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WASTE WATER HEAT RECOVERY (WWHR) FROM SHOWER DRAIN

Proposal – Working doc

How to evaluate the energy performance of
Waste Water Heat Recovery

Calculation module related to instantaneous WWHR

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Table of contents

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Foreword

Waste water heat recovery is a technology that is currently being developed and introduced in the EU building market. This technology may significantly contribute to improve the energy performance of domestic hot water systems, hence of the whole building.

Until now, this technology was taken into account into the energy performance calculation only in a few EU Member states. A literature review showed that the several implementations are all different and they often consider only part of the relevant influencing factors.

This document has been prepared by EPB Center experts, following a literature review and a technical consultation with relevant manufacturers of WWHR devices.

This document is a proposal for a calculation module related to instantaneous waste water heat recovery, whose main application is on shower drains. The proposed procedure is demonstrated in the accompanying spreadsheet.

This procedure has been designed so that it fits into the modular structure of EN-EPB standards. If a new work item for CEN standardisation would be introduced, then this document could be easily used as a contribution.

It can be also used in a national context, thanks to the clear data interface, which includes the following annexes:

- Annex A is a template to specify the relevant data for the use of this module
- Annex B are proposed default values

The drafting of this proposal is consistent with EN-EPB standard template.

This module can be used for hourly or monthly calculation interval.

Given the fact that this is a proposal, supporting information is provided in special boxes

like this example

to provide guidance information for the application and/or customisation of this proposed module.

1 Scope

This calculation procedure deals with instantaneous waste water heat recovery using a counter-flow heat exchanger between the drain water and the incoming cold water.

This calculation procedure doesn't cover storage heat recovery or the use of drain water as a source for a heat pump.

The proposed procedure calculates the recovered heat, to be taken into account in the overall calculation scheme.

2 Terms and definitions

3.1
drain water
water flowing out from the shower box

3.2
preheated water
domestic water flowing out from the heat exchanger

3.3
primary of the wwhr device
the high temperature side of the wwhr device, where heat is extracted from the water outflowing from the drain of the shower box.

3.4
secondary of the wwhr device
the low temperature side of the wwhr device, where the incoming cold domestic is preheated before being fed to the domestic hot water heater and/or the shower tap mixer.

3 Symbols and abbreviations

The symbols used in this document are listed in table 1.

Table 1 — Symbols

Symbol	Units	Description
Q	kWh	Amount of heat
V	m^3	Volume
V'	m^3/h	Volumetric flow rate
θ	°C	Temperature
ρ	kg/m^3	Density
c	kWh/(kg·K)	Specific heat
m	kg	Mass
l	m	Length
d	m	Diameter
k	-	Factor, coefficient

t	h	time
P	kW	Power
NTU	-	Number of thermal units of the heat exchagner
C*	-	Ration of heat capacities of primary and secondary side of a heat exchanger
η	-	Efficiency
∆T	K	Temperature difference

The subscripts used in this document are listed in table 2.

Table 2 — Subscripts

A	for type A connection	drain	shower box drain	shw	shower
aux	auxiliary	draw	at the tap (draw-off)	trans	transient
B	for type B connection	eq	equivalent	use	utilisation
box	shower box	exc	heat exchanger	W	domestic water
C	for type C connection	nd	need	wh	water heater
ci	calculation interval i	pre	preheated	wwhr	waste water heat recovery
cold	domestic cold water	rbl	recoverable	X	Any one of A, B or C
dis	distribution	sec	secondary	shw	shower

The abbreviation and acronyms used in this document are listed in table 3.

Table 3 — Acronyms

Acronym	Meaning
WWHR	Waste water heat recovery

4 Description of the method

This method is designed to calculate the heat recovered by an instantaneous heat recovery device from waste domestic hot water flowing to the sewer. An example of such an installation is given in figure 1.

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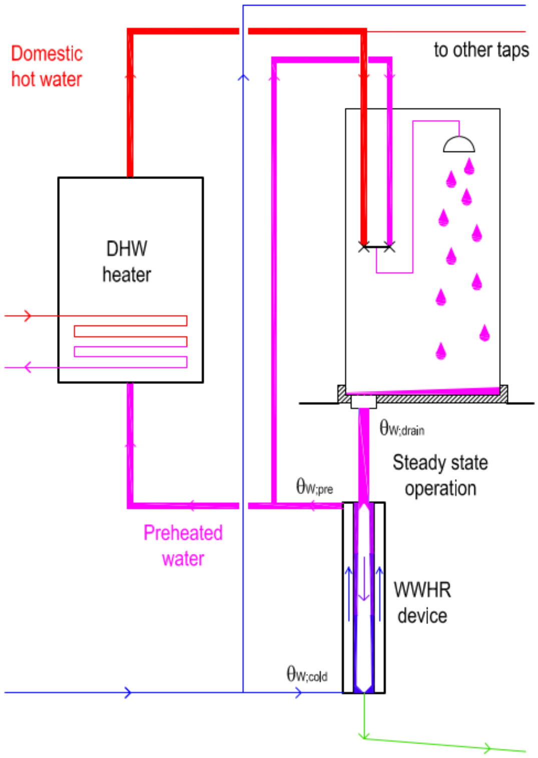

Figure 1 –Example of an instantaneous wwhr heat recovery device

This method is designed to provide the following calculation results:

— recovered energy, that can be subtracted from the needs in the domestic hot water system calculation;
— share of recovered energy per connection (to heater and/or to shower tap), for optional connection with a dynamic storage module.

The input data consists of:

— energy need for domestic hot water;
— product data;
— system configuration data, layout and control settings.

