Assessment of baseline conditions for all case studies

Deliverable D.1.1.

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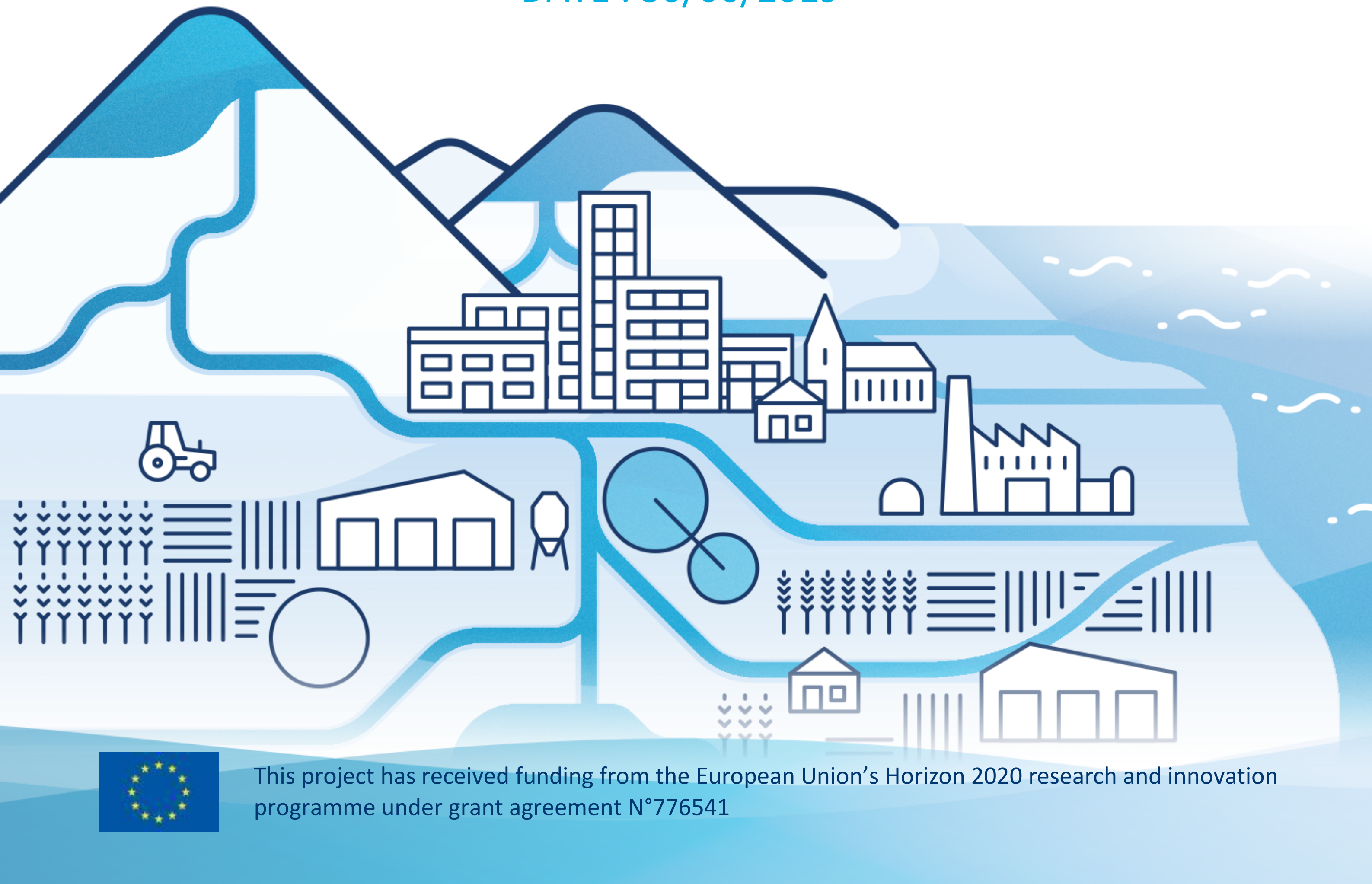

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Technical References

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
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Document history

V	Date	Beneficiary	Author
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Disclaimer

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°776541

Deliverable overview

NextGen aims to boost sustainability and bring new market dynamics throughout the water cycle at the 10 demo cases and beyond. Main objective of WP1 of the project is to provide evidence to demonstrate the feasibility of innovative technological solutions supporting a circular economy transition in the water sector. Through activities to close the water, energy and materials cycles in 10 demo cases, Work package 1 (WP1) will provide the necessary data to assess the benefits and drawbacks of the technologies (WP2), but also to provide evidence to convince stakeholders on their implementation (WP3), while overcoming the social and governance barriers and creating new business models to promote the implementation of those solutions (WP5 & WP6).

This report describes the baseline conditions of each of the sites involved in the project considering water, energy and material cycles. The baseline of the 10 sites (Altenrhein, Athens, Braunschweig, Bucharest, Costa Brava, Filton Airfield, Gotland, La Trappe, Spernal and Westland region) will be used at the end of the project so to define the improvement and/or drawbacks and benefits associated to the implementation of the NextGen solutions. This report corresponds to the first deliverable of the WP1, envisaged for June 2019, and complements the information collected for milestone MS3 on Methodology and specific objectives defined for each case study.

All the information of this report has been collected by the Cross-cutting Technology Group (CTG) Leaders since July 2018 through regular discussions with the different case study representatives and through different templates that have been prepared and compiled. Baseline of each case study has been defined for each of the nexus of NextGen project using key performance indicators (KPIs) linked to water, energy and materials. Potential interlinkages between case studies are also described in this document, aiming at increasing the uptake and impact of the NextGen solutions.

Acronyms

AD	Anerobic Digestion
AnMBR	Anaerobic Membrane Reactor
ATES	Aquifer Thermal Energy Storage
BET	Brunauer-Emmett-Teller
BOD	Biological oxygen demand
CE	Circular Economy
CFU	Colony Forming Units
CHP	Combined Heat and Power
COD	Chemical oxygen demand
CTG	Cross-Cutting Technology Group
EBCT	Empty bed contact time
EDC	Endocrine Disrupting Compounds
FOG	Fat, oil and grease
HT	High Temperature
KPI	Key Performance Indicator
MBBR	Moving Bed Bio Reactor
MNR	Metabolic Network Reactor
N	Nitrogen
NF	Nanofiltration
P	Phosphorous
PBR	Photobioreactor
PE	Population Equivalent
RO	Reverse Osmosis
SCP	Single Cell Proteins
SD	Standard Deviation
TOC	Total Organic Carbon
TPH	Thermal Pressure Hydrolysis
TrOCs	Trace Organic Compounds
TS	Total Solids
UF	Ultrafiltration
UV	Ultraviolet
VS	Volatile solids
WFD	Water Framework Directive
WP	Work Package
WWTP	Wastewater Treatment Plant

Objectives and methodology

Work Package (WP) 1 of the NextGen project provides evidence to demonstrate the feasibility of innovative technological solutions supporting a circular economy (CE) transition in the water sector. Through activities to close the water, energy and materials cycles in 10 demo cases, WP1 will provide the necessary data to assess the benefits and drawbacks of the technologies (WP2). The specific objectives of WP1 are to promote the feasibility and to prove the applied concepts by:

- Providing long-term credible data on performance of CE technologies and schemes for the water sector
- Deriving guidelines for optimized operation of CE systems
- Highlighting the potential for water reuse, nutrient & energy recovery depending on the local conditions.

The objective of this report D1.1 is to describe the baseline conditions of the currently existing infrastructure in the 10 demo sites of the NextGen project, considering the water, energy and material cycles. The information collected and summarized in this deliverable will be later used to demonstrate the benefits and improvements achieved with the NextGen solutions after implementation of the new CE concepts at the demo sites.

The Cross-cutting Technology Group (CTG) Leaders have been in contact with the different site representatives since July 2018 with whom regular discussions have been carried out in order to describe the sites and define the actions to be conducted within the NextGen project. Baseline conditions have been obtained through regular interviews and systematic data collection through templates, which have been adapted for each site considering its particularities.

Key performance indicators (KPIs) have been defined for each site and nexus, covering general aspects of the water, energy and material cycles such as the ones detailed in Table 1. Based on the general aspects described, specific operating or general parameters of each site have been compiled in spreadsheets, gathering the technical data from at least a complete year and highlighting the seasonal variations (if any) or deviations observed. The spreadsheets collected have been complemented with factsheets generally describing the sites and the technical solutions already in place. All the information has been assessed and summarized in this deliverable. KPIs obtained will be later used so to compare them with the ones obtained by the NextGen solutions.

Table 1. KPIs and general parameters considered for baseline definition in the NextGen sites

Nexus: Water

System	KPI proposed	Parameter to be determined
Waste water treatment and reuse	Water yield	Inlet and outlet flowrate of the system
	Water quality	Physicochemical and microbiological parameters from inlet and outlet. Emerging organic pollutant
	Energy consumption	Energy used for the treatment per m^3 produced
	Reagents & materials required	Amounts of reagents used for treatment or materials (activated carbon, resins, etc) per m^3 produced
	Wastes produced	Sludge generated
Rain water harvesting	Collection capacity	Average rainfall of the area
	Water quality	Physicochemical and microbiological parameters
Aquifer storage	Water yield	Water collected vs infiltrated
	Water quality	Physicochemical and microbiological parameters

Nexus: Energy

System	KPIs proposed	Parameter to be determined
Heat exchangers	Thermal energy recovery	- Inlet and outlet flowrates of the system - Pump power - Calculation of coefficient of performance - Energy savings
Anaerobic digestion	Methane and biogas yields	- Inlet and outlet flowrates of the system - Volatile solids and methane content - Gas production rate - Quantity of re-used heat/electricity - Energy savings
High Temperature Aquifer Thermal Energy storage (ATES)	Heat storage and recovery	- Energy and exergy analyses - Physical and thermal parameters of fluid and aquifer

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Nexus: Material

Materials	KPIs proposed	Parameter to be determined
$(NH_4)_2SO_4$	N recovery rate related to the influent to the WWTP & N recovery rate related to the influent to the recovery unit & Plant availability	Inlet and outlet flowrates of the system and the integrated recovery unit & Nitrogen content, total and volatile solids content. & Plant availability is estimated by the minimal efficacy in the year of application in % of total nitrogen
$Ca_5(PO_4)_3OH$	P recovery rate related to the influent to the WWTP & P recovery rate related to the influent to the recovery unit & Plant availability	Inlet and outlet flowrates of the system and the integrated recovery unit & Phosphorus content, total and volatile solids content. & Plant availability is estimated by P_NAC /P_TOTAL[1] [%]
Struvite		
PK-Fertilizer		
Proteins	Carbon and N recovery rate related to the influent to the MNR Carbon- and N-recovery rate related to the influent to the recovery unit	Inlet and outlet flowrates of the system and the integrated recovery unit & Nitrogen content, total and volatile solids content
Compost	Carbon and nutrient (N, P) recovery rate related to the effluent (wastewater sludge) of the sewer mining unit & Carbon and nutrient (N, P) recovery rate related to the wood and green waste originating from pruning [%]	Inlet and outlet flowrates of the system and the integrated recovery unit & Nitrogen and phosphorus content, total and volatile solids content
Digestate for direct field application	Carbon and nutrient (N, P) recovery rate related to the influent to the recovery unit	Inlet and outlet flowrates of the system and the integrated recovery unit &

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[1] P_NAC (phosphorus content of the fertilizer which is soluble by neutral ammonium citrate); P_TOTAL (total phosphorus content of the fertilizer)

Materials	KPIs proposed	Parameter to be determined
		Nitrogen and phosphorus content, total and volatile solids content
Recycled membrane	Flux [l m^{-2} h^{-1}] related to transmembrane pressure [bar] & Salt rejection compared to a commercial membrane of the same type	Flux, transmembrane pressure, electrical conductivity
Granulated activated carbon	Adsorption capacity compared to that of commercially available activated carbon via active surface (BET) & Lifetime until renewal compared to commercially available activated carbon (EBCT)	BET (Brunauer-Emmett-Teller), EBCT (empty bed contact time)

Baseline Conditions

Altenrhein (Switzerland)

Description of the site

General description considering the material and energy nexus

The Wastewater Treatment Plant (WWTP) of Altenrhein treats the sewage amount of 100.000 PE and receives sludge from an additional 200,000 PE from 17 WWTPs in the federal states of St. Gallen and Appenzell.

