SiEUGreen
Sino-European innovative green and smart cities

Sino-European Innovative Green and Smart Cities

D 2.4
Blue Technology (T2) Ready 2

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Due date: 30/04/2019
Version: 4.0

Co-funded by the Horizon 2020 programme of the European Union

Co-funded by the Chinese Ministry of Science and Technology

The project has received funding from the European Union's Horizon 2020 Research, and Innovation Programme, under grant Agreement N^o^ 774233

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Disclaimer

SiEUGreen

The project has received funding from the European Union's Horizon 2020 Research, and Innovation programme, under grant Agreement N 774233 and from the Chinese Ministry of Science and Technology.

Throughout SiEUGreen's implementation, EU and China will share technologies and experiences, thus contributing to the future developments of

The project SiEUGreen aspires to enhance the EU-China cooperation in promoting urban agriculture for food security, resource efficiency and smart, resilient cities.

The project contributes to the preparation, deployment and evaluation of showcases in 5 selected European and Chinese urban and peri-urban areas: a previous hospital site in Norway, community gardens in Denmark, previously unused municipal areas with dense refugee population in Turkey, big urban community farms in Beijing and new green urban development in Changsha Central China.

A sustainable business model allowing SiEUGreen to live beyond the project period is planned by joining forces of private investors, governmental policy makers, communities of

Technical References

Project Acronym:	SiEUGreen
Project Title:	Sino-European Innovative Green and Smart Cities
Project Coordinator:	Dr. Petter D. Jenssen, NMBU Phone: +4791377360 Email: petter.jenssen@nmbu.no
Project Duration:	January 2018 – December 2021

Deliverable N°:	D2.3-Blue technology (T2) ready-1
Dissemination level [1]:	PU (see explanation below)
Work Package:	WP 2 – Development of sustainable and circular urban farming system
Task:	T 2.2- "Cycles"/ Resource-efficient systems: Water and waste management
Lead partner:	1-NMBU
Contributing partner(-s):	1 – NMBU, 2 – NIBIO, 7AAKS, 8 – VILABS, 12-Scanwater, 13 – Hatay, 16-HHEPSTI,
Due date of deliverable:	30/04/2019
Actual submission date:	30/06/2019

[1] **PU** = Public

PP = Restricted to other program participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

Document History			
Version	Date	Author – Partner	Summary of Changes
1.0	28/05/2019	NMBU	Initial Draft
1.1	21/06/2019	NMBU, NIBIO	Revised draft version based on comments from NMBU and NIBIO
2.0	30/06/2919	NMBU, NIBIO	Final version submitted
3.0	24/10/2019	NMBU, NIBIO	Comments received from Commission on 14/10/2019 incorporated.
4.0	19/12/2019	NMBU	Comments received from Commission on 05/12/2019 incorporated.

Executive Summary

The SiEUGreen project aims to enhance the EU-China cooperation in promoting urban agriculture for food security, resource efficiency, and smart, resilient cities. Circular economy and utilization of domestic organic urban waste resources for the production of fertilizer and soil amendment products for urban and peri-urban agriculture, as well as energy for local use, are essential aspects of the showcases in Fredrikstad and Changsha, especially. The conversion of waste resources and water handling in the SiEUGreen project termed Blue Technology. This deliverable, D2.4 “Blue Technology (T2) Ready 2”, is based on research and investigations carried out in the first 18-month project period and presents blue technologies related to the collection of liquid waste for recycling that is ready for implementation in the SiEUGreen showcases and technologies for processing of grey and stormwater. The different technologies studied are presented in fact sheets. Presentation in fact-sheets facilitates later upgrading to practice abstracts. The latest updated status of the technologies and the potential challenges in the implementation of these technologies in urban settings are also presented.

The majority of the nutrients in wastewater is found in toilet waste or blackwater. If blackwater is collected in a concentrated form further processing by anaerobic digestion yielding biogas or composting is facilitated. Low flush and dry toilet systems are therefore evaluated.

Vacuum systems form the three leading manufacturers worldwide are investigated. Two of the manufacturers have most of their experience from the marine and one is specializing in the on-shore market. However, all three are gearing towards the on-shore market as this is the primary future market of vacuum toilet technology. All companies can deliver robust and reliable systems suitable for high-rise buildings as in the Fredrikstad and Changsha showcase. However, they are dependent on electricity supply and systems with small vacuum reservoirs are more vulnerable if the power goes than systems with large vacuum reservoirs (tanks or large piping systems). The systems require correct construction, operation, maintenance and trained caretakers.

Urine is mostly sterile and can be utilized in agriculture without other processing than six months of storage. Urine diverting toilets can also be used in high-rise buildings. However, due to some technical problems and user acceptance, few toilets are available on the market today, but a new Swiss urine-diverting toilet has a promising design and function. This toilet will be available on the market next year and is therefore not recommended in the SiEUGreen showcases other than that for demonstration.

Dry toilets are not suited for high-rise buildings but are ideal as a stand-alone toilet where there is no water infrastructure. However, user acceptance may be more difficult than for a vacuum toilet and similar to that of the urine-diverting toilet. A solar-driven toilet, developed at NMBU, is being used in the Århus showcase and will be investigated for user acceptance and compost quality.

SiEUGreen aims at treating the greywater (water from showers washing and sinks) to swimming water quality in a facility next to the building in the showcases in Fredrikstad and Changsha. Treating greywater decentralized will reduce the pressure on the existing sewers as the high-quality effluent can be safely discharged to the storm-water system. NMBU and NIBIO have developed biofilter wetland systems for the cold climate that produces swimming

water quality. A system has been in operation in Oslo since the year 2000 with good results. A similar system is suggested in the Fredrikstad showcase. However, the system has a footprint and the septic tank used for 64 flats, as in Fredrikstad, becomes both expensive and large. Trials have therefore been performed in the NMBU laboratories with an aerated moving bed biofilter system. The tests are promising and can cut the footprint of the septic tank and biofilter in the planned system to 1/10th. If ready before installation, more compact components will be used.

Fascinating trials have been performed in the NMBU laboratories using green walls for greywater treatment. The vertical greywater treatment system consists of vertical infiltration into porous media. Greywater treatment in a vertical vegetated wall can be integrated with hydroponic food production into a double skin facade for installation on new high-rise buildings or as a retrofit on existing buildings with adequate solar exposure.

Table of Contents

1. Introduction

The innovative technologies that are implemented at showcases within SiEUGreen are categorized as Green technologies, Blue technologies and Yellow technology. The green technology concerns with soil-based traditional plant growing, water-based hydroponic culture (soilless) and aquaponics (fish and plant), paper-based plant growing technology, and greenhouse technology.

The blue technologies include water and waste management, production of fertilizer and soil amendment from waste, resource recycling. The yellow technology includes biogas production from waste resources, seasonal solar storage, combined heat and power, and photovoltaic generation of electricity

These technologies will be implemented in the five SiEUGreen showcases in Europe and china. The selected blue technologies will reduce water consumption, facilitate recycling of nutrients to urban and peri-urban agriculture and thus, almost eliminate pollution of surface water. Biogas production from toilet waste (blackwater) and organic household waste (OHW) is a key treatment technology. CO_2, heat, and power from biogas combustion is utilized together with the nutrient rich digestate in a super-insulated greenhouse for local resource reuse and year around plant production.

This deliverable provides documentation for the full-scale implementation of blue technologies in the SiEUGreen showcases

Chapter 2 of this deliverable provides brief overview of the SiEUGreen technologies for wastewater management. The chapter also describes the readiness level of the technologies selected for implementation.

