Tsysret+dTsysfluct+dTsysstrat+dTsysdistr	
	solar and heat pump technology		
D26	Qrest	=(Qresthph/Qsolloadh) * QH6	per day-period
D27	Prest	=Qrest/hd	per day-period
	electric back-up		
D28	Prest1	= MIN(Prest;Pb8060)	IF(ELBU;0;Prest1)
D29	Qrest1	=Prest1*hd	

return temperature, which is to be taken into account. The modality of considering these new types in the model is under consideration (e.g. simple correction factor now, more complete modelling after a few years of practical experience).

Table D7 continued. Accounting parameters

Parameter	Equation		Boundary condition
	standby heat loss gas/oil (pref)		
D30	PH7	=Prest1+Penvoffrest	
D31	QH7	=hd*PH7	=MAX(0;QH7)
	fuel losses gas/oil (pref)		
D32	PH8	=PH7+(Qlosspurge + Qlossfuel)/hd	
D33	QH8	= hd*PH8	=MAX(0;QH8)
	steady state efficiency gas/oil (pref)		
D34	QH9	=QHss − Qenvonr+ Qtwostage	
	non-pref boiler (cascade) remaining load		
D35	Prest2	=Prest − Prest1	
D36	Qrest2	=Prest2*hd	
	standby heat loss gas/oil (no pref)		
D37	PH7b	=Prest2+Penvoffrestb	
D38	QH7b	=hd*PH7b	=MAX(0;QH7b)
	fuel losses gas/oil (no pref)		
D39	PH8b	=PH7b+(Qlosspurgeb + Qlossfuelb)/hd	=IF(Prest2>0;PH8b;0)
D40	QH8b	=hd*PH8b	=MAX(0;QH8b)
	steady state efficiency gas/oil (no pref)		
D41	QH9b	=QHssb − Qenvonrb+ Qtwostageb	=IF(Prest2>0;PH9b;0)
	standby heat loss gas/oil (total)		
D42	PH7tot	=PH7 + PH7b	
D43	QH7tot	=QH7 + QH7b	
	fuel losses gas/oil boiler (total)		
D44	PH8tot	=PH8 + PH8b	
D45	QH8tot	=QH8 + QH8b	
	steady state efficiency gas/oil boiler (total)		
D46	QH9tot	=QH9 + QH9b	
	electricity consumption gas/oil boiler		
D47	QH10	=Qbelon + Qbstbyel + Qpmpel	
	TOTAL		
D48	QH11	=dpm* (SUM(QH9tot) + SUM(QH10) + SUM(Qelbu) +SUM(Qtimer)) + SUM(Qsolnetconsh) + SUM(Qhpnetconsh)	

D2.7 Partitioning parameters

the ratio between the space heating load (*QH3*, see next par.) and the sum of space and water heating load is used to partition the solar and heat pump contribution between space heating and water heating.

CHfrac [dayperiod]= QH3/(Qtap+QH3) **D49**

To arrive at an average fraction per month the above value is weighted for the duration of the 5 day periods (2, 7, 5, 2, 8 hours):

CHfracm [month] = (2*CHfrac[morn]+7*CHfrac[mid]+5*CHfrac[eve]+2*CHfrac[late] **D50**
+ 8*CHfrac[night]*)/24

CHfracm is used as a multiplier to find the relative space heating contribution of solar (partsolh) and heat pump (parthph), also depending on the setting of usesol and usehp in the data report. Equations are

partsolh= CHOOSE(usesol;1;0;CHfracm) and ***parthph= CHOOSE(usehp;1;0;CHfracm)***. The complement (1-CHfracm) is used for the water heating contribution (see Annex E).

D3. Heat load profile

Default

The heat load per day-period is calculated using the input data and equations given in Annex C. Note that for load profiles XXL, 3XL and 4XL the indoor temperature is constant *Tin*=*Tinx*. For other load profiles there is a timer setting with *Tin*=*Tin00* (*autotimer*=yes). Optimiser is never applied in a default situation (default status *optimiser*=no). [8]

In a default situation the initial heat load energy ***QH3*** [in kWh] and power ***PH3*** [in kW] are given by

QH3 = QH [default] **D51a**

PH3 = PH [default] **D51b**

There will be no energy credit or penalty ***Qtimer*** [in kWh/a] from the time control setting:

Qtimer = 0 **D51c**

In case the autotimer and optimiser are different from default *QH* and *PH* have to be calculated also for another temperature regime. The table D7gives the relevant equations. The model selects the appropriate equations, based on setting of ***autotimer*** and ***optimiser***.

Table D8. Equations for QH3, PH3 and Qtimer; Select appropriate equation from table

	XXS to XL	XXL, 3XL and 4XL
autotimer = no	**D52abc** **QH3= QH** [Tinx] **PH3 = PH** [Tinx] **Qtimer** = **QH** [Tinx] − **QH** [Tin00]	**D53abc** **QH3= QH** [Tinx] **PH3 = PH** [Tinx] **Qtimer** = **0**
autotimer=yes; optimiser= no	**D54abc** **QH3= QH** [Tin00] **PH3 = PH** [Tin00] **Qtimer** = **0** *(default)*	**D55abc** **QH3= QH** [Tin00] **PH3 = PH** [Tin00] **Qtimer** = **QH** [Tinx] − **QH** [Tin00]
autotimer=yes; optimiser= yes	**D56abc** **QH3= QH** [Tin30] **PH3 = PH** [Tin30] **Qtimer** = **QH** [Tin30] − **QH** [Tin00]	**D57abc** **QH3= QH** [Tin30] **PH3 = PH** [Tin30] **Qtimer** = **QH** [Tinx] − **QH** [Tin30]

Note that autotimer requires *Tcontrol* ≥2 and *optimiser* requires *autotimer*. A switch from regime *Tinx* to *Tin00* results in a credit (*Qtimer*>0). A switch from *Tin00* to *Tin30* results in a higher heat load (*Qtimer*<0) and makes only sense if this heat loss can be recuperated by a higher efficiency through better operating conditions (which is rarely the case).

In case of a weather-controlled CH-boiler (*Tcontrol*=3 or 4) also –apart from the default *QH3* and *PH3*—the *QH* and *PH* have to be calculated with *Tin*=*TW* to find the energy and power heat load per day-period at the target regime ***QHW*** [in kWh] and ***PHW*** [in kW]

QHW = QH [TW] **D58**

PHW= PH [TW] **D59**

[8] Note that there is a possibility for simplification by eliminating the "optimiser" or using it as a reference for the default only. The "optimiser" has very little effect (<1%) and more often than not has a negative effect , depending on the other parameters.

D4. Heating power

The maximum heating power ***Pmax*** and the minimum heating power ***Pmin*** are established for the CH-boiler as a whole. This includes combustion, electric resistance and heat pump technologies. Solar technologies are excluded from this assessment, because in situations where the maximum heat load may actually be needed the contribution from these technologies is usually negligible.

In case of the electric resistance back-up heating being activated (*ELBU*=yes) and the nominal output of the heat pump *Phpnom* is not exceeding *MinOutput* then *Pmax*=*MinOutput*. Else, with *ELBU*=yes, then *Pmax*=*Phpnom*.
If *ELBU*=no then

Pmax = Phpnom +Pb8060 + Pb8060b **D60**

The minimum power output *Pmin* is calculated from the (modulating) turndown ratio of the heat pump technology or –if there is no heat pump technology—the gas- or oil-fired CH-boiler:

***Pmin*= IF(*Phpnom*>0; *turndownhp**Phpnom*; *Pbmin8060*)** **D61**

The actual flow rate ***realflow*** [in ltr./h] also depends on the *Tcontrol*. If *Tcontrol* ≤2 or ***varsp***=no then *realflow*=*fixflow* else

***realflow* = MAX(*minflow*; (*PH3*/*Pradnomsum*)*fixflow*)** **D62**

D5. Heat generator cycling[9]

Cycling (switching on/off) occurs when the power output of the heat generator does not match exactly the heat demand, specifically when the smallest possible generator capacity exceeds the heat demand. Probably due to the complexity of the phenomenon most standards disregard cycling --i.e. use steady state efficiency-- or treat it as a constant (PrEN 15316-4-1 Boiler Cycling Method, ASHREA 103-1993). Discrepancies between test results and monitoring of real-life energy efficiency indicate that cycling may be too important to ignore and most certainly that cycling frequency and time is far from constant over the heating season. The method here treats cycling frequency and time as variables over the heating season, to be derived from various generator, emitter, pump and control parameters. These latter parameters are also the inputs for the method in this section to calculate the (increase of) system feed- and return temperatures.

D5.1. Actual power output and ideal system temperature

The value of *Pmin*, confronted with the power demand per day-period in each load profile (PH3 and PHW) determines the auxiliary Boolean variable ***cycling***:

***cycling* =IF (OR(AND(*Tcontrol*=3;*PHW*<*Pmin*;*PHW*>0); AND(*PH3*<*Pmin*;*PH3*>0));1;0)** **D63**

The power ***Pb*** [in kW] that the heating installation supplies, depends on *cycling* and *Tcontrol*.

[9] Options for simplifying this section: Some of the parameters in the equations are actually constants for a given load profile and could be replaced by the actual data or a look-up table. The original structure, which is important for maintenance of the model, could then be moved to a separate Annex.

D64

CHOOSE	
Tcontrol	
if value	then equation
	Pb
1	= Pmax
2	= Pmax
3	= IF(cycling; Pmin; PHW)
4	= IF(cycling; Pmin; PHW)
5	= IF(cycling; Pmin; PH3)
6	= Pmax

At night the above also applies unless autotimer=yes, in which case Pb=0,3 (if optimizer=yes) or Pb=Pmax (if optimizer=no).

In the day-periods that there is a heat demand (*PH3*>0) the "ideal" (non-cycling) system temperature ***Tsysini*** can be calculated using the *radiator formula*

***Tsysini* = 20 + 50*POWER(*PH3*/*Pradnomsum*;1/*radc*)** **D65**

If there is no heat demand the model assumes a radiator temperature of 20 °C. For weather controlled generators the system temperature ***Tsyswini*** is calculated similarly, but using heat demand *PHW*. In other words, if *Tcontrol*=3 or *Tcontrol*=4 the system temperature is

***Tsyswini* = MAX(*Tsysini*; *TW*+*Cpar*+50**Cgrad**POWER(*PHW* /*Pradnomsum*; 1/*radc*)−*CL*))** **D66**

For the "*night*"-period replace *TW* (25 °C) with *TWN* (21 °C).

Differences with the equation for *Tsysini*:

- The "MAX" function prevents *Tsyswini* to be lower than *Tsysini*.
- *PHW* instead of *PH3*
- *TW* (or *TWN*) instead of a fixed 20 °C,
- A parallel shift correction of the heating curve *Cpar* (in K, 0<Cpar<10)
- A gradient correction of the heating curve *Cgrad* (1<Cgrad<3)
- An absolute correction *CL* due to the room thermostat (Tcontrol=4 only), but which can never result in a temperature lower that *Tsysini* because of the "MAX"function.

D5.2. System bandwidth and volume per cycle

If the system is cycling, the system temperature bandwidth *dTrad* [in K] depends on *Tcontrol* and its derived parameters (see also Annex C).

D67

CHOOSE	
Tcontrol	
if value	then equation
	dTrad
1	= 2*bband/((Tsysbini−20)/6
2	= 20*tband*(Tsysini−20)/50
3	= bband*(Tsyswini−20)/(50−20)
4	= bband*(Tsyswini−20)/(50−20)
5	= 20*tband*(Tsysini−20)/50
6	= 20*tband*(Tsysini−20)/50)

Radiator fill volume per cycle as a fraction of the radiator volume ***vradcyc***

vradcyc* = 0,5*heatut*******realflow***/(20****Pradnomsum***) **D68**

D5.3. Initial feed and return temperatures

The equations for the average initial system feed temperature ***Tsysi*** [in °C] are given below

D69 **Tsysi equations depending on Tcontrol**

CHOOSE	
Tcontrol	
if value	then equation
	Tsysi
1	Tsysbini+bband
2	MIN(Tsysbini+bband; IF(cycling; Tsysret+0,5*Pb/(realflow*0,00116); Tsysini+dTrad))
3	Tsyswini+dTrad
4	Tsyswini+dTrad
5	MIN(Tsysbini+bband; IF(cycling;Tsysret+0,5*(Pb/(realflow*0,00116));Tsysini+dTrad))
6	MIN(Tsysbini+bband; IF(cycling;Tsysret+0,5*(Pb/(realflow*0,00116));Tsysini+dTrad)))

In the night –period, the equation above is also valid, unless autotimer=yes. In that case Tsysi is either 50 °C (when optimiser=1) or 70 °C (when optimiser=0).

The equations for the average initial system return temperature during heat-up ***Tsysret*** [in °C] are given below

D70 **Tsysret equations depending on Tcontrol**

CHOOSE	If cycling and result <Tsysbini−bband (if not cycling then Tsysini−dTrad)
Tcontrol	
value	then equation
	Tsysret
1	= (Vpipe*(Tsysbini−dTrad) + heatut*realflow*((1−Vradcyc)*Tsysini + vradcyc*Tsysi))/ (Vpipe+heatut*realflow)
2	= Tsysini−dTrad +0,5*(heatut/(20*Pradnom1/realflow)) *(Pb−PH3)/(realflow*0,00116)
3	= (Vpipe*(Tsyswini−dTrad) + heatut*realflow*((1−Vradcyc)*Tsysini + vradcyc*Tsysi))/ (Vpipe+heatut*realflow)
4	= (Vpipe*(Tsyswini−dTrad) + heatut*realflow*((1−Vradcyc)*Tsysini + vradcyc*Tsysi))/ (Vpipe+heatut*realflow)
5	= (fixflow/realflow)*−dTrad+Tsysini + 0,5*(heatut/(20*Pradnom1/realflow))*(Pb−PH3)/(realflow*0,00116)
6	= (fixflow/realflow)*−dTrad+Tsysini + 0,5*(heatut/(20*Pradnom1/realflow))*(Pb−PH3)/(realflow*0,00116)

The average initial system return temperature during cool-down ***Tsysretcd*** [in °C] is given below

D71 **Tsysretcd equations depending on Tcontrol**

CHOOSE	
Tcontrol	
if value	then equation
	Tsysretcd
1	=Tsysbini−bband
2	= Tsysret
3	= Tsyswini−dTrad
4	= Tsyswini−dTrad
5	= Tsysret
6	= Tsysret

During the night the above is valid, unless autotimer=yes in which case

Tsysretcd [night] =MAX(20;IF(autotimer;MIN(N146-4;30);
CHOOSE(Tcontrol;Tsysbini-bband;
Tsysret;
Tsyswini-dTrad;
Tsyswini-dTrad;
Tsysret;
Tsysret)))

If ***heatut***+***cooldt***<=0 then ***Tsysravg***=22 else

Tsysravg **=** **(*heatut******Tsysret+cooldt******Tsysretcd*)** **/** **(*heatut+cooldt*)** **D72**

D5.4. Cool-down and heat-up periods

Average cool-down time ***cooldt*** [in h] during the day (not *night*):

D73 **Cooldt during day** (*morn, mid, eve, late*)

<table>
<tr><td colspan="4">cooldt [day]=</td></tr>
<tr><td colspan="4">condition IF: AND (PH3>0; PH3<Pb; Pb>0; Tsysini−dTrad>20)</td></tr>
<tr><td colspan="2">YES</td><td colspan="2">NO</td></tr>
<tr><td colspan="2">condition IF: Tcontrol=6</td><td colspan="2">condition IF: Tsysini>20</td></tr>
<tr><td>YES</td><td>NO</td><td>yes</td><td>no</td></tr>
<tr><td>(1−PH3/Pb)*1/fcyc</td><td>−1,5*LN((Tsysini−dTrad−20)/
(Tsysini+dTrad−20))+(wheatoff*dTrad)/PH3)</td><td>0</td><td>hd</td></tr>
</table>

The parameter wheatoff is the thermal mass of the CH-water in burner-off-mode (i.e. excluding distribution network) and ***wheatoff=massb*0,7*bh+(massw+2)*wh***, where ***bh*** is the specific heat of the boiler bh=0,00014 kWh/kg.K and ***wh*** is the specific heat of water 0,00116 kWh/kg.K. The mass of the boiler ***massb*** and the mass of the CH-water in the boiler heat exchanger ***massw*** (+ 2 kg for water in the in-boiler piping/ bypass) is in kg.

Average cool-down time *cooldt* [in h] during *night*-period

D74 **cooldt during night (*night*)**

<table>
<tr><td colspan="5">cooldt [night]=
condition IF: AND (PH3>0; PH3<Pb; Pb>0; Tsysini−dTrad>20)</td></tr>
<tr><td colspan="3">YES</td><td colspan="2">NO</td></tr>
<tr><td colspan="3">condition IF: autotimer</td><td colspan="2">condition IF: Tsysini>20</td></tr>
<tr><td>YES</td><td colspan="2">NO</td><td>YES</td><td>NO</td></tr>
<tr><td>hd − heatut</td><td colspan="2">condition IF: Tcontrol=6</td><td>0</td><td>hd</td></tr>
<tr><td></td><td>YES</td><td>NO</td><td></td><td></td></tr>
<tr><td></td><td>(1−PH3/Pb)*1/fcyc</td><td>−1,5*LN((Tsysini−dTrad−20)/
(Tsysini+dTrad−20))+(wheatoff*dTrad)/PH3);</td><td></td><td></td></tr>
</table>

Average heat-up time heatut [in h] during the day (not *night*):

D75 **heatut during day (*morn, mid, eve, late*)**

<table>
<tr><td colspan="4">heatut [day]=</td></tr>
<tr><td colspan="4">condition IF: AND (PH3>0; PH3<Pb; Pb>0; Tsysini−dTrad>20)</td></tr>
<tr><td colspan="2">YES</td><td colspan="2">NO</td></tr>
<tr><td colspan="2">condition IF: Tcontrol=6</td><td colspan="2">condition IF: Tsysini>20</td></tr>
<tr><td>YES</td><td>NO</td><td>YES</td><td>NO</td></tr>
<tr><td>(PH3/Pb)*1/fcyc</td><td>MIN(hd; (PH3/(Pb−PH3+0,1))*cooldt))</td><td>hd</td><td>0</td></tr>
</table>

Average heat-up time heatut [in h] during the *night*-period:

D76 **heatut during night (*night*)**

<table>
<tr><td colspan="6">heatut [night]=
condition IF: AND (PH3>0; PH3<Pb; Pb>0; Tsysini−dTrad>20)</td></tr>
<tr><td colspan="4">YES</td><td colspan="2">NO</td></tr>
<tr><td colspan="4">condition IF: autotimer</td><td colspan="2">condition IF
Tsysini>20</td></tr>
<tr><td colspan="2">YES
condition IF: optimiser</td><td colspan="2">NO
condition IF: Tcontrol=6</td><td>YES
hd</td><td>NO
0</td></tr>
<tr><td>YES</td><td>NO</td><td>YES</td><td>NO</td><td></td><td></td></tr>
<tr><td>QH3/ MAX(Pbmin5030;
0,3*Pb5030)</td><td>Pmax</td><td>(PH3/Pb)*1/fcyc</td><td>MIN(hd; (PH3/(Pb−PH3+0,1))*cooldt))</td><td></td><td></td></tr>
</table>

The table below shows the above equations in spreadsheet notation

Nr.	Equations 73-76 in spreadsheet notation
73	***cooldt*** [*day*]=IF(AND(PH3>0; PH3<Pb; Pb>0; Tsysini−dTrad>20); IF(Tcontrol=6; (1−PH3/Pb)*1/fcyc; −1,5*LN((Tsysini−dTrad−20)/(Tsysini+dTrad−20))+(wheatoff*dTrad)/PH3); IF(Tsysini>20;0; hd))
74	***cooldt*** [*night*]=IF(AND(PH3>0; PH3<Pb; Pb>0; Tsysini−dTrad>20); IF(autotimer; hd − heatut; IF(Tcontrol=6; (1−PH3/Pb)*1/fcyc; −1,5*LN((Tsysini−dTrad−20)/(Tsysini+dTrad−20)) +(wheatoff*dTrad)/PH3)); IF(Tsysini>20;0; hd))
75	Heatut[day]=IF(AND(PH3>0; PH3<Pb; Pb>0; Tsysini−dTrad>20); IF(Tcontrol=6; (PH3/Pb)*1/fcyc; MIN(hd;(PH3/(Pb−PH3+0,1))*cooldt)); IF(Tsysini>20;hd;0))
76	heatut[night]=IF(AND(PH3>0; PH3<Pb; Pb>0; Tsysini−dTrad>20); IF(autotimer; QH3/ IF(optimiser;MAX(Pbmin5030; 0,3*Pb5030); Pmax); IF(Tcontrol=6; (PH3/Pb)*1/fcyc; MIN(hd;(PH3/(Pb−PH3+0,1))*cooldt))); IF(Tsysini>20;hd;0))

D6. Cycling frequency

If *cooldt+heatut*=0 then the number of cycles per day-period ***Ncyc***=0 else

Ncyc = hd/(cooldt+heatut) **D77**

Total burner-on hours ***onhrs*** per day-period [in h.]:

onhrs = Ncyc * heatut **D78**

Total burner-off hours ***offhrs*** per day-period [in h.:

offhrs = Ncyc * cooldt **D79**

D7. Fluctuation losses

Auxiliary parameters for the determination of the indoor temperature fluctuation losses are

***xtband* = IF(*tband*>0;*tband*;IF(*bband*>0;*bband*/10;1/*fcyc*))** [in K] **D80**

***xtdelay* = IF(OR(*Tcontrol*=1;*Tcontrol*=3);0;*valvedelay*)** [in h] **D81**

The minimum cycle time of 0,01h (36s) in equation D83 is to avoid calculation errors with small numbers.

D82 Fluctuation due to valve control TfluctV	
TfluctV=	
condition IF: **heatut>valvedelay**	
YES	*NO*
0,25*valveband*(1+valvedelay/heatut)	**0,5*valveband**

D83 Fluctuation due to temp. control TfluctT	
TfluctT=	
condition IF: **heatut>0,01**	
YES	*NO*
0,25*xtband*(1+xtdelay/heatut)	**0**

D84 Total fluctuation	
dTfluct	
condition IF: **OR(Tcontrol=1; Tcontrol=3)**	
YES	*NO*
TfluctV	**0,5*(TfluctV + TfluctT)**

D8. Stratification losses

The stratification losses depend on building characteristics (***stratfactor***) as well as the system feed temperature calculated so far: ***Tsysi + dTsysfluct.***

dTstrat = stratfactor***MAX(1,5;1,5+(*****Tsysi+dTsysfluct*****−20)*0,05)** **D85a**

The stratfactor is defined in accordance with the principles of EN 15316-2-1 as

stratfactor = 0,5*(0,225+0,1*Qt/(Qv+Qt) + 0,5*Qv/(Qv+Qt)) **D85b**

With

- ***Qv*** is the specific ventilation loss ***Qv=ah*(qv*(1-qrec)+qinf)*** and
- ***Qt*** is the specific transmission loss ***Qt= AV * U***

Where ***ah*** is the specific heat of air 0,33 Wh/K.m3 and the values for ***qv, qrec, qinf, AV*** and ***U*** are taken from table I1 (Annex I) for the various load profiles.
During the night-period, where room temperature comfort is less relevant, dTstrat is multiplied by 50%.

