



EU Roadmap – call for action

The potential of resource recovery
from sewage

Interreg 
North-West Europe

WOW!

European Regional Development Fund



PHA bioplastic

Our ambition

The EU aims to be climate neutral in 2050. This ambitious goal not only entails no net emissions of greenhouse gases by 2050 but also efficient use of resources by moving to a clean, circular economy. To achieve this all sectors including the water sector need to make the transition towards a circular approach in an environmentally safe way. The Interreg Northwest Europe project WOW! (Wider business Opportunities for raw materials from Wastewater) aims to contribute to this through the recovery of valuable substances from sewage for use as resource or production of valuable products or sustainable energy.

Currently, sewage is a largely untapped resource for the circular economy. Valuable substances in sewage include, for example, phosphorus that can be used as recovered fertilizer, lipids as bio-fuel and cellulose for bio-chemicals and bio-composites. In addition, sewage provides a source for the production of biodegradable bioplastics (PHA), a possible replacement for the petroleum-based plastics that biodegrade very slowly and affect marine life. WOW! is all about the recovery and reuse of carbon based elements from sewage to make a transition to a circular approach. WOW! focusses on the recovery of lipids for biofuel, cellulose for bio-chemicals and activated carbon and fatty acids for PHA. As a result, these carbon based elements are no longer directly converted to CO₂ and/or CH₄ as

is happening in the current practice of sewage treatment, but converted to valuable products leading to decreased greenhouse gas emissions. Smarter use of secondary raw materials will create a safe and sustainable supply of raw



Biochar

materials to the industry. This helps create new jobs, supports innovation and boosts competitiveness. Smarter use of resources from sewage will also help protect the environment and at the same time preserve essential resources for current and future generations.

So enough reason to join and support our WOW! initiative for full recovery of valuable substances from sewage. Let's make the next step to a circular and sustainable future.



Cellulose pilot

Recovery of valuable substances from sewage is:

1. Fully in line with the **EU Green Deal** and proposed **EU Climate Law** that aim for an efficient use of resources by moving to a clean, circular economy.
2. A natural fit with **NextGenerationEU** which aid the transition towards a modern and more sustainable Europe.
3. Part of the realisation of a circular economy as stated in **Circular Action Plan** of the EC with a focus on waste prevention and keeping resources in the EU economy for as long as possible.
4. Making a contribution to a **climate neutral water sector** through the reduction of greenhouse gas emissions, improving energy efficiency and attainment of the SDGs such as Affordable and clean energy (7), Industry, innovation and infrastructure (9) and Responsible consumption and production (12).
5. An opportunity for Europe to **eco-innovate and develop and export new technologies**.
6. A way of helping the EU meet its goal of being a **global leader in sustainability**. Creating value in a more sustainable way!
7. In line with re-use of treated waste water whenever appropriate as stated in the **Urban Waste Water Treatment Directive** and the **Regulation on Minimum Requirements for Water Reuse**.
8. Contributes to the EU **sustainable chemical strategy** through the production and uptake of secondary raw materials in an environmentally safe way.

Policy recommendations

To enable the full potential of recovery and reuse and application of valuable resources and products from sewage, the WOW! consortium recommends that EU policymakers:

1. **Change the definition of “waste” in a way that doesn’t automatically imply all materials are classified as waste after being used once.** Resource valorisation is key. Define waste with new technologies and new products in mind, without making concessions to food safety and the environment. This is in line with the re-use of treated waste water and sludge whenever appropriate as stated in the Urban Waste Water Treatment Directive. A recent revision of this directive already arranges sewage valorisation specifically towards agriculture. This should be made broader.
2. **Use the review of the Urban Waste Water Directive and Sludge Directive to make recovery and reuse of resources from sewage attractive.** For example by fiscal measures or by making a certain percentage of recovered resources mandatory. Currently too much attention is placed on the immediate economic feasibility of new sustainable techniques. From practice it is clear that a certain scale is always needed to achieve cost reduction and improve economic feasibility of new techniques. A clear (financial) incentive for end-users and first movers could speed up the time to market enormously.
3. **Harmonize legislation with regard to the interpretation, assessment and process for end-of-waste.** This involves:
 - a transparent end-of-waste process with clear (end-of-waste) status demands and deadlines.
 - a European framework to assess the risks and quality of recovered products to be used by all national governments. An additional EU-sustainability certification on top of this could help in the public acceptance of product from sewage
 - An expansion of the options for agreeing to an end of waste status of the same type of raw materials for different locations and different customers.To realize efficient use of resources and aid the transition towards a modern and more sustainable Europe, innovations are needed. This requires European clarity of and more uniformity in the legal framework!
4. **Reduction of market barriers for processing, trading and selling of materials recovered from wastewater.** This includes:
 - Free trading of resources and products from sewage with and end-of-waste status within the EU.
 - A revision of the burden of proof that there is a market or demand for a material. Instead of a signed for instance also a letter of intent is allowed as burden of proof.
5. **Expand the legal obligations for the collection, recycling and use of recovered raw materials from sewage, whereby a water utility and a manufacturer takes responsibility.** The EU is aiming for a climate neutral water sector. To speed up this process and make sure this goal can be reached before 2050, collection, recycling and use of recovered raw materials from sewage should be considered the standard and no longer a possible free option to choose.