Chapter 3 presents the fact sheets on the blue technologies associate with source separation of wastewater and storm water handling.

Chapter 4 presents the data that are collected after the implementation of the technology in the showcases

Annex 1 provides the list of student research carried out in the context of testing the blue technologies in controlled laboratory environment prior to the implementation in the showcases.

2. Showcase Technologies for water and wastewater reuse

2.1 Overview of technologies for showcase deployment

The technologies under SiEUGreen that will focus on the reuse of various resources including land, water, waste nutrient, solar energy and biogas have already been established in the SiEUGreen grant agreement. The concept demonstrates a strong focus on agricultural food production with zero or minimum transport, solar energy utilization, water saving and wastewater reuse, waste recycling, residents involvement and organic green urban agriculture (UA) for smart city residents. The SiEUGreen model of recyclable resources is presented in Figure 1.

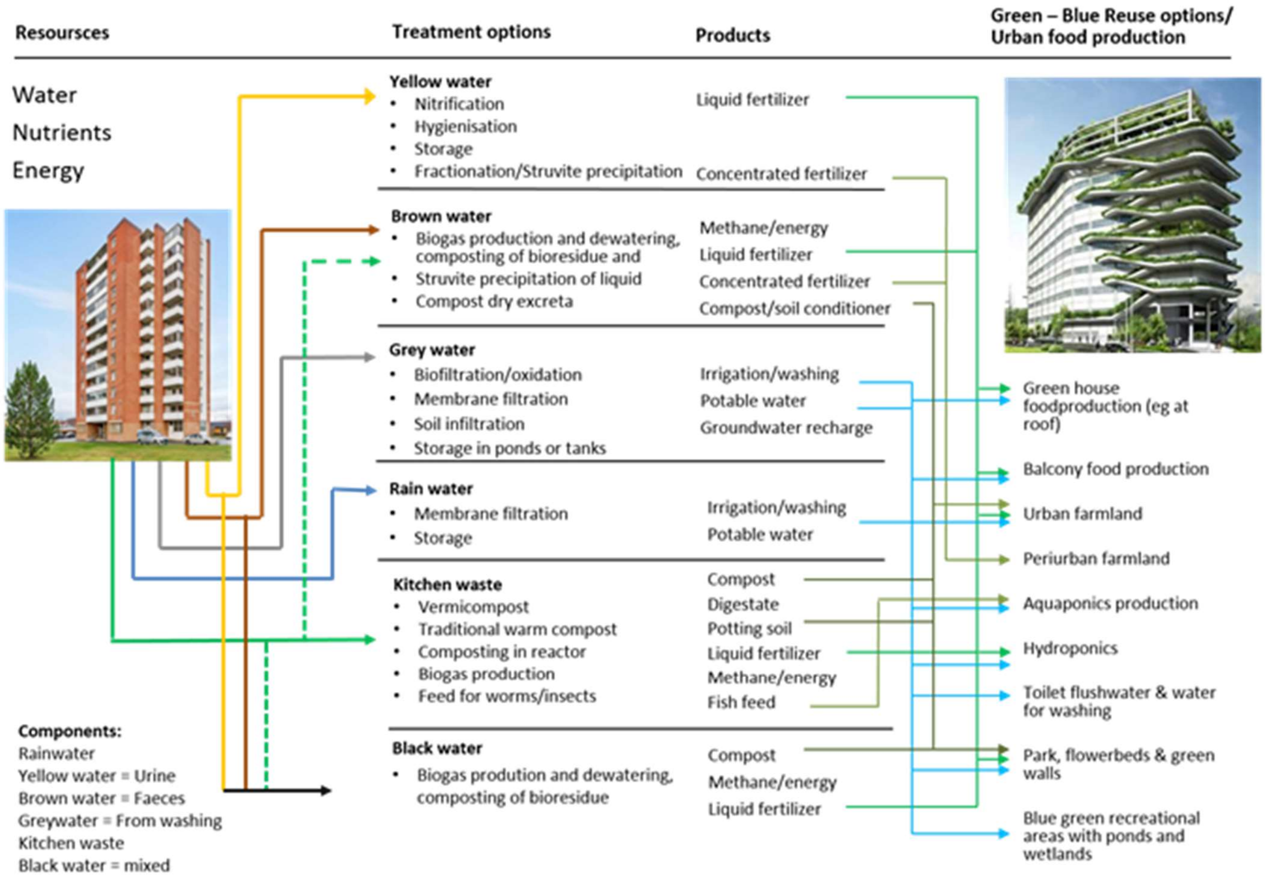

Fig. 1. SiEUGreen model of recyclable resources

The blue technologies have been categorized as (a) Technologies for processing of waste for recycling, (b) Technologies for source separation of wastewater (alternative toilet systems) and c) Technologies for storm water handling. This deliverable D2.4 presents the updated status of the blue technologies under categories (b) and (c).

2.2 Technology readiness level (TRL)

The TRL level of the technologies range from 3-9. Once the technology is deployed in the showcase it will pass three distinct phases (i) testing of technology in open environment ii) measurable data collection to feedback research and iii) adjustment and improvement of the technology to raise the TRL level.

3. SiEUGreen blue technology factsheets

This section provides the updated status of the technologies that are associated with source separation of wastewater and storm water handling. Description of technology options for toilet systems, grey water treatment and stormwater treatment are presented in factsheets based on literature, SiEUGreen investigations and our general knowledge. Additional information from SiEUGreen investigations are presented in Annex. The factsheets form the basis for our technology recommendations in the showcases.

Toilet systems include vacuum systems (chapter 3.1), urine diverting toilets (chapter 3.2) and solar dry toilet (chapter 3.3).

When the toilet waste is separated from the rest of the domestic wastewater stream the remaining wastewater from bathing, laundry and kitchen is defined as greywater, which need separate treatment. Although most of the pollutants follow the toilet waste, greywater still contain nutrients and organic matter, which represent a pollution risk for sensitive recipients. **Grey water** can be treated by:

1. On-site technical systems –> reuse, infiltration, discharge to surface water or piping
2. On-site nature-based systems –> reuse, infiltration, discharge to surface water or piping
3. Piping to municipal treatment

With proper on-site treatment, greywater can be reused. These uses include water for laundry and toilet flushing, and irrigation of plants. Treated greywater can be used to irrigate both food and non-food producing plants.

This report presents on-site greywater treatment using Biofilter/filterbed (constructed wetland) treatment systems (chapter 3.4), systems using biomembrane in combination with biofilter (chapter 3.5) and vertical systems using a green wall (chapter 3.6).

Due to climate changes, urbanization and increased focus on measures to prevent diffuse pollution there has been a development of more environmentally-conscious approaches to **storm water management** in the last 10-15 years. These measures – known as 'Sustainable urban drainage systems' (SUDS), 'best management practices' (BMPs) or 'blue-green infrastructure ', which include:

1. Green roofs and walls
2. Constructed wetlands, detention ponds, vegetated channels
3. Bioretention/rain garden/vegetated swales
4. Infiltration trenches and basins
5. Soil infiltration in turfgrass areas

The focus in SiEUGreen storm water handling has been to integrate measures, such as green-roofs and walls (chapter 3.7), wetland/infiltration systems (chapter 3.8), in green park areas connected to the apartment buildings to promote a healthy environment, reduce greenhouse gas emissions and increase the resilience to handle increased rainfall intensity and water shortages. The innovative part in SiEEGreen is to connect stormwater systems to other blue and green technology as e.g.

