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ANCHOR

# Monitoring greywater heat flows

## Work package (WP) 2.2

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ANCHOR Interreg North Sea Co-funded by the European Union A GREEN TRANSITION

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# 1. Introduction

Climate change is increasingly affecting urban environments worldwide through prolonged droughts, more frequent heat waves, extreme precipitation events, and rising pressures on freshwater resources [1]. These developments directly influence water availability and water quality, creating challenges such as water scarcity, urban flooding and salinization of freshwater bodies. At the same time, ongoing urbanisation and population growth are placing even greater pressure on urban infrastructure and natural resources. Consequently, water management is becoming a critical component of sustainable urban development and climate adaptation strategies. To address these challenges, cities must evolve towards more climate-resilient and resource-efficient systems [2]. In addition to resilience, future urban developments are expected to support circularity, sustainability, and social cohesion. Urban water reuse and resource recovery of valuable resources such as thermal energy, nutrients have emerged as promising approaches to achieving these goals by reducing freshwater demand, improving resource efficiency, and strengthening the overall resilience of urban water systems [3].

The ANCHOR project was established to accelerate this transition towards water-wise neighbourhoods within the North Sea Region [4]. By focusing on the neighbourhood scale, the project brings together multiple disciplines and sectors to develop practical tools and strategies that support the implementation of innovative urban water management solutions. Through a combination of demonstration sites, pilot projects, and an international knowledge network spanning the Netherlands, Belgium, Germany, and Sweden, ANCHOR generates system knowledge on urban water reuse and the resilience of urban water systems. Within this broader framework, the project assesses a range of environmental and technical impacts, including the reduction of micropollutant emissions, nutrient and energy recovery, greenhouse gas emissions, climate adaptation benefits, and the performance of innovative sewage infrastructure. Urban water reuse is therefore not considered as an isolated technological solution, but rather as part of a wider transformation towards circular and sustainable urban systems. Understanding these interconnections is essential for supporting governance decisions, socio-economic evaluations, and the large-scale implementation of water-wise neighbourhood concepts.

One of the key interconnections explored within this project relates to the links between urban water and energy systems of the built environment. creating opportunities to contribute to broader sustainability and climate objectives. This report specifically focuses on the activities conducted within work package 2.2 (WP2.2), with the primary goal to monitor heat flows from greywater. The transition towards a climate-neutral built environment has become a central element of European and international climate policy. The Paris Agreement, the European Climate Law, and the European Union's Fit for 55 package establish targets related to greenhouse gas emission reductions and climate neutrality by 2050 [5]. The building sector is included within these policy frameworks because of its contribution to overall energy consumption and greenhouse gas emissions. Within the European Union, buildings account for a substantial share of energy use and energy-related emissions, with space heating and domestic hot water representing as main end uses of energy.

## 1.1. Greywater as a thermal energy source

From a neighborhood-scale perspective, decarbonizing domestic hot water production is particularly relevant because of its close relationship with urban water flows and the broader transition towards climate-neutral built environments. In many European countries, including the Netherlands, natural gas has traditionally been the dominant energy carrier for space heating and domestic hot water production. International assessments by the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) identify electrification, energy efficiency improvements, and renewable energy deployment as key pathways for reducing greenhouse gas emissions from the building sector [6]. Within this context, urban water systems offer opportunities that extend beyond water management alone, as they can also function as sources of recoverable thermal energy.

Greywater, defined as wastewater originating from showers, baths, sinks and washing machines, is of particular interest for thermal energy recovery. Since it originates from heated domestic water use, greywater retains thermal energy that would otherwise be discharged as wastewater. Compared with many conventional environmental heat sources (e.g., air, surface water, groundwater), greywater temperatures are generally higher and less influenced by seasonal variations, while the resource is generated directly within residential areas. Measured greywater temperatures at the outlet of sanitary appliances, such as showers and washing machines, have been reported to range between 16 and 50 °C [7]. This combination of relatively high temperatures and local availability makes greywater a promising resource for reducing the energy demand associated with domestic hot water production and supporting both climate mitigation and circular resource management objectives. However, recovery of heat from greywater generally requires a separate collection of greywater and blackwater (toilet and kitchen). As most existing residential wastewater systems combine these flows into a single sewer network, the implementation of greywater-based heat recovery requires the installation of dedicated collection and transport infrastructure.

The potential for thermal energy recovery from wastewater and greywater has received increasing attention in recent years. Studies have demonstrated that wastewater streams contain substantial amounts of recoverable heat that can be utilized at multiple scales, including individual buildings, neighbourhoods, sewer networks, and wastewater treatment plants [8]. Across these applications, wastewater temperature and flow characteristics have been identified as key parameters for estimating thermal energy availability, assessing recovery potential, and evaluating the technical feasibility of recovery concepts [9]. The amount of thermal energy available for recovery also depends on the extent to which heat is lost during collection, transport, and storage [11]. Several factors influence the thermal characteristics of greywater systems, including the insulation of pipelines and storage tanks, storage volume, hydraulic retention time, and the surrounding ground and ambient temperatures. Seasonal variations also affect wastewater temperatures and heat losses to the environment.

Various technologies are available to recover and utilize thermal energy from greywater, often through a combination of heat exchangers and heat pump systems. The performance and viability of these technologies depend fundamentally on the characteristics of the wastewater stream, particularly its temperature and flow dynamics. Consequently, understanding greywater temperatures and flows is essential for quantifying heat recovery potential and evaluating the contribution that water-wise neighbourhoods can make to reducing greenhouse gas emissions. At the same time, the feasibility and overall performance of greywater heat recovery systems are influenced by the wider design and operation of the heat supply system. Relevant technical considerations include the selected energy system concept, the availability of alternative heat sources, the configuration of individual or collective heat networks, thermal storage capacity, required supply temperatures, and the available space for equipment installation [12].

## 1.2. Greywater heat recovery at different scales

Greywater heat recovery systems recover thermal energy from wastewater streams generated from showers, baths, sinks and washing machines. These recovery systems can be implemented at the building, local (district), or central scale. The scale of implementation strongly influences system design, recovery efficiency and the range of potential heat applications.

**Building scale heat recovery**

At the building scale, greywater heat recovery is typically implemented directly in the shower drain or within the building drainage system. Greywater transfers its heat to incoming cold water through a passive heat exchanger, without the need for a heat pump. Because heat is recovered immediately after use where greywater temperatures are highest, heat losses associated with wastewater transport are minimal, resulting in relatively high recovery efficiencies. The recovered heat is generally used to preheat domestic hot water or incoming shower water. Reported energy recovery rates for shower heat exchangers range between 57% and 64% of the energy used for shower heating [10]. However, effective building-scale greywater heat recovery generally requires separate collection of greywater and blackwater within the building. This differs from conventional residential wastewater systems, in which these streams are typically combined. The main limitation of building-scale systems is that greywater production is intermittent and directly linked to occupant behaviour, resulting in a non-continuous heat source. Furthermore, the absence of buffering or thermal storage limits the use of recovered heat to domestic hot water preheating rather than broader heating applications.

**Local scale greywater heat recovery**

Local scale systems collect and buffer greywater from multiple buildings through a separate greywater collection network. Generally, greywater is then treated to remove solids and other contaminants. After collection and treatment, greywater serves as a heat source for a heat pump, which elevates the recovered thermal energy to the required supply temperature. Compared to building scale systems, buffering creates a more continuous and reliable heat source, allowing better utilization of the available thermal energy. Pretreatment also reduces the risk of fouling and clogging of heat exchangers, improving operational performance and system reliability. However, greywater systems at the local scale typically require dedicated collection infrastructure and may experience more heat loss during collection, transport, and storage, resulting in lower source temperatures than those directly available within buildings.