These recommendations are based on several studies of the WOW! consortium (1, 2, 3) and interviews with stakeholders in the field of resource recovery. Besides recommendations for EU policymakers, also recommendations for Belgium, Germany, Luxembourg, The Netherlands and UK were formulated. These national call for action can be found [here](#).

Introduction – WOW!

Sewage contains valuable substances that could be used as raw materials for biobased products. However, in Europe this potential is hardly exploited yet. This results in loss of valuable materials. At the same time, the concerns about CO₂ emissions and the use of natural resources are increasing. In the INTERREG NWE project WOW! – Wider business Opportunities for raw materials from Wastewater, we aim to contribute to the transition towards circular use of sewage water.

To reach this, the following transition is needed:

- Sewage plants (STPs) have to shift from treating sewage to the production of valuable materials;
- Market parties have to regard sewage as a valuable source instead of 'dirty and unsafe water';
- Policies should better fit and stimulate this new circular approach.

Project focus

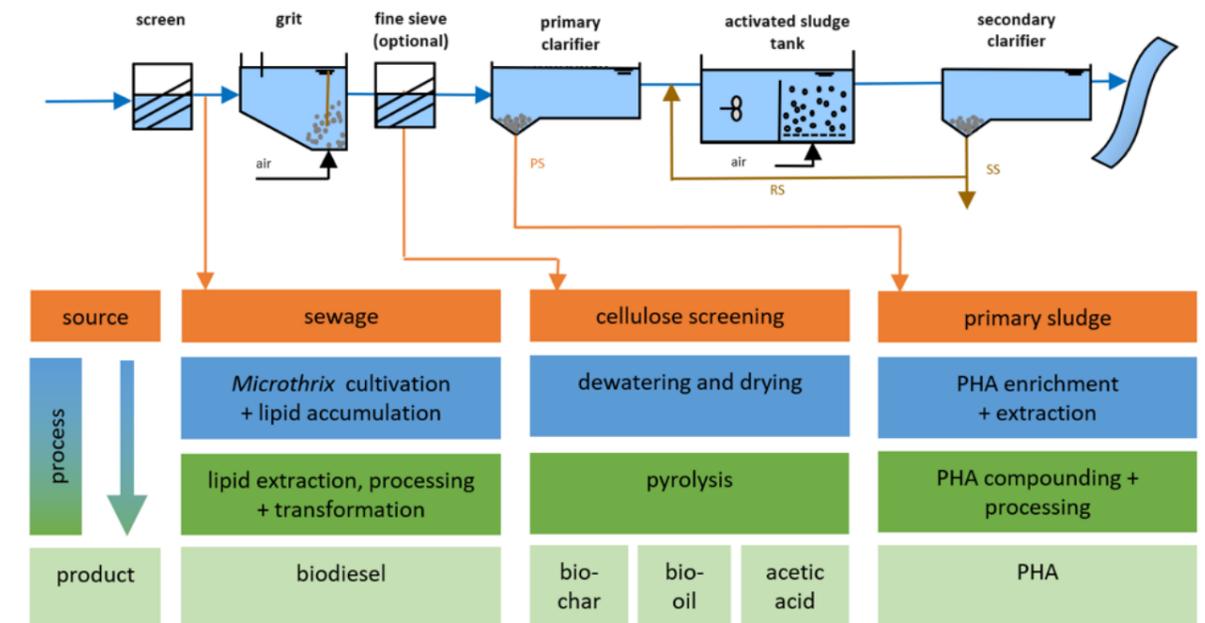
In WOW! project, sustainable value chains for five carbon-based elements (CBE) from sewage are developed: PHA based bioplastics, biofuel, bio-oil, biochar and acetic acid. The reason WOW! focusses on carbon based products is that especially in Northwest Europe sewage water contains high amounts of carbon based elements. This is mainly due to the toilet paper that is discharged through the lavatory in these countries (in contrary to other parts of the EU). In the current practice of sewage treatment across Northwest Europe, bacteria convert approximately 40% of the carbon based elements into CO₂. This way, 1 million tons of carbon is not put to valuable use. And it also results in increased CO₂ emissions.