- Polishing on-site treated greywater in stormwater ponds/wetlands
- Using collected rainwater from green roofs for irrigation of the park and urban farming areas
- Using fertilizer from on-site waste treatment for green roofs and walls and turfgrass areas

In addition, the project will test new technology or components as e.g. use of light-weight aggregates in green-roofs to improve insulation and water retention capacity.

There are many guidelines and review reports available presenting the technology, theory, practical experiences, suggestion of design and showcases for SUDS, as e.g. Ballard et al. 2016, Jotte et al. 2017, Åstebøl et al. 2013.

3.1 Alternative toilet systems - Vacuum-/low flush toilets

Resources	Blackwater
Expected products	Concentrated blackwater
Green-blue reuse options	Resource for biogas production

Short description of technology

The vacuum toilet technology was originally introduced to save water but have the same comfort as a traditional flush toilet. It has now become the standard toilet technology in marine applications. Vacuum toilets has also gained interest as part of innovative source separating sanitation system where water savings, and nutrient and energy recovery is important. Vacuum toilets are flush toilets based on a non-water transportation system and water is only used for cleaning the toilet bowl and pipes as well as noise reduction (WRS, 2001). Vacuum toilets are connected to vacuum sewers. Unlike typical gravity sewers, vacuum sewers use differential air pressure to transport the wastewater as all the sewer mains are under vacuum (negative pressure compared to atmospheric) (Dobrescu et al., 2011). It therefore removes faeces, urine and toilet paper with a minimal amount of water (0.5 to 1.2 litres). The high transport velocity of the air/water-mixture in the vacuum pipelines prevents deposits, odors and septic actions in the pipelines (GTZ, 2009).

Operation: In a central vacuum station a low pressure of about –0.6 bar is created by vacuum pumps also called vacuum generation units, which produce the vacuum in the piping system. When a toilet is flushed, the air at atmospheric pressure flows into piping through the toilet due to lower pressure in the pipes. The air travels at high velocity because of the pressure difference, carrying the wastewater with it. The main components of a vacuum sewer system include the toilet with vacuum valve, vacuum sewers, the vacuum generation unit and monitoring and control components. Some, often larger systems, have a vacuum tank and a discharge pump. Smaller systems have so called vacuumareators that produce vacuum on the intake side and pressure on the discharge side. In these systems there is no need for a vacuum tank.

Types of vacuum toilets

There are several suppliers of vacuum toilets and sewer systems. Evac and Jets are companies that have dominated marine market. The other company Roediger has mainly concentrated their work in the terrestrial market. These brands are the three main brands in the market. All manufacturers claim to have quiet toilet models. However, there is no independent or standard way of making the noise measurements.

Evac

Evac's vacuum systems consist of vacuum toilets and intake units that carry the sewage water to a central vacuum unit via a system of pipes. Evac Optima 5 Advanced vacuum toilet is claiming to have the quietest flush operation on the market. The water consumption is 1.2 L per flush for wall and floor models, and for 0.6 L for the urinal. Operation is provided by a pneumatic flush mechanism, with flush memory and vacuum sensor technology. About 60 liters air is expelled with each flush (https://evac.com/solutions/vacuumcollection/evacoptima5/).

Jets Vacuum toilet (by Jets Standard AS)

Jets base their both their large and small systems on a vacuumarator, hence they can avoid or minimize the need for a vacuum tank. For small systems a vacuum on demand (VOD) is available. In the VOD system, the vacuumarator starts when pressing the push button, vacuum builds up and the toilet flushes after a few seconds. These systems use less energy than the constant vacuum systems. The vacuumaerator macerates the waste into fine particles and pumps it to a tank or external sewer system as indicated in figure 1 (JETSGROUP, 2013). The water consumption is adjustable from 0-1.2 L per flush corresponding an estimated daily water consumption of 0-7.2 L per person.

Roevac Vacuum Toilet (Roediger Vakuum + Haustechnik)

Whereas the Jets and Evac has the vacuum valve and control mechanisms mounted in the toilet bowl Roediger uses a wall mount where the vacuum valve is separated from the toilet bowl. This can give a higher maintenance costs than the types with the valve mounted in the toilet. The toilet is flushed with about 1 liter of water per flush, measured during use. The toilet is estimated to give a daily flush water volume of 6 liters per person. The amount of water used per flush cannot be changed. The yearly consumption is about 10-12 kWh per person.

Challenges: Vacuum systems are robust and reliable today. However, they are dependent on electricity supply and systems with small vacuum reservoirs are more vulnerable, if the power goes, than systems with large vacuum reservoirs (tanks or large piping systems. The systems require correct construction, operation, maintenance. Requires trained caretakers.

Figure 1. System design example with various discharge options. (Source: JETSGROUP, 2013)

SiEUGreen investigations

An assessment has been made of the current market leading brands, by assessing technical specifications interviews with the manufacturers and users. When installed in the showcase water and energy consumption, reliability/maintenance need and noise as well as the user opinions will be collected.

Preliminary evaluation of sustainability parameters

Ecology	High	Med	Low	NA*	Economy	High	Med	Low	NA*
Treatment performance Phosphorus				X	Construction costs	X			
Nitrogen				X	O&M costs	X			
Organic matter, SS				X	Cost-efficiency	X			
Pathogens			X		Stability	X			
Resource recovery Nutrients Energy Water	X				Social				
Energy					Social acceptance		X		
Biodiversity				X	Technical				
Landscape aesthetics				X	TRL levels				
Planned for use in showcase	Fredrikstad								

*NA = data not available or not relevant

3.2 Alternative toilet systems - Urine diverting toilets

Treatment option/process	Toilet systems for urine separation
Resource	Human excreta urine (yellow water) and faeces (brownwater)
Expected products	Concentrated yellowwater and brownwater
Green-blue reuse options	Urban farm land and green areas, greenhouse, resource for fertilizer production, nutrient source in algae production

Short description of technology

It is well known that human urine can be a good fertilizer (Maurer et al. 2006). Technologies for separation of urine from wastewater flows have been applied for thousands of years in different parts of the world. In Europe, the purpose for urine separation has mainly been to use urine as fertilizer or to facilitate the treatment of faeces by reducing the amount of liquid in toilet waste.

Urine diversion devices include urinals, urine-diversion flush toilets (UDFTs) and urine-diverting dry toilets (UDDTs) (Münch and Winker, 2011, Rieck et al. 2012). In this context the toilet systems described use water. Most urine-separating toilets in Europe differ from ordinary toilets in that the bowls have two sections (Figure 1). A front bowl for urine collection and rear bowl for faeces and toilet paper. The design difference between the various models is the shape and size of the two compartments and in the way the flush water is introduced for the two compartments. Urine collected will be stored, while faeces goes to sewer, or local treatment (e.g. biogas or compost). Several toilet models were developed from 1970s. From 1990s urine separating toilets in porcelain were produced in Sweden and Germany by several manufacturers (Johansson 2000).

Urine separating toilets were implemented in ecological housing projects, both for holiday residences, houses and apartments blocks. Urine diversion has not yet gained widespread use in housing developments. There were challenges with the separation and the cleaning of the toilets. However the easiest way to retrofit a source separating system in existing buildings is to install a UDFT and use of urinals without water, are gaining popularity in Europe. There are many suppliers and models of urinals (Münch and Winker, 2011) and waterless urinals for men and women are now available (https://www.shelby.no/uridan).

New types of urine-separating toilets have recently been developed, which looks like ordinary toilets, including the toilet bowl, as e.g. the toilet "Safe" from Laufen (http://urinetrap.com/), which are available from spring 2020 (Figure 1-right).

