Interreg North-West Europe

WOW!

Deliverable T.3.2.1

Critical success factors for valorisation routes

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WOW! - Wider Opportunities for raw materials from Wastewater

Sewage contains valuable substances that can be used as raw materials for biobased products. However, to date this potential has hardly been exploited to its full potential in North-West Europe. This results in loss of valuable materials, CO_2-emmissions and less efficient use of natural resources. The Interreg North-West Europe project WOW! – (Wider business Opportunities for raw materials from Wastewater (sewage)) aims to make the transition to a more circular approach by matching supply and demand of cellulose, lipids and PHA bioplastics from sewage. The international consortium consists of partners from government, business and academia from the UK, France, Belgium, Germany, Luxembourg and the Netherlands.

There are market opportunities for raw materials from sewage. To meet the demand, sewage treatment plants and industry require alignment. This calls for a transition: sewage treatment plants need to switch from treating sewage as waste to treating sewage as valuable materials. Business models need to be adjusted to create sustainable business opportunities. Additionally, market parties need to regard sewage as a valuable source instead of 'dirty water'. Lastly, relevant policies and legislation should be amended to enable this new circular practice. To realise these opportunities the consortium aims to develop value chains for three different raw materials from sewage: cellulose, PHA bioplastics and lipids.

The following activities will be part of the project:

- ✓ Identify high potential value chains for raw materials from sewage.
- ✓ Develop a Decision Support Tool that guides water authorities in their transition towards a circular approach on sewage.
- ✓ Build and run three WOW! pilots to optimise and implement innovative recovery and upcycling techniques.
- ✓ Create bioproducts made out of sewage, such as bioplastics, biofuel and bio-char.
- ✓ Create National Policy Action Plans and an EU Policy Roadmap

This report on critical success factors for valorisation routes is input for the National Policy Action Plans and the EU Policy Roadmap.

Executive Summary

Sewage contains valuable substances that can be used as raw materials for biobased products. Different EU projects such as the Interreg NWE project WOW! – (Wider business Opportunities for raw materials from Wastewater) have shown that recovery of raw materials from sewage is technically possible and that there is a potential market opportunity for these raw materials. However, to date this potential has hardly been exploited to its full potential in Europe resulting in loss of valuable materials, CO_2-emmissions and less efficient use of natural resources.

This report describes critical success factors for the recovery of raw materials from sewage and bringing these resources to the market based on lessons learnt in EU subsidy projects. Why have some recovery techniques been successfully implemented while others are still in the pilot phase or did not succeed? Information was gathered via literature, an online questionnaire and interviews.

Based on the information gathered, two important **drivers** can be distinguished that determine whether resource recovery from sewage becomes a success in the EU:

1. Acceptance of raw materials from sewage
   Sewage has always been linked to unhygienic and pollution. To accept raw materials from sewage, first of all the organizations that are responsible for treating sewage (suppliers) need to realize that sewage is actually a valuable resource and not waste. For the acceptance of products from sewage by the customers (businesses and consumers), it is important that the hygienic and environmental safety can be assured. A promising option to achieve this is the development of a EU-Standard to assess the quality of new products from sewage and the introduction of EU-sustainability certification for all products.
2. Policies related to use of products from sewage
   The current European regulatory framework considers products made from sewage as waste. This means that for the application of these products it is needed to obtain an end-of-waste status. This is not an easy task since the requirements described in article 6 of the European Waste Framework Directive a) have a focus on minimising risks instead of maximising recovery of resources and b) can be interpreted in different ways. This leads to different interpretations of the European Waste Framework Directive between member states and therefore differences in costs, procedures, acceptance and practice of resource recovery around the EU. A solution to overcome this is an update of the existing European regulatory framework on waste and harmonise it with the Circular Economy Package to provide harmonised, clear and transparent guidance on preferred End-of-Life options and to facilitate optimal resource use (including waste). The latter can be stimulated by implementing favourable tax systems or by making a certain percentage of recovery mandatory, similar to what exists for biofuels.

Looking at the **critical success factors** for the recovery of raw materials from sewage, it is difficult to distinguish generic success factors. However, as a rule of thumb projects tend to be more successful if there is regular consultation with regional and national authorities and if a project is not afraid to take a next step in (legal) acceptance of a product if not all sign are green yet.

The drivers and critical success factors will be elaborated further in the National Policy Action Plans and the European Roadmap which are drafted as part of the WOW! project.

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1. Introduction

This report describes critical success factors for valorisation of resources from waste water (sewage) and. bringing these resources to the market. For this report, information from both inside and outside the water sector is used, including similarities and differences in the barriers faced and the way they were overcome.

Chapter 2 describes the general bottlenecks for the recovery of resources from sewage. The next chapter (CH 3) focuses on lessons learnt in different EU subsidy projects concerning (the solution of) these bottlenecks followed by a description of lessons learnt from other initiatives related to recovery of resources from wastewater (chapter 4). The final chapter provides an overview of the two of the critical drivers for success for valorisation of resources from waste water: social acceptance and policy.

Social and academic relevance

Most human activities that use water produce waste water. The use of fresh water increases and the amount of water waste produced, and its overall pollutant load, steadily increases. In all countries except the most developed, the vast majority of wastewater is directly released to the environment without proper treatment, which has harmful effects on human health, economic productivity, the quality of water resources gentle environmental, and ecosystems. Although wastewater is a key part of the water management, water, after being used, is too much often seen as a burden to be eliminated or as an embarrassment to ignore.

The results of this neglect are obvious. Immediate impacts, including deterioration of aquatic ecosystems and diseases waterborne caused by a supply of contaminated fresh water, have a significant impact on the well-being of communities and the means of subsistence of individuals. Persistent inability to consider wastewater as a social problem and major environmental could compromise other efforts to achieve the 2030 Agenda for sustainable development. Faced with constantly increasing demand, wastewater is growing as a reliable source of alternative water, thus changing the paradigm wastewater management of "treatment and disposal" to "re-use, recycling and resource recovery”. In this regard, wastewater is no longer considered a problem in quest for a solution but rather as a part of the solution to challenges societies face today. The potential benefits of extracting these resources from wastewater far exceed human health and the environment and have implications for food security and energy as well as mitigation of climate change. In a circular economy, in which economic development is in balance with the protection of natural resources and the sustainable development, wastewater represents widely available and valuable resources. The prospects are undeniably optimistic, if the actions are being taken now.[1]

Strengthening scientific knowledge and monitoring to understand and control risks, is one of the keys to increase water re-use. Management policies based on the precautionary principle are developed on the basis of existing regulations and other international guidelines (FAO, WHO). For most countries, regulations are non-existent, incomplete or inoperative and there is a strong deficit in scientific knowledge concerning the topic at hand. Without this knowledge, it is impossible to optimise the dimensioning of treatment plants, the choice of cultivation practices and adjust fertilisation. Indeed, wastewater has a fertilising power: it is estimated only if all the nutrients in the black water (faeces and urine) were valued in agriculture, we would save 30% of nitrogen fertilisers and more than 15% of phosphate fertilisers.[2]

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1 2017 UN World Water Development Report, Wastewater

2 Food and Agriculture Organisation, 2010

2. General bottlenecks in wastewater resource recovery

In the research project Sustainable Product, Energy and Resource Recovery from Waste water[3], funded by European Union's Horizon 2020 research and innovation programme, a study was performed to reveal the technologies and potentials to recover water, energy, fertilisers and products from municipal WWTPs and to analyse the various bottlenecks that may their hinder successful implementation. P. Kehrein e.a.[4] describe in this study that there is a variety of issues that may hinder the successful implementation of resource recovery routes mentioned in the scientific literature. These relate to nine bottlenecks that can be grouped into three categories (A, B, C).

(A) Economics and value chain:

1. Process costs: capital expenditures and operational costs (such as energy, water and personnel)
2. Resource quantity: compared with conventional production systems, often only small quantities of a resource can be recovered at a STP.
3. Resource quality: customers often demand a steady quality, which can be an issue in case of contaminants or impurities.
4. Market value and competition: conventional production systems can potentially outcompete recovered resources (for example because of lower production costs or a higher quality)
5. Utilisation and application: in some cases the usefulness of recovered resources might be unknown and new market niches, applications and partners have to be found to make a recovered resource route successful.
6. Distribution and transport: if recovered resources are sold to external customers and not used on site, distribution and transport have to be organised. This may be challenging due to geographical and temporal discrepancies between supply and demand, lack of infrastructure, or cost.

(B) Environment and health:

7. Emissions and health risks: The use of recovered resources or the recovery process may entail risks to human health due to contaminants, or may cause emissions and environmental problems. This may be due to insufficient process control.

(C) Society and policy:

8. Acceptance: User acceptance of resources recovered from wastewater (a faecal contaminated source) may be low due to fears or misconceptions about the risks they pose.
9. Policy: To be successful, resource recovery routes need adequate policy and legal frameworks. A lack of legislation, political will or economic incentives may hinder successful implementation.

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[3] See paragraph 3.1.14

[4] Environmental Science, Water Research & Technology; P. Kehrein, M. van Loosdrecht, P. Osseweijer, J. Dewulf, M. Garfi and J. A. Posada Duque, Environ. Sci.: Water Res. Technol., 2020, DOI: 10.1039/C9EW00905A, p. 23.