Up to now, the sludge treatment of the 300,000 PE comprises a digestion stage and a drying stage (see Figure 1). The heat for sludge drying is generated by burning biogas from the digester and by heat recovery from wastewater using heat pumps. The dried sludge is co-incinerated in the cement industry.

Currently, the nutrients which are contained in the sludge are not recovered and/or reused. However, this will change in the near future.

Figure 1. Picture of the drying unit of the sludge treatment stage

Scheme of the current treatment/site

Current scale

In the sludge treatment stage, the sludge of 300,000 PE is currently treated. This corresponds around 5,400 tons per year of dry matter.

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Description of system

The WWTP of Altenrhein treats on average 24,000 m³/d of wastewater corresponding to 100,000 population equivalents (PE). The average nitrogen and phosphorus concentrations in the influent to the WWTP are 34 mg/L and 6 mg/L, respectively. The total solids (TS) content is around 270 mg/L.

In addition to its own excess sludge (216 m^3/d), the WWTP receives 18 m^3/d sewage sludge from third parties, which is added to the digesters. This additional sludge contains 3.7% total solids and 2.6% volatile solids. Furthermore, 19 t/d of co-substrates with a TS content of 10.8% and a VS content of 10% are fed to the digester. The digestate is then combined with 180 m^3/d digested sludge from third parties to be dewatered. Referring to the influent to the WWTP and to the inputs from third parties, altogether, the nutrient loads entering the WWTP are 300 t/year of total nitrogen and 54 t/year of phosphorus. The composition of the co-substrates is highly variable over time. No data for their phosphorus (P) and nitrogen (N) content exist and thus, the amount of nutrients in the digester is not quantified.

Block diagram of the current treatment scheme.

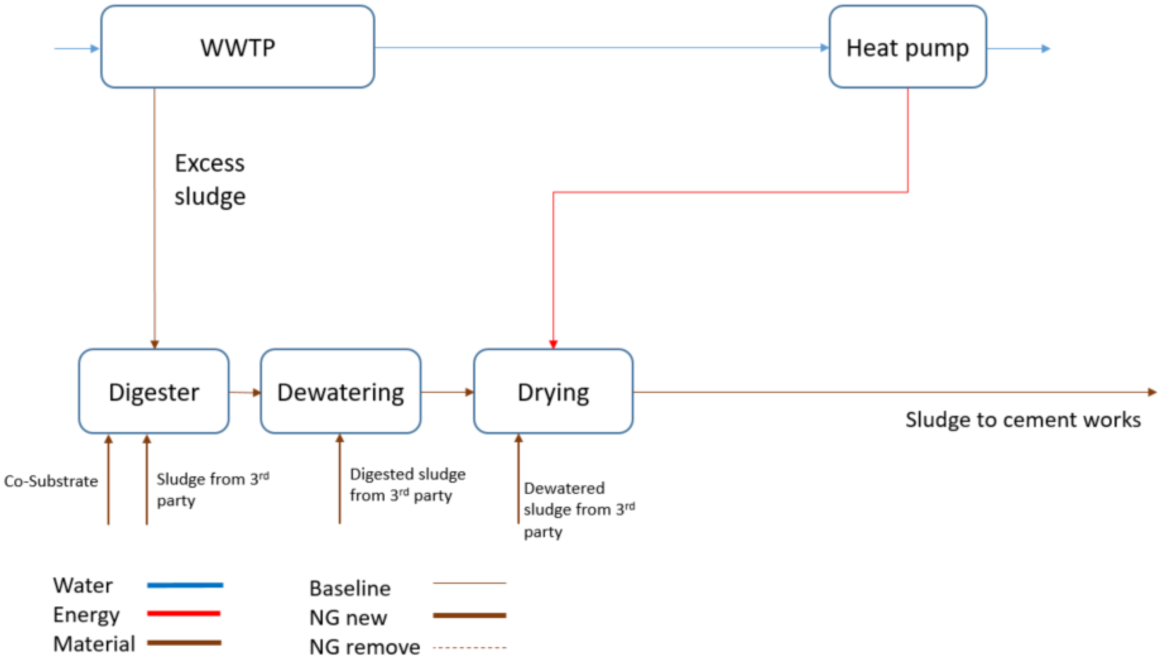

Figure 2. Scheme of the baseline scenario without NextGen technologies in Altenrhein

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Athens (Greece)

Description of the site

General description considering the water, energy and materials nexus

The Athens Urban Tree Nursery is part of the Goudi Park, an area in the process of redevelopment to become the key metropolitan park of the capital. The nursery comprises 4 ha of vegetation and it supplies all urban parks and green spaces of Athens with plant material.

Figure 3. Picture of the tree nursery site

Scheme of the current treatment/site

Current scale

Up to now, there is no treatment of wastewater and/or water reuse applied at the tree nursery.

Description of system

For irrigation, the tree nursery uses potable water from Athens's Water Supply and Sewerage Company (EYDAP). The pruning waste is accumulated in the nursery, not treated and partly transferred in Athens landfill. Fertilizers used in the nursery are bought from external sources. Electrical energy is supplied from the grid and the heating is based on petrol oil.

Furthermore, in the nearby sewer, the wastewater has a temperature between 16 °C and 18 °C and thus it is suitable for thermal energy recovery. Based on the number of households connected to the sewer pipe, the flow rate is estimated to around 140 m^3/d with a COD, nitrogen and phosphorus load of up to 27 t/year, 6 t/year and 0.6 t/year, respectively.

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Together with the material and nutrients resulting from the pruning waste, the nutrients from the sewage sludge have a very high potential as a substrate for the production of a valuable compost. In addition, if that wastewater would be treated, it might be reused for irrigation.

Block diagram of the current treatment scheme

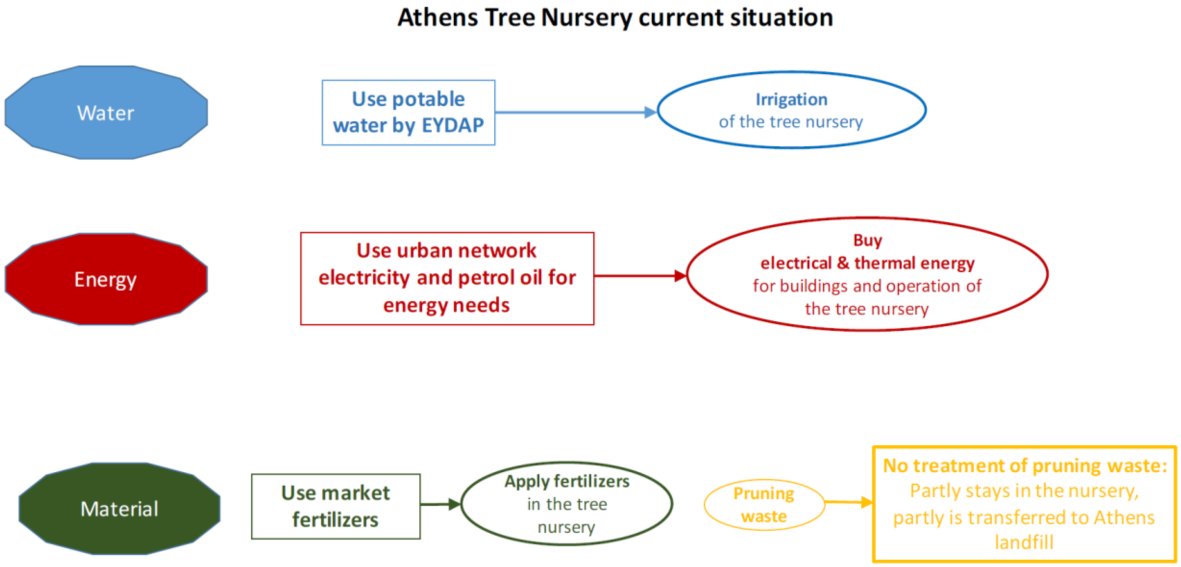

Figure 4. Scheme of the baseline scenario without NextGen technologies in Athens

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Braunschweig (Germany)

Description of the site

General description considering energy and materials nexus

Steinhof near Braunschweig, has a long tradition of water and nutrient reuse. Already at the end of the 19th century, fields were irrigated with sewage. From 1954 on, the wastewater was mechanically clarified and reused for irrigation. Finally, in 1979, the wastewater treatment plant (WWTP) was built. The current WWTP comprises a conventional activated sludge treatment system and a digestion stage. In summer, the digestate is directly reused on the fields, while in winter, the digestate is dewatered and either stored for the reuse in summer or incinerated.

Figure 5. Picture of the three digesters at the WWTP in Steinhof near Braunschweig.

Scheme of the current treatment/site

Current scale

The wastewater treatment plant treats the wastewater of 350.000 PE.

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Description of system

The WWTP treats on average 22.3 million m³ wastewater per year. This corresponds to 350,000 population equivalents (PE), even though the WWTP was designed originally for 275,000 PE. The COD-, N-, and P-loads of the WWTP are on average 16,000 t COD/year, 1,500 t N/year and 230 t P/year, respectively. In the conventional activated sludge treatment, the nitrogen is removed via nitrification and denitrification and the phosphorus by enhanced biological phosphorus removal.

Currently, the primary and excess sludge as well as fat, oil and grease (FOG) resulting from the fat separator are digested in three one-stage digesters. The digesters are operated parallel at a temperature of 37 °C and with an organic loading rate of around 2.4 kg VS/(m³*d). Their volumes are 2,100 m³, 4,450 m³ and 4,450 m³. On average, they produce 470 Nm³ biogas/h with a methane content of around 61%. Thus, the corresponding methane yield is 0.26 Nm³ CH_4/(kg VS).

Until 2016, in summer, the digestate was directly reused in agriculture, while in winter, the digestate was dewatered and stored. However, due to the new legislation in Germany, since 2017 only 70% of the digestate can be applied on the fields. The reasons are restricted periods for fertilization with digested sewage sludge and the limitation of the nitrogen load of the fields. Thus, the other 30% of the digestate are dewatered and incinerated.

