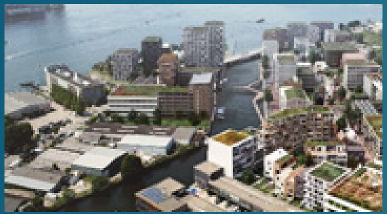
SENSE WP2

Overview demonstration projects



06-05-2020

Written by: Diederik van Duuren

Contributions from:
DuCoop | Dries Seuntjens
HamburgWasser | Wenke Schönfelder’Narne Hinrichsmeyer & Till Blumberg
HEEMwonen | Danique Rautert
NSVA | Hamse Kjerstadius
Waternet | Yvonne Hidding & Enna Klaversma

Table of content

Glossary

Black water	Wastewater originating from toilets (and food grinders).
Drinking water	Water that meets the standards of national Law and can be used for human consumption. It can be referred to as tap water, drinking water or potable water.
Grey water	Wastewater originating from kitchens, washing machines and showers.
Ground water	Water held underground in the soil or in pores and crevices in rock.
Household water	Water that can be used for non-potable water (quality) applications such as the toilet and washing machine.
Rainwater	Water originating from rain or melted snow.
Surface water	Water on the surface of the planet such as in a river, lake, wetland, or ocean. The quality is lower than groundwater and rainwater.
Yellow water	Wastewater that only contains urine.

Abbreviations

BW	Black water
CHP	Combined Heat & Power plant
DW	Drinking water
EBPR	Enhanced biological phosphorus removal
FW	Food waste
GW	Grey water
GWR	Grey water reuse
HW	Household water; or see TNPW
IE	Inhabitant equivalent
NF	Nano filtration
RWH	Rainwater harvesting
TNPW	Treated non-potable water; or see HW
UASB	Upflow Anaerobic Sludge Blanket Reactor
WW	Wastewater
WWTP	Wastewater treatment plant
YW	Yellow water

1. Introduction

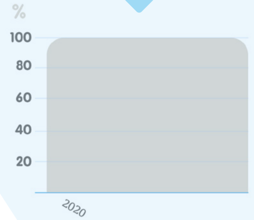
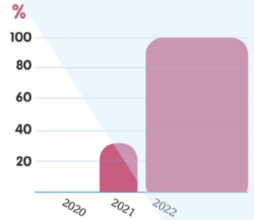
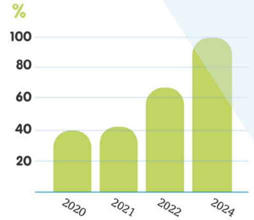
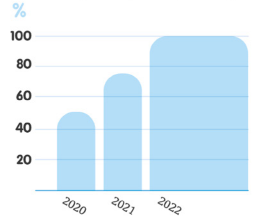
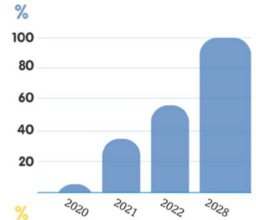
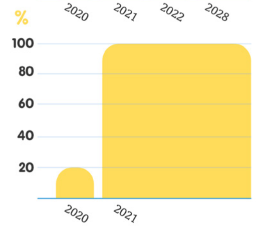
Large scale decentralised water demonstration projects will become a reality in the coming years. In Germany, the Netherlands, Belgium, and Sweden large groups of end-users will use vacuum toilets, food grinders, and live in a neighbourhood in which rainwater and grey water are used in several manners. All of these projects will have a dual-pipe system separating black and grey wastewater. The black water is digested. Energy, resources and nutrients will be recovered for different purposes. These systems are often referred to as New Sanitation (Swart & Palsma, 2013) or New Alternative Sanitation Systems (NASS) (DWA, 2010). Furthermore, stormwater is managed locally and potable water demand is reduced and/or supplied by locally produced (drinking)water in these water-wise neighbourhoods. All of these neighbourhoods include state-of-the-art solutions for climate change and resource scarcity under the umbrella of the circular economy (resource recovery) and water-food-energy nexus.

One of the current bottlenecks for the development of new sanitation is the uncertainty among property developers (and other stakeholders) about end-users' acceptance of new sanitation (Swart & Palsma, 2013). The planned large scale introduction as described above provides a window of opportunity to undertake a thorough study that addresses this issue. The Social Evaluation of New Sanitation Experiments (SENSE) project is developed to fill this gap.

The six selected demonstration projects differ in scale, socio-economic context, and technological configuration. Therefore, all projects will be compared based on their (1) site-specific context (2) technological configuration, and the (3) chosen communication and participation processes.

All project representatives have participated in developing the overview of this work package (WP 2 - Overview demonstration projects). This overview has the purpose to put results of SENSE into context and finding a match between research methods and the differences in project characteristics. Furthermore, participants gain knowledge and new insights based on this comparison.

2. Site specific context

	inhabitant equivalent (IE) planned [today]	households (hh), hotel (H), office building (OB), communal building (CB) such as school and sport facilities, shops (S)	why is new sanitation implemented on this location?	when is what percentage of the project inhabitat?
Schoonschip | Amsterdam **Floating sustainable pioneers** Located in a former harbour and brownfield area, young pioneers build their floating sustainable nieghbourhood.	115 IE [115 IE]	47 HH [47 HH]	**FLOATING BOATS** The residents started the project. A call for innovation with funding was raised.	
Cityplot | Amsterdam **Dense and small-scale Cityplot-blocks at IJ harbour** A project area within the large scale transformation of the brownfield harbour Buiksloterham in Amsterdam, designated for experimenting and innovation.	300 IE [0 IE]	250 HH [0 HH] 1 H [0 H]	**DENSE URBAN** It was allowed to innovate in this area and funding was made available by the Municipality.	
De Nieuwe Dokken | Ghent **Living by the water. Bathe in the light** Brownfield development in the harbour of Ghent into a mixed neighbourhood connected to the city centre with high sustainability standards.	1,200 IE [436 IE]	244 HH [75 HH] 3 OB [3 OB] 2 CB [2 CB] 20 S [20 CB]	**DENSE URBAN** Demanded by the Municipality for sustainability aims. Project developers where assigned based on sustainability indicators.	
Jenfelder Au | Hamburg **Green Energy from Black water** A transformation of a former military area into a new residential nieghbourhood in the outscurts of Hamburg.	2,000 IE [500 IE]	835 HH [250 HH]	**SEMI-URBAN** It was an opportunity for Hamburg Wasser because new pipes were necessary and the district was supposed to be upgraded and innovative.	
H+ | Helsingborg **more citizens, more businesses, more meeting places** Brownfield development of old harbour into a high level mixed (living and work) area in the city centre of Helsingbörg.	1,500 IE [100 IE]	343 HH [49 HH] 3 OB [0 OB] 1 CB [0 CB]	**DENSE URBAN** It was only choosen in order to live up to the environmental goals of the H+ urban renewal project.	
Superlocal | Kerkrade **Slow, less and local** Circular transformation project of four '60 high rise buildings into a smaller social housing neighbourhood in the outscurts of Kerkade.	250 IE [3 IE]	129 HH [3 HH] 1 CB [0 CB]	**SEMI-URBAN** The ambition is to reuse qualities from the project area. This includes materials, social structures, water, energy, and resources.	

2.1. Type of residents

Cityplot, Jenfelder Au, H+ and De Nieuwe Dokken are neighbourhoods with a mixed variety of residents. They have a mix of social housing, basic housing and market conform housing including luxury housing. Jenfelder Au has only a limited percentage of social housing and H+ none. The two extremes are Schoonschip with only market conform private houses and Superlocal with only social housing for rent. However, in Schoonschip the residents tried to include social housing with a housing corporation but it was not realised in the end. In Superlocal a number of residents will be granted permission to live in the area even when their income is too high but they are motivated based on the sustainable character of the neighbourhood. This way a more mixed community might be created.

Table 1: Type of households

	social housing	basic housing	market conform	for rent	to buy/ private	comment
Schoonschip	0%	0%	100%	0%	100%	houseboats
Cityplot						apartments and studio's
Nieuwe Dokken	20%	20%	60%	40%*	60%*	apartments and studio's
Jenfelder Au	5%	20%	75%	30%	70%	houses and apartments
H+	0%	0%	100%	10%	90%	houses and apartments
Superlocal	100%	0%	0%	100%	0%	houses and apartments

* expected guess

Jenfelder Au and Superlocal are located in semi-urban areas in the outskirts of their cities. Hence, also a small number of family houses will be realised (respectively 30% and 14%). All the other demonstration projects have only apartments or studios for inhabitants.