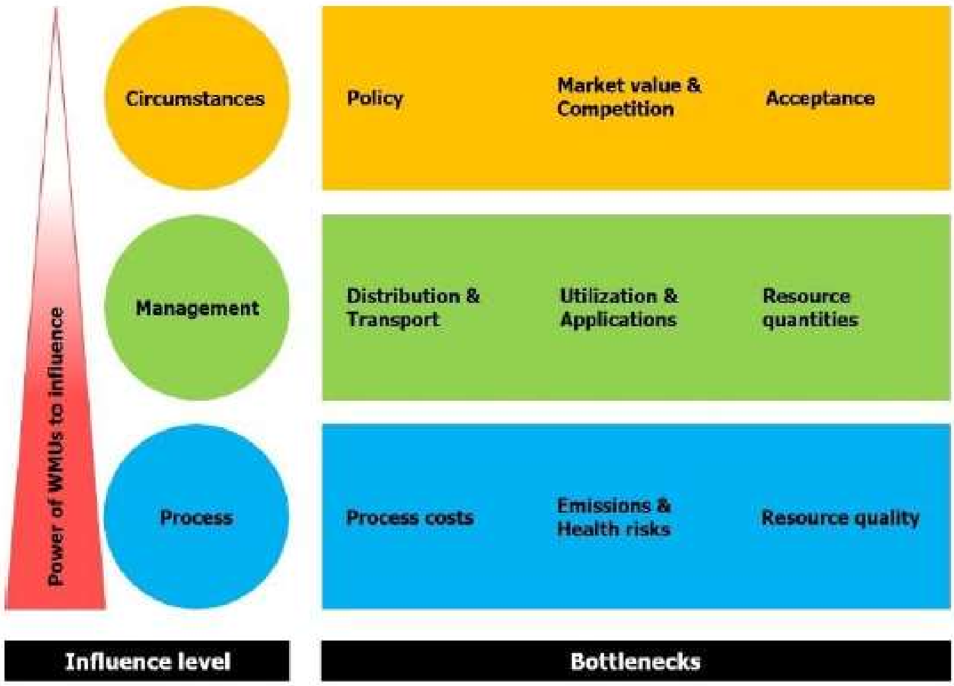

Figure 1 The power of utilities to influence identified bottlenecks for resource recovery[5]

Bottle necks related to Distribution & Transport, Utilisation & Applications, Resource quantities, Process costs, Emissions & Health risks and Resource quality can to a certain extend be influenced by the technology provider or water authority. This was also the case at Waternet in Amsterdam. Together with partners Waternet successfully implemented phosphorus recovery. Van der Hoek et al[6] describe that there is a wide variety of possible resources in wastewater that can be recovered. They defined that the problem is not the availability of technologies, but the lack of planning and design methodology to identify and deploy the most sustainable solutions in a given context, so they went ahead and developed a resource recovery policy. According to P. Kehrein et al[7] most of the bottlenecks are in the Economics and value chain development category. One success factor is to implement a resource recovery policy that proactively eases or even eliminates these bottlenecks.

As Figure 1 shows, the successful implementation of resource recovery routes also depends on factors that organisations and companies can hardly influence. These are Policy, Acceptance and Market Value and Competition.

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[5] P. Kehrein, 2020, p. 30.

[6] Elsevier; van der Hoek JP, de Fooij H, Struker A. Wastewater as a resource: Strategies to recover resources from Amsterdam's wastewater. Resources, Conservation and Recycling. 2016 Oct; 113:53–64.

[7] P. Kehrein, 2020, p. 23.

A general bottleneck for waste water resource recovery is related to the category "Society and Policy": the definition of waste.[8] As described in the State of the Art report[9] the end-of-waste concept was defined in the Waste Framework Directive 2000/98. The aim was to re-introduce recovered materials from waste streams, so that these streams cease to be waste when certain end-of-waste criteria are fulfilled. These materials would thus no longer be labelled as waste but as new and safe-to-use products. Only very few materials from waste water have received the end-of-waste status as according to Article 6 (1) and (2) of the Waste Framework Directive 2008/98/EC, certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in line with certain legal conditions, in particular:

- the substance or object is commonly used for specific purposes;
- there is an existing market or demand for the substance or object;
- the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products);
- the use will not lead to overall adverse environmental or human health impacts.[10]

The main material is the use of sewage sludge as feedstock or co-substrate for biogas production or as soil amendment product and for nutrient recovery strategies. Sludge originates from the process of treatment of wastewater. Due to the physical-chemical processes involved in the treatment, the sludge tends to concentrate heavy metals and poorly biodegradable trace organic compounds as well as potentially pathogenic organisms (viruses, bacteria etc) present in waste waters. Sludge is, however, rich in nutrients such as nitrogen and phosphorous and contains valuable organic matter that is useful when soils are depleted or subject to erosion. The organic matter and nutrients are the two main elements that make the spreading of this kind of waste on land as a fertiliser or an organic soil improver suitable.

The bottlenecks identified in this review hint clearly that the end-of-waste concept is yet insufficiently considered for most resources recoverable from municipal wastewater. Reasons are that active support from legislators and governance is lacking because recycling is mostly governed by fragmented decision-making in regional administrations. Active regulatory support such as recovery obligations or subsidies are yet not common practice in many countries.[11]

However, in May 2020, the new quality requirements for re-used wastewater have been formally approved in the European Parliament. This bill makes it possible to use treated wastewater for irrigation in agriculture and horticulture. The proposal was previously approved during negotiations between EU Member States, the European Commission and the European Parliament. The approval means that the law will actually be implemented. A positive result is important for the agricultural sector as increasing drought is a challenge farmers across Europe face. It is therefore crucial not only to use ground and surface water for irrigation, but also look at new sources. Wastewater can be treated in such a way that it can be re-used for sprinkling agricultural crops: a win-win situation for people, farmers and the environment. The proposal contains European quality criteria for the recycled water, which safeguards food safety and public health in all Member States. [12]

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[8] Env P. Kehrein, 2020, p. 23.

[9] WOW! Project Legal Framework for raw materials from sewage water, C. Wessels and P. Dijkshoorn, 2020, p. 16.

[10] https://ec.europa.eu/environment/waste/framework/end_of_waste.htm

[11] Env P. Kehrein, 2020.

[12] http://www.janhuitema.nl/persbericht-jan-huitema-vvd-europese-goedkeuring-voor-irrigatie-met-gezuiverd-afvalwater/

3. Lessons learnt from European projects

There are many European projects that deal with resource recovery that face the same legal and regulatory challenges as the WOW! project. Partners in these projects look for similar information and their questions are often similar. This is why we have taken the initiative to contact these projects and share information. This chapter gives an overview of the (lessons learnt of) Horizon2020 and Interreg EU projects that focus on resource recovery. This includes projects that deal with nutrients and focus on producing fertiliser, which is very specific legislation, because producers they also need to acquire an end-of-waste status for their products.

Horizon 2020

Horizon2020 projects deal with a wide spectrum of topics. Resource Recovery is part of "Climate action, Environment, Resource Efficiency and Raw materials". On this topic H2020-EU.3.5., 612 projects have received Horizon2020 subsidy. When the projects are filtered with the words "resource recovery", eleven projects are listed:

1. SMART-Plant Scale-up of low-carbon footprint material recovery techniques in existing wastewater treatment plants.
2. INCOVER Innovative Eco-Technologies for Resource Recovery from Wastewater.
3. SYSTEMIC Systemic large scale eco-innovation to advance circular economy and mineral recovery from organic waste in Europe
4. POWERSTEP Full scale demonstration of energy positive sewage treatment plant concepts towards market penetration.
5. Saraswati 2.0 Identifying best available technologies for decentralised wastewater treatment and resource recovery for India.
6. Water2REturn REcovery and REcycling of nutrients TURNing wasteWATER into added-value products for a circular economy in agriculture.
7. SMART GROUND SMART data collection and inteGRation platform to enhance availability and accessibility of data and infOrmation in the EU territory on SecoNDary Raw Materials.
8. GReen Desalination: A closed-loop technology for full recovery of water and raw materials from the wastewater effluent.
9. NEMO Near-zero-waste recycling of low-grade sulphidic mining waste for critical-metal, mineral and construction raw-material production in a circular economy.
10. PAVITRA GANGA Unlocking wastewater treatment, water re-use and resource recovery opportunities for urban and peri-urban areas in India.
11. HYDROUSA Demonstration of water loops with innovative regenerative business models for the Mediterranean region.

A search via Google with the keywords "Horizon resource recovery" showed five more possibly interesting projects:

12. AcceLerate Innovation in urban wastewater management for Climate change (Alice).
13. RECOVERY AND UTILISATION OF NUTRIENTS 4 LOW IMPACT FERTILISER (Run4Life).
14. Sustainable Product, Energy and Resource Recovery from Wastewater.
15. SCALABLE TECHNOLOGIES FOR BIO-URBAN WASTE RECOVERY (SCALIBUR).
16. Deep Purple Recover Energy and Valuable Resources from urban waste streams in Photobiorefineries with the help of purple phototropic bacteria.
17. NextGen Towards A Next Generation Of Water Systems And Services For The Circular Economy.

Other projects that were brought to our attention are:
18. STAR4BBI (Standards and Regulations for the Bio-based Industry).
19. Volatile (Biowaste derived volatile fatty acid platform for biopolymers, bioactive compounds and chemical building blocks).
20. REWAISE (REsilient WAter Innovation for Smart Economy)

Interreg and other European projects

Interreg is an European subsidy programme for planning and regional development. European Territorial Cooperation (ETC), better known as Interreg, is one of the two goals of cohesion policy and provides a framework for the implementation of joint actions and policy exchanges between national, regional and local actors from different Member States. The overarching objective of ETC is to promote a harmonious economic, social and territorial development of the Union as a whole. Interreg is built around three strands of cooperation: cross-border (Interreg A), transnational (Interreg B) and interregional (Interreg C).[13] Three of the Interreg priorities are Combating climate change, Environment and resource efficiency and Low-carbon economy.

A search via Google with the keywords "Interreg Resource Recovery" showed five more possibly interesting projects, which are not only Interreg projects:
21. NEREUS New energy and resources from urban sanitation.
22. Phos4You – PHOSphorus Recovery from waste water For your life.
23. ZELDA Zero Liquid Discharge Desalination.
24. LIFE ENRICH Enhanced Nitrogen And Phosphorus Recovery From Wastewater And Integration In The Value Chain.
25. RecoPhos Recovery of Phosphorus from sewage sludge and sewage sludge ashes with the thermo-reductive RecoPhos-Process .

[13] https://ec.europa.eu/regional_policy/nl/policy/cooperation/european-territorial/

3.1 General information on the resource recovery projects

The projects listed above will be looked at in more detail in this paragraph. A project is of interest if it has produced resources at a reasonable scale in Europe and/or can provide information on the regulatory aspects of resource recovery in the Interreg Northwest European region. If a project contains best practices, these are discussed in the next paragraph.

3.1.1 SMART-Plant Scale-up of low-carbon footprint material recovery techniques in existing wastewater treatment plants

ID: 690323
From: 1 June 2016 to 31 May 2020
SMART-Plant scaled-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that were otherwise lost.
Coordinated in: Italy
Programme: H2020-EU.3.5.4.
Link: https://cordis.europa.eu/project/id/690323
Within this the resources PHA, cellulose and bio-fertiliser are produced. The project will be further discussed in paragraph 3.2.1.

3.1.2 Innovative Eco-Technologies for Resource Recovery from Wastewater

ID: 689242
From: 1 June 2016 to 31 July 2019
INCOVER focuses on three recovery solutions from wastewater: 1) Chemical recovery (bio-plastic and organic acids) via algae/bacteria and yeast biotechnology; 2) Near-zero-energy plant providing upgraded bio-methane via pre-treatment and anaerobic co-digestion systems; 3) Bio-production and reclaimed water via adsorption, biotechnology based on wetlands systems and hydrothermal carbonisation.
Coordinated in: Spain
Programme: H2020-EU.3.5.4.
Link: https://cordis.europa.eu/project/id/689242/en
Within this project the resources bio-plastics, organic acids, biomethane, biofertiliser and biochar were produced at very small scale. The products don't seem to be applied nor has their been attention for regulatory aspects. This project will not be discussed any further.

