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EU4GREEN RECOVERY EAST

EU4GREEN RECOVERY EAST - recovery through a circular economy and pollution reduction in the eastern partnership countries (700002623)

EU BEST PRACTICES ON WASTEWATER TREATMENT

Energy Efficiency and Sludge Valorisation Solutions

ENVIRONMENT AGENCY AUSTRIA · EXPERTISE FRANCE GROUPE AFD · OiEau International Office for Water · OECD BETTER POLICIES FOR BETTER LIVES · UNECE · UNIDO UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION Progress by innovation

Authors: Arsha JAMES (UNIDO), Benoît FRIBOURG-BLANC (OiEau), Xavier GOOSENS (OiEau),
& Bogdanka RADETIC (UBA).

Layout: Elisa BEZIER (OiEau)

Date: March 2026

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This document was produced with the financial support of the European Union and written by the partners of the EU4Green Recovery East consortium.

PURPOSE AND SCOPE OF THE CATALOGUE

Wastewater treatment plants (WWTPs) play a critical role in protecting water resources, public health, and environmental quality. At the same time, they represent significant consumers of energy and operational resources within municipal infrastructure systems. Across Europe, increasing attention is being given to improving energy efficiency, climate resilience, and circularity of wastewater treatment processes in response to evolving environmental objectives, rising energy costs, and the transition toward climate-neutral infrastructure.

In this context, wastewater treatment facilities are progressively evolving from conventional treatment systems into integrated resource recovery hubs capable of generating renewable energy, recovering valuable materials, and reducing greenhouse gas emissions.

This catalogue presents a selection of European best practices and operational examples demonstrating innovative approaches to energy-efficient wastewater treatment and sludge valorisation. Each case study provides concise technical and operational information, together with indicative environmental and economic outcomes where available.

The examples included in the catalogue reflect different scales, operational contexts, and levels of technological maturity, illustrating both advanced infrastructure solutions and practical process optimisation measures.

The catalogue is intended to serve as a reference and knowledge-sharing resource for wastewater utilities, public authorities, technical operators, planners, policymakers, and other stakeholders involved in the modernisation and sustainable management of wastewater infrastructure. The documented practices may support strategic planning, operational improvement, investment prioritisation, and policy dialogue related to energy performance, climate resilience, and circular economy objectives within the wastewater sector.

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EU POLICIES AND FRAMEWORKS RELATED TO THE ENERGY EFFICIENCY OF WWTPS

The EU framework on energy use and climate neutrality is built around the European Green Deal and the European Climate Law, which makes climate neutrality by 2050 legally binding under Regulation (EU) 2021/1119 and sets an interim target of reducing net greenhouse gas emissions by at least 55% by 2030. At a strategic level, the legal framework links three key objectives: decarbonisation, energy efficiency, and energy security. Consequently, EU energy policy addresses not only energy supply, but also the transition of the overall energy system towards net-zero emissions.

In practice, this framework is supported by a broader package of energy and climate legislation, particularly the Renewable Energy Directive and related electricity market and reporting regulations, which promote cleaner energy use, renewable energy deployment, and more transparent emissions disclosure. In particular, the Energy Efficiency Directive establishes binding targets and measures to reduce energy consumption. It is reinforced by the "energy efficiency first" principle, which requires energy-saving measures to be considered in planning, policy, and investment decisions before more costly supply-side alternatives. The Directive requires Member States to contribute to a collective EU energy-efficiency target for 2030, with specific obligations relating to public buildings and an overall objective of reducing energy demand rather than expanding energy supply.

In this framework, the revised Urban Wastewater Treatment Directive, adopted in 2024, requires wastewater treatment plants (WWTPs) to significantly improve energy efficiency and increase on-site renewable energy generation, with the objective of achieving energy-neutral operations by 2045. The Directive aims to contribute to the progressive reduction of greenhouse gas (GHG) emissions resulting from urban wastewater collection and treatment activities, particularly through the promotion of energy efficiency and renewable energy production, thereby supporting the EU's 2050 climate neutrality target.

