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WHITE PAPER
ROLE OF WASTEWATER HEAT RECOVERY IN DECARBONISING EUROPEAN BUILDINGS

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1	August 2020	Support advocacy efforts aiming at higher recognition of WWHR systems in European legislation
2	November 2020	Impact of the Renovation Wave Strategy, 2030 WWHR Scenario, upgrade of products, calculation methodology, Minergie model,
3		

Disclaimer

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SUMMARY

Introduction

According to the European Commission, buildings are responsible for approximately 40 percent of energy consumption and 36 percent of CO_2 emissions in the EU. Renovation and improved energy efficiency have the potential to lead to significant energy and CO_2 emission savings.

Over recent years, the energy needed to produce hot water has become an ever-larger share of total household energy use at home due to the dramatic fall in energy required for domestic space heating. Every day, more than 22,000,000 m^3 of hot water are consumed by European homes alone. It is the main source of energy consumption for new housing, and yet 80 percent of this heat ends up in sewers and is wasted. Considering 80 percent of hot water is used in showers, harvesting heat from shower drains could be a simple way to save around 40 percent of energy and CO_2 emissions.

How it works

A wastewater heat recovery (WWHR) system can effectively recapture and reuse instantly up to 70 percent of the energy lost into the drain, reducing energy consumption in a cost-effective manner. It is a fit and forget solution: a simple system, with no moving parts, no storage, no control system and requires no electricity to operate. A specifically engineered heat exchanger transfers heat energy from the waste hot shower water to the incoming fresh water supply, warming it from around 10 up to 30°C. When the cold water arrives at the mixing valve, it is much warmer, and therefore substantially less hot water is required from the water heater or solar array. **Efficiency, as a percentage of energy gained from drain water, varies by systems used, up to the value of 70 percent.**

WWHR systems can be used in single- and multi-family homes, and non-residential premises with higher hot water consumption: sports facilities, hairdressers, hotels and swimming pools. Due to ease of installation, they can be applied in renovations as well.

EU technological lead

Europe has the greatest technological lead in the world on WWHR, with 326 patent applications since 2010, representing 70 percent of all patent applications in the world. Installed WWHR systems have already recovered 300 GWh corresponding to the annual domestic hot water consumption of 17,000 households.

How much CO_2 is saved?

In 2017, EU-28 domestic sanitary hot water accounted for 495 TWh energy which represents 14.8 percent of household final energy consumption (3,343,52 TWh). 80 percent of household hot water is used in showers, and shower water accounts for 396 TWh/year energy, or 3.2 percent of the EU-28 final energy consumption (12,329,08 TWh).

Providing the required energy for a shower mostly from fossil fuels in EU-28 leads to a high carbon footprint with emission of over 60 million tonnes CO_2 annually from electricity and gas alone. Assuming that the heat source is not changed, **37 percent of energy demand (i.e. 97.98 TWh) and related CO_2 emissions (*i.e.* 22.28 million tonnes) could be avoided by deploying WWHR systems**.

WWHR's contribution to the Renovation Wave targets

WWHR systems could make a significant contribution to the 2030 Renovation Wave targets by contributing 3.07 percent (1.54 Mtoe) towards the final energy savings target and 1.52 percent (4.20 Mt) towards the GHG emissions saving targets. This is based on the assumption that by 2030 half of the residential buildings targeted by the Renovation Wave strategy (14.35 million) and half of newly built dwellings (8 million) will deploy WWHR systems.

	Household Without WWHR		Household With WWHR		Household Saving with WWHR	
Hot water preparation	**Energy demand per year**	**CO_2 emissions per year**	**Energy demand per year**	**CO_2 emissions per year**	**Energy saving per year**	**CO_2 emissions saving per year**
Electricity	2,264 kWh	770 kg	1,430 kWh	486 kg	**833 kWh**	**283 kg**
Gas	231 m^3/year	414 kg	144 m^3/year	262 kg	**85 m^3/year**	**153 kg**

Table 1 – A sample calculation of annual energy consumptions and emissions of a shower with and without an average efficiency (56 percent) WWHR system

Policy recognition needed for WWHR

The benefits of WWHR in buildings are not adequately acknowledged in EU legislation, despite re-use of produced energy having a high potential in decarbonisation of sanitary hot water preparation. WWHR can contribute to the minimum requirements for renewable energy for all new or renovated buildings. Moreover, WWHR could be integrated into **EPBD, RED and EED** as an energy source generated on-site and can contribute to lower Primary Energy Consumption of hot water systems, as well as fulfil energy saving obligations as a durable, highly recyclable system with real-time energy recovery.

Role of Wastewater Heat Recovery in Decarbonising European Buildings

Introduction

According to the European Commission, buildings are responsible for approximately 40 percent of energy consumption and 36 percent of CO_2 emissions in the EU. Renovation and improved energy efficiency have the potential to lead to significant energy and CO_2 emission savings.

Over recent years, the energy needed to produce hot water has become an ever-larger share of total household energy use at home due to the dramatic fall in energy required for domestic space heating. Every day, more than 22,000,000 m^3 of hot water are consumed by European homes alone. It is the main source of energy consumption for new housing, and yet 80 percent of this heat ends up in sewers and is wasted. Considering 80 percent of hot water is used in showers, harvesting heat from shower drains could be a simple way to save at around 40 percent of energy and CO_2 emissions.

How Wastewater Heat Recovery (WWHR) Works

Principle

Most heat recovery systems have no moving parts and require no electricity to operate. A specifically engineered heat exchanger transfers heat energy from the waste hot shower water to the incoming fresh water supply, warming it from around 10 up to 30°C. When the cold water arrives at the mixing valve, it is much warmer, and therefore substantially less hot water is required from the water heater or solar array.

The shower is not only the application with the highest consumption of hot water, but also the place where heat exchange is easily possible. This is because a constant stream of warm wastewater flows downwards while a cold stream of fresh water flows upwards to the shower mixer. These two streams only need to be brought close together and massive energy savings can be achieved. In this case no storage and control system are necessary. A wastewater heat recovery system could effectively recapture and reuse instantly up to 70 percent of waste energy, reducing energy consumption in a cost-effective manner.