Technical potential for resource recovery in sewage treatment plants

In order to realize a successful circular approach for resource recovery at STPs, the technical feasibility needs to be shown. This applies to the recovery of raw materials as well as the possible processing and application of these materials. WOW! has shown in three pilots that it is possible to recover and process PHA, bio-oil, biochar, acetic acid and biodiesel.

- In the first pilot cellulose is recovered, dewatered and then dried. In a thermal degradation process the cellulose is heated to a temperature of 400 - 600 °C in an oxygen free environment (pyrolysis). During the pyrolysis process biochar, bio-oil and acetic acid are produced.
- In a second pilot the sewage inflow is used to cultivate *Microthrix* and to enrich lipids. In a next step the lipids are extracted, processed and transformed to biodiesel.
- The third pilot uses the primary sludge of STPs. In a biological process first volatile fatty acids (VFAs) are produced. In a second biological process these VFAs are used to produce PHA. Then the PHA is extracted, compounded and processed to an end product.

Through the pilots the TRL (Technology Readiness Level) of each of these processes was increased from TRL 3-4 (laboratory testing) to TRL7-8 (pilot scale demonstration). Next step will be the realization of a full scale installation.



Market potential for raw materials from sewage

The production of raw materials from sewage has a huge potential with many different applications

Biodiesel	Biochar	Bio-oil	Acetic-Acid	PHA
Fuel	Adsorption of micro pollutants such as pharmaceuticals in STP	Heat Electricity Fuel blending	Carbon source STP pesticide	Packaging Agriculture Construction

Based on the results from the pilots we calculated how much of each product could be produced at sewage treatment plants in Northwest Europe in the future and the possible share of these products at the worldwide market. Especially PHA and activated biochar can make a substantial contribution to the worldwide market.

Product	Production cost (€/kg)	Market prices (€/kg)
PHA	2.7	3.5 – 4.5
Biodiesel	1.1	0.8 – 1.04
Bio-oil	0.23	0.33 – 0.56
Activated char	1.4	1.5 – 2
Acetic acid	-0.13	0.5

Lipid production at lab scale



Climate relevance

In the current practice of sewage treatment in Europe, the carbon based elements in the sewage such as cellulose, saccharides, carbohydrates, proteins and fatty acids are converted by bacteria. Bacteria convert the carbon based elements mainly to CO₂ which is emitted into the air and thus contributing to climate change. This way yearly a substantial amount of CO₂ is emitted in Europe and at the same time this carbon is not put to valuable use.

Circularity relevance

WoW has shown that the recovery of carbon based elements from sewage results in valuable products such as biodiesel, biochar and PHA. These products can replace products that are currently made from natural resources (oil, coal). This contributes to a more circular economy in EU.



PHA extraction

1. EU Green Deal and EU Climate Law

The focus of WOW to recover valuable substances from sewage for use as resource or production of valuable products or sustainable energy needs to be understood in the context of the EU Green Deal and the proposed European Climate Law. The European Green Deal aims to make Europe climate neutral by 2050. To make this objective legally binding, the Commission proposed the European Climate Law, which compared to the Green Deal even sets a more ambitious net greenhouse gas emissions reduction target of at least -55% by 2030⁴.

In order to achieve the net greenhouse gas emissions reduction target, it is stated that emissions must be reduced in all sectors, from industry and energy, to transport and farming. This includes actions focused on investing in environmentally-friendly technologies and supporting industries to innovate. To execute the actions needed, one third of the 1.8 trillion euro

investments from the NextGenerationEU Recovery Plan, and the EU's seven-year budget will go towards the realisation of the European Green Deal⁵. Additional funding is available to help create new eco-friendly jobs, support educational opportunities and train people in new skills facilitating Europe's transition to a green economy.