Block diagram of the current treatment scheme

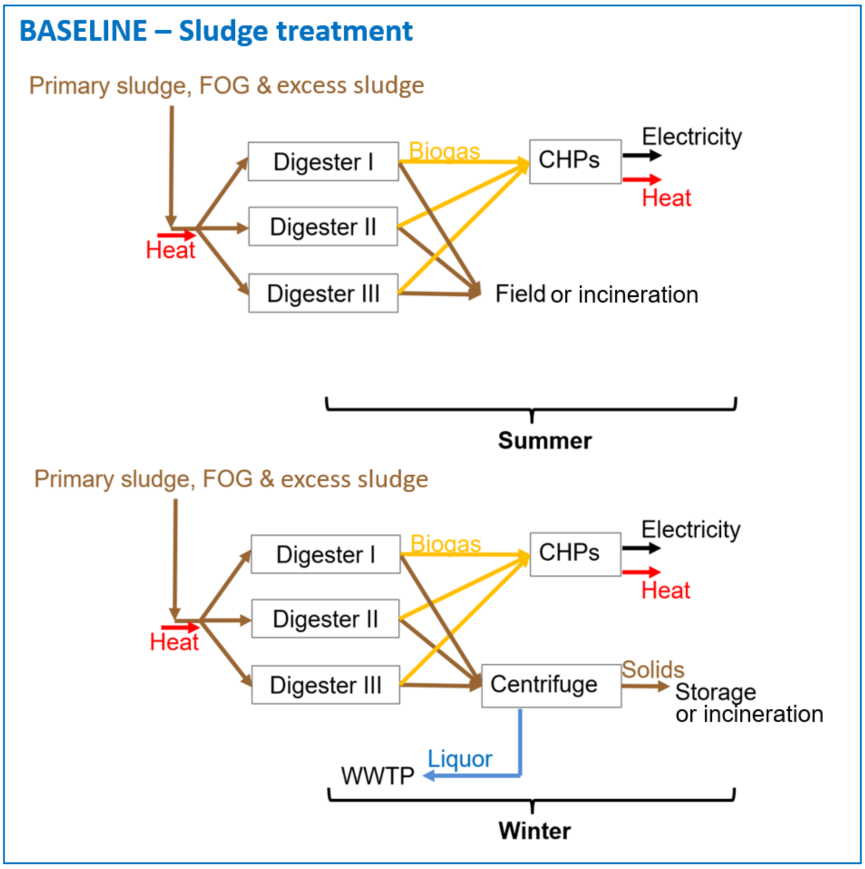

Figure 6. Scheme of the baseline scenario without NextGen technologies in Braunschweig

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Due to the very high nutrient loads of the WWTP, the operator decided, instead of extending the nitrification and denitrification stages as well as the P-removal unit, to build a nutrient recovery unit for nitrogen and phosphorus in order to achieve the required effluent quality.

Furthermore, the long tradition in Braunschweig to reuse the digested sludge in agriculture will change. The new technologies should produce secondary fertilizers and enable to further close the nutrient cycle.

Bucharest (Romania)

Description of the site

General description considering water, energy and materials nexus

Bucharest is Romania's largest city and capital. The water system has undergone significant transitions in recent decades with new drinking water and wastewater treatment plants as well as distribution system leakage reductions.

The Glina WWTP is designed for 1.2M PE. Biological sludge was sent to anaerobic digestion, dewatered and landfilled until 2015, but nowadays it is valorized in agriculture and its biogas is used to produce electricity. This is in line with the Romanian Strategy on Wastewater Sludge Management favoring development of land application of sludge or its use for cement. The operator faces the following challenges: the management and valorization of the sludge, the nutrient removal and the optimization of the energy management.

Figure 7. Aerial view of the Glina WWTP (source: google maps).

Scheme of the current treatment/site

Current scale

The Glina WWTP has a capacity of 690,000m^3/day – full scale.

Description of system

The Glina WWTP consists in the following processes:

- Mechanical treatment with coarse and fine screens, grit and grease removal and primary settling;
- Biological treatment in an activated return sludge process and secondary settling;

- Sludge stabilization by digestion and dewatering (belt filter-presses/centrifuges) of stabilized sludge.

Step 1

The first step in the sewage sludge treatment plant is thickening. In this step, the primary sludge is thickened in primary sludge gravity thickeners and the excess activated sludge (biological sludge) in addition of polymer is concentrated in gravity belt thickeners.

Step2

The second step is digestion. The five existing digesters of 8,000 m^3 volume each are used for the anaerobic digestion of the thickened sludge. The process is a mesophilic high rate anaerobic digestion. So, the thickened mixture sludge is stabilized anaerobically by fermentation under mixing and permanent recirculation at 35-37°C.

Step 3

The digested sludge is dewatered on belt filter presses and centrifuges with addition of polymer and lime.

Step 4

Land application (agriculture).

Block diagram of the current treatment scheme

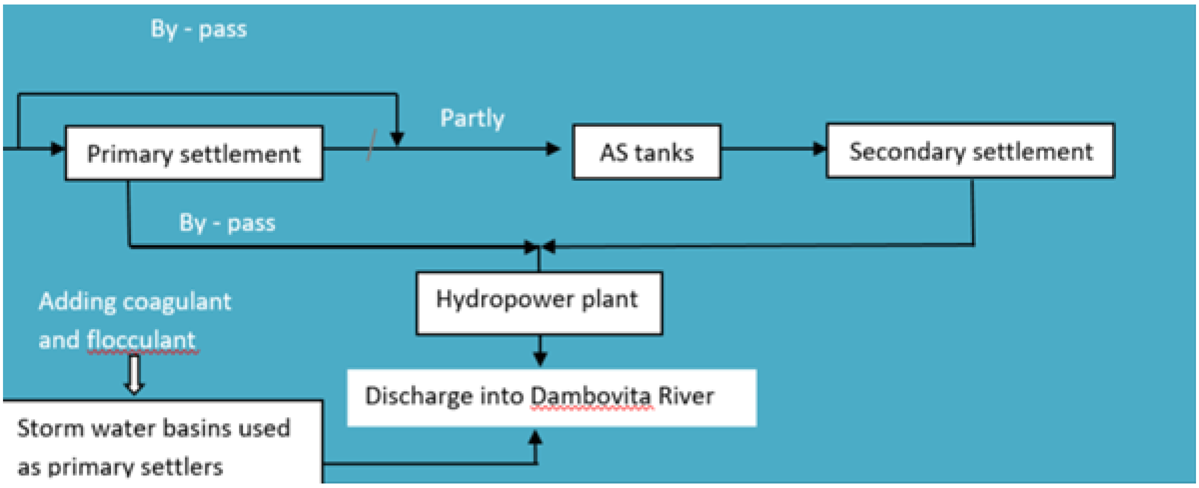

Figure 8. Current wastewater treatment process used in Bucharest.

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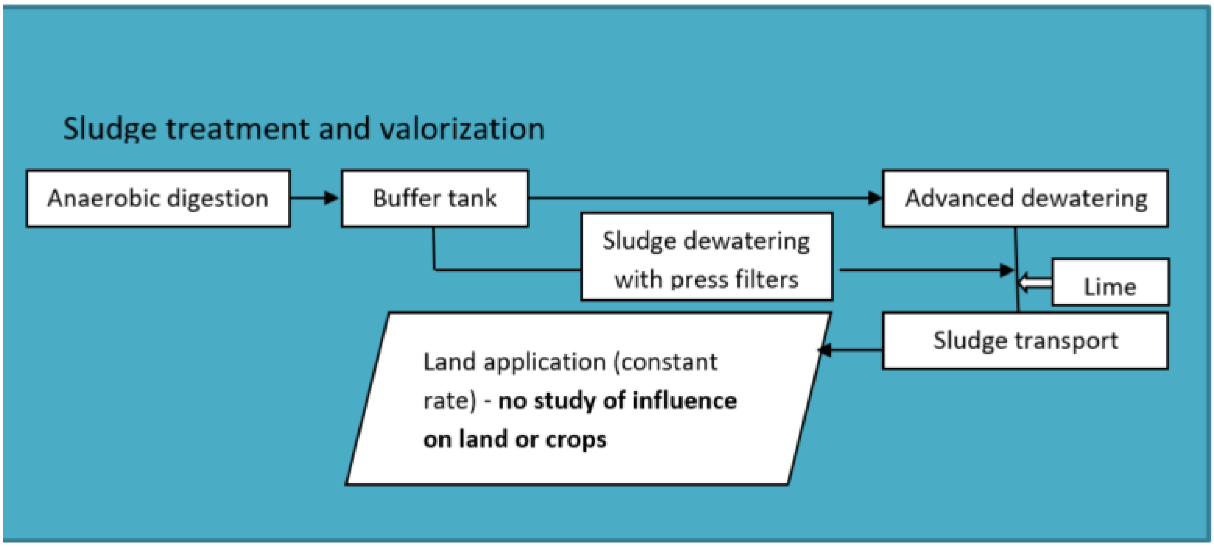

Figure 9. Sludge treatment in Bucharest.

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Costa Brava Region (Spain)

Description of the site

General description considering water and materials nexus

Costa Brava is a region of Catalonia (Spain). It is a touristic area located by the Mediterranean Sea which leads to an area with high seasonal water demand, frequent water scarcity episodes which can also cause saltwater intrusion. It is one of the first areas applying water reuse in Europe. In total 14 full-scale tertiary treatments provide 4 Mm^3/year (2016) for agricultural irrigation, environmental uses, non-potable urban uses and, recently, indirect potable reuse.

The wastewater treatment plant (WWTP) of Tossa de Mar has a surface of 1.7 Ha. It works with one-line treatment with an average flowrate of 7.4 m^3/h, and ranging from 4.5 m^3/h during winter period (values from 2018) to a maximum of 11 m^3/h reached in summer. On this WWTP several technical demonstrations will be conducted within the NextGen framework.

Figure 10. Aerial view of the WWTP of Tossa de Mar.

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Scheme of the current treatment/site

Current scale

The tertiary treatment of the Tossa WWTP has a maximum treatment capacity of 35 m^3/h. However, during summer 2018, the mean treated flowrate was around 1 m^3/h (SD = 0.1 m^3/h).

Description of system

The WWTP of Tossa de Mar consists of a pre-treatment (screening system, a grit chamber and a primary clarifier (currently not in operation), a secondary treatment (biological reactor and three settling tanks) and a tertiary treatment (flocculation/coagulation, lamella clarifier, sand filter, UV and chlorine disinfection tank). Finally, the site also includes a sludge anaerobic digester and a sludge drying bed. Dried sludge is then composted and applied in agriculture (Figure 11).