In addition, the shower water is relatively unpolluted, compared to other domestic wastewater from kitchen sinks, and is therefore also ideal for heat exchange.

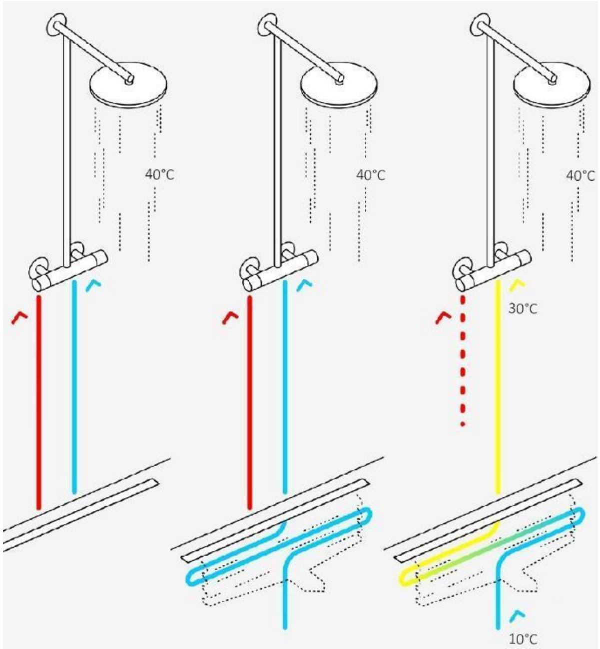

Figure 1 – Fresh water incoming at 10°C and preheated to 30°C arriving at the mixing valve, reducing the need for hot water from the boiler.

The recaptured heat from the shower might also be used to preheat the tank water.

For more schemes (individual and multi-dwelling solutions) see Annex 1.

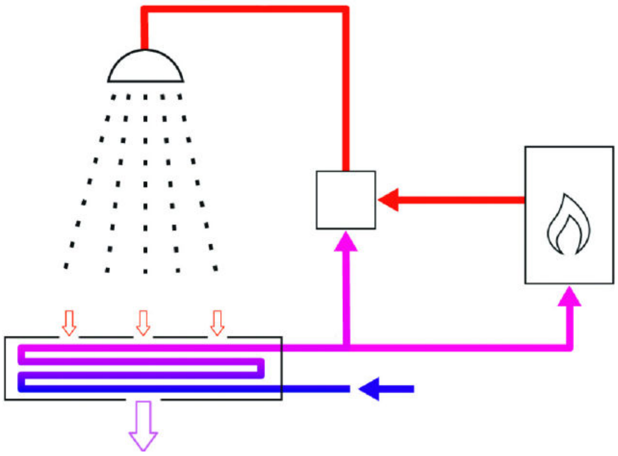

Figure 2 - The preheated fresh water goes to a mixing valve or to a storage tank.

EFFICIENCY

System efficiency varies by manufacturer and product. The lower the flow rate, the higher the efficiency – the higher the flow rate – the higher the performance. Efficiency, as a percentage of energy gained from drain water varies by system used, up to 70 percent**.**

More details can be found in Annex 2.

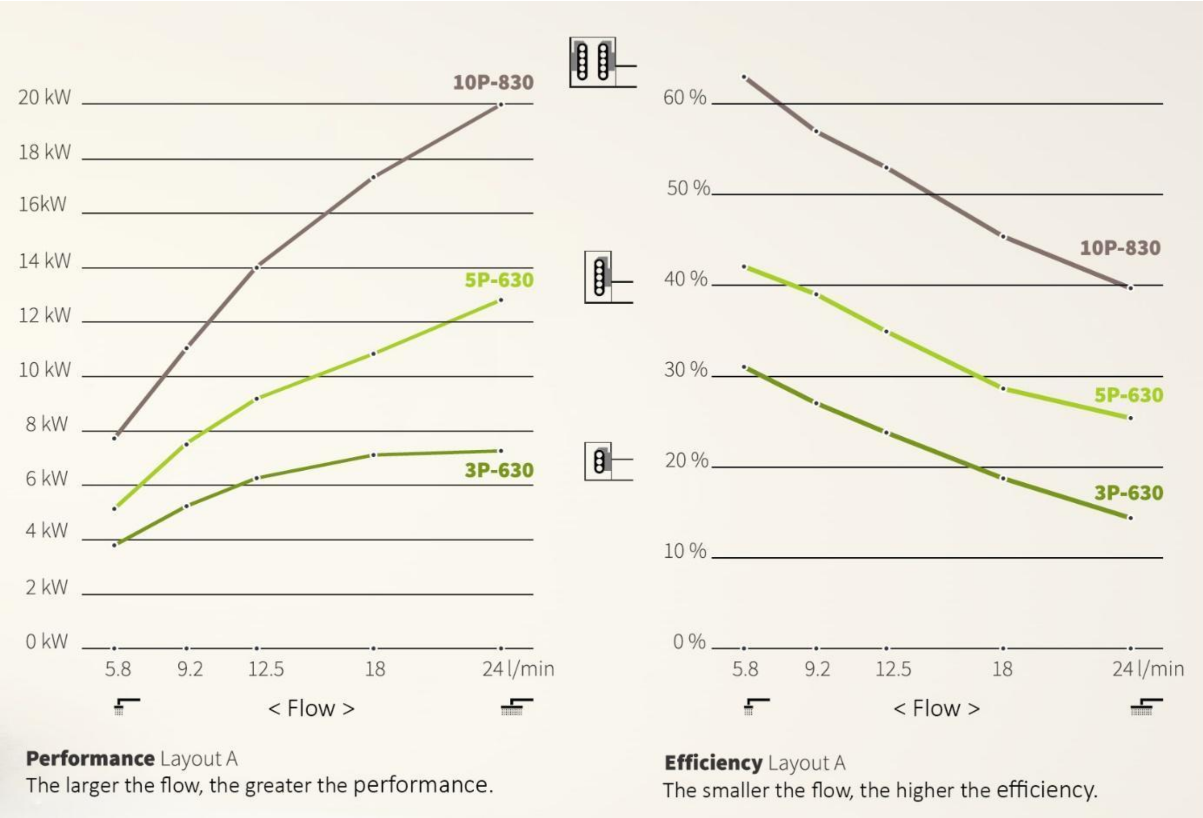

Figure 3 - Example of performance and efficiency of a selected WWHR unit (for 3-pipe, 5-pipe and 10-pipe types of products see in Annex 2).