The method takes into account:

— steady state properties of the WWHR heat exchanger, that can be taken from a testing report according to an existing current national standard;
— connection type of the WWHR device;
— the effect of transient operation;
— operating conditions, such as domestic hot water heater set temperature;
— climatic data, such as cold water temperature.

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5 Calculation method

5.1 Output data

The output data are listed in Table 4.

Table 4 — Output data of this method:

Description	Symbol	Unit	Intended destination module
Recovered heat	$Q_{\mathrm{Wwwhr;rvd;ci}}$	kWh	M8–1
Recovered heat through the shower mixer	$Q_{W;wwhr;rvd;shw,ci}$	kWh	M8-1
Recovered heat through the water heater	$Q_{W;wwhr;rvd,wh,ci}$	kWh	M8-1 – M8-7
Preheated water temperature	$\theta_{W;pre,ci}$	°C	M8-1
Energy for auxiliaries	$W_{wwhr;aux,ci}$	kWh	M8-1

5.2 Input data

5.2.1 Product data

5.2.1.1 Product description data (qualitative)

There is no applicable product description data.

If cross flow heat exchanger should be introduced, is should be specified if the heat exchanger is:
- either of the counterflow type
- or of the cross-flow type
to select the suitable efficiency calculation equations depending on the configuration.

5.2.1.2 Product technical data

The required technical data for this calculation procedure are listed in table 5. Additional details are given in the following clauses.

Table 5 — Product technical input data list

Characteristics	Symbol	Catalogue unit	Validity interval	Ref.	Varying
Steady state efficiency of the WWHR device at balanced test condition X	$\eta_{wwhr;X}$	%	0…100	Local	NO
Primary and secondary flow rate at balanced test condition X	$V'_{wwhr;X}$	l/min	0…1000	Local	NO
Volume of water in the WWHR device	$V_{wwhr;W}$	l	0…100	Local	NO
Mass of the heat exchanger	$m_{wwhr;exc}$	kg	0…1000	Local	NO
Specific heat of the heat exchanger material	$c_{wwhr;exc}$	kWh/kg K	0…0,01	Local	NO
Rated power of auxiliaries	$P_{\mathrm{wwhr;aux}}$	-	[0:1]	Local	NO

5.2.1.3 Steady state efficiency of the heat exchanger with balanced flow rates

The steady state efficiency of the heat exchanger with balanced flow rates in condition X $\eta_{wwhr;X}$ is defined as the following ratio of temperatures:

$$\eta_{wwhr} = \frac{\theta_{W;pre,ci} - \theta_{W;cold,ci}}{\theta_{W;drain} - \theta_{W;cold,ci}} \quad (1)$$

where

- $\theta_{W;pre;ci}$ is the preheated water temperature at calculation interval ci (outlet to secondary of the wwhr device);
- $\theta_{W;cold;ci}$ is the cold domestic water temperature at calculation interval ci (inlet to secondary of the wwhr device);
- $\theta_{W;drain}$ is the inlet temperature of the drain water temperature (inlet to the primary of the wwhr device);

and the temperatures are measured after that they have reached steady state conditions given the testing flow rates. Figure 2 identifies the above listed temperatures.

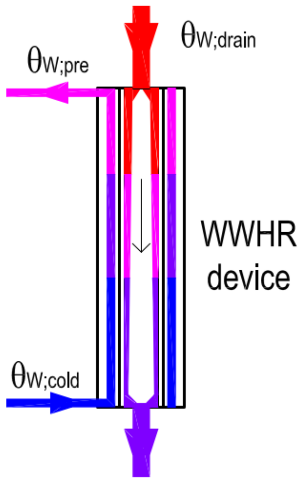

Figure 2 – Temperatures involved in the definition of η_{wwhr}

NOTE Equation (1) is always true (also for unbalanced operation) because the flow rate on the secondary side is always less than or equal to the flow on the primary side of the wwhr device and there is the same fluid (water) on both sides.

The efficiency $\eta_{wwhr;X}$ is declared by the manufacturer, based on a test performed according to a relevant standard such as:

- NEN 8801 – Annex J
- UK SAP

The value of $\eta_{wwhr;X}$ shall be only the steady state value, which is the ration of temperatures given in equation (1). It shall not include any transient effect.

The value should be declared at least for two operating conditions, encompassing the foreseen operating flow rate.

5.2.1.4 Primary and secondary flow rate at balanced test condition X

The primary and secondary flow rate at balanced test condition X $V'_{wwhr;X}$ is the value set when measuring $\eta_{wwhr;X}$. Recommended values are given in informative annex B, table B.2.

The value is declared by the manufacturer together with the corresponding value of $\eta_{wwhr;X}$.

5.2.1.5 Volume of water in the WWHR device

The volume of water in the WWHR device $V_{wwhr;W}$ is the total volume of cold domestic water and drain water accumulated in the primary and secondary side of the wwhr device during steady state operation.

The value is declared by the manufacturer.

NOTE The volume of water in the secondary side is the geometrical internal volume because domestic cold water is pressurized. The volume of water in the primary side is usually less than the geometrical internal volume because of open channel and gravity flow in the drain pipes.

5.2.1.6 Mass of the wwhr heat exchanger

The mass of the wwhr heat exchanger $m_{wwhr;exc}$ is the value declared by the manufacturer.

The mass of all the materials that are in contact with cold water and drain water shall be considered.

If this value is not known, the total mass of the device is used.

5.2.1.7 Specific heat of the heat exchanger material

The specific heat of the heat exchanger material $c_{wwhr;exc}$ is the value declared by the manufacturer.

If no data is available, default values are given in annex B, table B.3

5.2.1.8 Rated power of auxiliaries

For wwhr devices that require auxiliary energy, the rated power of auxiliaries $P_{wwhr;aux}$ is the value declared by the manufacturer.