Social acceptance and hygiene

Not all users are comfortable with urine diverting toilets and the handling of the waste. To achieve a hygienically acceptable product the urine should be stored at least 6 months before application (WHO 2006). Stored urine will normally have a bad smell due to high pH (>9) and ammonia volatilization. Problems with precipitation of in pipes are reported, but can be overcome with the right design. There has been concern about pharmaceuticals in urine used as fertilizer, but the root membrane will screen out many larger molecules as pharmaceuticals and their metabolites. However, this issue needs further research.

Storage and use

When urine is stored, urea will normally hydrolyze quickly, by the urease enzyme and ammonium is formed. Generation of ammonium raises the pH. This means that the nitrogen will be lost as ammonia gas.

However, if stored in closed containers losses will be small. But the liquid will smell, and, thus, be unpleasant to handle.

If the purpose of urine separation is to export nutrients more than 40-50 km, the water content should be reduced (Jenssen and Refsgaard 1998). Struvite precipitation will capture most of the phosphorus and some nitrogen into a salt that can be shipped. To export all nutrients, the water should be evaporated, but prevention of ammonia volatilisation is needed. This can be achieved by adding acid, as ammonia volatilisation will cease when pH become acidic. It can also be achieved by nitrification (see factsheet) as this transforms some ammonium to nitrate reduces the pH. However, it can also be achieved by preventing hydrolysis of urea. This can be achieved if pH is immediately raised to about 12. SLU has done some research where pH was raised using wood ash (Senecal and Vinnerås 2017). This technology has reached TRL 8 and is implemented in housing projects.

If the nutrients can be used locally in urban agriculture, there is no need to reduce water content, but nitrification may be used to make the liquid smell free and enhance the availability of the nutrient for plants (see factsheet).

Figures presenting the technology or process

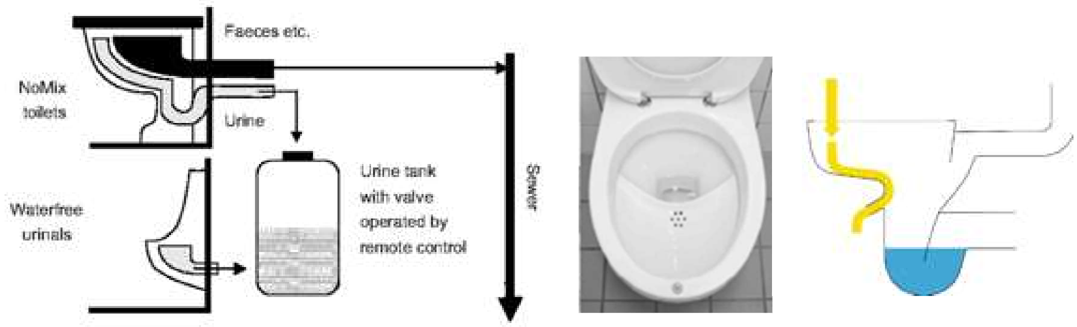

Figure 1. Principles of urine source separation technology and example of two toilets with and without (type Laufen: SAVE) a separate bowl for urine collection.

Challenges with implementation in the urban setting

Parameter	Low	Medium	High	NA
Space requirement		X		
Odour and nuisance		X		
Hygiene		X		
Regulation		X		
Public acceptance	X			

SiEUGreen investigations

Experiences with different toilet types described in literature have been evaluated. We recommend implementation and testing of the last generation of toilet systems, which are socially acceptable, as e.g. toilet "Safe" from Laufenas a showcase demonstration. Possible options for producing acceptable liquid fertilizer by nitrification should be included.

Preliminary evaluation of sustainability parameters

Ecology	High	Med	Low	N.A.	Economy	High	Med	Low	NA*
Treatment perform. Phosphorus	X				Construction costs				X
Nitrogen	X				O&M costs				X
Organic matter, SS				X	Cost-efficiency				X
Pathogens				X	Stability	X			
Resource recovery Nutrients	X				Social				
Energy				X	Social acceptance				X
Biodiversity				X	Technical				
Landscape aesthetics				X	TRL levels	5-7			

Planned for use in showcase	Fredrikstad. We suggest including at least 1 urine diverting toilet (type Laufen SAVE) and 1 urinal from showroom/visitor centre.
Possible use in other showcases	

*NA = data not available or not relevant

3.3 Alternative toilet systems - Dry toilets

Treatment option/process	Solar assisted dry/composting toilet system
Resource	Human excreta (organic household waste)
Expected products	Compost, compost and urine when urine diversion is applied
Green-blue reuse options	Urban farm land and green areas, greenhouse, resource for struvite production, nutrient source in algae production

Short description of technology

A dry or composting toilet collects human excreta without the use of water. Such toilets can be equipped with urine diversion either in the form of a urine diverting toilet bowl or a urine diverting insert in bench type toilets. There is a variety of designs; toilets with exchangeable compartments, multiple compartments or with one compartment (Fig.1). The latter with or without a sloping bottom. Excreta is treated by storage where upon desiccation occurs. Due to a low content of readily degradable carbon in excreta and an unfavourable C/N ratio. The C/N ration is approximately 7 in excreta but should be around 30 for composting. As a result, significant composting of excreta alone is not achieved. By adding a bulking material with readily available C-material a temperature increase and composting can be achieved. In some toilets, organic household waste is added. However, good composting needs mixing of the material. Some toilets therefore are equipped with manual or electrically driven mixing devices. In a solar assisted system, the process is enhanced by utilizing the sun to provide heat for the composting/desiccation/hygienization processes. Small PV panels can be used to power fans that enhance air flow that can help reduce smell as well as evaporation of excess liquid.

Figures presenting the technology or process

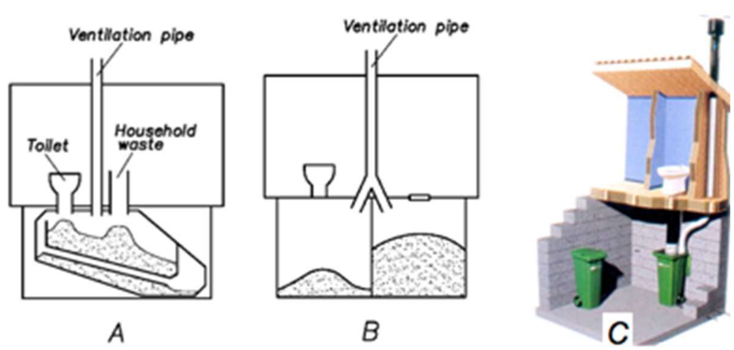

Figure 1. *Dry/composting toilets. A: single chamber, B: dual chamber, C: removable chambers*

Figure 2. Left: Urine diverting insert in a simple bench toilet. Right: urine diverting toilet bowl.

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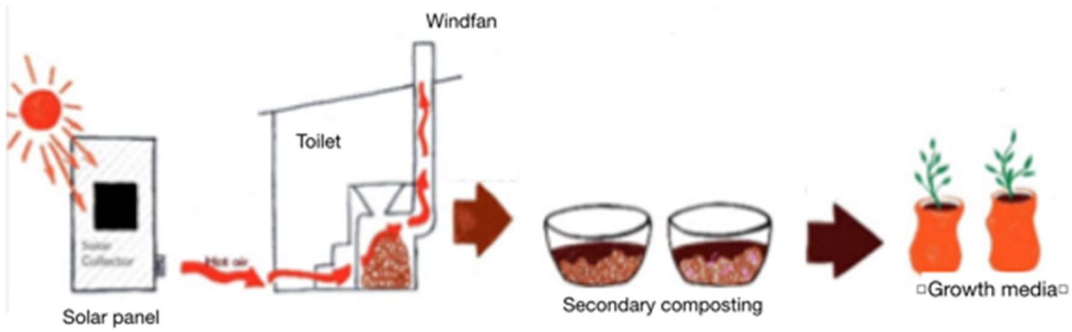

Figure 3. Principle of the solar assisted toilet to be used in SiEUGreen case Århus. The solar panel is attached to the south side of the toilet and provides both warm air and electricity to power a fan.