Figure 4 - Shower pipe heat exchanger with over 60% efficiency.

Current Market Situation

Europe has the greatest technological lead in the world on this subject, with 326 patent applications since 2010, which is 70 percent of all patent applications in the world. Together, WWHR systems have already recovered 300 GWh corresponding to the annual domestic hot water consumption of **17,000** households.

The most used system is the vertical pipe with more than 150,000 systems already installed in Europe.

WWHR systems can be used in single- and multi-family homes, and non-residential premises with higher hot water consumption: sports facilities, hairdressers, hotels, and swimming pools.

Due to ease of installation, they can be applied in renovations as well.

Countries with highest market share: UK, FR, NL: all three have WWHR recognised as an energy efficiency measure in their building codes.

Acknowledgement of WWHR technology in national building codes and standards:

France: RT2012 and forthcoming RE2020 where WWHR can contribute to targets for heat from renewables.

The Netherlands: WWHR systems are included in the calculation software for new construction projects as they have a positive bearing on the energy performance of a building. This is the case for the existing EPC (energy performance coefficient) regulation. It will also be the case with the BENG (nearly energy neutral buildings) regulation that will be used from 01 January 2021.

UK: In October 2019, the Ministry of Housing, Communities and Local Government (MHCLG) published a consultation on the Future Homes Standard, regarding changes to Part L of the Building Regulations for new dwellings. WWHRS is widely recognised as one of the most cost-effective SAP-listed energy efficiency technologies available, and proposed changes to Part L in 2020 suggest WWHRS will have an even bigger impact under the new regulations.

EVALUATION OF WWHR POTENTIAL FOR DECARBONISATION

HOUSEHOLD LEVEL: CALCULATION OF ANNUAL ENERGY CONSUMPTION AND EMISSIONS OF A SAMPLE SHOWER SYSTEM WITH AND WITHOUT WWHR

Energy consumption and emissions of shower systems depend on many variables, e.g. temperature of incoming cold, hot water and shower water used, shower time, fuel used to heat water (electricity, gas…) size/design of shower enclosure and flow rate.

Assumptions used in calculation:

Shower time:	9 min./shower
Cold water temperature:	10°C
Hot water temperature from the boiler:	60°C
Mixed shower water temperature:	38°C
Flow rate:	9.2 l/min
Number of days:	365 (one shower/person/day)
Number of residents per home:	2.30
WWHR unit efficiency:	***56% (market average)***

CO_2 emission coefficient (based on Dutch standard NTA8800, “Energy performance of buildings - Determination method”):

Electricity:	0.34 kg/kWh
Gas:	0.183 kg/kWh

	Household Without WWHR		Household With WWHR		Household Saving with WWHR	
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Electricity	2,264 kWh	770 kg	1,430 kWh	486 kg	**833 kWh**	**283 kg**
Gas	231 m^3/year	414 kg	144 m^3/year	262 kg	**85 m^3/year**	**153 kg**

Table 2 – A sample calculation of annual energy consumptions and emissions of a shower with and without an average efficiency (56 percent) WWHR system

In this sample household, with deployment of an average efficiency WWHR system, 833 kWh electrical energy and related 283 kg of CO_2 emissions can be saved, or consumption of 85 m3 natural gas, equivalent to 153 kg CO_2 can be avoided.

37 percent of energy consumption and CO_2 emissions are avoided by deploying WWHR system with an average efficiency (56 percent).

More details and calculations with different flow rates and WWHR efficiency are provided in Annex 3.

RETURN ON INVESTMENT

Electricity and natural gas prices vary across Member States and there is a wide range of WWHR systems available on the market, so the exact return on investment needs to be calculated specifically for each project.

An average family can save around €50-150 annually on their hot water bill after deployment of a WWHR unit and this justifies the investment into this safe, energy efficient, environmentally friendly, simple, and easy to install, operate and maintain system with a long lifespan.

EU-28 LEVEL: ENERGY CONSUMPTION AND CO_2 EMISSIONS OF SHOWERS, ENERGY SAVING AND DECARBONISATION POTENTIAL

In 2017, EU-28 domestic sanitary hot water accounted for 495 TWh energy which represents 14.8 percent of household final energy consumption (3,343,52 TWh)[1].

As per the table below, 80 percent of household hot water is used in showers[2], and shower water accounts for 396 TWh/year energy, or 3.2 percent of the EU-28 final energy consumption (12,329,08 TWh).

Use of hot water in households according to JRC report "MEErP Preparatory Study on Taps and Showers"	Share
Bath	6%
Shower	**80%**
Tap, washbasin	7%
Tap, kitchen - drinking/cooking	0%
Tap, kitchen - dish washing	5%
Tap, indoor - clothes washing	2%
Tap, indoor - other uses	0%
Outdoor	0%
Total hot water demand in taps and showers	**100%**

Table 4 – Use of hot water in households

Providing the required energy for a shower mostly from fossil fuels in EU-28 (47 percent gas, 19 percent electricity, 11 percent oil and petroleum products, 11 percent derived heat, 2 percent solid fuels and 10 percent renewables and wastes) leads to a high carbon footprint with CO_2 emissions of over 60 million tonnes CO_2 annually just from electricity and gas, see table below.