D9. Distribution losses

Distribution temperature ***Tdistr*** during the day is

Tdistr **= 0,5*(*****Tsysravg + Tsysi*****) +** ***dTsysfluct*** **+** ***dTsysstrat*** **D86a**

In the night period it depends on whether night setback (autotimer=1) is used:

Tdistr=IF(autotimer;(Tsysretcd*cooldt+0,5*(Tsysret+Tsysi)*heatut)/(cooldt+heatut); 0,5*(Tsysravg+Tsysi)) +dTsysfluct+dTsysstrat **D86b**

If *Pmax*=0 and the result<0 then the intermediate power requirement *P_distr* is 0, else

P_distr **=0,001*** ***pdistr******(*****Tdistr*****−20)** **D87**

Values for ***pdistr*** can be found in Annex C.

D10. Solar

The table below gives the consecutive expressions to be solved to calculate the solar contribution to space heating ***Qsolnetsaveh*** and the remaining space heating load after the solar contribution ***Qsolresth***. The expressions are taken from EN 15316-4-3 with a second iteration to include the tank and piping losses (***Qsoltankh*** and ***Qsolpipeh***) in the load. The calculation is done per month, starting from a space heating load Qsolloadh, which is QH6 summed per month.

Table D9. Solar contribution to space heating Qsolnetsavew and remaining space heating load Qsolrestwper month		
Eq. Nr.	**Expression**	Boundary condition
D88	Trefh =100	
D89	Asolh= partsolh * Asol	
D90	Vsolh= partsolh * Vsol	
D91	Ccaph = POWER(75*Asolh/Vsolh;0,25)	IF(Vsolh>0; Ccaph;0)
D92	Xh1= Asolh*(a_c+ UL)*ηloop*(Trefh − Toutm) * Ccaph * 732 / (Qsolloadh*1000)	IF(AND(Qsolloadh>0;Asolh>0);X1;0)
D93	Yh1= Asolh*IAM*η0*ηloop*qsolm*732 / (Qsolloadh*1000);0)	IF(Qsolloadh>0;Y1;0)
D94	Qsolh1= Qsolloadh * (1,029*Yh1 − 0,065*Xh1 − 0,245*Yh1*Yh1 + 0,0018 * Xh1*Xh1+ 0,0215*Yh1*Yh1*Yh1)	MAX(0; MIN(1;Qsolh1/Qsolloadh))*Qsolloadh)
D95	Qsoltankh= partsolh*0,001*UA*(60− (Toutm+solposh*(20−Toutm))) *(Qsolh1/Qsolloadh)*732	IF(Qsolloadh>0;Qsoltankh;0)
D96	Qsolpipeh= partsolh*0,02*Qsolloadh*(Qsolh1/Qsolloadh)	IF(Qsolloadh>0;Qsolpipeh;0)
D97	Qsolloadh2= Qsolloadh+Qsoltankh+Qsolpipeh	
D98	Xh2= Asolh*(a_c+ UL)*ηloop*(Trefh − Toutm) * Ccaph * 732 / (Qsolloadh2*1000)	IF(AND(Qsolloadh2>0;Asolh>0);X2;0)
D99	Yh2= Asolh*IAM*η0*ηloop*qsolm*732 / (Qsolloadh2*1000);0)	IF(Qsolloadh2>0;Y2;0)
D100	Qsolh2= Qsolloadh2 * (1,029*Yh2 − 0,065*Xh2 − 0,245*Yh2*Yh2 + 0,0018 * Xh2*Xh2+ 0,0215*Yh2*Yh2*Yh2)	MAX(0;MIN(1;Qsolh2/Qsolloadh2))*Qsolloadh2
D101	Qsolloadresth = Qsolloadh2 – Qsolh2	
D102	Qsolauxlossh = partsolh * 0,001 * (2000*qsolm/Q_solm)*solauxh*(2,5−0,85*solpos)	IF(Asol>0; Qsolauxlossh; 0)
D103	Qsoltankrecovh = (solpos*0,55)*0,001*UA*(60 − (Toutm+solpos*(20−Toutm))) * (Qsolh2/Qsolloadh2) * 732	IF(Qsolloadh2>0; Qsoltankrecovh;0)
D104	Qsolnetsaveh= Qsolloadh−Qsolloadresth−Qsolauxlossh+Qsoltankrecovh	MIN(Qsolloadh; MAX(0; Qsolnetsaveh))
D105	Qsolresth = Qsolloadh – Qsolnetsaveh	
D106	Qsolnetconsh = Qsoltankh+Qsolpipeh+Qsolauxlossh-Qsoltankrecovh	

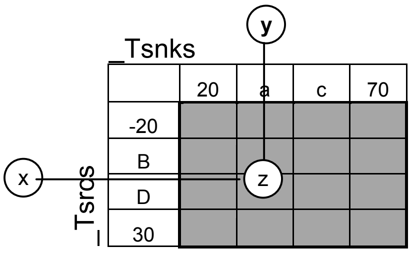
The annual net consumption of the solar installation ***Qsolnetconsh***, as consequence of pump, tank, piping etc. is a direct input to the total annual energy consumption QH11 (see equation D48).

The remaining space heating load *Qsolresth* is used as an input for the calculation of the heat pump technology contribution. Note that if there is no solar contribution (*Qsolnetsaveh*=0) the remaining load equals the original space heating load *Qsolloadh*.

D11. Heat pump

D11.1 Asssesment of 'Seasonal' and part-load correction factors

Starting point are two matrices of (at least) 4 x 4 points resulting from section D2.5: one _HPPmatrix for the correction factors of the power output Phpnom and another one –with identical sink and source temperatures-- for the correction of the COP, called _COPmatrix. The array of sink temperatures, indicated as [20;a;c;70] in the picture below, will be called _Tsnks. The array of source temperatures [-20;b,d;-30] will be referred to as _Tsrcs.



Goal is the assessment of an unknown value z=correction factor for a given source temperature x=Tsrc and and a given sink temperature y=Tsnkin each day-period. The source temperature Tsrc depend on the source-type (air, water, brine) and the "season", i.e. the month and day-period. The source temperature per day-period is identical for space heating and water heating (see also paragraph E9). An overview of source temperatures per day-period is given in table C5. The type of source is chosen through the parameter HPtype (param. nr. 16.3)

Tsrc = CHOOSE(HPtype;Tsrc_brine;Tsrc_water;Tsrc_airmix;Tsrc_airmix; Tsrc_water; Tsrc_water) D107

where Tsrc_airmix indicates an air-source heat pump, but with a correction for the possible use of (also) ventilation exhaust air:

Tsrc_airmix = IF(Phpnom*hpaf>0;MIN(MAX(20;Tout);((Phpnom*hpaf-ventmix*ventex)*Tout + ventmix *ventex *MAX(20;Tout)) /(Phpnom*hpaf));0) D108

The sink temperature is specific for space and water heating. For space heating it depends on the system feed temperature for a specific day-period, established for the heating system in previous paragraphs, with a declared maximum Tsnkmax [declared by manufacturer as param. nr. 16.6]

Tsnk = IF(Tsysfeed<Tsnkmax;Tsysfeed;Tsnkmax) D109

With the Tsrc and Tsnk for a specific day-period, the correction factor can be found first by finding the 4 given neighbouring values within the matrices _HPPmatrix and _COPmatrix and then making an interpolation on the basis of how far the sink- and source temperatures of these neighbouring values are from the actual Tsnk and Tsrc.

For this the function MATCH is used, which first finds –for a given reference-- the closest lower value in the _Tsnks and the _Tsrcs arrays. I This results in the values ***col*** and ***row***. Col and Row identify the 4 neighbouring source temperature, sink temperature and correction values inside _Tsrcs, _Tsnks and _HPPmatrix or _COPmatrix. As a final step the weighted interpolation between the neighbouring values val1 to val4 and val1cop to val4cop is done. Note that src1 to src4 and snk1 to snk4 are identical for _HPPmatrix and _COPmatrix, so they have to be assessed only once.

Table D10. Assessment per day-period of space heating correction factor for output power *hppcorrh* and Coefficient of Performance *COPcorrh*

Eq.nr.	Equation
D110	**col** = MATCH(x; [-20;b;d;30]) → address of the column number [1-4]
D111	**row** = MATCH(y; [20;a;c;70]) → address of the row number [1-4]
D112 (a)	**src1** = INDEX(_Tsrcs;row)
D112 (b)	**src2** = INDEX(_Tsrcs;row)
D113 (a)	**src3** = INDEX(_Tsrcs;row+1)
D113 (b)	**src4** = IINDEX(_Tsrcs;row+1)
D114 (a)	**snk1** =INDEX(_Tsnks;col)
D115 (a)	**snk2** =INDEX(_Tsnks;col+1)
D115 (b)	**snk3** = INDEX (_Tsnks;col+1)
D114 (b)	**snk4** =INDEX(_Tsnks;col)
D116	**Val1** =INDEX(_HPPmatrix; row;col)
D117	**Val2** = INDEX(_HPPmatrix;row;col+1)
D118	**Val3** =INDEX(_HPPmatrix;row+1;col+1)
D119	**Val4** = INDEX(_HPPmatrix;row+1;col)
D120a	**hppcorrh** = val3*ABS(((src1−Tsrc)*(snk1−Tsnk))/((src1−src4)*(snk1−snk2)))+ val4*ABS(((src2−Tsrc)*(snk2−Tsnk))/((src1−src4)*(snk1−snk2)))+ val1*ABS(((src3−Tsrc)*(snk3−Tsnk))/((src1−src4)*(snk1−snk2)))+ val2*ABS(((src4−Tsrc)*(snk4−Tsnk))/((src1−src4)*(snk1−snk2)))
D121	**Val1cop** =INDEX(_COPmatrix;row;col)
D122	**Val2cop** =INDEX(_COPmatrix;row, col+1)
D123	**Val3cop** =INDEX(_COPmatrix;row+1;col+1)
D124	**Val4cop** = INDEX(_COPmatrix;row+1;col+1)
D125a	**COPcorrh** = val3cop*ABS(((src1−Tsrc)*(snk1−Tsnk))/((src1−src4)*(snk1−snk2)))+ val4cop*ABS(((src2−Tsrc)*(snk2−Tsnk))/((src1−src4)*(snk1−snk2)))+ val1cop*ABS(((src3−Tsrc)*(snk3−Tsnk))/((src1−src4)*(snk1−snk2)))+ val2cop*ABS(((src4−Tsrc)*(snk4−Tsnk))/((src1−src4)*(snk1−snk2)))

Because the calculations for the heat pump performance according to prEN 15316-4-2 in the next parahgraph are done per month and not per day-period, the monthly averages of ***hppcorr*** and ***COPcorrh*** have to be established from the length (in h.) of each day-period. Below the monthly averages ***hppcorrhm*** and ***COPcorrhm*** are given:

hppcorrhm = (2*hppcorrh[morn] +7*hppcorrh[mid] +5*hppcorrh[eve] +2*hppcorrh[late] +8*hppcorrh[night])/24 D120b

COPcorrhm = (2*COPcorrh[morn] +7*COPcorrh[mid] +5*COPcorrh[eve] +2*COPcorrh[late] +8*COPcorrh[night])/24 D125b

D11.2 Heat pump contribution to space heating and rest load

The table below gives the equations calculating the heat pump contribution to space heating, mostly per month, following prEN 15316-4-2. The initial heat pump load ***Qloadhph*** is given by what remains from the total heat load after a possible solar contribution, if any. This is then compared to the maximum output ***Qhpmaxh*** [in kWh/month] to find the load factor ***FCh***. ***Qhpmaxh*** takes into account the 'seasonal' output power correction ***hppcorrhm*** and the partitioning between space and water heating ***parthph***,

FCh and the declared 50% part load efficiency ***COP50*** [param. nr. 16.5] are used to establish the part load efficiency correction factor ***COPpartcorrh***. Combining the latter with the COP correction for sink- and source temperature ***COPcorrhm*** the final and overall COP correction factor ***COPcorr2h i***s found. With ***COPcorr2h*** and the heat demand in that month (maximized by ***Qhpmax***) the gross monthly primary energy consumption ***Qhpcons*** can be assessed. This last parameter takes into account whether the power source is electric (primary energy conversion factor 2,5) or fossil (factor 1).

Additionally the auxiliary energy ***Qhpauxh*** is calculated from the declared value for ***hpaux*** [param. nr. 16.7], for which the manufacturer has followed indications outlined in paragraph B6. Partitioning between space and water heating with parameter ***parthph***. For the heat pump 55% of the auxiliary energy is assumed recovered (corrected for primary energy conversion).

With the above the total monthly energy consumption ***Qhpnetconsh***, energy saving ***Qhpnetsaveh*** and remaining energy ***Qresthp*** can be assessed for the heat pump. Because the remaining energy has to be filled in by a back-up heater and the following calculation, at least for a fossil fuel fired back-up heater, will be not per month but per day-period, the monthly ***Qresthp*** to the value ***Qrest*** per day-period using the original input load ***QH6*** have to be recalculated. The power requirement per day-period ***Prest*** [in kW] is derived from ***Qrest***, dividing by the length of the day-period ***hd*** (in h.).

Note that the annual sum of ***Qhpnetconsh***, is a direct input to the total annual energy consumption QH11 (see equation D48).

Table D10. Heat pump contribution to space heating and remaining load Qrest and Prest

Eq.nr	Description	Equation	Boundary condition
D126	Heat load for heat pump (month)	**Qhploadh = Qsolresth**	
D127	Maximum output available (month)	**Qhpmaxh= parthph*Phpnom*hppcorrhm*732**	
D128	Load factor (month)	**FCh=Qhploadh/Qhpmaxh**	IF(Qhpmaxh>0;FCh;0)
D129	Part load correction (month)	**COPpartcorrh=COP50+2*(1−COP50)* (MAX(0;MIN(1;FCh)−0,5))**	
D130		**void**	
D131	final Cop correction (including part load, month)	**COPcorr2h= COPpartcorrh*Copcorrhm?*COPnom**	
D132	Heat delivered (month)	**Qhph=MIN(Qhploadh; Qhpmaxh)**	
D133	Primary energy consumed (month)	**Qhpcons=IF(HPtypeh<4; 2,5; 1)* (Qhph/COPcorr2h)**	IF(AND(Phpnom>0;COPcorr2h>0); Qhpcons;0)
D134	Auxiliary (primary) energy (month)	**Qhpauxh= parthph * primenergy *0,001* 732*FCh *hpaux**	IF(Phpnom>0;Qhpauxh;0) IF(FCh>1;FCh=1;FCh)
D135	Auxiliary heat recovered (month)	**Qhprecovh =0,55*Qhpauxh/primenergy**	
D136	Net energy consumed (month)	**Qhpnetconsh=Qhpcons+Qhpauxh−Qhprecovh**	

D137	Net energy saved (Month)	**Qhpnetsaveh= Qhph – Qhpnetconsh**	
D138	Heat load remaining (month)	**Qresthph = Qhploadh−Qhph**	IF(Qresthph<0;0;Qresthph)
D139	Heat load remaining (day-period)	**Qrest = (Qresthph/Qsolloadh) * QH6**	A montly value (Qresthph/Qsolloadh) is transformed to dayperiod by multiplying with QH6
D140	Power load remaining (day-period	**Prest= Qrest/ hd**	

D12. Electric back-up in primary energy *ELBU*

Inputs are

- the remainder of the load ***Prest*** and ***Qrest*** (=Prest*hd), after the contribution of the solar collector (if any) and heat pump (if any),
- the primary energy conversion factor ***primenergy*** (2,5)
- the Boolean variable (yes/no) ***ELBU*** indicating whether or not an electric back-up space heater is used.

The primary energy consumption of the electric back-up space heater is ***Qelbu***:

Qelbu* = IF(*ELBU*; *primenergyQrest*; 0)** **D141**

If *ELBU*=yes then there is no remainder of the load. If *ELBU*=no then
Prest1=Prest and *Qrest1=Qrest*

D13. Standby heat loss (*pref*)

Standby heat power losses:

Pbstby = p_bstby * Qb8060 **D142**

If *Prest1*=0 or *Tdistr*<=20 then envelope losses in burner-off mode ***Pbenvoff*** [in kW] is 0 else

***Pbenvoff* = *Pbstby**POWER((*Tdistr* −20)/20;1,25)** **D143**

Equation from prEN 15316-4-1

Pilot flame energy consumption per day-period

Qign = offhrs*Pign [in kWh] **D144**

If *Qrest1*=0 then the off-mode envelope energy losses ***Qenvoff*** are equal to ***Qign*** else the number of *offhrs* is corrected for the latest energy data (expression *QH3*/*Qrest1*) and multiplied with the envelope power losses *Pbenvoff*. To this the pilot flame energy Qign is added.

Qenvoff* = *offhrs** (*QH3*/*Qrest1*)**Pbenvoff* + *Qign **D145**

Qenvoff has to be corrected for waste heat recovery. The waste heat recovery either follows from the parameter *combicomp* (in case *combicomp*=yes) or from the parameter ***qrecovb_winter*** (for months Oct.-April) and ***qrecovb_transit*** (for months May and Sept.). The "MIN" function makes sure that the largest of the two is always taken into account.

D146	Envelope power losses during burner off *Penvoffrest*
Penvoffrest *condition IF:* **combicomp**	
YES	*NO*
MIN((1−CHfrac) *Qenvoff/hd; (1−qrecovb_winter) *Qenvoff/hd)	**(1−qrecovb_winter) * Qenvoff/hd**

D14. Fuel losses

Under the heading "fuel losses" the heat losses during the purge-phase (combustion fan on) of each cycle ***Qlosspurge*** and the fuel losses ***Qlossfuel*** of each cycle are defined.

If *Prest1*=0 then the purge losses *Qlosspurge*=0 else they depend on

- the pre-purge time *tpurge* [in h, see ref. conditions for values],
- the lowest heat input power ***Qbmin8060*** [in kW],
- the air factor *lambda* with a small correction of 0,1 [-],
- the specific heat of air ***ah*** [0,33 Wh/K.m3],
- the difference between the outdoor temperature and the temperature of the boiler heat exchanger [***Tsysi+dTsysfluct+dTsysstrat−Tout***, in K] and
- the number of cycles in the day-period *Ncyc*

$$Qlosspurge = tpurge*Qbmin8060*(0{,}1+lambda)*0{,}001*ah*(Tsysi+dTsysfluct+dTsysstrat-Tout)*Ncyc \quad \text{D147}$$

If *Prest1*=0 then the fuel losses *Qlossfuel*=0 else they depend on

- The fuel loss factor *flf* [see Annex C for values]
- The heat energy demand so far [*QH7* + *Qlosspurge*, in kWh]
- The ratio between the total number of cycles *Ncyc* and a reference value of 14.000 cycles

$$Qlossfuel = (QH7+Qlosspurge)*flf*(dpm*SUM(Ncyc)/14000) \quad \text{D148}$$

D15. Steady state efficiency (*pref*)

D15.1. Overall efficiency

The overall steady state efficiency implies an extrapolation from a number of anchor-points. The principle is illustrated in the matrix below:

Tsysrini →

(Pb/Pb8060) ↓

	60>Tsysrini>dptc	dptc>Tsysrini>30		30>Tsysrini
η8060	?	?	η5030	?
?	?	?	?	?
η8060min	?	?	η5030min	?

The extrapolation is done in 3 steps. First the extrapolation in the top row of the matrix is done (nominal power level but different temperatures), expressed as ***Csysmax***. Then the extrapolation in the bottom row of the matrix (minimal power level but different temperatures), expressed as ***Csysmin*** (minimal power level at different return temperatures). Finally ***η8060*** is introduced, which wasn't taken into account in *Csysmax* and *Csysmin*, and make the interpolation between *Csysmax* and *Csysmin*, depending on the actual power level

D149 **Csysmax**

Csysmax= *condition IF:* **Tsysrini<60**		
YES		*NO*
condition IF: **Tsysrini>dptc**		**0**
YES	*NO*	
(60−Tsysrini)*0,001	**(60−dptc)*0,001 +** **((η5030 − η8060) – (60−dptc)*0,001) *** **(dptc −Tsysrini)/(dptc − 30))**	

D150 **Csysmin**

Csysmin= *condition IF:* **Tsysrini<60**		
YES		*NO*
condition IF: **Tsysrini>dptc**		**0**
YES	*NO*	
(60−Tsysrini)*0,001	**(60−dptc)*0,001 +** **((η5030min − η8060min) − (60−dptc)*0,001) *** **(dptc −Tsysrini)/(dptc − 30))**	

IF ***Pb8060***=0 then steady state efficiency ***ηb*** = 0 else

$$\eta b = \eta 8060 + Csysmax + (Prest1/Pb8060)*(\eta 8060min + Csysmin - \eta 8060 - Csysmax) \quad \text{D151}$$

The energy demand including steady state loss ***QHss*** = 0 if *ηb*=0 and *QH8*=0 else

$$QHss = QH8/ \eta b \quad \text{D152}$$

The energy loss only due to the steady state losses is *QH9 – QH8* [in kWh]. Of this the share of envelope losses is calculated.

D15.2. Envelope losses during on-mode

The envelope heat power losses ***Penvon*** are calculated. These depend on the envelope heat losses at 50 °C *Pbstby*, corrected for the actual average boiler temperature 0,5*(*Tsysfeed* + *Tsysrini*). The equation comes from prEN 15316-4-1.

$$Penvon = Pbstby*\text{POWER}((0,5*(Tsysfeed+Tsysrini) - 20)/20;1,25) \quad \text{D153}$$

Conditions are that *Prest1*>0 and the average system temperature is higher than ambient (0,5*(*Tsysfeed*+*Tsysrini*)>20)

Penvon is then used to calculate the heat energy loss in burner-on mode ***Qenvon***. Multiplier is the number of burner-on hours onhrs, corrected for the actual energy demand (multiplier *Qrest1*/*QH3*). As a safety measure the number is maximised to the highest possible number of hours per day-period hd. Also the value of *Qenvon* can never be higher than 75% of the total steady state energy losses (see prEN 15316-4-1). Within these boundaries

$$Qenvon = Penvon * \text{MIN}(hd; onhrs * (Qrest1/QH3)) \quad \text{D154}$$

Qenvon indicates losses that are "recoverable". ***Qenvonr*** indicates envelope losses that are actually "recovered". The fraction that is recovered depends either on the parameter *combicomp* (see Annex C13) certain types combi-boilers or on the parameter *qrecovb_winter* (for Oct.-April) and *qrecovb_transit* (for May and Sept, *qrecovb_transit*=0). The variable *qrecovb_winter* depends on the position of the boiler in the heated space of the dwelling.

If *QH3*>0 then

D155 **Recovered envelope heat losses Qenvonr during burner on** (if QH3>0)	
Qenvonr = *condition IF:* **combicomp**	
YES	*NO*
MAX (CHfrac * Qenvon; qrecovb_winter * Qenvon)	**qrecovb_winter*Qenvon**

The MAX function makes sure that in case of *combicomp*=yes the model always selects the highest value of the two recovery options. Note that equation D155 is valid for the period Oct.-April. For the transit period (May+Sept.) use *qrecovb_transit* and for the summer (June-Aug.) use *qrecovb_summer* instead of *qrecovb_winter.*

D15.3. Twostage

In case of a multi-stage boiler, instead of a step-less modulating boiler, there is a correction on the steady state efficiency, which amounts to 5% of the envelope losses. This correction is activated when *twostage*=yes [param. nr. 3.3, yes/no]

Qtwostage* = 0,05 * *twostage* * *Qenvon D156

All in all, the energy requirement after this stage is ***QH9***

QH9* = *QHss – Qenvonr + Qtwostage D157

D16. Standby heat loss (nopref)

Starting point is the remaining power ***Prest2*** and energy ***Qrest2*** (see eq. D35, D36).