**Central scale wastewater heat recovery**

At the central scale, heat is recovered from wastewater at a wastewater treatment plant (WWTP). This approach, referred to as thermal energy from wastewater, is a form of aquathermal energy recovery that utilizes the thermal energy from municipal wastewater. Unlike greywater heat recovery systems at the building and local scale, this form of heat recovery does not require the separation of greywater and blackwater. Due to the large and continuous wastewater flows available, central-scale systems can recover substantial amounts of thermal energy and are typically integrated with large heat pumps and district heating networks. In some cases, seasonal thermal energy storage, such as aquifer thermal energy storage (ATES), can be incorporated to balance seasonal variations in heat demand and supply. The large wastewater volumes provide a stable and reliable heat source. However, wastewater temperatures at the WWTP are generally lower than at the building or local scale because of heat losses during transport through the sewer network. In practice, heat recovery is often applied to treated wastewater effluent rather than untreated influent. Sufficient treatment is needed to prevent fouling of heat exchangers that could reduce the efficiency of the heat pump. The economic viability of central-scale systems depends on the availability of sufficient heat demand near the WWTP, as the costs and heat loss associated with heat distribution increase with transport distance. Therefore, the ANCHOR project focuses on resource recovery within decentralized urban water systems at the building and neighborhood scale. Consequently, the assessment of central scale heat recovery at wastewater treatment plants falls outside the scope of this research.

### 1.3. Research objective

This report describes the monitoring results and evaluation of heat flows within greywater systems, considering the pathway from the household or building scale to the local and central (communal) scale. The objective of this research within the ANCHOR Interreg project is to collect, describe, and analyse monitoring data related to greywater heat, including temperature and flow characteristics. The report serves primarily as a description and evaluation of the available dataset and, where available, provides insight into the thermal characteristics of greywater systems at various scales. The implementation, performance assessment, and replication potential of greywater heat recovery concepts are addressed separately within the ANCHOR replication model report (WP 2.8).

The study focuses on three demonstration sites for which greywater temperature monitoring data are available: **De Nieuwe Dokken (Ghent, Belgium)**, **Oceanhamnen (Helsingborg, Sweden)**, and **SUPERLOCAL (Kerkrade, the Netherlands)**. These sites differ in terms of scale, building characteristics, greywater collection systems, and treatment configurations. For each location, relevant system characteristics will be described and evaluated. The monitoring data will be used to assess the thermal characteristics of greywater throughout the system and to compare heat flows between the demonstration sites.

## 2. ANCHOR demonstration sites with greywater heat monitoring

### 2.1. De Nieuwe Dokken, Ghent (Belgium)

De Nieuwe Dokken is a circular urban development project located in the former harbour area of Ghent, Belgium. The district combines residential buildings, commercial functions, educational facilities, and public spaces within a highly sustainable neighbourhood designed around the principles of resource recovery and circular infrastructure. When fully developed, the district will serve approximately 1,200 residents across more than 400 dwellings and community buildings.

A key feature of De Nieuwe Dokken is its integrated water, energy, and nutrient recovery system, operated by the local cooperative DuCoop. Wastewater streams are collected separately, with greywater from showers, sinks, and household appliances isolated from blackwater and organic kitchen waste. This separation enables targeted resource recovery and maximizes the value that can be extracted from each wastewater stream.

Heat recovery from greywater is an integral part of the district's energy system. After collection, greywater is treated locally and passes through a heat exchanger that extracts residual thermal energy from the wastewater. The recovered heat is used for the district's low-temperature heating network, contributing to the neighbourhood’s space heating and domestic hot water demand. In addition, energy recovery from blackwater is possible through biogas production during anaerobic digestion. As this report focuses on heat flows in greywater systems, energy recovery from blackwater is not considered further.

Monitoring activities focus on both the thermal performance of the decentralized greywater treatment and heat recovery infrastructure. To support these activities, dedicated temperature and flow sensors were installed as part of the ANCHOR project to collect monitoring data of the greywater system. The temperature and flow rate of the greywater are measured, allowing the available thermal energy and the efficiency of the heat recovery process to be assessed. The district heating network is also monitored to determine how much heat is recovered and utilized.

*Figure 1: Impression of demonstration site De Nieuwe Dokken, Ghent (Belgium)*

## 2.2. Oceanhamnen, Helsingborg (Sweden)

Oceanhamnen is a waterfront redevelopment project in Helsingborg, Sweden, transforming a former harbor area into a sustainable mixed-use district. Once completed, the development will feature approximately 350 apartments, 32,000 m² of office space, and public areas that combine living, working, and recreation in an urban environment. Sustainability is a central focus of the project. Oceanhamnen is one of the first districts in Sweden to implement a source-separated wastewater system, collecting black water, greywater, and food waste in separate streams to improve resource recovery and reduce environmental impact. Therefore, in the district itself a treatment facility was developed.

To maximize energy efficiency, several properties are equipped with greywater heat recovery systems that capture residual heat from greywater and use it to preheat water for the building's heating system through passive heat exchangers. Additional thermal energy is recovered at the treatment facility, where a heat pump extracts heat from the collected greywater stream before discharge. To characterize the thermal energy available within the system and support the evaluation of heat recovery performance, temperature and flow sensors were installed at both the building level and the treatment facility, providing insight into greywater flows, temperature profiles, and heat transport throughout the local system.

*Figure 2: Impression of demonstration site Oceanhamnen, Helsingborg (Sweden)*

## 2.3. SUPERLOCAL, Kerkrade (the Netherlands)

SUPERLOCAL is a circular urban redevelopment project located in Kerkrade, the Netherlands. The project has transformed a former residential area into a sustainable neighbourhood comprising two apartment buildings with 113 dwellings and 15 single-family homes. A key principle of the development was the reuse of materials from the original buildings, demonstrating a circular approach to construction and urban regeneration.

Sustainability and resource recovery are embedded throughout the design of the neighbourhood. Rainwater is collected and treated to drinking water, while greywater from showers and sinks is separately collected and treated through a helophyte-based system. Blackwater and food waste are collected through a vacuum sewer system and processed through anaerobic digestion, producing biogas that can be converted into heat and electricity. The remaining digestate has the potential to be reused as fertilizer for local urban farming.

The original SUPERLOCAL concept included shower heat recovery systems to capture thermal energy from greywater and improve the energy performance of the buildings. However, these systems were not implemented due to budget constraints. As a result, no heat recovery currently takes place within the neighbourhood, and no direct monitoring of heat flows, wastewater temperatures, or thermal energy recovery is conducted at the household or building level.

Monitoring activities are primarily focused on the local greywater treatment facility and the municipal wastewater network. At the helophyte system, sensors were placed in the collection tank to measure greywater temperature and flow rate. These measurements provide insight into the quantity and thermal characteristics of the greywater stream. In addition, the water board of Limburg (WBL) measures the temperature and flow rate of the wastewater at a nearby central (municipal) wastewater treatment plant. This data was made available for this project to enable a comparison between heat flows at local and central levels.

*Figure 3: Impression of demonstration site SUPERLOCAL, Kerkrade (the Netherlands)*

## 3. Approach on greywater heat monitoring

The assessment of greywater heat recovery performance requires an evaluation of both the temperature and the flow rate of the greywater heat recovery system. The actual heat recovery can be determined by combining the measured greywater flow rate with the temperature difference between the inlet and outlet of the heat exchanger. This temperature difference represents the amount of thermal energy extracted from the greywater. Ideally, monitoring data should include the greywater flow rate together with the inlet and outlet temperatures of the heat exchanger. These measurements enable the quantification of the thermal energy extracted from the wastewater stream over time. When site-specific monitoring data are unavailable, representative temperature and flow data from comparable systems can be used to estimate heat recovery performance. In addition, the physical properties of water, such as its density and heat capacity, are required to convert the measured temperature reduction into an estimate of recovered energy.