Investing in the recovery of valuable substances from sewage not only financial but also in making it easier to realize (legislation) is a "no regret" measure matching the main goals of the EU Green Deal and EU climate law. It supports the effective transition towards a fair and prosperous society, with a modern, resource efficient and competitive economy and also creates a predictable business environment for water utilities, industry and investors in relation to emission reductions needed towards 2050.⁶

2. NextGenerationEU

NextGenerationEU is the temporary EU recovery tool to help repair the immediate economic and social damage caused by the coronavirus pandemic. NextGenerationEU supports the modernisation of the EU through research and innovation; fair climate and digital transitions; preparedness, recovery and resilience so the European Union is better prepared for current and future challenges. One of the European flagship areas for NextGenerationEU is Power up which focusses on clean technologies and renewables in order to stimulate a climate neutral circular economy^{7,8}.

Recovery of valuable substances from sewage for use as resource or production of valuable products or sustainable energy directly contributes to the Power up Flagship. Not only by introducing new clean technologies, but also by producing renewable products and reducing the CO₂ emission of sewage treatment plants.



Bio oil

⁴ https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/climate-action-and-green-deal_en (21 July 2021)

⁵ https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en (21 July 2021)

⁶ https://ec.europa.eu/clima/sites/default/files/eu-climate-action/docs/factsheet_ctp_en.pdf (21 July 2021)

⁷ https://ec.europa.eu/info/strategy/recovery-plan-europe_nl

⁸ https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en#the-recovery-and-resilience-facility

3. Circular Action Plan European Commission

In 2015, the European Commission adopted its first circular economy action plan (CEAP). A new CEAP was adopted in March 2020 and is one of the main building blocks of the European Green Deal. The CEAP includes measures along the entire life cycle of products to help stimulate Europe's transition towards a circular economy, boost global competitiveness, foster sustainable economic growth, generate new jobs and to halt biodiversity loss^{9,10}.

One of the aims of the new CEAP is to ensure that waste is prevented and the resources used are kept in the EU economy for as long as possible. With regard to closing the loop from waste to resources, six tools are proposed¹¹:

1. **QUALITY STANDARDS** - the lack of adequate tools to ensure the quality of secondary raw materials is a barrier to their take-up in the EU economy. Common standards are needed to build and support trade. The Commission will develop such standards where needed.
2. **COMMON RULES ON FERTILIZERS** – diverging rules and standards hamper the manufacturing of organic and waste-based fertilisers from inputs such as food waste, sewage sludge or manure. This resulted in 2020 in the Regulation laying down rules on the making available on the market of EU fertilising products (2019/1009)¹².
3. **USING WATER AGAIN** – reuse of treated wastewater is a promising and underexploited option in Europe. This can alleviate pressure on natural resources that are already scarce, and the reuse of water in agriculture also contributes to nutrients recycling. This resulted in 2020 in the Regulation on minimum requirements for water reuse(2020/741)¹³.
4. **PLASTIC AS A RECYCLABLE RESOURCE** – smart design and proper sorting can increase the recycling rates of plastics and avoid landfilling, incineration and use of virgin materials. The Commission will elaborate a strategy addressing issues such as recyclability, biodegradability, the presence of hazardous substances of concern in certain plastics, and marine litter.
5. **USE OF CHEMICALS FITTING THE CIRCULAR MODEL** – to increase safety, facilitate recycling and improve the trust in and uptake of secondary raw materials, the Commission will promote nontoxic material cycles involving less and better traced chemicals of concern. The Commission will also examine how chemicals, products and waste legislation can best work together, including proposals to improve the tracking of chemicals of concern in products.
6. **CROSS-BORDER TRADE** – to facilitate the cross-border circulation of secondary raw materials, the Commission will simplify cross-border formalities through the use of electronic data exchange. It will also support an EU-wide research on raw material flows through the Raw Materials Information System.

The WOW!-project aims to recover valuable substances from sewage for use as resource or production of valuable products or sustainable energy. This contributes to the tools 'using water again' by recovering resources from sewage making it easier to re-use the treated wastewater. WoW also contributes to 'plastic as a recyclable resource' and the 'use of chemicals fitting the circular model' by producing biodegradable plastics from sewage and the production of chemicals from sewage. As mentioned in the policy recommendations, WOW! also recognizes that quality standards and cross-border trade are essential for a successful realization of recovery of products and energy from sewage.

4. Climate neutral water sector

According to the European Green Deal emissions, must be reduced in all sectors in order to achieve the EU net greenhouse gas emissions reduction target. This also applies for the water sector taking into consideration that clean and affordable (drinking) water is one of the fundamental rights of people living in the EU as also stated in the UN Sustainable Development Goals (SDGs).