If no auxiliary energy is required, then $P_{wwhr;aux} = 0$.

5.2.2 Process design description and data

5.2.2.1 List of process design data

The process design data are given by the identifiers listed in table 6 and the data listed in table 7.

Table 6 — Process design identifiers

Description	Identifier	Validity interval	Varying
Type of hydraulic connection of the wwhr device	WWHR_CONN	A, B and C	NO

Table 7 — Process design data

Description	Symbol	Unit	Validity interval	Varying
Volume of water in the shower box and drain	$V_{shw,box}$	l	0…100	NO
Length of the pipes for preheated water	$l_{pre,i}$	m	0…1000	NO
Inner diameter of pipes	$d_{in;pre,i}$	m	0,00…1,00	NO

5.2.2.2 Connection type

The wwhr device can be connected in the domestic hot water so that the preheated water is feeding:

— both the domestic hot water heater and the cold water tap, which is called connection type A;

— only the cold water tap, which is called connection type B;

— only the domestic hot water heater, which is called connection type C;

The connection types are indicated by the identifier WWHR_CONN. The values are listed in table 8.

Table 8 — Values of identifier WWHR_CONN

Description	Identifier	Varying
Connection type A	*WWHR_CONN_A*	NO
Connection type B	*WWHR_CONN_B*	NO
Connection type C	*WWHR_CONN_C*	NO

The three possible connections are illustrated in figures 3 to 5.