In case of a non-preferential boiler basically the same equations apply as in sections D13 to D15 but some boiler-specific parameter names change. The table gives an overview

Table D11. Heating parameters non-preferential boilers

Eq. nr.	Parameter name	Equation	Boundary condition
D158	Pbstbyb	= p_bstbyb * Qb8060	
D159	Penvoffb	= Pbstbyb * POWER((Tdistr −20)/20;1,25)	=IF(Tdistr<=20;0;Penvoffb)
D160	Qignb	= offhrs * Pignb	
D161	Qenvoffb	= offhrs * (QH3/Qrest1)*Pbenvoffb + Qignb	
D162	Penvoffrestb (if combicomp)	= MIN(Prest2+(1−CHfrac) * Qenvoffb/ hd; Prest2 +(1−qrecovb_winter) * Qenvoffb/hd)	
D163	Penvoffrestb (else)	= Prest2 + (1−qrecovb_winter) * Qenvoffb/hd	
D164	Qlosspurgeb	= tpurge * Qbmin8060b * (0,1+lambda) * 0,001 * ah *(Tsysi+dTsysfluct+dTsysstrat−Tout) * Ncyc	
D165	Qlossfuelb	= (QH7b?+Qlosspurgeb?) * flf * (dpm*sum(Ncyc)/14000)	
D166	Csysmaxb	=(60−dptc) * 0,001 + ((η5030b − η8060b – (60−dptc)*0,001) * (dptc −Tsysrini)/(dptc − 30))	
D167	Csysminb	=(60−dptc) * 0,001 + ((η5030minb − η8060minb) − (60−dptc)*0,001) * (dptc −Tsysrini)/(dptc − 30))	
D168	ηbb	= η8060b + Csysmaxb + (Prest1/Pb8060b) * (η8060minb + Csysminb − η8060b – Csysmaxb)	= IF(Qb8060b>0; ηbb;0)
D169	QHssb	= QH8b / ηbb	= IF(ηbb>0;QH8b / ηbb;0)
D170	Qtwostageb	= 0,05 * twostageb * Qenvonb	
D171	Penvonb	= Pbstbyb*POWER((0,5*(Tsysfeed+Tsysrini) −20)/20;1,25)	
D172	Qenvonb	= MAX(0,75*(Qrest1-QH8b);Penvonb* MIN(hd; onhrs* (Qrest1/QH3)))	= IF(Qb8060b>0; Qenvonb;0)
D173	Qenvonrb	= MAX (CHfrac * Qenvonb; qrecovb_winter * Qenvonb); qrecovb_winter*Qenvonb)	= IF(combicomp=yes,

D17. Fuel losses (nopref)

See Table D10.

D18. Efficiency (nopref)

See Table D10.

D19. Standby heat loss (total)

Equations D42, D43 apply.

D20. Fuel losses (total)

Equations D44, D45 apply.

D21. Efficiency (total)

Equations D46 apply.

D22. Electricity consumption

Recalculate the number of *onhrs* and *offhrs*, depending on the final energy demand.
The final number of burner-on hours ***onhrsz*** is 0 when *QH3*=0. Also it cannot exceed the total number of hours per day-period hd (*onhrsz*<=*hd*). Within these boundary conditions

onhrsz =(QH9tot / QH3)*onhrs **D174**

The final burner-off hours ***offhrsz*** are the complement of the *onhrsz*:

offhrsz = hd – onhrsz **D175**

First the ***powerratio*** of the preferential boiler is calculated in case *PH8*>0 and *Pmax*>0 (else result is 0). This *powerratio* is either the turndown ratio or the ratio between the power demand *PH8* and the maximum power of the installation *Pmax*, whichever is highest.

***powerratio* = MAX(*turndown*;*PH8*/*Pmax*))** **D176**

During the night-period, or rather during the reheat hours in the very early morning, and in case of *autotimer*=yes and *optimizer*=no the power ratio is at its maximum:

powerratio = Pb/Pmax **D177**

If *heatload*>0 and *Pmax*>0 (else ***Qbelon***=0) the primary energy consumption of the electricity use during burner-on modes is

***Qbelon*= (*elminonz* + MAX(0;*powerratio*−*turndown*)*(*elmaxonz*−*elminonz*)) * *onhrsz* * *primenergy* − *qrecovb_winter*))** **D178**

The primary energy consumption of the electricity consumption in standby (pump off, burner off) is

Qbstbyel= offhrsz*elstby*primenergy **D179**

The primary energy consumption of the electricity consumption for the pump during burner- off ***Qpmpel*** is never higher than a maximum of *hd*elpmpz*(primenergy−qrecovb_winter*). Within that boundary condition and during the day (*morn, mid, eve, late* periods)

Qpmpel[day] = (*realflow/fixflow*)Ncyc***MIN(*tpmp;cooldt*)**elpmpz*(primenergy−recovb_winter*)** **D180**

During the *night*-period also the pump-setback ***pmpsb*** [param. nr. 9.x, yes/no] may play a role.

Qpmpel[night] = (realflow/fixflow)*Ncyc*MIN(IF(pmpsb;0;tpmp);cooldt))*elpmpz *(primenergy −qrecovb_winter) **D181**

For the months of May and September the parameter *qrecovb_transit* has to be used instead of *qrecov_winter* in the equations D178, D180 and D181.

The total electricity consumption of the boiler ***QH10*** is

QH10 = Qbelon + Qbstbyel + Qpmpel **D182**

D23. Model outputs: space heat efficiency

The annual net heat load per load profile is given by ***QH*** (equation nr. C5), corresponding to **Output A.1. "Space heat load"** [in kWh/a] in the Data Report (see Annex B).
The sum of the primary energy consumption of the CH-boiler is given by **QH11** (equation D48, in section D2.6). QH11 corresponds to **Output A.2. "Space heat primary energy use" [** in kWh/a].

Output A.3 "Space heat efficiency" is the ratio between Outputs A.1 and A.2:

Output A.3 = Output A.1 / Output A.2

D183

Which is equivalent to space heating efficiency ***ηch***

ηch **= net heat load *QH* / primary energy consumption *QH11***

Using table C15 in Annex C the (provisional) efficiency rating can be assessed.

ANNEX E: WATER HEATING MODEL

E1. Inputs

On the basis of the inputs from Annex B and C this annex gives the mathematical model used to evaluate the energy efficiency of dedicated water heaters or the water heating function of a CH-combi. The diagram below gives an overview of the steps in the mathematical model

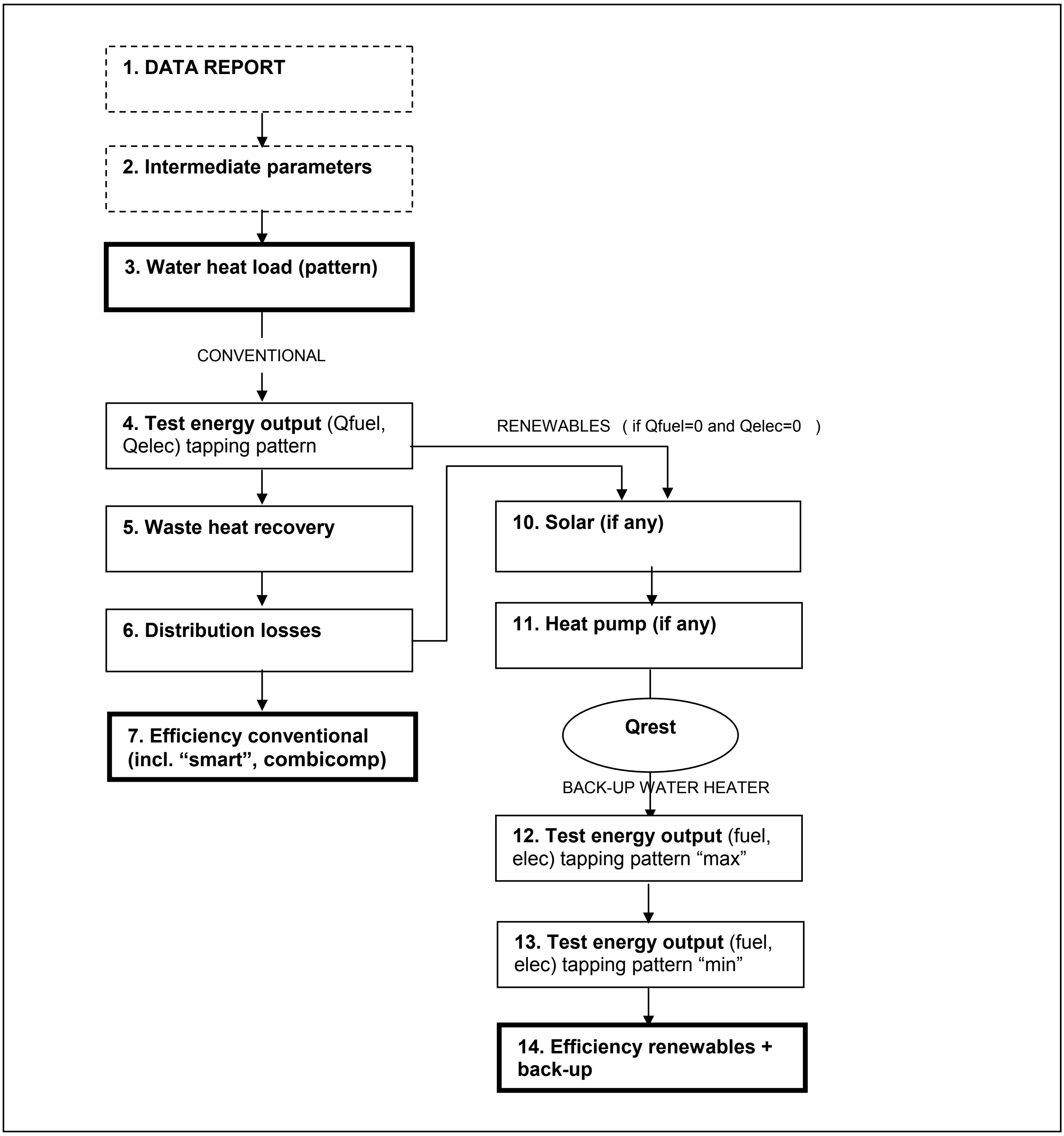


Fig. 7. Water heating (WH sheet) structure, Summary.

E2. Intermediate parameters

Equation D10 for waste heat recovery parameter ***qrecov*** applies.

Equations D11, D12 and D13 for solar technology apply to calculate ***a_c, ηloop*** and ***UL***.

Equation D14 applies to calculate ***Tsrc_ventmix*** for heat pump technology that (also) uses ventilation exhaust air.

The extrapolation of test-points for heat pump technology to arrive at least at a 4x4 matrix follows the methodology and equations as in section D2. 5. The resulting matrices _HPPmatrix, _COPmatrix and the arrays of sink and source temperatures _Tsnks and _Tsrcs are identical to the ones calculated there.

Accounting parameters for the water heating function are less numerous and integrated in the following sections.

Sections E4 to E6 deal with conventional water heaters. Sections E7 to E11 deal with the efficiency assessment of water heaters that (also) employ renewable energy sources. Note that the model assumes the latter when Qfuel [param. nr. 12.1] + Qelec [param. nr. 12.2] = 0. Otherwise, a conventional water heater is assumed.

E3. Load

For the most part the water heating efficiency assessment is based on test results with the tapping pattern pertaining to the selected water heating load (param. nr. 11.1 in the data report in Annex B). For this part it is immaterial whether a multiplier is used: the efficiency stays the same. For a relatively smaller part of the efficiency assessment, i.e. relating to waste heat recovery and distribution losses, it is assumed that the full testing pattern represents a peak situation, i.e. in the weekends, and that on average only 60% of the indicated hot water energy of the tapping pattern will be used.
The 24-hour hot water energy output of a test-tapping pattern ***Qref*** [in kWh/d] is given in the last row of table C4 in Annex C. For the conversion from this test load energy to the average annual heat load ***Qaload*** a factor 0.6 (60%) is applied during 366 days (actually 365,2 but rounded upwards to be consistent with a month period of 30,5 days).

***Qaload* [selected load]= 0.6 * 366 * *Qref* [selected load]** **E1**

The actual annual energy consumption ***Qanet*** is derived from the fossil-fuel consumption *Qfuel* [in kWh] and the electricity consumption *Qelec* [in kWhe] for the test-tapping pattern, also with a multiplier of 0,6 during 366 days. For the electricity consumption *Qelec* the primary energy conversion factor *primenergy* (=2.5) is applied. The expression also takes into account the presence of the smart control ***dhwsmart*** [yes/ no= 1/ 0], which results in a 10% efficiency improvement (see Annex H).

***Qanet* [generic] = (1-*dhwsmart**0,1) * 0.6 * 366 * (*Qfuel*+*primenergy**Qelec*))** **E2a**

Note that for electric water heaters (*Qfuel*=0; *Qelec*>0) the efficiency improvement of the smart control can never lead to a primary energy efficiency of more than 40%, hence the function below gives a boundary condition in case Qfuel=0:

***Qanet* [electric water heater] = MAX (*primenergy* * *Qaload*; *Qanet* [generic])** **E2b**

Note that the ratio (*Qaload/Qanet*) gives the net efficiency for the water heating (excl. distribution losses and without credits for waste heat recovery.

E4. Waste heat recovery

E4.1 Recoverable losses

The calculation of recoverable losses only applies to conventional water heaters. For water heaters with solar and/or heat pump technology the recoverable and recovered losses are treated in section E6.

Basis for the calculation is the assessment of the total losses ***Qwaste*** from the fossil energy consumption *Qfuel* [in kWh] and the electricity consumption *Qelec* [in kWhe] for the tapping pattern compared to the useful energy in the hot water ***Qref*** [in kWh, Qref defined in Annex C].

Qwaste* = *Qfuel* + *Qelec* − *Qref E3

For electric water heaters all waste heat is recoverable : ***Qrwaste*** = *Qwaste*

For conventional dedicated fossil-fuel fired water heatersand for combi-boilers where Qcombicomp=no the recoverable fraction follows from

1. the corrected dew point dptc . [see equation C13, Annex C]
2. the combustion efficiency ηcomb [param. nr. 13.1, in %]
3. the flue gas temperature Tflue [param. nr. 13.2, in °C]
4. the latent heat loss LHL, depending on the fuel [param. nr. 6.2, if gas then 10% else 6%]

The expression for recoverable waste heat loss is in this case

***Qrwaste* [dedicated gas/oil water heater] = *Qwaste* − (1−*ηcomb)**Qfuel* − IF(*Tflue*<*dptc*+20; ((*Tflue*−20)/(*dptc*+20))**LHL*Qfuel; LHL*Qfuel*))** E4

For fossil-fuel fired combi-boilers without separate cylinders, i.e. *combicomp*=yes, the credits come from the combicomp variable (see below).

E4.2 Recovered loss

The percentage of waste heat recovered for the water heater is determined by the parameters boilpos, air_intake, volumeb and noisew and result in the reference value qrecov explained in Annex D2 and equation D10.

The annual credit for heat recovery ***Qarecover*** [in kWh/a] again takes into account only 60% of the test load for a total of 366 days/a (actually 365,2 but rounded to upper value to be consistent with an average month period of 30,5 days/month)

Qarecover* = 0,6 * 366 * − *qrecov* * *Qrwaste E5

For combi-boilers where *combicomp*=yes the credit depends on the remaining envelope losses in burner-on mode (*Qenvon-Qenvonr* summed over a year) and burner-off mode (*QH7-Qrest1* summed over a year) :

***Qcombicomp* =** E6
-30,5 * {(SUM(*Qenvon*)-SUM(*Qenvonr*))+(SUM(*QH7*)−SUM(*Qrest1*))}

(this assumes that a calculation for space heating demand has been performed and values for *Qenvon, Qenvonr, QH7* and *Qrest1* are known).

E5. Distribution losses

The distribution losses depend on the *airintake* [param. nr. 7.1, values 1/2/3 corresponding to “none (electric)”, “room sealed” / “open”] and *volumeb* [param. nr. 7.3, in m³], as is shown in the table. Values take into account only distribution losses inside dwellings. For collective/centralized systems as well as circulation systems extra distribution losses and –in case of an extra store—storage losses are to be taken into account in application-oriented measures (see also Annex J).[10]

Table E1. Determination of parameter Qwdistr

parameter = Qwdistr [kWh/a]										
air_intake	volumeb	Load profile								
[−]	[m3]	XXS	XS	S	M	L	XL	XXL	3XL	4XL

[10] Under consideration: Add forfaitary extra distribution losses for load profiles XXL, 3XL, 4 XL because at least in part they will be used in centralised systems.

none (electric)	<=0,5	15	15	15	15	15	15	15	15	15
	>0,5	80	80	120	240	240	240	240	480	960
roomsealed	<=0,1	15	15	80	120	240	240	240	480	960
	>0,1, <0,15	80	80	120	160	240	240	240	480	960
	>=0,15	80	80	120	240	240	240	240	480	960
open	any value	80	120	240	240	240	240	240	480	960

The primary energy for distribution ***Qadistr*** is found by applying the previously found net efficiency (*Qaload/Qanet*) to the established ***Qwdistr*** [in kWh/a]:

Qadistr = (Qanet/Qaload)*Qwdistr **E7**

E6. Model output: efficiency conventional Water Heater

The preliminary annual energy consumption of the water heater ***Qawh*** results from the summation of the energy consumption for water heating *Qanet* and the distribution losses *Qadistr*

Qawh=Qanet+Qadistr **E8**

For the final annual energy consumption of the conventional water heater ***Qatot*** also the credits (negative value!) from the waste heat recovery *Qarecover* and the compensation for the combi-boiler ***Qcombicomp*** have to be taken into account

Qatot = Qawh + Qarecover + Qcombicomp **E9**

The calculation of Qcombicomp can only be performed if calculation of space heating section is completed with ***Qcombicomp*** = ***Qenvon*** − ***Qenvonr*** + ***QH7*** (if ***combicomp*** and ***Qfuel***+***Qelec*** >0)

The total efficiency of the conventional water heater ***ηwh*** is given by

ηwh = Qaload/ Qatot **E10**

In the Data Report (Annex B), Output B.1 "Water heat net load" corresponds to ***Qaload***. Output B.2. "Water heat primary energy use" is ***Qatot*** and Output A.3 "Water heat energy efficiency" is given by ***ηwh.***

E7. Water heater with renewables: load and partitioning

E6.1. Load

The annual reference load *Qaload* [in kWh/a] and the distribution losses *Qadistr* [in kWh/a] are used as an input for the monthly solar load ***Qsolloadw***:

***Qsolloadw = (Qaload + Qadistr*)/12** **E11**

E6.2. Multiple functionality

In case the solar and/or heat pump capacity is used for both space and water heating, this capacity is partitioned according to the space heating energy load *QH3* and the water heating energy load *Qtap* per day-period as was already shown in Annex D. *QH3* comes from the space heating model. *Qtap* per dayperiod is given in Annex C.

CHfrac= QH3/(Qtap+QH3) **E12**

To arrive at an average fraction per month the above value is weighted for the duration of the 5 day periods (2, 7, 5, 2, 8 hours):

***CHfracm*= (2**CHfrac[morn]*+7**CHfrac[mid*]+5**CHfrac[eve*]+2**CHfrac[late]*
+ 8**CHfrac[night*])/24**

E13

CHfrac is used to partition the capacity of solar and heat pump technology for the water heater as a function of parameters *usesol* and *usehp*.

For a more compact representation the following auxiliary parameters are defined:

***partsolw* = CHOOSE(*usesol*; 0; 1; 1−*CHfracm*)** E14

***parthpw* = CHOOSE (*usehp*; 0; 1; 1−*CHfracm*)** E15

E14 **partsolw depending on usesol**

CHOOSE	
usesol	
if value	then equation
	partsolw
1	= 0
2	= 1
3	= 1−CHfracm

E15 **parthpw depending on usehp**

CHOOSE	
usesol	
if value	then equation
	parthpw
1	= 0
2	= 1
3	= 1−CHfracm

E8. Solar contribution

The table below gives the consecutive expressions to be solved to calculate the solar contribution to water heating ***Qsolnetsavew*** and the remaining water heating load after the solar contribution ***Qsolrestw***. The expressions are taken from EN 15316-4-3 with a second iteration to include the tank and piping losses (***Qsoltankw*** and ***Qsolpipew***) in the load. The calculation is done per month.

Table E2. Solar contribution to water heating Qsolnetsavew and remaining water heating load Qsolrestw per month

Eq. Nr.	Expression	Boundary condition
E16	Trefw =11,6+1,18*40+3,86*Tcold−2,32*Toutm	
E17	Asolw= partsolw * Asol	
E18	Vsolw= partsolw * Vsol	
E19	Ccapw = POWER(75 *Asolw/ Vsolw;0,25)	IF(Vsolw>0; Ccapw;0)
E20	Xw1= Asolw*(a_c+ UL) *ηloop*(Trefw − Toutm) * Ccapw * 732 / (Qsolloadw*1000)	IF(AND(Qsolloadw>0;Asolw>0);X1;0)
E21	Yw1= Asolw*IAM*η0*ηloop*qsolm*732 / (Qsolloadw*1000);0)	IF(Qsolloadw>0;Y1;0)
E22	Qsolw1= Qsolloadw * (1,029*Yw1 − 0,065*Xw1 − 0,245*Yw1*Yw1 + 0,0018 * Xw1*Xw1+ 0,0215*Yw1*Yw1*Yw1)	MAX(0; MIN(1;Qsolw1/Qsolloadw))
E23	Qsoltankw= partsolw *0,001*UA*(60− (Toutm+solpos*(20−Toutm))) *(Qsolw1/Qsolloadw)*732	IF(Qsolloadw>0;Qsoltankw;0)
E24	Qsolpipew= partsolw*0,02*Qsolloadw*(Qsolw1/Qsolloadw)	IF(Qsolloadw>0;Qsolpipew;0)
E25	Qsolloadw2= Qsolloadw+Qsoltankw+Qsolpipew	
E26	Xw2= Asolw*(a_c+ UL)*ηloop*(Trefw − Toutm) * Ccapw * 732 / (Qsolloadw2*1000)	IF(AND(Qsolloadw2>0;Asolw>0);X2;0)
E27	Yw2= Asolw*IAM*η0*ηloop*qsolm*732 / (Qsolloadw2*1000);0)	IF(Qsolloadw2>0;Y1;0)
E28	Qsolw2= Qsolloadw2 * (1,029*Yw2 − 0,065*Xw2 − 0,245*Yw2*Yw2 + 0,0018 * Xw2*Xw2+ 0,0215*Yw2*Yw2*Yw2)	MAX(0; MIN(1;Qsolw2/Qsolloadw2))
E29	Qsolloadrestw = Qsolloadw2 – Qsolw2	
E30	Qsolauxlossw = partsolw * 0,001 * (2000*qsolm/Q_solm)*solaux*(2,5−0,85*solpos)	IF(Asol>0; Qsolauxlossw; 0)
E31	Qsoltankrecovw = (solpos*0,55)*0,001*UA*(60 − (Toutm+solpos*(20−Toutm))) * (Qsolw2/Qsolloadw2) * 732	IF(Qsolloadw2>0; Qsoltankrecovw;0)
E32	Qsolnetsavew= Qsolloadw−Qsolloadrestw−Qsolauxlossw+Qsoltankrecovw	MIN(Qsolloadw; MAX(0; Qsolnetsavew))
E33a	**Qsolrestw** = Qsolloadw – Qsolnetsavew	
E33b	**Qsolnetconsw** =Qsoltankw+Qsolpipew+Qsolauxlossw-Qsoltankrecovw	

The net energy consumption of the solar installation ***Qsolnetconsw*** is used in the calculation of the output.