The urban wastewater treatment sector has considerable potential to reduce its own energy consumption while increasing renewable energy production. This may be achieved, for example, through greater utilisation of available space at WWTPs for solar energy generation, the production of biogas from sludge, and the recovery of heat, kinetic energy, and other renewable energy sources.

More specifically, the new Directive applies to all collection systems and connected treatment plants with a capacity of 10,000 population equivalent (PE) or above. The Directive establishes the following obligations and targets:

- Energy audits of operating urban wastewater treatment plants and associated collection systems must be carried out every four years:
  - By 31 December 2028 for WWTPs treating a load equal to or greater than 100,000 PE and the connected collection systems;
  - By 31 December 2032 for WWTPs treating a load equal to or greater than 10,000 PE but less than 100,000 PE and the connected collection systems.

- Member States shall ensure that, at national level, the total annual energy generated from renewable sources, on-site or off-site, by or on behalf of the owners or operators of WWTPs treating a load equal to or greater than 10,000 PE is at least equivalent to:

20% of the total annual energy used by these plants on 31 December, 2030;

40% by 31 December, 2035;

70% by 31 December, 2040;

100% by 31 December, 2045;

PATHWAYS TO PROCESS IMPROVEMENT AND ENERGY OPTIMISATION

Wastewater treatment plants (WWTPs) represent significant energy consumers within municipal infrastructure, yet they also hold untapped potential as resource recovery hubs. Across the EU, a growing number of facilities have been transformed from energy-intensive operations into net energy producers and suppliers of valuable resources such as biogas, heat, and nutrients.These success stories demonstrate that wastewater treatment can evolve from a purely compliance-driven service into an economically viable and environmentally beneficial component of the circular economy.

In many cases, substantial gains can also be achieved through practical, low-cost measures that optimise existing processes and equipment. Establishing such measures as a first step not only enhances efficiency but also creates a stronger baseline for the integration of more advanced solutions over time.

Process control adjustments

Fine-tuning process parameters (e.g., aeration rates, retention times, load distribution) allows plants to better match treatment intensity with actual influent conditions. This reduces unnecessary energy use while maintaining compliance with treatment standards.

SCADA system (Supervisory Control and Data Acquisition)

SCADA systems enable real-time monitoring and control of plant operations, allowing operators to identify inefficiencies, optimise equipment performance, and respond quickly to changing conditions. It could also be linked or upgraded with prediction and artificial intelligence.

Upgrade or optimisation of pumps and blowers

Pumps and blowers account for a major share of electricity use in WWTPs. Efficiency gains can be achieved through proper sizing, use of variable frequency drives (VFDs), optimised scheduling, and regular maintenance. Even minor adjustments in operation can lead to measurable energy savings.

Optimisation of aeration systems

Aeration systems can be optimised through dissolved oxygen (DO) control systems, better diffuser performance, and alignment with real-time demand using simple programmable logic controller (PLC) systems or the use of prediction and artificial intelligence. Avoiding over-aeration can significantly reduce energy consumption without compromising biological treatment efficiency.

Process management of sludge

In aerated systems, sludge recirculation is an important parameter. For example, sludge age (solids retention time, SRT) can be adjusted to optimised levels to avoid excessive aeration requirements.

Disposal and re-use of sludge

Sludge extracted from treatment plants contains a high amount of fermentable organic matter and of water which must be handled adequately. Improved sludge handling such as optimising thickening, digestion, and dewatering processes, can reduce follow up fermentation which generate odours, and energy demand and operational costs. It also minimises unnecessary costs in transportation, storage and disposal. Sludge can also be treated to extract relevant resources.

Co-treatment of sludge with agricultural waste

In regions with significant agricultural activity, sludge from WWTPs could potentially be co-digested with agricultural waste in a regional anaerobic digestion facility. This increases energy recovery potential and can offset part of the plant's energy demand, improving overall energy efficiency.