Figure 4. A prototype of the solar assisted toilet installed at Oslo´s largest art exhibition center, Høvikodden.

Challenges with implementation in the urban setting

Parameter	Low	Medium	High	NA
Space requirement		x		
Odour and nuisance	x			
Hygiene			x	
Regulation				x
Public acceptance				x

Comments:

Composting toilets are generally not suited in urban settings, but can be used as a stand-alone toilet in cities. Smell (inside and outside) has not been a problem in this prototype of the solar driven toilet (see above). However, composting toilet need proper maintenance routines providing for cleaning and emptying when necessary.

SiEUGreen investigations

A version of this toilet will be placed a one of the urban gardens in Århus, Denmark. The investigations will include the public perception of the toilet, the quality of the compost produced and need for maintenance.

Preliminary evaluation of sustainability parameters

Ecology	High	Med	Low	NA	Economy	High	Med	Low	NA*

Treatment performance Phosphorus	x				Construction costs		x		
Nitrogen		x			O&M costs			x	
Organic matter, SS	x				Cost-efficiency		x		
Pathogens	x				Stability		x		
Resource recovery Nutrients		x			Social				
Energy	x				Social acceptance		x		
Biodiversity					Technical				
Landscape aesthetics					TRL levels	7			
Other comments									
Planned for use in showcase	Århus								
Possible use in other showcases	Fredrikstad, Hatay, Beijing								

*NA = data not available or not relevant

3.4 Biofilter/filterbed greywater treatment systems

Treatment option/process	Greywater treatment – Biofilter/filterbed/constructed wetland
Resource	Greywater from apartments
Expected products	Water for irrigation of green areas and water as landscape elements in parks connected to apartments
Green-blue reuse options	Green house, urban farmland, balcony food production, aquaponics, hydroponics, water for parks and flowerbeds, potable water if further treatment by membrane filtration and UV

Short description of technology

Greywater treatment by using single-pass biofiltration in porous media and intermittent loading are well known and widespread technology for small wastewater flows for houses and cabins in the Nordic countries. Design guidelines are for such biofilters are available (VA-Miljøblad 60). Constructed wetlands, also called filterbeds are engineered systems using vegetation, soil, and organisms to treat wastewater (Kadlec and Wallace 2009). Constructed wetlands can remove a range of pollutants (such as organic matter, nutrients, pathogens, heavy metals) from the greywater. The two main types of constructed wetlands are subsurface flow and surface flow systems. The planted vegetation plays an important role in contaminant removal. The filter bed, consisting usually of sand, gravel, fabricated media such as light-weight aggregates has an equally important role to play.

Subsurface flow constructed wetlands (CWs) with pre-treatment biofilters for Nordic climate conditions have been pioneered in Norway (Jenssen et al., 1993). These CWs show excellent performance and produce an effluent quality that is independent of season (Jenssen et al., 2005). The biofilter reduce the organic load and contribute to nitrification. The biofilter can be integrated on top of the wetland filter or as part of landscape beautification in the urban settings (Fig.1).

The experience with greywater treatment in biofilter/filterbed are good, with high and stable removal of organic matter and suspended solids. Phosphorus removal can also be good if special filter media with high P-binding capacity is used.

In Norway there are technical guidelines for design of constructed wetlands treating ordinary wastewater and greywater (VA Miljøblad 49). Systems need to be designed according to these recommendations for approval.

Due to strict phosphorus treatment requirements in Norway the greywater systems must be designed for high phosphorus removal. Typical design includes 3-5 m^3 filer media per PE connected to the system. For systems treating many PE these systems can have a large footprint. If there is a chemical pretreatment stage the volume and area can be reduced.

Figures presenting the technology or process

Figure 1. Filterbed system with integrated aerobic biofilter for greywater treatment (Jenssen and Vråle, 2003) and a biofilter combined with constructed wetlands for greywater treatment in Oslo

Challenges with implementation in the urban setting

Parameter	Low	Medium	High	NA
Space requirement			X	
Odour and nuisance	X[1]	X		
Hygiene		X[2]		
Regulation		X		
Public acceptance			X	

Comments: 1) The systems should have an aerobic pretreatment e.g a biofilter. 2) The water flow in the wetland is subsurface, but sufficient cover material should be used to avoid water contact e.g. by children playing.

SiEUGreen investigations

A biofilter/filterbed greywater treatment system is designed for showcase Fredrikstad. However, urban use require small footprint and work to make the systems more compact is ongoing. After showcase implementation the project will evaluate re-use options for treated greywater.

Preliminary evaluation of sustainability parameters

Ecology	High	Med	Low	N.A.	Economy	High	Med	Low	NA*
Treatment performance Phosphorus	X				Construction costs	X			
Nitrogen		X			O&M costs		X		
Organic matter, SS	X				Cost-efficiency			X	
Pathogens	X				Stability	X			
Resource recovery Nutrients		X			Social				
Energy			X		Social acceptance	X			X
Biodiversity	X	X			Technical				
Landscape aesthetics	X	X			TRL levels	>7			
Other comments									
Planned for use in showcase	Fredrikstad								

Possible use in other showcases	Yes

*NA = data not available or not relevant

3.5 Greywater treatment in compact systems

Treatment option/process	Greywater treatment in compact systems
Resource	Greywater
Expected products	Source of alternative water
Green-blue reuse options	Green house, hydroponic culture, urban farmland, balcony food production, parks and flowerbeds, ground water recharge, safe discharge

Short description of technology

In greywater treatment, biofiltration is one of the most important separation processes that can be employed to remove organic matter. It consists of any type of filter with attached biomass on the filter media (Chaudhary et al., 2003). It can be fixed or moving bed and aerated or anaerobic. The biofiltration step can be applied as primary or secondary treatment depending on the need. Aerobic biofiltration is applied as a vertical down flow step prior to the horizontal constructed wetlands (Jenssen and Vråle, 2003) or in a compacted package treatment plants (Heistad et al., 2006, Heistad et al., 2001). A compact and reliable biological aerated filtration (BAF) system can also provide effective reduction of organic matter (BOD), suspended solids and microbiological contaminants from the greywater (Lazarova et al., 2003) and full nitrification (Mendoza-Espinosa and Stephenson, 1999).

The success of a biofilter in the different systems depends on the growth and maintenance of microorganisms (biomass) on the surface of filter media. For effective performance, it is necessary to understand the mechanisms of biomass attachment, growth and detachment on the surface of the filter media. For treatment of greywater with high organic matter (high strength greywater) aerobic technologies may have limited applications due to extensive energy requirements for oxygen supply, oxygen transfer limitations, large quantity of sludge production and difficulties in solids settling and thickening. In such situations, biologically aerated filtration preceded by an anaerobic filter may be effective with low energy requirement and less sludge production.

Process:

In a biofiltration system, the pollutants are dominantly removed due to biological degradation rather than physical straining. With the progression of the filtration process, microorganisms (aerobic, anaerobic, and facultative bacteria) gradually develop on the surface of the filter media and form a biological film or slime layer known as biofilm. The development of biofilm may take few days or months depending on the influent organic concentration, hydraulic retention time, the composition of the greywater. The membrane bioreactor (MBR) which combines biodegradation with membrane filtration for solid liquid separation has been regarded as an innovative technology for greywater treatment due to its process stability and its ability to remove pathogens (Li et al., 2009). The crucial point for the successful operation of these biofilter systems is to control and maintain a healthy biomass on the surface of the filter.