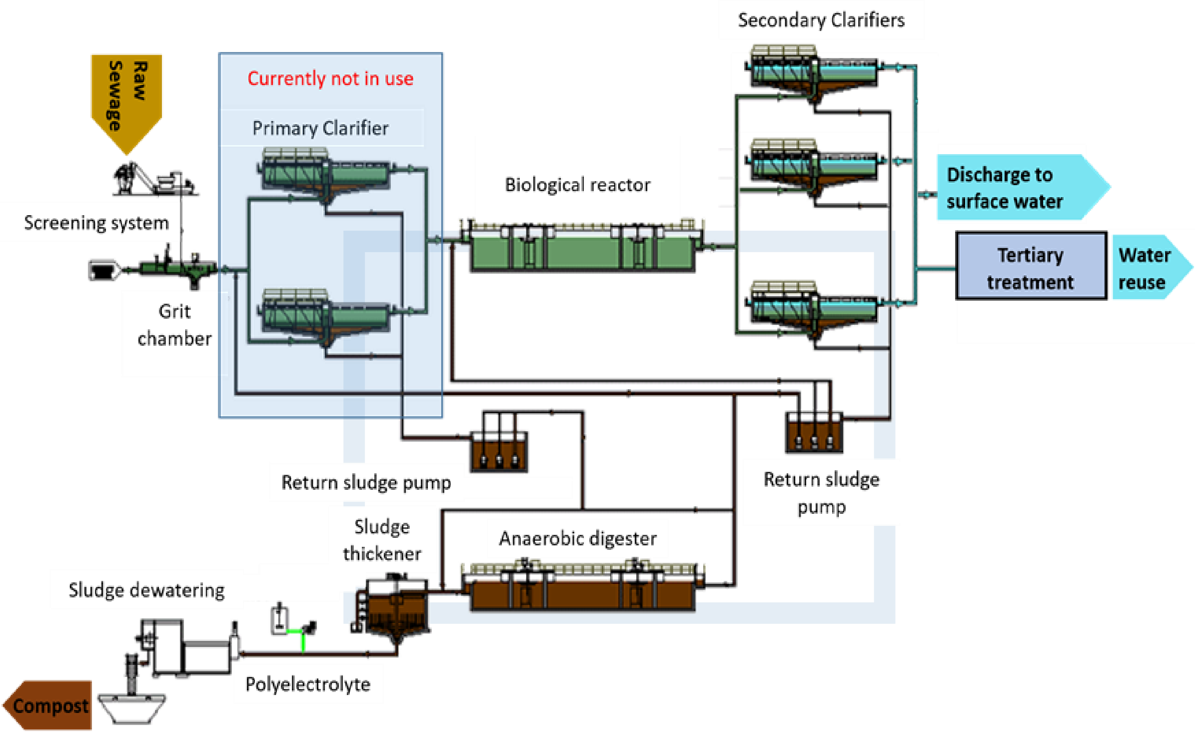

Figure 11. Scheme of the WWTP of Tossa de Mar.

After the pre-treatment, wastewater is treated by a conventional activated sludge system. Effluent from this secondary treatment presents a mean of COD = 40 mg O_2/L (SD = 10 mg O_2/L), BOD5 = 7 mg O_2/L (SD = 3 mg O_2/L), a total nitrogen (TN) content of 36 mg/L (mainly ammonia) (SD = 11 mg/L), and a total phosphorous (TP) of 4 mg/L (SD = 2 mg/L). *E.coli*, somatic bacteriophage and aerobic bacteria are also quantified, being their geometric average values the following ones: $3.4 \cdot 10^5$ CFU/100mL (SD = $6 \cdot 10^5$ CFU/100mL), $8 \cdot 10^4$ CFU/100mL (SD = $7 \cdot 10^4$ CFU/100mL) and $1.3 \cdot 10^5$ CFU/100mL ($9.8 \cdot 10^4$ CFU/100mL), respectively.

Mainly during the summer period, the number of tourists and the wastewater flowrate to be treated increases; a part of the effluent from the secondary treatment (0.5 m^3/h) is sequentially treated by a tertiary treatment.

The tertiary treatment of the WWTP of Tossa de Mar includes the following steps (schematized in the block diagram of Figure 12):

a) Flocculation/coagulation process, where chlorine is periodically added for avoiding algae growth, followed by a lamella clarification.
   Around 80 g/m^3 PAX coagulant (SD = 20 g/m^3) and 0.02 g/m^3 Hyfloc SS140 polyelectrolyte (SD = 0.01 g/m^3) were used during summer 2018. 125 g/m^3 chlorine (SD = 15 g/m^3) were added as a pre-chlorination step during all that year.
b) Single media sand filtration.
c) Disinfection process: a medium pressure UV lamp (Berson Inline 400 Special 10 kW) with a theoretical maximum dose of 48 mJ/cm^2 + post-chlorination step (around 60 g/m^3 chlorine (SD = 75 g/m^3) were added during 2018).

The effluent from tertiary system is used for agricultural irrigation and environmental and non-potable water uses. The excess water flows to the sea. In this case, COD, BOD_5, TN and TP of the tertiary effluent are not measured. *E.coli*, somatic bacteriophage and aerobic bacteria are quantified together with *Legionella spp*. and the intestinal nematodes. The geometric average for microorganisms, except intestinal nematodes, are the following ones: *E.coli* < 1 CFU/100mL, *Legionella spp*. = 50 CFU/L, intestinal nematodes < 1 egg/10L, somatic bacteriophage = 15 CFU/100mL (SD = 15CFU/100mL) and aerobic bacteria = 16,000 CFU/100mL (SD = 18,000 CFU/100mL). These values keep constant along the year, except the quantity of aerobic bacteria that slightly increase for summer period at 22,000 CFU/100mL (SD = 21,000 CFU/100mL).

In the framework of the NextGen project, UF and NF modules with regenerated membranes will be installed after the sand filter, aiming to improve the final water quality for broadening its application in more restrictive reuses such as private garden irrigation or indirect potable reuse. These uses are the most stringent quality requirements according to the Spanish legislation RD1620/2007. Consequently, the characterization of the effluent from the sand filter has been carried out by Eurecat Technological Centre using specific analytical campaigns during NextGen. The values of physicochemical parameters are similar to those from the secondary effluent, described above. Besides, in this case, around 180 trace organic compounds have been quantified during sampling campaign, including neonicotinoids, Endocrine Disrupting Compounds (EDCs), Pharmaceutical compounds, chlorophenoxy herbicides, pesticides included in the WFD 2013/39/UE or in the Execution Decision 2015/495 (Watch List). In addition, compounds with interests from the Catalan Administration have been included.

Tris(chloroisopropyl) phosphate (TCPP), caffeine and tris(2-butoxyethyl) phosphate (TBEP) are the most relevant EDC detected from the effluent of the sand filter. In October 2018, their values were around 1340 ng/L, 890 ng/l and 700 ng/l, respectively. Their presence increased at 1600 ng/L TCPP, 1600 ng/L caffeine and 810 ng/L TBEP in March 2019Regarding the pesticide family, the compounds which are present are the AMPA (a degradation by-product from glyphosate) (722 ng/L, Oct 2019) and Diuron (700 ng/L, Oct 2019).

The most prominent pharmaceuticals found are hydrochlorothiazide (2500 ng/L) , a diuretic medication often recommended to treat high blood pressure, iopromide (600 ng/L), used as a contrast medium; the antibiotic azithromycin (500ng/L); the salicylic acid (390 g/L); drugs for treating high blood pressure such as valsartan (380 ng/L), irbesartan (350 ng/L) and losartan (310 ng/L); and some anti-inflammatory drugs such as ibuprofen (310 ng/L).

Block diagram of the current treatment scheme

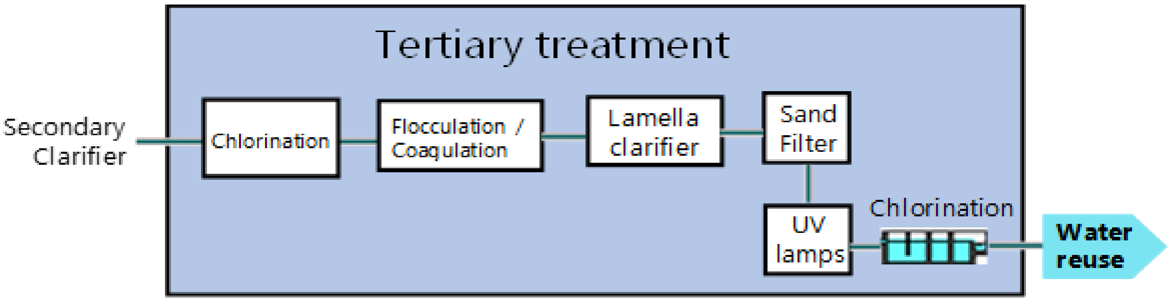

Figure 12. Scheme of tertiary treatment of the WWTP of Tossa de Mar.

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Filton Airfield (United Kingdom)

Description of the site

General description considering water, energy and materials nexus

The former Filton Airfield has been recognised as one of the most important brownfield development opportunities in the UK. The 143-ha site is located in the Bristol northern fringe and forms a connection between the Bristol city northern boundary and the conurbations wider northern fringe. The main feature in this site is the runway, which is 2,467 m long and 91 m wide (Figure 13).

A master plan for this site includes providing live and work opportunities and an efficient traffic and transport network. In addition, a 17,000-seat venue at the Brabazon Hangars will be built within the existing structure on the edge of the former Filton Airfield.

Figure 13. Aerial view of the Filton Airfield.

Scheme of the current treatment/site

Current scale

1.43 km^2 site plus the Brabazon Hangars:

- 2,675 homes
- 0.25 km^2 of employment space
- 0.56 km^2 of housing
- 0.18 km^2 of mixed use
- 0.44 km^2 of green space and transport infrastructure
- The Brabazon Hangars
  - Three separate bays
  - Total length 352 m

- Height 35 m
- Total area 400,000 sq ft (≈37,000 m^2)

Description of system

Figure 14 presents a masterplan for the Filton Airfield, including residential properties, schools and commercial buildings. In the Filton, rainwater harvesting for residential properties and commercial buildings (including Brabazon Hangars) will be demonstrated.

For example, rainwater harvesting (RWH) systems installed at domestic residences can provide a non-potable water supply for use in toilet flush, laundry machines and garden irrigation. As described in Figure 15, a traditional RWH configuration in the UK that underground tanks are installed although ground level tanks are often installed. The system includes guttering, filters, pumps, pipes, valves, storage tanks and supply systems. Including traditional RWH systems, there are emerging RWH technologies available in the UK market (Figure 15). It is vital to find the most suitable configurations for the house building trends in the Filton Airfield.

Within the NextGen, existing and innovative RWH configurations will be evaluated to support designers, households and water companies in understanding the broader opportunities for re-using the rainwater as an alternative source thus reducing the clean water demand within the Filton area. Consequently, this will be a compelling case to showcase a multi-benefit range of RWH system configurations and cautious approaches to respond to the residential property scale and decision makers.

In addition, the NextGen project aims at the investigation of sustainable energy management strategies. The activities include a feasibility study of heat recovery from wastewater and local biogas production and utilisation. Figure 16 shows one of the options of heat recovery from wastewater. The warm water used in showers/bath is discharged into the sewer system. The average temperature of domestic wastewater is between 25 and 30 °C. This is still much higher temperature than the incoming cold water, indicating that low-grade heat in the warm water discharged to the drain can be used to preheat the incoming cold water. This results in the reduction of the domestic hot water energy requirement in residential and commercial areas and contributes to provide valuable information on practical aspects such as heat availability (efficient) and sewer design for the area.

Block diagram of the current treatment scheme

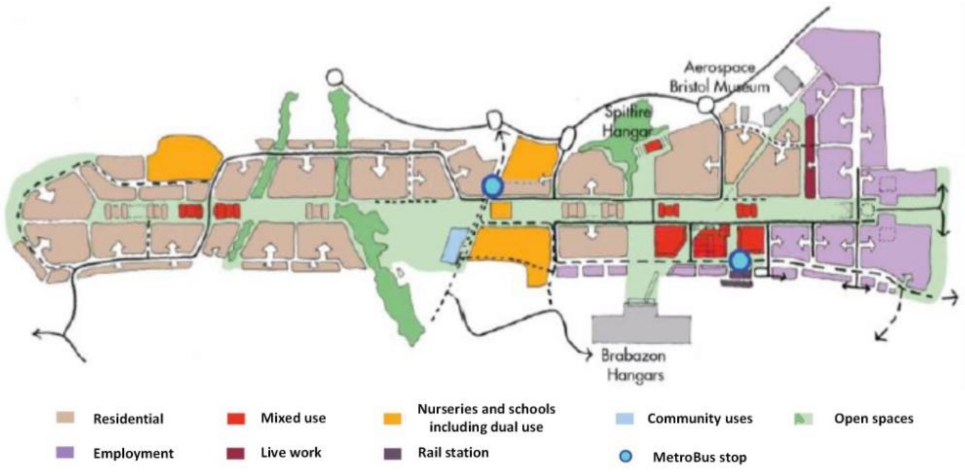

Figure 14. Filton Airfield development plan and the Brabazon Hangars.

