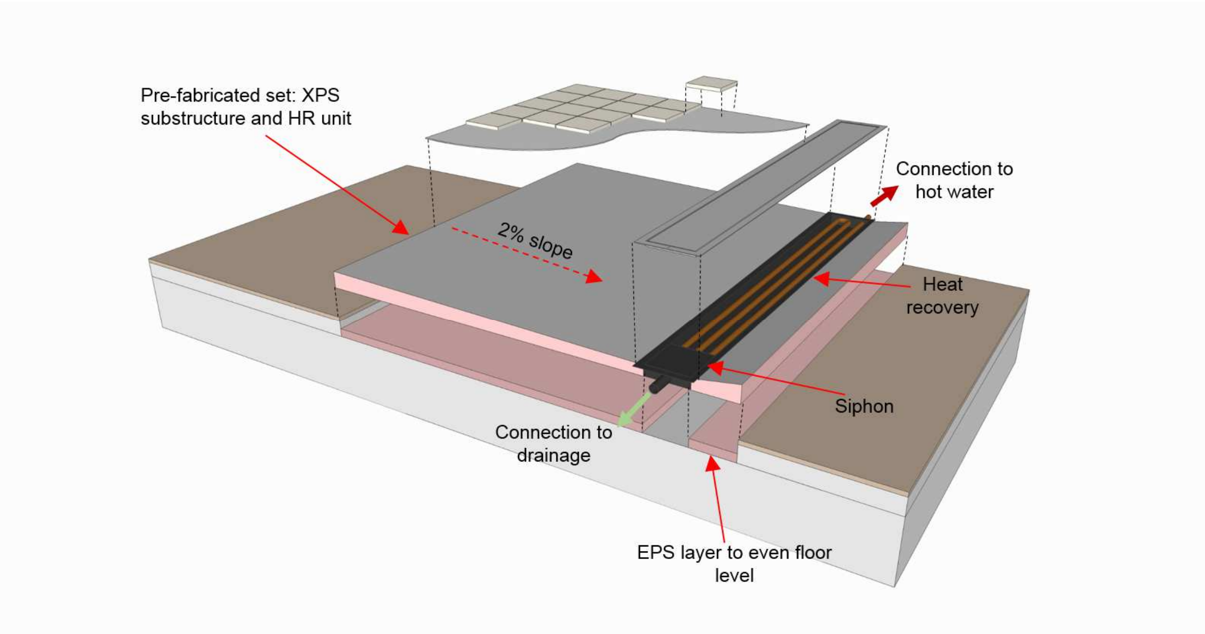
# D5.1.12_Drain_Water_Heat_Recovery_in_Retrofits




**INTELLIGENT ENERGY – EUROPE II**

Energy efficiency and renewable energy in buildings

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[Improving the energy performance of step-by-step refurbishment and integration of renewable energies]

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# Abstract

The goal of a step-by-step refurbishment is to minimize the total energy consumption of a building. At the end of the retrofit, the building's heating consumption may be smaller than its domestic hot water consumption. Therefore, hot water should be considered in a step-by-step refurbishment plan, too.

One of the options to reduce hot water energy consumption is the principle of heat recovery from flowing, warm drain water. The corresponding devices are small, simple, and without moving parts. They can save approximately one third of the useful hot water consumption.

This document describes the principle of drain water heat recovery, outlines a calculation procedure for the resulting energy savings, informs about certification and efficiency classes, and provides hints for the construction of such devices.

# 1 Drain Water Heat Recovery in Retrofits

## 1.1 Principle

In this publication, the term drain water heat recovery (DWHR) describes a passive method to reduce the total energy demand of buildings. In particular, DWHR reduces the useful energy required for water heating by using heat from flowing waste water to preheat the domestic hot water (DHW). Typically, these systems do not require large storage tanks, heat is only transferred from the flowing drain water to the incoming water.



**Figure 1 - Examples for DWHR systems**

Due to the high heat transfer coefficient of water it is possible to achieve steady-state efficiencies of the heat exchanger itself of more than 70%.

The systems recover heat only when the flows of waste water and fresh water occur simultaneously. They are particularly interesting for heat recovery from showers, but do not e.g. reduce the energy required for bathing. Storage and distribution losses also remain unaffected.

## 1.2 Calculation of Energy Savings

The calculation methodology that is outlined here refers to showering because it is the most important application in this respect. Other hot water uses can be treated similarly. The method has been implemented in the Passive House Planning Package PHPP in version 9.

The steady-state efficiency of the heat exchanger itself at balanced mass flows can be calculated from (cf. Table 1 in section 1.2.1 for an explanation of the symbols)

$$\eta_{T,HX} = \frac{T_{CW}' - T_{CW}}{T_{DW}' - T_{CW}}$$

It is important to note that there are relevant heat losses in the shower between the shower head and the drain (whereas heat losses in the pipes can be neglected). Considering these, the fraction of the hot water load that is actually covered by the system under steady-state conditions is given by

$$\eta_{DWHR} = \frac{\dot{m}_{CW}\left(T_{CW}' - T_{CW}\right)}{\dot{m}_{DW}\left(T_{SW} - T_{CW}\right)}$$

Differences between the mass flows will occur if only one of the hot and cold water connections of the shower are connected to the DWHR. In this case, the mass flows can be calculated from the temperatures $T_{SW}$, $T_{CW}$, and $T_{HW}$.