The remaining water heating load *Qsolrestw* is used as an input for the calculation of the heat pump technology contribution. Note that if there is no solar contribution (*Qsolnetsavew*=0) the remaining load equals the original water heating load *Qsolloadw = Qaload + Qadistr*.

E9. Heat pump contribution

The methodology for the heat pump water heater is the same as the one for the heat pump space heater, except for a different sink temperature and the inclusion of a hot water tank. The first leads to an adjustment of the seasonal correction. The second leads to an adjustment of the load parameters.

<u>*E9.1. Seasonal correction*</u>

The heat pump water heater (stand-alone or combi) uses the same methodology for 'seasonal correction' of output power and COP as the space heater, described in par. D 2.5. Also, not only the equations are the same, but most of the results are identical: the arrays of source- and sink temperatures ***_Tsrcs*** and _Tsnks, the matrices with correction factors _HPPmatrix and _COPmatrix.

And even the source temperature Tsrc, and therewith the value for row, src1, src2, src3 and src4, are identical as the ones in par. D11.

For the seasonal correction, the only change is in the sink temperature Tsnk. The water heating sink temperature *Tsnkw* is given by the minimum feed temperature required to realize the tapping pattern ***Tsinkhw*** [in °C] or the input parameter for the maximum sink temperature ***Tsnkmax*** [param. nr. 16.6, in °C], whichever is lowest.

Tsnkw* = MIN*(Tsinkhw;Tsnkmax) **E34**

The value of *Tsinkhw* is set at 65 °C, corresponding to a feed temperature of the heat exchanger to the tank, needed to realize a draw-offs of 55-60 °C (temperature difference between feed- and tank temperature of 5-10 K).

The different sink temperature Tsinkw results in different ‘neighbouring’ sink values snk1 to snk 4. As a consequence the final correction factors are different. In order to make the distinction with Annex D, the equations numbers and parameters below use the postfix “w” but are otherwise the same as in Annex D, except for Tsnk.

Table E3. Assessment per day-period of water heating correction factor for output power *hppcorrw* and Coefficient of Performance *COPcorrw*

Eq.nr.	**Equation**
D110w	**colw** = MATCH(Tsnkw;_Tsnks)
D114w (a)	**snk1w** =INDEX(_Tsnks;colw)
D115w (a)	**snk2w** =INDEX(_Tsnks;colw+1)
D115w (b)	**snk3w**= INDEX (_Tsnks;colw+1)
D114 w(b)	**snk4w** =INDEX(_Tsnks;colw)
D116w	**Val1w** =INDEX(_HPPmatrix; row;colw)
D117w	**Val2w** = INDEX(_HPPmatrix;row;colw+1)
D118w	**Val3w** =INDEX(_HPPmatrix;row+1;colw+1)
D119w	**Val4w**= INDEX(_HPPmatrix;row+1;colw)
D120wa	**hppcorrw** ==val3w*ABS(((src1-Tsrc)*(snk1w-Tsnkw))/((src1-src4)*(snk1w-snk2w)))+ val4w*ABS(((src2-Tsrc)*(snk2w-Tsnkw))/((src1-src4)*(snk1w-snk2w)))+ val1w*ABS(((src3-Tsrc)*(snk3w-Tsnkw))/((src1-src4)*(snk1w-snk2w)))+ val2w*ABS(((src4-Tsrc)*(snk4w-Tsnkw))/((src1-src4)*(snk1w-snk2w)))
D121w	**Val1copw** =INDEX(_COPmatrix;row;colw)
D122w	**Val2copw** =INDEX(_COPmatrix;row, colw+1)
D123w	**Val3copw** =INDEX(_COPmatrix;row+1;colw+1)
D124w	**Val4copw** = INDEX(_COPmatrix;row+1;colw+1)
D125wa	**COPcorrw** = val3copw*ABS(((src1-Tsrc)*(snk1w-Tsnkw))/((src1-src4)*(snk1w-snk2w)))+ val4copw*ABS(((src2-Tsrc)*(snk2w-Tsnkw))/((src1-src4)*(snk1w-snk2w)))+ val1copw*ABS(((src3-Tsrc)*(snk3w-Tsnkw))/((src1-src4)*(snk1w-snk2w)))+ val2copw*ABS(((src4-Tsrc)*(snk4w-Tsnkw))/((src1-src4)*(snk1w-snk2w)))
Recalculation per month	
D120wb	**hppcorrwm**=(2*hppcorrw[morn]+7*hppcorrw[mid]+5*hppcorrw[eve]+2*hppcorrw[late]+ 8*hppcorrw[night])/24
D125wb	**COPcorrwm**=(2*COPcorrw[morn]+7*COPcorrw[mid]+5*COPcorrw[eve]+2*COPcorrw[late]+8*COPcorrw[night])/24

E9.2 Hot water tank

In prEN 15316-4-2the sanitary hot water tank is only partially taken into account. In the method an adjustment had to made because in a water heater using heat pump technology, this tank plays a role in two ways:

- It results in standby heat losses and
- It places restrictions on the hot water capacity of the heat pump technology. E,g. if the tank is too small it is less capable of meeting the requirements of the tapping pattern and therefore a larger part of the tapping pattern has to be filled in by the back-up heater. Compare: in solar technology this restriction is expressed by the parameter Ccapw.

The standby heat losses ***Qhptankw*** depend on the measured power loss Pstbyhp [param. nr. 16.9, in W]. The monthly value of *Qhptankw* is given by the equation

***Qhptankw = parthpw* * 0,001*Pstbyhp*732** E35

Boundary condition IF(*Phpnom*>0; *Qhptankw*; 0)

The hot water capacity of a hot water tank depends on its effective volume *Vhp* [param. nr. 16.8, in ltr.] and its stratification. For a full coverage of the tapping pattern the nominal volume *Vhp* should be 1,66 times the largest tapping in the waterload. This parameter follows from the tapping patterns and is called ***tapmax*** (in ltr., see reference conditions Annex C).

Stratification is measured in standards EN 12897, EN 60379, prEN 50440 as the variable that is named here ***V40hp*** [param. nr. 16.10].

V40hp is the total energy equivalent of litres of 40 °C hot water at inlet temperature of 15 °C and a storage tank initial temperature of 65 °C that can be drawn off at an outlet water temperature above or equal to 40 °C, expressed as the fraction of the nominal tank volume Vhp. Theoretically, the maximum value of V40hp with this definition is 2. Tests may also be performed at different inlet, outlet and initial storage temperatures, e.g. as defined in prEN 15332, but shall always be recalculated to the definitions above. In such a case the manufacturer is required to state the actual temperatures and the calculation method used.

the correction for the tank volume for the heat pump water heating function is now

***Vhp* / (2 /V40hp * 1,66 * *tapmax*)** E36

This expression is part of the water heater load *Qhploadw* .

E9.3 Heat pump parameters

The table below gives the consecutive expressions to be solved to calculate the heat pump contribution to water heating Qhpnetconsw and the remaining water heating load after the heat pump contribution Qresthpw. The calculation is done per month.

Table E4. Heat pump contribution to water heating Qhpnetconsw and remaining water heating load Qresthpw per month		
Eq. Nr.	Expression	Boundary condition
E37	Qloadhpw =Qsolrestw	
E38	Qhptankw = parthpw*0,001*Pstbyhp*732 (identical to E35)	=IF(Phpnom>0; Qhptankw;0)

E39	Qhploadw=(Tsnkmax−10)/(Tsinkhw−10) * (Vhp / (2/V40hp * 1,66 * tapmax)) * Qloadhpw+Qhptankw	IF((Tsnkmax−10)/(Tsinkhw−10)>1; (Tsnkmax−10)/(Tsinkhw−10)=1)
		
		IF(Vhp /(2,2/V40hp*1,66*tapmax) >1; Vhp /(2,2/V40hp*1,66*tapmax) =1)

E40	Qhpmaxw= parthpw*Phpnom*732*hppcorrwm	
E41	Fcw= Qhploadw/ Qhpmaxw	IF(Qhpmaxw; Fcw;0)
E42	COPpartcorrw= COP50+2*(1−COP50)* (FCw−0,5))	Fcw=MAX(0;MIN(1;Fcw))
E43	COPcorr2w=COPcorrwm*COPpartcorrw*COPnom	
E44	Qhpw= MIN(Qhploadw;Qhpmaxw)	
E45	Qhpwcons= IF(HPtype<4; primenergy; 1)* (Qhpw/COPcorr2w)	IF(AND(Phpnom>0;COPcorrw>0); Qhpwcons;0)
E46	Qhpaux=parthpw*primenergy*0,001*732*hpaux* FCw	IF(Phpnom>0;Qhpaux;0), IF(Fcw>1; Fcw=1)
E47	Qhprecovw=0,55*(Qhptankw+Qhpauxw/ primenergy)	
E48	Qhpnetconsw= Qhpwcons+Qhpauxw+Qhptankw−Qhprecovw	
E49	Qhprestw =Qloadhpw+Qhptankw – Qhpw	MAX(0;Qresthpw)

Heat pump energy consumption ***Qhpnetconsw*** is a direct input for the final energy consumption. The remaining water heating load after the contribution of the heat pump and/or solar ***Qhprest-w*** is an inputfor the calculation of the back-up water heater.

E10. Back-up water heater

The annual load input for the back-up water heater is the summation of the remaining monthly load after the heat pump:

Qloadrest=SUM(Qhprestw)

E50

The energy consumption of the back-up water heater is determined by extra-/interpolation of the primary energy consumption data found in the tests at two different load patterns waterloadmin and waterloadmax [param. nr. 18.1 and 18.4]. The hot water energy equivalent per 24h [in kWh/d] Qaloadmin and Qaloadmax of these two patterns can be looked up in table C4. The difference between those two, multiplied with the number of days and the factor 0,6 explained earlier, is called dQaload [in kWh/a]

dQaload= Qaloadmax − Qaloadmin

E51

Then the actual primary energy consumption per 24h for each tapping pattern is assessed. This amounts to Qfuelmin+primenergy*Qelecmin for the smaller pattern and Qfuelmax+primenergy*Qfuelmax for the larger tapping pattern. The difference between the the two tests outcomes, projected over a year, is called ***dQanet*** [in kWh/a]

dQanet= 366*0,6*((Qfuelmax-Qfuelmin)+primenergy*(Qelecmax-Qelecmin)) **E52**

With the above the increment ***Inc*** [in kWh/kWh] can be defined

Inc= dQanet/ dQaload **E53**

Inc is used to make the extrapolation to find the primary energy use for the back-up heater ***Qgrossrest*** [in kWh/a] for the situation that Qloadrest>0:

Qgrossrest =MAX(Qloadrest;IF(Qloadrest>0;366*0,6*(Qfuelmin+primenergy*Qelecmin)+Inc*(Qloadrest-Qaloadmin);0)) **E54**

E11. Model output: efficiency of Water Heaters with renewables

The total energy consumption for the water heater follows from the annual consumption data of back-up heater, the solar installation and the heat pump. In case of a fossil-fuel fired combi-boiler as a back-up heater and *combicomp*=yes then the credit is also applied .

E55

Qatot2 = Qgrossrest + SUM(Qsolnetconsw)+ SUM(Qhpnetconsw) + Qcombicomp
Note that *Qcombicomp* is a negative value (or 0).

The total efficiency of the water heater with solar and/or heat pump technology *ηwh2* is given by

ηwh2 = Qaload/ Qatot2 **E56**

E12. Final rating

In the Data Report (Annex B), Output B.1 “Water heat net load” corresponds to ***Qaload***.
Output B.2. “Water heat primary energy use” is ***Qatot*** for conventional water heaters (Qfuel+Qelec>0) and ***Qatot2*** for water heaters with renewables***.*** Output A.3 “Water heat energy efficiency” is given by ***ηwh*** for conventional water heaters and ηwh2 for water heaters with renewables .

B.1= Qaload **E57**

B.2= IF(Qfuel+Qelec>0; Qatot; Qatot2) **E58**

B.3= IF(Qfuel+Qelec>0; ηwh; ηwh 2) **E59**

Annex F: Test EIWH

NOTE: This section is under review by an industry expert group and will be revised.

Scope
This Annex describes a test method for (closed) electric instantaneous water heaters (EIWH) that can be used to generate the value *Qelec* for the selected tapping pattern. The measuring equipment should respond fast enough to enable correct measurement of power, including reactive power.

General conditions for measurements
- Ambient temperature: 20ºC ± 2 K
- Cold water inlet temperature: 10ºC ± 2K
- Flow rate: 1%
- Power supply (voltage, frequency): 0.2 %
- Water pressure (dynamic) at the water inlet: within the range indicated by the manufacturer
- Mounting / positioning of appliance: according to manufacturers instructions

Preparation of hydraulic appliances
- In order to simulate aging effects, hydraulic appliances shall be switched on/off at nominal power 5000 times. This produces a 'patina' on the electric contacts of the appliance.

List of measurements to be carried out:
- Water flow rate (l/min);
- Power consumption (effective power per time interval) (kWh) ;
- Cold water inlet temperature (ºC);
- Hot water outlet temperature (ºC);
- Elapsed time (s).

Test procedure

step 1 Measurement of static losses

- For hydraulic instantaneous water heaters: Measure at nominal load the difference in effective power at the connection to the power chord and the connectors to the heating elements. The difference in power is called ***Ploss*** [in kW].
  For electronic instantaneous water heaters: Measure at nominal load the difference in effective power at the connection to the power chord and the power control connections. The difference in power is called ***Ploss1*** [in kW]. For the same load measure the difference in effective power at the power control connections and the connectors of the heating element(s). The
- difference in power is called ***Ploss2*** [in kW]. The total power loss *Ploss* = *Ploss1* + *Ploss2*. The power losses in the power control unit are assumed to be transferred to the heating of the water and considered useful energy.
- In order to increase exactness of results the measurement can be done with measuring devices operating in their optimal measurement range and using a measurement time interval as long as necessary to attain reliable results
- Uncertainty of voltage measurement: ± 0.2%;
- Uncertainty of current measurement: ± 0.2%;
- Combined measurement tolerance: ± 0.4%;
- Since electronic controlled appliances apply phase-angle control the energy loss for part load operation can be derived through linear interpolation. Determine the static power ***Pstatic*** [in kW] for each type of draw-off defined in the tapping pattern.

Step 2 Measurement of start-up losses

- The test shall measure the time it takes for the appliance to reach the required minimum outlet temperature per tapping: **t_*start*** [in s]. This is done using the prescribed flow rate.
- The test method assumes that the power consumption during the start-up period is equal to the power consumed in static mode for that specific draw-off.
- The accuracy of the flow rate measurement is ± 0.1 l/min
- The accuracy of measurement of temperature is ± 0.2 K;
- The accuracy of measurement of time is at least ± 0.1 seconds for electronic measuring devices;
- The measurement procedure can be repeated to enhance accuracy of readings.

Step 3 Calculation of energy losses

Calculate per tapping:

- the energy loss for the tapping: ***Qtaploss = Qtap / (Ploss/Pstatic)*** [kWh]. *Qtap* is the useful energy content per draw-off [in kWh], defined in the table C4.
- the start-up energy loss: ***Qstart [*kWh*] = t_start* / 3600 * *Pstatic***.

Calculate the energy input per tapping. Add these to calculate the daily cycle energy input *Qelec* [in kWh/d].

Qelec = (tapping 1; Qtaploss+Qstart+Qtap)+(tapping 2; Qtaploss+Qstart+Qtap) + etc.

ANNEX G: Determination of flue gas temperature and combustion efficiency

NOTE: This section is to be deleted and a reference to EN standard will be used in Annex B.

This Annex describes the measurement of combustion efficiency (*ηcomb*) and flue gas temperature (*Tflue*) of fossil fuel-fired water heaters (including combined boilers). The text is based upon a test procedure described in 1.BImSchV (14.3.1997 and amended on 3.5.2000, 27.7.2001 and 14.8.2003)

List of measurements

- Combustion air temperature (°C);
- Flue gas temperature (°C);
- Oxygen content of flue gases (%, dry flue gas), or carbon dioxide content of flue gases (%, dry flue gas).

Point of measurement

1. The point of measurement for *Tflue* and oxygen/carbondioxide shall be behind the final heat exchanger, before or at the connection to the flue duct or chimney. In case the heat generator is operated with a flue gas scrubber / cleaner the measurement shall take place behind this cleaner. If no predefined point is available the measurement point shall be located at twice the diameter of the flue gas duct behind the connection of the heat exchanger to the flue duct or flue gas cleaning facility;
2. A measuring point on a different location as stipulated under 1. is admissible if the flue gas flow at that point is constant and reproducible and does not introduce significant heat loss with respect to measurements as under 1.;
3. The measuring socket should be clean from dust or soot particles that may interfere with the measurement;
4. The measurements shall be performed in the centre of the stream of flue gas;
5. The oxygen- or carbon-dioxide-content and the flue gas temperature shall be measured at the same time at the same point;
6. The temperature of the combustion air shall be measured close to the combustion air inlet port of the appliance in case of open installations. For closed (room sealed) appliances the temperature of the combustion air shall be measured at an appropriate point in the combustion air supply duct.

Requirements for performing measurements during operation

1. Before starting the measurements the correct functioning of the measurement instrument should be ascertained. Consult the guidelines or instructions by the manufacturer/supplier of the measuring instrument;
2. The measurements shall be performed during continuous operation of the heater/boiler at nominal load or at the maximum rated load in a way that allows representative and comparable results for comparative heat generators;
3. In order to comply with item 2. measurements for oil-fired installations with jet burners and for gas-fired installations shall start not sooner than two minutes after ignition of the burner;
4. For oil-fired installations with an atmospheric burner the measurement shall start not sooner than two minutes after reaching nominal load operation;
5. For water heaters the temperature of the heat generator shall be at least 55ºC before measurement commences. This does not apply to water heaters that are designed to operate at temperatures below 55ºC (condensing appliances, low temperature boilers with temperature control).

Determination of flue gas losses

1. The oxygen- or carbon dioxide-content of the flue gases shall be measured;
2. The temperature difference between the flue gas and combustion air shall be measured;
3. The flue gas losses with measurement of oxygen-content shall be calculated using the formula below:

$$q_A = (t_A - t_L) * \left(\frac{A_2}{21 - O_2} + B \right)$$

In case the carbon dioxide-content is measured the calculation of flue gas losses is as follows:

$$q_A = (t_A - t_L) * \left(\frac{A_1}{} + B \right)$$

$\overline{\quad CO_2 \quad}$

Where:

q_A	= Flue gas loss in %
t_A	= Flue gas temperature in ºC
t_L	= Combustion air temperature in ºC
CO_2	= Volume of carbon-dioxide in dry flue gas in %
O_2	= Volume of oxygen in dry flue gas in %

And:

	Heating oil	Natural gas	Town gas	Coke oven gas	Liquid gas and liquid/air mix gas (a.o. LPG)
A1	0.50	0.37	0.35	0.29	0.42
A2	0.68	0.66	0.63	0.60	0.63
B	0.007	0.009	0.011	0.011	0.008

*Calculation of **ηcomb** and **Tflue***

1. The combustion efficiency *ηcomb* (DATA REPORT! 14.1) is calculated as: $\boldsymbol{\eta comb = 1 - q_A}$;
2. The average flue gas temperature *Tflue* (DATA REPORT! 14.2) equals t_A : $\boldsymbol{Tflue = t_A}$.

ANNEX H: Definition Smart control

H1. Definition of "smart control" for Instantaneous Water Heaters

Comprises sophisticated control to supply the desired/required power to the heating system by means of:

1. Power control capable of switching any required power between at least 50% and maximum rated power with a maximum power resolution of 200W depending on flow rate and water temperature to minimize power consumption;
2. devices to detect at least the flow rate and the inlet or outlet temperature;
3. device which calculates without user intervention the power required to stabilise the temperature of the outlet water at the desired level in-between switch on flow rate and power limit, regardless of:
   - flow rate;
   - water pressure;
   - inlet temperature.
4. with a maximum deviation of 5% between the actual power of the power control and the physical power demand.

Compliance is checked by measurement at minimum 5 different operating points within the specified operating range whereas the operating points should be selected at equidistant points distributed over the variable power part.

H2. Definition of "smart control" for Storage Water Heaters

H2.1 Definition

Smart control is a concept that allows energy saving in a storage water heater, using electronic controls for optimizing stored water temperature and / or time for better energy efficiency at same levels of comfort and safety. Different approaches of smart control are possible, for example based on auto-learning of consumer behaviour, or based on end-consumer self programmation of his own tapping profile.

H2.2 Measurement procedure

Each manufacturer asking smart control bonus must be able to use an efficient smart control solution, to reach at least 10% consumption reduction, compared to the same appliances not equipped with smart controls. In order to demonstrate this, a manufacturer has to assess smart technology in a real life test, using following procedure.

- Manufacturer has to choose a sample of WH equipped with his smart control solution
- Manufacturer has to test the smart control on the basis of a real life situation, following a simple procedure:
  - The appliance will be submitted to the same test procedure as for a usual efficiency test, but using at least for one week a daily tapping profile as shown in following table, in order to allow consumer behaviour learning and/or to measure energy consumption without smart control activation. The manufacturer may choose to perform the test for a longer period than the minimum one week period.
  - In a second step, the test is performed for the same period as for the first step, using the same repetition of tapping profile, but with smart control function activated (following manufacturer instructions for end-user in case of not automatic functioning)..

    The electricity consumption is measured during the second step and compared to the electricity consumption of the first step. The second step value has to be at least 10% lower than the first step value.
  - The tapping profile by day has to follow the table below, where WHL is the tapping profile chosen by the manufacturer corresponding to the product tested.

    And WHL-1 is the WHL corresponding to the immediate lower tapping profile.

Learning week	"Smart" week
Day 1 : WHL	Repetition in the same order
Day 2 : WHL-1	
Day 3 : WHL	
Day 4 : WHL -1	
Day 5 : WHL	
Day 6 : No tapping	
Day 7 : No tapping	

- The complete above mentioned procedure has to be performed without activation of eventual specific national requirements

H2.3 Labeling process

First step : Manufacturer has to test the smart control technology as described under point 2°, in order to demonstrate its 10% efficiency
Second step : Manufacturer has to test all his products with "smart control" feature for measuring base Qelec value according to the different tapping profile chosen, but making the test without smart control activation (only one day test). For each tested product, manufacturer has to deliver "smart control technology measurement" (carried out following the measurement procedure at point 2°, declaring his intention to use this specific technology for this specific product.
Third step : Labeling efficiency is calculated by manufacturer using Qelec result of the test (without smart control activation) and applying smart control bonus to the result obtained.

H2.4 Verification process

Market surveillance authorities, to verify the declaration of water heaters using smart controls should set randomly the sequence of tapping during the first step. This should avoid that simple pre-programmed appliances are sold as smart controls, but are not able to save energy or to satisfy real end-user needs.

ANNEX I: Background space heating load profiles

I1. Building characteristics

The load profiles are based on building characteristics, as determined in the preparatory study Task 3 reports [VHK 2007]. Average EU building data are a weighted average of data for each individual Member State.