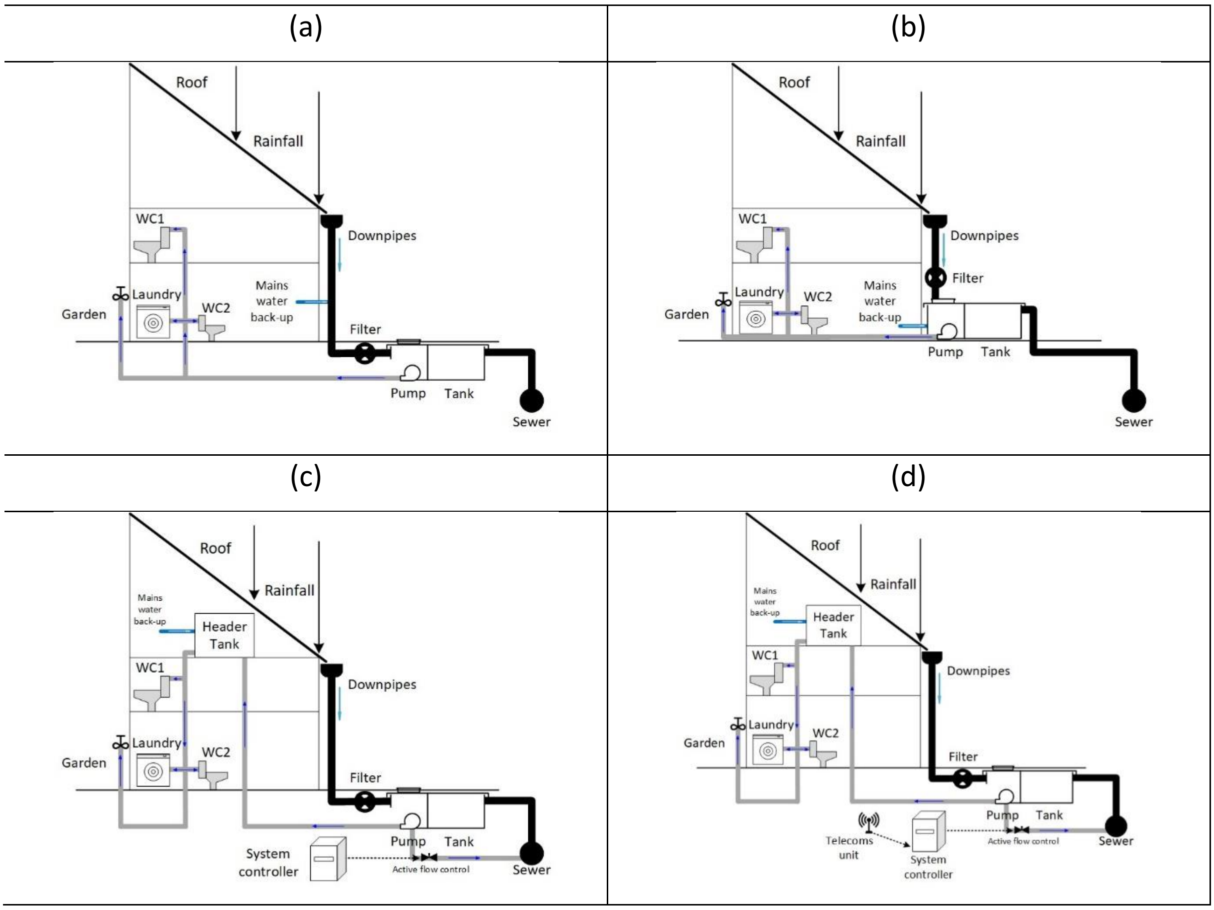

Figure 15. Traditional (a) below ground tank and (b) above ground tank and innovative (c) KloudKeeper and (d) real time control RWH system configurations.

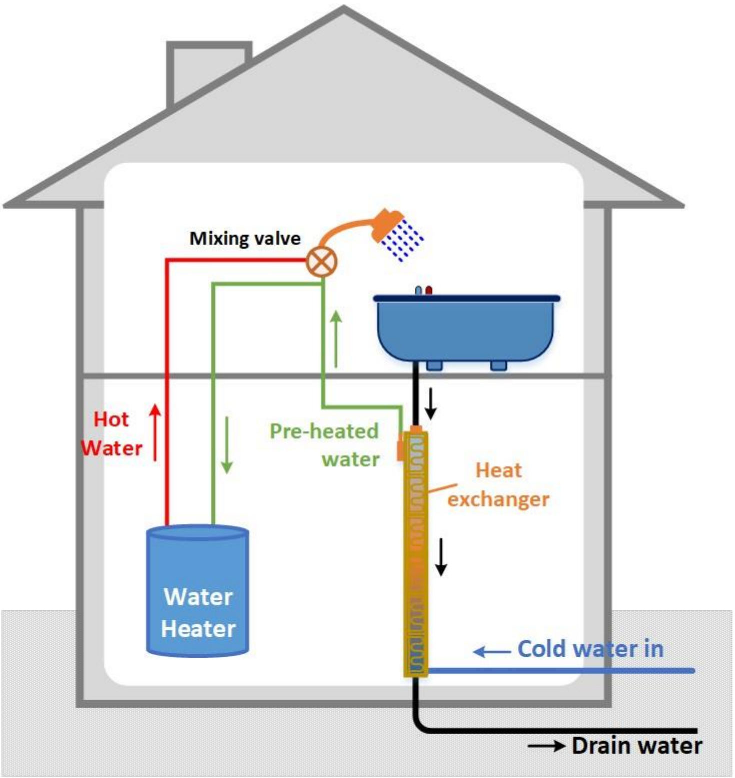

Figure 16. The concept of wastewater heat recovery system in a house.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°776541

Gotland (Sweden)

Description of the site

General description considering water, energy and materials nexus

Testbed Storsudret:

A testbed is a physical or virtual environment where companies, academia and other organizations can interact in the development, testing and implementation of new products, services, processes or organizational solutions in selected areas. The testbed in Gotland is situated at the southernmost part, Storsudret and is nationally funded for the development of small-scale techniques for water supply. Storsudret covers an area of 14 km^2, mainly rural land with a population of 900 inhabitants during winter and 2,100 during summer together with 5,000 cattle and 5,000 hotel nights.

The future demand of drinking water is estimated to 200,000 m^3 per year including local population, tourists, cattle and future exploitation. The annual amount of precipitation (minus evapotranspiration) at Storsudret is calculated to 23,000,000 m^3, which means that approximately 1% of the annual precipitation would cover the supply of potable water. However, since precipitation mainly fall through a short period of time (winter), the possibilities to convert precipitation to groundwater are limited. The area has large ditches which effectively transport excess water to the sea. The testbed consists of an integrated system based on small scale methods like:

- rainwater harvesting from drainage ditches and artificial surface water dams,
- artificial infiltration of groundwater,
- construction of groundwater dams for subsurface water storage and wastewater reuse.


Vändburgs gamla hamn 180108.Foto Gunnar Britse

Figure 17. Picture of the site.

Scheme of the current treatment/site

Current scale

The total water demand is 130,000 m^3 per year of which 30,000 m^3 per year is fed through main water supply network and another 100,000 m^3 is produced from the private wells.

Description of system

Today the water supply systems consist of one municipal drinking water pipe for half of the population at Storsudret. The rest of the inhabitants has their own wells. The municipal water system is fed by water from the central part of the island Gotland through a pipeline. The municipality's original plan was to feed this pipeline with desalinated water, but the current plan is that the testbed will provide enough of water so that a desalination plant can be avoided. About 20% of the sewage water, which is currently transported through a pipeline 40 km north to a WWTP in central Gotland, will be recovered in a local WWTP and reused as potable water. 30,000 m^3 of drinking water is transported to Storsudret by the municipal pipeline every year and 100,000 m^3 of water is produced by private wells.

At the opposite direction, the plan is to pump sewage water to a Waste Water Treatment Plant (WWTP), close to the Desalination plant.

The central WWTP consist of a screen before the moving bed bio reactor (MBBR). Sludge is removed through a settling tank before a chemical precipitation step where an iron based (Fe^{3+}) chemical is added under mixing. Sludge is removed in a settling tank before the discharge to the receiving water in the Burgsvik Bay.
The plant presents an influent flowrate of 16.2 m^3/h (SD = 12.7 m^3/h), increasing this value in winter to 31 m^3/h (SD = 12.7 m^3/h). The electricity consumption of the whole plant is around 0.84 kWh/m^3 and the main reagent used is the coagulant PIX111 (27.5 g/m^3).

The effluent from this WWTP presents a mean of COD = 40 mg O_2/L (SD = 20 mg O_2/L), BOD7 = 10 mg O_2/L (SD = 8 mg O_2/L), a total nitrogen (TN) content of 33 mg/L (SD = 26 mg/L) and a total phosphorous (TP) of 0.15 mg/L (SD = 0.1 mg/L). These parameters increase during summer period up to 70 mg O_2/L (SD = 8 mg O_2/L), 20 mg O_2/L (SD = 5 mg O_2/L), 65 mg/L (SD = 15 mg/L) and 0.2 mg/L (SD = 0.02 mg/L) of COD, BOD_7, TN and TP, respectively. Microorganism content are not measured in this case.

The main wastes produced in the WWTP constitutes of biological sludge and sludge from the chemical precipitation. Sludge from the settling tank after the moving bed bio reactor (MBBR) is stabilised with air and thickened before it is mixed with sludge from the settling tank after chemical precipitation. The mixed sludge is thickened before transport to the wastewater treatment plant in Klintehamn for digestion and dewatering. Around 99 m^3/month of sludge are generated and transported to Klintehamn. The dry matter is not measured but can be estimated in the range of 2-4%.

The rainfall climatology of the Storsudret area is around 338 mm/year (data from regional weather station, Hoburgen year 2018 and 2019). The quality of the surface water and groundwater as well as the sediments are determined. Around 35 -40 mS/m could be found in surface water or in groundwater. However, punctually, conductivity has increased in groundwater up to 160 mS/m. Rainwater presents a little organic content, being lower in groundwater (TOC = 5- 20 mg/L) than in surface water (TOC = 35 mg/L). Dissolved organic matter is one thousand times less than TOC.