3.1.3 SYSTEMIC Systemic large scale eco-innovation to advance circular economy and mineral recovery from organic waste in Europe

ID: 730400
From: 1 June 2017 to 31 May 2021
SYSTEMIC aims to recover nutrients from organic waste and to reduce the import of P as finite irreplaceable resource in mines.
Coordinated in: Netherlands
Programme: H2020-EU.3.5.4.
Link: https://cordis.europa.eu/project/id/730400 and https://systemicproject.eu/
Within this project the resource phosphate is produced. This project will be further discussed in paragraph 3.2.2.

3.1.4 POWERSTEP Full scale demonstration of energy positive sewage treatment plant concepts towards market penetration

ID: 641661
From: 1 July 2015 to 30 June 2018
This project aims to design energy positive waste water treatment plants.
Coordinated in: Germany
Programme: H2020-EU.3.5.4.
Link: https://cordis.europa.eu/project/id/641661
This project focuses on energy and will not be discussed further.

3.1.5 Saraswati 2.0 Identifying best available technologies for decentralised wastewater treatment and resource recovery for India

ID: 821427
From: 1 August 2019 to 31 July 2023
The aim of SARASWATI 2.0 is to identify best available and affordable technologies for decentralised wastewater treatment with scope of resource and energy recovery and re-use in urban and rural areas. Further, it addresses the challenge of real time monitoring and automation.
Coordinated in: Austria
Programme: H2020-EU.3.5.4. , H2020-EU.3.5.2.2.
Link: https://cordis.europa.eu/project/id/821427
This project focuses on India and will not be discussed further.

3.1.6 Water2REturn REcovery and REcycling of nutrients TURNing wasteWATER into added-value products for a circular economy in agriculture

ID: 730398
From: 1 July 2017 to 31 December 2020
Water2REturn runs a full-scale demonstration process for integrated nutrients recovery from wastewater from the slaughterhouse industry using biochemical and physical technologies and a positive balance in energy footprint. The project aims to close the loop by demonstrating the benefits associated with nutrients recycling through the implementation of different business models for each final product. Economic, governance and social acceptance aspects through the whole chain of water will be considered and targets essentially two market demands: 1) Demand for more efficient and sustainable production methods in the meat industry; and 2) Demand for new recycled products as a nutrient source for agriculture.
Coordinated in: Spain
Programme: H2020-EU.3.5.2.3. , H2020-EU.3.5.4. , H2020-EU.3.5.2.2.
Link: https://cordis.europa.eu/project/id/730398 and https://water2return.eu/
This project produces with the resources Nitrate, phosphate concentrate, hydrolysed sludge, algal biomass, organic fertiliser and two bio stimulants. One of the deliverables will be a policy-briefing and road map to foster EU implementation of nutrient recovery from industrial waste water streams. This deliverable is not yet available.

3.1.7 SMART GROUND SMART data collection and inteGRation platform to enhance availability and accessibility of data and infOrmation in the EU territory on SecoNDary Raw Materials

ID: 641988
From: 1 October 2015 to 31 March 2018
This project deals with resource recovery from landfills.
Coordinated in: Italy
Programme: H2020-EU.3.5.4.
Link: https://cordis.europa.eu/project/id/641988
This project shows what waste remains in which landfills and will not be further discussed.

3.1.8 GReen Desalination GReen Desalination: A closed-loop technology for full recovery of water and raw materials from the wastewater effluent

ID: 674455
From: 1 May 2015 to 31 October 2015
This project focussed on technology to (a) provide a near-market solution to the complex issue of sustainable brine handling, (b) improve the efficiency and overall costs of desalination; and (c) recover raw materials.
Coordinated in: Greece
Programme: H2020-EU.3.5. , H2020-EU.2.3.1.
Link: https://cordis.europa.eu/project/id/674455 and https://zerobrine.eu/ and https://cordis.europa.eu/project/id/730390

The company that exploits the results of this project is the company Sealeau. Sealeau focuses on dissolved solids removal and is part of the Horizon2020 Zero Brine project. Work package 9 of this project is about developing an Innovation Deal that will address legislative barriers for the market uptake of the ZERO BRINE methods (including end-of-waste criteria, REACH regulation). It examines the relevant BREFs and provides suggestions for the update the Best Available Technology to the European Commission. Furthermore, it develops minimum quality standards (requirements) for salt re-use in different applications (end-markets) and assesses the environmental impacts associated with brine discharge. This is an interesting work package, however, the Zero Brine project runs until May 2021 and the first results will not be available until the end of 2020.

3.1.9 NEMO Near-zero-waste recycling of low-grade sulphidic mining waste for critical-metal, mineral and construction raw-material production in a circular economy

ID: 776846
From: 1 May 2018 to 31 October 2022
The project focuses on the recovery of. base metals such as Cu, Zn, Ni, Pb; critical metals such as Sc, Nd, Y, Sb; SCM and aggregates.
Coordinated in: Finland
Programme: H2020-EU.3.5.3.
Link: https://cordis.europa.eu/project/id/776846
This project recovers metals and this is not relevant for the recovery or resources from waste water.

3.1.10 PAVITRA GANGA Unlocking wastewater treatment, water re-use and resource recovery opportunities for urban and peri-urban areas in India

ID: 821051
From: 1 February 2019 to 31 January 2023
The EU-funded PAVITRA GANGA project is part of the EU/India cooperation and aims to support wastewater treatment and re-use proposals in urban and peri-urban sites of India.
Coordinated in: Belgium
Programme: H2020-EU.3.5.4. , H2020-EU.3.5.2.2.
Link: https://cordis.europa.eu/project/id/821051
This project focuses on India and will not be discussed further.

3.1.11 HYDROUSA Demonstration of water loops with innovative regenerative business models for the Mediterranean region

ID: 776643
From: 1 July 2018 to 31 December 2022
HYDROUSA aims to provide innovative, regenerative and circular solutions for (1) nature-based water management of Mediterranean coastal areas, closing water loops; (2) nutrient management, boosting the agricultural and energy profile; and (3) local economies, based on circular value chains. HYDROUSA water loops will include water from non-conventional sources including wastewater, rainwater, seawater, groundwater and vapour water, all resulting in recovered and marketable products.
Coordinated in: Greece
Programme: H2020-EU.3.5.2.3. , H2020-EU.3.5.4. , H2020-EU.3.5.2.2.
Link: https://cordis.europa.eu/project/id/776643 and https://www.hydrousa.org/
Work package 7 of Hydrousa deals with the analyses of the impact of different policy and institutional requirements on the implementation of HYDROUSA. This will be further discussed in paragraph 3.2.4.

3.1.12 AcceLerate Innovation in urban wastewater management for Climate change (Alice)

ALICE aims to accelerate innovation by bringing together and exchanging knowledge between the key players who can, together, address the future techno-economic, governance and societal challenges arising from climate change.
Links: https://cordis.europa.eu/project/id/734560 and https://www.alice-wastewater-project.eu/
In this project there is no recovery from resources and it will therefore not be discussed in further detail.

3.1.13 RECOVERY AND UTILISATION OF NUTRIENTS 4 LOW IMPACT FERTILISER (Run4 Life)

ID: 730285
From: 1 June 2017 to 31 May 2021
Coordinated in: Spain

Domestic wastewater (WW) is an important carrier of nutrients usually wasted away by current decentralised WW treatments (WWT). Run4Life proposes an alternative strategy for improving nutrient recovery rates and material qualities, based on a decentralised treatment of segregated black water (BW), kitchen waste and grey water combining existing WWT with innovative ultra-

low water flushing vacuum toilets for concentrating BW, hyper-thermophilic anaerobic digestion as one-step process for fertilisers production and bio-electrochemical systems for nitrogen recovery. It aims for 100% nutrient (NPK) recovery, >15 times current P and N recovery rates and >90% water re-use.
Links: https://cordis.europa.eu/project/id/730285 and https://run4life-project.eu/ and https://run4life-project.eu/legal-and-regulatory-framework-workshop/

This project focuses on fertilisers and provides information on the specific legislation in certain countries. It will be further discussed in paragraph 3.2.3.

3.1.14 Sustainable Product, Energy and Resource Recovery from Wastewater

The SuPER-W European Joint Doctorate programme trains early-stage researchers (ESRs) in developing technologies for water, energy, nutrient and metal re-use, and bioproduction from (waste)water.
Links: https://cordis.europa.eu/project/id/676070 and https://www.superw.ugent.be/
This project focuses on technology development and is not discussed any further.

3.1.15 SCALABLE TECHNOLOGIES FOR BIO-URBAN WASTE RECOVERY (SCALIBUR)

SCALIBUR creates a holistic consortium to cut urban biowaste and replace it with a new production chain of biomaterials, forming a partnership of end users to recover and transform biowaste from three municipalities, namely Madrid (ES), Albano (IT) and Kozani (EL), into value added products. During SCALIBUR a complete study of the quality, logistics and management schemes for municipal solid waste (MSW) and urban sewage sludge (USS) will be performed, to integrate innovative systems and technologies and obtain high-value biobased products. In SCALIBUR, HORECA waste will be transformed to proteins, lipids and chitin from insect rearing, while the organic fraction of MSW will generate biopesticides and bioplastics by high-solid enzymatic hydrolysis followed by fermentation. The resulting biogas from MSW and USS will be upgraded by bioelectrochemical treatment to produce commodity chemicals and bioplastics, such as PHBV.
Links: https://cordis.europa.eu/project/id/817788 and http://www.scalibur.eu/
The part of the website on value added products does not yet contain any information. The project runs until October 2022 and this information will be available at a later moment.

3.1.16 Deep Purple Recover Energy and Valuable Resources from urban waste streams in Photobiorefineries with the help of Purple Phototropic Bacteria

ID: 837998
From: 1 May 2019 to 30 April 2023
DEEP PURPLE aims to transform diluted urban bio-wastes, including mixed waste streams, organic fraction of municipal solid waste (OFMSW), wastewater (WW) and sewage sludge (SS), into feedstock for bio-industry to obtain sustainable bio-products. The DEEP PURPLE concept is based on the metabolism of Purple Phototrophic Bacteria (PPB) to extract and recover high added-value compounds for the bio-based industry such as polyhydroxyalkanoates (PHA), ectoine and cellulose in 2 demo sites (ES, CZ).
Coordinated in: Spain
Programme: H2020-EU.2.1.4, H2020-EU.3.2.6
Link: https://cordis.europa.eu/project/id/837998

The Deep Purple project has not generated results on legislation yet. This project focusses on the recovery of nutrients and energy from wastewater. The project just started last year, so no results are yet available.