Table I1. Average EU building characteristics (used for profiles)

Description	Param	Unit	Values								
Profile			0 -none	1 -XXS	2 -XS	3 -S	4 -M	5 -L	6 -XL	7 -XXL	8 -3XL	9 -4XL
example				6-new ap	2-avg new	5-ex ap	1-avg ex	3-house ex	8-nwbld8	7-exbld8	9-bld20	10-block
geometry	**F**	m2	0	78	101	67	86	106	628	532	1693	5078
	V	m3	0	232	288	196	245	292	1852	1571	4994	14981
	h	m	0	2,95	2,85	2,95	2,84	2,75	2,95	2,95	2,95	2,95
	AV	m^{-1}	0	0,40	0,51	0,40	0,51	0,60	0,40	0,40	0,40	0,40
insul	**U**	W/m².K	0	0,53	0,53	1,03	1,03	1,03	0,53	1,03	0,86	0,86
ventilation	**qinf**	m³/m³.h	0	0,12	0,14	0,15	0,19	0,22	0,12	0,15	0,14	0,14
	qv	m³/m³.h	0	0,47	0,47	0,65	0,65	0,65	0,47	0,65	0,59	0,59
	qrec	%	0	5%	5%	3%	4%	3%	5%	3%	4%	4%
solar	**sgf**	%	0	5%	5%	5%	5%	5%	5%	5%	5%	5%
thermal mass	**tm**	Wh/m³.K	0	17,8	17,8	17,8	17,8	17,8	17,8	17,8	17,8	17,8
	tmfc	#	0	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96
internal heat	**Uij**	W/m².K	0	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60
	qinfi	m³/m³	0	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
	b	#	0	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50

I2. Meteorological data and internal gains

For the load profiles the average EU meteorological data were used from JRC Ispra. These values for the outdoor temperatures (***Tout*** in °C) and global solar irradiance (***qsol*** in W/m²) are given in Table C5.

Internal gains ***qgain*** are estimated on the basis of on one hand the average values found in the national building regulations (ca. 5-6 W/m² heated floor area ***F***) and the data from prEN 13709, which gives significantly higher values and which subdivides the gains per day-period. The estimate is given in the table below:

Table I2. Internal gains

Day-period	times	qgain W/m²F
morn	7.00-9.00 h	5,9
mid	9.00- 16.00h	0
eve	16.00-21.00h	5,92
late	21.00-23.00h	14,8
night	23.00-7.00h	4,94
Average		**6,31**

I3. Initial indoor temperatures

For the initial indoor temperature setting there is a fixed regime at 19 °C [Tinx] and a setback regime. The latter is a multi-zone temperature regime with optimal setback per zone. It is calculated as a 'reduced setback' regime, i.e. there could be a heat demand during setback-periods if the indoor temperature drops below the setback temperature. For the average EU climate the indoor temperature never drops below 15 °C and therefore the 'reduced setback' equals the 'full setback'.

Assumes comfort-temperatures 19/18/21 °C initial room-temperature setting for day/night/bath zones, representing 50/40/10% of the heated space. Setback temperature is 15 °C. Setback period for the day-zone is night. Comfort-period for the night-zone is eve. Comfort-periods for the bath-zone are morn and late (see table).

Table I3. Initial indoor temperature settings *Tset* for setback-regime

setting	**fi**	**Aij***		Temperature setting				
Regime 19/18/21	**%**	**%**		***morn***	***mid***	***eve***	***late***	***night***
Zone 1 (day)	50%	50%		19,0	19,0	19,0	19,0	15,0
Zone 2 (night)	40%	10%		15,0	15,0	18,0	15,0	15,0
Zone 3 (bath)	10%	10%		21,0	18,0	18,0	21,0	18,0

The parameter fi is the fraction of the heated space for each zone (array [fi_1;fi_2;fi_3]) . The parameter Aij is the relative surface area (with respect of the heated floor area F in m²) between the zones i and j and will be used to calculate the internal heat transfer. The values in the table are for a 2-storey dwelling with A12=50%, A23=10% and A13=10%.

Note that the proposed initial temperature regimes are not the actual settings, but reflect what the settings would be in an **ideal situation** where there are no fluctuation and stratification losses and no detrimental effects of internal heat transfer and thermal mass.

The settings are based on a comparison of indoor temperatures in national EPB legislation in Germany, France, UK and Netherlands. More specifically, the temperature regime is in line with a fixed temperature regime of 19 °C for all zones.

I4. Boiler and radiator capacity

The minimum required boiler output capacity (MinOut in Table C3) is calculated for the parameters given in the sections above according to EN 12831 [see VHK 2007 Ecoboiler, Task 5]. It uses an outdoor temperature of –10 °C, a temperature correction factor for cold bridges of 1,15 and a heat-up correction of 1,2 (see preparatory study, Task 5, Chapter 2, VHK 2007).

The radiator capacity is based on an outdoor temperature Tout = –10 °C and maximum achievable indoor temperatures of 21, 18 and 24 °C for day-zone, night-zone and bath-zone respectively. Following the outcomes of the 'Optimus' project and other studies of installation practice, a safety-factor ***Csafe***=2,5 was applied. Formula for the nominal radiator capacity ***Pradnom*** in zone i (EN 442, in kW) in the coldest day-period (usually Jan. morn.) :

Pradnom [i] =0,001 * Csafe * fi_[i] * (V * (Tin−Tout) * (ah*(qv*(1−qrec)+qinf) + AV*U) − F * (qgain +qsol * sgf)) I1

I5. Specific loss and gains

Equations for ***qloss*** and ***Qgains***, as given in Annex C, Table C2, are

qloss = V * (ah*(qv*(1−qrec)+qinf)+AV*U) [in W/K.m3] **I2**

Qgains = F*(qgain +qsol*sgf) [in W] **I3**

According to equation C3 qloss has to be multiplied with (Tin−Tout) and Qgains have to be subtracted to find the heat energy load QH.

I6. Indoor temperature profile: Thermal mass

The final temperature profiles in Table C3 were calculated from:

- The initial indoor temperature regime
- Building characteristics
- Meteorological data

The building characteristics include not only the general heat balance data for the building as a whole, but also specific parameters for the

- thermal mass (***Tm, tmfc***) and
- internal heat transfer (***Uij, qinfi*** and ***b***).

I6.1 Correction of Tset for the lowest possible temperature Tsetc

Despite of the initial set temperatures ***Tset***, the indoor temperature cannot drop below a level that is determined by the outdoor temperature, the internal and solar gains and the capability of the building shell to keep these internal and solar gains inside. For average EU this will have its main effect in the months of April, May, September and October. But also during the day (“mid” period) in the months of March and November the gains can be such that the actual indoor temperature without heating will be above the level of Tset.

Therefore, for
- each time-period [morn; mid; eve; late; night] ,
- each zone with ***fi*** = [fi_1; fi_2; fi_3] = [50%; 40%; 10%] as % of heated volume and
- each month in the maximum heating season [Jan; Feb; Mar; Apr; May; Sept; Oct; Nov; Dec]

the corrected indoor set temperature ***Tsetc*** in °C is given by

Tsetc = MAX (Tset ;Tout + fi * Qgains / qloss) **I4**

I6.2 Initial Energy Requirement QH1 from Tset

For
- each time-period [morn; mid; eve; late; night] with length ***hd***= [2; 7; 5; 2; 8], in h,
- each zone with ***fi*** = [fi_1; fi_2; fi_3] = [50%; 40%; 10%] as % of heated volume and
- each average month in the maximum heating season, Sept.-May

the energy demand QH1 [in kWh] is calculated using the initial indoor temperature settings Tset from table I3, following the general format

QH1 = hd * 0,001 * fi * ((Tsetc − Tout)*qloss − Qgains) **I5**

for ***QH1*** ≥ 0 (else ***QH1***=0)

with power demand ***PH1*** in kW

PH1 = QH1/hd **I6**

For the influence of thermal mass on the temperatures during setback-periods a simplification of EN 832 is used, calculating first average cool-down speed during the period –depending on building and weather— and then the heat-up speed –depending also on the installation. The length of the day-period, the heat-up speed and the comfort-temperature to be reached at the beginning of the consecutive period then results in the length of the cool-down period and thereby the lowest setback temperature actually reached.

I6.3 Cool down

The indoor temperature at the end of a setback over a full period with length ***hd*** [in h] in a zone with ***fi*** [in % of ***V***] is given by the parameter ***Tinsb*** in °C, within the boundary condition that QH1>0 (else ***Tinsb= Tsetc***). Following EN 832 the equation for ***Tinsb*** in each zone, setback time-period and month is

Tinsb = Tout + tmfc * (Tsetc_prev−Tout) * EXP (−hd /(0,001*(Tsetc_prev−Tout)* fi * tm * V / PH1)) **I7**

where

- ***Tout*** is the outdoor temperature in °C
- ***tmfc*** is the thermal mass correction factor (typical range 0,95-0,99)
- ***Tsetc_prev*** is the corrected set indoor temperature in the previous time-period
- ***tm*** is the specific thermal mass per m³ of heated volume V, typically 18 Wh/m³.K

Note that the notation EXP(x) is used instead of the conventional e^x format for reasons of legibility and compatibility with spreadsheet and software applications.

From this the average cool-down speed ***vcd*** [in K/h] is derivedfor the setback time-period, zone and month

vcd = (Tsetc_prev – Tinsb) / hd **I8**

Note that in the further calculations with vcd this assumes that the cool-down is linear. In reality the cool-down is a curve, but the error is deemed acceptable.

Also note that if there are consecutive cool-down periods, e.g. for Zone 2, that "***Tsetc_prev***" in the above equations has to be replaced by "***Tinfsb_prev***", i.e. the temperature at the end of the previous cool-down period.

I6.4. Heat-up

We calculate the heat-up time ***thu*** [in h.] at the end of a setback period and before a comfort-period. It is the time that it takes to get the temperature from a cool-down level of ***Tinsb*** back to the required level of the next period **Tsetc_next** if needed (***thu*** cannot be negative, else ***thu***=0).

thu = ((Tsetc_next−Tinsb) * 0,001 * tm * V * fi + TMrad * (PH1_next / Pradnom) * 50) / (Pradnom*Preheat−PH1_next) **I9**

where

- **fi** = [***fi_1; fi_2; fi_3***] = [50%; 40%; 10%] as % of heated volume for each zone
- ***TMrad*** is the specific thermal radiator mass which is for the reference radiators (20 litre water/ kW) ***TMrad***= 0,0232 * Pradnom in kWh/K with
- ***Pradnom*** in kW is the nominal radiator capacity according to EN 442 =[***Pradnom1; Pradnom2; Pradnom3***].
- ***PH1_next*** is the power demand in the next time-period
- ***Preheat*** is the turndown ratio of the boiler for reheating in % , which is 30% in case of an optimizer, otherwise 100%.

Note that ***Pradnom*** –and therefore also ***TMrad***—are specific for a certain zone.

The equation for ***thu*** is a simplification of EN 832, with little other excuse that it is less complex and error-prone than the one in EN 832 and gives plausible results. The left hand side of the upper equation gives the thermal mass of the building shell, whereas the right hand side gives the thermal mass of the radiator, which is composed of a specific thermal mass ***TMrad*** and the assumed radiator temperature heat-up that is required, given by ***(PH1_next/ Pradnom) * 50***. This factor 50 is the temperature difference between a radiator at nominal capacity (65/75 °C = average 70 °C) and the ambient (assumed 20 °C). The ratio

PH1_next/ Pradnom is an approximate indication of the radiator temperature that will be required, within that range of 20-70 °C. The approximation introduces an error, but one that is acceptable.

It has to be taken into account that a part of the radiator power is used not just for reheating the zone but also for compensating the power loss during the reheat period. For the latter a power loss in the next period is assumed. This explains the lower equation that does not just simply take the radiator power ***Pradnom***, corrected for a possible part load factor ***Preheat***, but also subtracts ***PH1_next*** to find the effective radiator power that can be used for the reheating.

The heat-up speed ***vhu*** in K/h is now given, provided that ***thu***>0 (else ***vhu***=0), by

vhu = (Tsetc_next−Tinsb) / thu **I10**

I6.5 Corrected heat-up and cool-down

The above equations for cool-down start from a cool-down over the full setback time-period, but it has to be taken into account that the reheat-time will reduce the cool-down period. This will lead to less cool-down and then also a shorter reheat time, which then again leads to a slightly longer cool-down etc..

This iterative process is solved with an equation for an approximately corrected heat-up time thuc in h using the average cool-down speed ***vcd*** and average heat-up speed ***vhu***.

thuc = thu * vhu / (vcd + vhu) **I11**

the corrected cool-down time ***tcdc*** [in h] is then found by subtracting thuc from the total length of the setback period ***hd*** [in h].

tcdc = hd – thuc **I12**

Boundary condition is that (***vcd+vhu***)>0 else ***thuc***= 0.

To find the corrected temperature at the end of the cool-down period Tinsbc the expression for ***Tinsb*** is used but replacing the original full length of the period “hd” by the reduced cool-down period tcdc:

Tinsbc = Tout + tmfc * (Tsetc_prev−Tout) *
EXP (-tcdc /(0,001*(Tsetc_prev−Tout)* fi * tm * V / PH1)) **I13**

I6.6 Average temperature during setback period

Full setback
Once ***thuc***, ***tcdc*** and ***Tinsbc*** are established, the average indoor temperature over a setback period after including the thermal mass ***Tintm*** can be found by the expression

Tintm [setback-period] ***= (tcdc * 0,5*(Tsetc_prev + Tinsbc) + thuc * 0,5 * (Tinsbc + Testc_next)) / hd*** **I14**

Reduced setback
The equation above applies to a so-called “full setback”-regime, i.e. where there is no limit to the temperature drop in the setback-period. However, the indoor temperature settings in Table I3 do specify a minimum temperature Tset (15 °C) during setback periods.Thus, additional calculations for this “reduced setback” regime are required to find the energy requirement in a steady-state period to keep the indoor temperature from dropping below 15 °C.

For the energy requirement during such a period an expression similar to the one for ***QH1*** can be used, with a value of Tset=15 °C. The length of this steady-state period is given by the total length hd of the setback period minus the time-period it takes to cooldown to 15°C from a previous comfort period and the time it takes to reheat to the required level of a next comfort-period. For this the calculated average cool-down speed ***vcd*** and the heat-up speed ***vhu*** is used.

So, if ***Tinsbc<=Tsetc*** then the steady state period between cool-down and heat-up in a setback period ***tss*** [in h] is given by

tss = hd – (Tsetc_prev − Tsetc) * vcd – (Tset_next – Tsetc) * vhu I15

The introduction of tss leads to a re-assessment of the “reduced” heat-up and cool-down times thucr and tcdcr for the relevant periods. Because the start-temperature is known, thucr can be assessed with the heat-up speed

thucr = (Tsetc – Tsetc_next)/vhu I16

and the remainder of thucr and tss gives the cool-down time:

tcdcr = hd – tss – thucr I17

The average temperature over the “reduced” setback-period ***Tintmr*** can now be calculated

Tintmr [setback-period] **=** I18
(tcdcr * 0,5*(MAX(Tsetc_prev;Tinsbc) +Tsetc) + thucr * 0,5 * (Tsetc + Tsetc_next) + tss * Tsetc) / hd

Calculation of energy demand

For the calculation of the intermediate energy demand there are two approaches. The first approach uses QH2" and makes a distinction between the cooldown, steady state and reheat periods within a day-period and calculates the energy demand for each single subperiod. Apparantly this is more precise and allows the drawing of a differentiated temperature curve for each zone. For this reason it is useful and equations are given below.

The energy demand ***QH2***”[in kWh] during comfort-periods is identical to ***QH1***:

QH2” [comfort-period] ***= hd * 0,001 * fi * ((Tsetc - Tout) * qloss − Qgains)*** I19

And during setback-periods the energy demand is given by the reheating energy and the heat demand during the steady state period between cool-down and heat-up:

QH2” [setback-period] ***= thucr*Pradnom*Preheat + tss * 0,001 * fi * V* ((Tsetc − Tout)*qloss - Qgains)*** I20

Note that the use of the radiator capacity in the zone ***Pradnom*** is only allowed in this case, i.e. when not all reheating takes place simultaneously. Otherwise, the boiler capacity Pmax is the limiting factor and (Pradnom[zone]/ Pradnomsum)*Pmax should be used. ***Pmax*** is given in Annex D and is the maximum heat output of the heat generator(s).

The average power demand per period ***PH2”*** [in kW] becomes

PH2” = QH2”/hd I21

For the purpose of establishing an appropriate temperature profile the approach above is less suited, because it does not anticipate the equalizing effect of the internal heat transfer in the next paragraph, nor the carry-over of thermal mass effects from previous day-periods. For this reason a second method of assessing QH2 is used, whereby the average temperature (Tintmr) over the whole day-period is the calculation basis for the load profile. The outcome is not very different from QH2" (-4%) but the temperature differences during the day are less differentiated and the setback effects concentrate in the night period. The equation for the comfort-period is as above (QH2 = QH2”). The equation for the setback-period is

QH2 [setback-period] = hd * 0,001 * fi * ((Tintmr – Tout) * qloss – Qgains) I22

For PH2 the same equation as for PH2” applies (PH2=QH2/hd)

I7. Indoor temperature profile: Internal heat transfer

I7.1 Assessment per zone

The internal heat transfer between zones follows EN 832. The values of coefficients for internal infiltration (***qinfi***) and internal transmission (***b***) are an estimate based on the two extremes found, i.e. in UK and German EPB legislation.

The internal heat transfer power Piht between the three zones is given by

$$Piht\,[1\rightarrow 2] = 0{,}001*(Tintm[\text{zone 1}] - Tintm[\text{zone 2}])*(Aij\_1*F*b*Uij + fi\_1*V*qinfi*ah) \qquad \text{I23a}$$
$$Piht\,[1\rightarrow 3] = 0{,}001*(Tintm[\text{zone 1}] - Tintm[\text{zone 3}])*(Aij\_2*F*b*Uij + fi\_2*V*qinfi*ah) \qquad \text{I23b}$$
$$Piht\,[3\rightarrow 2] = 0{,}001*(Tintm[\text{zone 3}] - Tintm[\text{zone 2}])*(Aij\_3*F*b*Uij + fi\_3*V*qinfi*ah) \qquad \text{I23c}$$

Please note that Piht [1→3] may be negative or positive depending on whether it is a comfort-period (zone 3 warmer than zone 1) or a setback-period (zone 1 may be warmer).

In a **multi-zone** compensation, e.g. with a weather controlled T-control and good hydraulic controls, the heating power demand PH3 per zone to arrive at temperature Tinht=Tset is given by

$$PH3\,[\text{zone 1}] = PH2\,[\text{zone 1}] + Piht[1\rightarrow 2] + Piht\,[1\rightarrow 3] \qquad \text{I24a}$$
$$PH3\,[\text{zone 2}] = PH2\,[\text{zone 2}] - Piht\,[1\rightarrow 2] - Piht\,[3\rightarrow 2] \qquad \text{I24b}$$
$$PH3\,[\text{zone 3}] = PH2\,[\text{zone 3}] - Piht\,[1\rightarrow 3] + Piht\,[3\rightarrow 2] \qquad \text{I24c}$$

During the **comfort-periods** and in a **single-zone** compensation, e.g. with a room thermostat in Zone 1 and manual radiator valves or TRVs with a wide control band, the heating power demand PH3 to arrive at temperature ***Tiniht=Tset*** is given only for Zone 1:

$$PH3\,[\text{zone 1}] = PH2\,[\text{zone 1}] + Piht[1\rightarrow 2] + Piht\,[1\rightarrow 3] \qquad \text{I25a}$$

The other zones then follow the increase of the boiler water temperature provoked by the thermostat in Zone 1, which with manual valves or TRVs with a large control band (TRV 2K) is assumed unrestricted within a band of ± 1K.

$$PH3\,[\text{zone 2}] = PH2\,[\text{zone 2}] - Piht\,[1\rightarrow 2] - Piht\,[3\rightarrow 2] + (Pradnom2/Pradnom1)*(Piht[1\rightarrow 2] + Piht\,[1\rightarrow 3]) \qquad \text{I25b}$$

$$PH3\,[\text{zone 3}] = PH2[\text{zone 2}] - Piht\,[1\rightarrow 3] + Piht\,[3\rightarrow 2] + (Pradnom3/Pradnom1)*(Piht[1\rightarrow 2] + Piht\,[1\rightarrow 3]) \qquad \text{I25c}$$

Within a band of ± 1K the temperature may deviate slightly upwards or downwards from Tsetc:

$$Tiniht\,[\text{zone 2}] = Tintm\,[\text{zone 2}] + (PH3\,[\text{zone 2}] - PH2\,[\text{zone 2}])/(V*fi\_2*qloss) \qquad \text{I26a}$$
$$Tiniht\,[\text{zone 3}] = Tintm\,[\text{zone 3}] + (PH3\,[\text{zone 3}] - PH2\,[\text{zone 3}])/(V*fi\_3*qloss) \qquad \text{I26b}$$

The reference for the temperature profiles is the single zone approach (thermostat + TRV 2K)

For the **setback-periods**, in both single- and multi-zone approach, the heating power requirement follows the equations of the multi-zone approach. The temperature is calculated, also for Zone 1, following the format for Zones 2 and 3 in a single-zone approach.

Effectively, the differences between a single zone and a multi-zone compensation are very small (6-7% of internal heat transfer losses, <0,3% of total load) and –e.g. when using this type of modeling also in an EPB calculation—this distinction could also be neglected.

I7.2 Final result: average indoor temperature per dwelling

To arrive –for each time period-- from the indoor temperatures per zone to the average indoor temperature per dwelling, ***Tin00*** or ***Tin30*** depending on whether Preheat=100% or Preheat=30%, the relative volume of each zone is used as a weighting factor:

$$Tin00 \text{ or } Tin30 = fi\_1 * Tiniht\,[\text{zone 1}] + fi\_2 * Tinht\,[\text{zone 2}] + fi\_3 * Tinht\,[\text{zone 3}] \qquad \text{I27}$$

The result is given in Table C3, two data-sets (***Tin00*** and ***Tin30***) with –per loadprofile (XXS-4XL)—a series of 45 temperatures, corresponding to 9 months (Sept-May) with each 5 time-periods [morn; mid; eve; late; night]. This series of 45 temperatures is more detailed than the monthly approach in EN 832 and EN 13790 (9 values) because it is the minimum required to make a meaningful calculation of the effect of thermal mass and internal heat transfer. On the other hand, it is also more manageable than the hourly approach (ca. 5000 values) which is also allowed under EN 13790.

A further simplification with respect of some other modeling tools like TRNSYS is given by the basically linear and analytical approach, instead of the iterative approach. The latter is theoretically more correct, but also much more complex and difficult to use in a legislative context where outcomes cannot be ambiguous. In that light, the possible error from this limear approach is deemed acceptable.

Finally, it is an advantage that the approach is 'parameterized', i.e. it uses variables and equations and –as little as possible—look-up tables and long lists of constants. This allows for greater flexibility and makes it relatively easy to adjust the temperature profiles for local circumstances, e.g. for EPB-type approach.

I8. Temperature profiles per Member State

As an example of the flexibility mentioned this paragraphs gives an overview of the inputs, both meteorological and in terms of building characteristics, for the capitals of each EU Member State. In fact, these data were originally used to arrive at weighted figures for the EU-average and could be used to create temperature profile for each of the capital cities.

For internal gains qgain the values in table I2 apply for all Member States. For sgf, tmfc, Uij, qinfi and b there are no differentiating data available and it is assumed that the values in I1 apply for all Member States. The heated floor area F is calculated from the heated volume V and floor height h (F=V/h). Data stem from 2006 and relate to the EU-25. Data for Bulgaria and Romania can be added later.