Schoonschip, Superlocal and Jenfelder Au are mainly neighbourhoods for living. Cityplot, H+ and Nieuwe Dokken are a more mixed dense urban area in which working, living, leisure and public facilities are combined. Here, schools, swimming halls, sports facilities, hotels, shops, and offices are connected to water services.

2.2. Ownership

In most demonstration projects the inhouse technologies are owned by either housing organisations (Cityplot, Superlocal & Jenfelder Au) and/or private homeowners (Schoonschip, Cityplot, Jenfelder Au & H+). In all these cases, the outdoor technologies (water treatment etc.) is owned by specific (waste)water utilities and Governmental organisations. In most of these cases these organisations have a monopoly in providing these different water services stated by National law. The only exception is De Nieuwe Dokken. Here owners and renters of apartments are shareholders of the utility service cooperative DuCoop. When DuCoop makes more than 6% profit, they will receive money as a shareholder. They can also financially participate in DuCoop with a maximum of EUR 5,000 which gives them a different status as a shareholder. The project developer, tripple P investment funds and cooperatives, drinking water utility Farys and CEIP (clean energy investment projects) are shareholders as well in the case of De Nieuwe Dokken.

3. Technological configuration

Besides the role of residents, the major change in these neighbourhoods are the technological configurations at the local scale. This includes both outdoor en indoor technologies which will be discussed separatly.

3.1. Outdoor

For this overview the different outdoor technologies have been categorised as follows: (1) rainwater; (2) drinking water; (3) grey water; (4) black water; (5) food waste; (6) energy.

1. Rainwater harvesting (RWH) is one of the oldest water management solutions in human history. Although not being a common practice in the Western world anymore, some of the demonstration projects reintroduce this technology. In Schoonschip some private households harvest rainwater (collect and store) and use it for toilet flushing. However, since vacuum toilets are used only a limited amount of potable water usage is saved this way. In the Nieuwe Dokken some collective apartment blocks will have RWH. Also for household water (HW) purposes such as toilets. Superlocal is the only demonstration project that does RWH on the entire community scale and uses the water for drinking water (DW) purposes after treatment. Jenfelder Au collects RW and infiltrates it. The other demonstration projects discharge it into rivers and harbours.
2. In all projects, expect Superlocal, DW is produced on a centralised scale. In Superlocal DW is produced on the community scale by a decentralised water treatment facility. RW is the source for the production of the DW and it is supplemented by centralised DW when a shortage is at hand.
3. In all projects, a separate GW-sewage system is implemented. In the following projects GW is treated on the community scale: H+ GW is reused for public functions; in the Nieuwe Dokken GW is reused by a factory as process water and for toilet flushing; in Superlocal GW is naturally treated and reused for a shared laundry and infiltrated; in Jenfelder Au tests will be run with two types of GW treatment. In the project in Amsterdam GW is treated on a centralised scale in a mixed WWTP.

4. BW is treated in all projects on the community scale. All projects use digestors (often UASB-reactor). In some projects, the focus is on recovering energy (e.g. Jenfelder Au), while other projects focus more on the recovery of nutrients and resources (e.g. Schoonschip, CiyPlots, Superlocal). In the projects, H+ and the Nieuwe Dokken both energy recovery (in the form of biogas and heat) and the recovery of nutrients and resources are central to the BW treatment. These last two projects already found potential users of the produced fertilizers. Other projects, are still in search of useful applications of the end-products.
5. In most of the projects where food waste is collected, it goes into the BW vacuum sewage system and is digested together with the BW. Two exceptions are: (1) H+, here a separate FW digestor is built. This means that a third sewage system - FW low pressure sewer (LPS) - is in place in this project. (2) The Nieuwe Dokken has a separate vacuum sewer line connecting all the centralized food grinders.
6. Biogas as an outcome product of the BW (and FW) treatment and heat from GW are the two main sources of energy. These sources are transformed into district heating, electricity, re-used and delivered to the centralised grid in the form of electricity and gas. Two outliers are surface water heat exchange in Schoonship and the recovery of energy from the centralised grid (due to over-pressure) in Superlocal (this last one is still in the research phase.

Technological configuration outdoor

	Rainwater	Drinking water	Grey water	Black water	Food waste	Energy
Schoonschip	RWH in some private households for HW purposes (toilet flushing). Rest of rainwater is discharged into surface water bodies.	DW is produced in a centralised treatment facility using ground water and distributed to the neighbourhood.	GW is separatly collected and transported to a mixed sewage system which is treated at a centralised WWTP.	BW is separatly collected and digested in a neighbourhood UASB-reactor. Than the Oland reactor (N removal) and at the end phosphate recovery (struvite).	Standard centralised food waste management.	A surface water heat exchanger is installed for the neighbourhood. The biogas from the UASB-reactor is reused for the digestor itself.
Cityplot	Rainwater is collected in a rainwatersewage system and discharged into surface water bodies.	DW is produced in a centralised treatment facility using ground water and distributed to the neighbourhood.	GW is separatly collected and transported to a mixed sewage system which is treated at a centralised WWTP.	BW is separatly collected and digested in a neighbourhood UASB-reactor. Than the Oland reactor (N removal) and at the end phosphate recovery (struvite).	Some food waste is added to the BW vacuum system and treated localy. The rest follows the standard centralised food waste management.	The biogas from the UASB-reactor is reused for the digestor itself.
De Nieuwe Dokken	RWH in some appartment blocks for HW purposes (toilet flushing). Rest of rainwater is discharged into surface water bodies.	DW is produced in a centralised treatment facility using ground water and distributed to the neighbourhood.	GW is separatly collected, heat is recovered, and locally treated with ultra filtration to HW quality. DW utility Farys will upgrade this using RO to process water standards at the factory.	BW is separatly collected and digested in a neighbourhood UASB-reactor. Struvite precipitation is implemented.	A central food waste point is connected to the BW UASB-reactor process.	Heat is recovered from grey water and in the nearby factory (cooling). The biogas from the reactor is burned. All this heat is used for district heating. Solar panels with batteries provide electricity for installations.
Jenfelder Au	Stormwater is seperatly transported to open infiltration buffers. An overflow to a nearby river is possible in extreme cases.	DW is produced in a centralised treatment facility using ground water and distributed to the neighbourhood.	GW is separatly collected and two types of treatment will be tested (fixed bed bioreactor with lamella separator and membrane bioreactor). Other reuse options will be tested.	BW is mixed before the digester with heated fermenting sludge that is recirculating from and into the digester. Also, fatty water is added to the BW digester.	Fatty water from kitchens in Hamburg is added to the digestion process. Food waste is managed on a centralised scale.	The biogas from the digestor is converted into electricity and heat in a CHP-plant. This is reused in the digestor, used for district heating and delivering electricity to the grid.
H+	Stormwater is discharged in to the ocean.	DW is produced in a centralised treatment facility using surface water (Lake Bohlmen) and distributed to the neighbourhood.	GW is locally treated in a EBPR activated sludge with fecl3 precipitation, nanofiltration and ozontion (for OMP removal). Permeate is post treated to DW standard and the bleed water discharged in to the ocean.	BW is separatly collected and digested in a neighbourhood UASB, nutrient recovery as struvite and ammonium sulphate (ammonia stripper).	FW is collected in a seperate LPS system and treated in a seperate UASB-reactor. Effluent will be joined with BW effluent and undergo the same nutrient extraction steps.	Biogas from both digestors is delivered to the centralised gas grid.
Superlocal	Collective RWH from roofs and paved surfaces. Rainwater is treated to drinking water quality. Overflow to water square and infiltration ponds.	Most of the DW is produced locally from RWH. The rest (ca. 10%) is supplied by the centralised DW system. This source is surface water in Germany.	GW is locally treated in a vertical aerated helophytefilter. Research will be done to test if it is of good quality to use it as HW for a shared laundry.	BW is separatly collected and digested in a neighbourhood UASB-reactor, nutrient recovery as struvite are currently being developed.	FW is added to the BW vacuum sewage after which it is digested in the UASB-reactor.	Biogas from the digestor is reused for heating the digestor. Energy is produced using a turbine at a nearby location where pressure reduction is necessary in the centralised system.