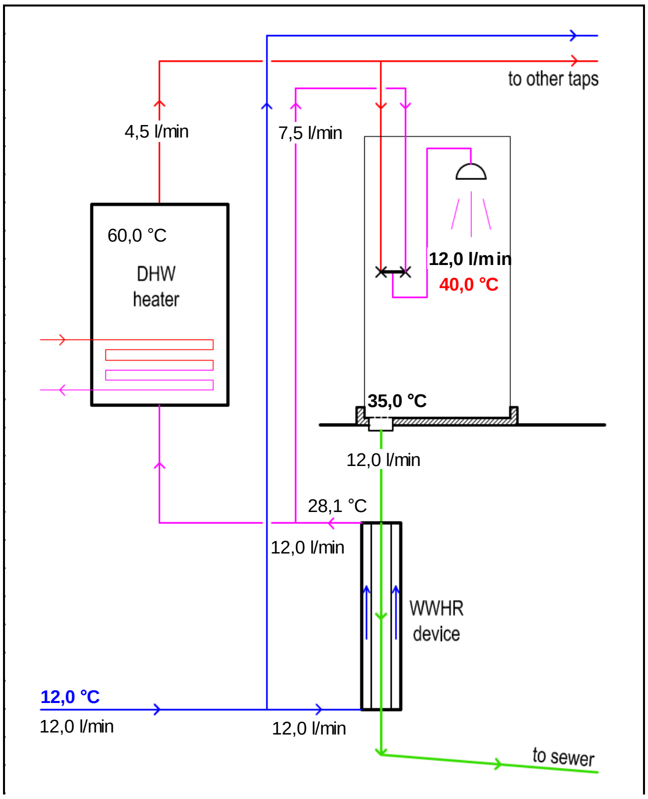

Figure 3 – Connection type A

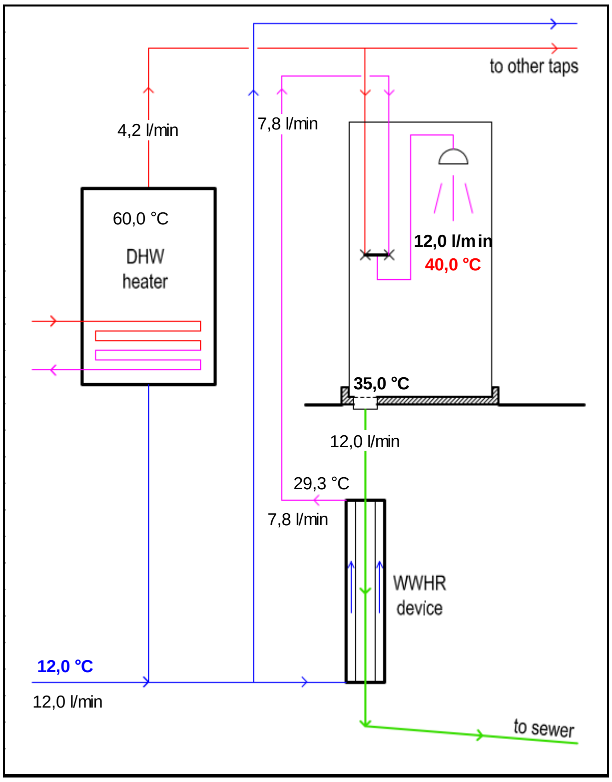

Figure 4 – Connection type B

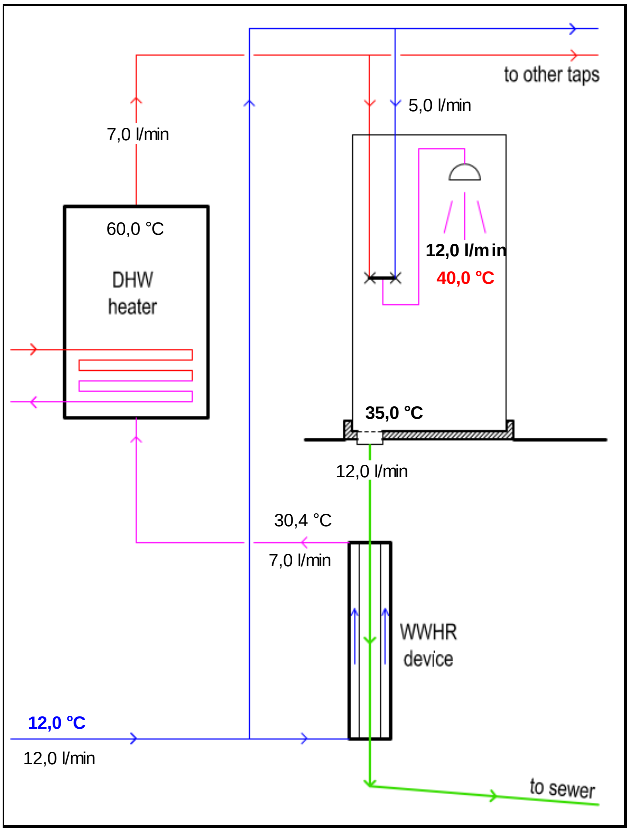

Figure 5 – Connection type C

5.2.2.3 Volume of water in the shower box and drain

The volume of water in the shower box and drain $V_{shw,box}$ is the total volume of water which is accumulated during steady state operation of the shower in:

- the shower box floor and walls;
- the shower box drain and syphon;
- the connecting drain pipe from the shower box up to the wwhr device.

If this value is not known, default values are given in annex B, table B.4.

The value can be less than the geometrical volume of the siphon and drain pipe due to open channel, gravity flow

5.2.2.4 Length and inner diameter of the preheated water pipes

These are the lengths $l_{pre,I}$ and corresponding inner diameters $d_{in;pre,i}$ of all the preheated water pipes connecting the wwhr device outlet to:

- the domestic hot water heater;
- and/or the cold water tap of the shower mixer.

The domestic hot water pipes from the domestic hot water heater outlet up to the hot water tap of the shower mixer shall not be considered here. They are already taken into account in the distribution losses, module 8-5.

5.2.3 Operating conditions data

The required operating conditions data for this calculation procedure are listed in Table 9.

Table 9 — Operating conditions data list

Description	Symbol	Unit	Range	Origin Module	Varying
Draw-off temperature	$\theta_{W;draw}$	°C	0…100	M8-2	NO
Domestic hot water distribution temperature	$\theta_{W;dis,ci}$	°C	0…100	M8-1	YES
Cold water temperature	$\theta_{W;cold,ci}$	°C	0…100	M8-2	YES
Domestic hot water needs in the calculation interval	$Q_{W;nd,ci}$	kWh	0…1000	M8-1	YES
Fraction of needs related to showers connected to the wwhr device	$k_{W;nd;shw}$	p.u.	0,00…1,00	Local Or M8-2	YES
Temperature at shower drain	$\theta_{W;drain}$	°C	0…100	Local	NO
Shower event flow rate	$V'_{shw,ci}$	l/min	0…10	Local or M8-2	YES
Shower event duration	$t_{shw,ci}$	min	0…100	Local or M8-2	YES

The operating conditions are calculated in the module specified in the column “origin module” of table 8.

Default values for the data that are or may be “local” are given in annex B, table B.5

5.2.4 Constants and physical data

The required constants and physical data are listed in table 10.

Table 10 — Constants and physical data

Name	Symbol	Unit	Value
Specific heat of water	c_w	kWh/(kg·K)	0,001163
Density of water	ρ_w	kg/m^3	1000

5.3 Calculation time intervals

The methods described in this clause are suitable for hourly or monthly calculation intervals.

The output calculation interval is the same as the input calculation interval.

This method is static. The hourly time interval is far longer than the duration of a shower event. Dynamic effects within a shower event are taken into account by a utilisation factor.

5.4 Calculation procedure flow chart

The reference flow chart of the calculation described in this document is given in annex C.

5.5 Calculation procedure

5.5.1 Domestic hot water needs related to WWHR device

The domestic hot water needs related to showering and wwhr $Q_{W;nd;sh,ci}$ are given by:

$$Q_{W;nd;shw,ci} = Q_{W;nd,ci} \cdot k_{W;nd;shw} \tag{2}$$

where

- $Q_{W;nd;ci}$ are the domestic hot water for the calculation interval ci
- $k_{W;nd;shw}$ is the part of domestic hot water needs related to showering, defined in clause 5.2.3

The corresponding volume of domestic hot water for showering and wwhr $V_{W;nd;sh,ci}$, is given by

$$V_{W;nd;shw,ci} = \frac{Q_{W;nd;shw,ci}}{\rho_W \cdot c_W \cdot (\theta_{W;draw} - \theta_{W;cold,ci})} \tag{3}$$

where

- ρ_W is the density of water as specified in clause 5.2.4;
- c_W is the specific heat of water as specified in clause 5.2.4;
- $\theta_{W;draw}$ is the domestic hot water draw off temperature, defined in module M8-2.
- $\theta_{W;cold}$ is the domestic cold water temperature, defined in module M8-2.

5.5.2 Efficiency of the WWHR device with balanced flow rate

The efficiency of the WWHR device with balanced flow rate $\eta_{wwhr,ci}$ is given by:

$$\eta_{wwhr,ci} = \eta_{wwhr,A} + (\eta_{wwhr,B} - \eta_{wwhr,A}) \cdot \frac{V'_{shw,ci} - V'_{wwhr;A}}{V'_{wwhr;B} - V'_{wwhr;A}} \tag{4}$$

where

- $\eta_{wwhr,X}$ is the efficiency of the wwhr device at balanced operation in condition X, as defined in clause 5.2.1.3.
- $V'_{wwhr,X}$ is the balanced flow rate in condition X, as defined in clause 5.2.1.4.
- $V'_{shw,ci}$ is the shower event flow rate at during calculation interval ci, as defined in clause 5.2.3.

