Assessment of baseline conditions for all case studies

Deliverable D.1.1.

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[1] PU = Public
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Executive summary

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 demo cases involved in NextGen before the start of the project and all pre-existing infrastructures and systems – prior to NextGen interventions across 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 to demonstrate the benefits and improvements achieved within the NextGen project, through the implementation of new CE solutions by the project, at each demo case.

This report corresponds to the first deliverable of the WP1, 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 demo case representatives and through different templates that have been prepared and compiled. Baseline of each demo case has been defined for all demo cases of NextGen project using key performance indicators (KPIs) linked to water, energy and materials. Potential interlinkages between demo cases are also described in this document, aiming at increasing the uptake and impact of the NextGen solutions.

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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
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UF	Ultrafiltration
UV	Ultraviolet
VS	Volatile solids
WFD	Water Framework Directive
WP	Work Package
WWTP	Wastewater Treatment Plant

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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 define the baseline conditions of the 10 demo sites of the NextGen project **before the start of the project** and to describe all **pre-existing** infrastructures and systems – prior to NextGen interventions across water, energy and material cycles.

The information collected and summarized in this deliverable will be later used to demonstrate the benefits and improvements achieved **within the NextGen project**, through the implementation of **new CE solutions by the project**, at each demo case.

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 demo cases 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 all sites**, covering **general aspects** of the water, energy and material cycles such as the ones detailed in Table 1. Based on these general aspects, **specific KPIs and parameters at each site** have been compiled in spreadsheets, gathering technical data from at least a complete year of monitoring and highlighting the seasonal variations (if any) or deviations observed. The spreadsheets collected have been complemented with factsheets describing the sites and the technical solutions that were already in place before the start of the project. This information has been compiled, assessed and summarized in this deliverable.

The same KPIs will be later used to compare the performance of the demo cases, after the NextGen solutions have been deployed, and **quantify relevant improvements**.

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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
$Ca_5(PO_4)_3OH$ Struvite PK-Fertilizer	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] [%]
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 & Nitrogen and phosphorus content, total and volatile solids content

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

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Materials	KPIs proposed	Parameter to be determined
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)

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Baseline Conditions

#1. Braunschweig (Germany)

#1.1. General description of the site

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

#1.2. State of play at the start of NextGen

Scale

The wastewater treatment plant treats the wastewater of 350.000 PE.

Description of the pre-existing system

The WWTP treats on average 20.7 million m^3 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.

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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 2.45 kg VS/(m^3*d). Their volumes are 2,100 m^3, 4,450 m^3 and 4,450 m^3. On average, they produce 470 Nm^3 biogas/h with a methane content of around 61%. Thus, the corresponding methane yield is 0.26 Nm^3 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 pre-existing treatment scheme

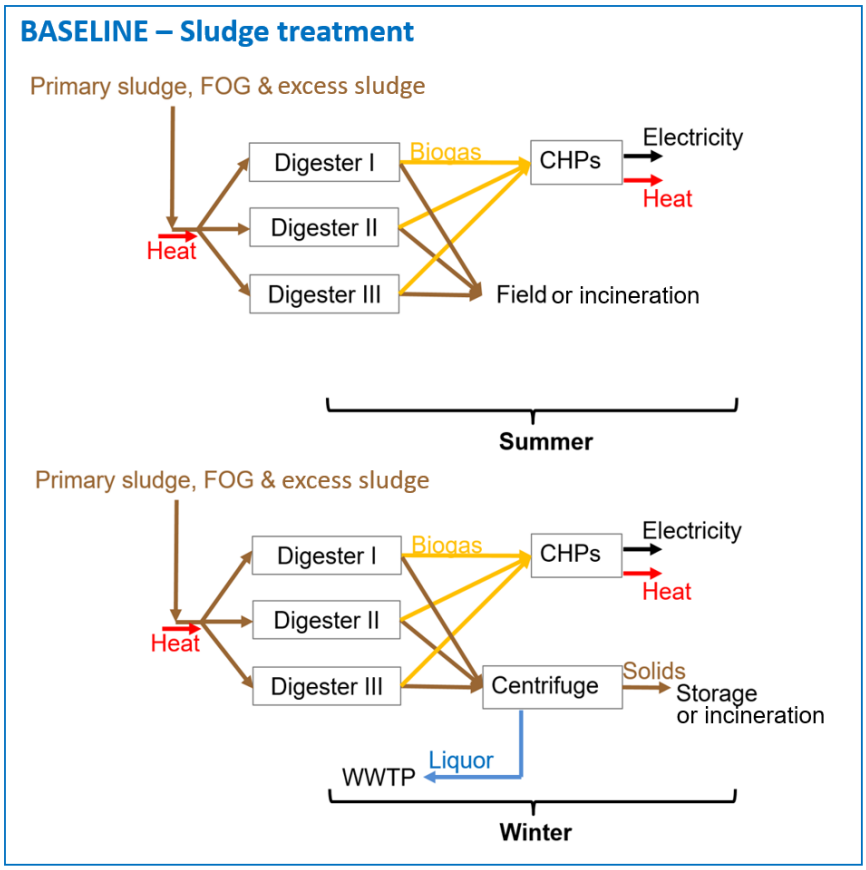

Figure 2. Scheme of the baseline scenario without NextGen technologies in Braunschweig

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.

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#1.3. Baseline conditions

Table 2a and 2b summarize the baseline conditions that existed in the case study **before** the start of NextGen. These data were collected in D1.1 to be made available to other workpackages (e.g. in the analysis performed within WP2) and be compared with the results obtained **after** NextGen solution to quantify improvements.

Table 2a. Summary of baseline conditions for the Braunschweig site for energy.

BASELINE - CURRENT SYSTEM			Units	Mean	Min	Max	Standard deviation	Frequency and number of measurements	Comments
	Digester I	Organic loading rate	kg VS/(m^3*d)	3,90	2,60	4,90			
		Digester Volume	m^3	2.100	2.100	2.100			
		Gas production rate	Nm^3/h	122	45	193	52	continuous flow measurement	2013-2018
		Methane content	%	60	60	61	1	continuous flow measurement	2017-2018
		Methane yield	Nm^3 CH_4/(kg VS)	0,21	0,12	0,27			
	Digester II	Organic loading rate	kg VS/(m^3*d)	1,8	1,6	2,0			
		Digester Volume	m^3	4.450	4.450	4.450			
		Gas production rate	Nm^3/h	174	92	300	71	continuous flow measurement	2013-2018
		Methane content	%	62	61	62	1	continuous flow measurement	2017-2018
		Methane yield	Nm^3 CH_4/(kg VS)	0,32	0,19	0,50			
	Digester III	Organic loading rate	kg VS/(m^3*d)	2,40	1,60	2,90			
		Digester Volume	m^3	4.450	4.450	4.450			
		Gas production rate	Nm^3/h	173	72	253	60	continuous flow measurement	2013-2018
		Methane content	%	61	61	61	-	continuous flow measurement	2017-2018
		Methane yield	Nm^3 CH_4/(kg VS)	0,24	0,15	0,29			
	All	Total Organic	kg VS/(m^3*d)	2,45	1,80	2,90			
		Digester Volumes	m^3	11.000	11.000	11.000			
		Gas production rate of all digestors	Nm^3/h	470	413	516	42	continuous flow measurement	2013-2018
		Methane content	%	61	61	61	1	continuous flow measurement	2017-2018
		Methane yield	Nm^3 CH_4/(kg VS)	0,26	0,31	0,24			

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Table 2b. Summary of baseline conditions for the Braunschweig site for material

BASELINE - CURRENT SYSTEM									
Parameter			**Units**	**Mean**	**Min**	**Max**	**Standard deviation**	**Frequency and number of measurements**	**Comments**
Flow rates	Wastewater to the WWTP	Flowrate	m^3/a	20.685.280	19.561.080	22.302.960	1.193.865	**yearly average values of 6 years (2013-2018)**	2013-2018
	Effluent from WWTP	Flowrate	m^3/a	20.130.850	18.900.500	22.245.600	1.446.054	**yearly average values of 6 years (2013-2018)**	2013-2018
	Summer: Digestate to **field**	Massflow	m^3/a	87.525	65.374	103.810	14.499	**yearly average values of 6 years (2013-2018)**	In summer, the digestate is directly
	Winter: Solids from WWTP to **storage --> field**	Massflow	t/a	2.305	2.274	2.336	44	**yearly average values of 2 years (2017-2018) since incineration is in operation**	2017-2018
	Summer & Winter: Solids from WWTP to **incineration**	Massflow	t/a	6.388	5.677	7.099	1.005	**yearly average values of 2 years (2017-2018) there was no operation before**	2017-2018
N- & P-concentrations & TS and VS contents	Wastewater to (the WWTP) primary clarifier, after sand trap	TP	mg P /l	11	9	12	1	yearly average values of 6 years	2013-2018
		TN	mg N /l	74	67	79	4	yearly average values of 6 years	2013-2018
		terable substan	mg/L	277	233	327	34	yearly average values of 6 years	2013-2018
		COD_{hom}	mg/L	778	684	836	55	yearly average values of 6 years	2013-2018
		COD_{filt}	mg/L	401	361	438	26	yearly average values of 6 years	2013-2018
		TS_{calc}	mg/L	544	474	596	40	yearly average values of 6 years	2013-2018
		VS_{calc}	% TS	95	92	99	3	yearly average values of 6 years	2013-2018
	Effluent from WWTP	TP	mg P /l	0,7	0,54	0,83	0,11	yearly average values of 6 years	2013-2018
		TN	mg N /l	12	10	14	1	yearly average values of 6 years	2013-2018
		Filterable subst	mg/L	11	8	19	4	yearly average values of 6 years	2013-2018
		COD_{hom}	mg/L	42	37	46	3	yearly average values of 6 years	2013-2018
		COD_{filt}	mg/L	33	31	35	1	yearly average values of 6 years	2013-2018
		TS_{calc}	mg/L	33	28	42	5	yearly average values of 6 years	2013-2018
		VS_{calc}	% TS	85	65	91	10	yearly average values of 6 years	2013-2018
	Summer: Digestate to field	TP	g P_2O_5 /(kg TS)	75	71	79	3	yearly average values of 6 years	2013-2018
		TN	g N /(kg TS)	75	66	97	12	yearly average values of 6 years	2013-2018
		TS	%	2,6	2,4	3	0,2	yearly average values of 6 years	2013-2018
		VS	% TS	70	69	71	1	yearly average values of 6 years	2013-2018
	Winter: Solids from WWTP to storage --> field	TP	g P_2O_5 /(kg TS)	75	75	75	0	yearly average values of 2 years	2017-2018
		TN	g N /(kg TS)	59	58	60	1	yearly average values of 2 years	2017-2018
		TS	%	24	23	24	0,3	yearly average values of 2 years	2017-2018
		VS	% TS	70	69	70	1	yearly average values of 2 years	2017-2018
	Summer & Winter: Solids from WWTP to incineration	TP	g P_2O_5 /(kg TS)	75	75	75	0	yearly average values of 2 years	2017-2018
		TN	g N /(kg TS)	59	58	60	1	yearly average values of 2 years	2017-2018
		TS	%	24	23	24	0,3	yearly average values of 2 years	2017-2018
		VS	% TS	70	69	70	1	yearly average values of 2 years	2017-2018

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#1.4. Objectives of the NextGen solutions for Braunschweig

The Braunschweig case study demonstrates strategies for closing the **material** and **energy** cycles via the recovery of phosphorus as struvite, the recovery of nitrogen as ammonium sulphate solution and the recovery of energy in the form of biogas and heat. Therefore, the implementation of a thermal pressure hydrolysis between the two stages of the anaerobic digestion system will increase the recovered energy due to an increase in the methane yield of the system. In addition, the internal heat management will be analysed and different operational strategies will be checked to make the maximum use of the available heat.

#1.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for Braunschweig

Table 3 collects the specific KPIs for Braunschweig, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

Table 3. Objectives and specific KPI for the Braunschweig case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#1 Braunschweig (DE)	Energy	To produce and recover biogas	Methane yield [m³ CH_4/(kg VS)]
		To recover thermal energy	Quantity of reused heat (seasonal) [%]
	Materials	Struvite production	P-recovery rate related to (a) the influent to the WWTP and (b) the influent to the recovery unit [%]
			Plant availability of struvite [%]
		$(NH_4)_2SO_4$ production	N-recovery rate related to (a) the influent to the WWTP and (b) the influent to the recovery unit [%]
			Plant availability for N (minimum efficacy in the year of application in % of the total nitrogen)

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#2. Costa Brava Region (Spain)

#2.1. General description of the site

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 3. Aerial view of the WWTP of Tossa de Mar.

#2.2. State of play at the start of NextGen

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 the pre-existing 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 4).

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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.