3.2. Indoor

For this overview, the different indoor technologies have been categorised as follows: (1) vacuum toilet; (2) food waste grinders; (3) recirculation shower; and (4) other shared services.

1. All demonstration projects use vacuum toilets. A mix of producers and suppliers is either demanded by water utilities or free of choice for developers. In most projects, the toilets are named by their technology, namely ‘vacuum toilets’. Other wording chosen for communictaion is ‘toilets’ and ‘water-saving toilets’.
2. FW grinders are implemented on the domestic level in three of the six projects (Cityplot, H+ and Superlocal). These three projects and the Nieuwe Dokken also have shared FW grinder locations. Such as at the pentry’s of office buildings (H+), in the basements next to other waste separation options (Nieuwe Dokken), in hallways of each floor (Superlocal) and hotels (Cityplot). Some are free to use and others are controlled by a chip (including payments).
3. Recirculation showers are only introduced in two of the demonstration projects and only by a limited number. In Schoonschip some of the floating boats have them installed and in Superlocal only three experimental dwellings will introduce them. The water and energy-saving potential are high but the technical and social experiences are low so far.
4. Other shared services related to the water systems are identified in: the Nieuwe Dokken - shared mobility services that run on electricity of solar panels; Jenfelder Au - fat water collection from kitchens in the city; H+ - shared laundry services and a public swimming pool that uses the treated GW; and Superlocal - shared laundry services and a shared car wash that both uses treated GW.

Sound insulation

One of the main barriers identified concerning end-user acceptance is sound nuisance within homes, between neighbours and in the piping system in apartment buildings. Sound nuisance is created by vacuum toilets, FW grinders and the adjacent vacuum sewage system.

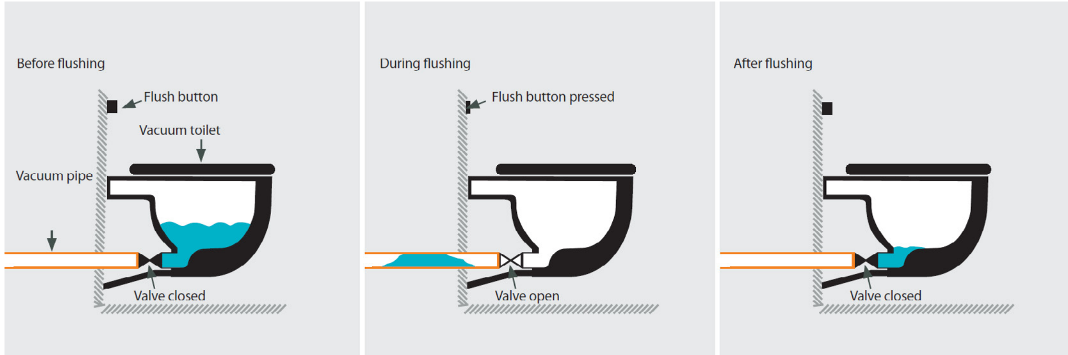
Most EU member state regulations incorporated a maximum sound level of 30 dB(A) for neighbours and 35 dB(A) experienced for in house sound levels created by sanitation technologies. Older versions of vacuum toilets produced a sound of 80 to 90 dB(A) at the source. However, the newer generation of silent - soft sound - vacuum toilets create around 67 to 72 dB(A) at the source. Compared to conventional toilets this is more or less the same (69 to 75 dB(A)). Nonetheless, sound effects are not only created by and around the toilet but can also be created by vibrations (far more pressure is used in comparison with conventional toilets), and in the piping of buildings. Therefore, the installation of these systems is far more sensitive to failures than conventional sewage systems and installers are often not trained for the installation these type of systems. Schoonschip is the only project wherein extra insulation measures are not taken. In Amsterdam issues with incorrect installation has resulted in the removal and cancellation of a part of the Cityplot apartments. Guidelines and procedures are therefor created by different demonstration projects. Hamburgs document is the most elaborate version (see summary on page 9).

Technological configuration indoor

	Vacuum toilet	Sound insulation	Individual FW grinder	Collective FW grinder	R-Showers	Shared services
Schoonschip	✓ Supplier: **Bio compact** Type: **[Jets Jade]**	✗ No	✗ No	✗ No	✓ Some of the houseboats have a recirculation shower.	No
Cityplot	✓ Supplier: **Evac** Type: **[Evac Optima] & [Optima S]**	✓ Construction measures which were described in the PRD by biocompact have been implemented.	✓ For private homeowners this will be suggested for the kitchen. For social housing/rent it will not since it is too expensive.	✓ A hotel will probably have food waste grinders.	✗ No	No
De Nieuwe Dokken	✓ Supplier: **Quavac** Type: **[Optima 5]** Accesible toilets (for disabled and children) are conventional toilets but connected to the sewage system with abreaktank.	✓ Construction measures have been taken.	✗ No	✓ There is a centralized food waste grinder installed that can process 10 L of foodwaste. Supplier is Rödiger which developed this type for DuCoop with a badge for users.	✗ No	Shared mobility services that run on biogas.
Jenfelder Au	✓ Supplier: **Rödiger** Type: **[Silence** 95%] Supplier: Jets Type: **[Charme** 5%]	✓ Construction measures are described in full detail in appendix A. Short summary on previous page.	✗ No	✗ No	✗ No	Fat water collection from kitchen in Hamburg.
H+	✓ Supplier: **Jets** Type: **[3 types]** Choice up to project developer	✓ Developers follow Jets installation advice (and newly updated from Amsterdam). Such as polo piping, rubber clamps, not attaching to sound carrying material.	✓ FW grinders in every kitchen (dual sink). So far Insinkerator 100 are chosen by developers.	✓ FW grinders in every entry of office buildings. So far Insinkerator 100 are chosen by developers.	✗ No	Shared laundry services. Public swimming pool using treated water.
Superlocal	✓ Supplier: **Quavac** Type: **[Evac Optima 5S]** Supplier: **Jets** Type: **[Jade Soft Sound]** Choice up to project developer	✓ Rubber between toilet and wall, strong wall, extra strong piping, flexible kit, insulation of piping, enough space between wall and piping, rubber clamps.	✓ FW grinders in every house (not in appartments). So far Insinkerator LC-50 from Quavac.	✓ Centralised FW grinders in every floor of the appartment building with a badge for users. So far Insinkerator LC-50 from Quavac.	✓ The three experiment dwellings will have recirculation showers.	Shared laundry services including grey water reuse. Shared car wash.

Functioning vacuum toilet

The negative pressure applied in the pipeline system continues into the houses to the individual sanitary elements. The separation of the vacuum system from the atmosphere is executed via valve units in the toilets, which are pneumatically controlled. The flush button, shut-off unit and water valve are the main components of a vacuum toilet. The user initiates the flushing of the sanitary unit via the flush button, whereupon the valve unit opens automatically, usually parallel timewise to the opening of the water valve. Blackwater is transported towards the vacuum station via the pressure difference in relationship to the atmosphere. In addition to the blackwater, a defined amount of air, approx. 60 litres, is sucked into the system. This air volume allows the transport process of the blackwater regardless of the gradient of the vacuum pipe. After approx. 1.5 seconds, the valve unit closes automatically. After completing the process, similar to conventional systems, a small amount of flush water is refilled as a deposit.



Copyright HAMBURG WASSER see handbook.

Inhouse insulation measures

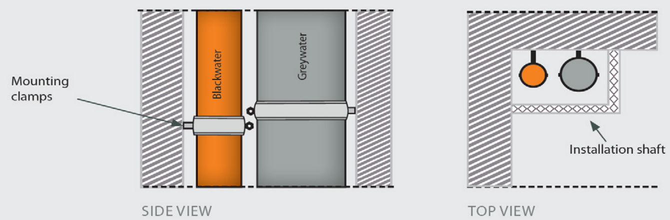
The following measures are often recommended for installing the vacuum toilet in households and apartments. Differences may exist between type of dwelling.

- All toilets and vacuum pipes should be arranged on heavy solid structural elements.
- Walls should have relatively high insulation standards. Small area breakthroughs are recommended for internal walls.
- Use of heavier doors with a maximum slit of 4 mm.
- The ducts of the vacuum pipes through the floor slabs must be structure-borne sound decoupled and executed with the aid of suitable fire barriers.
- Installation of “standard” sockets and switches for internal walls is permitted with regard to sound insulation. For instance, provide attachment points of toilet frame with rubber blocks to prevent hard-on-hard contact.
- Insulating vacuumpiping in dwellings.
- Hydrant of vacuum sewage should be mounted with a acoustic bracket.
- Toiletframe should not be in contact with floor
- Toiletframe whould not be in direct contact with wall, use a kit layer.
- Shafts/manholes with vacuum pipes lead exclusively through ancillary rooms. Rooms for permanent residence are to be kept free from these shafts.