Note: temperature data for Athens, Greece to be reviewed (update pvgis)

Table I4 . Outdoor temperatures in °C per time-period in country capitals over the heating season [JRC]

	EU	AT	BE	CY	CZ	DK	EE	FI	FR	DE	GR	HU	EI	IT	LT	LI	LU	MT	NL	PL	PO	SK	SI	ES	SE	UK
Weight %	**100**	1,6	2,4	0,1	2,1	1,3	0,3	1,3	14,4	19,0	2,7	2,0	0,8	13,0	0,5	0,6	0,1	0,1	3,3	5,7	2,6	0,9	0,4	10,2	2,1	12,5
Outdoor temperatures in °C																										
JAN																										
morn	2,2	-1,6	2,4	8,3	-1,9	0,5	-3,5	-4,2	2,9	-0,7	6,8	-2,0	5,1	6,5	-2,9	-4,6	0,5	10,8	2,5	-2,8	9,3	-1,4	-1,2	3,3	-1,4	4,2
mid	4,4	-0,1	4,0	14,6	-0,6	1,2	-2,7	-3,7	4,8	0,9	10,2	0,1	6,5	10,1	-2,2	-3,4	2,2	13,2	3,8	-1,5	12,1	0,2	1,9	7,7	-0,9	5,9
eve	4,5	-0,1	4,3	13,1	-0,7	1,2	-2,9	-3,8	5,1	1,0	9,6	0,0	6,2	10,5	-2,4	-3,6	2,3	12,7	4,0	-1,7	11,7	-0,1	2,1	8,1	-1,1	5,9
late	3,4	-0,9	3,6	10,3	-1,5	0,9	-3,4	-4,3	4,2	0,3	7,9	-1,0	5,3	8,7	-3,0	-4,4	1,7	10,9	3,4	-2,5	9,8	-0,7	0,7	6,2	-1,4	5,0
night	2,2	-1,6	2,5	6,8	-1,9	0,6	-3,4	-4,5	3,0	-0,5	6,3	-2,0	5,1	6,4	-3,0	-4,6	0,7	10,5	2,6	-2,8	9,1	-1,4	-1,0	3,5	-1,4	4,3
FEB																										
morn	3,1	0,4	3,8	8,6	-0,1	1,0	-4,2	-5,3	4,1	1,0	6,7	-0,8	5,2	6,1	-3,1	-3,5	1,9	10,6	3,8	-1,5	10,3	0,2	-0,4	4,0	-2,0	4,8
mid	6,4	3,9	6,0	15,1	2,9	2,3	-2,8	-3,8	6,9	3,6	11,1	3,8	7,2	11,0	-1,4	-1,5	4,5	13,5	5,7	1,0	13,7	3,9	5,1	10,1	-0,4	7,2
eve	6,4	3,9	6,2	13,4	2,8	2,2	-3,0	-4,1	7,0	3,9	10,3	3,5	6,9	10,8	-1,5	-1,5	4,7	12,8	5,7	1,0	13,2	3,7	5,3	10,4	-0,5	7,2
late	4,8	2,2	5,1	10,3	1,4	1,6	-3,9	-5,2	5,8	2,6	8,3	1,3	6,1	8,5	-2,6	-2,8	3,4	11,3	4,9	-0,2	11,5	1,9	2,7	7,5	-1,3	6,1
night	2,9	0,2	3,7	6,1	-0,1	0,9	-4,3	-5,6	4,1	1,1	5,7	-1,1	5,1	5,5	-3,3	-3,6	1,9	9,9	3,8	-1,5	9,9	0,0	-0,4	3,8	-2,0	4,7
MAR																										
morn	5,2	3,6	5,5	11,9	2,3	1,8	-2,4	-3,4	6,4	2,4	8,2	3,0	6,3	9,0	-1,6	-1,8	4,1	12,1	5,4	0,5	12,7	3,4	4,0	7,7	-0,3	6,1
mid	9,2	7,6	8,7	17,0	6,0	4,1	0,7	0,0	10,4	6,0	12,6	8,3	8,7	13,6	2,1	2,1	8,0	15,2	7,9	4,1	16,5	7,7	10,0	14,2	2,5	9,1
eve	8,8	7,1	8,5	15,4	5,9	3,4	0,3	-0,2	9,9	6,1	11,6	7,9	7,9	12,5	1,9	2,1	7,8	14,0	7,4	3,9	15,7	7,3	9,6	14,2	2,0	8,5
late	6,6	4,9	6,8	12,5	3,7	2,2	-1,5	-2,3	7,8	4,0	9,1	4,8	6,8	9,8	-0,3	-0,4	5,7	12,3	6,1	1,7	13,7	5,0	5,9	10,5	0,5	7,0
night	4,1	2,4	4,9	8,9	1,4	1,0	-3,2	-4,2	5,4	1,7	6,1	1,5	5,7	6,8	-2,5	-2,7	3,4	10,2	4,7	-0,5	11,7	2,4	2,0	6,4	-1,1	5,4
APR																										
morn	8,7	8,6	8,2	16,6	7,2	5,8	3,4	2,6	8,7	7,1	12,2	9,4	8,0	11,8	4,9	5,6	7,2	14,3	8,4	6,9	14,3	8,9	8,7	10,3	3,9	8,3
mid	12,9	13,1	11,9	19,9	11,7	8,3	6,4	5,8	12,8	11,9	16,4	14,5	10,4	15,8	9,0	10,3	11,4	17,4	11,4	11,3	17,6	13,5	13,7	15,9	6,8	11,5
eve	12,3	12,7	11,3	18,6	11,1	7,4	5,8	5,4	12,1	11,8	15,1	14,0	9,4	14,6	8,5	10,1	10,9	16,1	10,4	10,8	15,8	12,8	13,1	15,7	5,9	10,5
late	9,3	9,4	8,7	16,3	7,9	5,5	3,5	3,0	9,1	8,5	12,2	10,3	7,5	12,1	5,7	6,7	7,9	13,9	8,2	7,7	13,8	9,5	9,6	11,7	3,7	8,1
night	6,8	6,7	6,5	14,4	5,0	4,1	1,4	0,6	6,7	5,4	9,6	7,0	6,2	9,3	2,8	3,4	5,3	12,2	6,5	4,8	12,6	6,8	6,4	8,5	1,9	6,3
MAY																										
morn	13,8	14,8	12,9	22,2	13,3	10,8	9,1	8,7	13,4	12,9	18,3	16,2	10,9	17,3	10,6	11,6	12,3	19,0	12,8	13,3	16,9	15,3	14,8	14,8	9,1	11,9
mid	17,8	19,2	16,3	24,7	17,6	13,1	11,7	11,5	17,3	17,5	22,6	20,9	13,2	21,1	14,5	15,9	16,4	21,9	15,5	17,6	20,1	19,7	20,0	20,1	11,8	15,0
eve	17,2	18,7	15,8	23,5	17,1	12,2	11,2	11,2	16,8	17,5	21,0	20,3	12,3	19,7	13,9	15,6	16,1	20,6	14,5	17,0	17,9	18,9	19,2	20,0	10,8	14,2
late	14,3	15,2	13,3	21,4	13,8	10,3	9,0	8,7	13,8	14,3	17,9	16,9	10,5	17,5	11,1	12,5	13,0	18,7	12,2	13,8	15,0	15,3	15,6	16,2	8,3	11,7
night	10,9	11,7	10,3	19,7	10,2	8,6	6,8	6,2	10,6	9,9	14,7	13,0	8,6	14,0	7,5	8,3	9,6	16,3	10,2	10,2	14,2	11,8	11,0	11,9	6,1	9,2
SEP																										
morn	14,4	12,9	13,5	24,8	11,8	13,2	10,6	10,1	13,7	12,2	19,8	13,4	13,2	18,5	10,3	9,6	12,1	22,3	14,3	11,1	19,7	13,2	12,8	16,9	11,9	14,0
mid	18,9	17,3	17,3	28,5	16,4	15,6	14,1	13,7	18,5	16,9	25,0	18,9	15,7	23,2	14,7	14,6	16,6	25,3	17,2	15,7	23,5	17,8	18,6	23,2	14,8	17,4
eve	17,9	16,6	16,2	26,9	15,5	14,5	13,0	12,7	17,2	16,3	23,1	18,0	14,3	21,9	13,8	13,8	15,5	23,9	15,8	14,8	20,9	16,8	17,6	22,8	13,7	16,1
late	14,5	13,3	13,2	24,5	12,1	12,6	10,5	10,1	13,6	12,8	19,7	14,0	12,3	18,8	10,8	10,3	12,0	21,8	13,4	11,5	18,3	13,4	13,1	18,0	11,4	13,5
night	12,1	10,7	11,5	21,9	9,5	11,5	8,4	7,9	11,3	10,1	16,2	10,6	11,6	15,7	7,9	7,1	10,1	19,8	12,3	8,6	17,9	10,8	10,2	14,6	9,9	12,1
OCT																										
morn	10,5	8,6	10,0	20,2	7,9	8,8	5,8	5,2	10,4	8,1	15,4	8,4	10,6	15,1	5,7	5,1	8,6	19,2	10,4	6,6	16,7	8,7	9,5	12,2	6,8	10,8
mid	14,2	12,4	12,9	25,5	11,2	10,6	7,8	7,2	14,1	11,6	20,3	13,8	12,5	19,6	8,3	8,2	11,9	22,3	12,7	10,3	20,0	12,6	14,1	17,9	8,7	13,5
eve	13,4	11,8	12,2	23,0	10,6	9,9	7,2	6,6	13,3	11,2	18,6	12,9	11,6	18,4	7,8	7,7	11,3	20,9	12,0	9,6	18,7	11,8	13,3	17,0	8,1	12,6
late	11,6	9,9	10,9	20,7	9,0	9,1	6,4	5,8	11,6	9,4	16,1	10,2	10,9	16,1	6,5	6,2	9,8	19,5	11,0	7,8	17,3	9,9	10,9	14,2	7,4	11,4
night	9,8	8,0	9,5	17,9	7,3	8,3	5,4	4,9	9,9	7,7	13,5	7,5	10,3	13,8	5,3	4,6	8,2	17,9	10,0	5,9	15,9	8,0	8,6	11,3	6,5	10,3
NOV																										
morn	6,2	3,7	5,9	14,5	2,8	4,7	1,4	0,8	6,1	3,2	11,5	3,7	7,5	11,3	1,2	0,6	4,3	15,7	6,6	2,0	12,8	4,1	4,7	6,9	2,9	7,2
mid	8,6	5,9	7,8	20,9	4,6	5,4	1,9	1,4	8,4	5,1	15,4	6,7	9,1	14,5	2,2	1,7	6,2	18,0	8,1	3,7	15,6	6,3	7,8	11,4	3,6	9,2
eve	8,4	5,8	7,8	18,7	4,4	5,2	1,8	1,2	8,2	5,1	14,4	6,3	8,9	14,4	2,0	1,5	6,2	17,3	8,0	3,3	14,8	5,8	7,3	11,0	3,4	9,2
late	7,4	4,9	7,0	16,3	3,7	4,9	1,7	1,1	7,4	4,4	12,8	5,2	8,3	13,1	1,7	1,1	5,4	16,0	7,4	2,8	13,5	5,1	6,1	9,2	3,2	8,4
night	6,1	3,8	6,0	13,0	2,8	4,7	1,4	0,8	6,1	3,3	10,7	3,7	7,5	11,2	1,3	0,6	4,4	15,2	6,6	2,0	12,5	3,9	4,5	6,7	2,9	7,3
DEC																										
morn	2,8	-1,1	2,9	10,6	-1,1	1,2	-3,1	-4,2	3,9	-0,4	8,3	-2,1	5,5	7,7	-3,6	-5,5	1,7	12,5	3,1	-3,0	10,2	-1,2	-0,2	3,8	-0,7	4,8
mid	4,6	0,2	4,2	16,4	-0,1	1,6	-2,4	-3,3	5,3	0,7	11,0	-0,1	6,6	10,7	-2,8	-4,1	2,8	14,4	4,1	-2,0	12,6	0,1	2,3	7,8	-0,5	6,0
eve	4,6	0,0	4,4	14,6	-0,3	1,5	-2,7	-3,4	5,5	0,7	10,2	-0,5	6,3	10,8	-3,1	-4,4	3,0	13,6	4,1	-2,3	12,1	-0,2	2,3	8,2	-0,7	5,9
late	3,6	-0,5	3,7	11,9	-0,7	1,3	-3,1	-3,7	4,7	0,3	8,6	-1,3	5,5	9,1	-3,7	-5,2	2,5	12,2	3,5	-3,0	10,2	-0,7	1,3	6,5	-0,7	5,1
night	2,8	-1,0	3,0	9,5	-1,1	1,2	-3,0	-3,8	4,0	-0,3	7,8	-2,1	5,5	7,6	-3,7	-5,3	1,8	12,2	3,1	-3,0	10,0	-1,2	0,0	4,0	-0,7	4,8
	2,2	-1,6	2,4	6,1	-1,9	0,5	-4,3	-5,6	2,9	-0,7	5,7	-2,1	5,1	5,5	-3,7	-5,5	0,5	9,9	2,5	-3,0	9,1	-1,4	-1,2	3,3	-2,0	4,2

Table I5 . Global solar irradiance qsol in W/m² per time-period in country capitals over the heating season [JRC]

	EU	AT	BE	CY	CZ	DK	EE	FI	FR	DE	GR	HU	EI	IT	LT	LI	LU	MT	NL	PL	PO	SK	SI	ES	SE	UK
Weight %	**100**	1,6	2,4	0,1	2,1	1,3	0,3	1,3	14,4	19,0	2,7	2,0	0,8	13,0	0,5	0,6	0,1	0,1	3,3	5,7	2,6	0,9	0,4	10,2	2,1	12,5
global solar irradiance in W/m²																										
JAN																										
morn	62	49	29	203	41	19	4	3	47	30	77	53	30	116	13	16	34	146	28	27	170	46	74	154	5	35
mid	218	193	128	458	160	110	79	76	172	144	409	201	157	338	93	114	135	412	131	131	445	191	255	423	84	166
eve	4	2	1	23	1	0	0	0	2	0	14	3	0	9	0	0	1	12	0	0	16	2	4	14	0	0
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FEB																										
morn	126	114	101	263	104	87	74	124	113	102	82	120	82	177	81	100	112	224	108	92	217	115	135	219	72	95
mid	309	288	261	516	251	217	228	223	284	260	427	304	225	383	232	259	282	490	267	242	457	291	337	473	211	253
eve	15	12	10	41	12	9	5	0	12	10	28	13	8	24	7	9	12	28	11	9	31	13	14	30	4	10
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	0	0	0	3	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
MAR																										
morn	217	236	164	328	187	171	182	185	213	173	153	221	176	277	187	209	178	318	173	182	326	216	218	352	177	167
mid	411	388	303	593	348	298	340	343	386	329	538	412	328	519	344	369	336	598	317	346	628	401	407	651	325	320
eve	41	29	31	64	35	35	34	35	41	32	52	41	33	52	36	42	33	59	33	34	60	41	41	67	34	31
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	6	9	4	9	5	5	5	5	6	4	5	6	5	7	5	6	4	8	5	4	8	6	6	9	5	4
APR																										
morn	301	295	258	357	277	291	301	302	305	276	284	309	271	345	299	298	272	373	283	269	347	308	292	359	287	270
mid	495	488	418	656	445	461	486	484	476	441	626	519	437	594	475	454	441	670	449	441	588	506	479	596	461	440
eve	78	75	69	76	74	81	84	85	83	75	80	77	74	81	83	86	72	82	77	71	81	79	74	86	80	71
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	18	17	17	14	18	21	22	23	20	19	12	18	19	17	22	23	17	16	19	17	17	18	17	18	21	17
MAY																										
morn	353	340	308	395	332	362	377	372	322	348	356	361	328	384	382	359	314	395	337	350	380	351	322	414	380	317
mid	541	526	459	652	497	531	562	551	476	522	656	556	481	612	567	523	472	667	496	528	635	538	502	666	576	466
eve	111	105	103	102	109	127	133	134	106	116	98	111	113	108	131	126	102	101	115	115	99	109	97	112	130	108
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	32	30	32	24	33	41	43	44	32	36	19	32	36	28	42	40	31	24	36	35	24	32	28	28	41	34
SEP																										
morn	259	255	210	361	218	216	192	183	265	220	247	276	212	323	216	210	236	345	215	208	371	270	251	366	209	212
mid	479	473	372	694	388	376	337	320	461	391	707	532	385	615	370	351	421	673	381	384	684	495	491	688	370	391
eve	54	52	46	69	47	48	43	41	58	47	67	54	45	63	49	49	50	65	47	44	74	56	49	72	46	44
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	9	9	8	10	9	9	8	8	11	9	6	9	8	10	10	10	9	10	9	8	12	10	8	11	9	8
OCT																										
morn	166	159	131	307	146	112	86	79	166	131	92	175	118	230	112	121	134	286	122	135	288	173	177	264	97	129
mid	375	367	283	617	327	259	204	191	349	301	543	410	278	509	246	255	294	597	277	307	590	387	380	562	233	296
eve	24	21	18	49	20	15	10	9	24	17	38	23	15	33	14	17	18	41	16	18	45	24	26	40	11	17
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	1	1	1	4	1	1	0	0	1	1	2	1	1	2	0	1	1	3	1	1	4	1	2	3	0	1
NOV																										
morn	76	62	48	226	48	36	13	10	66	45	60	77	44	134	24	33	58	181	48	41	204	80	88	160	20	48
mid	247	205	178	514	149	156	87	78	236	171	404	242	184	372	108	126	196	460	173	152	431	205	268	428	122	196
eve	6	4	2	27	3	0	0	0	4	2	17	5	1	12	0	1	4	17	2	2	24	1	6	16	0	2
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEC																										
morn	44	31	18	166	24	9	0	0	30	16	45	33	17	99	3	6	22	134	15	14	165	28	49	113	0	17
mid	177	144	103	423	111	86	48	44	141	106	356	155	117	307	56	70	115	382	102	92	409	140	190	347	51	121
eve	2	0	0	16	0	0	0	0	0	0	10	1	0	7	0	0	0	9	0	0	14	0	1	8	0	0
late	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
night	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table I6a . Building characteristics per load profile and EU Member State 2006 (Part 1) [VHK Ecoboiler 2007]

	EU	AT	BE	CY	CZ	DK	EE	FI	FR	DE	GR	HU	EI	IT	LT	LI	LU	MT	NL	PL	PO	SK	SI	ES	SE	UK
Relative weight in %																										
	100	1,6	2,4	0,1	2,1	1,3	0,3	1,3	14,4	19,0	2,7	2,0	0,8	13,0	0,5	0,6	0,1	0,1	3,3	5,7	2,6	0,9	0,4	10,2	2,1	12,5
XXS apartment new																										
V	232	236	245	232	246	242	219	211	259	267	280	192	223	192	468	248	255	221	258	232	183	276	224	225	299	163
h	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95
AV	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40
U	0,53	0,49	0,56	0,62	0,49	0,49	0,37	0,25	0,49	0,49	0,62	0,49	0,49	0,62	0,37	0,49	0,49	0,62	0,49	0,64	0,62	0,49	0,49	0,62	0,25	0,49
qinf	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12
qv	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47
qrec	5%	0%	0%	0%	0%	0%	0%	60%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	40%	0%	0%	0%	0%	0%	60%	8%
tm	17,8	18	18	18	18	18	18	12	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	12	18
XS average new																										
V	288	286	332	292	297	315	253	257	319	323	353	261	290	225	557	300	336	274	325	282	251	337	320	272	361	233
h	2,85	2,85	2,80	2,84	2,89	2,83	2,89	2,87	2,84	2,86	2,83	2,82	2,77	2,90	2,89	2,87	2,81	2,84	2,81	2,88	2,80	2,88	2,81	2,87	2,85	2,79
AV	0,51	0,50	0,55	0,51	0,49	0,52	0,46	0,48	0,51	0,49	0,52	0,53	0,58	0,45	0,46	0,48	0,54	0,51	0,54	0,47	0,55	0,50	0,54	0,51	0,50	0,56
U	0,53	0,49	0,56	0,62	0,49	0,49	0,37	0,25	0,49	0,49	0,62	0,49	0,49	0,62	0,37	0,49	0,49	0,62	0,49	0,64	0,62	0,49	0,49	0,62	0,25	0,49
qinf	0,14	0,13	0,14	0,14	0,13	0,14	0,13	0,13	0,14	0,13	0,14	0,14	0,15	0,13	0,13	0,13	0,14	0,14	0,14	0,13	0,14	0,14	0,14	0,14	0,13	0,14
qv	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47
qrec	5%	0%	0%	0%	0%	0%	0%	60%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	40%	0%	0%	0%	0%	0%	60%	8%
tm	17,8	18	18	18	18	18	18	12	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	12	18
S apartment existing = ca. new row house but with less m²																										
V	196	220	177	196	178	236	148	180	207	211	186	153	221	211	133	143	266	221	218	159	171	131	148	211	215	171
h	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95
AV	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,35	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40
U	1,03	1,00	1,40	2,00	1,00	0,60	1,20	0,70	0,90	0,80	1,40	1,00	1,00	1,40	1,00	1,00	1,10	1,40	0,65	1,00	1,20	1,00	1,20	1,20	0,70	1,05
qinf	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
qv	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65
qrec	3%	0%	0%	0%	0%	0%	0%	40%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	0%	40%	5%
tm	17,8	18	18	18	18	18	18	12	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	12	18
M average existing =ca. new house semi-detached																										
V	245	266	240	248	215	306	171	220	254	255	234	208	288	247	158	173	350	274	275	194	234	160	210	255	260	244
h	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84	2,84
AV	0,51	0,50	0,55	0,51	0,49	0,52	0,46	0,48	0,51	0,49	0,52	0,53	0,58	0,45	0,46	0,48	0,54	0,46	0,54	0,47	0,55	0,50	0,54	0,51	0,50	0,56
U	1,03	1,00	1,40	2,00	1,01	0,60	1,20	0,70	0,90	0,80	1,40	1,00	1,00	1,40	1,00	1,00	1,10	1,40	0,65	1,00	1,20	1,01	1,20	1,21	0,70	1,05
qinf	0,19	0,18	0,20	0,19	0,18	0,19	0,17	0,18	0,19	0,18	0,19	0,20	0,21	0,17	0,17	0,18	0,20	0,20	0,20	0,18	0,20	0,19	0,20	0,19	0,18	0,21
qv	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65
qrec	4%	0%	0%	0%	0%	0%	0%	40%	5%	5%	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	0%	40%	5%
tm	17,8	18	18	18	18	18	18	12	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	12	18
L existing house= ca. new house detached																										
V	292	316	261	292	259	351	220	275	290	308	268	237	294	358	220	220	385	319	300	253	253	187	234	290	308	261
h	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75
AV	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,55	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
U	1,03	1,00	1,40	2,00	1,00	0,60	1,20	0,70	0,90	0,80	1,40	1,00	1,00	1,40	1,00	1,00	1,10	1,40	0,65	1,00	1,20	1,00	1,20	1,20	0,70	1,05
qinf	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22	0,22
qv	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65
qrec	3%	0%	0%	0%	0%	0%	0%	40%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	0%	40%	5%
tm	17,8	18	18	18	18	18	18	12	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	12	18
XL low-rise row new (8 apt.) or semi-detached house existing																										
V	1852	1890	1959	1856	1965	1940	1750	1685	2074	2134	2239	1538	1787	1535	3746	1984	2039	1770	2067	1853	1468	2209	1794	1797	2396	1306
h	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95
AV	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40
U	0,53	0,49	0,56	0,62	0,49	0,49	0,37	0,25	0,49	0,49	0,62	0,49	0,49	0,62	0,37	0,49	0,49	0,62	0,49	0,64	0,62	0,49	0,49	0,62	0,25	0,49
qinf	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12
qv	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47
qrec	5%	0%	0%	0%	0%	0%	0%	60%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	40%	0%	0%	0%	0%	0%	60%	8%
tm	17,8	18	18	18	18	18	18	12	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	12	18
XXL low-rise row existing (8 apt.) or large detached house existing																										
V	1571	1759	1416	1568	1423	1888	1180	1441	1652	1685	1487	1227	1770	1685	1062	1142	2124	1770	1746	1273	1369	1048	1180	1685	1722	1369
h	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95
AV	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,35	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40
U	1,03	1,00	1,40	2,00	1,00	0,60	1,20	0,70	0,90	0,80	1,40	1,00	1,00	1,40	1,00	1,00	1,10	1,40	0,65	1,00	1,20	1,00	1,20	1,20	0,70	1,05
qinf	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
qv	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65
qrec	3%	0%	0%	0%	0%	0%	0%	40%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	0%	40%	5%
tm	17,8	18	18	18	18	18	18	12	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	12	18