Heat recovery is typically calculated for each measurement interval using the corresponding flow and temperature data. The temporal resolution of the dataset influences the accuracy of the assessment, as higher-resolution measurements are better able to capture short-term fluctuations in water use and wastewater temperature. Results can subsequently be aggregated to monthly or annual values. For temperature analyses, flow-weighted averages are generally preferred over numerical averages because this represents the thermal energy transported by the greywater stream more accurately. A more detailed assessment of the technical heat recovery potential is presented in work package 2.8, where a replication model was developed to simulate greywater heat recovery under different system configurations and operating conditions. By incorporating temporal variations in greywater generation, temperatures, and system characteristics, this model provides a more comprehensive evaluation of heat recovery performance and recovery potential.

The actual amount of recoverable heat from greywater depends on several factors:

- **Greywater temperature at the source:** The temperature of greywater when it is discharged from showers, baths, or washing machines determines the initial amount of thermal energy available for recovery. This temperature is influenced by user behavior and appliance characteristics.
- **Greywater flow characteristics:** Variations in flow rate and discharge patterns affect both the quantity of thermal energy available and the rate at which heat is transported through the

system. Temporal fluctuations in water use can result in periods of high and low heat availability.

- **Temporal fluctuations:** Variations in ambient temperatures throughout the year influence heat losses from greywater during transport and storage. As a result, greywater temperatures may differ between seasons, with generally higher heat losses occurring during colder periods.
- **Transport and buffering losses:** As greywater travels through pipes or is temporarily stored in tanks and buffer volumes, heat is transferred to the surrounding environment. The extent of these losses depends on residence time, pipe length, ambient conditions, and the thermal insulation of the infrastructure.
- **Heat recovery system performance:** The efficiency of different types of heat exchangers and heat pumps influence how much of the thermal energy can be recovered and utilized.

Together, these factors determine the difference between the theoretical heat content of greywater at the source and the amount of heat that can realistically be recovered within the system.

**It should be noted that a detailed assessment of actual greywater heat recovery could only be conducted for De Nieuwe Dokken as demonstration site. For this system, representative monitoring data was available, including greywater temperatures, flow rates, and heat pump performance data. In contrast, the available datasets for SUPERLOCAL and Oceanhamnen are limited to greywater discharge and greywater temperatures. As no measurements of heat recovery performance from the heat pump were available for these cases, only the theoretical heat recovery potential could be estimated.**

## 4. Results and discussion greywater heat monitoring

The greywater heat monitoring results are presented at three distinct scales: building, local, and central scale. This multi-scale approach provides insight into temperature losses occurring along the greywater flow path.

### 4.1. Building scale heat monitoring

At the building scale, heat recovery is only applied at the Oceanhamnen demonstration site in Helsingborg, Sweden.

The dataset comprises one week of measurements, including greywater temperature within the building and indoor air temperature. Greywater temperature was monitored using a probe installed in the greywater pipe system (Figure 5). In addition, temperature and flow rate data were recorded at the connected pumping station over the same monitoring period, providing information on greywater discharge characteristics and thermal conditions downstream of the building.

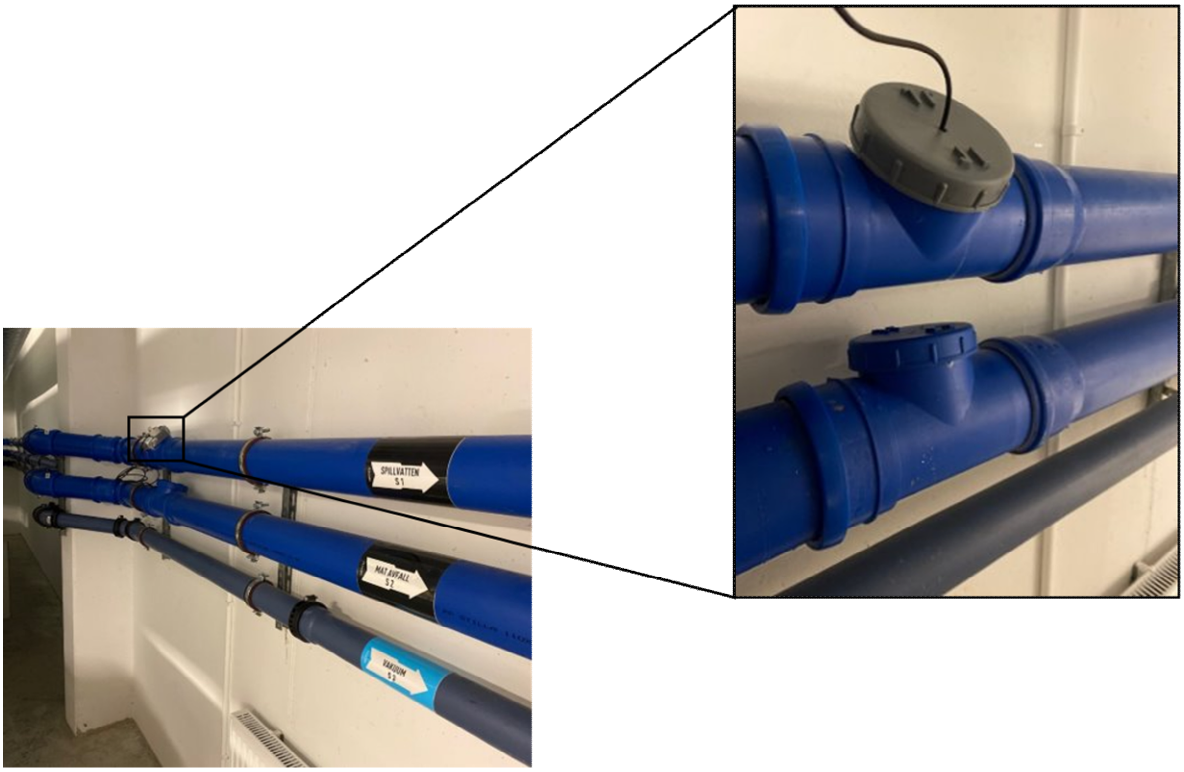

*Figure 4: Location of greywater temperature sensors inside one of the buildings of Oceanhamnen, Helsingborg (Sweden)*

During the monitoring period, the indoor temperature remained relatively stable, ranging from 21.8 to 23.0 °C. In contrast, greywater temperatures measured (Figure 6) within the building sewer network exhibited substantial variability, fluctuating between 16.9 and 39.3 °C. The lowest pipe temperatures recorded, below 20 °C, most likely occurred during periods when no greywater was being discharged or when only cold water was being used. As the system operates as a gravity sewer, the pipe remains empty between discharge events and is exposed to airflow through the ventilated network. Consequently, the measured temperature is influenced by heat transfer between the building interior and the outdoor environment. The resulting temperature therefore reflects a mixture of indoor and outdoor thermal conditions. Heat losses are likely increased by a chimney effect within the sewer network, as the connected valve chambers are not insulated and allow ambient air circulation through the system. A comparable demonstration site in Ghent is equipped with insulated valve chambers, which are expected to reduce these thermal losses. The temperature measurements of Oceanhammen indicate that the chimney effect results in a temperature drop up to 5 °C during the measurement period (May). In winter, the thermal losses are expected to be even higher.