The recovery of valuable substances from sewage for use as resource or production of valuable products or sustainable energy can greatly contribute to both reduction of greenhouse gas emission and clean and affordable (drinking) water. In the current practice of sewage treatment in Europe, the carbon based elements in the sewage such as cellulose, saccharides, carbohydrates, proteins and fatty acids are converted by bacteria. Bacteria convert the carbon based elements mainly to CO₂ which is emitted into the air and thus contributing to climate change. This way yearly substantial amounts of CO₂ are emitted in Europe and at the same time this carbon is not put to valuable use.

WOW! has shown that it is possible to convert cellulose, saccharides, carbohydrates, proteins

and fatty acids in sewage to valuable products. Through the recovery of these carbon based elements, they are no longer converted to CO₂ which can lead to a CO₂ emission reduction up to 40%. This greatly contributes to the net zero emission goals that are set by the EU. One of the products (activated) biochar could even contribute to better water treatment through the adsorption of organic pollutants such as medicines.

Besides the emission of CO₂, also emissions of greenhouse gases other than CO₂, such as CH₄ and N₂O occurs at sewage treatment plants. Methane can leak from biogas plants due to poor design or maintenance, and N₂O can be emitted in biological processes for nitrogen removal. Emission of CH₄ and N₂O can be minimised if carbon based elements in sewage can be converted to valuable products.



5. Innovation, development and export of new technologies

Already in 2011, the EU realised that Eco-innovation and green technologies are the key to Europe's future. The EU's economic prosperity and well-being is intrinsically linked to its natural environment, and the global demand for renewable energy and resource-efficient solutions will be a source of jobs and economic growth in the years to come. This led to the still running eco-innovation plan with the aim of accelerating market uptake of eco-innovation by addressing its barriers and drivers. The need for innovation, development and export new technologies was repeated in the EU Green deal and even strengthened with the goal to help European companies to become world leaders in clean products and technologies.

Sewage treatment and especially the recovery of resources from sewage is a growing global mar-

ket, expanding in parallel to population growth. Still, over 80% of the world's wastewater – and over 95% in some least developed countries – is released to the environment without appropriate treatment leading to diseases and environmental pollution. This is an opportunity for Europe. European water utilities and industries are leading in the implementation and development of new sewage treatment technologies not only focused on providing clean water but also recovering valuable resources. This is also shown by the WOW project that successfully developed and tested techniques to recover carbon based elements from sewage resulting in different valuable products. These eco-innovations improve the competitiveness of the EU water sector, and introduces new export opportunities for European companies.

⁹ https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en

¹⁰ https://ec.europa.eu/environment/topics/circular-economy/first-circular-economy-action-plan_en#ecl-inpage-944

¹¹ <https://ec.europa.eu/environment/system/files/2021-04/Waste%20to%20resources.pdf>

¹² <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R1009>

¹³ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R0741>

¹⁴ <https://ec.europa.eu/environment/ecoap/about-action-plan/objectives-methodology>

¹⁵ <https://www.impel.eu/wp-content/uploads/2019/12/The-European-Green-Deal-Communication.pdf>



6. Global leader in sustainability

One of the explicit aims of the European Commission is to make the EU a world leader in sustainability. As a global leader, the EU wishes to continue to lead international efforts and address environmental challenges and promote the implementation of ambitious environment, climate and energy policies across the world¹⁶. One of the main targets is of course the ambition to have no net emissions of greenhouse gases by 2050. For this the EU want to set standards for sustainable growth across global value chains¹⁷. To ensure the availability and sustainable management of water and sanitation for all (SDG #6) is one of these global value chains (with a clear link to Life below water #14 and Life on land #15).

Resource recovery from sewage can be considered as a very attractive way to make the water sector more sustainable while at the same time producing valuable resources. Europe can take a leading role in the transition of the water sector because of the already existing high quality of water treatment combined with the great innovation capacity of the European water sector (both water utilities and industries).

7. Urban Waste Water Treatment Directive

Article 12.1 of the European waste-water treatment directive UWWTD (91/271/EEC) states that treated waste water shall be reused whenever appropriate. Disposal routes shall minimize the adverse effects on the environment. This also applies for sludge arising from waste water treatment according to article 14.1¹⁸. However, currently the re-use of waste water and sludge arising from waste water treatment is only very limited and a free option to choose for water utilities.