Table I6b . Building characteristics per load profile and EU Member State 2006 (Part 2) [VHK Ecoboiler 2007]

3XL high-rise (20 apt, 1/3 new + 2/3 exist)

	EU	AT	BE	CY	CZ	DK	EE	FI	FR	DE	GR	HU	EI	IT	LT	LI	LU	MT	NL
V	4994	5409	4791	4992	4810	5716	4110	4567	5378	5503	5213	3992	5327	4904	5870	4268	6287	5310	5560
h	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95
AV	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,35	0,40
U	0,86	0,83	1,12	1,54	0,83	0,56	0,92	0,55	0,76	0,70	1,14	0,83	0,83	1,14	0,79	0,83	0,89	1,14	0,60
qinf	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14
qv	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59
qrec	4%	0%	0%	0%	0%	0%	0%	47%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	27%
tm	17,8	18	18	18	18	18	18	12	18	18	18	18	18	18	18	18	18	18	18

	PL	PO	SK	SI	ES	SE	UK
V	4399	4205	4305	4154	5166	5840	4043
h	2,95	2,95	2,95	2,95	2,95	2,95	2,95
AV	0,40	0,40	0,40	0,40	0,40	0,40	0,40
U	0,88	1,00	0,83	0,96	1,00	0,55	0,86
qinf	0,14	0,14	0,14	0,14	0,14	0,14	0,14
qv	0,59	0,59	0,59	0,59	0,59	0,59	0,59
qrec	0%	0%	0%	0%	0%	47%	6%
tm	18	18	18	18	18	12	18

4XL blockheat (60 apt. 1/3 new + 2/3 existing)

	EU	AT	BE	CY	CZ	DK	EE	FI	FR	DE	GR	HU	EI	IT	LT	LI	LU	MT	NL
V	14981	16228	14374	14976	14431	17148	12331	13701	16135	16509	15638	11977	15981	14712	17610	12803	18861	15930	16680
h	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95
AV	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,35	0,40
U	0,86	0,83	1,12	1,54	0,83	0,56	0,92	0,55	0,76	0,70	1,14	0,83	0,83	1,14	0,79	0,83	0,89	1,14	0,60
qinf	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14
qv	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59	0,59
qrec	4%	0%	0%	0%	0%	0%	0%	47%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	27%
tm	17,8	18,0	18,0	18,0	18,0	18,0	18,0	12,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0

	PL	PO	SK	SI	ES	SE	UK
V	13196	12616	12915	12461	15498	17519	12130
h	2,95	2,95	2,95	2,95	2,95	2,95	2,95
AV	0,40	0,40	0,40	0,40	0,40	0,40	0,40
U	0,88	1,00	0,83	0,96	1,00	0,55	0,86
qinf	0,14	0,14	0,14	0,14	0,14	0,14	0,14
qv	0,59	0,59	0,59	0,59	0,59	0,59	0,59
qrec	0%	0%	0%	0%	0%	47%	6%
tm	18,0	18,0	18,0	18,0	18,0	12,0	18,0

New house (comparable to S but with more m²) No load-profile but for information

	EU	AT	BE	CY	CZ	DK	EE	FI	FR	DE	GR	HU	EI	IT	LT	LI	LU	MT	NL
V	343	340	361	344	357	361	326	321	364	390	403	296	297	326	776	382	370	319	355
h	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75
AV	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60
U	0,53	0,49	0,56	0,62	0,49	0,49	0,37	0,25	0,49	0,49	0,62	0,49	0,49	0,62	0,37	0,49	0,49	0,62	0,49
qinf	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
qv	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,47
qrec	5%	0%	0%	0%	0%	0%	0%	60%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	40%
tm	17,8	18,0	18,0	18,0	18,0	18,0	18,0	12,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0

	PL	PO	SK	SI	ES	SE	UK
V	368	271	394	358	310	429	249
h	2,75	2,75	2,75	2,75	2,75	2,75	2,75
AV	0,60	0,60	0,60	0,60	0,60	0,60	0,60
U	0,64	0,62	0,49	0,49	0,62	0,25	0,49
qinf	0,15	0,15	0,15	0,15	0,15	0,15	0,15
qv	0,47	0,47	0,47	0,47	0,47	0,47	0,47
qrec	0%	0%	0%	0%	0%	60%	8%
tm	18,0	18,0	18,0	18,0	18,0	12,0	18,0

Annex J: Items not covered

The mathematical model is to be used for implementing measures in the context of the Directive on Eco-design of Energy-using Products (32/2005/EC), which is a product-oriented directive in the context of Art. 95 of the European Treaty and which uses CE-marking as an instrument. In other words, implementing measures apply to features of the products as they leave the factory gates. They do not apply to the application/ installation of these products e.g. in buildings and are therefore complementary to and not a substitution of application-oriented measures such as the ones relating to energy performance of buildings, energy certification etc..

Having said that, it has been the aim of the mathematical model to facilitate and simplify the rule-making in the context of application-oriented measures as much as possible e.g. by using a fixed set of standard reference conditions, as shown in Annex C, D and E. But this implies that for off-standard conditions and situations where the local circumstances significantly deviate from the reference conditions the application-oriented measures shall make corrections. Furthermore, it is a major task for application-oriented measures to make sure that the appropriate CH Boiler and Water Heater is chosen for a specific building and user.

The data and model in the underlying document aim to facilitate the necessary assessments and corrections at the level of application-oriented measures. The list below gives a non-exhaustive overview of items that are not covered in the mathematical model for Eco-design and that are to be addressed in application-oriented measures.

A.

Subjects related to CH-Boilers and Water Heaters that are not covered and should be corrected in application-oriented measures?

- Deviations from CH distribution losses (exceptions in terms of Upipe, hlf, L; these can be traced from the model)
- Deviations from standard emitter (radiator, 20 l/kW, radc=1,3), e.g. convectors, floor heating, etc. improve Tstrat
- Deviations from standard WH distribution losses, e.g. circulation systems (pump + higher distribution losses) and collective/central systems.[11]
- Multi-zone and double circuit lay-outs (improve control efficiency Tfluct and lower Tdistr)

B.

Which EPB subjects are currently not covered, but could/should be covered by similar approach as Ecoboiler?

- Central and local **ventilation** systems (focus on controls and waste heat recovery; high saving potential)
- Space **cooling** (RAC, CAC)
- **Micro-/mini-CHP**:
- **Air heating** systems (in Europe usually the heating mode of air conditioners)
- **Local heaters** (could be the future BAT because zero-distribution losses, but generator efficiency needs to improve and safety is an important issue)
- **Solid fuel boilers/ heaters.**
- **Components** (e.g. indirect cylinders)

C.

Possible assessment-procedure in application-oriented measures, using the rating from Eco-design measures.

1. **Building shell heat load.** Assessment of transmission losses (geometry, orientation, U, R values, climate), standard ventilation losses (qinf and qv), solar and internal gains
2. **Ventilation correction.** Based on ventilation controls and waste heat recovery of the system → Result: net heat load.

[11] Example of complementary approach in **ITG Institut for für Technische Gebäudeausrüstung**, *Ergänzung des Ecohotwater-Modells für eine gesamt-energetische Bewertung von Trinkwarmwassersystemen*, for Stiebel-Eltron, Dresden, Germany, Jan. 2008.

3. **Heating system capacity** selection (XXS, XS, S, M, L etc.) in accordance with net heat load. If there is no match, then there should be penalty (to calculate from Ecoboiler model)
4. **Space heating (CH) efficiency xx%** taken from the technical fiche of the Ecoboiler label (A-G rating is a check!
5. **Corrections (if necessary) on this efficiency** (see section A)
6. **Apply efficiency to net heat load of building/dwelling**→ primary space heating energy per annum

7. **Add: Water heating** primary energy from the load (XXS – 4XL) indicated on the water heater label (could be a combi) and apply the efficiency from the technical fiche (A-G rating is extra check)

8. **Add: Space cooling requirement**. From building features on one hand and equipment fiche/label on the other hand.

9. **Add: Electricity use as appropriate**. E.g. lighting, Specific Fan Power x running hours of ventilation system, appliances. Apply primary energy conversion factor (2,5). Check coherence with internal gains.

10. **Sum** outcomes of points 6, 7, 8 and 9 to find **total primary energy and efficiency** (e.g. in kWh/m².a).

ANNEX K: List of parameters

Table K1 lists the most important parameters in order of appearance in the Annexes B to I and per Annex alphabetically.

Table K1. List of parameters

name	description	unit	name	description	unit
ANNEX B					
a_1	first-order collector loss coefficient	W/m²*K	**Qelec**	electricity consumption of water heating test	kWh/day
a_2	second-order collector loss coefficient	W/m²*K	**Qelecmax**	Electricity consumption of back-up water heating test at maximum load	kWh/day
airfuelmix	type of air-fuel mixing technology	-	**Qelecmin**	Electricity consumption of back-up water heating test at minimum load	kWh/day
airintake	identifier of type of combustion	-	**Qfuel**	fuel consumption of water heating test (in GCV)	kWh/day
Asol	collector aperture area **Asol**	m2	**Qfuelmax**	fuel consumption of back-up water heating test at maximum load (in GCV)	kWh/day
autotimer	identifier of usage of automatic timer	-	**Qfuelmin**	fuel consumption of back-up water heating test at minimum load (in GCV)	kWh/day
boilpos	designated boiler position in- or outdoors	-	**solaux**	solar electric pump power	W
Cgrad / Cpar / CL	setting **Cgrad / Cpar / CL**	- / K / K	**solpos**	solar tank position (boolean value)	-
combicomp	does product comply with 'combicomp' definition ?	-	**Space heat efficiency**	space heating efficiency	-
COP50	COP correction factor at 50% load	-	**Space heat load**	space heating calculated load	kWh/a
COPnom	nominal COP heat pump	-	**Space heat primary energy use**	space heating final primary energy consumption	kWh/a
Date	date	-	**SPACE HEATING LOAD**	identifier of space heating load pattern	-
dhwsmart	does WH comply with definition smart control?	-	**Tcontrol**	space heating temperature control identifier	-
dpt	stochastic fuel dewpoint	ºC	**Testpoints (table left)**	heat pump testpoints of COP and Pnom for various Tsrc/Tsnk (table)	-
ELBU	wil electric back-up (Joule-effect) be used for space heating?	-	**Tflue**	water heating average flue gas temperature	ºC
elmaxon	electric power consumption at nominal boiler power Pbnom	kW	**tpmp**	pump runtime after boiler off	h
elminon	electric power consumption at minimal boiler power Pbmin	kW	**Tsink / Tsource**	sink and source temperatures of correction factors COP/ Pnom of heat pump	ºC
elpmp	electric power consumption of pump (pump only)	kW	**Tsnkmax**	maximum heat pump sink temperature	ºC
elstby	electric power consumption of boiler at burner off (no purge)	kW	**turndown**	turndown ratio boiler	-
Energy label Space Heat	Energy label class Space Heating	-	**turndownhp**	turndown ratio heat pump	-
Energy label Water Heating	Energy label class Water Heating	-	**twostage**	identifier for two-stage burner (boolean value)	-
hpaux	heat pump auxiliary electric power consumption	W	**UA**	tank heat loss coefficient	W/K
HPtestpoint_a	heat pump correction factor for COP/Pnom at testoint a	-	**UAsol**	heat transfer rate of solar heat exchanger	W/K
HPtestpoint_b	heat pump correction factor for COP/Pnom at testoint b	-	**Upipesol_m**	specific solar collector loop loss	W/m*K
HPtestpoint_c	heat pump correction factor for COP/Pnom at testoint c	-	**usehp**	identifier of heat pump usage (HW, CH or both)	-
HPtestpoint_d	heat pump correction factor for COP/Pnom at testoint d	-	**usesol**	identifier of solar system usage (HW, CH or both)	-
HPtestpoint_e	heat pump correction factor for COP/Pnom at testoint e	-	**V40hp**	water heating tank capacity as energy equivalent of litres of 40ºC	ltr
HPtype	heat pump type selection	-	**varsp**	identifier of usage of variable speed (boolean value)	-
IAM	incidence angle modifier	-	**Vcontrol**	identifier of type of valve control (boolean value)	-
ID	number for type/model identification	-	**ventmix**	identifier of usage of (also) ventilation exhaust air (boolean value)	-
Lpipesol	total solar collector loop pipe lenght	m	**Vhp**	heat pump nominal tank volume	ltr
Manufacturer	identifier for manufacturer	-	**volumeb**	CH boiler, CH combi or water heater volume of envelope	m3
massb	boiler mass (empty)	kg	**vsol**	solar part of solar tank nominal volume	ltr
massw	water content of boiler heat exchanger	kg	**Water heat**	water heating efficiency	-

Model	identifier of model	-
noiseh	noise level of boiler measured as sound power at nominal load	dB(A)
noisew	noise level of water heater measured as spound power at nominal load	dB(A)
Optimiser	boolean value for use of optimiser	-
p_bstby	standby heat loss as % of Qb8060	-
pdrop	pressure drop over the boiler (if no internal pump)	mbar
Phpnom	nominal heating power of heat pump	kW
Pign	pilotflame power boiler	kW
pmpconfig	identifier of type of pump configuration	-
pmpsb	boolean value for pump setback	-
Pstbyhp	reference heat loss heat pump tank	kW
Qb8060	nominal heat input CH boiler at 80/60 ºC	kW

energy eff.		
Water heat net load	water heating calculated load	kWh/a
Water heat primary energy use.	water heating final primary energy consumption	kWh/a
WATER HEATING LOAD	identifier of water heating load pattern	-
Waterloadmax	identifier of maximum load pattern for back-up water heating	-
Waterloadmin	identifier of minimum load pattern for back-up water heating	-
η0	zero-loss collector efficiency	-
η5030	efficiency at nominal power and 50/30 ºC	-
η5030min	efficiency at minimal power and 50/30 ºC	-
η8060	efficiency at nominal power and 80/60 ºC	-
η8060min	efficiency at minimal power and 80/60 ºC	-
ηcomb	water heating combustion efficiency	-

ANNEX C

bband	boiler thermostat temp.band	K
CHfrac	partitioning of load between to space heating (load for water heating = 1-CHfrac)	-
dpm	average number of days per month (fixed 30.5)	days
elmaxonz	final max. electric power of boiler if pmpconfig is 2/3 (kW)	kW
elminonz	final min. electric power of boiler if pmpconfig is 2/3 (kW)	kW
elpmpz	final electric power of pump if pmpconfig is 2/3 (kW)	kW
f	system water flow rate (l/min)	ltr/min
F	average heated floor area	m2
fcyc	defines cycles per hour for Tcontrol chrono proportional	-
fixflow	nominal pump flow rate	ltr/h
flf	fuel loss factor	-
hd	length of day-period	h
hlf	heat loss factor (-)	-
hpaf	air flow needed for ventilation air heat pump (fixed at 300)	m³/h*kW
lambda	defines air factor depending on type of air fuel mixing technology	-
Lpipe	specific pipe length of CH distribution per m² floor area	m/m²
Maxoutput	required maximum heat output per load profile	kW
minflow	average pump flow rate for variable speed pump	ltr/h
Minoutput	required minimum heat output per load profile	kW
Pb8060	nominal heat output of preferential boiler at 80/60 temp.regime	kW
Pb8060b	nominal heat output of non-pref. boiler at 80/60 temp.regime	kW
Pdistr	specific distribution power requirement (per degree temp. difference)	W/K
pdropref	reference pressure drop over the boiler (kW)	mbar
PH	heating power demand per day-period (varies with settings autotimer/optimiser)	kW
Ppmpboiler	reference pump power for the boiler	kW
Ppmploop	pump power needed for the distribution network	kW
Ppmptot	total pump power needed for boiler and network	kW

Pradnomsum	total nominal radiator power - per load profile	kW
Q	useful energy content of water withdrawal (tapping)	kWh
Q_solm	solar irradiation - monthly average	kWh/m²
Qgains	energy from solar and internal gains	W
QH	initial space heating energy load (varies per control settings)	kWh
qloss	heat loss factor (varies per chosen heat load pattern)	W/K
Qref	daily water heating load (sum of useful energy per tapping)	kWh
qsol	solar irradiance - per m² floor area and per day period	W/m²
qsolm	monthly average solar irradiance	W/m²
radc	space heating radiator constant	-
tband	room thermostat temp.band	K
Tin00	multi-zone temp.regime with setback, no optimiser	ºC
Tin30	multi-zone temp.regime with setback, with optimiser	ºC
Tin	indoor temperature	ºC
Tinx	fixed temperature setting for all day-periods	ºC
Tm	water temperature from which counting of useful energy content begins	ºC
Tout	outdoor temperature	ºC
Toutm	outdoor temperature - monthly average	ºC
Tp	minimum water temperature to be achieved during tapping	ºC
tpurge	boiler purge time	h
Tsrcbrine	brine soil temperature - per day period	ºC
Tsrcwater	water soil temperature - per day period	ºC
Tsysbini	initial system temperature at boiler	ºC
TW	target temperature regime for weather controlled ('morn' to 'eve')	ºC
TWN	target temperature regime for weather controlled ('night')	ºC
Upipe	specific heat loss of space heating pipe	W/m*K
valveband	temperature difference per Vcontrol type	ºC

Pradnom1	day-zone radiator capacity - per load profile	kW
Pradnom2	night-zone radiator capacity - per load profile	kW
Pradnom3	bath-zone radiator capacity - per load profile	kW

valvedelay	time delay per Vcontrol type	h
ventex	available ventilation exhaust air flow	m³/h
Vpipe	total water volume in CH distribution pipes	ltr

ANNEX D		
a_c	resulting collector heat loss coefficient	W/m²*K
ah	specific heat of air (0.33 Wh/Km^3)	Wh/K*m3
Asolh	space heating fraction of solar collector	m2
Ccap	Ccap value	- or m²/ltr
cooldt	average cool-down time during the day or 'night'	h
COPcorr2h	space heating final COP correction including part load - month	-
COPcorrh	space heating correction factor for nominal heat pump COP per day-period	-
COPcorrhm	NEW ! space heating correction factor for nominal heat pump COP per month	-
COPpartcorrh	space heating COP part load correction - month	-
Csysmax	extra-/interpolation nominal power at different temperatures	%
Csysmaxb	non-pref. boiler	%
Csysmin	extra-/interpolation minimal power at different temperatures	%
Csysminb	non-pref. boiler	%
cycling	boolean parameter describing whether boiler cycling occurs	-
dptc	air factor corrected fuel dewpoint	ºC
dTfluct	total temperature fluctuation from valves and Tcontrol	K
dTrad	system temperature bandwidth	K
dTstrat	stratification losses temperature band	K
dTsysdistr	accounting parameter; increase system temp. due to distribution losses	K
dTsysfluct	accounting parameter; increase system temp. due to fluctuation losses	K
dTsyssttrat	accounting parameter; increase system temp. due to stratification losses	K
FCh	space heating load factor for heat pump - month	-
heatut	average heat-up time during day-periods or 'night' period	h
hppcorrh	correction factor for nominal heat pump power output per day-period	-
hppcorrhm	correction factor for nominal heat pump power output as monthly average	-
Ncyc	calculated number of cycles per day-period	-
nightcorr	correction factor for stratification during night period	-
offhrs	preliminary total burner-off hours per day-period	h
offhrsz	final number of burner-off hours - per day-period	h
onhrs	preliminary total burner-on hours per day-period	h
onhrsz	final number of burner-on hours - day-period	h
p_bstbyb	standby heat loss as % of Qb8060 of non-pref. boiler	-
P_distr	power requirement due to distribution	kW
parthph	partioning of heat pump load to CH	-
partsolh	partitioning of solar system load to CH	-

QH7b	accounting parameter - non-pref. boiler heat demand incl. standby losses	kWh
QH7tot	accounting parameter - final heat demand incl. standby losses	kWh
QH8	accounting parameter - heat demand including fuel losses	kWh
QH8b	accounting parameter - non-pref. boiler heat demand including fuel losses	kWh
QH8tot	accounting parameter - final heat demand incl. fuel losses pref. and non-pref. boiler	kWh
QH9	accounting parameter - heating energy demand including steady state losses	kWh
QH9b	accounting parameter - non-pref. boiler heating energy demand incl. on-mode loss	kWh
QH9tot	accounting parameter - final heating energy demand incl. on-mode loss	kWh
Qhpauxh	space heating heat pump auxiliary energy consumed (primary)	kWh
Qhpcons	primary energy consumed by hp for space heating - per month	kWh
Qhph	space heating delivered by hp - per month	kWh
Qhploadh	space heating load for heat pump	kWh
Qhpmaxh	space heating maximum heat pump output available	kWh
Qhpnetconsh	space heating net energy consumed - month	kWh
Qhpnetsaveh	space heating energy credits from heat pump contribution	kWh
Qhprecovh	space heating auxiliary heat recovered	kWh
QHss	space heating steady state energy loss incl. Qrest1	kWh
QHssb	steady state energy loss incl. Qrest1 for non-pref. boiler	kWh
QHW	initial space heating energy load for weather c. systems	kWh
Qign	pilot flame energy consumption	kWh
Qignb	pilot flame energy consumption non-pref. boiler	kWh
Qsolloadh	space heating load before solar contribution (equals QH6)	kWh
Qsolloadh2	space heating load put on solar system, 2nd iteration	kWh
Qsolloadresth	space heating load remaining after 2nd solar iteration	kWh
Qlossfuel	space heating energy loss from fuel losses	kWh
Qlossfuelb	space heating energy loss from fuel losses non-pref. boiler	kWh
Qlosspurge	space heating energy loss from purge losses	kWh
Qlosspurgeb	space heating energy loss from purge losses non-pref. boiler	kWh
Qlosstwostage	space heating energy loss from two-stage burner boiler	kWh
Qpmpel	space heating electric energy demand of pump	kWh
qrecov	annual average heat recovery factor (water heater, with noisew)	-
qrecovb_summer	heat recovery factor summer months Jun - Aug	-
qrecovb_transit	heat recovery factor transit months May + Sep	-
qrecovb_winter	heat recovery factor winter months Oct - Apr	-
Qrest	accounting parameter; heat demand remaining after hp/solar contribution	kWh