Once greywater enters the pumping pit, temperature fluctuations are noticeably reduced, with observed temperatures ranging from 17.4 to 26.0 °C. This reduced variability is attributed to the permanent water volume present in the pit, which continuously mixes incoming greywater with already stored greywater, thereby dampening short-term temperature spikes. To better characterize greywater temperatures during discharge events, an event-based analysis was performed. A discharge event was defined as a temperature increase of at least 0.5 °C between consecutive measurements and was considered to end once the temperature decreased by at least 0.5 °C. Average greywater temperatures were subsequently calculated for each identified event and aggregated across the monitoring period. This approach resulted in an average greywater temperature of 26.4 °C. The average greywater temperature in the pumping pit was 20.8 °C during periods when the discharge was at least 10 $m^3/h$. Compared with the average temperature measured within the building, this indicates an average temperature reduction of 5.6 °C between the building and the collection point.

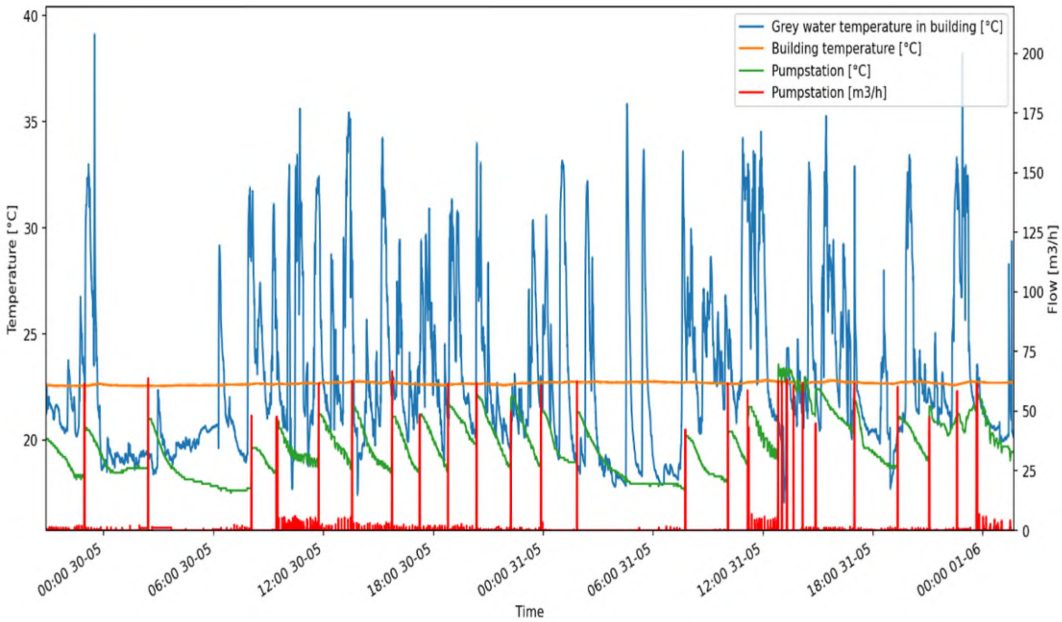


*Figure 5: Example of monitored flow rate and temperature of greywater inside and outside one of the buildings of Oceanhamnen, Helsingborg (Sweden)*

## 4.2. Local scale heat monitoring

Measured heat recovery data were available for the demonstration site De Nieuwe Dokken. For the other two locations (Oceanhamnen and SUPERLOCAL), the available data consisted of temperature and flow rate measurements.

### 4.2.1. De Nieuwe Dokken, Ghent (Belgium)

Greywater monitoring at demonstration site De Nieuwe Dokken was conducted at multiple locations throughout the collection and treatment system (Figure 7). Measurements were taken at the pumping pits serving individual building blocks, as well as at the local wastewater treatment plant (WWTP). The temperature records from Pergola (orange) and DEK (green) represent greywater discharged from individual buildings, while Noordveld (blue) reflects the combined greywater flow from four buildings (Pergola, Koopvaerders, Bijoux, and Dubbeltuupe). At the local WWTP, greywater temperature was monitored at the influent (brown) and after the nitrification process (grey). No temperature measurements were available right before and after the heat exchanger. Therefore, the direct temperature reduction across the heat exchanger could not be determined from the monitoring data.

To estimate the potential thermal recovery, it was assumed that the greywater temperature after nitrification is representative of the temperature before entering the heat exchanger. Based on this assumption, together with flow rate measurements and heat pump energy data, a theoretical greywater temperature after heat extraction was calculated. This estimate enabled an assessment of the potential impact of heat recovery on the greywater temperature profile.

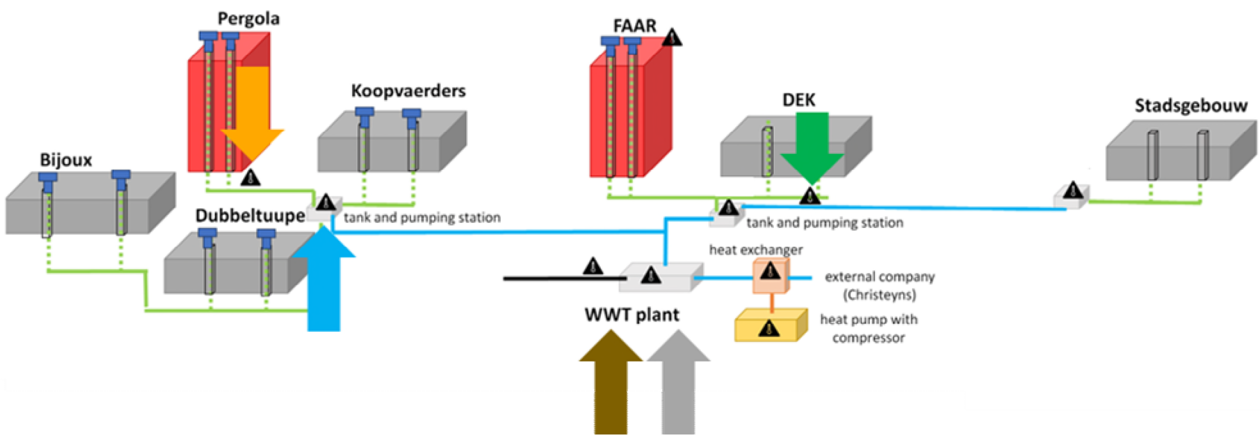


*Figure 6: Overview of greywater temperature measurements points at De Nieuwe Dokken, Ghent (Belgium)*

Because monitoring data were available for both 2023 and 2024, seasonal and annual average greywater temperatures could be determined for each monitoring location. The results clearly demonstrate the influence of seasonal conditions, with the highest greywater temperatures occurring during summer and the lowest during winter (Table 1).

At the building scale, the average greywater temperatures measured at Pergola and Noordveld were comparable, while Noordveld receives greywater from four buildings (including Pergola). In contrast, the average greywater temperature at DEK was approximately 2.0 °C lower. This difference may be attributed to the smaller number of connected households. Lower discharge frequencies can result in longer stagnation periods within the sewer network and pumping pit, allowing the system to cool more between discharge events and increasing heat losses to the surroundings.

Figure 8 illustrates the differences in temperature variability between the monitoring locations. Pergola and DEK exhibit relatively large fluctuations in greywater temperature, reflecting the intermittent discharge patterns of individual buildings. In contrast, the temperature profile at Noordveld is considerably more stable because greywater from four buildings is combined, resulting in a larger and more continuous greywater flow. This buffering effect becomes even more pronounced further downstream at the local WWTP, where mixing of greywater streams and larger storage volumes further reduce temperature fluctuations.