	Share in heating shower hot water	Energy Demand Total (TWh/y)	Saving potential with WWHR (37%) (TWh/y)	CO_2 emission coefficient (NTA 8800) kg/kWh	CO_2 emissions (million tonnes/y)	Saving potential with WWHR (37%) (m. t./y)
Electricity	19%	74.89	**27.21**	0.34	25.46	**9.92**
Gas	47%	189.91	**70.27**	0.183	34.75	**12.86**
TOTAL		**264.81**	**97.98**		**60.22**	**22.28**

Table 5 – Energy demand, CO_2 emissions and saving potentials from heating shower hot water in EU- 28.

POTENTIAL OF ENERGY AND EMISSIONS SAVING IN EU-28: Assuming just electricity and gas as energy sources, 37 percent (from household level calculation above) of energy i.e. 97.98 TWh and CO_2 emissions, i.e. 22.28 million tonnes, could be avoided annually by deploying WWHR systems

In addition to the above savings in residential buildings, WWHR systems can be deployed in non-residential premises with higher hot water consumption, e.g. sports facilities, hairdressers, hotels and swimming pools, representing additional energy and CO_2 saving potential.

A 2030 WWHR Scenario – energy saving potential in 2030

In October 2020, the European Commission published its Renovation Wave Strategy[4] to improve the energy performance of buildings. The Commission aims to at least double renovation rates in the next ten years and make sure renovations lead to higher energy and resource efficiency. By 2030, **35 million buildings could be renovated.** In our calculation we assume 82 percent of this are residential dwellings[5]. In addition to this, by 2030 around **16 million new dwellings** will be completed in the EU.

In the table below annual energy saving for a "2030 WWHR scenario" is calculated for the year of 2030, if 50 percent of new built and energy renovated dwellings deploy WWHR systems by 2030:

2030 WWHR scenario	Renovated	Newly built
Number of dwellings by 2030	28 700 000	16 000 000
2030 WWHR Scenario – number of dwellings by 2030 (50 percent of dwellings deploying WWHR)	14 350 000	8 000 000
Household annual energy saving (kWh/year) See Table 3	800	800
Total annual energy savings in 2030 (TWh/year)	11.48	6.40
Grand total energy savings in 2030 (TWh/year)	**17.88**	
Grand total energy savings in 2030 (Mtoe/year)	**1.54**	

Table 6 – 2030 WWHR scenario - energy saving potential in 2030

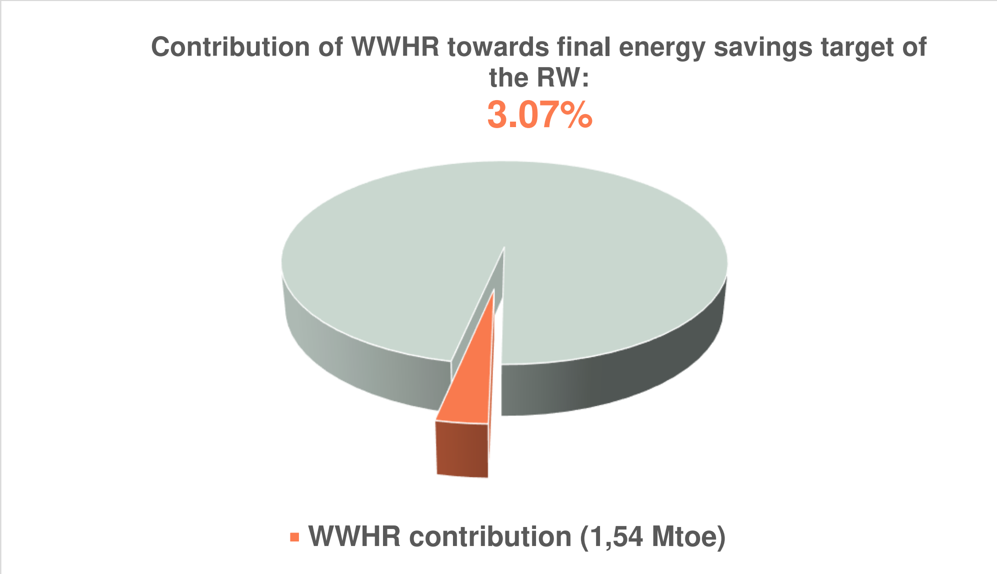
Contribution to the Renovation Wave Strategy targets

The Commission has proposed in the Climate Target Plan 2030[6] to cut net greenhouse gas emissions in the EU by at least 55% by 2030 compared to 1990.

According to the Renovation Wave Strategy, to achieve the 55% emission reduction target, by 2030 the EU should reduce buildings' greenhouse gas emissions by 60%, their final energy consumption by 14% and energy consumption for heating and cooling by 18% (compared to 2015).

	Final Energy Consumption (Mtoe) -14% (2030 vs. 2015)	GHG (Mton CO_2-eq) -60% (2030 vs. 2015)
2015	370	456
2030 (BSL scenario)	334	239
2030 Green Deal (REG scenario)	320	180
Savings needed	**50**	**276**