3.1.17 NextGen Towards A Next Generation Of Water Systems And Services For The Circular Economy

ID: 776541
From: 1 July 2018 to 30 June 2022
The NextGen initiative aims to evaluate innovative and transformational circular economy solutions and systems that challenge embedded thinking and practices around resource use in the water sector. The ambition is to produce new understandings to underpin the exploitation of techniques and technologies that enhance our ability to recover, refine, re-use, repurpose, capture value from, and extend the use-life of, an ever-increasing range of resources and products, thereby projecting the European water and allied sectors as global circular economy pioneers.
Coordinated in: the Netherlands
Programme: H2020-EU.3.5.2.3. , H2020-EU.3.5.4. , H2020-EU.3.5.2.2.
Link: https://cordis.europa.eu/project/id/776541and https://nextgenwater.eu/
This project focuses on sharing the collective experiences and insights in circular technologies for wastewater. Input from NextGen partners is used in the description of general bottlenecks in wastewater resource recovery.

3.1.18 Standards and Regulations for the Bio-based Industry (STAR4BBI)

ID: 720685
From: 1 September 2016 to 31 August 2019
The project aimed to establish a coherent, well-coordinated and favourable regulatory / standardisation framework for supporting the development of a cutting edge bio-economy for Europe. More specifically, support to the standardisation process for the concrete development of new value chains based on lignocellulosic feedstocks and biomass from forests, from agriculture and from organic waste will be provided. The main objective of the STAR4BBI project is promoting a level playing field for bio-based products. The focus of the project will be on finding practical ways to modify regulations in such a way that alternative wording, product specifications, and/or measuring methods will eliminate hurdles without compromising the initial objectives of the standard or regulation.
Coordinated in: The Netherlands
Programme: Horizon2020
Link: https://cordis.europa.eu/project/id/720685
This project had studied seven bio-based value chains in Europe and will be further discussed in paragraph 3.2.7.

3.1.19 Biowaste derived volatile fatty acid platform for biopolymers, bioactive compounds and chemical building blocks (VOLATILE)

ID: 720777
From: 1 December 2016 to 30 November 2020
VOLATILE aims in the development of an innovative Volatile Fatty Acids Platform for the bioconversion of municipal solid bio-waste fraction and sludgy biowaste from other industries. The project will also work on solutions to typical barriers beside others such as quality requirements, continuous and sufficient feedstock supply or interaction between members of value chain using

agent-based modelling. Also the effect of legal stimuli and restrictions and subsidies and taxes will be studied and a link between product requirements and markets will be established. VOLATILE will prepare a Roadmap indicating future research needs but also giving suggestion for legislative improvements.
Link: https://cordis.europa.eu/project/id/720777
This project is further described in paragraph 3.2.8.

3.1.20 REWAISE (REsilient WAter Innovation for Smart Economy)

ID: 869496
From: 1 September 2020 to 31 August 2025
Coordinated in: Spain
The project aims to demonstrate:
'value from water' by recovering nutrients and minerals
'value in water' by focusing on the economic value of water
'value through water' as an important part of society by developing a digital platform that supports decision-making in managing water.

The project will assess innovative technologies including magnesium recovery from brine, vivianite recovery from sludge, drinking water treatment using ceramic NF/UF membranes, and many others. The work will be undertaken by researchers at nine different labs in Poland, Sweden, the UK and Spain. In addition to creating new value chains, the project also aims to evaluate the social impact that the implementation of the assessed technologies will have.
Link: https://cordis.europa.eu/project/id/869496 and http://rewaise.eu/
As the project just started, there are no results to share yet.

3.1.21 NEREUS New energy and resources from urban sanitation

From: 13 July 2017 to 31 December 2021
The NEREUS project will tackle the common 2SEAS area challenges by boosting further the development of green economy and transforming wastewater into a valuable source of water, resources (e.g. cellulose, nutrients), and energy that could be re-used.
Coordinated in: Belgium
Programme: Interreg2seas
Link: https://www.interreg2seas.eu/en/nereus
This project focusses on the recovery of nutrients and energy from wastewater and will be discussed in paragraph 3.2.5.

3.1.22 Phos4You PHOSphorus Recovery from waste water For Your life

From: 2016 to 2020
Phos4You (P4Y) addresses the phosphorus (P) challenge. P is a nutrient essential for all living organisms. Though it is a finite resource on earth, P is largely wasted today. The EU acknowledged this by adding Phosphate rock to its list of critical raw materials in 2014. There is a need to boost the use of secondary raw P. The project addresses rural, urban and port areas in NWE.
Coordinated in: Germany
Programme: InterregNWE
Link: https://www.nweurope.eu/projects/project-search/phos4you-phosphorus-recovery-from-waste-water-for-your-life/

This project focusses on the recovery of nutrients and energy from wastewater and will be discussed in paragraph 3.2.6.

3.1.23 ZELDA Zero Liquid Discharge Desalination

From: July 2013 to June 2017
The main objective of ZELDA project was to demonstrate and disseminate the technical feasibility and economical sustainability of decreasing the overall environmental impact of desalination systems for freshwater production by adopting brine management strategies based on the use of electrodialysis metathesis (EDM) and valuable compound recovery processes with the final aim of reaching a zero liquid discharge (ZLD) process.
Coordinated in: Spain
Programme: LIFE+
Link: http://zelda.ctm.com.es/en
This project focusses on zero liquid discharge with the production of drinking water from seawater or brackish water and will not be discussed further.

3.1.24 LIFE ENRICH Enhanced Nitrogen And Phosphorus Recovery From Wastewater And Integration In the Value Chain

From: September 2017 to February 2021
The objective of the project is to contribute to the circular economy through the recovery of nutrients from wastewater and their use as crop fertilisers. LIFE ENRICH aims to develop innovative technologies that will enable an efficient recovery of both Nitrogen and Phosphorus contained in the wastewater, as ammonium salts and struvite, respectively. The products obtained will be blended in order to obtain suitable fertilisers for the target crops.
Coordinated in: Spain
Programme: LIFE16 ENV/ES/000375
Link: http://www.life-enrich.eu/

LIFE ENRICH aims to contribute to the circular economy through the recovery of nutrients from wastewater and their use in the fertiliser industry. The project will bring this objective to the practise by developing an innovative treatment train integrating leading-edge technologies that will enable an efficient recovery of both Nitrogen (N) and Phosphorus (P) contained in the wastewater, as ammonium salts and struvite, respectively. The products obtained will be blended in order to obtain suitable fertilisers for the target crops. In parallel to the technical development, a business model for the entire nutrient recycling value chain will be defined. The goal of the project is the operation of a treatment train which will enable to recover 40% of P (50% as struvite) and 15% of N from wastewater.

This project focusses on the recovery of nitrogen and phosphorus salts from wastewater, as ammonium salts and struvite. The project has no information on legal or societal aspects and will not be discussed further.

3.1.25 RecoPhos Recovery of Phosphorus from sewage sludge and sewage sludge ashes with the thermo reductive RecoPhos-Process

ID: 282856
From: 1 March 2012 to 28 February 2015

Natural phosphate sources low in heavy metals are getting scarce. Containing about 15 mass-% of P2O5, sewage sludge ash can be considered a secondary phosphorus (P-) source. The P-content in the European sewage sludge could currently replace roughly 15% of the phosphate imports into the EU.
Coordinated in: Austria
Programme: FP7-Environment
Link: https://cordis.europa.eu/project/id/282856
This project was finalised over five years ago. It focused on the recovery of phosphorus from sewage sludge ashes and will not be discussed further.

3.2 Best Practices from European projects

This paragraph describes the best practices from the European projects mentioned in paragraph 3.1.

3.2.1 SMART-Plant Scale-up of low-carbon footprint material recovery techniques in existing wastewater treatment plants

SMART-Plant pilots scaled-up eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and closed the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. Nine pilot systems were placed for two years in real operating environments at five sewage treatment plants, including two post-processing facilities. The systems were automatized with the aim of optimising wastewater treatment, resource recovery, energy-efficiency and reduction of greenhouse emissions. A comprehensive SMART portfolio comprising biopolymers, cellulose, fertilisers and intermediates are recovered and processed up to the final ready-for-sale end-products. The project proves the feasibility of circular management of urban wastewater and environmental sustainability of the systems, demonstrated through Life Cycle Assessment and Life Cycle Costing approaches to prove the global benefit of the scaled-up water solutions.[14]

Report 4.4 Environmental Impact Report, including Life Cycle Assessment[15] provides an environmental assessment for all SMART-plant products. If the complete value chain is taken into account, including the valorisation of the end-products, material recovery leads to environmental benefits for waste water treatment plants, reduced primary energy demand and greenhouse gas emissions, without compromising the treatment quality. Some of the conclusions from the study are:

- Depending on the technology and material recovered, up to 68% of primary energy demand and 71% of greenhouse gas emissions could be mitigated by integration of material recovery at a municipal WWTP.
- Savings predominantly relate to operational savings at the WWTP, such as reduced energy demand, less use of chemicals and/or less sludge to be disposed.
- Some technologies have the potential to improve the treatment performance of the plant. For all technologies that were researched, the primary function of the WWTP was not compromised by material recovery.

[14] https://cordis.europa.eu/project/id/690323
[15] Horizon 2020 research and innovation programme, Project: No 690323 SMART-Plant, Deliverable: D17 Relative Number in WP D4.4, Environmental Impact Report, incl. LCA (Life Cycle Assessment) Version 2.0, 2020, p. 13.

The product quality of the recovered materials from sewage water was analysed for a wide range of inorganic and organic contaminants to assess potential risks for human health and ecosystems during their application. Overall, no excessive transfer of hazardous pollutants from wastewater into SMART products could be detected. Results from 15 samples show that low contamination of SMART products can be detected for selected contaminants, which is due to their origin from municipal wastewater. In particular, sludge and sludge-based products such as compost contain a range of inorganic and organic contaminants which may pose a potential hazard for human health or ecosystems during their application in agriculture. Detected risk potentials from heavy metals or organic compounds in SMART products used on agriculture are low, but should be further investigated and legally regulated in the future. In general, new legislation in this sector is required to define acceptable levels of contamination in recovered materials from municipal wastewater, especially for application as fertilizer in agriculture.[16]

Barriers recognized in SMART-plant that hinder the application of resource recovery technologies and re-use of wastewater-originated valuable materials are relevant scale and long-term viability in real wastewater treatment plants; social and psychological barriers; lack of communication with decision makers; differences in acceptance and practice of resource recovery around the world; lack of linkage and translation from science and innovation to practice and markets; lack of linkage of developments in water industry and other industries.