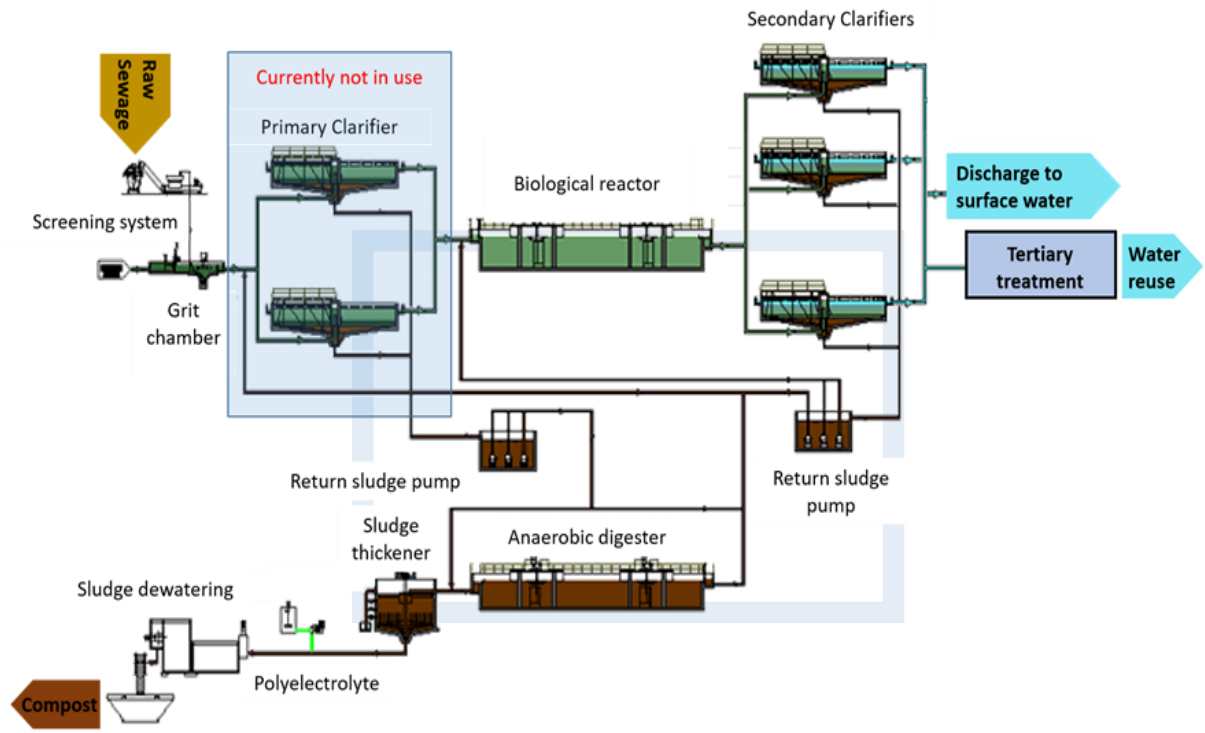

Figure 4. Scheme of the WWTP of Tossa de Mar.

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

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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).

Block diagram of the pre-existing treatment scheme

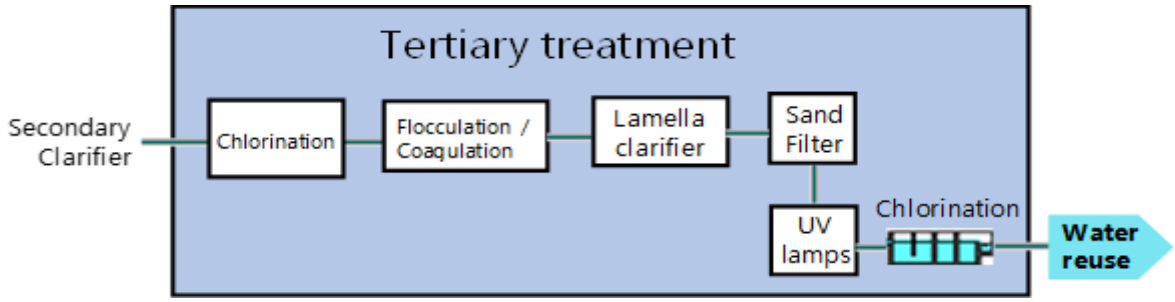

Figure 5. Scheme of tertiary treatment of the WWTP of Tossa de Mar.

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#2.3. Baseline conditions

Table 4 summarizes the baseline conditions that existed in the case study **before** the start of NextGen. These data were collected in D1.1 to be made available to other workpackages (e.g. in the analysis performed within WP2) and be compared with the results obtained **after** NextGen solution to quantify improvements.

Table 4. Summary of baseline condition for the Costa Brava site

		Parameter	Mean value for 2018	Standard deviation	Frequency of the measures	Summer mean value	Standard deviation	Winter mean value	Standard deviation	Considered years for the analysis
Water yield of the system	**Effluent form secondary treatment**	Flowrate (m^3/h)	7,4	3,1	Every day	11,0	2,2	4,5	0,8	2018
	Effluent from the tertiary treatment	Flowrate (m^3/h)	0,5	1,1	Every day	1,0	0,2	1,2	2,0	2018
	Effluent from the sand filter (inlet to NextGen processes)	Flowrate (m^3/h)	0,5	1,1	Every day	1,0	0,2	1,2	2,0	2018
Water quality	**Effluent form secondary treatment**	COD (mg O_2 /l)	42,6	10,3	Once/ week (winter) Twice / week (summer)	50,0	5,4	33,3	3,2	2017 / 2018
		BOD_5 (mg O_2 /l)	7,3	3,1	Once/ week	9,0	4,3	5,3	1,9	2017 / 2018
		pH	7,6	0,1	Once/ week	7,6	0,1	7,5	0,2	2018
		CE (µS/cm)	1455	166	Once/ week	1591	31	1298	195	2018
		TSS (mg/l)	10	5	Once/ week	14	5	6	1	2018
		Turbidity (NTU)	5,7	2,5	Once/ week	7,0	2,1	3,1	0,6	2018
		Redox (ut. pH)	101	13	Once/ week	92	8	110	15	2018
		Disolved O_2 (mg O_2/l)	Not measured							2018
		N Kjeldahl (mg N/l)	36	11	Once/ week	42	7	22	8	2018
		N- NH_4^+ (mg N/l)	34	11	Once/ week	41	7	20	8	2018
		N- NO_3^- (mg N/l)	0,3	0,2	Once/ week	0,2	0,1	0,5	0,3	2018
		N-NO_2^- (mg N/l)	0,1	0,2	Once/ week	0,05	0,04	0,3	0,2	2018
		Total nitrogen (mg N/l)	36	11	Once/ week	42	7	23	8	2018
		Total phosphorus (mg P/l)	4	2	Once/ week	4	2	3	1	2018
		E.coli (CFU/100 ml)	340917	598913	Twice / week	487000	848244	76500	59231	2018
		Legionella spp. (CFU/l)	Not measured							2018
		Intestinal Nematodes (egg/10l)	Not measured							2018

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	Parameter	Mean value for 2018	Standard deviation	Frequency of the measures	Summer mean value	Standard deviation	Winter mean value	Standard deviation	Considered years for the analysis
	Somatic bacteriophage (CFU/100ml)	79433	71388	Once / month	95800	80145	85000	79272	2018
	Aerobic bacteria (CFU/100ml)	132283	98144	Once / month	222000	78230	46600	30602	2018
Effluent form tertiary treatment	COD (mg O_2 /l)	Not measured. Assumption: similar values of secondary effluent							2018
	BOD_5 (mg O_2 /l)	Not measured. Assumption: similar values of secondary effluent							2018
	pH	7,7	0,2	Once / week	7,6	0,1	7,7	0,2	2018
	CE (µS/cm)	1538	147	Once / week	1648	46	1407	164	2018
	TSS (mg/l)	6	2	Once / week	8	2	4	1	2018
	Turbidity (NTU)	3,6	0,9	Twice / week	4,5	0,3	2,6	0,6	2018
	Redox (ut. pH)	277	47	Once / week	253	31	282	46	2018
	Disolved O_2 (mg O_2/l)	7	2	Once / week	5	1	8	1	2018
	N. Kjeldahl (mg N/l)	Not measured. Assumption: similar values of secondary effluent							2018
	N- NH_4^+ (mg N/l)	Not measured. Assumption: similar values of secondary effluent							2018
	N- NO_3^- (mg N/l)	*Not measured. Assumption: similar values of secondary effluent*							2018
	N-NO_2^- (mg N/l)	Not measured. Assumption: similar values of secondary effluent							2018
	Total nitrogen (mg N/l)	Not measured. Assumption: similar values of secondary effluent							2018
	Total phosphorus (mg P/l)	Not measured. Assumption: similar values of secondary effluent							2018
	E.coli (CFU/100 ml)	1	0	Twice / week	1	0	1	0	2018
	Legionella spp. (CFU/l)	50	0	Once / month	50	0	50	0	2018
	Intestinal Nematodes (egg/10l)	1	0	Once / month	1	0	1	0	2018
	Somatic bacteriophage (PFU/100ml)	15	9	Once / month	18	15	13	5	2018
	Aerobic bacteria (CFU/100ml)	16341	18464	Once / month	22403	21086	16367	23808	2018
Effluent from the sand filter (inlet to NextGen processes)	COD (mg O_2 /l)	< 50 (LOQ)	-	3 times / year	< 50	1 measure	54,7	1 measure	2019
	BOD_5 (mg O_2 /l)	Not measured. Assumption: similar values of secondary effluent							
	pH	7,9	0,1	3 times / year	7,9	1 measure	7,8	1 measure	2019
	CE (µS/cm)	1789	167	3 times / year	1590	1 measure	2000	1 measure	2019
	TSS (mg/l)			3 times / year		1 measure		1 measure	2019
	Turbidity (NTU)	8,3	0,2	3 times / year	6,4	1 measure	10	1 measure	2019
	N Kjeldahl (mg N/l)	Not measured. Assumption: similar values of secondary effluent							2019
	N- NH_4^+ (mg N/l)	43,0	0,9	3 times / year	42	1 measure	44	1 measure	2019
	Total phosphorus (mg P/l)	3,4	0,5	3 times / year	2,8	1 measure	3,9	1 measure	2019
	E.coli (CFU/100 ml)	0	-	Twice / year	0	1 measure	0	1 measure	2018

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		Parameter	Mean value for 2018	Standard deviation	Frequency of the measures	Summer mean value	Standard deviation	Winter mean value	Standard deviation	Considered years for the analysis
		Legionella spp. (CFU/l)	< 70	-	Twice / year	< 70	1 measure	< 70	1 measure	2018
		Intenstinal Nematodes (egg/10l)	< 1	-	Twice / year	< 1	1 measure	< 1	1 measure	2018
		[Trace organic] (ng/L)	The measurements have been started the October 2018 by Eurecat							2018
Energy consumption	**Tertiary treatment**	Whole plant (kWh/m^3)	0,8	0,1		0,8	0,1	0,8	0,1	2018
		Coagulation/Floculation + Chlorination (kWh/m^3)	Not measured individually							2018
		Sand filter	Not measured individually							2018
		UV lamps	Not measured individually							2018
Reagents & materials required	**Tertiary treatment**	Coagulant PAX (g/m^3)	43	40		80	22	0	0	2018
		Flocculant Hyfloc SS140 polyelectrolyte (g/m^3)	0,01	0,01		0,02	0,01	0,00	0,00	2018
		Sodium hypochlorite pre-chlorination (g/m^3)	123	16		121	12	116	19	2018
		Sodium hypochlorite post-chloration (g/m^3)	62	75		45	24	30	19	
		Antiscaling agents (g/m^3)	0	0		0	0	0	0	2018
		Sand (filter) (g/m^3)								2018
		UV lamps (nº lamps/year)	2016 --> 3 units; 2017 --> 3 units; 2018 --> 1 unit (a medium pressure UV lamps (Berson Inline 400 Special 10 kW) with a theoretical maximum dose of 48 mJ/cm^2)							2016 - 2018
Waste produced	**Tertiary treatment**	Polluted sand (g/m^3)	4,4	6,8		6,0	6,9	0,0	0,0	2018 / 2017
		Flocculated / coagulated waste (g/m^3)	39	24		28	11	37	28	2018
		Moisture of the floc/coag. Waste (%)	Not determined.							2018
		UV lamps at the end-of-life (nº lamps/year)	2016 --> 3 units; 2017 --> 3 units; 2018 --> 1 unit (a medium pressure UV lamps (Berson Inline 400 Special 10 kW) with a theoretical maximum dose of 48 mJ/cm^2)							2016 - 2018

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#2.4. Objectives of the NextGen solutions for Costa Brava

The Costa Brava case study demonstrates strategies for closing the **water** and **material** cycles via the regeneration of disposed reverse osmosis (RO) membranes in order to obtain different molecular cut-offs to be used for ultrafiltration (UF) and nanofiltration (NF) processes. The purpose of the reuse water will comprise private garden irrigation and indirect water reuse. Due to the regeneration of the RO membranes, their time-life will be increased, and thus, the generated quantity of this waste will be diminished.

#2.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for Costa Brava

Table 5 collects the specific KPIs for Costa Brava, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

Table 5. Objectives and specific KPI for the Costa Brava case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#2 Costa Brava (ES)	Wastewater treatment and reuse	To increase the production of regenerated water for private garden irrigation	Water yield of the system [% of regenerated water produced]
		To reduce the salinity of the effluent	Salt rejection yield (% salt removal vs inlet flow)
		To reduce the content of trace organic compounds (TrOCs) of the regenerated water	Global removal yield for several priority/emergent pollutants [%]
		To reduce the TSS and turbidity of the effluent	TSS and turbidity removal yield vs inlet flow to the system [%]
		To reduce the pathogens content of the effluent	*[E.coli]* final effluent [CFU/100mL]
			[Intestinal nematodes] final effluent [egg/L]
			[Legionella spp.] final effluent [CFU/100mL]
	Energy	To reduce electricity consumption of the Nextgen UF & NF processes compared with conventional ones	Electricity consumption [kWh/m^3 regenerated water]
	Materials	Evaluation of the viability of the RO recycled membranes	Flux [l m^{-2} h^{-1}] related to transmembrane pressure [bar]
			Salt rejection [%] compared to a commercial membrane of the same type

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#3. Westland Region (Netherlands)

#3.1. General description of the site

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 6), 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.

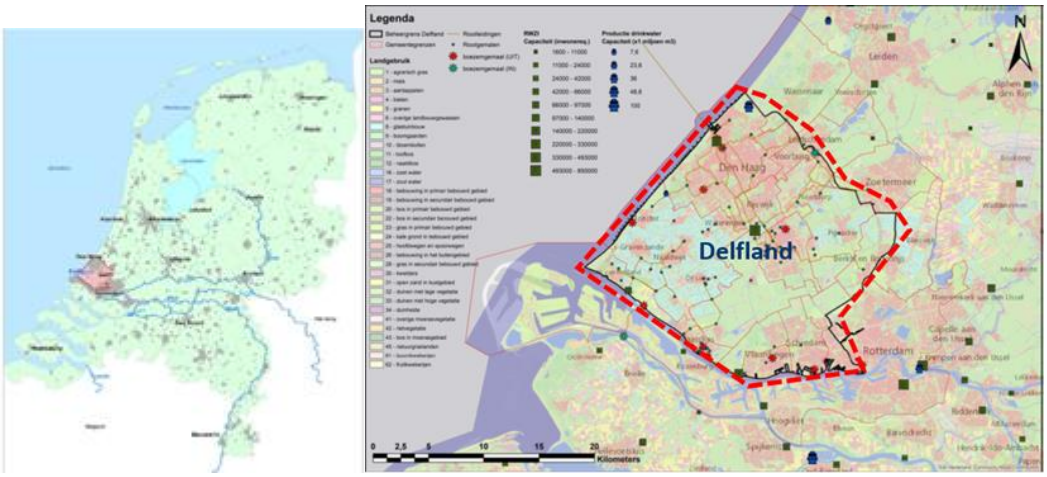

Figure 6. Region of Delfland including the Westland horticulture region in the Netherlands.