Block diagram of the current treatment scheme

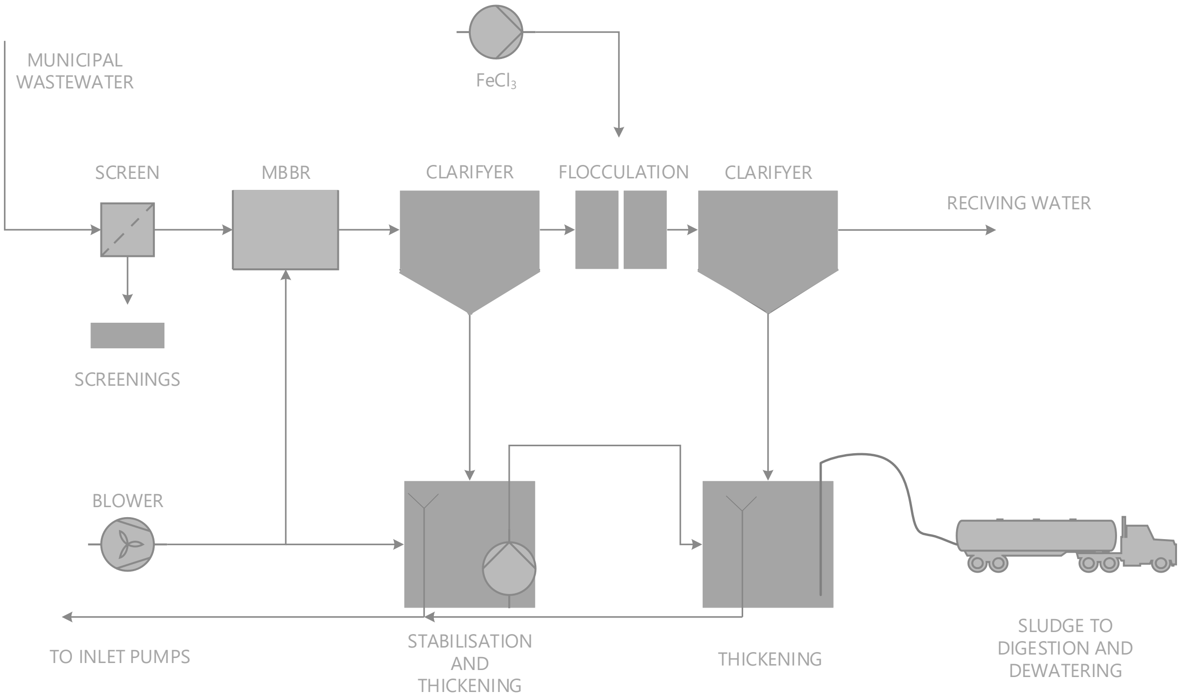

Figure 18. Scheme of the centralized WWTP system of Gotland.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°776541

La Trappe (Netherlands)

Description of the site

General description considering water, energy and materials nexus

The Koningshoeven BioMakery (Figure 19) is a biological wastewater treatment system based on modular and functional reactor based ecological engineering. The BioMakery is powered by Metabolic Network Reactor (MNR) technology, which uses 2-3,000 different species of organisms ranging from bacteria to higher level organisms such as plants. The BioMakery serves as a test facility for advanced circular space technology developed within the micro-ecological life support system alternative (MELiSSA) program of ESA. SEMiLLA formerly known as IPStar has a mandate to implement this technology in civil society. Coupling MNR with MELiSSA advanced separation and photobioreaction based technologies reusable water will be produced while growing biomass that can be used as slow-release fertilizer for the plant nursery, as fish fodder, or as human food.

Figure 19. Picture of the Koningshoeven BioMakery (exterior and interior view).

Scheme of the current treatment/site

Current scale

Treatment capacity of the municipal MNR: 17.5 m^3/d (Designed)

Treatment capacity of the brewery MNR: 320 m^3/day (Designed, max 336 m^3/day)

MELiSSA pilot plant: 100-300 L/day (i.e. a part of the effluent of the MNR)

Description of system

There are two wastewater streams: municipal and brewery wastewater (Figure 20). The designed flow rates for both streams are 17.5 and 320 m^3/day, respectively. The municipal MNR line is designed to treat an influent with COD 1,130 mg/L, BOD_5 570 mg/L, TSS 660 mg/L, TN 290 mg/L, ammonia 220 mg/L, and TP 20 mg/L. For the brewery MNR line is designed for a wastewater composition of COD 1,904 mg/L, BOD_5 3,080 mg/L, TSS 252 mg/L, TN 34.5 mg/L, ammonia 2.7 mg/L, and TP 15.2 mg/L. The effluent composition from the municipal MNR system is set for non-potable applications and should comply with the following standards: COD < 125 mg/L, BOD_5 < 20 mg/L, TSS < 30 mg/L, TN < 10 mg/L, ammonia < 2 mg/L, and TP < 0.5 mg/L.

At the La Trappe case, NextGen will demonstrate the feasibility of the combined approach of the MNR and the Bio-Makery. Key actions include water recovery for fit-for-use industrial use such as irrigation and potentially bottle washing and materials (carbon, nitrogen, and phosphorus) recovery from wastewater.

To achieve water quality levels suitable for the reuse, the combination of MNR and membrane separation technologies (nanofiltration and reverse osmosis) will be implemented. Nanofiltration (NF) and reverse osmosis (RO) are physical separation technologies and commonly applied for the removal of organic compounds, such as micro pollutants and mono and divalent ions. As shown in Figure 21, NF and RO play a crucial role in removing pathogens and organic compounds thus producing high quality water from wastewater streams.

RO process produces clean water, and as well as wastewater (referred to as RO concentrate). RO concentrate produced from water reclamation contains high concentration of organic and inorganic compounds. NextGen will also demonstrate the treatment of the RO concentrate towards photobioreactors (PBR) and its feasibility of recovering nutrients as fertilisers and proof they are suitable to be used for various applications.

Block diagram of the current treatment scheme

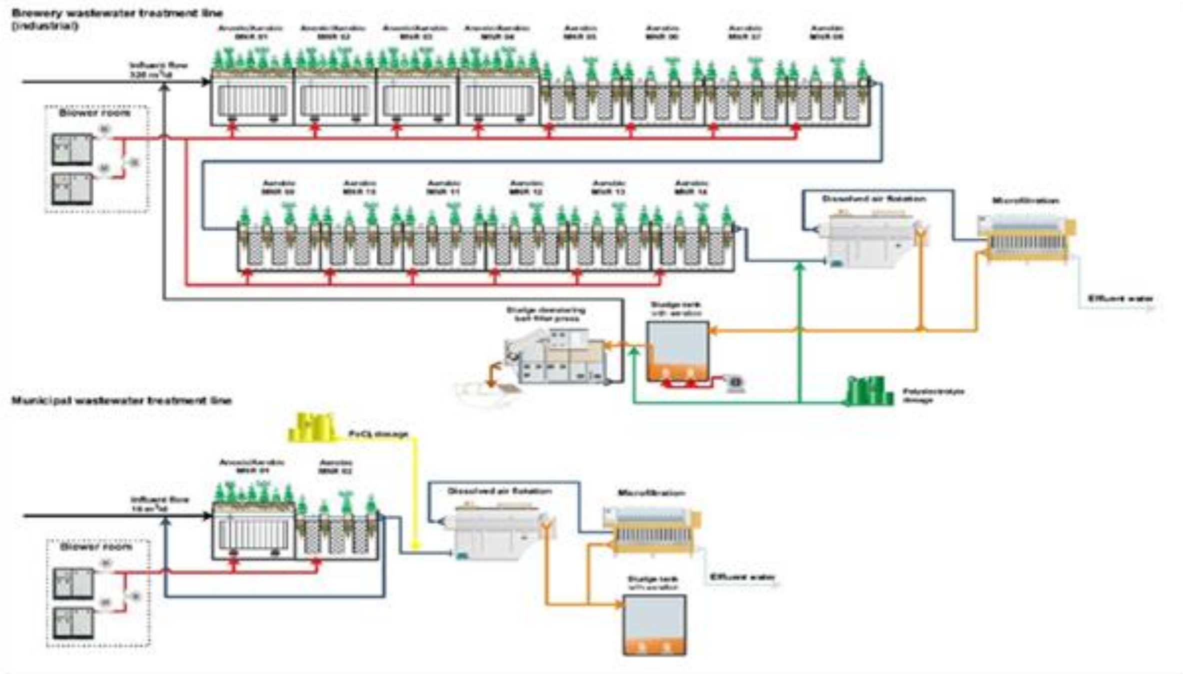

Figure 20. MNR system for industrial and municipal wastewater treatment.

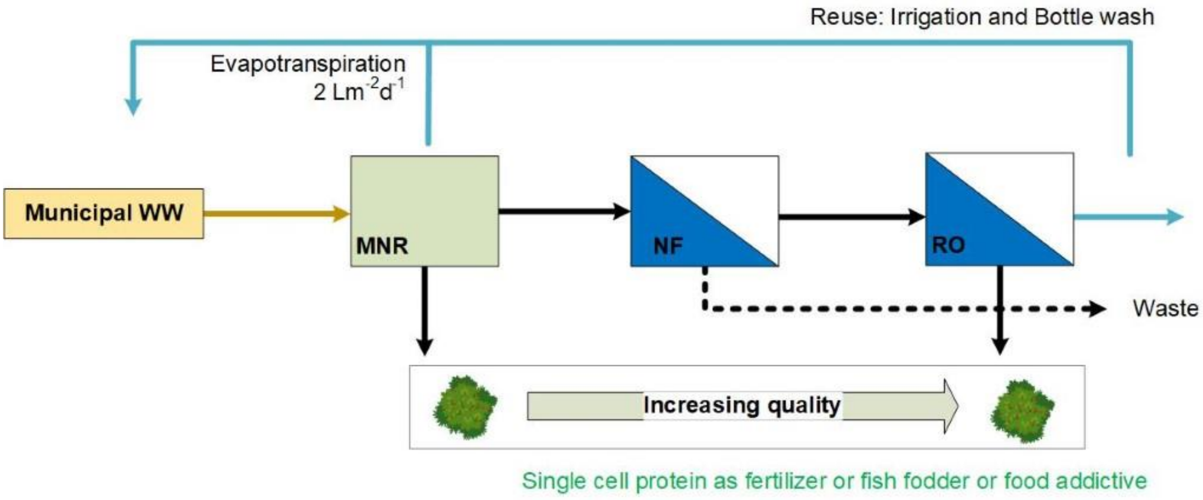

Figure 21. Schematic diagram of the MNR hybrid system.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°776541

Spernal (United Kingdom)

Description of the site

General description considering water, energy and materials nexus

Spernal WWTP serves the towns of Redditch and Studley located approximately 24 km south of Birmingham (UK). The area has a residential population of approximately 85,000. The treated effluent is currently discharged to the River Arrow, which is designated as a sensitive area under the Urban Wastewater Treatment Directive (UWWTD) and has an overall water body status of moderate under the Water Framework Directive (WFD). Sludge from the site and other local rural works is treated in conventional anaerobic digesters and dewatered before being recycled to local farmland and industries. The biogas produced by digesters is burnt in combined heat and power (CHP) engines to produce heat and electricity.

A multi-stream technology demonstration plant incorporates an anaerobic membrane bioreactor (AnMBR) complete with a membrane degassing unit to recover dissolved methane for water and energy reuse, and a pilot scale nutrient adsorption step for nitrogen and phosphorus recovery. Through such demonstration to close the water, energy and materials cycles, the necessary data to assess the benefits of the technologies will be provided.

Figure 22. Aerial view of the Spernal WWTP.