The business models to close the recovered materials value chains were analysed with reference to different regulatory models for water tariff settings. Water price reduction has been estimated and considered in the social life cycle assessment, and have a relevant role. The distributor model was preliminary estimated to reduce the risk of closing the value chain for the water utilities, but its impact is weaker for countries where the water tariff setting is more elastic. However, still the quality standard, regulation and legislation concerning secondary raw materials and recovered materials is the main barrier for market uptake. For one of the products from SMART-plant an end-of-waste process has started: cellulose in the Netherlands (see §4.4).

3.2.2 SYSTEMIC Systemic large scale eco-innovation to advance circular economy and mineral recovery from organic waste in Europe

SYSTEMIC aims to re-enter recovered nutrients from organic waste into the production cycle. The project strives to offer solutions for pressing environmental issues and to reduce the import of phosphorus as finite irreplaceable resource. The project focus is on anaerobic digestion (AD) value chains and aims to turn biomass waste into valuable products while reducing water pollution, greenhouse gas emission and creating quality jobs in rural areas.

The project's Market research report[17] describes 35 European biogas plants that use different technologies for digestion and digestate treatment and have produce different nutrient products. Waternet and GMB are two of them, both produce digestate from sewage sludge. The report describes the current and future niche markets and barriers to overcome for the recovered nutrients to be successfully marketed.

[16] Environmental Impact Report, incl. LCA (Life Cycle Assessment) Version 2.0, 2020, p. 14.

[17] https://systemicproject.eu/wp-content/uploads/D-3.4-Market-research-in-Europe.pdf, February 2020, M. Verbeke e.o. Vlaams Coordinatiecentrum Mestverwerking

Currently, for both Waternet and GMB, the solid fraction of the digestate is incinerated because next to nutrients and organic matter it can contain heavy metals, pharmaceuticals, hormonally active substances and persistent organic pollutants. Dutch and European (waste) legislation and risk perception of customers prevents direct use of this end-product. GMB further processes the struvite and applies the produced ammonium sulphate as a fertiliser in agriculture. At Waternet struvite is recovered from digestate and is sold to ICL Fertilisers as secondary raw material for phosphorus fertilisers. Currently only 20% of the total phosphorus present in the digestate can be recovered as struvite and Waternet has the ambition to increase the amount of recovered phosphorus.

For recovered fertilisers, different type of end users are defined in the report: farmers, horticulturalists, home gardeners and the mineral fertiliser industry, who have different interests. These vary from branding, performance, volume and price to contaminants and nutrient content.

The SYSTEMIC report on regulations governing anaerobic digesters and nutrient recovery and re-use in EU member states (2019) shows the power of supportive legislation on renewable energy supply. In some cases the legislation is so successful, that it actually hinders resource recovery as the production of renewable energy is financially more attractive because of the subsidy scheme.

3.2.3 RECOVERY AND UTILISATION OF NUTRIENTS 4 LOW IMPACT FERTILISER (Run4Life)

Run4Life aims to demonstrate an alternative strategy for improving the recovery of resources from wastewaters, using a decentralised approach where black water (toilet wastewater), grey water (other domestic wastewaters) and organic kitchen waste are collected separately. Each separate flow receives the treatment needed for efficient resource recovery. End users and other stakeholders along the value chain are involved in this transition to local resource recovery and re-use.

Run4Life, short for “Recovery and Utilisation of Nutrients 4 Low Impact Fertiliser” is based on source-separated collection of domestic wastewaters and kitchen waste, with each flow receiving optimal treatment for resource recovery and subsequent safe re-use. Active measures such as knowledge brokerage activities will be developed as engagement strategy to advocate the institutional, legal and social acceptance of Run4Life nutrient recovery technologies.
The Run4Life project works towards multiple results such as a decreased dependence on primary nutrient resources and increase European resource security, the reduction of adverse effects of nutrient emissions on the environment, closing water and nutrient cycles throughout the production and consumption value chain, an improvement of the quality of collected data on nutrient flows to support investments in the recycling of recovered nutrients and the creation of new business opportunities in the EU, to generate new green jobs and export industries around the recovery and recycling of nutrients, contributing to the exploitation of innovative solutions in the global market.[18]

Run4Life will advance the current concept of Circular Economy by potentially recycling up to 100% of the nutrients present in household wastewater and organic kitchen waste (N, P, K and micronutrients), also recovering > 90% of grey water as reclaimed water. This avoids inefficient conventional removal and disposal of nutrients and water associated to linear systems, as current

[18] https://run4life-project.eu/

end-of-pipe approaches can only reach a very partial recovery (< 5% and < 50% for N and P, respectively). Whereas first separate collection systems for urban household kitchen waste and wastewaters have been implemented, products are currently not being re-used, mainly because hygienic and environmental safety of these products is not yet assured, and no clear market structure exists - prohibiting their re-use according to current legislation and leading to poor social acceptance. However, new EU politics on Circular Economy, Water Re-use and Nutrient Recovery are forcing a change aimed at increasing the efficiency and minimising wastes and environmental impact.

Run4Life will respond to the following requirements: i) integrating nutrient recovery in the water sector; ii) producing hygienically safe products (fertilisers and reclaimed water) for re-use in agriculture/industry/toilets; iii) online monitoring and processes simulation; and iv) making the strategy cost competitive and close to market by including LCA, a new business model and prospective end-users' participation, among others. In this way, nutrient recovery processes can be tailored to specific local priorities and will be slightly varied to adapt Run4Life to local conditions and requirements.

As part of the project a workshop was organised on December 2, 2019. Conclusions[19] were, amongst others:

- Promoting recycled nutrients should be part of the Circular Economy package.
- Procedures need to be simplified and there needs to be a mutual recognition between EU members.
- The conformity assessment of the product should be clear, transparent and sound.

3.2.4 HYDROUSA Demonstration of water loops with innovative regenerative business models for the Mediterranean region

HYDROUSA will provide innovative, regenerative and circular solutions for (1) nature-based water management of Mediterranean coastal areas, closing water loops; (2) nutrient management, boosting the agricultural and energy profile; and (3) local economies, based on circular value chains. The services provided lead to a win-win-win situation for the economy, environment and community within the water-energy-food-employment nexus.

HYDROUSA water loops will include water from non-conventional sources including wastewater, rainwater, seawater, groundwater and vapour water, all resulting in recovered and marketable products. HYDROUSA will demonstrate at large scale the feasibility and sustainability of innovative, low-cost water treatment technologies to recover freshwater, nutrients and energy from wastewater, salt and freshwater from seawater, and freshwater from atmospheric water vapour. Water conservation solutions including aquifer storage and sustainable agricultural practices including fertigation will be applied. The solutions will be demonstrated on 3 major touristic islands in Greece. Detailed technical and financial deployment plans will be established for replication in additional 25 locations worldwide. Through the on-site water loops of HYDROUSA, complex supply chains for resource recovery are not required, as producers are directly involved as consumers of derived products. HYDROUSA will combine traditional skilled workmanship with modern ICT integration in beautiful and smart automation systems. HYDROUSA will revolutionise water value chains in Mediterranean areas and beyond, from water abstraction to sewage treatment and re-

[19] https://run4life-project.eu/wp-content/uploads/2019/12/20191202-R4L-LRFW-06-Round-table-intro-USC.pdf

use. The proposed HYDROUSA solutions show massive potential to change the way humans interact with water, food and energy. [20]

The involvement of affected population and stakeholder groups is a major focal point of HYDROUSA, which will ensure the successful implementation and continued innovation even after the project end. It seeks to close all water cycles at a local level with existing resources, promoting the concept of the decentralised saving, treatment and re-use of water, materials and energy. The project has every potential of triggering radical changes in agriculture and water management in general. Thus, the main ambition of HYDROUSA is to develop a novel circular business model, which is suitable for Mediterranean and other water-scarce regions. The model is based on the valorisation of non-conventional water sources to generate water suitable for different uses (irrigation, potable, domestic use) as well as produce high added value products (agricultural crops, superfoods, edible salt, compost, essential oils) to regenerate the interrelated circular economy loops. The main advantage of the HYDROUSA approach is that all recovered products and resources will be exploited locally for the benefit of local communities and agricultural cooperatives, minimising in this way the long supply chains, the high transportation costs and eliminating externalities. This model strongly supports the concept of social justice and fairness in the utilisation of resources among communities.

HYDROUSA will support governments to identify water and water-related small and decentralized services delivering regenerated closed loops. Possible further actions will be directed to creating regulatory and institutional clarity, generating conducive environment for the decentralized service delivery models. A major focus is on rural, water-scarce decentralized areas, HYDROUSA water loops could be a support towards the European Green Deal without leaving individual houses or small regions behind and ensure a fair and inclusive transition

3.2.5 NEREUS New energy and resources from urban sanitation

The NEREUS aims to boost the development of green economy and transform wastewater into a valuable source of water, resources (e.g. cellulose, nutrients), and energy that could be re-used. More specifically, due to climate change, water scarcity is increasingly problematic resulting in a growing need to re-use wastewater. Finite nutrients such as phosphorus are crucial for agriculture and currently not recovered from wastewater. As a result, these resources cannot be re-used in a meaningful manner (e.g. as fertiliser). Wastewater also contains energy/heat that could be used as a sustainable source of energy in order to reduce CO_2 emissions. Although there is a growing conviction that future arrangements for the treatment of wastewater should be based on the principles of a circular economy, and although the technology is available, decision makers are still hesitant to make use of them due to the lack of practical evidence.

One of the planned deliverables of the NEREUS project is a decision support tool (DST) providing policy recommendations and specific information on suitable technologies. This DST is however not yet available, but WOW! partner VITO is the lead partner of NEREUS and there is thus close contact with the project.