Pb	power supplied by boiler	kW
Pb5030	nominal heat output of preferential boiler at 50/30 ºC	kW
Pbenvoff	envelope losses in burner off-mode	kW
Pbenvoffb	envelope losses non-pref. boiler in burner off-mode	kW
Pbmin5030	minimal heat output at 50/30 ºC	kW
Pbmin8060	minimal heat output at 80/60 ºC	kW
Pbstby	standby power heat loss (at burner off)	kW
Pbstbyb	standby power heat loss non-pref. boiler (at burner off)	kW
Penvoffrest	heating power demand due to envelope losses off-mode	kW
Penvoffrestb	heating power demand due to envelope losses off-mode (standby) non-pref. boiler	kW
Penvon	heating power demand due to envelope losses on-mode	kW
PH3	accounting parameter: initial heating power demand	kW
PH4	accounting parameter: heating power demand at fluctuation losses	kW
PH5	accounting parameter: heating power at stratification loss	kW
PH6	accounting parameter: heating power at distribution loss	kW
PH7	accounting parameter: heating power demand including standby losses	kW
PH7b	accounting parameter: heating power demand non-pref. boiler including standby losses	kW
PH7tot	accounting parameter: heating power demand incl. standby losses total	kW
PH8	accounting parameter: heating power demand including unburnt fuel losses	kW
PH8b	accounting parameter: heating power demand including fuel loss non-pref. boiler	kW
PH8tot	accounting parameter: heating power demand incl.fuel losses total	kW
PHW	initial heat load power (for weather c. systems)	kW
Pignb	pilotflame power non-pref. boiler	kW
Pmax	maximum heating power output (including back-up)	kW
Pmin	minimum heating power output	kW
powerratio	either turndown ratio or ratio between power demand PH8 and Pmax	-
Prest	accounting parameter; power demand remaininng after hp/solar contribution	kW
Prest1	accounting parameter; power demand for back-up heating	kW
Prest2	accounting parameter; power demand for non-preferential boiler	kW
primenergy	primary energy conversion factor (fixed = 2.5)	-
Q10	total electric energy consumption (as primary energy) of boiler	kWh
Qbelon	primary energy consumption of electricity use with burner in on-mode	kWh
Qbmin8060	minimal heat input boiler at 80/60 ºC	kWh
Qbmin8060b	minimal heat input non-pref. boiler at 80/60 ºC	kWh
Qbstbyel	primary energy consumption of electricity use with boiler in standby	kWh
Qelbu	primary energy consumption of back-up space heater	kWh
Qenvoff	boiler envelope losses in off-mode	kWh
Qenvoffb	non-pref. boiler envelope losses in off-mode	kWh

	remaining after hp/solar contribution	
Qrest1	accounting parameter; space heating energy demand for electric back-up heating	kWh
Qrest2	accounting parameter; space heating energy demand by non-pref. boiler	kWh
Qresthph	space heating energ demand after hp contribution	kWh
Qsolresth	space heating load after solar contribution	kWh
Qsolh1	space heating energy from solar system, 1st iteration	kWh
Qsolh2	space heating energy from solar system, 2nd iteration	kWh
Qsolh2	space heating energy from solar system, 2nd iteration	kWh
Qsolnetsaveh	space heating energy credits from solar contribution	kWh
Qsolpipeh	pipe losses for solar water heating	kWh
Qsolauxlossh	space heating electric energy penalty for solar pump operation	kWh
Qsoltankh	space heating solar tank losses	kWh
Qsoltankrecovh	heating energy recovered from solar tank storage	kWh
Qtimer	energy penalty from autotimer operation	kWh
Qtwostage	envelope losses of two-stage boiler	kWh
Qtwostageb	envelope losses of two-stage non-pref. boiler	
realflow	space heating actual system flow rate	ltr/h
stratfactor	stratification factor (from building characteristics)	?
Tdistr	distribution temperature	ºC
TfluctT	space heating temperature fluctuation due to temp.control	K?
TfluctV	space heating temperature fluctuation due to valve control	K?
Trefh	space heating solar reference temperature	ºC
Tsrc_ventmix	source temperature for ventilation air heat pump	ºC
Tsysfeed	accounting parameter - system feed temperature	ºC
Tsysi	average initial system feed temperature	ºC
Tsysini	“ideal” (non-cycling) system temperature	ºC
Tsysravg	system return temperature average	ºC
Tsysret	average initial system return temperature during heat up	ºC
Tsysretcd	average initial system return temp. during cool-down (ºC)	ºC
Tsysrini	accounting parameter - return temperature during heat up	ºC
Tsyswini	"ideal" (non-cycling) system temperature for weather c. systems	ºC
twostageb	identifier for two-stage burner of non-pref. boiler (boolean value)	-
UL	collector loop pipe loss per m² solar collector	W/m²*K
Vradcyc	radiator fill volume per cycle as fraction of the radiator volume	m3??
Vsolh	space heating fraction of solar storage tank	ltr
wheatoff	specific heat CH water circulation	kWh/K
Xh1	space heating solar X-value, 1st iteration	-
Xh2	space heating solar X-value, 2nd iteration	-
xtband	temperature band fluctuation	K

Qenvon	boiler envelope losses in on-mode	kWh
Qenvonb	non-pref. boiler envelope losses in on-mode	kWh
Qenvonr	recovered envelope losses in on-mode	kWh
Qenvonrb	recovered envelope losses in on-mode non-pref. boiler	kWh
QH10	accounting parameter - electric energy demand for boiler	kWh
QH11	accounting parameter - total space heating primary energy demand	kWh
QH3	accounting parameter - initial heat load energy	kWh
QH4	accounting parameter - heat demand at fluctuation losses	kWh
QH5	accounting parameter - heat demand at stratification loss	kWh
QH6	accounting parameter - heat demand at distribution loss	kWh
QH7	accounting parameter - heat demand incl. standby losses	kWh

xtdelay	time delay fluctuation	h
Yh1	space heating solar Y-factor, 1st iteration	-
Yh2	space heating solar Y-value, 2nd iteration	-
η5030b	efficiency at nominal power and 50/30 ºC non-pref. boiler	-
η5030minb	efficiency at minimal power and 50/30 ºC non-pref. boiler	-
η8060b	efficiency at nominal power and 80/60 ºC non-pref. boiler	-
η8060minb	efficiency at minimal power and 80/60 ºC non-pref. boiler	-
ηb	steady state efficiency	-
ηbb	steady state efficiency non-pref. boiler	-
ηch	space heating efficiency	-
ηloop	solar collector loop efficiency	-

ANNEX E		
Asolw	water heating fraction of solar collector	m2
COPcorr2w	water heating final COP correction including part load - month	-
COPcorrw	water heating correction factor for nominal heat pump COP per day-period	-
COPcorrwm	water heating correction factor for nominal heat pump COP per month	-
COPpartcorrw	water heating COP part load correction - month	-
dQaload	water heating back-up calculation parameter	kWh
dQanet	water heating back-up calculation parameter	kWh
dQanetmax	water heating back-up calculation parameter	kWh
dQanetmin	water heating back-up calculation parameter	kWh
FCw	water heating load factor for heat pump - month	-
hppcorrw	correction factor for nominal heat pump power output per day-period	-
hppcorrwm	correction factor for nominal heat pump power output as monthly average	-
Inc	water heating accounting parameter for calculation of back-up heating	-
LHL	latent heat loss, depending on fuel (gas 10%, other 6%)	-
parthpw	partioning of heat pump load to water heating	-
partsolw	partitioning of solar system load to water heating	-
Qadistr	water heating distribution losses energy (primary)	kWh
Qaload	net water heating load in mathematical model	kWh
Qaloadmax	calculation parameter maximum water heating back-up load	kWh
Qanet	annual energy demand water heating based upon test pattern	kWh
Qanetmax	calculation parameter water heating back-up energy consumption at maximum load	kWh
Qanetmin	calculation parameter water heating back-up energy consumption at minimum load	kWh
Qaoadmin	calculation parameter minimum water heating back-up load	kWh
Qarecover	water heating heat loss recovery credit	kWh
Qatot	final energy consumption water heating	kWh
Qatot2	final energy consumption of water heating with renewables	kWh
Qawh	water heating load and distribution energy consumption	kWh

Qhpnetconsw	water heating net energy consumed - month	kWh
Qhprecovw	water heating auxiliary heat recovered	kWh
Qhptankw	standby heat losses heat pump water storage tank	kWh
Qhpw	water heating energy delivered by heat pump	kWh
Qhpwcons	water heating primary energy consumed by heat pump	kWh
Qloadrest	accounting parameter - water heating back-up	kWh
Qsolloadrestw	water heating load remaining after 2nd solar iteration	kWh
Qsolloadw	water heating load before solar contribution	kWh
Qsolloadw2	water heating load put on solar system, 2nd iteration	kWh
Qresthpw	water heating load after hp contribution	kWh
Qsolrestw	water heating load after solar contribution	kWh
Qrwaste	recoverable fraction from heat losses	kWh
Qsolnetsavew	water heating energy credits from solar contribution	kWh
Qsolpipew	pipe losses for solar water heating	kWh
Qsolauxlossw	water heating electric energy penalty for solar pump operation	kWh
Qsoltankrecovw	heating energy recovered from solar tank storage	kWh
Qsoltankw	water heating solar tank losses	kWh
Qsolw1	water heating energy from solar system, 1st iteration	kWh
Qsolw2	water heating energy from solar system, 2nd iteration	kWh
Qwaste	water heating initial energy losses	kWh
Qwdistr	water heating distribution losses	kWh
Trefw	water heating solar reference temperature	ºC
Tsinkhw	water heating heat pump sink temperature required by the tapping pattern	ºC
Tsnkw	water heating heat pump operational sink temperature	ºC
Tsrcw	water heating heat pump source temperature	ºC
Vsolw	water heating fraction of solar storage tank	ltr
WH-credit combicomp	water heating credit from CH combi operation	kWh

Qcombicomp	energy credit for CH-combi operation	kWh	**Xw1**	water heating solar X-value, 1^{st} iteration	-
Qgrossrest	calculation parameter back-up water heating	kWh	**Xw2**	water heating solar X-value, 2^{nd} iteration	-
Qhpauxw	water heating heat pump auxiliary energy consumed (primary)	kWh	**Yw1**	water heating solar Y-factor, 1^{st} iteration	-
Qhploadw	water heating load for heat pump	kWh	**Yw2**	water heating solar Y-value, 2^{nd} iteration	-
Qhpmaxw	water heating hp maximum heat pump output available	kWh	**ηwh**	water heating efficiency	

ANNEX F					
Ploss	EIHW test parameter - measured power loss in EIWH	kW	**Qstart**	EIHW test parameter - energy loss during waiting time (varies per type of draw-off)	kWh
Ploss1	EIHW test parameter - measured power loss before power control unit	kW	**Qtaploss**	EIHW test parameter - energy loss during tapping (varies per type of draw-off)	kWh
Ploss2	EIHW test parameter - measured power loss after power control unit	kW	**t_start**	EIHW test parameter - waiting time (varies per type of draw-off)	s
Pstatic	EIHW test parameter - measured power loss in electronic controlled EIWH per tapping	kW			

ANNEX G					
CO2	volume of carbond-dioxide in dry flue gas (%)	%	**tA**	water heating flue gas temperature	ºC
O2	volume of oxygen in dry flue gas (%)	-	**tL**	combustion air supply temperature	ºC

ANNEX I					
Aij	relative surface area between zones	%	Tinsb	Indoor temperature at the end of a setback period after a cool-down	ºC
AV	geometry - surface/volume ratio	1/m	Tinsbc	Corrected lowest indoor temperature aduring setback period	ºC
b	internal heat - ???	-	Tintm	Indoor temperature after taking into account the effect of thermall mass	ºC
Csafe	safety factor radiator capacity	-	**Tiniht**	Indoor temperature after taking into account both the effect of thermal mass and internal heat transfer	ºC
fi	fraction of heated space per zone	-	**tm**	thermal mass of building	Wh/m^3*K
h	geometry - height	m	**tmfc**	thermal mass of building factor	-
Piht	Internal heat transfer power	kW	tss	Steady state period during setback	
qgain	internal gains per m^2 floor area	W/m^2	**U**	overall building insulation value	W/m^2*K
qinf	ventilation - air infiltration	m^3/m^3*h	**Uij**	building internal heat production	W/m^2*K
qrec	factor for energy recovery of ventilation air	-	**V**	building volume	m3
qv	ventilation rate	m^3/m^3*h	vcd	Cool-down speed (during setback)	K/h
sgf	solar gain factor	-	vhu	Heat-up speed (during setback)	K/h
tcd	Cool-dwon time during setback	h			
tcdc	Corrected cool-down time during setback	h			
thu	Heat-up time from Tinsb to Tset_next	h			
thuc	Corrected heat-up time Tinsbc to Tset_next	h			

Annex L: References

Note:

In the Mathematical Model over 50 harmonised standards or similar (including EPB-related standards) and 18 national EPB regulation/standards come together. The Mathematical model uses the JRC database PVGIS, which contains solar and outdoor temperature data for every location in the EU. Backgrounds are explained in the VHK 2007 preparatory studies for the Eco-design of CH Boilers and Eco-design of Water Heaters for the European Commission. In total the two studies contain 1500 pages, 500 tables and use over 1000 references. The preparatory studies were followed by a group of experts and all drafts and intermediate results since the beginning of 2006 were published on public project websites www.ecoboiler.org and www.ecohotwater.org for external scrutiny and comments. During July-Aug. 2007 the final drafts of the preparatory studies have been open for comments, which were then discussed during Workshops 10-11 Sept. 2007.

Harmonised standards (in numerical order)

EN 255-3: 1997. Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors - Heating mode - Part 3: Testing and requirements for marking for sanitary hot water pumps. 1.3.1997

prEN 267:2005. Forced draught oil burners - Definitions, requirements, testing, marking. Will replace EN 267:1999.

EN 297:1994. Gas-fired central heating boilers - Type B11 and B11BS boilers fitted with atmospheric burners of nominal heat input not exceeding 70 kW.

EN 303-1:1999. Heating boilers - Part 1: Heating boilers with forced draught burners - Terminology, general requirements, testing and marking.(most recent amendment EN 303-1:1999/A1:2003)

EN 303-2:1998.. Heating boilers - Part 2: Heating boilers with forced draught burners - Special requirements for boilers with atomizing oil burners.(most recent amendment EN 303-2:1998/A1:2003)

EN 303-3:1998. Heating boilers - Part 3: Gas-fired central heating boilers - Assembly comprising a boiler body and a forced draught burner. (most recent amendment EN 303-3:1998/A2:2004. see also EN 303-7: 2004)

EN 303-4:1999. Heating boilers - Part 4: Heating boilers with forced draught burners - Special requirements for boilers with forced draught oil burners with outputs up to 70 kW and a maximum operating pressure of 3 bar - Terminology, special requirements, testing and marking.

EN 303-6:2000.. Heating boilers - Part 6: Heating boilers with forced draught burners - Specific requirements for the domestic hot water operation of combination boilers with atomizing oil burners of nominal heat input not exceeding 70 kW.

EN 303-7 (draft dec. 2003). Heating boilers - Part 7: Gas-fired central heating boilers equipped with a forced draught burner of nominal heat output not exceeding 1000 kW.

EN 304:1993. Heating boilers - Test code for heating boilers for atomizing oil burners.
Most recent amendment: EN 304:1993/A2:2003.

EN 442-2:1996. Radiators and convectors - Part 2: Test methods and rating. Most recent amendment EN 442-2:1996/A2:2003.

EN 483:1999 en. Gas-fired central heating boilers - Type C boilers of nominal heat input not exceeding 70 kW. (most recent amendment EN 483:1999/A2:2001 and prA4:2005).

EN 625:1995. Gas-fired central heating boilers - Specific requirements for the domestic hot water operation of combination boilers of nominal heat input not exceeding 70 kW

EN 656:1999. Gas-fired central heating boilers - Type B boilers of nominal heat input exceeding 70 kW but not exceeding 300 kW. Most recent amendment: EN 656:1999/Ontw. A1:2005

EN 676:2003. Automatic forced draught burners for gaseous fuels. Latest amendment: EN 676:2003/pr A2:2005 . Reference to directive 90/396/EEG PBC 142:2005.

EN 677:1998 en. Gas-fired central heating boilers - Specific requirements for condensing boilers with a nominal heat input not exceeding 70 kW.

EN 832: 1998. Thermal performance of buildings - Calculation of energy use for heating - Residential buildings. (Latest amendment 2002-2003; EN 13790 is the follow-up of EN 832 but EN 832 will continue to exist because it is referenced in legislation of several Member States)

NPR-CEN/TR 1749:2006 Classification of gas appliances by type. Technical report prepared under the aegis of the Sector Forum Gas Utilisation committee to provide guidance to CEN Technical Committees.

EN 12309-2:2000. Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances with a net heat input not exceeding 70 kW - Part 2: Rational use of energy

EN 12831:2004. Heating systems in buildings - Method for calculation of the design heat load.

EN 12897; 2006. Water Supply – Specification for indirectly heated unvented (closed) storage water heaters.

EN 12975-1: 2006. Thermal solar systems and components - Solar collectors - Part 1: General requirements

EN 12975-2: 2006. Thermal solar systems and components - Solar collectors - Part 2: Test methods

EN 12976-1:2006. Thermal solar systems and components - Factory made systems - Part 1: General requirements

EN 12976-2:2006.Thermal solar systems and components - Factory made systems - Part 2: Test methods

ENV 12977-2:2001. Thermal solar systems and components - Custom built systems - Part 2: Test methods. 1.5.2001.

ENV 12977-3:2001. Thermal solar systems and components - Custom built systems - Part 3: Performance characterisation of stores for solar heating systems (eventually to be replaced by prEN 12977-3: 2006)

EN-ISO 13790:2004. Thermal performance of buildings - Calculation of energy use for space heating (replaces EN 832).

EN 13203-1:2006. Gas-fired domestic appliances producing hot water - Appliances not exceeding 70 kW heat input and 300 litres water storage capacity - Part 1: Assessment of performance of hot water deliveries. 1.7.2006.

EN 13203-2:2006. Gas-fired domestic appliances producing hot water - Appliances not exceeding 70 kW heat input and 300 l water storage capacity - Part 2: Assessment of energy consumption. 1.7.2006.

prEN 13203-3:2007. Solar supported gas-fired domestic appliances producing hot water - Appliances not exceeding 70 kW heat input and 500 liters water storage capacity - Part 3: Assesment of energy consumption.

prEN 13836:2006. Gas-fired central heating boilers - Type B boilers of nominal heat input exceeding 300 kW, but not exceeding 1000 kW .

EN 14511-1: 2007. Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors for space heating and cooling - Part 1: Terms and definitions. 1.12.2007 (replaces EN 14511-1:2005)

EN 14511-2: 2007. Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors for space heating and cooling - Part 2: Test conditions. 1.12.2007 (replaces EN 14511-2:2004)

EN 14511-3: 2007. Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors for space heating and cooling - Part 3: Test methods. 1.12.2007 (replaces EN 14511-3:2004)

EN 14511-4: 2004. Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors for space heating and cooling - Part 4: Requirements. 1.12.2007 (replacesDec. EN 14511-4:2004)

CEN/TS 14825:2003. Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling - Testing and rating at part load conditions

prEN 15034:2004 en. Heating boilers - Condensing heating boilers for fuel oil.

prEN 15035:2004. Heating boilers - Room sealed operations for boilers for fuel oil.

EN 15036-1: 2006. Heating boilers - Test regulations for airborne noise emissions from heat generators - Part 1: Airborne noise emissions from heat generators.

EN 15232:2007. Energy performance of buildings - Impact of Building Automation, Controls and Building Management. 1.8.2007. (replaces prEN 15232: 2005)

EN 15316-1: 2007. *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 1: General (draft),*1.8.2007 (replaces prEN 15316-1: 2005)

EN 15316-2-1: 2007, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2-1: Space heating emission systems,* 1.8.2007 (replaces prEN 15316-2-1: 2005)

EN 15316-2-3: 2007. *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2-3: Space heating distribution systems,* 1.8.2007 (replaces prEN 15316-2-3: 2005)

EN 15316-3-1:2007. Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-1: Domestic hot water systems, characterisation of needs (tapping requirements) 1.8.2007 (replaces prEN 15316-3-1: 2005)

EN 15316-3-2:2007. Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-2: Domestic hot water systems, distribution. 1.8.2007 (replaces prEN 15316-3-1: 2005)

EN 15316-3-3:2007. Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-2: Domestic hot water systems, generation. 1.8.2007 (replaces prEN 15316-3-3: 2005)

prEN 15316-4-1: 2005 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-1: Space heating generation systems, combustion systems. Oct. 2005

prEN 15316-4-2:2005. Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-2: Space heating generation systems, heat pump systems. Oct. 2005.

EN 15316-4-3:2007. Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-3: Space heating generation systems, thermal solar systems. 1.8.2007 (replaces prEN 15316-4-3:2005).

EN 15332:2007. Heating boilers - Energetic assessment of hot water storage systems. 1.11.2007 (replaces prEN 15332:2005).

EN 15456: 2006, *Heating boilers - Electrical power consumption for heat generators - System boundaries - Measurements,* 02.2006

prEN 50440:2005. Efficiency of domestic electrical storage water-heaters. 1.10.2005 (is planned to replace EN-IEC 60379 when approved)

EN-IEC 60379:2004. Methods for measuring the performance of electric storage water-heaters for household purposes. 1.3.2004.

References to Energy Performance of Buildings legislation and national standards

[EU] DIRECTIVE 2002/91/EC of the European Parliament and of the Council on the energy performance of buildings, 16.12.2002

[BE] Flanders EPB, Energiebesparingsregeling 2005.

[FR] RT2005 (Réglémentation Thermique), *Th-CE 2005*, 2006

[DE] EnEV (Energie Einsparungs Verordnung 2002), DIN V 4701-10, DIN 18599

[NL] EPN Energie Prestatie Norm. NEN 5128. NPR 5128

[IT] Decreto n.192 del 19.8.2005. Decreto n.412 (1993), UNI 10348 (1993)

[DK] Lov nr. 585 om fremme af energibesparelser i bygninger, 17.06.2005. BOILSIM tool for labelling.

[SE] Swedish Building Regulations (BBR), Energy Decalaration of Buildings Act 2006. ENORM calculation method.

[UK] Building Regulations, Part L. Standard Assessment Procedure (SAP)

[EI] Dwelling Energy Assessment Procedure DEAP, software “PASSES”

[FI] Finnish Building Regulations. As reported by Minna Sunnika 2005

[PO] Thermal Building Regulations (RCCTE) in decrees 78/2006, 79/2006 and 80/2006

[ES] Spanish Building Code (CTE), Regulations of Thermal Installations in Buildings (RITE) and Complementary Technical Instructions (ITE). 2006.

[CH] Swiss EPB standard SIA 380/1, Quality label ‘Minergie’.

[US] DOE Minimum Standard AFUE (Annual Fuel Utilization Efficiency) based on ASHRAE 103-1993.

[CA] AFUE based on CAN/CGA P.2-1999

[AU] Minimum efficiency (AEC, Annual Energy Consumption) in AS4552-2000 (AG102)

[JP] Law No. 49, notifications No. 434 and 435 of Dec. 2002, TopRunner.

Other

[JRC] JRC, European Commission, Joint Research Centre, Institute for Environmental and Sustainable technology (IES), Ispra. Database for meteorological and solar data PVGIS, containing salar and outdoor temperature data for every location in the EU. Data are supplied for 15 minute intervals, from which averages for “morn” (7-9h), “mid”(9-16h), “eve”(16-21h) and “night” (23-7h) were calculated for all EU capitals. The EU values is the weighted average (by no. of dwellings per Member State)
URL: http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php#

[VHK Ecoboiler 2007] Kemna, R., Van Elburg, M. et al. , Preparatory Study on Eco-design of Central Heating Boilers (Lot 1), Van Holsteijn en Kemna BV for the European Commission, DG TREN, Unit D3, Delft, Sept. 2007.

[VHK Ecohotwater 2007] Kemna, R., Van Elburg, M. et al. , Preparatory Study on Eco-design of Water Heaters (Lot 2), Van Holsteijn en Kemna BV for the European Commission, DG TREN, Unit D3, Delft, Sept. 2007.

[VHK 2005] Kemna, R., Van Elburg, M. et al., Methodology Study Eco-design of Energy-using Products (MEEUP Methodology Report), Van Holsteijn en Kemna BV for the European Commission, DG TREN, Unit D3, Delft, Nov. 2005.