Energy Recovery from Wastewater

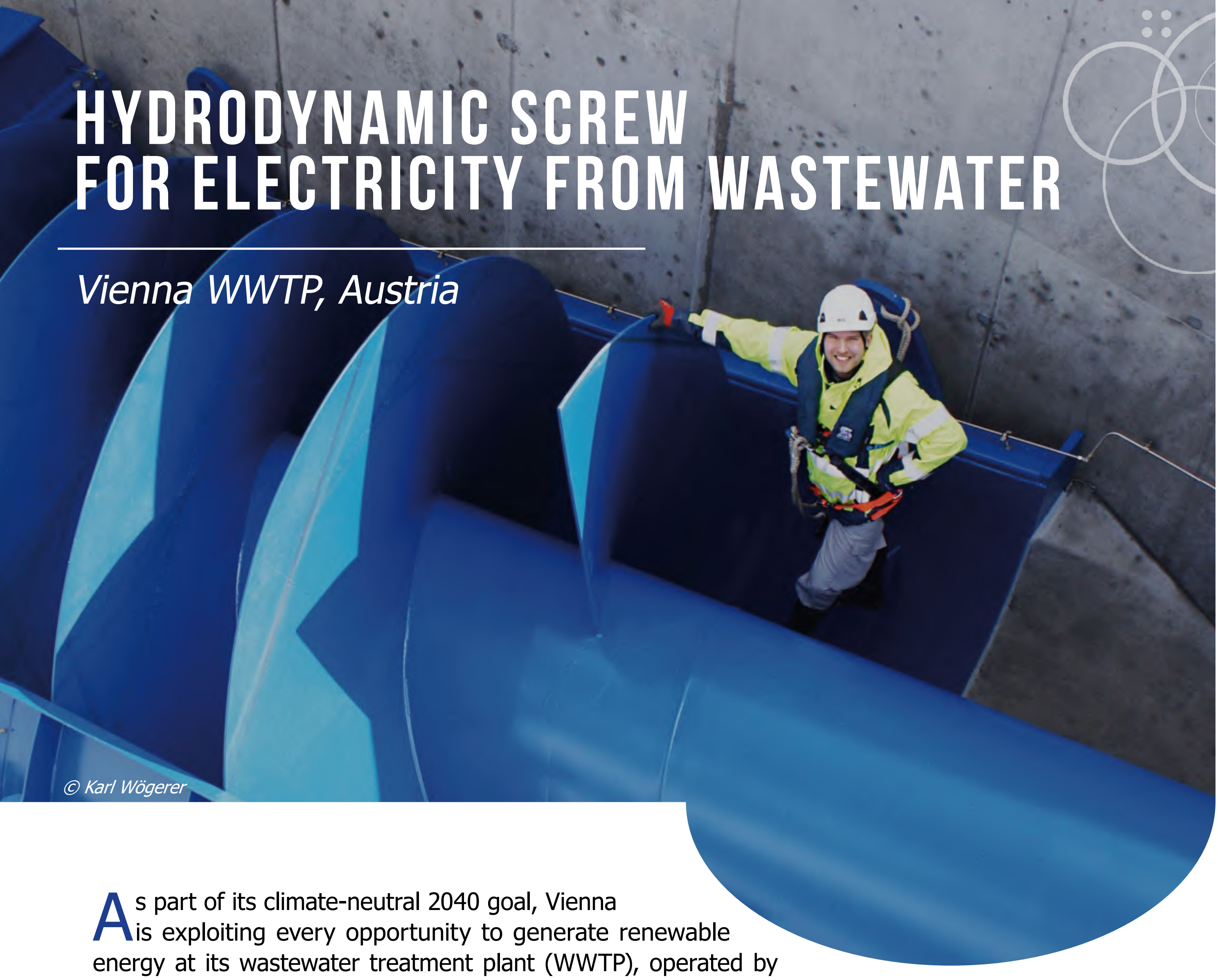
Wastewater entail an energy recovery potential beyond digestion of sludge, especially by recovering heat via heat pumps or when there is a significant elevation difference via microturbines.

While these measures provide accessible and cost-effective opportunities for improving energy performance, they represent only the first step in a broader pathway toward optimisation. Achieving deeper and more sustained efficiency gains may require the adoption of innovative technologies and system-level interventions.

The following case studies illustrate such advanced approaches, highlighting how targeted investments and technological solutions can further enhance energy performance and support the transition toward more sustainable wastewater treatment systems.