Types of biofiltration systems:

Different types of biofilter technology for removing organic matter, phosphorus nitrogen and heavy metals from wastewater are available today. Most of them are categorized as Fixed-film filter bed or fluidized filter beds. MBR systems being the advanced technologies appear to be attractive with respect to all aspects including high efficiency resulting in high hygienic quality of water, low energy consumption and small footprint (Li et al., 2009). The technology should be

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chosen based on the simplicity of the system (operation and management), area and energy requirement, treatment efficiency and the desired end use.

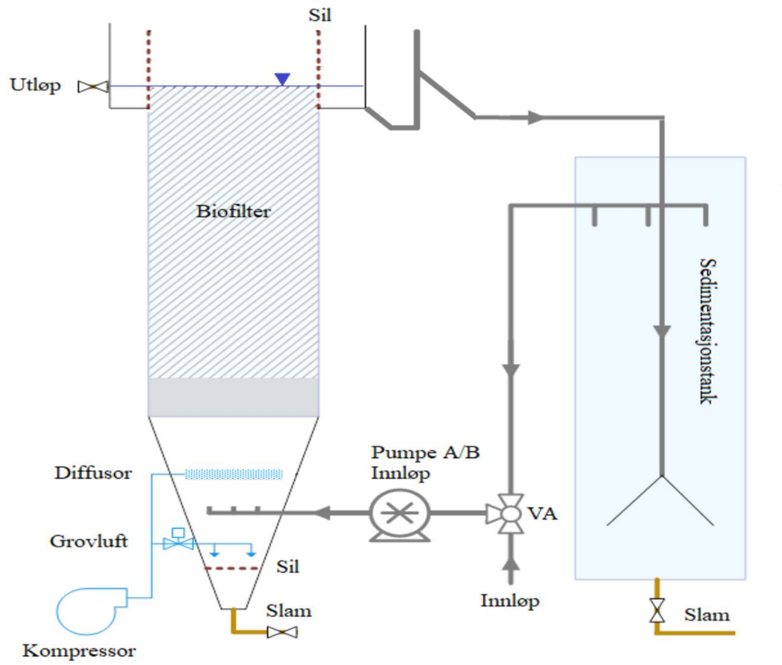

Figure 1. Biological aerated filtration system (Rummelhoff, 2019)

SiEUGreen investigations

The combination of vertical flow (VF) aerated biofilter (which can be integrated with compacted BAF, Vegetated/green wall) and HSSF CWs can be combined with MBR and UV in order to enhance the overall treatment performance. Moreover, the systems should be evaluated in terms of their pharmaceutical and performances in the removal of personal care product (PCCP) residues and surfactants.

Preliminary evaluation of sustainability parameters

Ecology	High	Med	Low	N.A.	Economy	High	Med	Low	NA *
Treatment perform. Phosphorus	X				Construction costs			X	
Nitrogen		X			O&M costs				X
Organic matter, SS	X				Cost-efficiency				X
Pathogens		X			Stability	X			
Resource recovery Nutrients Water Energy	 X X 			 X	Social				
Energy			X		Social acceptance	X			
Biodiversity	X				Technical				
Landscape aesthetics	X				TRL levels				
Planned for use in showcase	Fredrikstad on the condition that a reliable system is available at the time of implementation								

*NA = data not available or not relevant

3.6 Green wall for greywater treatment

Treatment option/process	Greywater treatment – **Green wall**
Resource	Greywater
Expected products	Source of alternative water
Green-blue reuse options	Green house, Hydroponic, urban farmland, balcony food production, parks and flowerbeds, ground water recharge

Short description of technology

The concept of green wall or vegetated wall for greywater treatment is similar to that of the constructed wetland treatment system, and in particular to that of the vertical flow constructed wetland with water recycling and trickling filter or recycled vertical flow constructed wetland (RVFCW) (Gross et al., 2007). Like constructed wetlands (CWs), green walls are engineered systems which are designed and constructed to utilize the natural processes operating as a bio filtration system and provide treatment mostly through physical and biochemical processes as the water percolates vertically down through the filter media. Integration of building infrastructures as a component of on-site greywater treatment with green wall technology provides many environmental and financial benefits, as the green wall plants obtain water and nutrients from the system (Eregno et al., 2017).

Green walls can, therefore, undertake the functions of constructed wetlands particularly in densely populated areas with comparable treatment efficiency, but with very small footprint (Prodanovic et al., 2018). Green wall infrastructures for greywater treatment or post-treatment can have multitude benefits. As a living wall system employing ornamental plants provides aesthetic values, increase biodiversity, create and improved micro-climate, source of urban organic food production. In addition, green walls provide effective thermal insulation and energy savings for the buildings (Pérez et al., 2014, Jim and He, 2011) and reduce noise (Perini and Rosasco, 2013, Azkorra et al., 2015). The treated water can then be recycled into the buildings for non-potable uses.

Process:

The vertical greywater treatment system consists of vertical infiltration into porous media. Different sets of filter media can be used. Biofilm processes, sorption mechanisms and straining provides the treatment. Greywater treatment in a vertical vegetated wall can be integrated with hydroponic food production into a double skin facade for installation on new high-rise buildings or as a retrofit on existing buildings with adequate solar exposure.

Challenges:

Position of the wall to solar exposure. Winter conditions.


Figure 1. Vegetated greywater treatment walls (Svete, 2012) and Hydroponic feed production from treated greywater.

SiEUGreen investigations
May be used and investigated in the showcase Fredrikstad.

Preliminary evaluation of sustainability parameters

Ecology	High	Med	Low	NA	Economy	High	Med	Low	NA*
Treatment performance Phosphorus	X				Construction costs			X	
Nitrogen		X			O&M costs				X
Organic matter, SS	X				Cost-efficiency				X
Pathogens		X			Stability	X			
Resource recovery Nutrients Water Energy	 X X			 X	Social				
Energy				X	Social acceptance	X			
Biodiversity	X				Technical				
Landscape aesthetics	X				TRL levels				
Other comments									
Planned for use in showcase	Fredrikstad								
Possible use in other showcases									

*NA = data not available or not relevant

3.7 Green roof light weight aggregate (LWA) and green walls rainwater treatment

Treatment option/process	Storm water treatment – Green roof
Resource	Precipitation (rain and snow melt)
Expected products	Water for irrigation of green areas and water as landscape elements in parks connected to apartments
Green-blue reuse options	Green house, urban farmland, balcony food production, aquaponics, hydroponics, water for parks and flowerbeds

Short description of technology

A green roof of a building is partially or completely covered with vegetation and a growth medium, with a waterproofing membrane. It may also include additional layers, such as a root barrier and drainage and irrigation systems. The depth of the growing media depends on vegetation type. Trees, shrubs and herbs need thick soil layers while Sedum or mosses need thin soil layers. Green roof absorb stormwater and temporarily stores it. The absorbed water will be used by the vegetation, transpired and most importantly will reduce the quantity of runoff getting into the stormwater system and also enhances the quality of the stormwater (Jotte et al. 2017).

A **green wall** is partially or completely covered with greenery that includes a growing medium and an integrated water delivery system. A green wall is also known as a living wall or vertical garden. It provides insulation to keep the building's inside temperature consistent. Green walls may be indoors or outside, freestanding or attached to an existing wall, and come in a great variety of sizes. Green walls can also be used for greywater treatment in growing seasons (section 3.2.3)

Figures presenting the technology or process

Figure 1. Green roof real scale test laboratory with sedum spp and 15 cm lightweight aggregates at NMBU, Campus Ås, Norway.