[20] https://cordis.europa.eu/project/id/776643

3.2.6 Phos4You PHOSphorus Recovery from waste water For Your life

Phos4You (P4Y) addresses the phosphorus (P) challenge. Phosphorus is a nutrient essential for all living organisms. Though it is a finite resource on earth, phosphorus is largely wasted today. The EU acknowledged this by adding phosphate rock to its list of critical raw materials in 2014. There is a need to boost the use of secondary raw phosphorus. The project addresses rural, urban and port areas in Northwest Europe (NEW). Phosphorus is needed in rural areas as fertiliser or feed additive (often produced in port areas). Phosphorus is transferred within food to urban areas where 82% of NWE-citizens live in, and wasted there (via sewage and waste). P4Y specifically targets recovery from municipal WWTP. In 2015, NWE imported 100% of its mineral P-need. 45% of the demand could be supplied by circular economy. Phos4You supports 44 enterprises by producing demonstrators in real life conditions of six P-recovery technologies for municipal sewage water and five new products from P-recycling processes for fertiliser. The project aims to develop a EU-Standard to assess quality of new fertiliser products from municipal waste water and further outputs increasing social acceptance are developed. It also plans to develop a consistent legal framework pushing P-recycling forward. Information about the standard or the framework is not yet available.

3.2.7 Standards and Regulations for the Bio-based Industry (STAR4BBI)

This project aimed to establish standardisation framework for supporting the development of a cutting-edge bioeconomy for Europe. More specifically, support to the standardisation process for the concrete development of new value chains based on lignocellulosic feedstocks and biomass from forests, from agriculture and from organic waste will be provided. The main objective of the STAR4BBI project was promoting a level playing field for bio-based products. The focus of the project was to find practical ways to modify regulations in such a way that alternative wording, product specifications, and/or measuring methods will eliminate hurdles without compromising the initial objectives of the standard or regulation.[21]

In this project seven bio-based value chains were researched. Interactions with stakeholders for identifying and discussing proposed solutions were undertaken. The following specific suggestions are made for policy makers in order to establish a supportive and investment-friendly regulatory and standardisation framework for the bioeconomy, enabling the full deployment of future innovations:

- integration of a fossil carbon tax will allow taxation of fossil carbon in chemicals, materials and products, which would be considerably complex when implementing a CO_2 tax.
- introduction of sustainability certification for all products is needed, including a multi-level EU Ecolabel to provide more transparency for relevant stakeholders in knowing how sustainable their product is.
- implement measures with regard to genome-editing techniques to update the existing EU regulation, more precisely use the GMO definition of the Cartagena Protocol in order to capture both the end-product and the used technique.
- update the existing European regulatory framework on waste and harmonise it with the Circular Economy Package to facilitate optimal resource use (including waste) and to provide harmonised guidance on preferred End-of-Life (EOL) options.

[21] https://cordis.europa.eu/project/id/720685/fr

With regard to composting test methods, the conclusion is that changing the standard (EN 13432) is not the solution for the current challenges in the market situation. However, the European Standard, which was developed in 2000, should be aligned with current practice. As composting processes have changed considerably since then, the goal is to come to an agreement that matches the industrial practices of today and the near future with what can be achieved for compostable plastics and for products for which composting may have benefits.

In order to create a level playing field, it is proposed to introduce a policy framework dedicated to bio-based materials called the Renewable Materials Directive, similar to what exists for biofuels.

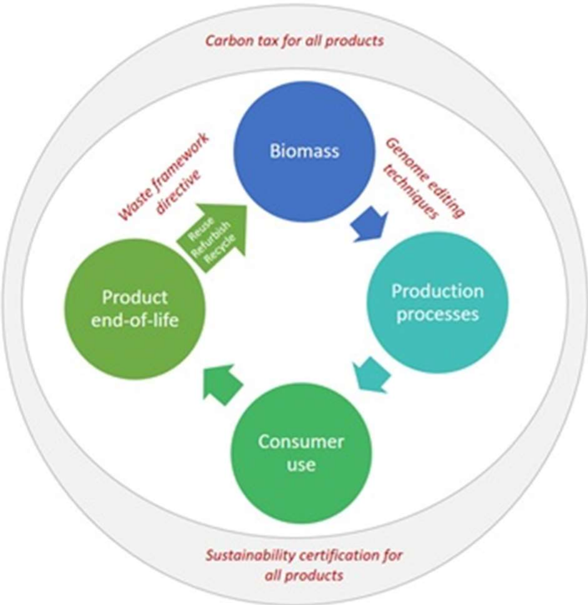

Figure 2 Selected topics for which measures are proposed by the STAR4BBI project

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far):

1. The bioeconomy is still far away, and getting there requires a transition towards the use of bio-based feedstock in a circular economy and needs stimulating research. A centralised advising authority should provide uniform advises and guidelines for EOL routes for products, bundling of knowledge and know how, learning from best practices, etc. In connection the (independent) authority should provide criteria and certification systems for different stages along the life-cycle of packaging products.
2. Packaging product design should keep re-use and recycling possibilities in mind. Ultimately, ‘design for recycling’ involves the entire life-cycle of products. It is proposed that regulations be modified to include the value of digestion and composting of biodegradable plastics in the recycling targets, regardless of whether these processes deliver compost or digestate. An independent organisation would need to be responsible for balanced life-cycle impact data on bio-based materials and products, and as far as fossil-based or other products are being used, these should be included as well.

3.2.8 Biowaste derived volatile fatty acid platform for biopolymers, bioactive compounds and chemical building blocks (VOLATILE)

The Volatile project aims for the development of an innovative Volatile Fatty Acids Platform for the bioconversion of municipal solid bio-waste fraction and sludgy biowaste from other industries. The volatile fatty acids will be recovered continuously using sophisticated membrane technology and will be provided as feedstock / carbon source for value added fermentation approaches such as biopolymer PHA to be tested in material applications, single cell oil as precursor for oleochemical industry as well as long chain unsaturated health-promoting Omega-3 fatty acids to be used as food ingredient or nutraceutical. PHA will be obtained by bacterial fermentation, single cell oil from yeast cultivation and Omega-3 fatty acids via heterotrophic microalgae. The process development will be accompanied by a LCA study in order to ensure an environmentally friendly process design.

The project also works on solutions to typical barriers beside others such as quality requirements, continuous and sufficient feedstock supply or interaction between members of value chain using agent-based modelling. Also, the effect of legal stimuli and restrictions and subsidies and taxes will be studied and a link between product requirements and markets will be established. Volatile prepared a Roadmap indicating future research needs but also giving suggestion for legislative improvements. Primary law and secondary sources are investigated, summarised and evaluated with regards to their relevance for the project as well as their direct and indirect effect on the Volatile value chain area, including potential end uses. A CEN workshop has been initiated to discuss with external stakeholders' rules for the VFAP (Volatile Fatty Acid Platform) & to set-up standard requirements in the form of a CEN workshop Agreement. It is an evaluation procedure for biogas plant owners and operators to assess in a simple way whether such a modification of their system is ecologically and economically meaningful against the background of e.g. location and the feedstock used. Furthermore, the process developed is intended to provide information on potential value chains that are available in this respect.[22]

For Belgium, a report[23] was prepared on national and local level barriers and stimuli to VFA (Volatile Fatty Acid) based value chains for the Brussels Capital Region, Flanders and Wallonia. Conclusions for Flanders are:

- Waste prevention is embedded into preventing the use of primary raw materials and sustainable materials management in a green economy which corresponds to the goal of saving primary resources by using secondary materials.
- The Action Plan on Sustainable Collection of Biomass(waste)streams 2015-2020 promotes nutrient recuperation from digestate and biobased products.
- Sewage treatment plant sludge may be fermented in Flanders and used e.g. as a "black soil"
- The transition to a circular economy that is also an important policy issue in Flanders is expected to favour material recovery from organic waste like VFA production, but currently there is no active support or legislation.

[22] https://www.cen.eu/news/workshops/Pages/WS-2018-008.aspx
[23] Deliverable D 2.3 Report on national and local level barriers and stimuli to VFA based value chains

4. Success stories and failures: lessons learnt from other initiatives

To get a better understanding about the lessons learnt in other projects, we reached out to multiple organisations to analyse their projects. This chapter gives an overview of the results focused on the re-use of raw materials from sewage and social acceptance.

4.1 PYREG plant: phosphorus recovery from sewage

This project, the construction of a PYREG plant for sewage sludge treatment at the Linz-Unkel Sewage Treatment Plant, was developed by four main actors:

- Zweckverband Abwasserbeseitigung Linz-Unkel (Sewage disposal association Linz-Unkel)
- ELIQUO GmbH. The ELIQUO WATER GROUP bundles the European activities of the company SKion GmbH in the field of municipal water and waste water treatment
- PYREG GmbH. PYREG GmbH is a multi-award-winning company for mechanical engineering and environmental technology. With more than 30 employees at the Dörth location it produces carbonisation systems for the thermal recycling of organic material
- Engineering office Siekmann + Partner

The project has been initiated in Germany and expanded to Sweden. Its goal is to recover phosphorus with fertiliser production by carbonisation of sewage sludge. The water used is municipal waste water. This project applied in Germany for an end-of-waste status meaning that waste ceases to be waste and obtains a status of a product (or a secondary raw material).

The German Ministry of Agriculture as well as the Ministry of Environment Rheinland Pfalz, KEMI Sweden and STRUBIAS have been contacted. However, obtaining the end-of-waste status has met some obstacles as the requirements as well as the status were unclear. The responsible authority remains vague and whether it is a regional, national or European responsibility is ambiguous. The procedure took up to five years and has had a cost higher than € 100.000 spent on field trials, pot trials, research and development and analysis.

Lessons learnt are that requirements need to be clear at the start of the procedure, processing times need to shortened and the German government needs to sort out at which governmental level the responsibilities lies to decide on resource recovery from sewage water (and obtaining an end-of-waste status).

4.2 Kaumera: bio-based polymer from sewage

This project was developed by five main actors:

- TU Delft (Delft University of Technology)
- Chaincraft (ChainCraft develops mixed culture fermentation technologies in order to produce sustainable biobased chemicals)
- RHDHV (an international engineering consultancy firm with headquarters in The Netherlands)
- STOWA (foundation for research on water management)
- Regional Water Authorities Rijn and IJssel and Vallei & Veluwe

The project is based in the Netherlands. Its goal is to produce Kaumera Nereda® gum, a bio-based polymer made by bacteria consisting of a complex structure of many proteins and polysaccharides. Kaumera has, depending on the combination with other substances, hydrophilic or hydrophobic characteristics and has promising applications for use as bio stimulant, binder and coating in agri- and horticulture, composite materials (isolation and construction materials) and coating of concrete.

The Kaumera consortium applied for an end-of-waste status in the Netherlands to obtain the status of a product. They started with the end-of-waste application for the city of Zutphen where Kaumera is produced from process water of dairy industry Friesland Campina. This is still under consideration. In order to start with the end-of-waste procedure the environmental agency of the city of Nijmegen has been contacted as well as the consortium who dealt with the end-of-waste process for struvite (also see §4.5). An obstacle that was encountered to get an end-of-waste status was the “proof of market” criterium that states that final contract with end users is needed. However, these users are only willing to sign if Kaumera is a material and not waste. Discussions are still ongoing about this issue. For the end-of-waste process most of the work was done by the consortium itself.