Piping insulation measures

- The use of hydrodynamically-efficient fittings and vacuum drainage is also sound-insulating, i.e. separating 90° bends in two 45° bends, or the use of a 45° inlet instead of a blunt rightangle (90°) inlet.
- DW and drainage pipes are to be installed soundproofed in front of the wall. To this end, structureborne sound-insulated pipe clamps should be used and structure-borne sound bridges should be avoided.
- When mounting pipes using clamps, they must always be provided with a sound-absorbing rubber insert. They also should not be tightened excessively to prevent the transmission of structure-borne noise through the clamp to the masonry.

Overview of GW and BW piping



Maximum permissible sound pressure level in rooms in need of protection from technical installations pursuant DIN 4109/1

Noise source	Type of rooms in need of protection	
	Living and sleeping rooms	Teaching and working rooms
	Characteristic sound pressure level db (A)	
Water installations (Water supply and sewage plants together)	≤ 30 [a]	≤ 35 [a]
Other household service facilities	≤ 30	≤ 35
Operation from 6 am to 10 pm	≤ 35	≤ 35
Operation at night from 10 pm to 6 am	≤ 25	≤ 35

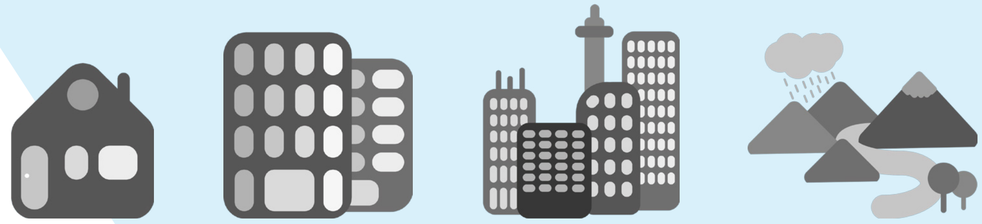
a) Isolated, short-duration peaks which occur when operating the valves and devices (opening, closing, switching, interrupting and similar), are not not to be considered at this point.

3.3. Framework for comparing urban water systems

The framework developed for SENSE applies a functional, rather than a technical, taxonomy to model different water, energy and food (incl. nutrients and resources) streams. It is based on Hook et al. (2018) but extended to conceptualise the transport and treatment requirements of water in urban systems including the interlinkages of energy production and food related aspects. It effectively acts as a discretization of a 2D space that plots water quality against spatial scale of water use and shows the interconnections with energy and food in order to present an integrated Water-Food-Energy Nexus approach. Nonetheless the framework of Hook et al. (2018) is an ideal starting point since water is a substance that remains (it only changes in quality, and to a smaller extent in form such as evaporation). On the other hand, energy can be created and used, hence it does not remain. While food (agriculture, nutrients, resources etc.) come in a variety of forms and often use water as a medium. Water as a source, creator, transporter and carrier is the basis of this SENSE framework.

Following the approach of Makropoulos et al. (2008) five distinct water quality categories are considered in the SENSE framework. Hence, water quality is not defined by a single parameter. The five categories are:

- **Potable water** (shown as white circle)
- **Treated non-potable water** (shown as green circle)
- **Natural sinks/sources** (shown as blue circle)
- **Grey water** (shown as grey circle)
- **Black water** (shown as black circle)



The second consideration is the choice of a four-tiered spatial scale. This was done in the context of the dominant paradigm for urban water systems, that of centralised, asset rich infrastructure, being challenged by calls to decentralise, with the literature identifying fully decentralised versus distributed systems as distinct future states. (Sitzenfrei, et al. 2013, Makropoulos and Butler 2010, Mitchell 2006). This results in 4 scales for consideration: domestic/household scale, community/neighbourhood scale (representing distributed infrastructure), centralised/city scale (centralised infrastructure), and the wider system service provisions. For this last category it means that cities/centralised are dependent on sources and perhaps treatment steps that are beyond the centralised system such as (international) rivers and long-distance water transports. This last scale highlights dependencies of centralised systems and cities.

Aim

The aim of the framework is to make it possible to compare the different demonstration projects, see and understand their differences regarding technologies and scale. This way solution pathways are represented in a similar way.

Rules

To construct a scenario (urban water system), nodes are connected by directional links according to the following rules, which simulate the operation of the real network:

- Horizontal links represent transport processes.
- Upwards-directed vertical links represent treatment processes.
- Downwards-directed vertical links represent water quality deterioration.
- Diagonal links, which would represent simultaneous transport and treatment, are not permitted.
- All nodes must have inputs and outputs except Natural sink/source nodes, which can be inputs or outputs.
- The Potable domestic node must be included in the system.

Adding energy and food to the urban water system

All SENSE demonstration project go beyond the realm of water and enter the domains of sustainable (energy) production, waste management, and resource recovery. We therefore include a row for energy and one for food. Energy can come in different forms such as electricity, heat and biogas which can be named accordingly but no specific rows are created for these different forms of energy production in order to keep the framework as simple as possible. For the food dimension of the water-food-energy nexus it is even more complicated. Food is seen here as actual food for consumption, food as waste, nutrients, related resources, and the production side of food such as agriculture. Since the different food streams connected to water and energy are more or less limited in the demonstration projects of SENSE one row for food is included in the framework.

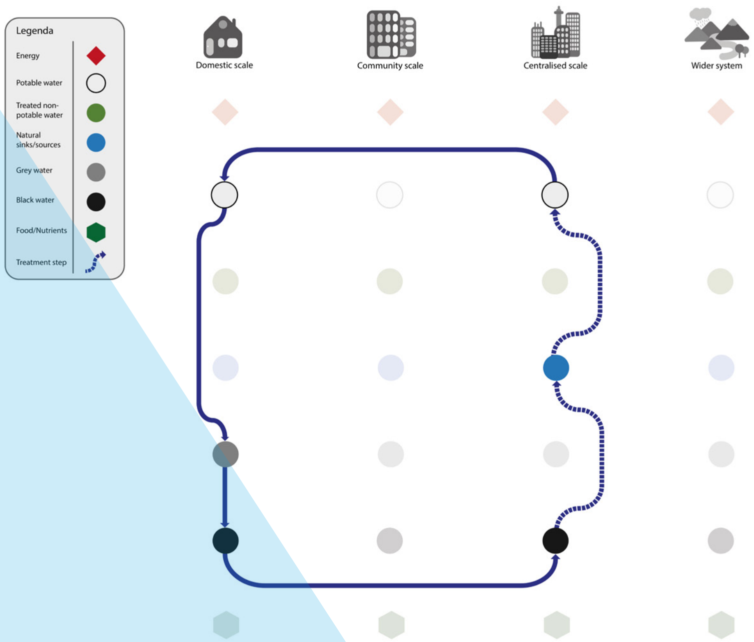


Figure 1: SENSE demonstration project Framework

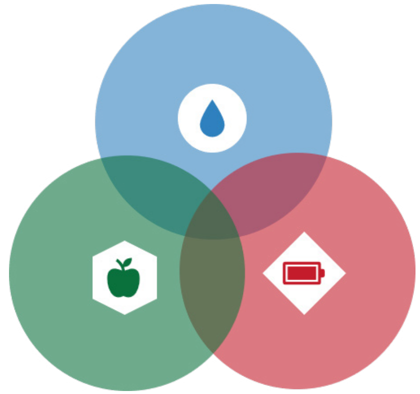
Flows

The thickness of the flows indicates the amount that is transported or treated. The thicker the flow the more water is transported and energy is produced. Nonetheless, it provides only an indication of the ratio and no precise measurement will be presented. Leakage, brime and other losses are not included because they will make the framework more complex and they won't provide the information about the different solutions pathways.