5.5.3 Recoverable heat and wwhr device heat exchanger efficiency

5.5.3.1 General

Depending on the value of the identifier WWHR_CONN:

- the fraction of recoverable heat in the calculation interval ci $k_{wwhr;rbl,ci}$;
- and the efficiency of the heat exchanger of the wwhr device at calculation interval ci $\eta_{wwhr,ci}$;

are calculated

- according to clause 5.5.3.2 if WWHR_CONN_A;
- according to clause 5.5.3.3 if WWHR_CONN_B;
- according to clause 5.5.3.4 if WWHR_CONN_C.

5.5.3.2 Recoverable heat and wwhr device heat exchanger efficiency for connection type A

The recoverable fraction of needs for type A connection at calculation interval ci $k_{wwhr;rbl;A,ci}$ is given by:

$$k_{wwhr;rbl;A,ci} = \frac{\theta_{W;drain} - \theta_{W;cold,ci}}{\theta_{W;draw} - \theta_{W;cold,ci}} \tag{5}$$

where

- $\theta_{W;drain}$ is the domestic hot water temperature at the shower drain, defined at clause 5.2.3.

The efficiency of the heat exchanger of the wwhr device for type A connection at calculation interval ci $\eta_{wwhr,ci;A}$ is given by

$$\eta_{wwhr,ci;A} = \eta_{wwhr,ci} \tag{6}$$

5.5.3.3 Recoverable heat and wwhr device heat exchanger efficiency for connection type B

The recoverable fraction of needs $k_{wwhr;rbl;B,ci}$ and the efficiency of the heat exchanger of the wwhr device $\eta_{wwhr,ci;B}$ for type B connection at calculation interval ci $k_{wwhr;rbl;A,ci}$ is calculated with the following iterative procedure.

The initial value of the efficiency $\eta_{wwhr,ci;0}$ is given by:

$$\eta_{wwhr;ci;0} = \eta_{wwhr;ci} \tag{7}$$

The initial value of the thermal length of the wwhr device heat exchanger $NTU_{wwhr,0}$ is given by:

$$NTU_{wwhr;0} = \frac{\eta_{wwhr;ci;0}}{1 - \eta_{wwhr;ci;0}} \tag{8}$$

The initial value of the ratio of flow rates of the wwhr device heat exchanger $C^*_{wwhr;0}$ is given by:

$$C^*_{wwhr,0} = \frac{\theta_{W;dis,ci} - \theta_{W;draw}}{\theta_{W;dis,ci} - \theta_{W;cold,ci} - \eta_{wwhr;ci;0} \cdot \left(\theta_{W;drain} - \theta_{W;cold,ci}\right)} \tag{9}$$

where

- $\theta_{W;dis,ci}$ is the distribution domestic hot water temperature, calculated by module M8-1.

For each iteration i, the following values are calculated:

- a new value of the thermal length of the wwhr device, $NTU_{wwhr,i}$:

$$NTU_{wwhr;i} = \frac{NTU_{wwhr;0}}{C^*_{wwhr,i-1}} \tag{10}$$

It is assumed here that the global heat exchange coefficient (UA value in W/K) of the heat exchanger doesn't change significantly. The only change is a reduction of flow rate on the primary side.
An analysis of data from the SAP database, where flow rate and efficiency are given for several values of the flow rate, showed clearly that despite the change in both primary and secondary flow rate, there is little change in the heat exchange coefficients.

— a new value of the efficiency of the wwhr device heat exchanger, $\eta_{wwhr,ci;i}$:

$$\eta_{wwhr;ci;i} = \frac{1 - e^{-NTU_{wwhr;i}\cdot(1-C^*_{wwhr,i-1})}}{1 - C^*_{wwhr,i-1}\cdot e^{-NTU_{wwhr;i}\cdot(1-C^*_{wwhr,i-1})}} \tag{11}$$

— a new value of the ration of the flow rates of the wwhr device heat exchanger $C^*_{wwhr;i}$:

$$C^*_{wwhr,i} = \frac{\theta_{W;dis,ci} - \theta_{W;draw}}{\theta_{W;dis,ci} - \theta_{W;cold,ci} - \eta_{wwhr;ci;i}\cdot\left(\theta_{W;drain} - \theta_{W;cold,ci}\right)} \tag{12}$$

The iteration is repeated N times until the change in efficiency is less than 0,01, that is:

$$\left|\eta_{wwhr;ci;i} - \eta_{wwhr;ci;i-1}\right| < 0{,}01 \tag{13}$$

N is the index i for the last iteration.

Usually 5 iterations are sufficient. Convergence is easy

When the iteration is completed,

— the recoverable fraction of needs with type B connection at calculation interval ci $k_{wwhr;rbl;B,ci}$ is given by:

$$w_{wwhr;rbl;B,ci} = \frac{\theta_{W;drain} - \theta_{W;cold,ci}}{\theta_{W;draw} - \theta_{W;cold,ci}}\cdot C^*_{wwhr,N} \tag{14}$$

— the efficiency of the wwhr device heat exchanger at calculation interval ci $\eta_{wwhr,ci;B}$ is given by:

$$\eta_{wwhr;ci;B} = \eta_{wwhr;ci,N} \tag{15}$$

where N is the index of the last iteration, when convergence is reached.