#3.2. State of play at the start of NextGen

Scale

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

Delfland total surface area: 405 km^2

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

0.52 M households served

100-150 PJ Waste heat supply (industry)

40,000 industries served

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

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Description of the pre-existing system

The water system of Delfland/Westland

Distinguished are the surface water, ground water and rainwater system.

- Surface water system. The main principle of the water system in the Delfland/Westland region is based on water level management. This as well for the rural as the urban area. When the water level in the channels and ditches exceeds a pre-established value the excess of water is quickly discharged to the rivers and sea. When the level is lower than the pre-established value water is let in from the rivers. So in periods of drought the surface water system is filled by external surface water from the rivers and in the case of Delfland especially from the Brielse Meer. The area of Delfland is similar with the catchment area of the waterboard Delfland (Hoogheemraadschap van Delfland).

-Ground water. Because the region of Delfland is located near the Northsea and parts of the ground level are below sea level the is a predominantly seepage of brackish/saline water. Therefor the groundwater in the Delfland region is predominantly brackish/saline and is in the range of about 200 – 6000 mg Cl/L (till about 1/3 of the salinity of sea water).

-Rainwater. The annual average amount of rainwater is about 845 mm/year. The horticulture uses rainwater as freshwater irrigation water. In general rainwater is used to maintain water levels.

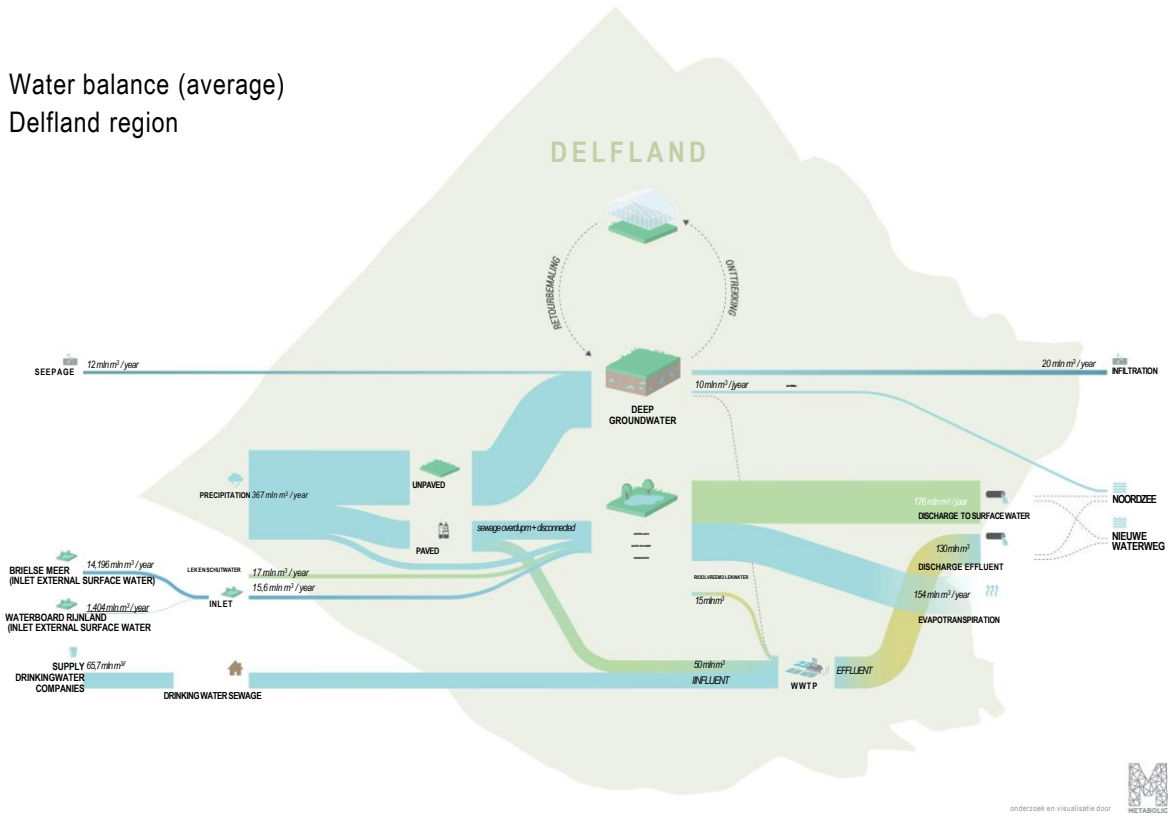

Figure 7 Quantification of the various freshwater sources in the Delfland region. Main sources are precipitation, inlet of the surface water and inlet of water for the production of drinking water.

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Drinking water provision/wastewater supply (waterchain)

Drinking water is provided by the drinking water companies of Delfland and Evides. Both drinking water companies prepare the drinking water out of surface river water. This water is temporary stored into the sandy dunes along the shore or into large water basins. The raw water is purified and transported as drinking water to the households, industries etc. In general the drinking water is of an high quality and is not chlorinated.

After using, the water is drained by a mixed or separate sewage system to the wastewater treatment plants where it is partly purified and discharged in the river or sea. In the Delfland region there are four wastewater treatment plants (WWTPs);

- Harnaschpolder/Houtrust. Developments relate to resource recovery (nutrients) and energy recovery (fermentation)

- Groote Lucht. Developments on this location relate to the reuse of freshwater ('waterfactory). The effluent is complementary purified by nature-based solutions (waterharmonica)

- Hoek van Holland. Developments relate to waterpurification and development of a central collective waterpurification system for treatment of horticulture wastewater and waterreuse.

The Urban water system.

Cities as Rotterdam, Delft and The Hague are (partly) located in the Delfland region. The main principle is water level management (see surface water system). In addition, the water policy in cities is mainly focused to prevent flooding. Surplus of water at extreme showers is quickly discharged through the sewage water system towards the rivers. Moreover, through this policy and hardening of the surface groundwater levels are often nog supplemented with enough water.

Water and energy in horticulture

The horticulture (Westland) which is a large sector in the Delfland region prefere the use of rainwater as irrigation water source. The water quality criteria are high, them sodium concentration in the irrigation water has to be below the 0.5 mmol Na/L (approximately 10 – 15 mg Na/L). Frequently exceed of these limits can result in crop damage. This means in practice that rainwater is the only water source which satisfies these criteria. Other water sources have to treated and desalinated by reverse osmosis. To harvest and collect the rainwater, the horticulture companies make use of water basins. The average size of the water basins is about 800 m^3/ha (= 80 mm/ha). This means that only a part of the annual rainfall (average 845 mm) is effectively captured. However, in periods of shortage of rainwater, the farmers use brackish/saline groundwater as an additional water source. This water is desalinated by reverse osmosis (RO). The freshwater fraction is used as irrigation water, the membrane concentrate is discharged into deeper subsurface (saline) aquifers. The discharge of membrane concentrate into the subsurface is from an environmental and policy point of view unwanted and discussed. The r=main reason is that in time it results in an increasing salinity of the groundwater system.

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In the current greenhouses water, gas, and power are utilized as shown in Figure 9. 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.

The surface water quality in especially the Westland horticulture region is poor and polluted with too much nutrients and pesticides (also called plant productions products (PPPs). In order to improve the water quality the horticulture farmers are obliged by law to purify the drain water to achieve a reduction in the emission of pesticides by at least 95%.

The water use in the horticulture greenhouses is very efficient. About 85% of the farmers cultivate crops on substrate water basis. The roots of the plants are 'connected' with the substrate water system. The irrigation water is recirculated continuously, nutrients are added when required and the water is disinfected by UV radiation. The water is drained when sodium concentrations exceeds the limit of about 0.5 mmol Na/L.

The farmers are free in the choice of the water purification equipment, but the equipment has to be certified, which means that the selling company must demonstrate before that the reduction of emission of pesticides can be achieved.

Moreover, it is possible that the farmers combine the wastewater streams and purify it collectively or central collective purified at the wastewater treatment plant (WWTP location Hoek van Holland).

Energy. 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.

ASR systems

The purpose of an ASR (Aquifer Storage Recovery) system is to store excess of rainwater in a subsurface aquifer and recover it again when irrigation water is needed and water in the basin is depleted. In general above ground space is limited in the Westland horticulture area. Therefore, the average size of the water basin in the Westland is relatively small and only collect a part of the rainwater. To harvest the rainwater more effective an ASR system was developed and applied for the Westland situation. Figure 7-2 shows a scheme of the ASR system. In the first stage fresh water is injected into the brackish/saline water aquifer. The water is stored and recovered. For the case in the Westland the ASR system is combined with a reverse osmosis (RO) system. This is needed because the recovery of fresh water is decreased due to the presence of saline groundwater. Moreover the water demand with crops as tomatoes the demand exceeds the annual rainwater supply. The membrane concentrate ('brine') is discharged in the deeper subsurface.

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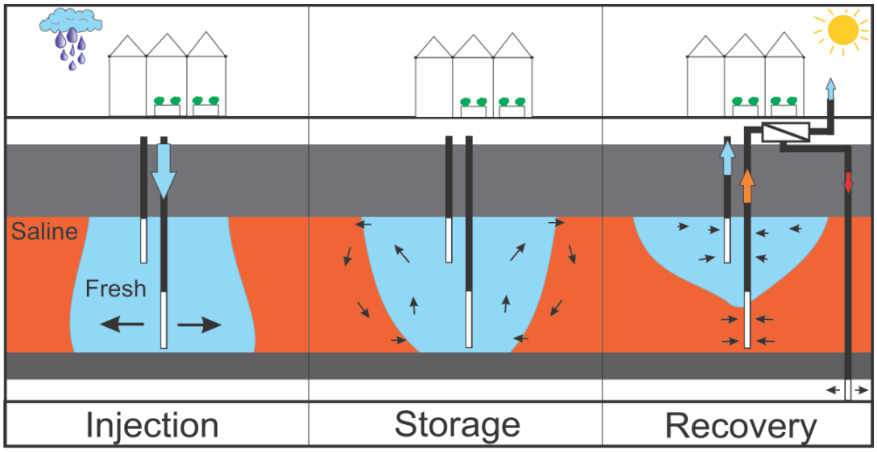

Figure 8. Scheme of the ASR system in the Westland area at Prominent in Gravenzande

In the horticulture area of the Westland aquifers play an important role in balancing the supply and demand in as well freshwater as heat. Excess energy from the industry (harbor area of Rotterdam) will possibly be stored in aquifers by making use of Aquifer Thermal Energy Systems (ATES) during NextGen project.

Block diagram of the pre-existing treatment scheme

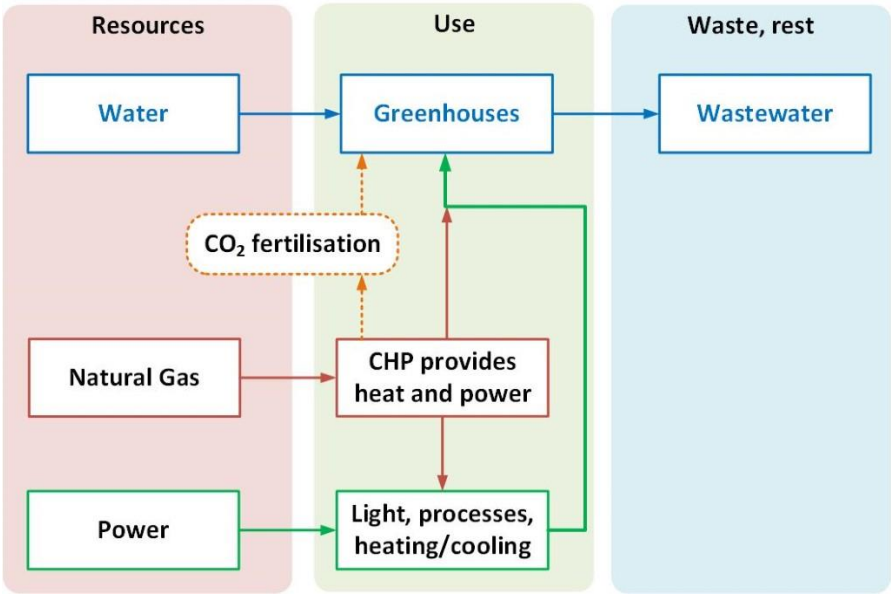

Figure 9. Diagram of the current system in the green houses

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#3.3. Baseline conditions

Table 6 summarizes the baseline conditions that existed in the case study **before** the start of NextGen. These data were collected in D1.1 to be made available to other workpackages (e.g. in the analysis performed within WP2) and be compared with the results obtained **after** NextGen solution to quantify improvements.

Table 6a. Summary of baseline condition for the pre-existing system (ASR) in the Westland case study for water.