Also, the REACH process started with a justification document to point out that Kaumera is a polymer according to the REACH definition. The REACH process has started in December 2019 and will entail substantial costs (> €50.000 per location) considering the price for legal expertise and required analysis.

4.3 Reinighof: recovery of phosphorus and recycling of nutrients

This project, subsidised by the Deutsche Bundesstiftung Umwelt was developed by four main actors:

- TU Kaiserslautern (Technische Universität Kaiserslautern)
- Department for Resource Efficient Wastewater Treatment
- OtterWasser GmbH (engineering company for integrated settlement technology)
- Dr. Bruch& Partner – Gend-of-wasteissenschaftler & Ingenieure

The project is based in Germany. Its goal is to decentralise the wastewater treatment and resource recovery system in a rural area without connecting it to the central WWTP. Their three main objectives are to:

1) recover phosphorus from urine as struvite.
2) further treat urine supernatant by special sand filter and constructed wetland.
3) recycle nutrients from faeces by composting.

The project has not applied for an end-of-waste status as the material will be used on own property. The project has been running for over a year. It consists of the recovery of phosphorus from urine as it can reach 90% with light overdosage of magnesium with enough reaction time. With a mixture of faeces, straw and grass clippings, a temperature sufficient for sanitation can be achieved during the hot rotting process. The main barriers encountered during this project have been the planning and constructing of the plant as well as the operational improvement of the facility.

4.4 Application of cellulose from sewage in asphalt

This project was developed by two main actors: CirTec BV and KNN Cellulose BV. In 2010, a consortium in the Netherlands was formed to produce clean cellulose from sewage and apply it as an additive in asphalt. This was necessary as cellulose is considered a waste product. The recipient, in this case the supplier of additives to the asphalt producer, needed to have a permit to receive waste or the product must have an end-of-waste status. A potential customer usually does not have a waste permit and does not want to be associated with waste. Obtaining an end-of-waste status is therefore the most obvious, but this is no easy task. To start a procedure and be able to request an end-of-waste status Article 6 of the European Waste Framework Directive requires:

- a “demonstrated market”. To be able to demonstrate that a market exists, it is mandatory to demonstrate that a re-usable product of guaranteed quality can be produced.
- A dossier that shows that the end product has no adverse effects on the environment and/or human health. This has to be provided for each end product (not the raw material). It is not clear what parameters must be monitored or examined, at what frequency and for how long to provide the desired certainty that there are no adverse effects.

The Green Deal Resources, which permitted innovative small scale application of products made of raw materials from sewage, made it possible to recover and re-use cellulose at pilot scale in 2015. Since there is currently no legal basis for the use of the recovered cellulose as raw material further development was slow. In order to boost large-scale recovery and re-use of cellulose and develop a structural market, an installation on the Sewage Treatment Plant (STP) Geestmerambacht was established that produces 400 kg of pure cellulose on a daily basis. Due to the availability of product, a good and complete safety file could be built up and potential customers could test the quality of the product and the applicability.
The Green Deal Resources, has ended early 2019. Without this legal framework, it is nearly impossible to further innovation. Potential customers are no longer allowed to test whether products recovered from sewage can be applied in their production process. It makes is hard to validate that a raw material is safe and applicable, without incurring excessive costs or legal acrobatics. This limits innovation, development and scalability.

Because in principle an end-of-waste status must be established for each end product (not for the raw material), the costs associated with a repeated application seem to be an obstacle on the economic feasibility of recovery. An application for the end-of-waste status for cellulose as a raw material for building materials (a clustered application) is currently under review by the Dutch ministry of Infrastructure and Water Management. Their conclusion is expected within a few months. In this context, it should be highlighted that an approval in the Netherlands does not mean that the raw material is also accepted in other EU countries. In Belgium, it was explicitly indicated that a new procedure must be started here.

4.5 Struvite (ammonia and phosphate)

4.5.1 The Netherlands

In 2013, the extraction of struvite from municipal sewage was started in the Netherlands. The water authorities had already approached the government at an early stage to have struvite admitted as a fertiliser. In 2013, the Fertiliser Act Experts Committee issued a positive recommendation and at the beginning of 2015, phosphates recovered, including struvite, were included as a category in the Fertilisers Act. The first barrier to the use of the secondary raw material struvite was overcome.

From agriculture, there was initially little interest for struvite, partly due to the phosphate surplus in the Netherlands. Fertiliser manufacturer ICL was interested in struvite as a replacement for phosphate ore. This revealed a second barrier to bring struvite to market as a fertiliser. Since struvite is extracted from sewage, it is considered a waste product. Admission as a fertiliser in the Netherlands does not mean that the waste status will expire. Waste can be used as fertiliser, for which the waste regulations do not apply for transport, storage and application. Use of struvite as a raw material for making (artificial) fertilisers is not an application in accordance with the Fertilisers Act. This means that a company that desires to use struvite as a raw material in its production process either needs a permit to receive waste or requires struvite with an end-of-waste status. Exporting struvite also requires an end-of-waste status to avoid an EVOA export procedure.[24]

In order to supply ICL and other manufacturers, the struvite-producing water authorities have each prepared a file to demonstrate that the four end-of-waste criteria are met. The web test "Is it waste?" from Rijkswaterstaat Living Environment (Part of the Dutch Ministry of Infrastructure and Water management) was used for this. This is a tool that is made available to companies, in case of doubt, to check whether something is a waste substance or not, without providing conclusive legal status. The procedure is only for one specific waste form done by a certain company. This means that comparable waste streams may be treated significantly different.

The legality of marketing struvite is only based on the "Is it waste?" web test assessment. This situation leads to significant legal uncertainty. An inspector may for instance determine that struvite is a waste product and impose fines. Ultimately, this can lead to legal proceedings where the Court determines whether a product can be classified as waste. To offer increased legal certainty with regard to the end-of-waste status, three routes can be taken:

1) Request a ruling from the competent authority. Competent authorities in the Netherlands are the 29 regional environmental services (mandated by municipalities and Provinces) or the Habitat and Transport Inspection (Inspectie Leefomgeving en Transport) in case of cross-border transport. For struvite that is produced and traded within the Netherlands, this would be a time-consuming endeavour.
2) Request a legal opinion. A legal opinion is not a decision but a compelling opinion of the Directorate General for Public Works and Water Management that has been coordinated with the environmental services.
3) A national end-of-waste scheme.

In 2016, the water authorities consulted with the Ministry of Infrastructure and Water Management and RWS living environment about a national end-of-waste scheme for struvite and other recovered substances from waste water. Following this consultation, it was decided to first go through a legal judgment as a test case for the struvite of one installation for one specific application. The struvite of the water authority of Amsterdam and surrounding area (Waternet) was chosen as the source of the raw material for ICL and the production of phosphate fertiliser.

The process of these proceedings is still ongoing. A third barrier was exposed during the assessment. Due to its origin, struvite can contain medicine residues and pathogens. There is no testing framework for this. RWS Living Environment has therefore asked the National Institute for Public Health and the Environment (RIVM) for advice on the risks of drug residues and pathogens. According to RIVM, there are no indications that the use of struvite poses an increased risk to the environment or public health. RIVM indicates, however, that this conclusion is based on very little measurement data. In consultation with all parties involved, it was therefore decided to perform additional measurements of drug residues and pathogens in multiple sewage treatment plants. This is to give the conclusion with regard to medicines and pathogens more power so that RWS can give a well-founded legal opinion. The measurements were completed and it is expected that by the end of 2020 - after four years - struvite will get an end-of-waste status. The legal opinion is issued for one specific chain with one producer and one buyer, but is in practice also considered

[24] Regulation 1013/2006

valid for comparable situations. To cover all the different production methods and applications, some legal judgments will have to be applied for. The procedures will go faster as all information is now available.

The struvite of a number of Dutch water authorities has been sold commercially since about four years, as the water authorities consider it to be a product and not waste. As a fertiliser, struvite is allowed to be sold, transported and used in the Netherlands. However, as a product, or as a raw material for production of fertiliser (in the case of ICL) the end-of-waste status is required unless the producer of fertilizers has permission to use waste in their production process.

A fourth barrier that has not yet been solved is the export of struvite to other Member States where there is more demand for phosphate. There are still few Member States in which struvite has reached the end-of-waste status and is a product, whereas in a number of Member States the route to an end-of-waste status is still unclear.

4.5.2 Germany

The German organisation *Berliner Wasserbetriebe* produces struvite and sells the produced struvite under the product name "Berliner Pflanze". The product has been classified as a fertiliser according to the European fertiliser ordinance. Furthermore, the production and sale of the substance struvite was registered under the REACH ordinance with Berliner Wasserbetriebe as "Lead Registrant". General information on the substance can be found under the EC number 232-075-2 on the ECHA website[25]. Other producers can refer to it and carry out a co-registration at the ECHA (European authority for REACH) (simplified procedure) and receive a Letter of Access. For the co-registration, documents such as an analysis to prove that it is the same substance are required.

4.5.3 United Kingdom

In general, in the UK struvite can be granted the end-of-waste status on case to case basis to be applied as raw material. *Chrystal Green*, struvite recovered from sewage sludge via Ostara's Pearl process, has gone through the legal process with Thames Water. It had, amongst others, to prove the comparable nutrient release, that it's not toxic, that there is no interference with plant growth, etc. *Chrystal Green* from the facility of Thames Water has an end-of-waste status. The product is widely distributed as a fertiliser in the UK, Europe and North America. In the Netherlands, *Chrystal Green* is produced at the sewage treatment plant Amersfoort since 2018.[26] Local partners offer sewage treatment plants long-term contracts with buyers to build a business case to invest in the technology. Chrystal Green has been registered as fertiliser in the EU.[27] Technically, however, in the Netherlands it is still a waste material.

4.5.4 Belgium

At the WWTP of Leuven (Belgium), Aquafin operated a struvite plant until 2019. The struvite plant was started in 2013 as a pilot plant and was one of the first plants to recover struvite from the digested sludge before dewatering using the NuReSys® technology. The struvite was sold to a company that specializes in the production of inorganic fertilizers made mainly on the basis of by-products from the agri-food industry. This company obtained a derogation to use struvite for compound NPK fertilizers on the Belgian market. The struvite was thus blended with other by-products to produce a fertilizer with a balanced NPK-ratio.