Challenges with implementation in the urban setting

Parameter	Low	Medium	High	NA
Space requirement		X		
Odour and nuisance	X			
Hygiene			X	
Regulation		X		
Public acceptance			X	

Comments:

SiEUGreen investigations

Experiences with green roofs in cold climate areas have been compiled. The project will implement a selection of storm water technologies including green roofs. These systems will be integrated as attractive elements of the living quarters. Investigations will evaluate the systems operation, their multifunctionality and how these systems can support the on-site wastewater systems. Social acceptance will be investigated.

Preliminary evaluation of sustainability parameters

Ecology	High	Med	Low	N.A.	Economy	High	Med	Low	NA*
Treatment perform. Phosphorus			X		Construction costs		X		
Nitrogen		X			O&M costs			X	
Organic matter, SS	X				Cost-efficiency				X
Pathogens		X			Stability	X			
Resource recovery Nutrients		X			Social				
Energy			X		Social acceptance	X			X
Biodiversity	X				Technical				
Landscape aesthetics	X				TRL levels	>7			

Other comments

Amundsen and Sleipnes (2019) present an investigation how stormwater treatment can be integrated as park elements and included in the water management in the Fredrikstad showcase. Investigation of green roofs show that light weight aggregates can be used as filter media to increase water retention.

Planned for use in showcase	Fredrikstad (green roofs, walls, wetland and vegetated channel)
Possible use in other showcases	Yes

*NA = data not available or not relevant

3.8 Stormwater treatment in wetland/pond systems

Treatment option/process	Storm water treatment – constructed wetlands and ponds
Resource	Precipitation (rain and snow melt)
Expected products	Water for irrigation of green areas and water as landscape elements in parks connected to apartments
Green-blue reuse options	Green house, urban farmland, balcony food production, aquaponics, hydroponics, water for parks and flowerbeds

Short description of technology

Constructed wetlands are engineered systems using vegetation, soil, and organisms to treat stormwater. Constructed wetlands also act as a biofilter and/or can remove a range of pollutants (such as organic matter, nutrients, pathogens, heavy metals) from the water. The two main types of constructed wetlands are subsurface flow and surface flow systems. The planted vegetation plays an important role in contaminant removal. The filter bed, consisting usually of sand and gravel, has an equally important role to play. Wetlands can also be part of ponds and channels/streams.

Figures presenting the technology or process

Figure 1. Constructed stormwater wetlands, ponds and channels in Ski and Oslo, Norway.

Challenges with implementation in the urban setting

Parameter	Low	Medium	High	NA
Space requirement			X	
Odour and nuisance	X			
Hygiene			X	
Regulation		X		
Public acceptance			X	

Comments:

SiEUGreen investigations

Examples of full-scale stormwater systems have been visited and evaluated. Water quality data has been collected and will be compiled for a selection of urban constructed wetlands and ponds and treatment evaluated, included hygienic parameters. Integration of stormwater treatment and on-site waste handling will be evaluated.

The project will implement a selection of storm water technologies and these systems will be integrated as attractive showcase elements. Investigations will evaluate the systems operation, their multifunctionality and how these systems can support the on-site wastewater systems. Social acceptance will be investigated.									
Preliminary evaluation of sustainability parameters									
Ecology	High	Med	Low	N.A.	Economy	High	Med	Low	NA*
Treatment performance Phosphorus			X		Construction costs		X		
Nitrogen		X			O&M costs			X	
Organic matter, SS	X				Cost-efficiency				X
Pathogens		X			Stability	X			
Resource recovery Nutrients		X			Social				
Energy			X		Social acceptance	X			X
Biodiversity	X				Technical				
Landscape aesthetics	X				TRL levels	>7			
Other comments		**Storm water treatment – Preliminary report on SiEUGreen investigations** A selection of urban stormwater systems in Norway (Oslo region) have been visited and their functionality been investigated. In general, the systems show good improvement of water quality parameters, such as suspended solids, nitrogen, phosphorus and *E.coli*, but efficiency vary with season, hydraulic loading and design. Multistage systems provide better removal. Urban wetlands and ponds attract animals such as birds. These may pollute the water. It is not recommended to facilitate stormwater ponds and wetlands for bathing due to hygienic risk (Paruch et al. 2018). Stagnant water in ponds and wetlands may develop conditions for algal growth, resulting in reduced water quality. For park elements water should be recirculated by including vegetated channels and bioretention in periods without precipitation. Amundsen and Sleipnes (2019) present an investigation how stormwater treatment can be integrated as park elements and included in the water management in the Fredrikstad showcase. Investigation of green roofs show that light weight aggregates can be used as filter media to increase water retention.							
Planned for use in showcase		Fredrikstad (wetland and vegetated channel)							
Possible use in other showcases		Yes							

3.9 Stormwater treatment by rainbeds and infiltration systems

Treatment option/process	Storm water treatment – rainbeds and infiltration
Resource	Precipitation (rain and snow melt)
Expected products	Water for irrigation and infiltration in green areas and water as landscape elements in parks connected to apartments
Green-blue reuse options	Water for parks and flowerbeds
Short description of technology	

In rainbeds/raingardens stormwater is collected into the treatment area, constructed depressions within the landscape, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. Runoff passes first over or through a sand bed, which slows the runoff's velocity, distributes it evenly along the length of the ponding area, which consists of a surface organic layer and/or groundcover and the underlying planting soil. The plants—a selection of wetland edge vegetation (plants that can tolerate both saturated and dry soil), such as wildflowers, sedges, rushes (e.g. Bamboo), ferns, shrubs and small trees—take up excess water. Water filters through soil layers before entering the groundwater system by infiltration, or a drainage system. Vegetated swales (bioswales), are similar to rain gardens, but they are linear features, typical located along property lines and streets, intended to convey stormwater towards a drainage feature.

Stormwater can be infiltrated in local soil if the conditions allow for infiltration. In areas of highly permeable (sand and gravel or well aggregated soils) soils large quantities can be infiltrated. Some water can always be infiltrated if the soils are dry, but in low permeability soils (fingrained soils) the amount can be very limited. The hydraulic capacity can also limit infiltration. The infiltration capacity depends on soil type, soil thickness porosity, aquifer properties and season.

Figures presenting the technology or process

Figure 1. Example of a rainbed at NMBU (Gómez, 2016).

Challenges with implementation in the urban setting

Parameter	Low	Medium	High	NA
Space requirement		X		
Odour and nuisance	X			
Hygiene	X			
Regulation	X			
Public acceptance			X	

SiEUGreen investigations

The project will implement a selection of storm water technologies including rainbeds and these systems will be integrated as attractive showcase elements. Investigations will evaluate the systems operation, their multifunctionality and how these systems can support the on-site waste systems. Social acceptance will be investigated.