		Parameter	Mean value for 2018	Standard deviation	Comments
Water yield of the system	**Current system**	Rainfall climatology of the area (mm/year or L/m^2/year)	**720**	**ca. 100**	This is the amount of rainwater fallen in the Delfland area (Westland + Rotterdam). The long year average is 845 mm/y. Rainwater harvesting as source for irrigation water is common in horticulture
		Volume of water recovered vs rainfall (m^3/year)	6,500,000	2,000,000	The 6.5 M m^3 is approximately the annual amount of water collected by the horticulture in the Westland area (harvesting efficiency: 40%)
Water quality	**Quality of rainwater harvested**	COD (mg O_2 /l)	32	-	-
		BOD_5 (mg O_2 /l)	5.7	-	-
		pH	6.2	-	-
		TSS (mg/l)	17	-	-
		N Kjeldahl (mg N/l)	1.9	-	-
		Total nitrogen (mg N/l)	1.9	-	-
		Total phosphorus (mg P/l)	0.4	-	-
Energy consumption	**Current water storage / infiltration / pumping system**	Whole system (kWh/m^3)	0.55	-	-

Table 6b. Summary of baseline condition for Aquifer Thermal Energy Storage (ATES) systems in Westland

		Parameter	Mean value for 2018	Standard deviation	Comments
Aquifer Thermal Energy Storage systems (ATES)	**Primary energy**	Reduction of consumption (%)	50		
	Thermal	T cold well (^{0}C)	5		
		T warm well (^{0}C)	18		
		Heat demand warm well (TJ)	23		
		Cooling demand cold well (TJ)	16		

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#3.4. Objectives of the NextGen solutions for Westland

The main objective of the Westland demo case is the **demonstration of an integrated approach for a circular water system at the Delfland region**. In the region already numerous initiatives exist of circular technologies related to e.g. rainwater harvesting and reuse in horticulture, aquifer thermal energy storage, and resource recovery from WWTPs. In NextGen, a regional management strategy for a circular water-energy-materials system will be implemented, supported by a CoP to have active cooperation between stakeholders.

The key innovations and actions:

1. For the transition towards a more **circular water** system in the Delfland region, an integrated assessment of performance of technologies and strategies will be done. This assessment will include:
   - the use of alternative water sources (through region-wide rainwater storage and reuse using large scale *Aquifer Storage & Recovery* systems *(ATES)* and *reuse of WWTP effluent*) and advanced water treatment systems (*recycling and purification*) for the ***horticulture*** sector,
   - and several ***urban*** water management systems (*rainwater harvesting, grey water recycling, green roofs and domestic water saving*).
2. For an integrated **water-energy** approach in the Delfland region, the contribution of ATES to the overall energy balance will be assessed. This assessment will include:
   - a feasibility study of a *High Temperature-Aquifer Thermal Energy Storage system (HT-ATES)* at the ***horticulture*** Koppert Cress, and the role HT-ATES could play in the South-Holland heat roundabout.
3. For the upscaling of the **recovery of materials and resources** from the water system, a novel business model of reused materials brokerage will be demonstrated.

#3.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for Westland

Table 7 collects the specific KPIs for Westland, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

Table 7. Objectives and specific KPI for the Westland case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#3 Westland Region (NL)	Wastewater treatment	To reduce the emission of PPPs/pesticides in surface water	Water purification units installed on various scale levels (individual/collective/central collective)
	Rainwater harvesting	To increase the self sufficiency of fresh water in the Delfland (Westland) region	% rainwater used for water related functions in cities, horticulture, etc.
	Energy	To develop a High Temperature ATES system	Efficiency comparison with ATES

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#4. Altenrhein (Switzerland)

#4.1. General description of the site

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 10). 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 10. Picture of the drying unit of the sludge treatment stage

#4.2. State of play at the start of NextGen

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.

Description of the pre-existing system

The WWTP of Altenrhein treats on average 24,000 m^3/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%

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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 pre-existing treatment scheme

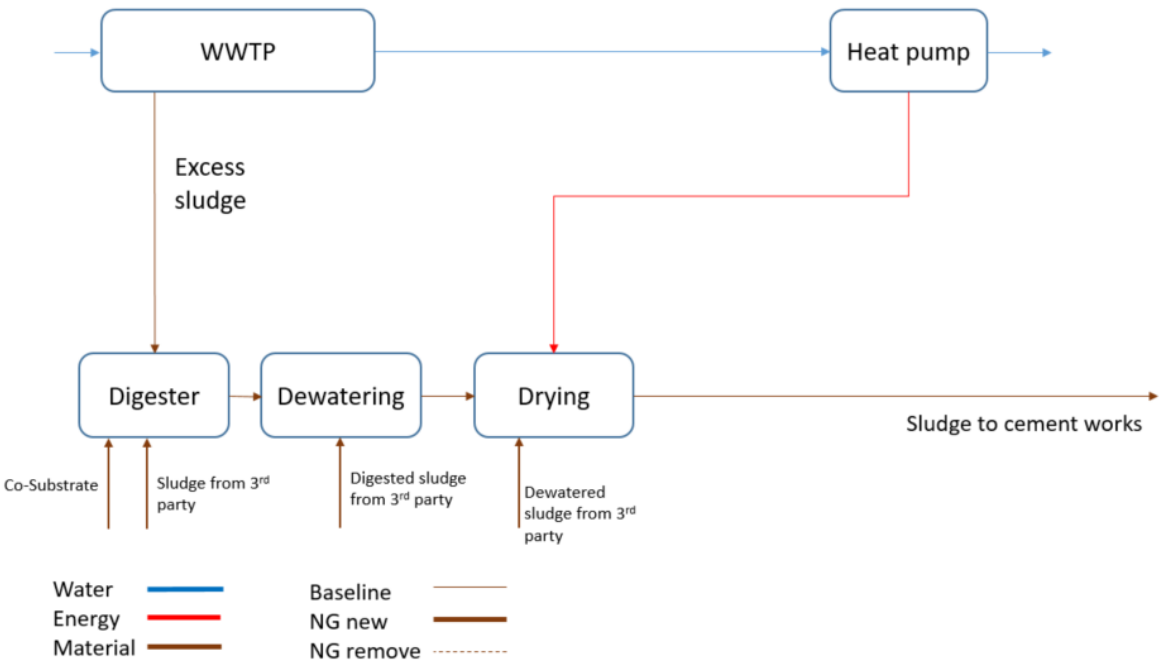

Figure 11. Scheme of the baseline scenario without NextGen technologies in Altenrhein

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#4.3. Baseline conditions

Table 8 summarizes the baseline conditions that existed in the case study before the start of NextGen. These data were collected in D1.1 to be made available to other workpackages (*e.g.* in the analysis performed within WP2) and be compared with the results obtained **after** NextGen solution to quantify improvements.

Table 8. Summary of baseline condition for the Altenrhein site.

BASELINE - CURRENT SYSTEM									
Parameter			**Units**	**Mean**	**Min**	**Max**	**Standard deviation**	**Frequency and no. of measurements**	**Comments**
Flow rates	Wastewater to the WWTP	Flowrate	m^3/d	**23975**	**8198,4 (1130)**	**120191 (178601)**	**2930**	continuous flow measurement	Min and Max values are means over 5 years with all time min/max in brackets.
	Effluent from the WWTP to the Ozonation	Flowrate	m^3/d	**24285**	**5909,8 (164)**	**71910,8 (76342)**	**1884**	continuous flow measurement	Min and Max values are means over 5 years with all time min/max in brackets.
N- & P-concentrations & TS and VS contents	Wastewater to the WWTP	TP	mg P /l	6,2	0,9	12,9	0,6	160	mean samples per year, over a course of 5 consecutive years (2013 - 2017)
		TN	mg N /l	33,8	7,2	60,2	1,9	160	
		TS	mg TS /l	266,6	40,4	911,2	32,5	160	
		VS	% TS	n.a.	n.a.	n.a.	n.a.	n.a.	no data was measured by ARA
	Effluent from the WWTP to the Ozonation	TP	mg P /l	0,21	0,07	0,50	0,02	164	
		TN	mg N /l	24,60	7,40	50,00	3,05	160	
		TS	mg TS /l	2,62	0,48	8,32	0,45	166	
		VS	% TS	44	n.a.	n.a.	23	n.a.	no min/max values were measured by

Parameter			**Units**	**Value or Range**	**Comments/Referenz**
GAC	Reference values of commercial available GAC	Active surface	m^2/g	800 - 1200	Henning, K.-D., & Kienle, H. von. (2010). Carbon, 5. Activated Carbon. In Ullmann's Encyclopedia of Industrial Chemistry. https://doi.org/10.1002/14356007.n05_n04
		EBCT	min	~ 15	EMV Project of ARA Altenrhein describs a flow of 80l/s for each of the 8 filter cells (47 m2). This leads to a vFilter of 0.102 m/min. With a GAC height of 1.5 m, which is considered standard, EBCT is calculated: hGAC/vFilter = 14.7 min (Source: AVA
PK-fertilizer	Reference values of commercial available PK-	Plant availabili ty	%	100	Plant availability of P in Triplesuperphosphate

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#4.4. Objectives of the NextGen solutions for Altenrhein

For an advanced sludge management, the implementation of a pyrolysis process is planned to produce granular activated carbon (GAC) from sewage sludge and local biomass. The pyrolysis process will also be used for the production of a PK-fertilizer, which is upgraded with an external source of potassium. The waste heat of the pyrolysis process shall be used for district heating or for sewage sludge drying. Furthermore, a plant for nitrogen recovery via a stripping membrane system will be implemented in order to recover ammonia for the production of ammonium sulphate solution.

#4.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for Altenrhein

Table 9 collects the specific KPIs for Altenrhein, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

Table 9. Objectives and specific KPI for the Altenrhein case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#4 Altenrhein (CH)	Materials	PK-fertilizer or NPK(S)-fertilizer production	P-recovery rate related to (a) the influent to the WWTP and (b) the influent to the recovery unit [%]
			Plant availability of the PK-fertilizer [%]
		$(NH_4)_2SO_4$ production	N-recovery rate related to (a) the influent to the WWTP and (b) the influent to the recovery unit [%]
		Renewable granulated activated carbon (GAC) viability	Adsorption capacity compared to that of commercially available activated carbon [%] via active surface (BET)
			Lifetime until renewal compared to commercially available activated carbon (EBCT)

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#5. Spernal (United Kingdom)

#5.1. General description of the site

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 12. Aerial view of the Spernal WWTP.

#5.2. State of play at the start of NextGen

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

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Description of the pre-existing 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 13.

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 13). 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 13, 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 pre-existing treatment scheme

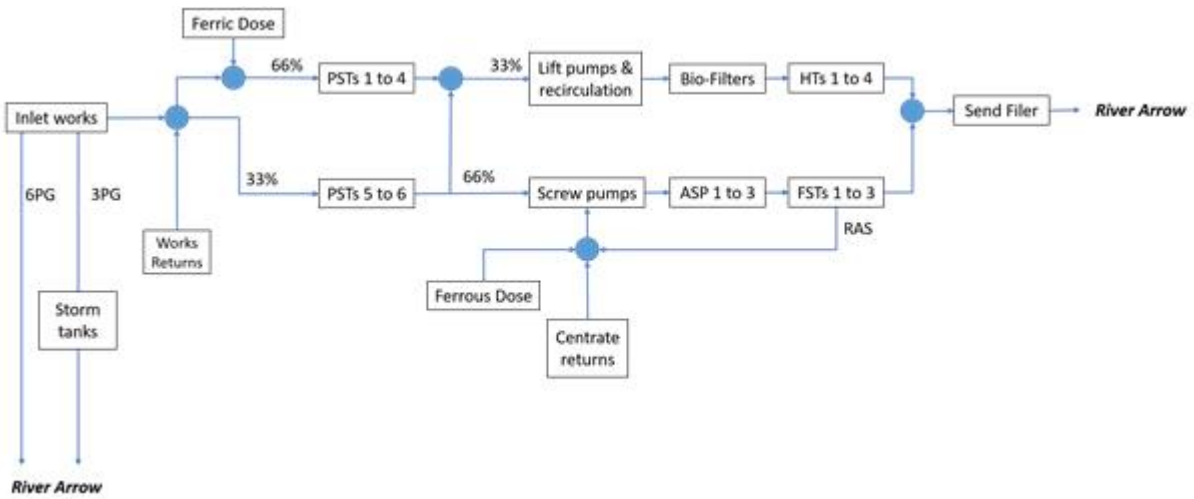

Figure 13. Scheme of the existing WWTP of Spernal (PST: Primary settlement tank; ASP: activated sludge process; HT: homogenize tank; FST: final settlement tank; RAS: returned activated sludge).

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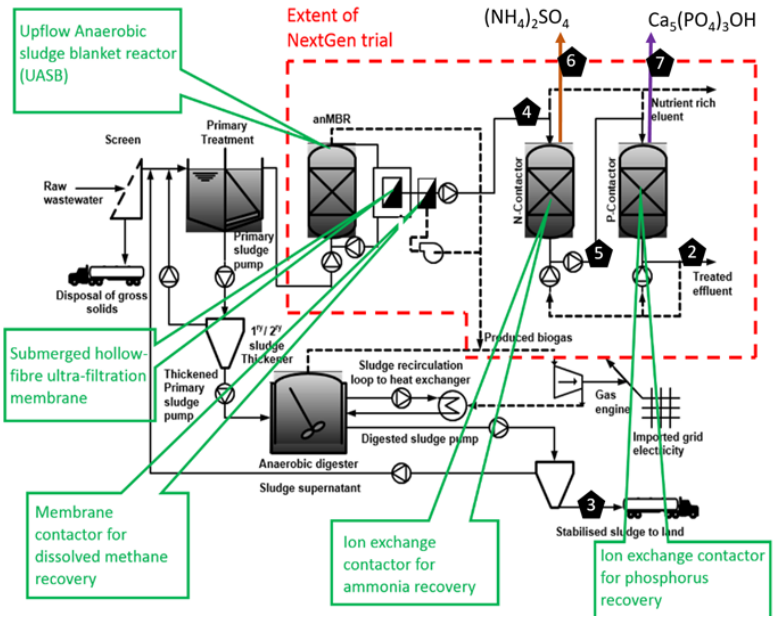

Figure 14. Scheme of the Spernal WWTP with the NextGen.

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#5.3. Baseline conditions

Table 10a, 10b and 10c summarize the baseline conditions that existed in the case study **before** the start of NextGen. These data were collected in D1.1 to be made available to other workpackages (*e.g.* in the analysis performed within WP2) and be compared with the results obtained **after** NextGen solution to quantify improvements.

Table 10a. Summary of baseline condition for the Spernal site for water.