The recovery of resources from sewage (both waste water and sludge) using techniques developed by the WOW! project but also techniques developed by other projects such as SMART-plant, POWERSTEP, SCALIBUR and NEREUS can give a boost to the re-use of waste water and sludge. The last revision of the UWWTD already arranges sewage valorisation specifically towards agriculture. The current discussion on a new revision of the UWWTD mainly focusses on phosphorus recovery but this should be made broader towards other applications. To further speed up this process collection, recycling and use of recovered raw materials from sewage should be considered the standard on no longer a possible free option to choose.



PHA from sewage



Pilot scale pyrolysis reactor for cellulose pilot

8. Sustainable chemical strategy

On 14 October 2020, the European Commission published a Chemicals Strategy for sustainability towards a toxic-free environment. This strategy is part of the EU's zero pollution ambition, which is one of the key commitments of the European Green Deal. The EU's chemicals strategy aims to better protect citizens and the environment and boost innovation for safe and sustainable chemicals, adding to the already sophisticated chemicals laws that the EU has in place such as REACH. This is needed because global chemicals production and use is expected to double by 2030 (compared to 2019) while currently most chemicals have hazardous properties which can

harm the environment and human health^{19,20}. One of the actions of the Chemicals Strategy is boosting the investment and innovative capacity for production and use of chemicals that are safe and sustainable by design, and throughout their life cycle. The recovery of resources from sewage can contribute greatly to this action because it is not only a circular and sustainable way of producing chemicals but some of the products such as bioplastic PHA cause no harm to the environment and human health even after end-of-life since the bioplastic is fully biodegradable.

¹⁶ https://ec.europa.eu/international-partnerships/topics/green-deal_en

¹⁷ https://ec.europa.eu/commission/presscorner/detail/en/fs_19_6721

¹⁸ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0271>

¹⁹ https://ec.europa.eu/environment/strategy/chemicals-strategy_en

²⁰ <https://ec.europa.eu/environment/pdf/chemicals/2020/10/Strategy.pdf>

The sceptics' corner

Products from sewage treatment plants are unhygienic and polluted

To receive an end-of-waste status, all products from sewage need to comply with the criteria that are described in the Waste Framework Directive (2008/98/EG). One of these criteria states that the use of a product may not lead to overall adverse environmental or human health impacts. This needs to be proven by the organization applying for an end-of-waste status for a product from sewage and is checked by National authorities. To further improve this, in the policy recommendations of this EU roadmap we suggest the implementation of a European framework to assess the risks and quality of recovered products to be used by all national governments. An additional EU-sustainability certification could additionally help in the public acceptance of product from sewage.

The recovery of substances from sewage as a resource or production of products or energy is commercially not viable

Techno Economic Assessments of the WOW! techniques have proven that, even when environmental costs are not taken into consideration, resource recovery from sewage can be viable choosing the right (centralized) infrastructure for processing of the resources and good cooperation between water utilities and industry where water utilities focus on sewage treatment and industries on resource processing.

Most wastewater treatment plants are already built, and it is difficult to implement new concepts

The different techniques for recovery of substances can also be used to upgrade existing plants, working with existing infrastructure to reorganise or retrofit assets to realize climate neutral sewage treatment. In Eastern Europe, much of the wastewater infrastructure still needs to be built, and should be designed with modern techniques. Within WOW!, a Decision Support Tool (DST) was created that can help

water utilities to decide which techniques are feasible for individual sewage treatment plants. Also other EU projects have created such tools.

Resource recovery is a distraction; the focus should be on water quality

There is no competition with water quality issues. Sewage treatment plants that also recover valuable resources can produce effluent water of the same or even better quality as conventional plants. Moreover, resource recovery can lead to lower energy cost for the regular sewage treatment and also reduce CO2 emissions, thus contributing to a climate neutral water sector.

Sewage treatment is too small a sector to make a difference to the circular sustainable economy

Based on the results from the pilots of the WOW! project we calculated how much of each product could be produced at sewage treatment plants in Northwest Europe in the future and the possible share of these products at the worldwide market. Especially PHA and activated biochar can make a substantial contribution to the worldwide market.²¹

The resource recovery technologies are too complex and not mature

Every new technology is complex to begin with. However, with the proper expertise and experiments many challenges can be solved. The WOW! resource recovery techniques have been proven on pilot scale at existing sewage treatment plants. The equipment used consists of modified conventional equipment. Considering the use of this type of equipment for other industrial processes at large-scale, scaling up the resource recovery from sewage would be straightforward.

Contact

Additional information is available on the [WOW! website](#)

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