HYDRODYNAMIC SCREW FOR ELECTRICITY FROM WASTEWATER

Vienna WWTP, Austria



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As part of its climate-neutral 2040 goal, Vienna is exploiting every opportunity to generate renewable energy at its wastewater treatment plant (WWTP), operated by ebswien. Vienna WWTP requires around 63 GWh of energy per year, equivalent to 25,000 households.

Vienna WWTP already generates more clean energy than it consumes from various measures. Its self-sufficiency rate is 113% for electricity and 176% for heat. Part of the extensive measures that led to this result is a hydrodynamic screw, which has been in use since 2013. It generates around 480,000 kWh of green electricity annually.

RATIONALE

The hydraulic screw was installed at the Vienna WWTP as part of the SternE project. The project supports the climate targets of the City of Vienna and the EU. It also reflects ebswien's corporate guidelines to use all resources as sustainably as possible.

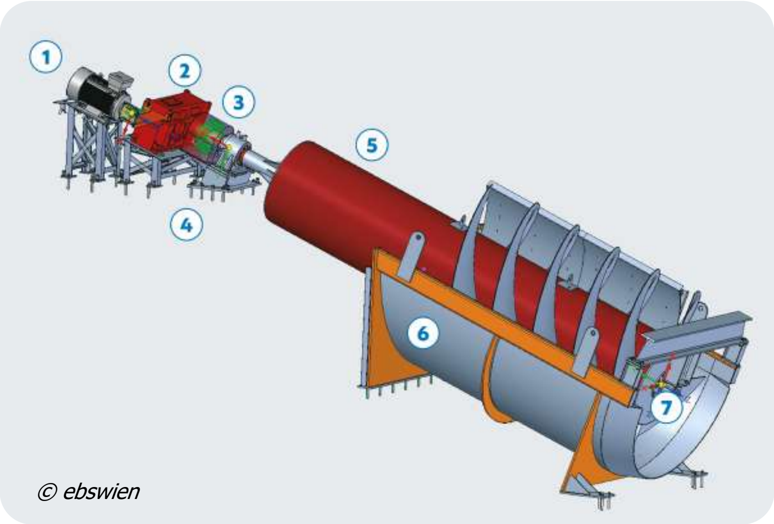
In the future, the EU will require WWTPs to operate in a climate-neutral manner. The Vienna WWTP already meets this requirement, the hydrodynamic screw is doing its part to achieve this.

DESCRIPTION OF THE PROCESS

The hydrodynamic screw makes advantage of the 1.7 m difference in height between the second biological treatment stage and the outlet channel. Based on the principle of the "Archimedes screw," the treated wastewater flowing over the thread of the screw sets it in a rotating motion. A gearbox and a generator convert this motion into electrical power.

1. Generator
2. Gearbox
3. Coupling
4. Upper screw bearing
5. Screw
6. Screw trough
7. Lower screw bearing

Representation of Hydrodynamic Screw



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ECONOMIC ASPECTS

- Investment cost = € 490,000
- Generates 480,000 kWh of green electricity annually

ENVIRONMENTAL BENEFITS

- It contributes significantly to improving the energy self-sufficiency of the wastewater treatment plant
- Reduction of more than 200 tonnes of CO_2 emission per year

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Contact

Mr. Karl Wögerer
ebswien kläranlage & tierservice Ges.m.b.H.
www.ebswien.at/klaeranlage
E-mail: k.woegerer@ebswien.at

KAPLAN TURBINE FOR ELECTRICITY FROM WASTEWATER

Vienna WWTP, Austria

As part of its climate-neutral 2040 goal, Vienna is exploiting every opportunity to generate renewable energy at its wastewater treatment plant (WWTP), operated by ebswien. Vienna WWTP requires around 63 GWh of energy per year, equivalent to 25,000 households. Vienna WWTP already generates more clean energy than it consumes from various measures.

Its self-sufficiency rate is 113% for electricity and 176% for heat. Part of the extensive measures that led to this result is a Kaplan turbine, which has been in use since 2009. It generates around 1,300,000 kWh of green electricity annually.

RATIONALE

Wastewater treatment is an energy-intensive process and depends on varying wastewater volumes and pollutant loads. Although the external factors cannot be controlled, energy use can be reduced through process optimisation and the integration of renewable energy sources.