[25] https://echa.europa.eu/de/information-on-chemicals, Struvite, EC-No.: 232-075-2, CAS-No.: 7785-21-9.
[26] https://www.agro-vital.eu/crystal-green-en-derogatie/
[27] https://www.eliquo-we.com/nl/pearl.html

No harmful microbial pathogens are present in the struvite. The struvite plant was stopped in 2019 because Aquafin shifted their focus to maximizing biogas production at WWTPs. This could not be combined with struvite production.[28]

Struvite in general can only be put on the local market of the member state, provided it complies with the fertilizer regulation of that state. In Belgium, environment and waste is a local jurisdiction. Struvite made from wastewater should comply with the Flemish waste regulation (VLAREMA) for it to be used as a source material for a fertilizer. VLAREMA considers wastewater sludge as a waste and thus also struvite produced from the sludge. Treated wastewater sludge (and struvite) is eligible to be used in fertilizers if a raw materials declaration (end-of-waste status) is granted. Therefore the concentration of heavy metals, aromatic compounds and mineral oil should be below certain limits. Getting a raw materials declaration takes about 3 months and is not costly. The declaration is location-bound and only valid for the process described in the application. When the process is changed, a new materials declaration is needed.

The use of the raw material as a fertilizer is regulated in the Belgian fertilizer regulation. The regulation lists fertilizers that do not qualify as CE-fertilizers but that can be placed on the Belgian market. For fertilizers not on this list (such as struvite), a derogation (exemption) can be granted by the federal agency for the safety of the food chain. The derogation is the concern of the final fertilizer producer. Each producer needs to get his own derogation.[29]

4.6 Grit

In many European sewage treatment plants, grit removal is one of the first treatment steps. For example, in Germany and the Netherlands grit has been removed during sewage treatment for over 60 years[30], long before the end-of-waste discussion started. The recovered material is applied in the building sector. In the UK, however, grit cannot be applied in the building sector. It's use is limited to the reinforcement of landfills.

[28] Phosphorus recovery as struvite from digested sludge – experience from the full scale
Bart Saerens, Sam Geerts and Marjoleine Weemaes, in preparation

[29] Personal communication Bart Saerens

[30] Zandverwijdering op RWZI's in Nederland, 2017, STOWA, https://edepot.wur.nl/421210

5. Critical drivers for success – social acceptance and policy

In this report various projects, challenges and success stories have been described. This finale chapter focuses on two important drivers that determine whether resource recovery from wastewater becomes a success in the EU: social acceptance and policy & legislation.

5.1 Social acceptance

United Nations Sustainable Development Goal 12 addresses the need to reduce the production of waste and usage of natural resources and to decrease the amount of energy used to support the world's economy until 2030.[31] To achieve this goal, especially in the light of a rising global waste production, drastic steps need to be taken. Thus, society is under heightened pressure to adopt more sustainable products and materials. The re-use and recycling of materials from sewage contributes to the reduction of waste and usage of natural resources. Examples are the production of lipids, PHA and cellulose from sewage water. Although using materials retrieved from sewage water maybe an environmentally-friendly alternative, the success of these products will be determined by their public acceptability.[32]

The adoption of new technologies and processes can be risky and complex. The re-use of resources from sewage water, a faecal contaminated source, also faces the issue of social acceptance. Despite the social pressure and the potential of raw materials from sewage, developments are moving slow. Research is being carried out at both Cranfield University and at the University of Groningen into the social acceptance of raw materials from sewage water.

Cranfield performed an online survey in England, to investigate views from the construction industry around the adoption of materials containing recovered cellulose. Preliminary findings indicate that construction professionals from all domains were largely supportive and are highly interested in the use of sustainable building materials. Architects were identified as the most influential in terms of materials selection, while regulatory requirements, low cost, and reduced carbon footprint were viewed as the most important drivers that determine materials selection. Conversely, key barriers to the uptake of cellulose materials consisted of a lack of a relationship between the producers of recovered cellulose and prospective customers in the construction sector, insufficient fit with the culture of the clients and end-users, and money sunk into existing materials. Respondents anticipated that home end-of-wasteners/homebuyers would be the group with the greatest negative perceptions towards the use of materials with recovered cellulose.[33]

Results of a study from the University of Groningen show that in almost all layers of the population in the Netherlands, independent what age, respondents are positive about products in which cellulose from sewage water is processed. With an online survey with a representative sample of the Dutch population, biospheric and hedonic values were measured. The results show that for people with stronger biospheric values, emphasising biospheric attributes elicits more positive emotions. For people with stronger hedonic values, there is no effect of value-framing. This suggests that emphasising biospheric attributes could

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[31] Sustainable consumption and production. (2015). United Nations Sustainable Development. https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

[32] Ljungberg, L. Y. (2007). Materials Selection and Design for Development of Sustainable Products. Materials & Design, 28(2), 466-479.

[33] E. A. Gallagher, C. Shannon, H. M. Smith: Evaluating Construction Industry Views on Recovered Cellulose as a Component of Building Materials

increase willingness to use and purchase these products, which ultimately helps to limit greenhouse gas emissions.[34]

Social acceptance needs to be perceived as an important point of attention at an early stage in water re-use project planning. Public participation is essential to meet people's needs, to collect local knowledge so as to help improve the design of the project and to build vital institutional trust. On the other hand, if citizens have experience of immediate and severe water shortages, their acceptance of such schemes increases even when these involve direct potable re-use.[35]

5.2 Policy & legislation

The EU aims to make Europe the first climate neutral continent in which the net Greenhouse Gas emissions in 2050 are zero, the economy grows without depleting resources and includes all humans and regions.[36] The European Green Deal is the plan to make the EU's economy sustainable, by turning climate and environmental challenges into opportunities. "There is only one planet Earth, yet by 2050, the world will be consuming as if there were three."[37] ; with this statement the EC launched a new Circular Action Plan for a cleaner and more competitive Europe in March 2020.

The Circular Action Plan calls to double the EU's circular material use rate in the coming decade. The Commission plans to develop an Integrated Nutrient Management Plan, to ensure more sustainable application of nutrients and to stimulate the markets for recovered nutrients. The Commission will also consider reviewing directives on wastewater treatment and sewage sludge.

Water and sewage water related resource recovery initiatives take place in many European countries as shown in this report. Initiatives are challenging existing system structures, which is typical for systemic eco-innovations. Struvite is one example of a resource from sewage water and can be applied as sustainable fertiliser of sustainable source of phosphorus (see §4.5). The earth's phosphorus resources are not endless and located outside Europe. Recovery and re-use of phosphorus is essential. Water authorities in the Netherlands approached the Dutch government as early as 2013 to have struvite admitted as a fertiliser. In 2016 the formal proceedings to get an End-of-Waste status for struvite started. After seven years, however, there is still no the end-of-waste status given. In the UK and Belgium, struvite from specific locations has an end-of-waste status. In Denmark there is a general end-of-waste status for struvite, whereas in Germany for one specific location struvite is "tolerated" (has no formal status but is not forbidden). This example shows that European legislation is implemented differently in the various member states. It also shows that product recovery is hindered by regulation instead of stimulated and that the process to acquire an end-of-waste status takes a long time.

One of the key issues that currently hampers the recovery and re-use of materials from sewage is the uncertainty and the legal implications of reclassifying raw materials from sewage water as new materials and products that can be brought to market. Despite the overarching European legal framework, Member States are still given considerable leeway regarding the re-use of raw materials from sewage. This leads to different interpretations of EU legislation. For instance a product that has received an end-of-waste status based on the Waste Framework Directive in the Netherlands, will still be considered waste in other

[34] O.D. de Hoog (2019): From Toilet to Table
[35] P. Kehrein. Environmental Science, Water Research & Technology
[36] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_nl
[37] https://ec.europa.eu/environment/circular-economy/

Member States. This means that the transportation is subject to waste legislation and the plant where material goes to has to have a waste authorisation. Despite the fact that products can be traded freely within the EU, a product recovered from waste cannot. Resources from sewage water are a feedstock for biobased materials. By limiting the trade of a product with a national end-of-waste status, the EU doesn't realise the circular potential of recovered resources. A positive example is the legislation in Italy, which was recently changed so that sewage treatment plants are rewarded if they recover resources from sewage water. This shows how legislation can treat sewage treatment plants as resource and energy providers to facilitate the transition to circular economy.

Points of improvement apparent from this report are:

1. Europe lacks specific recovery and re-use policies for sewage water resources. Use the review of the Urban Waste Water Regulation and the Sludge Regulation to make the recovery and re-use of resources from sewage water attractive with specific policies, for example by implementing favourable tax systems or by making a certain percentage of recovery mandatory.
2. Change the definition of "waste" in a way that not all materials are waste after being used once. Waste valorisation is key. Define waste with new technologies and new products in mind, without making concessions to food safety and the environment.
3. Harmonise legislation:
   - The end-of-waste judgement is a right, not a favour.
   - Create EU-wide quality requirements
   - The end-of-waste process should be clear, transparent and have deadlines
   - Provide national governments with a framework to assess the risks of recovered products.

These points of improvement will be discussed in the National Policy Action Plans and the European Roadmap that are drafted as part of the Wow! project.

In summary, it is acknowledged that policy frameworks have significant implications for the implementation of circular approaches around wastewater, and that it is difficult to view the requirements around resource recovery in isolation. It is also acknowledged that there is significant variation between Member States in how they interpret and implement the policy frameworks, and that national regulatory requirements in these areas create an even more complex governance picture. Nonetheless, this report has highlighted certain regulatory pinch points that, if not addressed, could act as barriers to the uptake of circular approaches in the wastewater sector. Uncertainty over new requirements for the application of biosolids to agricultural land, uncertainty over regulatory requirements for products recovered from sewage water such as the REACH registration and uncertainty over the general legislative status of applications as it is not clear which authorities are responsible for it. All infrastructure sectors, by their nature, are subject to multiple policy frameworks. A transition towards a circular economy creates opportunities for new services and new forms of value creation, both within and between sectors. However, when circular models are introduced, the overlaps and potential tensions between different sectors, and between different regulatory frameworks, are made much more apparent. This is particularly true for the tension between frameworks aimed primarily at protecting the environment and public health and measures aimed at incentivising product recovery. Such tensions need to be reconciled, across all sectors, if circular economy models are to be truly realised. By taking a system view of policy frameworks and examining regulatory requirements across all steps of potential value chains (rather than treating individual steps in isolation), we can more easily identify, and take steps to resolve, particular points of tension.[38]

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[38] Smith, H. Realising the circular economy in wastewater infrastructure – the role of governance.

Project partners

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