Parameter			Units	Mean value for 2018	Standard deviation	Frequency of the measures	Summer mean value	Standard deviation	Winter mean value	Standard deviation	Considered years	Comments
Water yield of the system	Influent to the Spernal WWTP	Flowrate	m^3/h	1267	447	Daily	1114	344	1422	484	2018	
	Effluent from the Spernal WWTP	Flowrate	m^3/h	1097	324.7	Daily	921.4	195.8	1283.7	330.7	2018	
Water quality	Influent to the Spernal WWTP	COD	mg O_2 /l	861.2	520.8	Twice per month	947.7	604.5	759	405.1	2018	
		BOD_5	mg O_2 /l	276.1	172.3	Twice per month	322.7	192.8	221.09	132.3	2018	
		TSS	mg/l	515.2	300.6	Twice per month	536.9	358.3	489.6	228.9	2018	
		Total nitrogen	mg/l	32.6	7.15	twice per month	34.7	4.33	30	9	2018	
		N- NH4+	mg N/l	31	8.22	Twice per month	34.2	4.58	27.2	10	2018	
		Total phosphorus	mg P /l	7.49	3.33	Twice per month	8.46	3.5	6.34	2.87	2018	
	Effluent from the Spernal WWTP	COD	mg O_2 /l	44.6	11.5	Twice per month	43.69	11.1	45.7	12.46	2018	
		BOD_5	mg O_2 /l	3.62	2.69	Twice per month	4.2	2.7	2.9	2.62	2018	
		TSS	mg/l	9.79	6.85	Twice per month	7.2	3.65	12.8	8.57	2018	
		Total nitrogen	mg/l	34.5	5.18	Twice per month	34.09	5.56	35.04	4.92	2018	

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		N- NH4+	mg N/l	2.38	1.08	Twice per month	1.98	0.95	2.85	1.07	2018	
		Total phosphorus	mg P /l	1.18	0.3	Twice per month	1.25	0.29	1.09	0.31	2018	
Energy consumption	**Spernal WWTP**	Whole plant	kWh	3,909,703	-	-	-	-	-	-	2018	For year 1st April 2018 to 31st March 2019 Spernal consumed 3,909,703kWh with a cost for the import electricity of £73,647. Details: Site (CHPs) produced 4,645,443kWh, exported 1,224,711kWh and imported 491,873kWh (hence the cost).
Reagents required	**Spernal WWTP**	Ferric sulphate	kg/month	27000	-	-	-	-	-	-	2018	Ferric sulphate dosed into 4 of 6 primary settling tanks fro P removal.
		Ferrous chloride	kg/month	27000	-	-	-	-	-	-	2018	Ferous chloride dosed into activated sludge process.
		Polymer_thickening	kg/month	1000	-	-	-	-	-	-	2018	Surplus activated sludge thickening
		Polymer_dewatering	kg/month	6000	-	-	-	-	-	-	2018	Digested sludge dewatering

Table 10b. Summary of baseline condition for the Spernal site for materials.

Parameter			Units	Mean	Min-Max	Standard deviation	Frequency and number of measurements	Comments
Flow rates	**Wastewater to the WWTP**	Flowrate	m^3/d	30411	557-61010	10727	Daily, 357	Inlet FFT flow meter
	Effluent from the WWTP	Flowrate	m^3/d	26329.45	8509-50917	7793.4	Daily, 357	From Mcerts flow meter (2018)
	Solids from the WWTP	Massflowrate	t/d	0.297	0.113-0.712	0.187	Twice per month, 23	OSM sample data from 2018
		TN	g N /l	0.032	0.02-0.048	0.007	Twice per month, 24	UWWTD data from 2018

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Parameter			Units	Mean	Min-Max	Standard deviation	Frequency and number of measurements	Comments
N- & P-concentrations & TS and VS contents	Wastewater to the WWTP	TP	g P /l	0.007	0.003-0.016	0.003	Twice per month, 24	UWWTD data from 2018
		TS	mg/l	515.25	104-1490	300.6	Twice per month, 24	UWWTD data from 2018
		VS	% TS	VS not measured				
	Effluent from the WWTP	TN	mg N /l	32.76	19.75-43.03	6.47	Twice per month, 23	OSM sample data from 2018
		TP	mg P/l	1.2	0.65-1.87	0.29	Twice per month, 23	UWWTD data from 2018
		TS	mg/l	9.79	2-35	6.86	Twice per month, 23	UWWTD data from 2018
	Solids from the WWTP	TN	%DW	4.79	4.17-5.21	0.4	5	Sludge cake data from 2018
		TP	%DW	3.6	3.3-3.9	0.22	5	Sludge cake data from 2018
		TS	%	24.9	22.8-26.8	1.54	5	Sludge cake data from 2018
		VS	% TS	61.2	59.4-62.7	1.35	5	Sludge cake data from 2018

Table 10c. Summary of baseline condition for the Spernal site for materials.

Parameter			Units	Mean	Min-Max	Standard deviation	Frequency and number of measurements	Comments
Digester	#1	Total throughput	ton/day	14.62	2.15 - 23.88	3.24	399 / 94.1%	
		Organic loading rate to Digester	kg VS/(m^3*d)	1.061				The average VS input for 6 sludge sampling was 78.4%
	Digester Volume		m^3	10800				
	#2	Gas production rate	Nm^3/d	13156	3925 -22774	4143	424/100%	Gas measurements seems too high
	#2	Methane content	%	53.6%	40.2%-63.7%	0.096	399/94.1%	
	Calculated	Methane yield	Nm^3 CH_4/(kg VS)	507.2	216.4-999.9	200.22	57/13.44%	

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#5.4. Objectives of the NextGen solutions for Spernal

The aim of the Spernal case is to demonstrate a pilot-scale anaerobic membrane bioreactor (AnMBR) for water and energy reuse and nitrogen and phosphorus recovery. Water cycle solutions will be demonstrated via external reuse of high-quality treated effluent (e.g. farming and industrial use). The resource recovery AnMBR effluent will be conducted using adoption of ion exchange technologies. The Spernal demo case will incorporate AnMBR with a membrane degassing unit to recover dissolved methane and generate electricity and thus reducing energy consumption.

#5.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for Spernal

Table 11 collects the specific KPIs for Spernal, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

Table 11. Objectives and specific KPI for the Spernal case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#5 **Spernal (UK)**	Wastewater treatment and reuse	To increase the quality of the regenerated water to be used for several applications	Water yield of the system [% of regenerated water produced] and its use
			Water quality: removal yield [%] of the several parameters (outlet vs inlet) - BOD [mg/L] - COD [mg/L] - TSS [mg/L] - Turbidity [NTU] - TN [mg/L] - TP [mg/L] - Ppathogens removal: E.Coli [CFU/100 ml], Legionella spp. [CFU/100 ml]
	Energy	Energy recovery – create energy neutral WWTP and export to community (biogas)	Methane yield [m^3 CH_4/(kg VS)]
			Quantity of re-used heat (seasonal) [%]
			Electricity recovery [kWh/m^3 regenerated water]
	Materials	$Ca_5(PO_4)_3OH$	P recovery rate [% or kg/day]
		$(NH_4)_2SO_4$ production	N recovery rate [% or kg/day]

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#6. La Trappe (Netherlands)

#6.1. General description of the site

The Koningshoeven BioMakery (Figure 15) 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 15. Picture of the Koningshoeven BioMakery (exterior and interior view).

#6.2. State of play at the start of NextGen

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)

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Description of the pre-existing system

There are two wastewater streams: municipal and brewery wastewater (Figure 16). 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 pre-existing treatment scheme

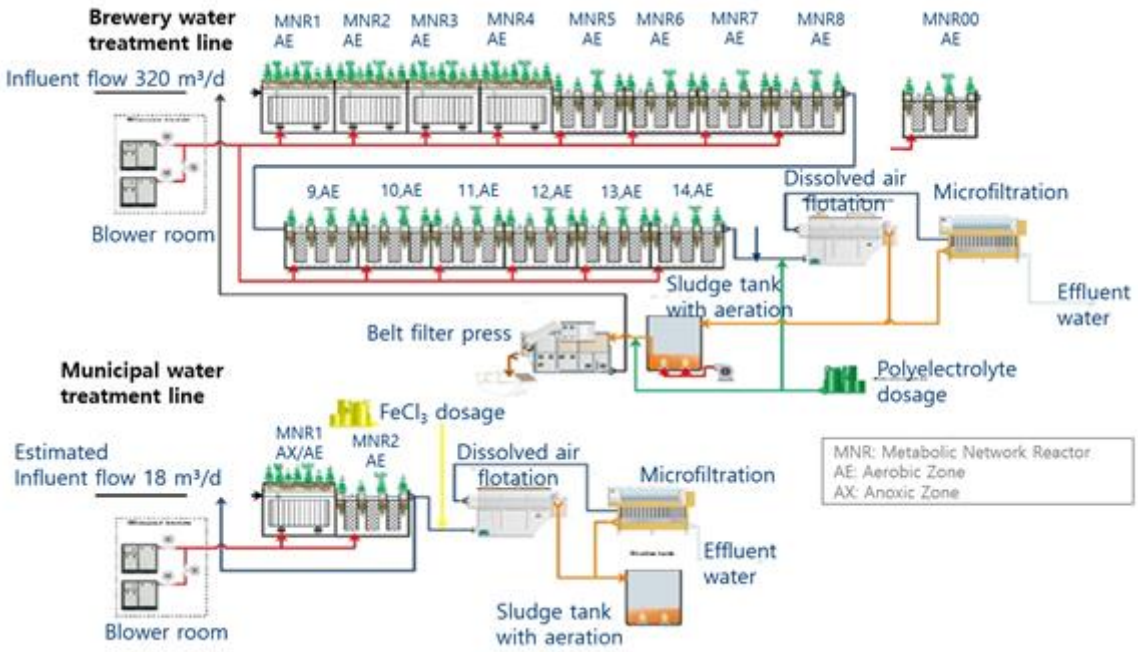

Figure 16. MNR system for industrial and municipal wastewater treatment.

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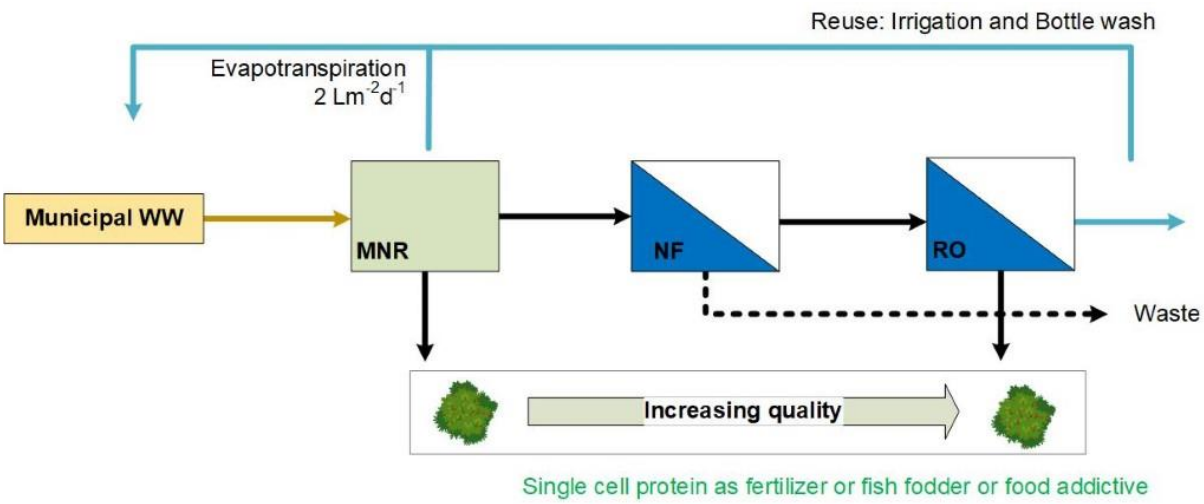

Figure 17. Schematic diagram of the MNR hybrid system.

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#6.3. Baseline conditions

Table 12a and 12b summarizes the baseline conditions that existed in the case study **before** the start of NextGen. These data were collected in D1.1 to be made available to other workpackages (*e.g.* in the analysis performed within WP2) and be compared with the results obtained **after** NextGen solution to quantify improvements.

Table 12a. Summary of baseline condition for the La Trappe site.

Parameter			Units	Mean value for 2018	Comments
Water yield of the system	**Influent to the municipal MNR (Biopolus Metabolic Network Reactor)**	Flowrate	m^3/d	17.5	these are design parameters, measurements will start during the summer 2019
	Effluent from the municipal MNR (Biopolus Metabolic Network Reactor)	Flowrate	m^3/d	17.5	these are design parameters, measurements will start during the summer 2019
Water quality	**Influent to the municipal MNR**	COD	mg O_2 /l	1130	these are design parameters, measurements will start during the summer 2019
		BOD_5	mg O_2 /l	570	these are design parameters, measurements will start during the summer 2019
		TSS	mg/l	660	these are design parameters, measurements will start during the summer 2019
		Total nitrogen	mg N/l	290	these are design parameters, measurements will start during the summer 2019
		N- NH4+	mg N/l	220	these are design parameters, measurements will start during the summer 2019
		Total phosphorus	mg P /l	20	these are design parameters, measurements will start during the summer 2019
	Effluent from the municipal MNR	COD	mg O_2 /l	< 125	these are design parameters, measurements will start during the summer 2019
		BOD_5	mg O_2 /l	< 20	these are design parameters, measurements will start during the summer 2019
		TSS	mg/l	< 30	these are design parameters, measurements will start during the summer 2019
		Total nitrogen	mg N/l	< 10	these are design parameters, measurements will start during the summer 2019
		N- NH4+	mg N/l	< 2	these are design parameters, measurements will start during the summer 2019

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Parameter			Units	Mean value for 2018	Comments
		Total phosphorus	mg P /l	< 0.5	these are design parameters, measurements will start during the summer 2019
Energy consumption	Municipal MNR	Whole plant	kWh/m³	n/a	energy recovery is not applicable in our demo case
	Brewery line or MNR	Whole plant	kWh/m³	n/a	energy recovery is not applicable in our demo case
		Pumping	kWh/m³	n/a	energy recovery is not applicable in our demo case
		Other: FeCl3	m³/d	0.01	these are design parameters, measurements will start during the summer 2019
	Brewery line or MNR	Some substances to conditionate the water used for beer production?	g/m³	n/a	no information about it (note: the only connection between our project and the beer production is that we treat their effluent)
Waste produced	Municipal MNR	Activated sludge (dry matter)	kg/d	12.3	these are design parameters, measurements will start during the summer 2019
		Moisture of the activated sludge	(%)	1.5	these are design parameters, measurements will start during the summer 2019
	Brewery line or MNR	Some waste produced during the beer production?	g/m³	n/a	no information about it (note: the only connection between our project and the beer production is that we treat their effluent)

Table 12b. Summary of baseline condition for the La Trappe site for materials.