5.5.3.4 Recoverable heat and wwhr device efficiency for connection type C

The initial value of the efficiency $\eta_{wwhr,ci;0}$ is given by:

$$\eta_{wwhr;ci;0} = \eta_{wwhr;ci} \quad (16)$$

The initial value of the thermal length of the wwhr device heat exchanger $NTU_{wwhr,0}$ is given by:

$$NTU_{wwhr;0} = \frac{\eta_{wwhr;ci;0}}{1 - \eta_{wwhr;ci;0}} \quad (17)$$

The recoverable fraction of needs for type C connection at calculation interval ci $k_{wwhr;rbl;A,ci}$ is given by:

$$k_{wwhr;rbl;A,ci} = \frac{\theta_{W;draw} - \theta_{W;cold,ci}}{\theta_{W;dis,ci} - \theta_{W;cold,ci}} \quad (18)$$

The relative flow rate on the secondary side of the wwhr device heat exchanger $C^*_{wwhr;C}$ is given by:

$$C^*_{wwhr;C} = k_{wwhr;sec;C} \quad (19)$$

The thermal length of the wwhr device heat exchanger in unbalanced operation $NTU_{wwhr,C}$ is given by:

$$NTU_{wwhr;C} = \frac{NTU_{wwhr;0}}{C^*_{wwhr,C}} \quad (20)$$

It is assumed that the global heat exchange coefficient (UA value in W/K) of the heat exchanger doesn’t change significantly.
An analysis of data from the SAP database, where flow rate and efficiency are given for several values of the flow rate, showed clearly that despite the change in both primary and secondary flow rate, there is little change in the heat exchange coefficients.
For type B connection, the only change is a reduction of flow rate on the secondary side.

— the efficiency of the wwhr device heat exchanger at calculation interval ci $\eta_{wwhr,ci;C}$ is given by:

$$\eta_{wwhr;ci;C} = \frac{1 - e^{-NTU_{wwhr;C} \cdot (1 - C^*_{wwhr,C})}}{1 - C^*_{wwhr,C} \cdot e^{-NTU_{wwhr;C} \cdot (1 - C^*_{wwhr,C})}} \quad (21)$$

5.5.4 Correction factor for transient operation

The volume of water drawn during each shower event $V_{shv,ci}$ is given by

$$V_{shw,ci} = V'_{shw,ci} \cdot t_{shw,ci} \quad (22)$$

where

— $V'_{shw,ci}$ is the shower event flow rate during calculation interval ci, as defined in clause 5.2.3.

— $t_{shw,ci}$ is the duration of the shower event during calculation interval ci, as defined in clause 5.2.3.

The equivalent volume of water for the heat capacity of the wwhr device heat exchanger $V_{wwhr,eq;W}$ is given by:

$$V_{wwhr;eq;W} = \frac{m_{wwhr;exc} \cdot c_{wwhr;exc}}{c_W \cdot \rho_W} \quad (23)$$

where

— $m_{wwhr;exc}$ is the mass mass of the wwhr heat exchanger as defined in clause 5.2.1.6;

— $c_{wwhr;exc}$ is the specific heat of the wwhr heat exchanger material as defined in clause 5.2.1.7;

— ρ_W is the density of water as specified in clause 5.2.4;

— c_W is the specific heat of water as specified in clause 5.2.4;

The volume of preheated water during wwhr device operation V_{pre} is given by:

$$V_{pre} = \frac{\pi}{4} \cdot \sum_i d_{in;pre,i}^2 \cdot l_{pre,i} \quad (24)$$

where

— $d_{in;pre,i}$ is the inner diameter of the preheated water pipe i, as specified in clause 5.2.2.4;

— $l_{pre,i}$ is the length of the preheated water pipe i, as specified in clause 5.2.2.4;

— mass mass of the wwhr heat exchanger as defined in clause 5.2.1.6;

The equivalent volume of preheated water lost because of transient operation per shower event V_{trans} is given by:

$$V_{trans} = V_{shw;box} + V_{pre} + 0{,}5 \cdot \left(V_{wwhr;w} + V_{wwhr;eq;w}\right) \quad (25)$$

where

— $V_{shw;box}$ is the volume of water accumulated in the shower box and drain during wwhr device operation, as specified in clause 5.2.2.3;

— $V_{wwhr;W}$ is the volume of water accumulated in the wwhr device during operation, as specified in clause 5.2.1.5;

The utilization factor for transient operation $k_{wwhr;use}$ is given by:

$$k_{wwhr;use} = 1 - \frac{V_{trans}}{V_{shw,ci}} \quad (26)$$

5.5.5 Recovered heat

The heat recovered by the wwhr device at calculation interval ci $Q_{W;wwhr;rvd,ci}$ is given by

$$Q_{W;wwhr;rvd,ci} = Q_{W;nd;shw,ci} \cdot k_{wwhr;rbl;X} \cdot \eta_{wwhr,ci;X} \cdot k_{wwhr;use,ci} \quad (27)$$

where

- index X shall be A, B or C depending on the connection type (see 5.5.3).

The preheated water temperature at calculation interval ci $\theta_{W;pre,ci}$ is given by

$$\theta_{W;pre,ci} = \theta_{W;cold,ci} + \eta_{wwhr,ci,X} \cdot (\theta_{W;drain} - \theta_{W;cold,ci}) \quad (28)$$

The recovered heat through the connection to the shower mixer tap $Q_{W;wwhr;rvd;shw;X,c}$ depending on the connection type is given by:

- for connection type A:

$$Q_{W;wwhr;rvd;shw;A,ci} = Q_{W;wwhr;rvd,ci} \cdot \frac{\theta_{W;dis,ci} - \theta_{W;draw}}{\theta_{W;dis,ci} - \theta_{W;pre,ci}} \quad (29)$$

- For connection type B:

$$Q_{W;wwhr;rvd;shw;B,ci} = Q_{W;wwhr;rvd,ci} \quad (30)$$

- For connection type C:

$$Q_{W;wwhr;rvd;shw;C,ci} = 0 \quad (31)$$

The recovered heat through the water heater connection $Q_{W;wwhr;rvd;wh,ci}$ is given by:

$$Q_{W;wwhr;rvd;wh,ci} = Q_{W;wwhr;rvd,ci} - Q_{W;wwhr;rvd;shw;X,ci} \quad (32)$$

where

- index X shall be A, B or C depending on the connection type (see 5.5.3).