A comparison of the building-scale measurements with the WWTP influent data indicates that greywater temperatures in the collection tank of the WWTP were consistently higher than those measured at the upstream pumping pits. A possible explanation is the influence of the indoor temperature at the local WWTP, which provides more stable and generally warmer conditions than the sewer network. This trend continues throughout the treatment process. After nitrification, the average greywater temperature increased by nearly 2.0 °C. While a small contribution from biological activity cannot be excluded, the observed temperature increase is more likely the result of the indoor temperature, thermal buffering within the treatment tanks, and heat gains from pumps and recirculation equipment. These factors contribute to an elevated greywater temperature after greywater treatment, particularly during the biological treatment processes of nitrification and denitrification.

*Table 1: Overview of average greywater temperatures throughout the year at different locations*

| | Winter [°C] | Spring [°C] | Summer [°C] | Fall [°C] | **Average [°C]** |
|---|---|---|---|---|---|
| Pergola | 19.3 | 21.3 | 25.4 | 23.3 | **22.1** |
| Noordveld | 20.1 | 21.9 | 24.8 | 23.6 | **22.7** |
| DEK | 16.2 | 19.3 | 24.2 | 21.0 | **20.2** |
| WTTP collection tank | 20.8 | 23.2 | 26.6 | NA | **22.7** |
| WTTP after treatment | 21.1 | 24.1 | 29.5 | 27.5 | **24.5** |

Using heat pump monitoring data, including electricity consumption and total heat production, the actual amount of heat recovered from the treated greywater stream could be quantified. Using this data, it was also possible to determine the coefficient of performance (COP), defined as the ratio between total heat produced and the electrical energy consumed by the heat pump. The COP provides a key indicator of heat pump efficiency. Over the two-year monitoring period, the heat pump operated with a relatively stable average COP of 3.2. In contrast, the amount of heat recovered from greywater varied considerably over time (Figure 9). Heat recovery rates were highest from April 2025 onwards and remained elevated until the end of the monitoring period. The lower heat recovery observed during the first part of 2024 may be partly related to the smaller number of connected apartments, resulting in lower greywater volumes and reduced thermal energy availability. In addition, periods of system fouling were associated with reduced heat pump performance and temporary interruptions in operation. According to calculations, the average temperature drop resulting from heat extraction was estimated at 8.7 °C. Based on a specific heat capacity of water of 4.18 J/g/°C, this corresponds to an average heat recovery of 10 kWh/m$^3$ of greywater. It should be noted that the actual heat extraction varies depending on site-specific and operational conditions. Consequently, the recoverable heat in practice ranges from approximately 6 to 18 kWh/m$^3$ of greywater, with 10 kWh/m$^3$ representing the average observed value. According to internal calculations carried out by DuCoop, heat recovery from greywater could provide thermal energy to cover 15-20% of the annual heating demand of a modern apartment.

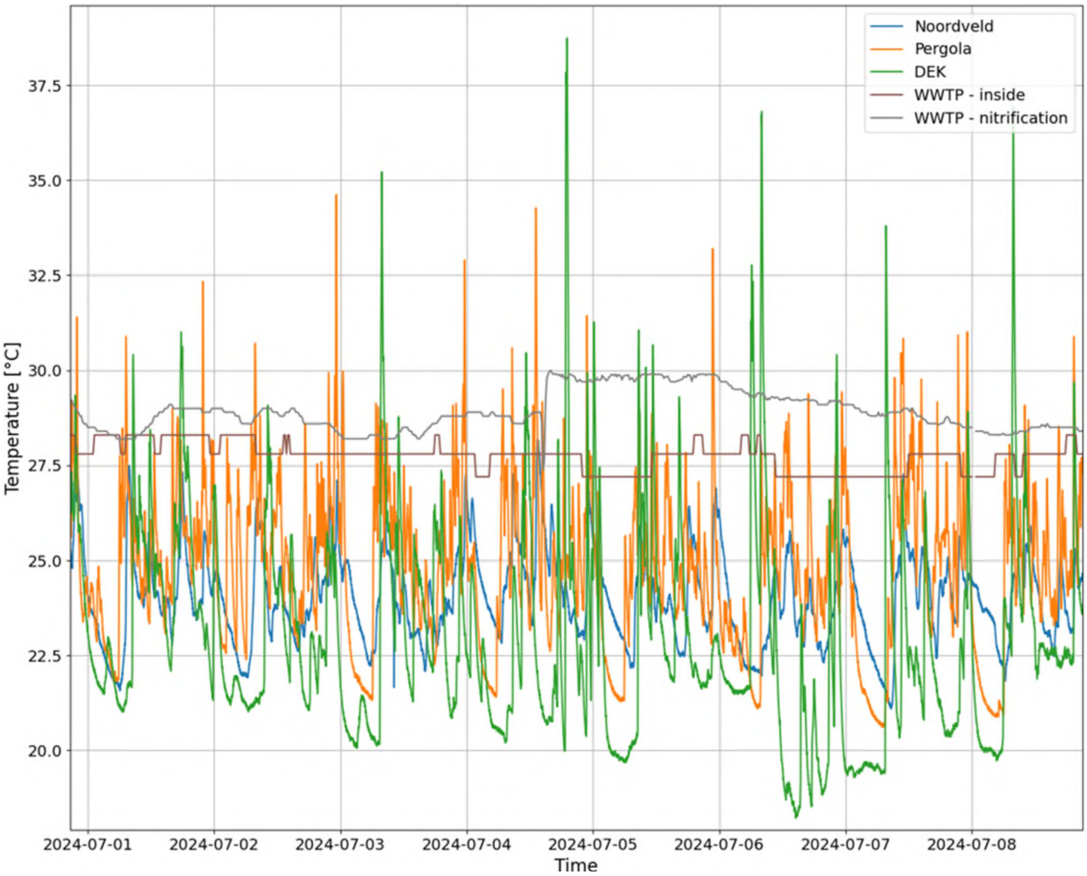


*Figure 7: Monitored temperature of greywater at local scale of De Nieuwe Dokken, Ghent (Belgium)*

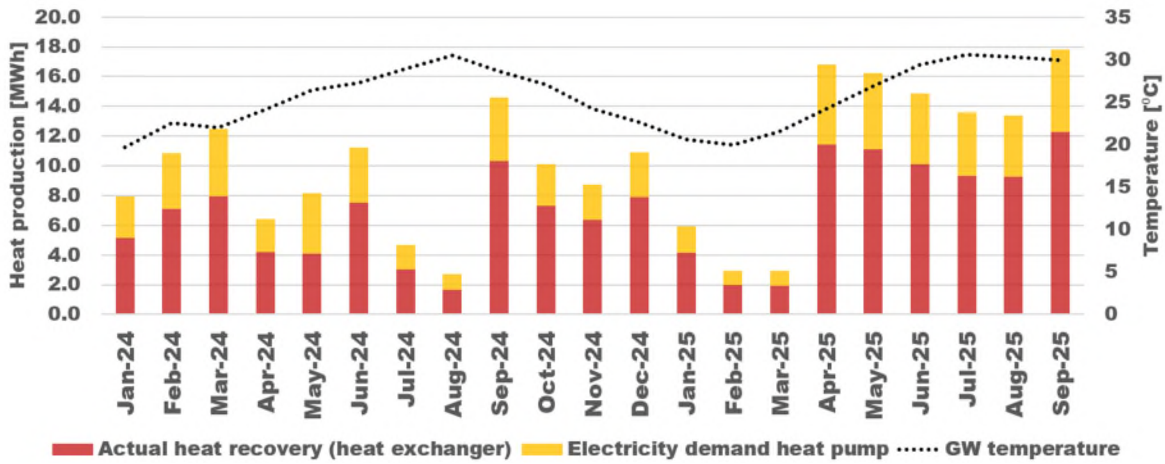


*Figure 8: Monthly heat recovery at local WWTP of De Nieuwe Dokken, Ghent (Belgium)*