Rules

Energy (shown as red square)

Food (shown as green hexagon)



To construct an integrated scenario (water-food-energy system), nodes are connected by directional links according to the following rules, which simulate the linkages of a real system:

- Horizontal links represent transport processes.
- Vertical links represent a link between water, energy and/or food.
- Diagonal links, which would represent simultaneous transport and linkages, are not permitted.
- The energy node only includes (sustainable) input that is linked to water or food and no outputs. Energy production can also be shown between different flows (of water) when energy is recovered and directly reused.
- The food node can both be input and output.

Energy inputs (production) are related to sustainable technologies linked to the water and/or food system. Windmills and solar panels are considered sustainable solutions but are not directly linked to the urban water system. Therefor they are not included in the framework. Energy usage on the other hand is almost represented in all of the activities (treatment, transport, usage etc.) which would make the framework less usable and is therefor excluded as well.

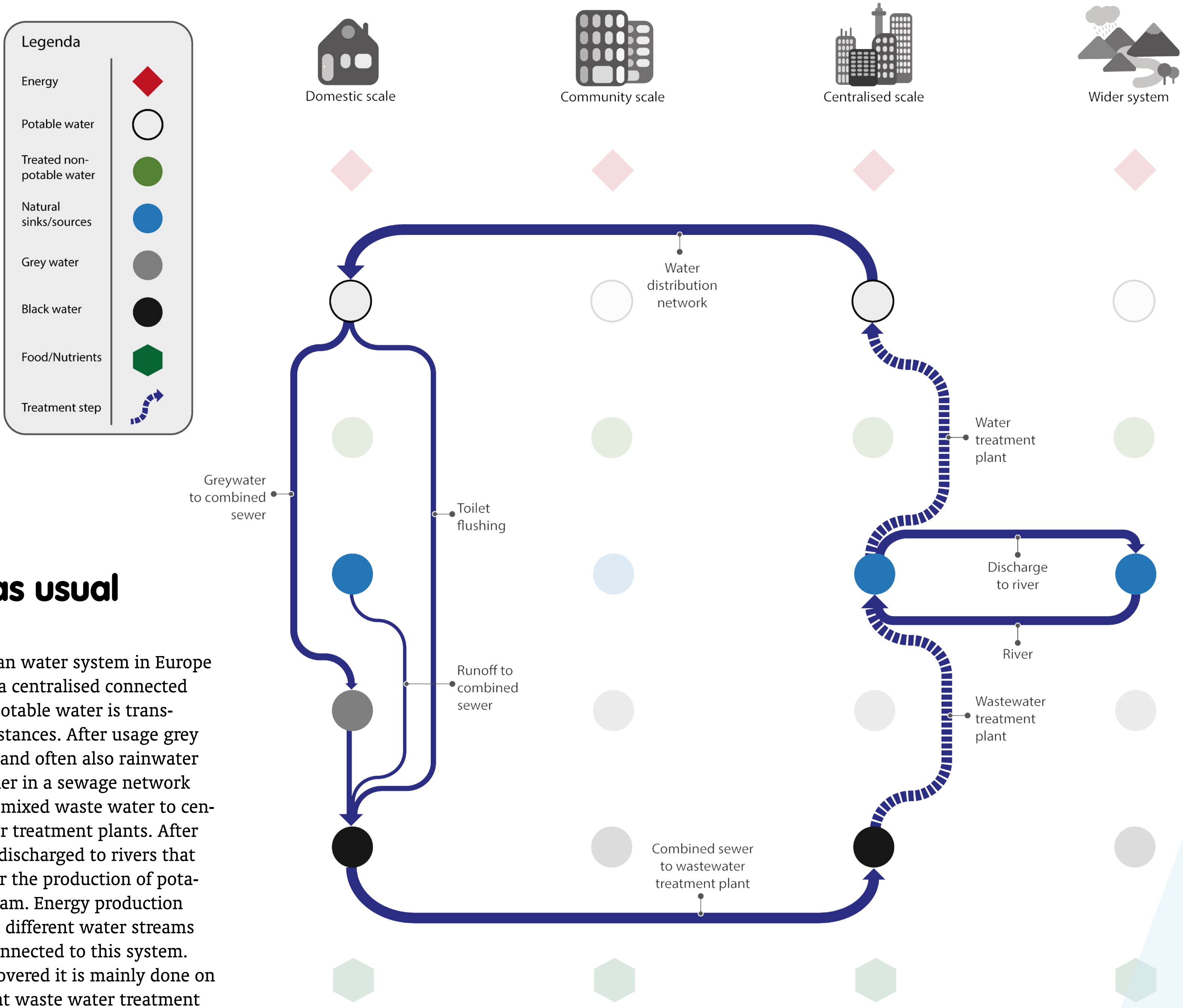
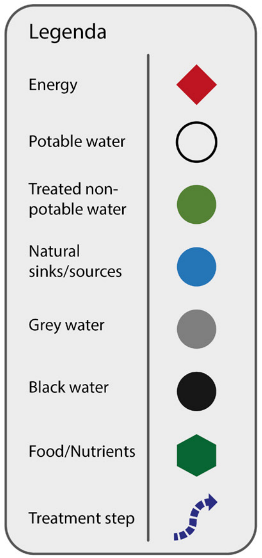
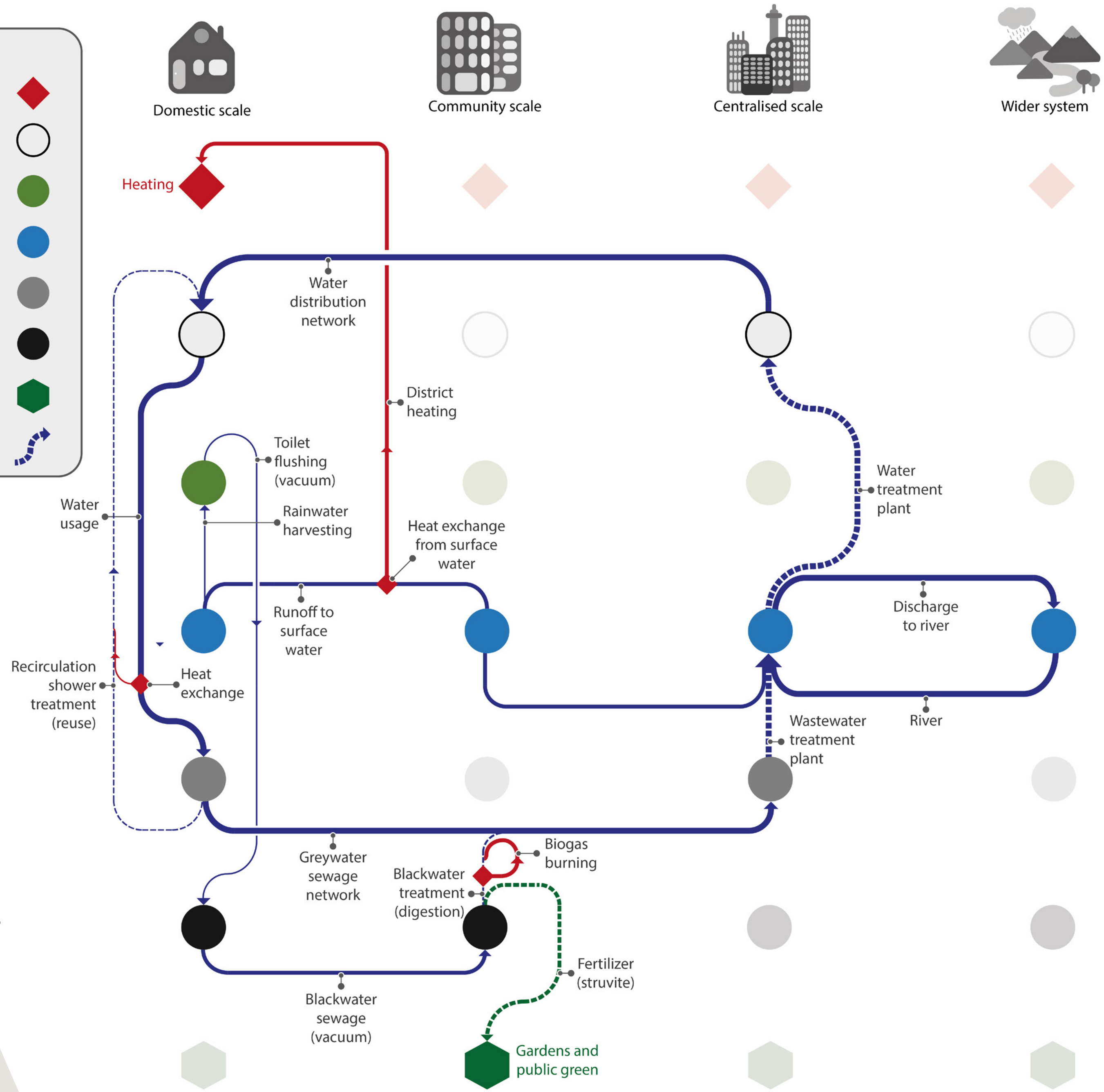


Figure 2: Business as usual urban water system

Business as usual (Europe)

A conventional urban water system in Europe is characterised by a centralised connected network in which potable water is transported over long distances. After usage grey water, black water, and often also rainwater are collected together in a sewage network that transports the mixed waste water to centralised waste water treatment plants. After treatment water is discharged to rivers that are often sources for the production of potable water downstream. Energy production that is linked to the different water streams is not commonly connected to this system. When energy is recovered it is mainly done on a centralised scale at waste water treatment plants. Food systems are only connected for watering purposes and so on.