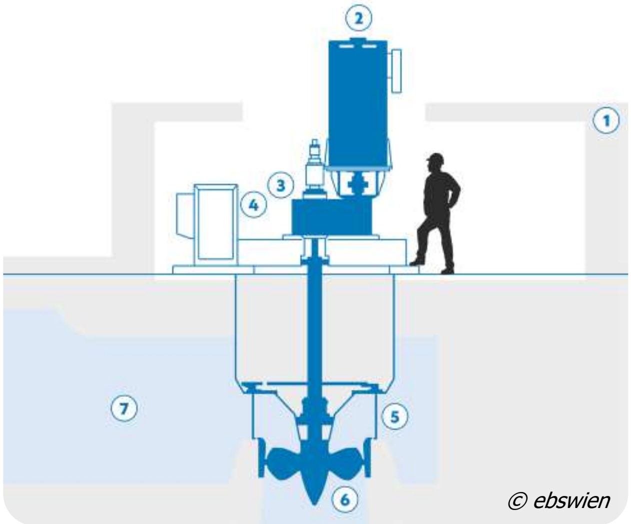
The SternE project, launched in 2006, aims to increase the plant's independence from fossil fuels in line with ebswien's corporate guidelines to use all resources as sustainably as possible. The project focuses on measures to lower energy demand while maintaining high treatment performance, including the installation of a Kaplan turbine to generate renewable electricity from treated effluent.

DESCRIPTION OF THE PROCESS

Every day, around 500 million litres of treated wastewater flow through Vienna WWTP into the Danube Canal via a natural gradient. We use this difference in level with the help of a Kaplan turbine to generate green electricity. The inflowing purified wastewater sets the blades of the Kaplan turbine installed in the outlet pumping station in motion.

A shaft drives the generator, which converts this mechanical motion into electricity. The Kaplan turbine, whose guide and impeller blades are adjustable, generates around 1,300,000 kWh of electricity annually. The turbine thus covers around 2% of the WWTP's total electricity requirements.

1. Pumping station
2. Generator
3. Gearbox
4. Hydraulic unit
5. Guide apparatus
6. Kaplan turbine
7. Discharge channel



TECHNICAL DETAILS

Flow rate	2.5-8 m³/s
Usable head	2.0-5.7 m
Impeller diameter	1,450 mm
Turbine speed	max. 220 rpm
Turbine Power	max. 380 kW
Overall efficiency	max. 84%

ECONOMIC ASPECTS

- Investment cost = € 643,000
- Generates 1.3 GWh of green electricity annually.

ENVIRONMENTAL BENEFITS

- It contributes significantly to improving the energy self-sufficiency of the wastewater treatment plant.
- Reduction of more than 500 tonnes of CO_2 emission per year.

Contact

Mr. Karl Wögerer
ebswien kläranlage & tierservice Ges.m.b.H.
www.ebswien.at/klaeranlage
E-mail: k.woegerer@ebswien.at

HEAT PUMPS AT VIENNA WWTP

Vienna WWTP, Austria

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As part of its climate-neutral 2040 goal, Vienna is exploiting every opportunity to generate renewable energy at its wastewater treatment plant (WWTP), operated by ebswien. Vienna WWTP requires around 63 GWh of energy per year, equivalent to 25,000 households.

Vienna WWTP already generates more clean energy than it consumes from various measures. Its self-sufficiency rate is 113% for electricity and 176% for heat. Part of the extensive measures that led to this result is heat pump, which has been in use since 2023.

RATIONALE

By 2040, district heating is expected to meet 56% of Vienna's total heat demand. As conventional heating systems and combined heat and power plants decline, renewable energy sources will need to take on a much larger role. Because heating represents one of the city's biggest sources of emissions, it also requires the largest investments to achieve climate targets.