Scheme of the current treatment/site

Current scale

Spernal WWTP:

Influent to the Spernal WWTP: 1,114 m^3/h summer mean and 1,422 m^3/h winter mean (2018)
Effluent from the Spernal WWTP: 921.4 m^3/h summer mean and 1,283.7 m^3/h winter mean (2018)

Energy demand = typically 9,000 kWh/d

Energy production = typically 15,000 kWh/d

Description of system

The Spernal WWTP is a medium sized plant and treats an average daily flow of 27 ML/d to a 10 mg BOD/L, 25 mg TSS/L, 5 to 10 mg NH_4/L and 2 mg P/L standard. The plant includes a preliminary treatment (6 mm screening and grit removal), conventional primary settlement tanks with iron dosing for P removal, secondary treatment comprising of trickling filters for 33% of the flow and activated sludge for the remainder and tertiary sand filters. The schematic diagram of the existing Spernal WWTP is shown in Figure 23.

The quality of wastewater influent shows a mean of COD = 861 mg O_2/L (SD = 521 mg O_2/L), BOD_5 = 276 mg O_2/L (SD = 172 mg O_2/L), total suspended solids (TSS) = 515 mg/L (SD = 301 mg/L), a total nitrogen (TN) content of 33 mg/L (SD = 7 mg/L), and a total phosphorus (TP) of 8 mg/L (SD = 3 mg/L). Effluent from the plant presents COD = 45 mg O_2/L (SD = 12 mg O_2/L), BOD_5 = 4 mg O_2/L (SD = 3 mg O_2/L), total suspended solids (TSS) = 10 mg/L (SD = 7 mg/L), a total nitrogen (TN) content of 35 mg/L (SD = 5 mg/L), and a total phosphorus (TP) of 1 mg/L (SD = 0.3 mg/L). In this case, the quantity of microorganisms for both influent and effluent is not shown as it is not measured regularly. The overall quality of both influent and effluent is better during the winter period.

Around 15 ton/day (1,061 kg VS/m^3d) sludge produced from the primary settlement tanks is treated by the anaerobic digestion process (Figure 23). It produces about 13,156 m^3/day biogas containing 40.2-63.7% methane (average 53.6%). The total methane gas production ranges from 216.4 to 999.9 m^3CH_4/kg VS (average 507.25 m^3CH_4/kg VS). Dewatered sludge of 0.297 ton/day is reused in agriculture.

As shown in Figure 23, the NextGen project demonstrates a 500 m^3/d AnMBR plant combined with a smaller (10 m^3/d) pilot plant for nutrient removal and recovery (nitrogen and phosphorous) using adsorption or ion exchange technologies. In addition, the water produced from the plant will be analysed to evaluate its quality for reuse (i.e. irrigation). Finally, methane/biogas yield from the system will be measured to quantify the potential for heat and electricity production. The project will confirm the optimal design and operating parameters and will deliver a comprehensive energy balance and cost benefit assessment. Therefore, the demonstration will provide a better understanding of anaerobic sewage treatment and confidence for operations and decision makers to accept this technology.

Block diagram of the current treatment scheme

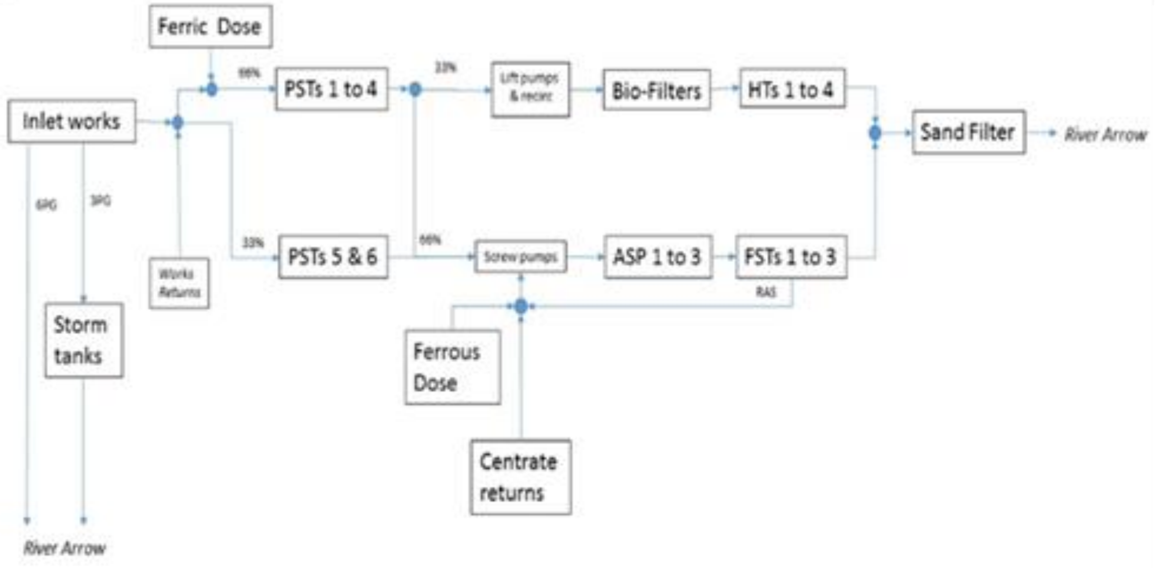

Figure 23. Scheme of the existing WWTP of Spernal (PST: Primary settlement tank; ASP: activated sludge process; HT: homogenize tank; FST: final settlement tank; RAS: returned activated sludge).

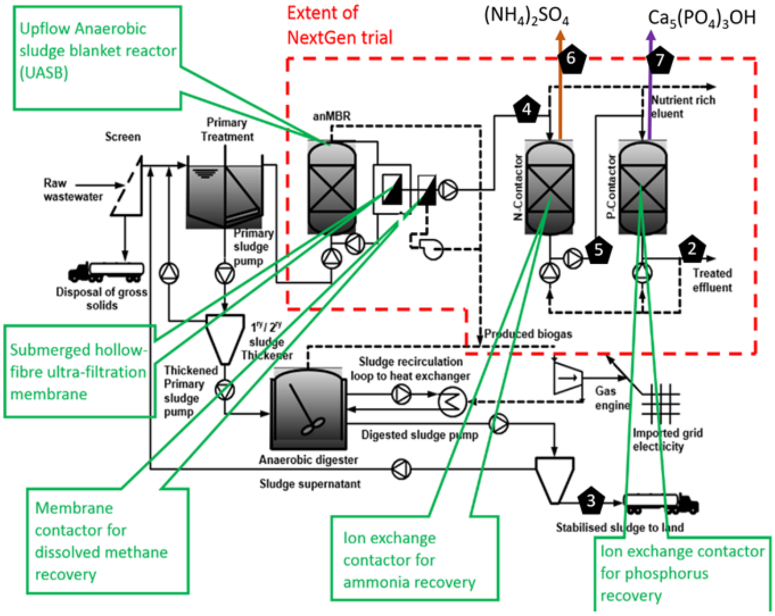

Figure 24. Scheme of the Spernal WWTP with the NextGen.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°776541

Westland Region (Netherlands)

Description of the site

General description considering water, energy and materials nexus

The Westland region in the Netherlands are dense urban and industrial areas and greenhouse horticulture complexes (22 km^2). Within NextGen, this area is referred to as Delfland (Figure 25), which is similar to the area of the Water Board of Delfland and contains the Westland area (rural area) and part of the cities of Rotterdam and The Hague (urban area).

The horticulture companies of Delfland use between 3,000 – 10,000 m^3/ha·year, depending on the crops grown. Vegetables as tomatoes and peppers use about 10,000 m^3/ha·y. The annual average rainfall is about 850 mm/y. In the Delfland area, although horticulture companies are exploring the rainwater harvesting for reuse, its efficiency is low. This is because of the relatively small water basins (average 800 m^3/ha), which means that approximately 40% of the total rainwater is collected.

These horticulture companies have insufficient freshwater for irrigation. Therefore, additional irrigation water is produced from brackish/saline groundwater desalination by reverse osmosis. The RO concentrate currently is discharged by infiltration into deeper saline aquifers. In addition, emissions of nutrients and pesticides are minimised by recirculating the water along the crops. Furthermore, evaporated water is recovered by condensation and brought back into the cycle.

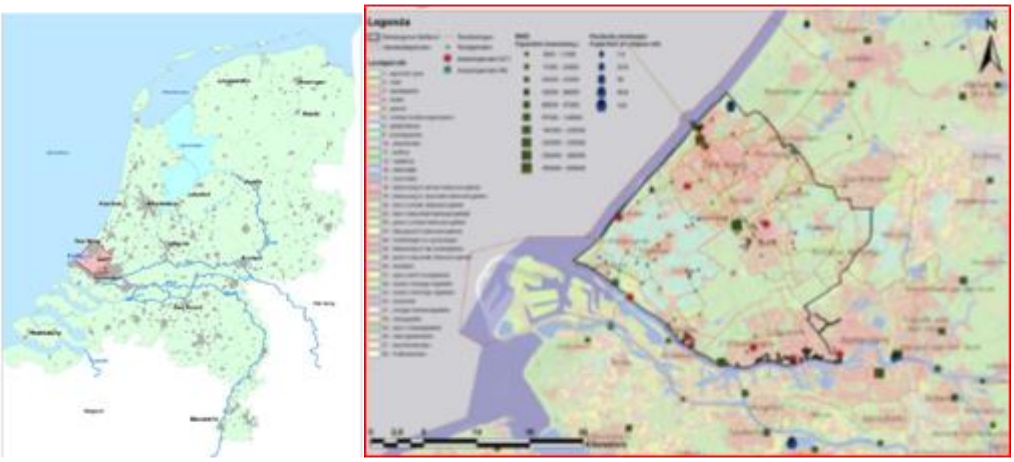

Figure 25. Location of Delfland (left) and aerial view of Westland region (right) in the Netherlands.

Scheme of the current treatment/site

Current scale

Westland total surface area: about 22 km^2 (2,200 ha)

The total amount of irrigation water needed: about 8-15 Mm^3/y

1.2 M households served

100-150 PJ Waste heat supply (industry)

40,000 industries served

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°776541

120-175 PJ Excess heat demand (horticulture, cities)

Description of system

In the current greenhouses water, gas, and power are utilised as shown in Figure 26. Water is used for irrigation and supply of substrate for growing the crops. The water is circulated along the plants and partly discharged as wastewater and replenished with freshwater. In this way the salt and nutrient content of the irrigation water is optimised and maintained. Many horticulture farmers use rainwater collection for their freshwater supply. However, there is little data on the water quality of the harvested rainwater. Literature data from 2015 indicate the following composition. COD 32 mg O_2/L, BOD_5 5.7 mg O_2/L, TSS 17 mg/L, TN 1.9 mg/L and TP 0.4 mg/L.

Natural gas is used for heating of the greenhouses and producing electricity through CHP engines. The electricity is used in the greenhouses for high intensity lighting (24 h per day) to grow the crops. CO_2 of the CHP engine is used to enrich the atmosphere of the greenhouses, again to increase crop yields.