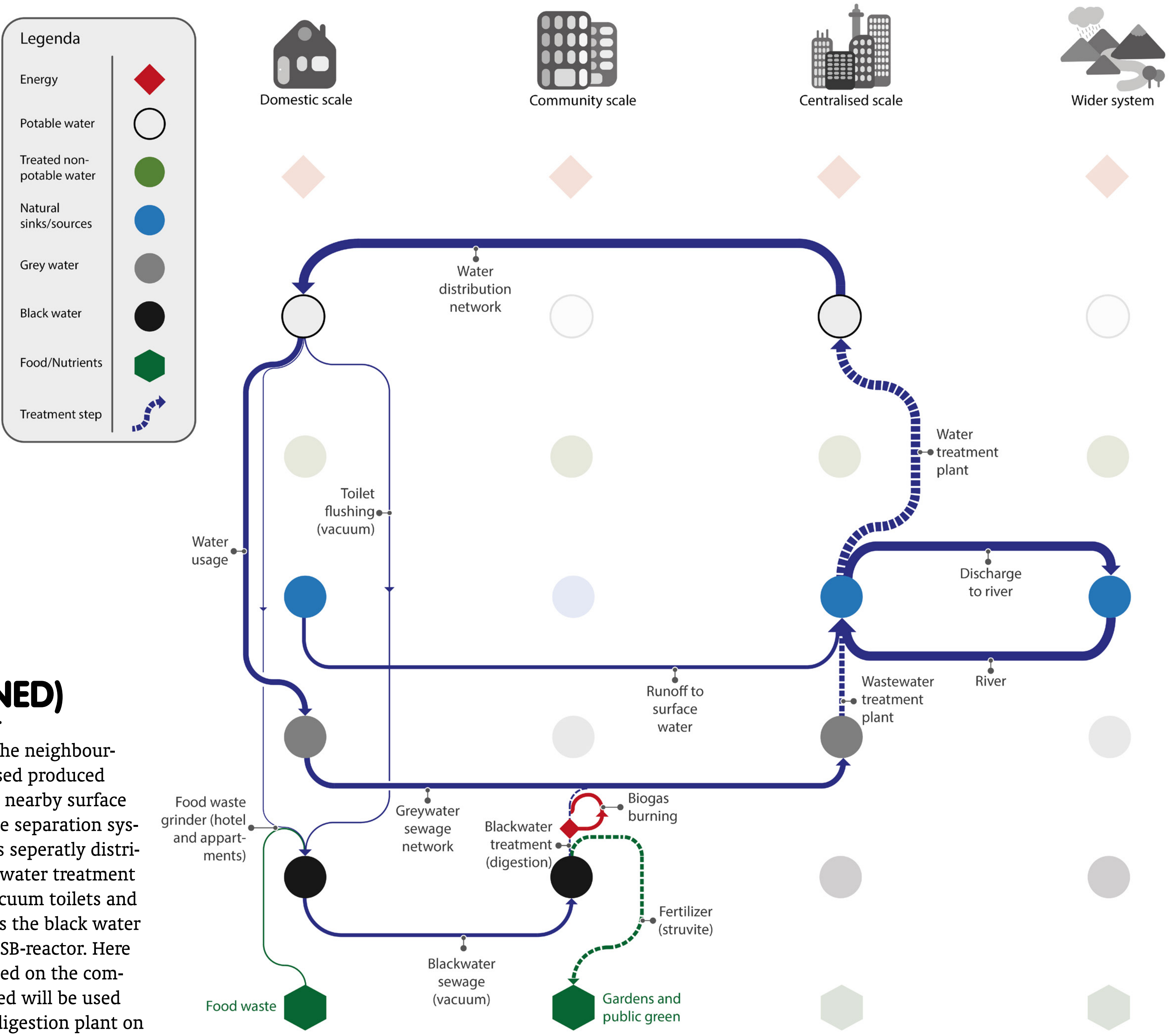


3.1. Schoonschip (Amsterdam, NED)

115 inhabitant equivalent

The urban water system of the community Schoonschip uses centralised produced potable water for all uses except for toilet purposes for which harvested rainwater is used. The excess runoff enters nearby surface waters. For sanitation a source separation system is in place. Grey water is distributed to a centralised wastewater plant. A vacuum system - vacuum toilets and food grinders - collects the black water that will be treated in an UASB-reactor. Here heat and struvite are produced on the community scale. Fertilizers will used locally and the biogas is burned to heat the installation. The small community has also a thermal energy surface water system for heating the houses. An extra inhouse technology are recirculation showers through which energy and water is directly reused.

Figure 1: Schoonschip urban water system

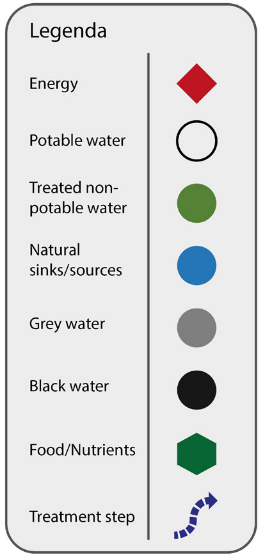


3.2. Cityplot (Amsterdam, NED)

300 inhabitant equivalent

The urban water system in the neighbourhood Cityplots uses centralised produced potable water. Runoff enters nearby surface water. For sanitation a source separation system is in place. Grey water is seperatly distributed to a centralised wastewater treatment plant. A vacuum system - vacuum toilets and food water grinders - collects the black water that will be treated in an UASB-reactor. Here heat and struvite are produced on the community scale. Biogas produced will be used for keeping the blackwater digestion plant on temperature. Fertilizers are used in gardens and public areas in the community.

Figure 2: Cityplot urban water system



3.3. De Nieuwe Dokken (Gent, BEL)

1200 inhabitant equivalent

The urban water system in the neighbourhood De Nieuwe Dokken uses centralised produced potable water. For sanitation a source separatiom system is in place. Grey water is treated (heat is recovered) and after treatment used for toilet flushing and transported to a nearby soap factory where it is treated and used as treated non-potable water (processwater). The heat that is produced in this factory is than transported back to the community and households. A vacuum system - vacuum toilets and shared food grinders - collects the black water that will be treated in an UASB-reactor. Here heat and nutrients are recovered on the community scale. The anaerobic sludge is transported to a centralised waste water treatment plant, treated and later incinerated. The fertilizers are used for farming in the community and blended into fertilizer mixes centrally.