Parameter			Units	Mean	Min-Max	Frequency and number of measurements	Comments
Flow rates	Municipal WW to municipal MNR	Flowrate	m³/d	17.5		these are design parameters, measurements will start during the summer 2019	
	Brewery WW to brewery MNR	Flowrate	m³/d	320	Max 336	these are design parameters, measurements will start during the summer 2019	
Organic C-, N- & P-concentrations & TS and VS contents	Municipal WW to municipal MNR	BOD	mg/L	570		These are design parameters, measurements will start during the summer 2019	
		COD	mg/L	1130			
		TN	mg N /l	290			
		TS	%	0.066			660 mg/l
	Brewery WW to brewery MNR	BOD	mg/L	3080			
		COD	mg/L	1904			
		TN	mg N /l	345			
		TS	%	0.0252			252 mg/L
	Effluent from MNRs to NF	BOD	mg/L	<20			
		COD	mg/L	<125			
		TN	mg N /l	< 10			
		TS	%	< 0.003			< 30 mg/l

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#6.4. Objectives of the NextGen solutions for La Trappe

The La Trappe case aims to demonstrate integrated technology developed within the microecological life support system alternative (MELiSSA) program of European Space Agency to convert it into a "Bio-makery". Key circular economy solutions to recover water and nutrients in Breweries are (a) to achieve water quality levels suitable for reuse as: irrigation water, bottle-washing water and ultimately make up water for beer production (by the integration of the MNR and the MELiSSA advanced separation (NF/RO)) and (b) to demonstrate the feasibility of recovering C and N from the wastewater as fertilizer and proof they are suitable to be used as plant or microbial protein for various applications (by the treatment of the RO-concentrate in the MELiSSA photobioreactors).

#6.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for La Trappe

Table 13 collects the specific KPIs for La Trappe, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

Table 13. Objectives and specific KPI for the La Trappe case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#6 **La Trappe (NL)**	Wastewater treatment and reuse	Water recovery for fit-for-use (irrigation and bottle washing or make up water for beer production)	Water yield of the system [% of regenerated water produced]
			Water quality: removal yield [%] of the several parameters (outlet vs inlet) - pH - BOD [mg/L] - COD [mg/L] - TOC [mg/L] - TSS [mg/L] - TDS [mg/] - Turbidity [NTU] - TN [mg/L] - TP [mg/L] - Pathogens removal: E.Coli [CFU/100 ml], Legionella spp. [CFU/100 ml] - Organics removal: pesticides, pharmaceuticals
	Energy	Electricity consumption of the water treatment system	Electricity consumption (kWh/m^3 produced)
	Materials	To recover carbon, nitrogen and phosphorus nutrients from wastewater effluent	C, P and N recovery rate related to the influent to the MNR [%]
			C, P and N-recovery rate related to the influent to the recovery unit [%]

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

#7. Gotland (Sweden)

#7.1. General description of the site

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.

Figure 18. Picture of the site.

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#7.2. State of play at the start of NextGen

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 the pre-existing 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.

Today 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%.

This WWTP will soon be closed down and the sewage from Sorsyudret will be pumped to the WWTP in Klintehamn but a part of the wastewater will be reused in the pilotplant. The concentrate from the reuse plant will be pumped to the Klintehamn WWTP.

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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 pre-existing treatment scheme

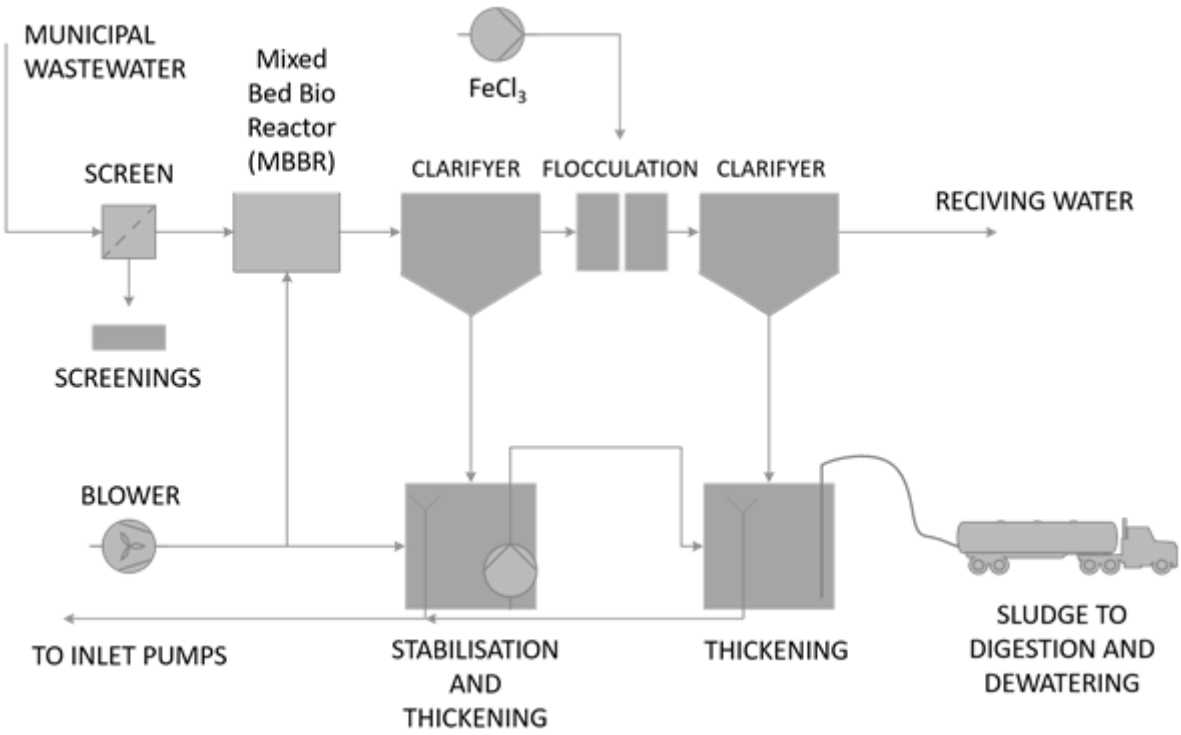

Figure 19. Scheme of the centralized WWTP system of Gotland.

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#7.3. Baseline conditions

Table 14 summarizes the baseline conditions that existed in the case study **before** the start of NextGen. These data were collected in D1.1 to be made available to other workpackages (*e.g.* in the analysis performed within WP2) and be compared with the results obtained **after** NextGen solution to quantify improvements.

Table 14. Summary of baseline condition for the Gotland site.

		Parameter	Mean value for 2018	Standard deviation	Frequency of the measures	Summer mean value	Standard deviation	Winter mean value	Standard deviation	Comments
Water yield of the system	**Current system**	Rainfall climatology of the area (mm/year)	338.5	-	Every 24h	0.84	2.36	1.39	2.43	From regional weather station, Hoburgen year 2018 and 2019
	Influent to the WWTP	Flowrate (m^3/h)	16.2	12.7	Month	7.9	2.5	31	10	
	Effluent from the WWTP	Flowrate (m^3/h)	14.9	10.8	Month	7.6	2.4	28	7.9	
Water quality	**Influent to the central WWTP**	COD (mg O_2 /l)	375	254	4 times/year	570	42	39	-	
		BOD_7 (mg O_2 /l)	168	132	4 times/year	275	7	3	-	
		Total nitrogen (mg N/l)	65	45	4 times/year	100	15	7	-	
		Total phosphorus (mg P/l)	8	6	4 times/year	12	1	1	-	
		TOC (mg C/L)	88	56	4 times/year	130	28	18	-	
	Effluent from the central WWTP	COD (mg O_2 /l)	43	22	10 times/year	73	8	28	1,73	
		BOD_7 (mg O_2 /l)	10	8	10 times/year	21	5	3	0,58	
		Total nitrogen (mg N/l)	33	26	10 times/year	66	16	11	8,3	
		Total phosphorus (mg P/l)	0,15	0,1	10 times/year	0,21	0,02	0,18	0,15	
		TOC (mg C/L)	17	8	10 times/year	28	3	11	1,27	

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		Parameter	Mjölhatteträsk (surface water)	Mjölhatteträsk (surface water)	Mjölhatteträsk (sediments)	Sandväten (ground water)	Vamlingbo (ground water)
Water quality	Quality of rainwater harvested (Data from groundwater except for Mjölhatteträsk which is a lake (surface water) and sadeiment from lake)	Cl^-	36	44	-	420	6.2
		Ca^{2+}	25	53	23	350	95
		pH	8.9	-	-	7,8	8.1
		CE	35	-	-	160	39
		TOC (unfiltered)	33	34	-	19	4.6
		DOC 0.45 µm	32		-	18	5.4
		TN (unfiltered)	2	2.6	0.82	0.8	1.5
		Ammonium NH_4^+	0.16	0.62	-	0.089	<0.03
		Total phosphorus	0.015	0.055	0.073	0.7	0,019
		NO_2^-	<0.01	<0.01	x	<0.10	<0.01
		NO_3^-	0.007	<0.005	x	0.089	1,4
		SO_4^{2-}	9.1	12	x	92	1,9
		PO_4^{3-}	<0.01	<0.01	x	<0.01	<0.01
		Mn	<0.05	0,017	0.021	0.68	0.028
		Fe	0.008	0.044	1	15	0.43
		Al	0.013	0.03	0.99	15	0.33
		Si	7.8	7.4	0.049	69	4.9
		Na	21	25	0.068	350	2.9
		Mg	17	23	0.71	85	2.1
		K	4.2	6	0.38	25	0.87
		S	11000	16000	-	130000	3100
		V	0.76	1.4	-	28	1.3
		Cr	0.12	0.27	1.97	15	0.59
		Co	0.11	0.12	0.35	6.5	0.31
		Ni	1	1.3	1.2	11	1.2
		Cu	1	0.69	1.05	17	1.5
		Zn	1.3	2.1	6.29	37	8.1
		As	1.6	2.9	0.23	8,8	0.65
		Sr	160	210	-	1200	170
		Mo	0.51	1.1	-	0.83	0.16
		Cd	0.012	0.006	0.06	0.26	0.018
		Ba	9.3	19	-	69	9.5
		Pb	0.43	0.8	2.51	22	0.84

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		Parameter	Mean value for 2018	Standard deviation	Frequency of the measures	Summer mean value	Standard deviation	Winter mean value	Standard deviation	Comments
Energy consumption	**Central WWTP**	Energy consumption (kWh/m^3)	0.84	-	-	-	-	-	-	-
Reagents & materials required	**Tertiary treatment**	Coagulant PIX111 (g/m^3)	27.5							
Waste produced	**Tertiary treatment**	Sludge volume (m^3/month)	98.7	70.2						

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#7.4. Objectives of the NextGen solutions for Gotland

At the Gotland case, NextGen will demonstrate how integrated, cost efficient, local small-scale technologies can solve the problem in a region with water shortage. On-line sensors for monitoring of groundwater level has been installed in the region and a connected data model will control the water balance though automatic floodgates and pumps. This system will hinder the rainwater to immediately run off to the river or the sea and will ensure an optimal water balance for production of tap water and to ensure the ground water level for private wells.

A membrane based on-site treatment of untreated wastewater will produce water for reuse and reduce the volume of polluted water to be pumped to a WWTP 45 km north from the testbed. This compact treatment concept will recover waste- and storm water directly from the sewage piping system, reduce the energy consumption and cost for long distance pumping and increase the wastewater treatment plants efficiency. To overcome the carbon footprint drawback of the wastewater reuse plant it will be powered by solar energy. The water collected during the water rich winter season will be stored in a lake and a recovered wetland. This stored surface water will be used during the dry summer season for production of tap water by membrane filtration. A part of the stored water will be delivered to land owners for irrigation.

The operator of the integrated system for sustainable water management (Region Gotland) together with the local NGO Forum Östersjön, will engage in direct exchange with the local farmers and other relevant stakeholders to optimize the new water management system. Through the CoP approach, the acceptance of the water management system, including wastewater reuse wuill be enhanced. A targeted water production capacity and fit-for-purpose water reuse, including on-line information on capacity variation over the year will be developed. Suitable models for cost recovery will be analyzed to enable a viable marketing of the innovative systems and technologies. Finally, partner Region Gotland will highlight the feasibility of a large-scale, decentralized water management system that can be used for other areqs at Gotland, in Sweden or globally.

The vision is that Gotland case will serve as a ‘first mover’ model for operators and decision makers in the Baltic Sea Region to invest in large-scale but decentralized, low cost water management systems. It will increase acceptance of wastewater reuse by citizens and surface- and ground water control by farmers. Extensive dissemination activities will promote the process and encourage other municipals and water companies to follow, especially for those EC countries where the water shortage is foreseen to increase due to climate change.

#7.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for Gotland

Table 15 collects the specific KPIs for Gotland, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

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Table 15. Objectives and specific KPI for the Gotland case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#7 **Gotland (SE)**	Wastewater treatment and reuse	To obtain regenerated water for being used as potable water	Water yield of the system [% of regenerated water produced]
			Water quality - Removal yield [%] of the following parameters (outlet vs inlet): conductivity, COD, ammonia,
	Rainwater harvesting	Rainwater harvesting and production of tap water by membrane filtration	Production capacity [m^3/year]
	Aquifer storage	Rainwater and lake water for UF cleaning	Pilot capacity [m^3/year]
			Water quality - Removal yield [%] of the following parameters (outlet vs inlet): metals, conductivity, color, COD, some anions and *E.coli*.
	Energy	Use of solar panels to minimize electricity consumption during wastewater treatment (summer)	Electricity consumption [kWh/m^3 regenerated water]

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#8. Athens (Greece)

#8.1. General description of the site

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 20. Picture of the tree nursery site

#8.2. State of play at the start of NextGen

Scale

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

Description of the pre-existing 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. 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.