Block diagram of the current treatment scheme

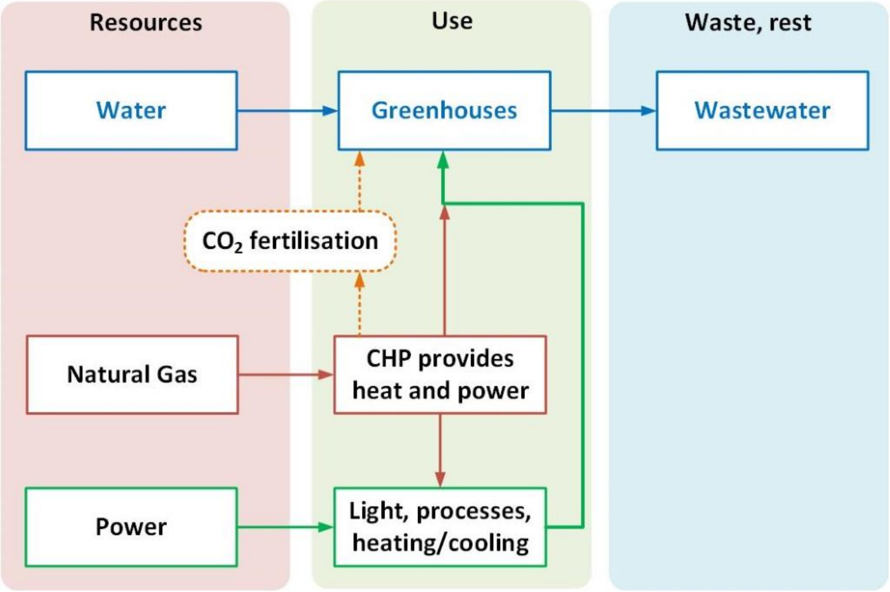

Figure 26. Diagram of the current system

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Potential interlinkages between demonstration cases

Water

Demonstrations in the water nexus are taking place in 8 sites of the project, as represented in Figure 27. Interlinkages in the water nexus can be found both in the origin of the water to be treated and final use of the water obtained. Rainwater harvesting and wastewater treatment are the two main activities being conducted in the different demo sites. Regarding rainwater harvesting, synergies between Gotland and Westland cases can be established, as water is recovered to be infiltrated into the aquifers. Feasibility of rainwater harvesting will also be investigated in the Filton Airfield case. In terms of wastewater treatment and reuse, synergies between La Trappe, Costa Brava and Athens can be found when using reclaimed water for irrigation. Synergies between Costa Brava and Gotland are also in place when reusing water for infiltration for indirect potable reuse.

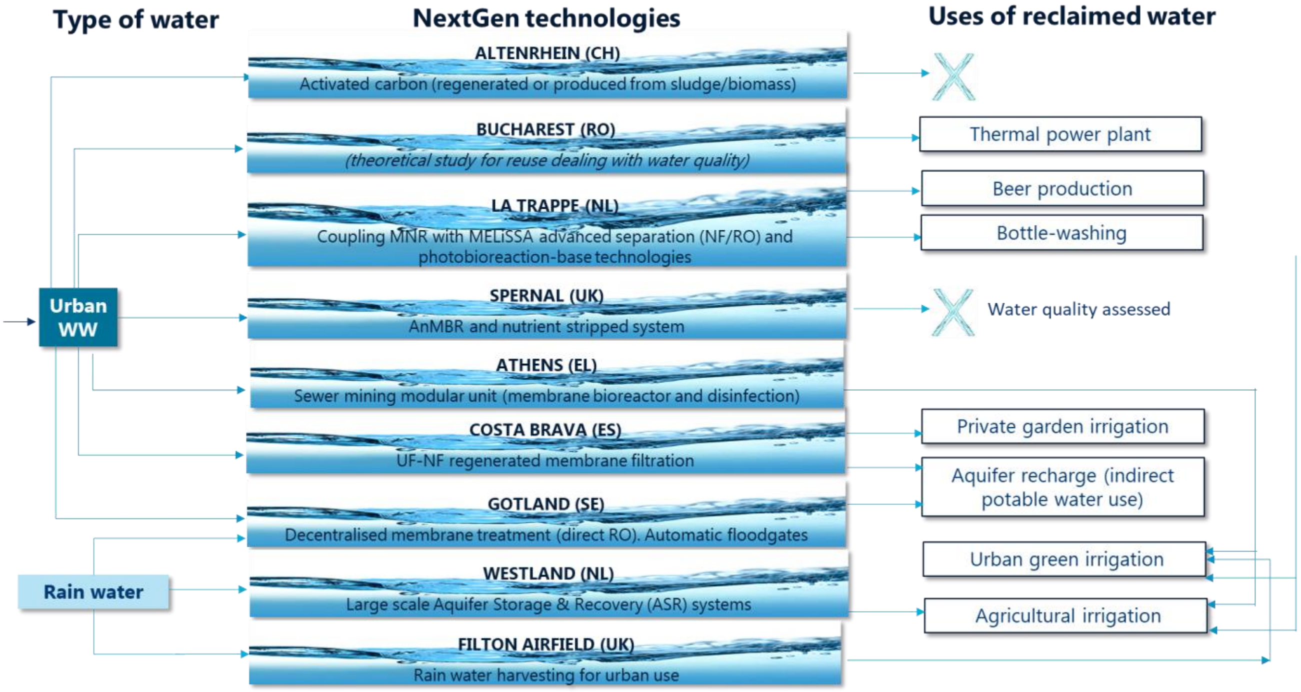

Figure 27. Water nexus scheme.

Materials

In the frame of the NextGen project, there are three categories of materials which will be produced and investigated (1) fertilizers/recyclates, (2) granulated activated carbon and (3) recycled membranes. Only in the category (1) fertilizers/recyclates, there are some synergies due to the production of the same products even though the production processes differ (Fig. 28).

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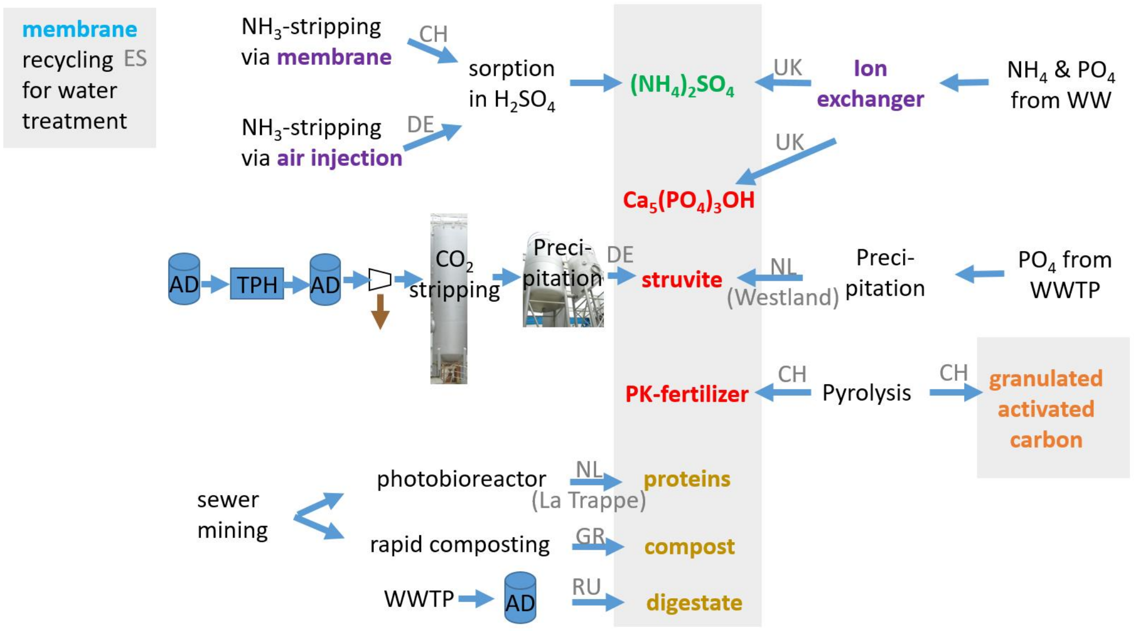

Figure 28. Overview on material related technologies in NextGen

In the case studies of Altenrhein, Braunschweig and Spernal, ammonium sulfate solution will be produced, although three different processes will be applied. In Braunschweig, the ammonia is recovered via air stripping, while in Altenrhein a gas separation membrane will be used. Then in both cases, the recovered ammonia reacts with sulfuric acid to ammonium sulfate solution in a scrubber. In Spernal, an ion exchanger is used for ammonia recovery and ammonium sulfate solution production. Struvite will be produced in Braunschweig as well as in Harnaschpolder in the Westland region via precipitation by the addition of magnesium chloride.

Energy

Demonstration of Energy is part of the case studies in Athens, Braunschweig, Spernal, Westland and Filton Airfield. Three energy aspects are covered in the NextGen project. In the first place the production and recovery of biogas and subsequent electricity and heat generation are included. Secondly, Heat Recovery from water streams is an important aspect and finally, sub-surface heat storage in aquifers is demonstrated. Figure 29 shows the connection between the different energy aspects in the cases of NextGen.

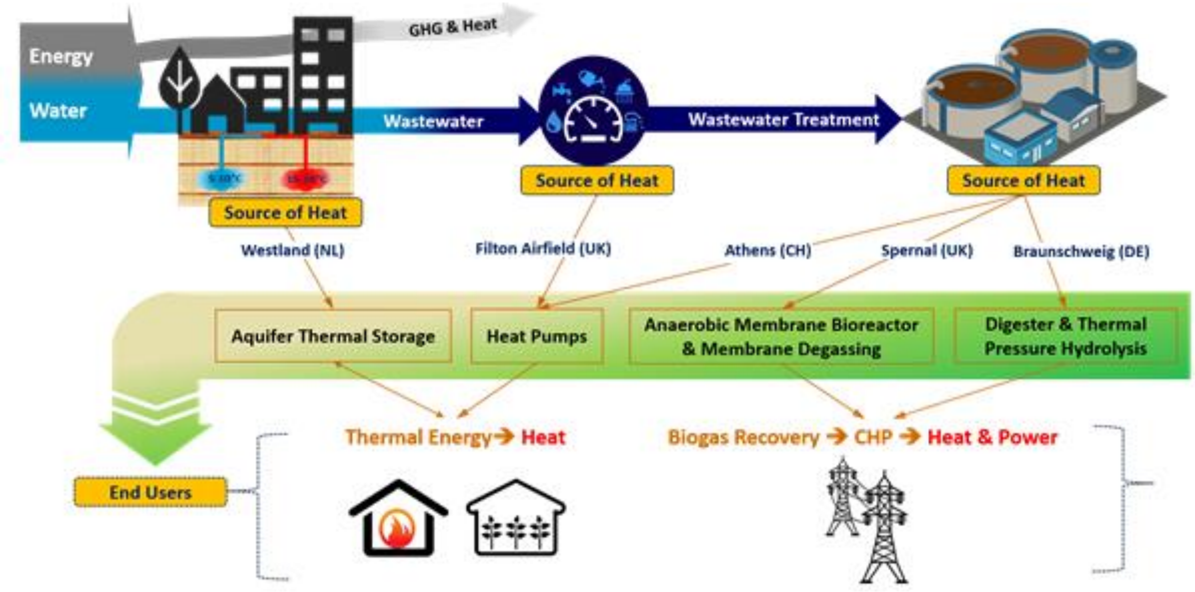

Figure 29. Synergies in Energy

Heat recovery will be practised in Filton Airfield and Athens. At these two sites heat recovery from municipal wastewater and/or harvested rainwater will be demonstrated. Heat recovery and storage will be demonstrated in the Westland region. ATES systems are capable of decoupling heat availability and heat demand through storage. Excess heat in warm periods can be abstracted for cooling and stored for cold periods when heating is required.

Energy production from wastewater is demonstrated in two systems: A more conventional system in Braunschweig will be compared to a novel design with an anaerobic membrane bioreactor in Spernal. In the latter case, methane will be collected through a membrane degasifyer.

Both systems will deliver heat and power, which can either be re-used on the demo sites or be transported to other potential end-users.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°776541