Table 7 – Final energy consumption and GHG emission savings needed



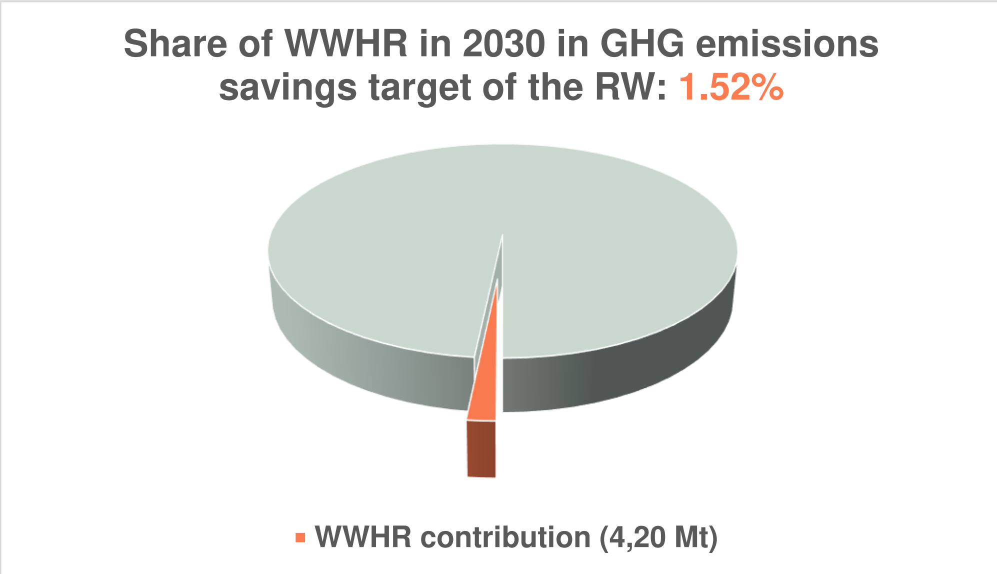


Figure 5 – Contribution of WWHR 2030 scenario to the Renovation Wave Strategy targets

WWHR systems could make a significant contribution to the 2030 Renovation Wave targets by contributing 3.07 percent (1.54 Mtoe) towards the final energy savings target and 1.52 percent (4.20 Mt) towards the GHG emissions saving targets. This is based on the assumption that by 2030 half of the residential buildings targeted by the Renovation Wave strategy (14.35 million) and half of newly built dwellings (8 million) will deploy WWHR systems.

EXAMPLE OF THE CONTRIBUTION OF A WWHR SYSTEM TO GREEN BUILDING CERTIFICATION

As most energy efficiency efforts focus on space heating, the energy needed for residential water heating is proportionally soaring and represents up to 45 percent of all energy needed in new buildings.[3]

In nearly zero energy buildings (NZEB), or higher energy performance buildings, the share of hot water can even be higher, as shown in figure 6—energy demand (kWh/m^2) evolution in buildings in Switzerland. Minergie is a registered quality label for new and refurbished low-energy-consumption buildings.

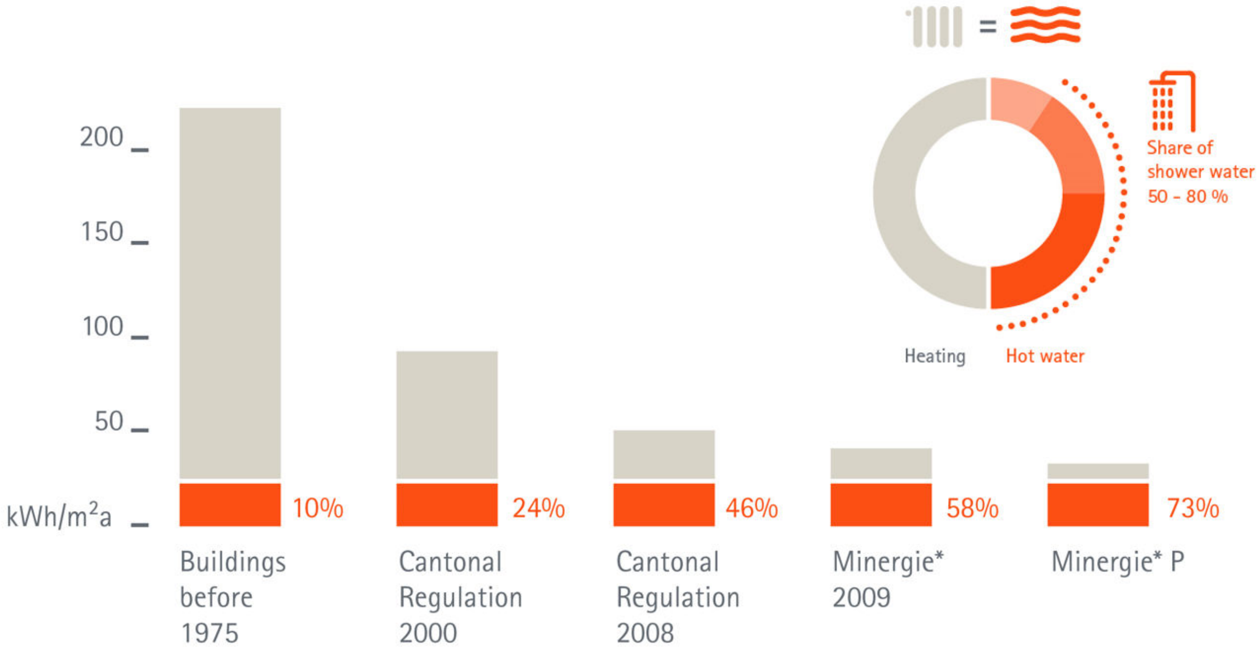


Figure 6 – Share of energy for hot water in Switzerland. Source: www.joulia.com.

Thanks to the WWHR unit, up to 50 percent of the energy of the total domestic hot water can be saved. This reduction makes it easier to achieve the green building label and a reduced energy index means savings in three ways:

- Hot water preparation system can be designed smaller
- Lower running costs for hot water production
- Reduced capacity of installed renewable systems (photovoltaic, solar thermal or heat pumps) or renewable energy generated on site can be used for purposes other than for hot water.

ADDITIONAL BENEFITS OF WWHR SYSTEM

1. Circular construction: systems have a long lifespan and contain easy to recycle and highly recycled materials (copper, stainless steel).
2. Real time production: the recovery and generation of energy adapt continuously and in real time with the usage, without over- or under-production (no storage and control system necessary)
3. Aesthetics: systems are integrated into showers, in ducts or technical rooms, so they are hidden.
4. Societal benefit (employment): innovative WWHR unit manufacturing companies are based in the EU and it is expected that by 2025 direct employment in France alone may reach 1,000 persons. More importantly, installation of WWHR units in both new build and renovation sectors requires a local workforce.

POLICY RECOGNITION NEEDED FOR WWHR

The benefits of WWHR in buildings are not adequately acknowledged in EU legislation, despite re-use of produced energy having a high energy saving and decarbonisation potential for sanitary hot water preparation. The policy asks to maximise impact of WWHR systems are provided below.