5.5.6 Auxiliary energy

The operation time of auxiliaries $t_{wwhr;aux,ci}$ is given by:

$$t_{wwhr;aux,ci} = \frac{V_{W;nd;shw,ci}}{V'_{shw,ci}} \quad (33)$$

The auxiliary energy used for the wwhr device $W_{wwhr;aux,ci}$ is given by:

$$W_{wwhr;aux,ci} = P_{wwhr;aux} \cdot t_{wwhr;aux,ci} \quad (34)$$

where

- $P_{wwhr;aux}$ is the power of auxiliaries, as defined in clause 5.2.1.8.

An additional stand-by power contribution might be relevant due to the very low duty cycle of domestic hot water use.

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6 Quality control

6.1 Calculation report

The calculation report shall include the values of the following data for each calculation interval.

— WWHR_CONN	Type of connection
— $Q_{W,nd,ci}$	Domestic hot water needs
— $Q_{W,nd;shw,ci}$	Domestic hot water needs related to wwhr recovery
— $Q_{Wwwhr;rvd;ci}$	Recovered heat
— $Q_{Wwwhr;rvdshw;ci}$	Recovered heat through the connection to the shower tap
— $Q_{Wwwhr;rvdshw;ci}$	Recovered heat through the connection to the water heater
— $\theta_{W;pre,ci}$	Preheated water temperature
— $W_{wwhr;aux,ci}$	Auxiliary energy
— $k_{wwhr;rbl,ci}$	Recoverable fraction of needs
— $\eta_{wwhr,ci}$	Steady state efficiency of the wwhr device heat exchanger

For a printed report, the hourly values shall be aggregated and presented as monthly values together with a sample hourly set for a typical day.

6.2 Error reporting

The following conditions shall be reported, when occurring:

- efficiency of WWHR device for connection type B fails to converge;
- any division by 0;
- input value of $\theta_{W;dis,ci}$ being lower than $\theta_{W;draw}$.

7 Compliance check

To check if the calculation procedure was applied correctly to the installed system, check the following items were correctly identified:

- type of connection;
- WWHR device steady state efficiency;
- distribution temperature;

and that the resulting values for

— $k_{wwhr;rbl,ci}$	Recoverable fraction of needs
— $\eta_{wwhr,ci}$	Steady state efficiency of the wwhr device heat exchanger

are consistent with the connection type and WWHR heat exchanger product data.

Annex A
(normative)

Template for input data

A.1 General

This template specifies the list of required input data

A.2 References

Table A.1 — References

Reference	Reference document	
	Number	Title
M1–1		
M1–7		
M1-2		
M1-9		
M1-13		
M2-2		
M3-1		
M8-1		
M5-8		
M3-8		
M3-9		

A.3 WWHR device product data

A.3.1 Default balanced flow rate for testing

The default value of the balanced flow rate $V'_{wwhr;X}$ when measuring $\eta_{wwhr;X}$ shall be provided in a table complying with the format given in Table A.2.

Table A.2 — Identifiers for heat pump energy carrier type

Condition	Flow rate l/min

A.3.1.1 Specific heat of the heat exchanger material

Default values of the specific heat of the heat exchanger material $c_{wwhr;exc}$ shall be provided in a table complying with the format given Table A.3.

Table A.3 — Default specific heat of the heat exchanger material

Material	Specific heat kWh/(kg·K)

A.4 System design data

A.4.1.1 Volume of water in the shower box and drain

The default value of the volume of water in the shower box and drain $V_{shw;box}$ shall be provided in a table complying with the format given in Table A.4.

Table A.4 — Volume of water in the shower box and drain $V_{shw;box}$

Description	$V_{shw;box}$ l

A.5 Default operating conditions data

Default values of operating conditions data shall be provided in a table complying with the format given in Table A.5.

Table A.5 — Default operating conditions data

Description	Symbol	Unit	Value
Temperature at shower drain			
Shower event flow rate			
Shower event duration			

Annex B
(informative)

Default values

B.1 General

The template in Annex A shall be used to specify the choices between methods, the required input data and references to other documents.

This annex B is only an example of such a set of data.

This annex is informative so that proposed default values can be replaced by national or regional specifications.

The shaded fields in the tables are part of the template and they shall not be modified.

B.2 References

The references, identified by the module code number, are given in Table B.1.

Table B.1 — References (See Clause 2)

Reference	Reference document	
	Number	Title
M1–1	EN ISO 52000-1	*Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures*
M8-1	EN 15316-1	*Energy performance of buildings. Method for calculation of system energy requirements and system efficiencies. General and Energy performance expression, Module M3-1, M3-4, M3-9, M8-1, M8-4*
M8-2	EN 12831-3	*Energy performance of buildings – Method for calculation of the design heat load – Domestic hot water systems heat load and characterization of needs, Module M8–2, M8–3*
M8-6	EN 15316-3	*Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies - Part 3: Space distribution systems (DHW, heating and cooling), Module M3-6, M4-6, M8-6*
M8-7	EN 15316-5	*Energy performance of buildings - Method for the calculation of system energy requirements and system efficiencies - Part 5: Space heating and DHW storage systems (not cooling), Module M3-7, M8-7*

B.3 WWHR device product data

B.3.1 Default balanced flow rate for testing

The default value of the balanced flow rate $V'_{wwhr;X}$ when measuring $\eta_{wwhr;X}$ are given in Table B.2.