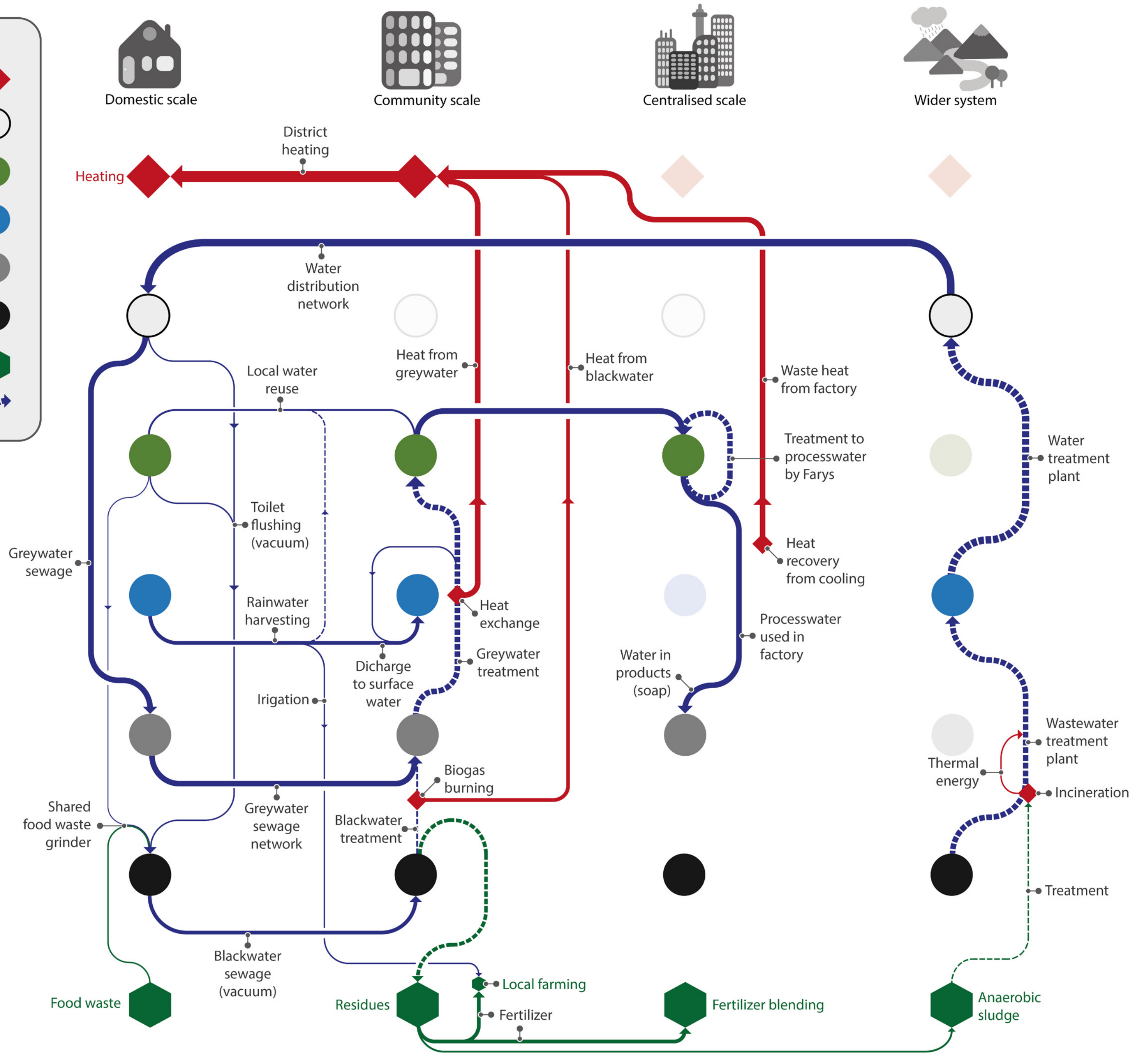
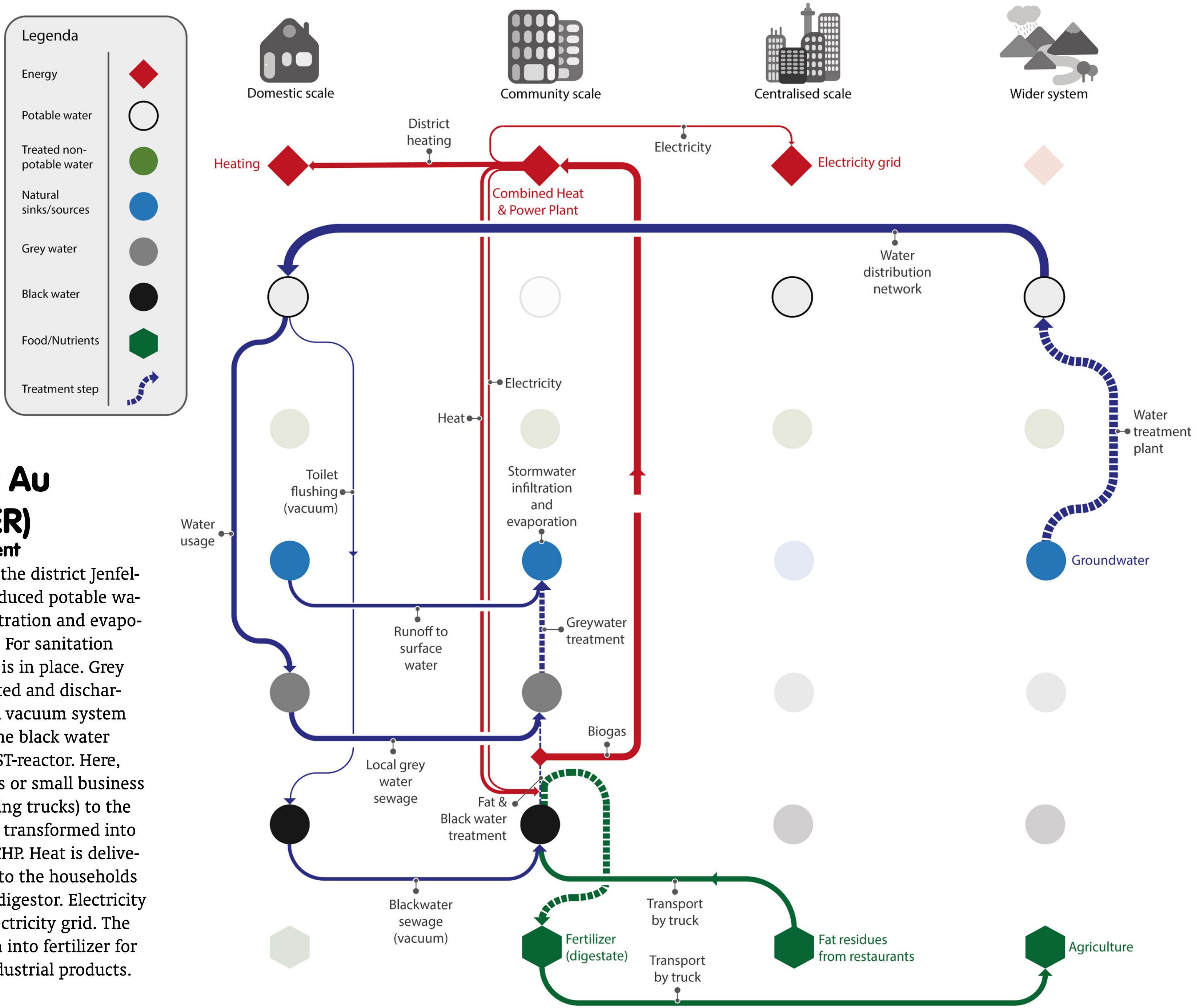


Figure 3: De Nieuwe Dokken urban water system



3.4. Jenfelder Au (Hamburg, GER)

2000 inhabitant equivalent

The urban water system in the district Jenfelder Au uses centralised produced potable water. Stormwater enters infiltration and evaporation ponds in the district. For sanitation a source separation system is in place. Grey water is planned to be treated and discharged into the river Rahlau. A vacuum system - vacuum toilets - collects the black water that will be treated in an CST-reactor. Here, also fat water from kitchens or small business in Hamburg are addedd (using trucks) to the digestion process. Biogas is transformed into heat and electricity in the CHP. Heat is delivered via the district heating to the households and partially reused in the digestor. Electricity is delivered into the city electricity grid. The digestate is planned to turn into fertilizer for agricultural purposes or industrial products.