1. **Energy Performance of Buildings Directive (EPBD):**
    - **EPBD article 2** to define WWHR as “energy from renewable sources”. It is important to distinguish this domestic (building level) waste heat from industrial waste heat for District Heating and Cooling.
    - **EPBD to recognise WWHR as an energy source generated on-site in primary energy factors** used for the determination of the primary energy use expressed in kWh/m^2/year with the aim to take contribution of WWHR to energy savings into account. In the definition of NZEB, recognition is needed that WWHR can reduce hot water needs.
    - **EPBD to introduce a building renovation passport** (as proposed in the Renovation Wave) to provide a long-term, step-by-step renovation roadmap, to explicitly include WWHR systems.
    - **EPBD to introduce minimum energy performance standards** for existing buildings (as proposed in the Renovation Wave), to reach a minimum renovation rate, consider WWHR in calculations.
    - **EPBD to introduce a ‘deep renovation’ standard** (as proposed in the Renovation Wave), to explicitly include WWHR.

2. **Renewable Energy Directive (RED)**
    - **RED (and/or EPBD) to introduce requirement to use “Minimum levels of renewables in buildings”** (as proposed in the Renovation Wave), facilitate use of waste heat at building level, take WWHR contribution into account.

3. **Energy Efficiency Directive (EED)**
    - Article 14 (Promotion of efficiency in heating and cooling): Member States shall include wastewater heat recovery systems in buildings in their energy efficiency and renovation programs (Long Term Renovation Strategies).

4. **Ecodesign and Energy Labelling Directive**
    - Energy labelling: package label for heating systems: include WWHR as a subsystem in the label (next to solar collectors, storage tanks, controllers, …)

ANNEX 1: SCHEMES OF DIFFERENT WWHR SOLUTIONS

Selected schemes are shown below for illustration purposes. For more information on schemes by manufacturers please visit the member section of the [WWHR Europe website](). Copyright of the pictures belongs to the product manufacturers.

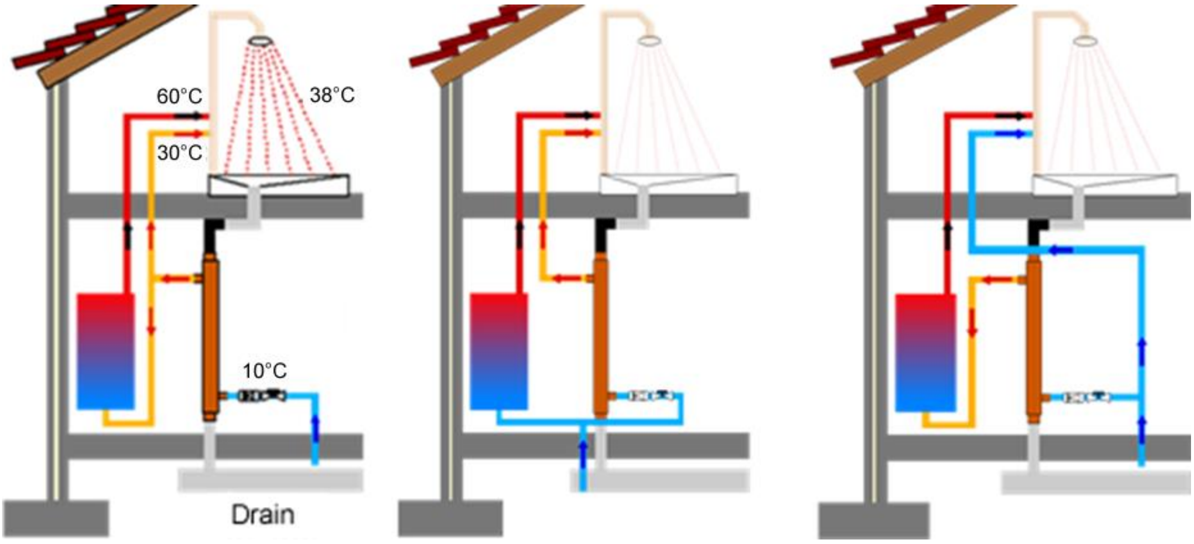


Figure 6 - Single shower, mixed (tap and storage tank), preheating tap and storage tank only

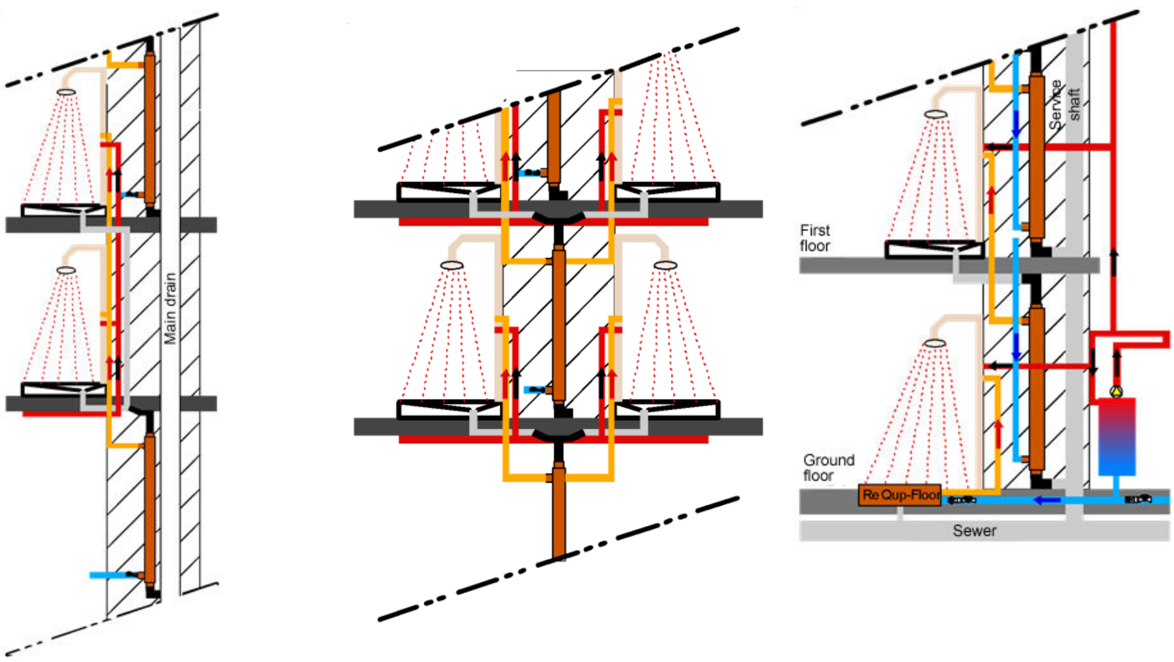


Figure 7 - Multi dwelling use, preheating for mixer taps and combination with storage tank