#### 4.2.2. Oceanhamnen, Helsingborg (Sweden)

Greywater temperatures at the Oceanhamnen demonstration site were monitored at three locations within the local WWTP (Figure 10). Measurements were taken before the collection tank (blue), after the collection tank (orange) and after biological treatment (green). The collection tank receives greywater from multiple buildings and therefore represents the collection point where separate greywater streams are combined. Temperature data from the WWTP were available for the calendar years 2023 and 2024, while building-scale temperature measurements were available for 2025. As a result, a direct comparison between building outlet temperatures and WWTP temperatures over the same monitoring period could not be made. Consequently, estimates of temperature losses between the buildings and the WWTP should be interpreted as indicative.

Over the monitoring period, the average greywater influent temperature at the WWTP was 21.5 °C. Following retention in the collection tank, the average temperature decreased to 20.7 °C. This reduction is likely attributable to heat losses during storage and mixing within the collection tank. After biological treatment, the average greywater temperature increased to 22.9 °C. A similar trend was observed at the De Nieuwe Dokken demonstration site. Although biological treatment processes may contribute marginally to heat generation, the observed temperature increase is more likely explained by the indoor temperature, thermal buffering within the reactors, and heat gains from pumps, aeration systems, and recirculation equipment. The monitoring results further indicate that greywater temperature fluctuations have reduced at the local WWTP. Temperature variations were highest at the WWTP influent and became progressively smaller after the collection tank and biological treatment.

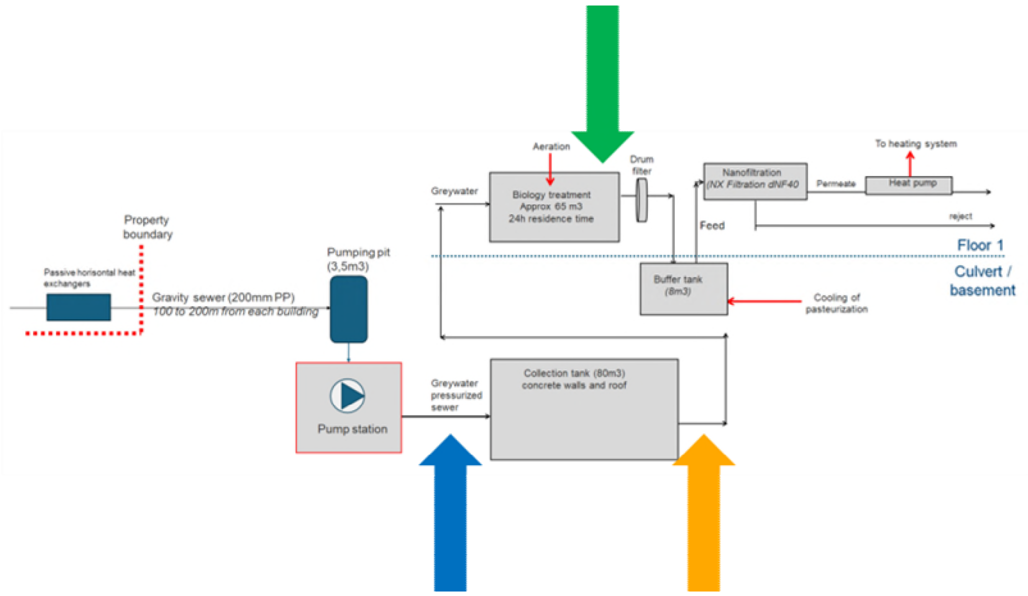


*Figure 9: Overview of greywater temperature measurements points at Oceanhamnen, Helsingborg (Sweden)*

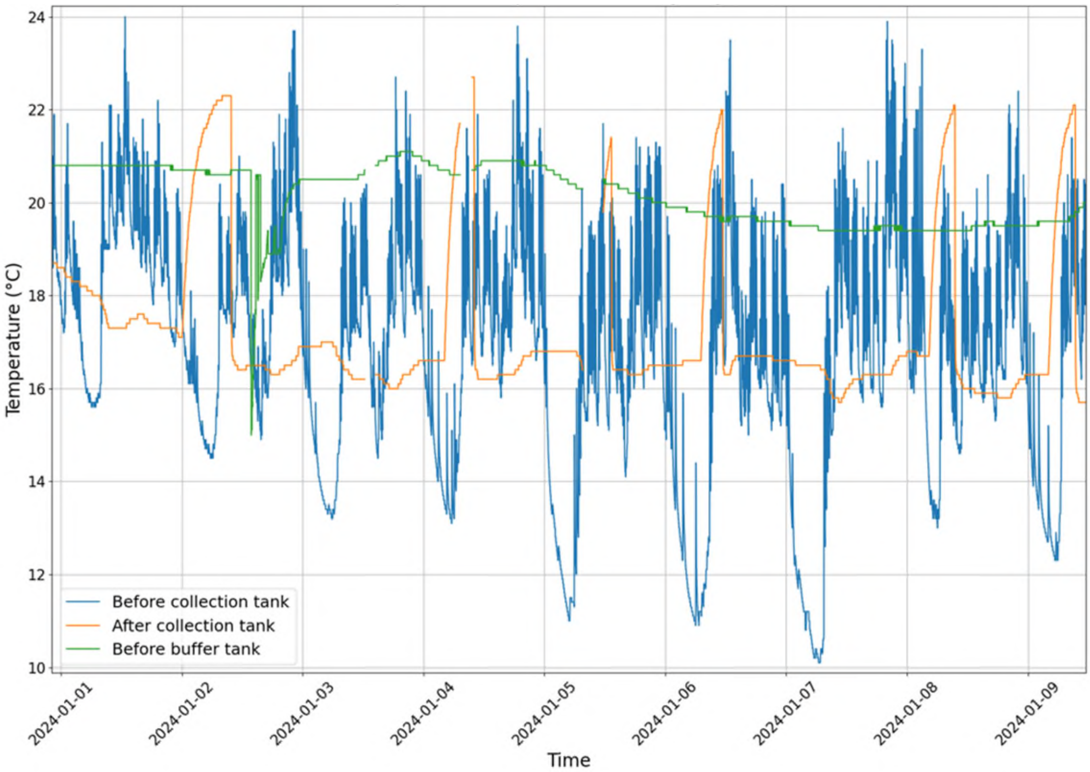


*Figure 10: Monitored temperature of greywater at local scale of Oceanhamnen, Helsingborg (Sweden)*

#### 4.2.3. SUPERLOCAL, Kerkrade (the Netherlands)

In contrast to demonstration sites De Nieuwe Dokken and Oceanhamnen, no greywater heat recovery is implemented at SUPERLOCAL. Greywater collected from the apartments and houses is transported to a pumping pit and subsequently treated in a helophyte filter as a nature-based treatment system. Consequently, the monitored greywater temperature reflects the thermal characteristics of the greywater system without the influence of active heat extraction.