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

Block diagram of the pre-existing treatment scheme

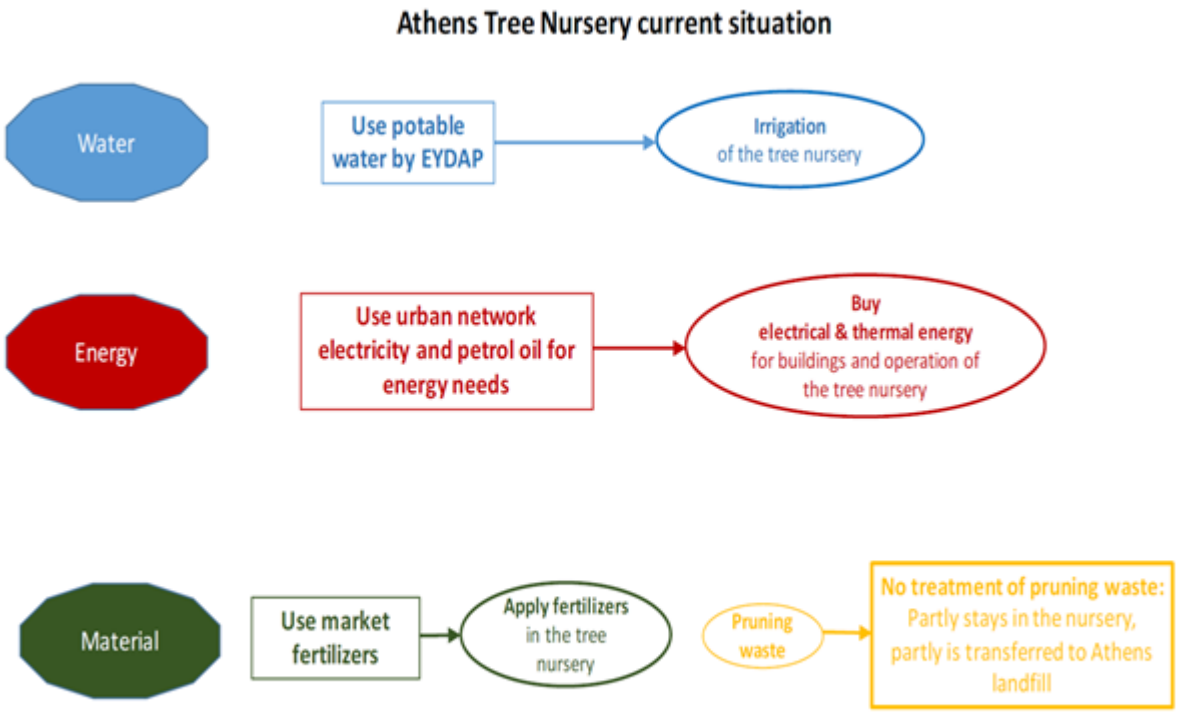

Figure 21. Scheme of the baseline scenario without NextGen technologies in Athens

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

#8.3. Baseline conditions

Table 16a, 16b and 16 c summarize the baseline conditions that existed in the case study before the start of NextGen. These data were collected in D1.1 to be made available to other workpackages (*e.g.* in the analysis performed within WP2) and be compared with the results obtained **after** NextGen solution to quantify improvements.

Table 16a. Summary of baseline condition for the Athens site in terms of water.

NextGen Athens Pilot system					
Parameter			**Units**	**Mean value for 2018**	**Standard deviation**
Water yield of the system	**Influent to the current sewer minimg modular unit (MBR & disinfection)**	Flowrate	m^3/d	25	
	Effluent from the current sewer minimg modular unit (MBR & disinfection)	Flowrate	m^3/d	25	
Water quality	**Influent to the sewer minimg modular unit (MBR & disinfection)**	COD	mg O_2 /l	531	114
		BOD_5	mg O_2 /l	253	74
		pH	upH	7,5	0,5
		CE	mS/cm		
		TSS	mg/l	247	78
		Turbidity	NTU		
		Total nitrogen	mg N/l	116	16
		N- NH4+	mg N/l	90	5
		Total phosphorus	mg P /l	12	1

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Table 16b. Summary of baseline condition for the Athens site in terms of energy.

NextGen - Athens - Baseline for thermal energy							
			Units	Mean	Min-Max	Frequency and number of measurements	Comments
Parameters	Wastewater in the sewer	Flowrate	m^3/d	139,0	135-149	Annually estimations - 2 in number	There is an estimation in this value, not an actual measurement.
	Wastewater temperature	Temperature	[° C]	17,0	16-18		
	Wastewater in contact with heat exchanger	Flowrate	l / hr	100,0			
	Energy abstracted from wastewater	Heat	kW	10,0			calculated
	Heat Pump power input	Work	kW	5,0			

Table 16c. Summary of baseline condition for the Athens site in terms of material

NextGen Athens baseline in terms of material							
Parameter			Units	Mean	Min-Max	Frequency and number of measurements	Comments
Flow rates	Wastewater in the sewer	Flowrate	m^3/d	139	135-149	Annually estimations - 2 in number	There is an estimation in this value, not an actual measurement.
	Processed wastewater of the sewer mining unit	Flowrate	m^3/d	25			
	Wastewater sludge to the mixing unit	Flowrate	m^3/week	2			
	Wood & green pretreated waste to mixing unit	Massflowrate	l/week	300			
	Compost (material product, expected)	Massflowrate	kg/week	100			
organic C-, N- & P-concentrations & TS and VS	Wastewater in the sewer	TN	mg N /l	116	16		
		TP	mg P /l	12	1		
		TS	mg /l	247	78		
		VS	mg /l	159	33		

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#8.4. Objectives of the NextGen solutions for Athens

The installation of a sewer mining modular unit for urban green irrigation at the point of demand will close the water loop and be of direct benefit for the sustainability of the new metropolitan park. Additionally, flexible energy recovery schemes will be implemented to minimize the pilot environmental footprint such as low-grade heat recovery from the effluent of the sewer mining modular unit. Finally, compost-based eco-engineered growing media products will be produced and reused as fertilizer onsite as part of a portfolio of autonomous, decentralized water, energy and materials circular solutions for cities in water scarce area.

#8.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for Athens

Table 17 collects the specific KPIs for Athens, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

Table 17. Objectives and specific KPI for the Athens case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#8 **Athens (EL)**	Wastewater treatment and reuse	To increase the production of regenerated water	Water yield of the system (produced/collected) [%]
		To improve the quality of regenerated water	Water quality Removal yield [%] of the several parameters (outlet vs inlet): BOD, COD, SS, turbidity, nutrients (N, P), pathogens (*E.Coli*)
	Energy	To determine electricity consumption for water treatment	Electricity consumption (kWh/m³ produced)
		Thermal energy recovery	Heat recovered related to the heat content of the wastewater [%]
	Materials	Compost production	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 [%]
		Reduction of reagents used for water treatment	Reagents required (kg of reagent/m³ produced)

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#9. Filton Airfield (United Kingdom)

#9.1. General description of the site

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 22).

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 22. Aerial view of the Filton Airfield.

#9.2. State of play at the start of NextGen

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)

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

Description of the pre-existing system

Figure 23 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 24, 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 24). 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 25 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 pre-existing treatment scheme

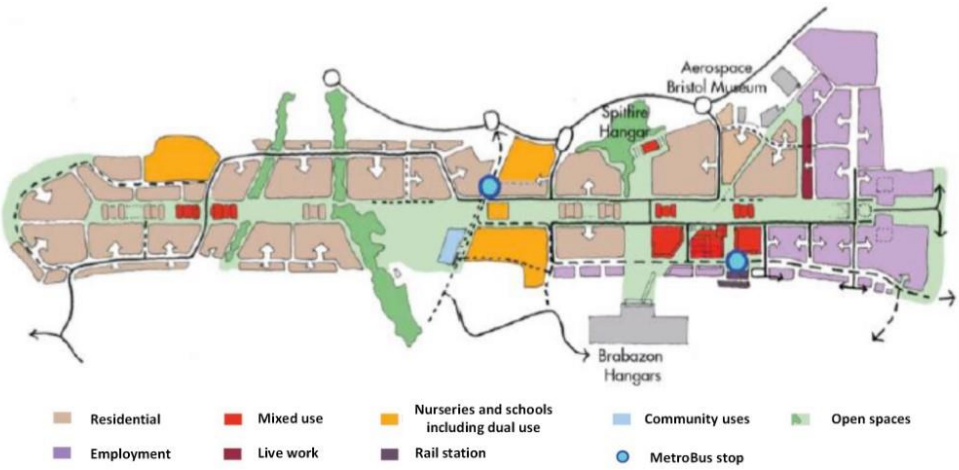

Figure 23. Filton Airfield development plan and the Brabazon Hangars.

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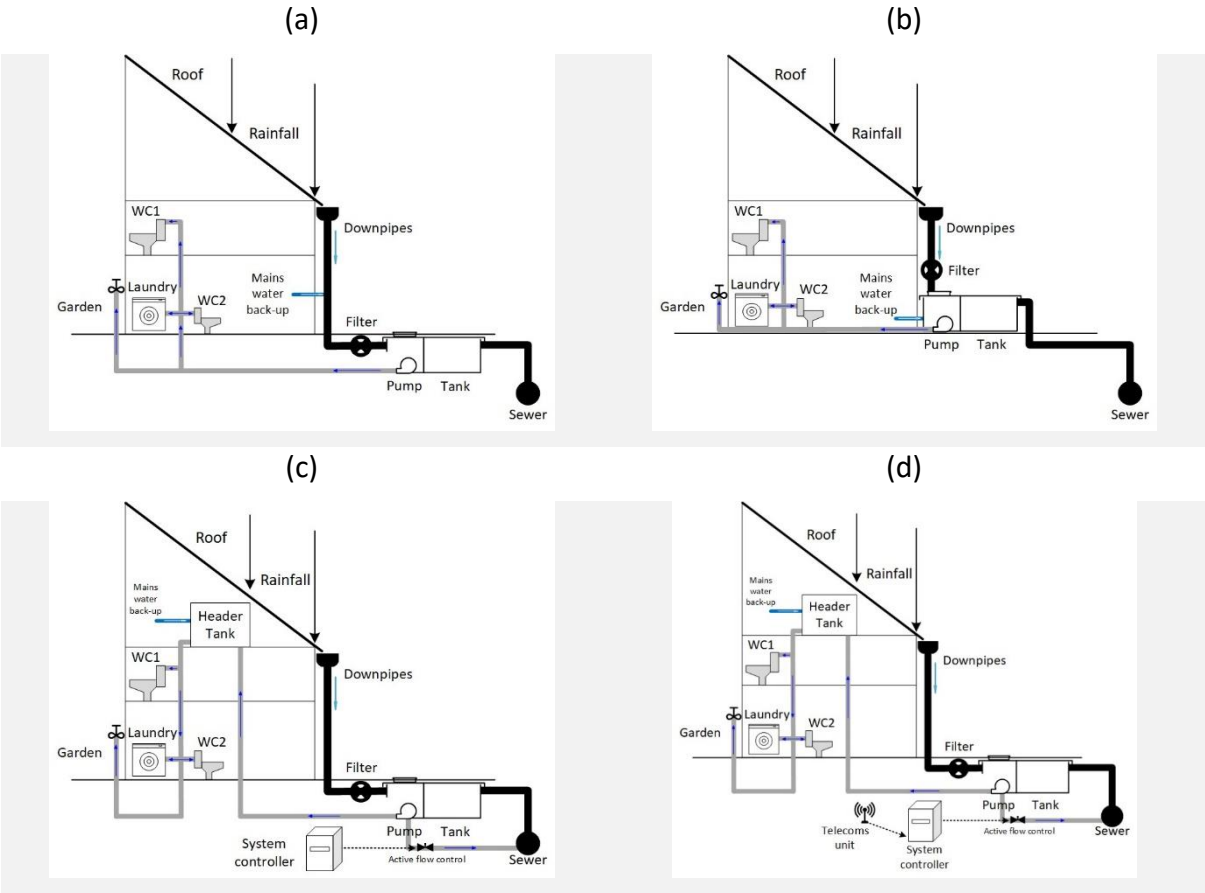

Figure 24. Traditional (a) below ground tank and (b) above ground tank and innovative (c) KloudKeeper and (d) real time control RWH system configurations.

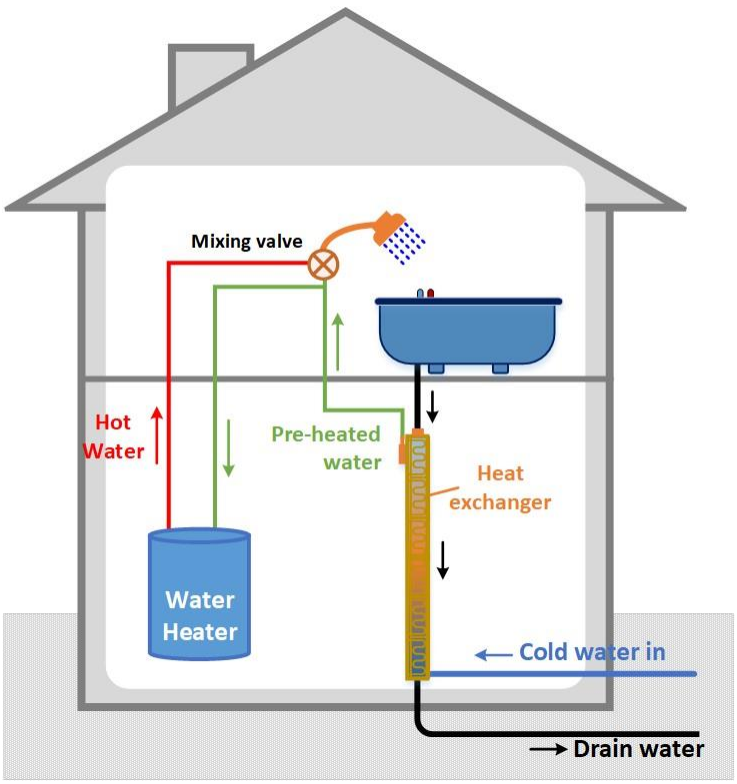

Figure 25. The concept of wastewater heat recovery system in a house.