Table B.2 — Default values of testing flow rates under balanced operation

Condition	Flow rate l/min
A	12,5
B	9,2

B.3.2 Specific heat of the heat exchanger material

Default values of the specific heat of the heat exchanger material $c_{wwhr;exc}$ are given in the following Table B.3.

Table B.3 — Default specific heat of the heat exchanger material

Material	Specific heat kWh/(kg·K)
Copper	0,0001075
Stainless steel	0,0001394

B.4 System design data

B.4.1 Volume of water in the shower box and drain

The default value of the volume of water in the shower box and drain $V_{shw;box}$ is given in Table B.4.

Table B.4 — Volume of water in the shower box and drain $V_{shw;box}$

Description	$V_{shw;box}$ l
All cases	1,0

B.5 Default operating conditions data

Default values of operating conditions data are given in Table B.5.

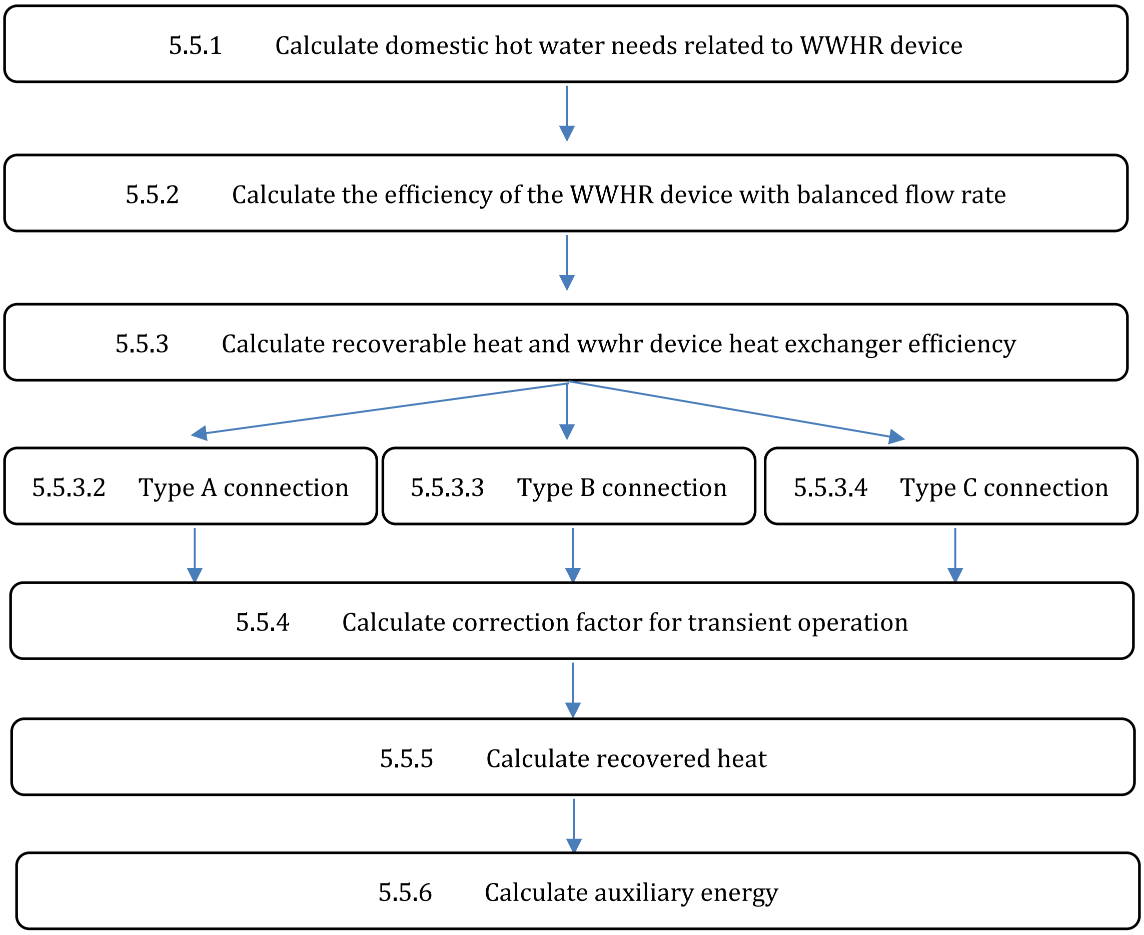
Table B.5 — Default operating conditions data

Description	Symbol	Unit	Value
Fraction of needs related to WWHR	$k_{W;nd;shw}$	-	0,80
Temperature at shower drain	$\square_{W;drain}$	°C	1,0
Shower event flow rate	$V'_{shw,ci}$	l/min	12,0
Shower event duration	$t_{shw,ci}$	min	5

Annex C
(informative)

Calculation flow chart

This annex illustrates the calculation sequence of this procedure. The same headings of the sections are used in the accompanying spreadsheet.



Annex D
(informative)

Calculation examples

See file Demo_WWHR_2023-09-22.xlsx.

Bibliography

[1] *The potential of waste water heat recovery systems in reducing the energy demand for water heating in the EU in a cost-efficient way – University of Innsbruck - 2022*

[2] *The Government's Standard Assessment Procedure for Energy Rating of Dwellings – SAP 10.2 – Version 10.2 – BRE - 2022*

[3] *NTA 8800 :2023*

[4] *Arrêté du 4 août 2021 - Méthode de calcul Th-BCE 2020*

[5] *Shower drain heat recovery – an introduction – Rehva Journal 02/2023*