Temperature monitoring was conducted at the pumping pit, where a sensor recorded (Figure 11) the temperature of the collected greywater. The monitoring period extended from June 2024 to November 2025. During this period, the helophyte treatment system experienced several operational disruptions. As a result, greywater was periodically diverted to the municipal sewer network rather than being discharged to the pumping pit upstream of the helophyte filter. These events should be considered when interpreting the monitoring results.

The data show a clear seasonal pattern in greywater temperature at SUPERLOCAL, with average temperatures ranging from 16.5 °C in winter to 22.4 °C in summer. This variation is likely influenced by ambient conditions and heat losses in the non-insulated collection, storage, and conveyance system. Because the helophyte system was not operational during most summer months, the dataset does not fully capture greywater temperatures under peak summer conditions. The highest average monthly temperature was recorded in September (24 °C), suggesting that temperatures may have been even higher during the warmest summer months. Overall, the results highlight the strong influence of seasonal conditions on greywater temperatures and the importance of thermal losses in the system when no thermal insulation is applied.

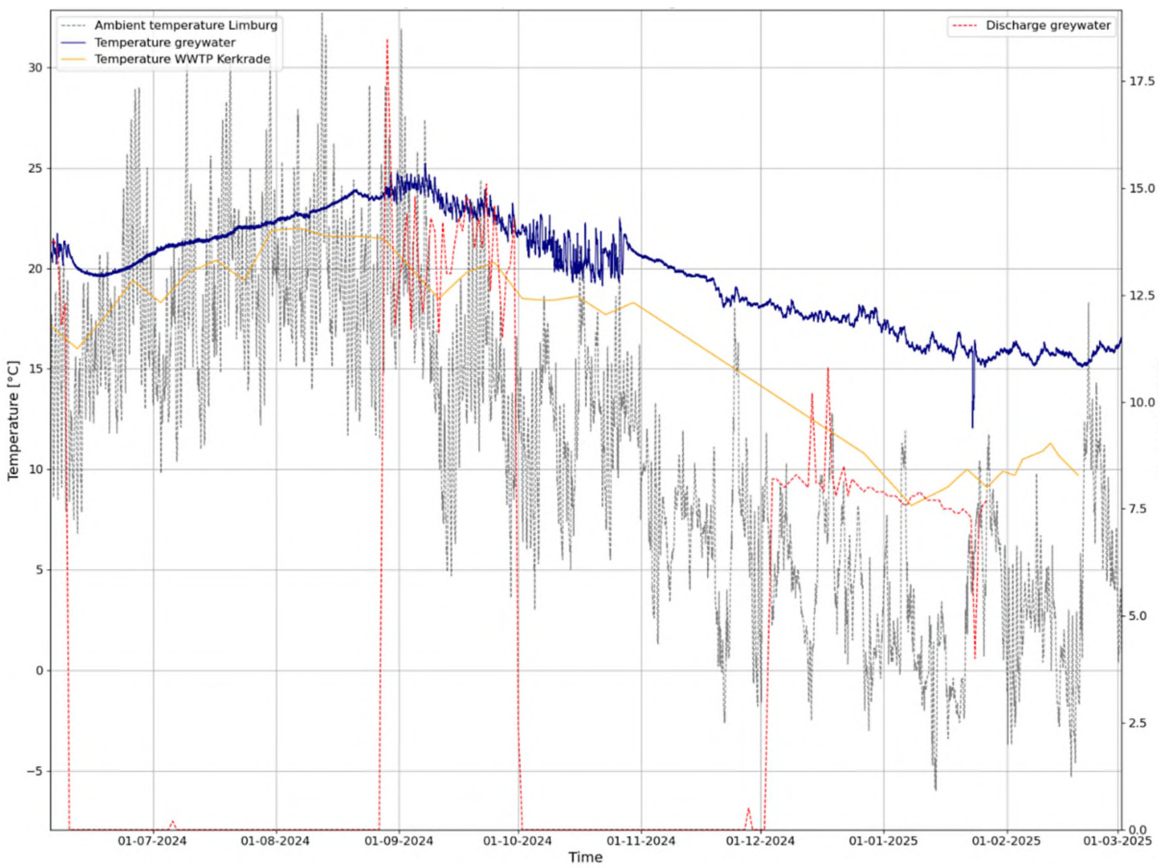


*Figure 11: Monitored temperature of greywater at local scale of SUPERLOCAL, Kerkrade (the Netherlands) and compared with wastewater influent temperature of a WWTP.*

### 4.3. Central scale wastewater heat monitoring

To explore the relationship between greywater temperatures at the local scale and municipal wastewater temperatures at the central scale, monitoring data from SUPERLOCAL and the nearby WWTP in Kerkrade (The Netherlands) were analysed. The availability of temperature measurements at both the local collection system and the wastewater treatment plant provided an opportunity to include this comparison in the study. To support consistency, WWTP temperature data from 2024 and 2025 were evaluated over a comparable period.

Figure 12 presents the temperature profiles of locally collected greywater and centrally collected municipal wastewater (grey and black water). Throughout the monitoring period, the average greywater temperature remained consistently higher than the wastewater temperature measured at the central WWTP. During winter, the average wastewater temperature at the WWTP was 10.5 °C, compared with 16.5 °C for the locally collected greywater. In summer, the average wastewater temperature increased to 20.7 °C, while the average greywater temperature reached 22.4 °C. The higher temperatures observed in the greywater stream can be attributed to the absence of dilution by rainwater and other lower-temperature wastewater sources that are present in municipal sewer systems. Consequently, higher thermal energy levels are maintained in the greywater, increasing the potential for heat recovery.

The monitoring results further indicate that the temperature difference between greywater and municipal wastewater is more pronounced during winter than summer. In winter, the average temperature difference amounted to approximately 5.2 °C, compared with only 1.7 °C during summer. Although the greywater temperature in summer may be somewhat underestimated due to the limited availability of representative monitoring data, the overall trend remains evident. This seasonal pattern suggests that ambient conditions have a stronger influence on wastewater temperatures during winter. Lower outdoor temperatures in winter lead to a greater temperature difference between wastewater and the surrounding environment, resulting in greater heat losses from the sewer network and consequently lower wastewater temperatures. Greywater collected in local systems is less exposed to these effects because of shorter transport distances and reduced dilution. As a result, a larger temperature advantage is maintained at the local scale during winter, whereas the temperature difference between greywater and municipal wastewater narrows during warmer periods. This is particularly important in winter, when the demand for heating is at its highest.

## 4.4. Lessons learned on heat recovery at different scale levels

The three demonstration sites provide valuable insights into the temperatures and flows of greywater and the opportunities for heat recovery at different spatial scales. Together with discussions on operations in the ANCHOR work group, the results demonstrate how greywater temperature, heat availability, system set-up and performance, and operational requirements vary between building scale, local scale and central scale.

**Lessons from De Nieuwe Dokken**

De Nieuwe Dokken demonstrates actual heat recovery from a decentralized greywater treatment and recovery system. As the design placed strong emphasis on thermal insulation of the greywater infrastructure, heat losses during collection and conveyance were minimized. Throughout the year, greywater temperatures after treatment typically remained between 17 and 30 °C.

The monitored heat recovery system showed that up to 15% of the local annual space heating demand of the residential buildings could be supplied through recovered greywater heat. These results confirm that greywater represents a viable source of renewable thermal energy within urban environments. At the same time, the findings underline the importance of reliable treatment system operation. Heat recovery performance depends directly on the availability and continuity of the greywater flow. Operational issues, such as fouling of the heat exchanger or treatment plant downtime, can substantially reduce the amount of recoverable heat. Therefore, robust system design, preventive maintenance, and reliable treatment performance are essential prerequisites for successful long-term heat recovery.