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9.3. Baseline conditions

The baseline conditions of the Filton Airfield demo site are not available as it is now set for redevelopment into a new sustainable housing and business area. The nextGen project goal will be integrated into the masterplan for the site development. Baseline data that can be incorporated in other work packages will be collected during the NextGen project activities.

#9.4. Objectives of the NextGen solutions for Filton

The main objective of the Filton case study is to demonstrate circular economy concepts in water, energy and materials cycles in a housing and business area. Specific focus will be on integrating circular water concepts that include rainwater harvesting. In addition, in terms of materials and energy recovery, this demo case will investigate sustainable strategies for nutrients recovery from domestic wastewater and reuse and heat recovery from urban wastewater to improve the energy efficiency of buildings.

#9.5. Specific Key Performance Indicators (KPIs) of the NextGen solutions for Filton

Table 18 collects the specific KPIs for Filton, against which data will be collected during the testing and demonstration phases of the project, to enable relevant LCC, LCA and other assessments to be performed under WP2 and other WPs.

Table 18. Objectives and specific KPI for the Filton case.

Case study	Topic	Objectives	Specific Key Performance Indicator (KPI)
#9 Filton Airfield (UK)	Rainwater harvesting	To increase urban reuse of water (water availability): rainwater harvesting and storage	Volume of rainwater collected and stored [m^3/year]
			Volume of water recovered vs rainfall [L/m^2]
			Water quality analysis - pH - Conductivity [mS/cm] - BOD [mg/L] - COD [mg/L] - TDS [mg/L] - TSS [mg/L] - Turbidity [NTU] - TN [mg/L] - TP [mg/L] - Pathogens removal: E.Coli [CFU/100 ml], Legionella spp. [CFU/100 ml]
	Energy	To evaluate local heat availability	Heat recovery [%]
	Materials	To explore nutrient recovery options related to the wastewater sludge and to the food waste	Nutrient (N, P) recovery rate [%]

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#10. Bucharest (Romania)

#10.1. General description of the site

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

#10.2. State of play at the start of NextGen

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.

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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 pre-existing treatment scheme

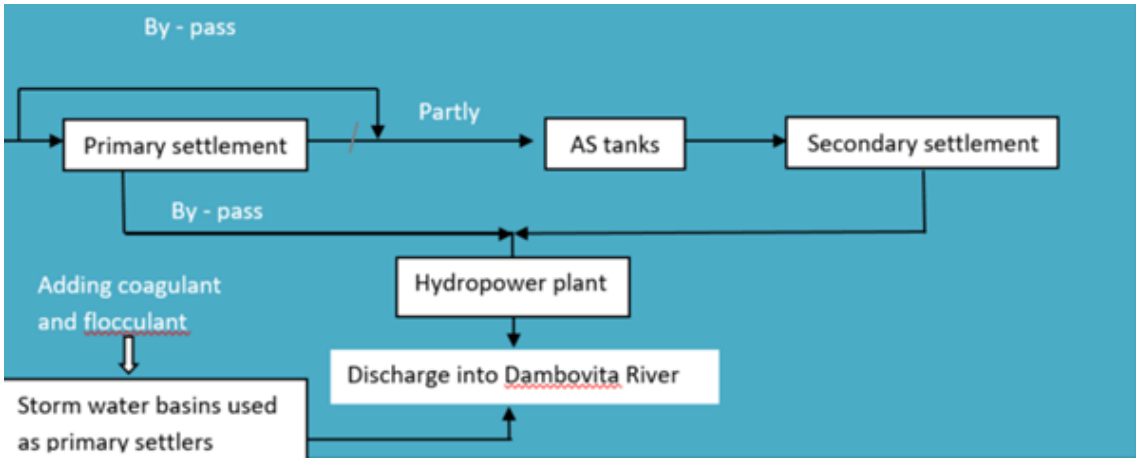

Figure 27. Current wastewater treatment process used in Bucharest.

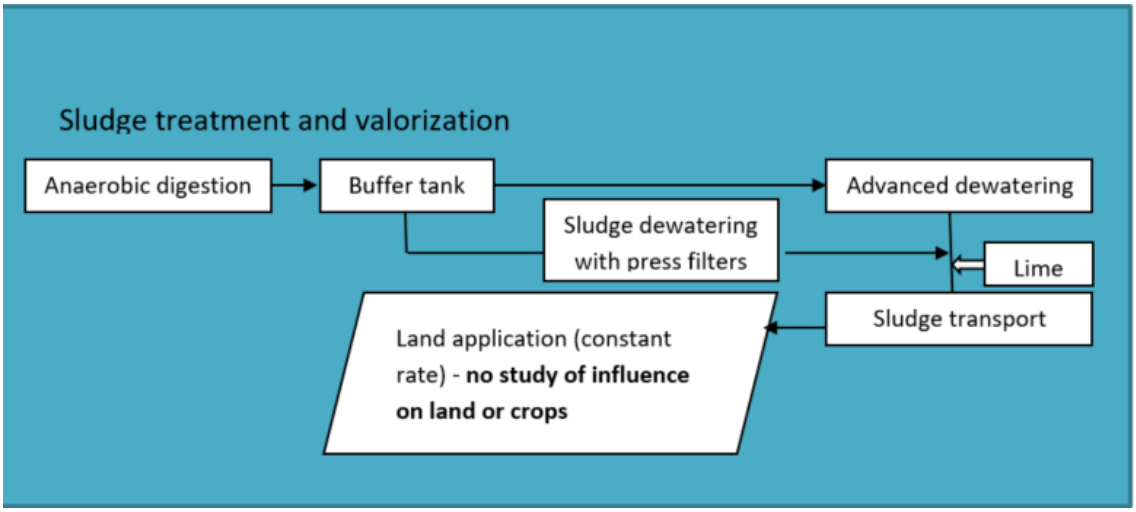

Figure 28. Sludge treatment in Bucharest.

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Synergies across demonstration cases

Water

Demonstrations relevant to close the water cycle are taking place in 8 sites of the project, as represented in Figure 29. Similarities 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. The 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.

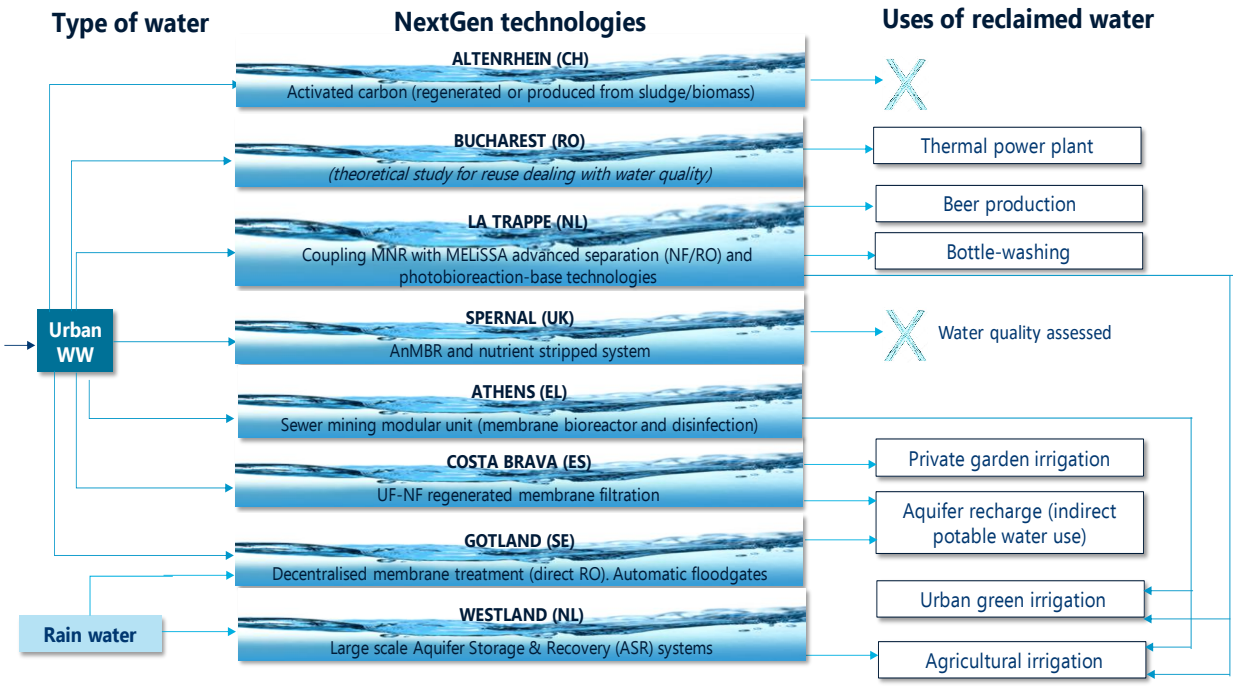

Figure 29. Overview on water related technologies in NextGen.

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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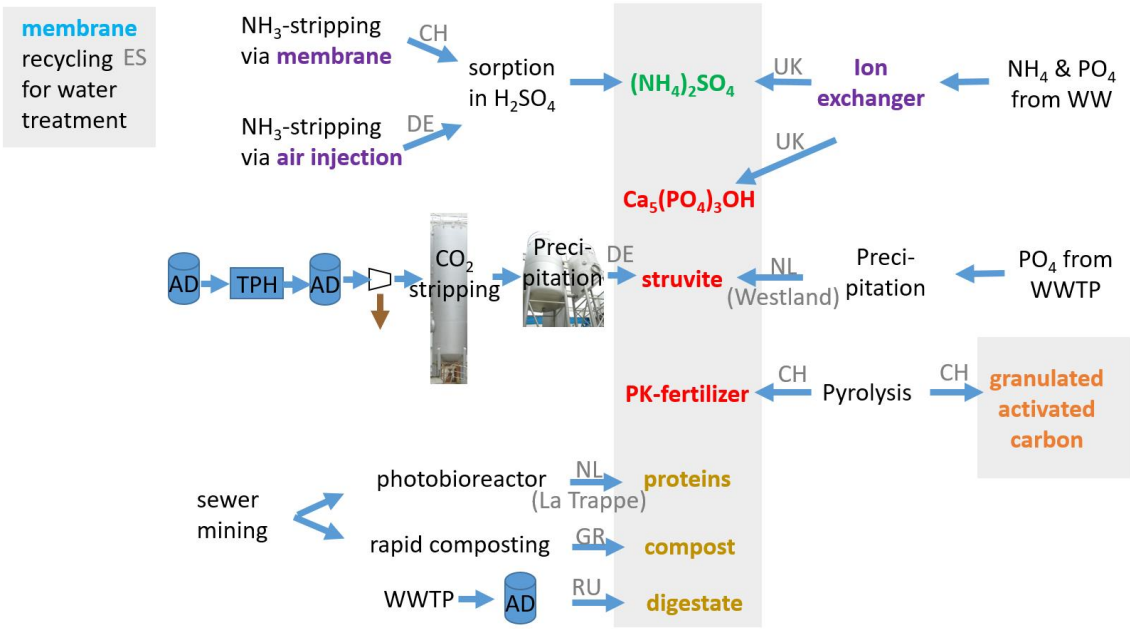

Figure 30. Overview on material related technologies in NextGen

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 circular solutions for energy is part of the case studies in Athens, Braunschweig, Spernal, Westland and Filton Airfield. All three main energy considerations (energy production, recovery and storage) are covered within NextGen: (a) **production** and recovery of biogas and subsequent electricity and heat generation: (b) heat **recovery** from water streams and (c) sub-surface heat **storage** in aquifers. Figure 31 shows the connection between the different energy aspects in the cases of NextGen.

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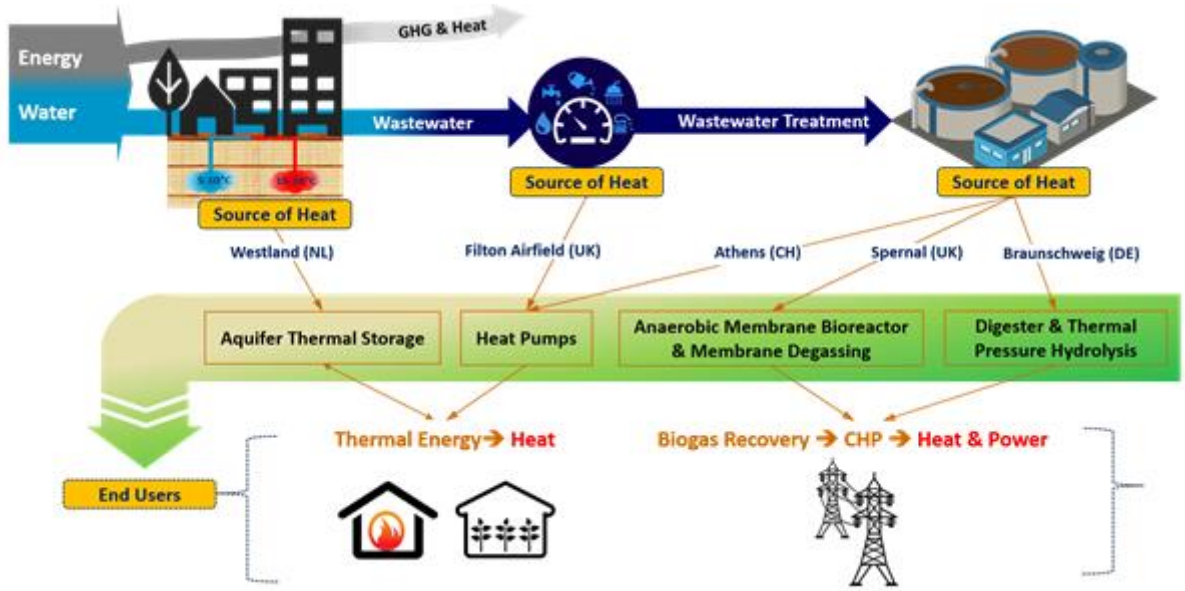

Figure 31. Overview on energy related technologies in NextGen

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.

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