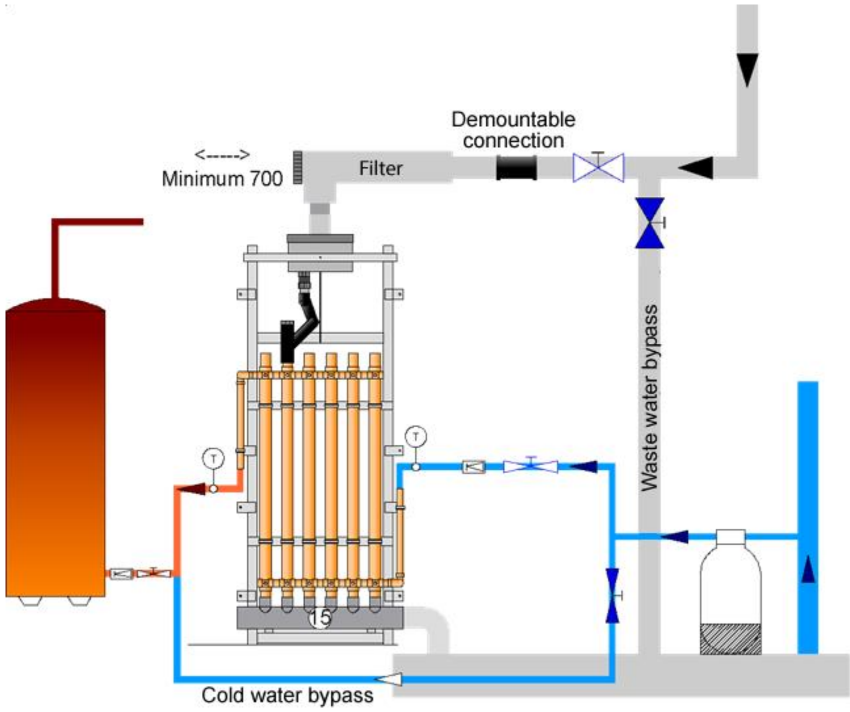


Figure 8 - Detailed scheme of storage tank connection

ANNEX 2: MATERIALS, PRODUCTS AND EFFICIENCY

European Copper Institute

The European Copper Institute (ECI) represents the copper industry. Copper is used extensively in technical building systems for delivering electricity, and heating and water services, representing 34 percent of annual copper use in the EU.

A sustainable metal

As a durable and sustainable metal with a long service life and infinite recyclability, copper plays a crucial role in the heating and cooling, drinking water piping, wiring and lighting of buildings. When it comes to making buildings 'greener' – i.e. with design, construction and operation that minimises negative impacts on the environment, or even offers positive contributions – key elements such as energy efficiency, circularity and smarter resource usage depend on copper.

Copper is the best heat conductor

Thanks to its thermal conductivity, copper is the ideal material for the manufacture of all types of heat exchangers. Copper heat exchangers are easily fabricated and have excellent corrosion resistance. There are many ways copper is used in heating and cooling applications. Copper is used as a bulk material to radiate heat, as a pipe to transfer refrigerants, as a surface to collect the sun's energy. It can be used as a heat pipe or part of a heat pump, as a fin material to transfer energy to and from the air or as a conductor of heat from one material to another. Simple or complex geometries can easily be made to maximize the cost efficiency of the transfer of energy.

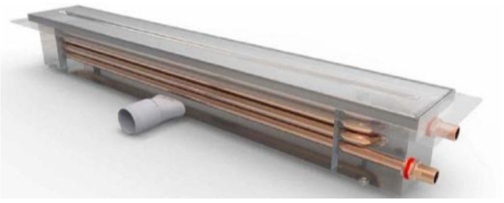
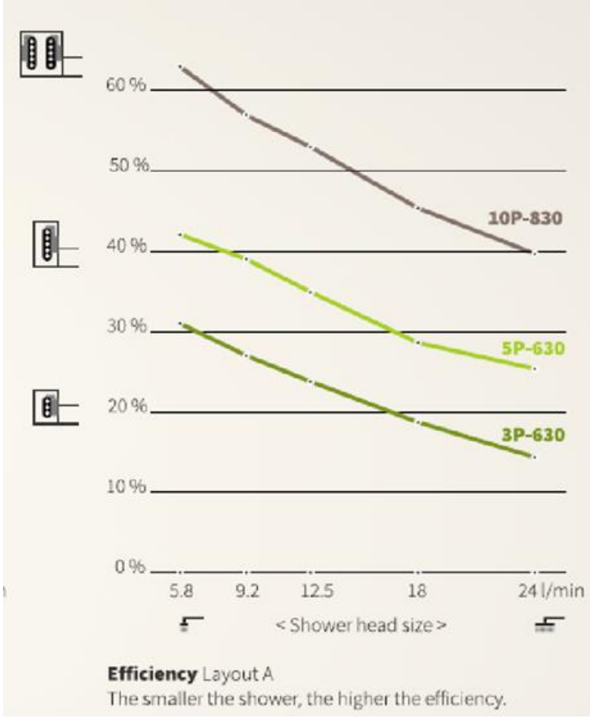
Copper content of WWHR systems