**Lessons from Oceanhamnen**

The monitoring results from Oceanhamnen provide insights into greywater heat flows at both the building and district scales. Building scale heat recovery systems remain relatively underexplored, particularly with respect to long-term thermal performance and operational reliability. The monitored horizontal greywater heat exchangers were found to be vulnerable to fouling, primarily due to the accumulation of fats and other solids within the pipe network. Regular flushing and maintenance are therefore required to maintain heat transfer efficiency. Vertical heat exchangers may offer an attractive alternative, as they are generally less prone to clogging and can potentially reduce maintenance requirements.

At the district scale, the heat pump installed at the local WWTP demonstrated stable operation and required only limited maintenance. Local heat recovery systems therefore appear to offer operational advantages compared with building scale heat exchangers. In addition, the monitoring results indicate that the collection and treatment of greywater can lead to additional heat into the wastewater stream. The added thermal energy suggests that heat recovery from collected and treated greywater may be more effective than recovery at the individual building scale. Furthermore, greywater heat recovery using heat pumps may offer additional opportunities within future district heating networks, while at Oceanhamnen the recovered heat is currently utilized within the local WWTP.

The monitoring data also highlighted substantial variations in greywater temperature at the building level. These fluctuations were amplified by heat losses in non-insulated sections of the collection system and by the intermittent nature of greywater discharges. Heat loss was also identified from the passive aeration of sewage pipes in the buildings with the "chimney effect" which might be extra worthwile to consider in colder climates. Consequently, building-scale heat recovery systems should be designed for highly variable heat flows. Under such conditions, passive heat exchangers may provide a more robust solution than systems requiring continuous and stable heat availability for greywater.

**Lessons from SUPERLOCAL**

Although SUPERLOCAL does not incorporate greywater heat recovery, the monitoring results provide valuable insight into the thermal behaviour and heat recovery potential of locally collected greywater. A comparison between locally collected greywater and municipal wastewater at the central WWTP showed that greywater consistently maintained higher temperatures throughout the year, with the difference being particularly pronounced during winter when lower ambient temperatures increased heat losses from the municipal sewer network. These measurements highlight the availability and seasonal dynamics of recoverable thermal energy in source-separated wastewater systems. Combined with future heat recovery applications, such systems could contribute to energy recovery and the resilience of urban wastewater infrastructure.

**Overall grey water temperature levels**

Across the three demonstration sites, a clear trend emerges: greywater retains substantially more thermal energy when collected and treated locally than when conveyed through municipal sewer networks (Table 2). Local collection systems typically maintain higher temperatures and are less affected by dilution and heat losses than centrally collected wastewater, particularly during winter.

Building-scale heat recovery offers direct access to this thermal resource but faces challenges related to highly variable flows, fouling, and maintenance. Neighbourhood- and district-scale systems benefit from larger and more stable flow rates and reduced temperature fluctuations, resulting in more reliable heat recovery. The results show that collecting and treating greywater can add extra thermal energy to the greywater flow, meaning that in some cases the temperatures are higher than those at building level. This additional heat represents provides an additional argument for implementing heat recovery at the neighbourhood scale. However, these systems require robust treatment infrastructure and well-controlled operation to ensure continuous heat availability.

*Table 2: Overview of all monitored temperature at the different scales*

| Scale | Demonstration site | Location | Winter [°C] | Spring [°C] | Summer [°C] | Fall [°C] | Average [°C] | Average [m³/day] |
|---|---|---|---|---|---|---|---|---|
| Building | Oceanhamnen | Building sewer | NA* | NA* | NA* | NA* | 26.4 | NA |
| Building | Oceanhamnen | Building pump pit | NA* | NA* | NA* | NA* | 20.8 | 23.1 |
| Local | De Nieuwe Dokken | Pergola | 19.3 | 21.3 | 25.4 | 23.3 | 22.1 | - |
| Local | De Nieuwe Dokken | DEK | 16.2 | 19.3 | 24.2 | 21.0 | 20.2 | - |
| Local | De Nieuwe Dokken | Noordveld | 20.1 | 21.9 | 24.8 | 23.6 | 22.7 | - |
| Local | De Nieuwe Dokken | WTTP collection tank | 20.8 | 23.2 | 26.6 | NA | 22.7 | - |
| Local | De Nieuwe Dokken | WTTP after treatment | 21.1 | 24.1 | 29.5 | 27.5 | 24.5 | 20.3 |
| Local | Oceanhamnen | WWTP influent | 18.1 | 19.9 | 23.6 | 22.5 | 21.5 | 83.0 |
| Local | Oceanhamnen | After collection tank | 17.1 | 19.2 | 23.1 | 21.9 | 20.7 | See influent |
| Local | Oceanhamnen | After biological treatment | 19.8 | 22.7 | 24.9 | 23.3 | 22.9 | NA |
| Local | SUPERLOCAL | Pump pit helofyte system | 16.5 | 16.4** | 22.4 | 21.3** | 20.5** | 10.6** |
| Central | SUPERLOCAL | Kerkrade WWTP (communal wastewater) | 10.5 | 14.6 | 20.7 | 18.2 | 15.8 | NA |

* Building-scale measurements at Oceanhamnen were available for only one week in 2025; therefore, seasonal averages could not be determined.
** The average temperatures reported here are not considered representative due to incomplete data and significant periods when the greywater system was out of operation. However, they have been included show the full dataset.

## 5. Overall conclusions and recommendations

The monitoring results demonstrate that greywater forms a consistent heat source with clear potential for energy recovery at the local scale. Average greywater temperatures measured within buildings remained relatively high (22.5 °C at Oceanhamnen), confirming the availability of substantial thermal energy immediately after use. During collection and transport, heat losses occur, illustrated by the temperature decrease to 19.7 °C in the building collection tank and by reductions observed in local collection systems.

At the local scale, average temperatures remained between approximately 20 and 25 °C. In both De Nieuwe Dokken and Oceanhamnen, indoor treatment conditions even increased greywater temperatures during treatment. The highest average temperature was observed after greywater treatment at De Nieuwe Dokken (24.5 °C), highlighting the suitability of treated greywater as a stable heat source for heat pump systems. Actual monitoring at this site showed an average heat pump COP of 3.2 and an average temperature reduction of 8.7 °C resulting from heat extraction. The results indicate that greywater heat recovery yields approximately 10 kWh/m³ on average, with values ranging from 6 to 18 kWh/m³ depending on the amount of recoverable heat available. To put these numbers into perspective, heat recovery from greywater has the potential to meet approximately 15-20% of the total heating demand of a modern apartment.

At the central scale, wastewater temperatures at the municipal WWTP were considerably lower (15.8 °C on average in Kerkrade) due to transport-related heat losses and dilution of colder water, such as black water from the toilet. However, the larger wastewater volumes provide a stable thermal resource and gives opportunities for large-scale heat recovery and seasonal thermal energy storage.

Overall, the results show that greywater has the advantage of high temperatures when recovered close to the source but has the disadvantage of highly fluctuating flows. Temperature fluctuations decrease further in the system, due to flow aggregation. Consequently, the most appropriate recovery concept depends on the intended application: building-scale systems are well suited for passive heat exchangers for domestic hot water preheating, local systems provide an attractive heat source for heat pumps, and central systems offer opportunities for integration with district heating and seasonal storage. In all cases, temperature dynamics, flow variation, and operational reliability should be considered as key design parameters for successful system implementation. In addition, the insights obtained from the greywater temperature monitoring will be used in the replication model developed within the project. By incorporating observed temperature levels, the model can provide an assessment of the benefits of local heat recovery under different situations.

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