Assuming a counterflow heat exchanger, the following equation holds:

$$\eta_{T,HX} = \frac{1 - e^{X}}{1 - \frac{W_{CW}}{W_{DW}} e^{X}}$$

where

$$X = UA\left(\frac{1}{W_{DW}} - \frac{1}{W_{CW}}\right)$$

For balanced mass flows these formulae become

$$\eta_{T,HX} = \frac{1}{\frac{W}{UA} + 1}$$

If $\eta_{T,HX}$ is measured under balanced mass flows, the above relationships allow for the determination of $UA$, from which $\eta_{T,HX}$ can also be calculated for unbalanced mass flows.

Furthermore, the efficiency of the heat exchanger at higher or lower mass flows can be estimated by a method based on the Number of Transfer Units of the heat exchanger.

Finally, considering just steady-state conditions is not adequate. There is some delay before all components have achieved their steady-state temperature. Such dynamic processes typically reduce the amount of heat recovered by another 10%.

Altogether, calculations as well as measurements show that for efficient DWHR units and appropriate installations the total reduction of heat consumption is approximately 35% of the energy used to provide the *useful* hot water demand.

### 1.2.1 Symbols, Units, Explanations

**Table 1 - Symbols, Units & Explanations**

| Symbols | Unit | Explanation |
|---|---|---|
| $\dot{m}_{CW}$ | [kg/min] | Water mass flow on fresh water side |
| $\dot{m}_{DW}$ | [kg/min] | Water mass flow on drain water side |
| $T_{CW}$ | [°C] | Fresh water temperature at entrance of heat exchanger |
| $T_{CW}'$ | [°C] | Fresh water temperature at exit from heat exchanger |
| $T_{DW}$ | [°C] | Drain water temperature at shower drain |
| $T_{DW}'$ | [°C] | Drain water temperature at heat exchanger |
| $T_{HW}$ | [°C] | DHW system temperature |
| $T_{SW}$ | [°C] | Water temperature used for showering |
| $UA$ | [W/K] | Heat transfer coefficient of the heat exchanger |
| $W_{CW}$ | [W/K] | Capacitance rate on fresh water side |
| $W_{DW}$ | [W/K] | Capacitance rate on drain water side |
| $\eta_{DWHR}$ | [-] | Fraction of shower water heat load covered by DWHR under steady-state conditions |
| $\eta_{T,HX}$ | [-] | Steady-state efficiency of heat exchanger |

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## 1.3 Requirements

From the above it can be seen that it is sufficient both for the characterisation of DWHR units and for the calculation of the expected savings to measure two properties:

- the steady-state efficiency at a typical flow rate
- the dead time

These values are used for certification as a Certified Passive House Component. To obtain the certificate, the units have to provide at least a reduction of the *useful* energy expenditure *for shower water*, i.e. $\eta_{DWHR}$ from above, by

30%

The steady-state efficiency of the DWHR typically needs to be 25 to 30% higher because of the temperature loss in the shower and the dynamic losses in the DWHR itself.

To distinguish between units of different efficiencies, Passive House efficiency classes were determined as given in Table 2.

**Table 2 - Passive House Efficiency Classes for Drain Water Heat Recovery**

| **Shower water - useful heat saved** | **Passive House Efficiency Class** | **Description** |
|---|---|---|
| ≥ 60% | phA+ | Very advanced component |
| ≥ 50% | phA | Advanced component |
| ≥ 40% | phB | Basic component |
| ≥ 30% | phC | Certifiable component |
| < 30% | | Not certifiable |

# 2 Application in Retrofits

The installation of a DWHR requires sufficient space for the unit and connections to the drain water as well as, ideally, to both the hot and cold water connection of the mixing tap. This is simple in new buildings, but may be very difficult in retrofits unless a major renovation of the whole hot and cold water system is required anyway.

Nevertheless, in many deep retrofits the bathrooms will be remodelled sooner or later to adapt to current comfort and design standards. This is a good opportunity to install a DWHR.

Design recommendations for DWHR systems in retrofits can be given as follows:

1. For any DWHR device whatsoever, there is some cost and effort involved in production and installation. Designers should consider aiming at the maximum possible efficiency to warrant this effort. Often high efficiency can be achieved by changing small details that provide turbulent flow, equal flow distribution, and optimized heat transfer in the solid parts of the heat exchanger.

2. If the flow of the drain water remains undisturbed, like in the duct-type DWHR units as shown in Figure 1 on the right, the units can be totally maintenance-free. For systems where regular cleaning is required it should be made as simple as possible.

3. Shower basins with an integrated DWHR (at a reasonable height difference), as shown in Figure 1 on the left, are particularly advantageous in retrofits. They can be installed as soon as the shower basin is changed and the cold water side of the mixing tap becomes accessible. It is not necessary to wait for all pipework in the building to be exchanged. In addition, the heat exchanger is situated very close to the drain and the shower head, thus minimizing dynamic lossses.

4. Horizontal drain pipe runs of several meters length are often available. It is possible to install duct-type DWHRs horizontally instead of the default exactly vertical installation, but their efficiency is reduced dramatically. Dedicated horizontal units with high efficiency would open the door for additional applications.

5. For typical DHW consumption levels in larger dwelling units, DWHR systems are economically interesting when considered over their total expected lifetime. For households with one or two persons, however, the economics become questionable. With increasing sales figures manufacturers should aim at reducing sales prices below the current levels. Given that DWHR units do not provide customers with additional benefits like increased comfort or prestige, the main argument for their installation will be the savings in DHW production cost.

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