Figure 4: Jenfelder Au urban water system

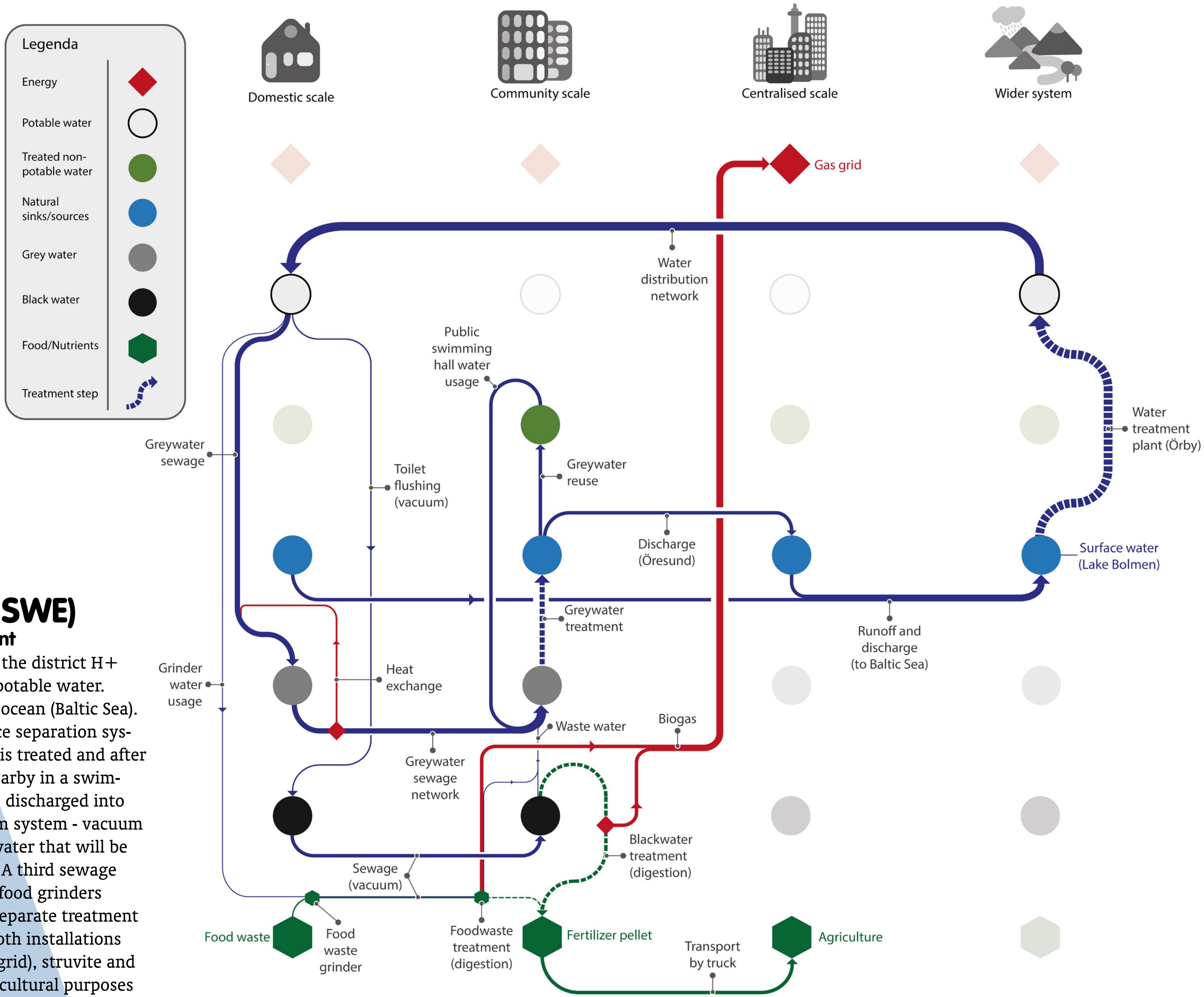


Figure 5: H+ urban water system

3.5. H+ (Helsingborg, SWE)

1500 inhabitant equivalent

The urban water system in the district H+ uses centralised produced potable water. Runoff goes straight to the ocean (Baltic Sea). For sanitation a triple source separation system is in place. Grey water is treated and after treatment 50% is reused nearby in a swimming facility and the rest is discharged into the surface water. A vacuum system - vacuum toilets - collects the black water that will be treated in an UASB-reactor. A third sewage stream is connected to the food grinders which will be treated in a separate treatment facility (also UASB). From both installations biogas (for centralised gas grid), struvite and ammonia stripping for agricultural purposes are recovered.

3.6. SUPERLOCAL (Kerkrade, NED)

250 inhabitant equivalent

The urban water system in the neighbourhood SUPERLOCAL uses harvested rainwater as the main source of potable water. Runoff overshotos will be infiltrated on site. For sanitation a source separation system is in place. Grey water is treated and after treatment (1) reused as treated non-potable water, (2) infiltrated, and (3) discharged to a nearby creek. A vacuum system - vacuum toilets and food grinders - collects the black water that will be treated in an UASB-reactor. The biogas is directly reused to heat the UASB-reactor. Fertilizers will be produced on the community scale and used for agro-forestry purposes nearby in the city. An extra technology are recirculation showers through which heat and water is reused.

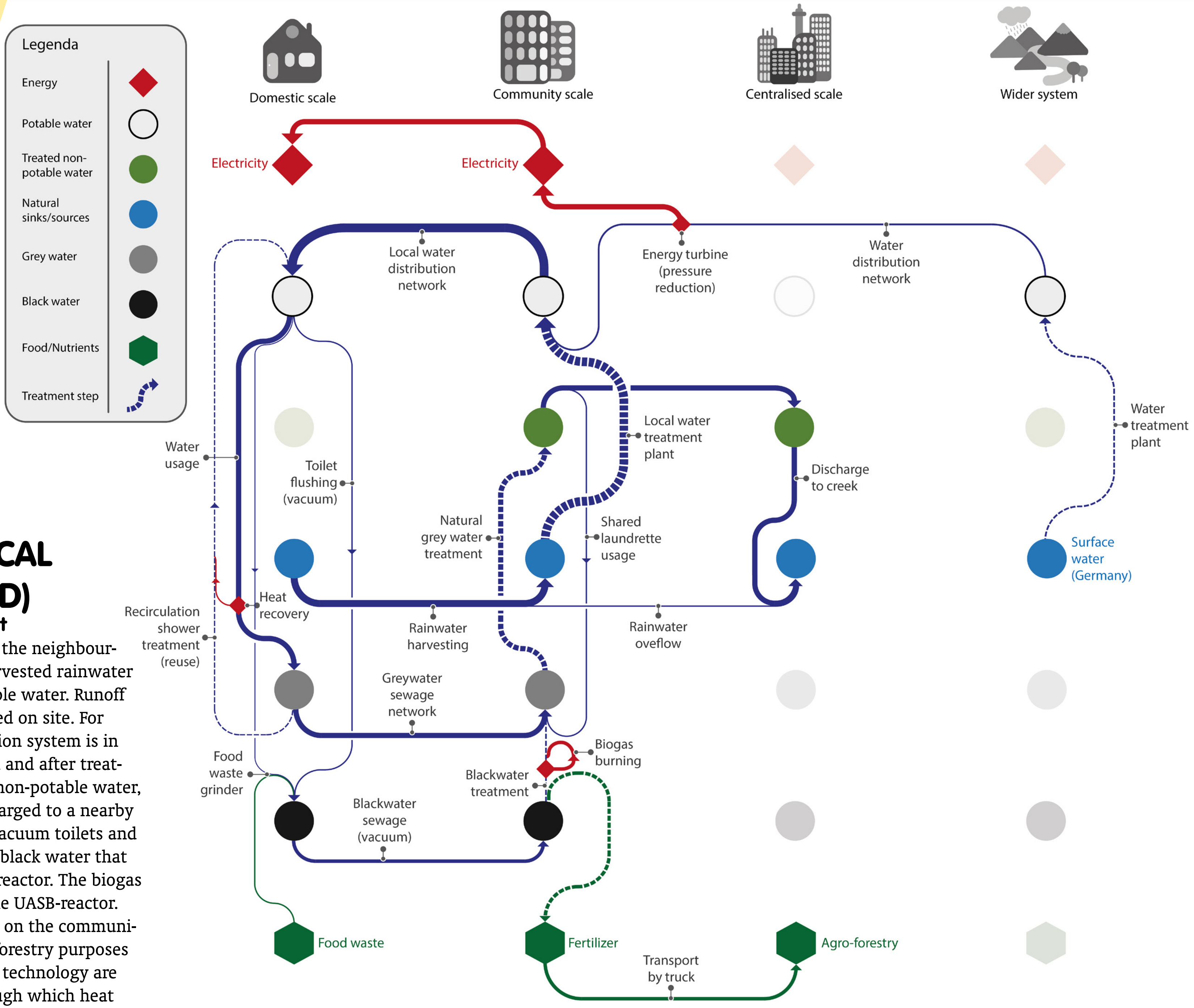


Figure 6: SUPERLOCAL urban water system

WP 2 Part two

This will follow soon…