Preliminary evaluation of sustainability parameters									
Ecology	High	Med	Low	N.A.	Economy	High	Med	Low	NA*
Treatment performance Phosphorus		x			Construction costs		X		
Nitrogen		X			O&M costs			X	
Organic matter, SS	X				Cost-efficiency				X
Pathogens		X			Stability	X			
Resource recovery Nutrients		X			Social				
Energy			X		Social acceptance	X			
Biodiversity	X				Technical				
Landscape aesthetics	X				TRL levels	>7			
Other comments		**Storm water treatment – Preliminary report on SieEUGreen investigations** Amundsen and Sleipnes (2019) present an investigation how stormwater treatment can be included in the water management in the Fredrikstad showcase. Schmidt (2018) investigated stormwater infiltration in urban parks (turfgrass)							
Planned for use in showcase		Fredrikstad (green roofs, walls, wetland and vegetated channel)							
Possible use in other showcases		Yes							

4. Research data to be collected to evaluate the technology in full scale operational environment

Technology	Research data to be collected in operation environment	Method of data collection
1. Vacuum- /low flush toilets	• Water consumption • Energy assessment • Operation and maintenance • Noise • Social acceptance	Registrations and/or calculation, Interviews
2. Urine diverting toilets	• Water consumption • Operation and maintenance need • Social acceptance	Registrations and/or calculation interviews
3. Solar dry toilet	• Amount of solar energy produced (heat and electricity) • Temperatures • Hygienization efficiency of the system • Compost quality • Operation and maintenance • Social acceptance	Registrations and/or Calculation Interviews
4. Greywater treatment using a Biofilter/Filterbed treatment system	• Water quality data (for heavy metals, nutrients (N, P, etc), oil and grease, pathogens,	Registrations and/or calculation

	surfactants, OM and suspended solids. • Performance efficiency • Amount and quality of water treated, energy used • Amount of water and energy saved from reuse of treated water • Risk assessment for fit-for-reuse • Environmental, social and economic gains (water quality benefits, biodiversity, and beautification • Operation and maintenance	Interviews
5. Green wall for greywater treatment	• Water quality data • Environmental, social and economic gains (water quality benefits, biodiversity, and beautification	Registrations and/or calculation
6. Green roof light weight aggregate (LWA) for water retention	• Amount of water retained • Environmental, social and economic gains • Operation and maintenance • Social acceptance	Registrations and/or calculation Interviews
7. Green wall for water retention	• Amount of water retained	Registrations and/or calculation
8. Wetland/pond and infiltration system for storm water disposal and reuse	• Water samples for heavy metals, nutrients (often from fertilizer and pet waste), OM, and suspended solids. • Environmental, social and economic gains (water quality benefits, biodiversity) • Operation and maintenance need • Social acceptance	Registrations and/or calculation Interviews

5. Adoption of the technology for implementation in the showcases

The selected technological options will facilitate the on-site treatment and safe recycling of resources from domestic wastewater and storm water. Adoption and implementation of these technologies in the urban setting is a key to the water management system. The recycling of water not only potentially contributes to local water and energy savings but also protects the environment.

It is important, however, to make sure that the chosen technologies are properly installed and monitored. Bad smell or hygienic risk is generally not recognized as challenges with the listed technologies here, when properly designed and maintained but smell and hygienic risks are extremely important to avoid.

Trained people must be responsible for operation and maintenance the systems for waste handling.

For systems as vacuum toilets, installation requires special expertise with knowledge of technical solutions. Users of such toilets must also be given information about the toilets and their use.

For systems including open waters (wetlands, ponds, channel), design should be in compliance with Norwegian guidelines.

6. Preliminary results of the laboratory tests of the technology

Preliminary results are presented in the Annexes and give basis for implementation of the different technologies into the showcases.

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Co-funded by the Horizon 2020 programme of the European Union

Co-funded by the Chinese Ministry of Science and Technology

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Annex

List of researches carried out by MSc students in the context of testing the blue technologies in controlled laboratory environment prior to implementation in the showcases.

Project Acronym:	SiEUGreen
MSc. Thesis Research Title:	Using Concept Selection Process to Secure Sufficient Storm-water Management Planning in Norwegian Municipalities
MSc. Students	***Sigrid Amundsen***, Vann- og miljøteknikk, Fakultet for realfag og teknologi, NMBU. ***Elise Mesøy Sleipnes***, Industriell økonomi, Fakultet for realfag og teknologi, NMBU
Abstract:	More intense precipitation events due to climate change, combined with increasing dense surfaces in urban areas, will lead to an increase in surface runoff that can be harmful to people, buildings and infrastructure. Increased focus on planning is therefore required in future stormwater management. In this thesis we examined whether Concept Selection Process (CSP) could be used to ensure integrated planning for Norwegian municipalities. In a CSP, different concepts are developed, and later weighed up against each other to find the concept that will be the most beneficial to society (e.g. a concept that leads to increased biodiversity). A typical CSP consists of five steps: a requirement analysis, goal and strategy document, an overall requirements document, alternative analysis and guidelines for the pre-project. In this thesis, CSP has been used to develop a stormwater solution for a development area in the city of Fredrikstad ("case area"). CSP is selected to ensure a comprehensive and holistic planning process, which will give the most beneficial solution for society (e.g. good solutions for utilization of storm water, biodiversity is maintained or increased, reduced risk of flooding and damaging storm water runoff in populated areas and downstream recipients). The toolkit used in the concept development in this thesis consists of green roofs, living walls, rain gardens, storm water ponds and rain barrels. CSP is an extensive process, and to adjust CSP to small stormwater projects both the demandoriented analysis and the guidelines for the project were excluded. To evaluate the concepts in the project, a Multiple-Criteria Decision Analysis (MCDA) and a sensitivity analysis, were used instead. These adjustments simplified the CSP and the MCDA ensured a holistic process when choosing the final concept. The CSP showed that the most beneficial concept for the case area included a stormwater pond, green roofs, a rain garden and living walls. This concept met the requirements from the

	interested parties, e.g. Fredrikstad municipality, and the future residents in the development area, as well as being beneficial for increased biodiversity and has low cost. The process of implementing the CSP in this thesis showed that CSP includes factors that are desirable in municipal stormwater planning, including social benefits, holistic thinking across disciplines and agency boundaries and extensive requirement analyses. We conclude that CSP can be a useful tool for municipalities to meet future climate changes and challenging stormwater events.

Project Acronym:	SiEUGreen
MSc. Thesis Research Title:	Evaluation of a compact unit for primary and secondary treatment of greywater
Responsible MSc. Students	Simon Rummelhoff, Vann- og miljøteknikk, Fakultet for realfag og teknologi, NMBU.
Abstract:	Water is a vital element of life. It is also becoming a perilously scarce resource. Technology facilitating reduced water consumption, and solutions permitting the re-utilisation of wastewater is therefore becoming extremely relevant. If the wastewater from a household is separated into greywater and blackwater, recycling is facilitated and more than 90% of the total could be recycled. As greywater is to be recycled in densely populated areas compact greywater treatment systems are needed. Biological aerated filters (BAF) has lately showed promising results as a low-cost technology offering small footprint and low energy consumption. In this thesis a BAF is tested with greywater, to reveal its potential as an element in a compact greywater treatment system. In the experiment diluted blackwater from "Kaja", a student dormitory at Norwegian University of Life Sciences (NMBU), were used. The reactor measured 0.24 m in diameter, with a filter dept of 0.9 m. Floating biofilm carriers were used as filter media, and it was operated in an upflow mode. The diluted blackwater had COD, BOD5 and TSS concentrations between 313 – 665, 115 – 343, and 142 – 273 mg/L respectively. Hence, representing a greywater by its organic matter and particle content. During 4 weeks of testing the reactor showed average 83-94 % removal of TSS, 83 – 89 % removal of BOD5, and 77 – 82 % removal of COD on loading rates between 100

	– 300 L/d. The BAF used the supplied air effectively and showed great potential of energy efficiency. Overall the reactor tested in this study showed promising results. However, as the experiments was conducted with diluted blackwater, testing with real greywater should be continued to give better understanding of the possibilities and limitations of using BAFs in a compact system when treating greywater.

Co-funded by the Horizon 2020 programme of the European Union

Co-funded by the Chinese Ministry of Science and Technology

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774233

SiEUGreen

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