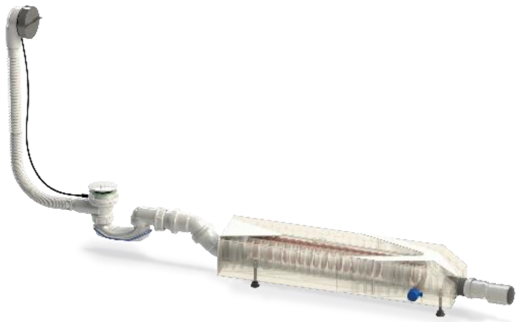
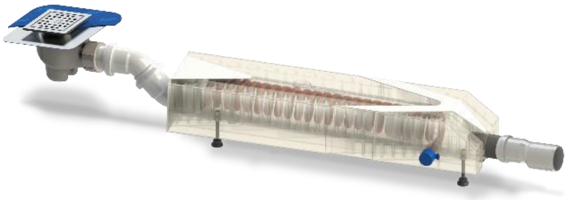
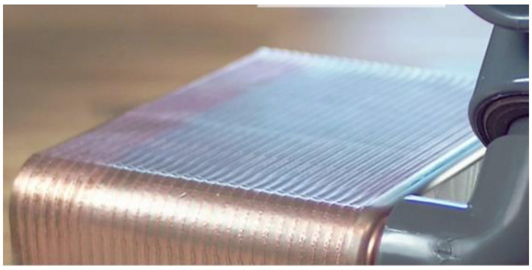
In WWHR systems **double-walled heat exchangers** are required by EN 1717 "Protection against pollution of potable water in water installations and general requirements of devices to prevent pollution by backflow". Double-walled tubes ensure that domestic hot water and grey water are reliably separated. Moreover, the standard-compliant leakage gap makes it possible to detect leakages.

Figure 9 - Double walled copper tubes, Source: Wieland

Copper content of WWHR systems varies from a few grams in a copper-brazed-plate heat exchanger to 15.6 kg in a vertical double-pipe system.

Products of some members of WWHR Europe are shown below to illustrate different systems. For more information on products, installation, efficiency and manufacturers please visit the members section of the [WWHR Europe website](). Copyright of the pictures belongs to the product manufacturers.

Horizontal type heat exchangers	
	
	Max. efficiency: At a flow rate of 9.2 l/min: 49.1%
	Max. efficiency: At a flow rate of 9.2 l/min: 57.3%
	
	

<table>
<tr><td></td><td>Efficiency: 43%</td></tr>
<tr><td></td><td rowspan="2">Efficiency: 25-39%</td></tr>
<tr><td></td></tr>
<tr><td></td><td rowspan="2">Efficiency depending on use 54-71%</td></tr>
<tr><td></td></tr>
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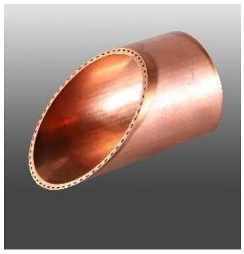
Vertical type heat exchangers	
  	Efficiency: 60-63.7%
	Efficiency: 78%
	Efficiency: 78%

	Efficiency: 53-74.8%
	Efficiency: 66%
	Efficiency at 5.8 L/min: 67%

Annex 3: Energy consumption and CO_2 emissions of shower systems

Basic data			
Heat capacity	4,187	Joule/Litre/°C	source
Average shower time	9	Minutes pppd	source
Cold water temperature	10	°C	according to the NEN7120
Required heating	28	▲T in °C	
Hot water temperature	60	°C	according to the NEN1006
Number of days	365	days	
CO_2 emission coefficient (NTA8800)			
Electricity	0.34	kg/kWh	
Gas	0.183	kg/kWh	
Ratio m^3 gas compared to kWh electricity	9.796		
Number of residents per home	2.30		source

Calculation of energy and CO_2 savings of different efficiency rate Wastewater Heat Recovery (WWHR) units

	Flow rate L/min.	Hot water L/min.	Hot water per person per year	unit	Hot water per household per year	unit	CO_2 emission pppy	unit	CO_2 emission per household per year	unit
WWHR efficiency	**61,80%**									
system without HR tube										
electrical	5.80	3.25	620	kWh/year	1,427	kWh/year	211	kg	485	kg
gas			63	m^3/year	146	m^3/year	114	kg	261	kg
system with HR										
electrical	5.80	1.93	368	kWh/year	847	kWh/year	125	kg	288	kg
gas			38	m^3/year	86	m^3/year	67	kg	155	kg
savings HR										
electrical	5.80	1.32	252	kWh/year	580	kWh/year	86	kg	197	kg
gas			26	m^3/year	59	m^3/year	46	kg	106	kg
WWHR efficiency	**56%**									
system without HR tube										
electrical	9.20	5.15	984	kWh/year	2264	kWh/year	335	kg	770	kg
gas			100	m^3/year	231	m^3/year	180	kg	414	kg
system with HR										
electrical	9.20	3.26	622	kWh/year	1430	kWh/year	211	kg	486	kg
gas			63	m^3/year	146	m^3/year	114	kg	262	kg
savings HR										
electrical	9.20	1.90	362	kWh/year	833	kWh/year	123	kg	283	kg
gas			37	m^3/year	85	m^3/year	66	kg	153	kg
WWHR efficiency	**53%**									
system without HR tube										
electrical	12.50	7.00	1,337	kWh/year	3076	kWh/year	455	kg	1046	kg
gas			137	m^3/year	85	m^3/year	245	kg	563	kg
system with HR										
electrical	12.50	4.56	871	kWh/year	2,004	kWh/year	296	kg	681	kg
gas			89	m^3/year	205	m^3/year	159	kg	367	kg
savings HR										
electrical	12.50	2.44	466	kWh/year	1,072	kWh/year	158	kg	364	kg
gas			48	m^3/year	109	m^3/year	85	kg	196	kg

REFERENCES

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4	Renovation Wave Strategy
5	EU Buildings Database
6	2030 Climate target plan