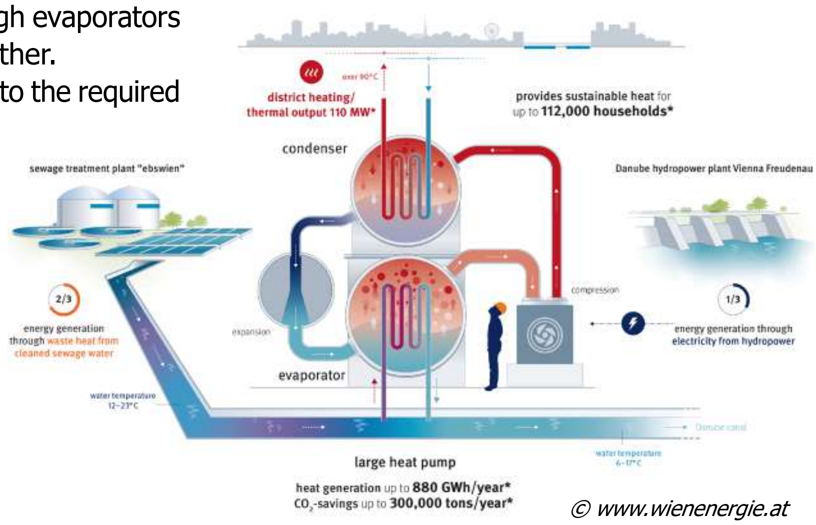
Reaching full decarbonisation will therefore require a fundamental transformation of how heat and hot water are supplied. District heating is a cornerstone of this transition. This project contributes to the decarbonisation of district heating by replacing fossil-based heat with locally available renewable energy.

DESCRIPTION OF THE PROCESS

Previously, purified wastewater from Vienna's treatment plant flowed directly into the Danube Canal. Now, before discharge, it passes through a large heat pump facility. Here, heat exchangers extract around 6°C from the treated water. Using advanced compression heat pump technology, low-temperature heat is upgraded to over 90°C, which is then delivered as hot water into the city's district heating network. In early 2023, three heat pumps for the first phase of the project were delivered. These pumps will extract approximately 6°C from the treated water.

This extracted waste heat is passed through evaporators (heat exchangers), where it is cooled further.
A compressor then raises the temperature to the required level for producing hot water.

The heat is then transferred to the district heating water via condensers (heat exchangers). A second phase will add another three heat pumps by 2030, increasing the system's capacity. To ensure the process is fully climate-friendly, the heat pumps are powered by renewable electricity from the nearby Freudenau hydropower plant.



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ECONOMIC ASPECTS

- €70 million investment
- 3 heat pumps with thermal output of 18MW each
- Heat generation of 440 GWh
- Reduces reliance on gas imports and helps stabilise heating costs

ENVIRONMENTAL BENEFITS

- Saves up to 150,000 tonnes of CO_2 annually
- Turns an unavoidable wastewater stream into a renewable energy source
- Cut greenhouse gas emissions by replacing fossil fuels with renewable heat
- Supplies 56,000 households with CO_2-free district heating
- Discharge cooler water into the river, helping counteract warming waters

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Contact

Ms. Tabea Gruber-Heusequin
Wien Energie
www.wienenergie.at
E-mail: Tabea.Gruber@wienenergie.at

CELLULOSE RECOVERY FROM SEWAGE SLUDGE

Geestmerambacht wastewater treatment plant, Netherlands

© www.cell-vation.com

Municipal wastewater contains a high concentration of suspended solids, of which up to 70% are cellulose fibers originating mainly from toilet paper. It increases the load on wastewater treatment plants, raising operational and energy demands.

CellPro is an innovative process that extracts and upcycles cellulose directly from municipal sewage streams, which can address this problem. Through this technology, cellulose fibers are recovered from incoming wastewater and refined into a high-quality, market-ready product known as Recell®. Within the EU-funded SMART-Plant project, a full-scale CellPro system with a treatment capacity of up to 90 m³/h was installed at the Geestmerambacht wastewater treatment plant.

RATIONALE

In the Netherlands alone, 180,000 tonnes of toilet paper are flushed away every year. Made from virgin tree-based cellulose, this material becomes waste after a single use. It is usually burned or landfilled, which is both costly and environmentally harmful. CellPro offers a circular alternative.

By integrating the technology within, or alongside, WWTP's primary treatment stage, toilet paper fibers can be recovered, and upcycled into a valuable cellulose product. This not only reduces the environmental footprint associated with disposal but also enables wastewater utilities to generate new resources from what was previously considered waste.

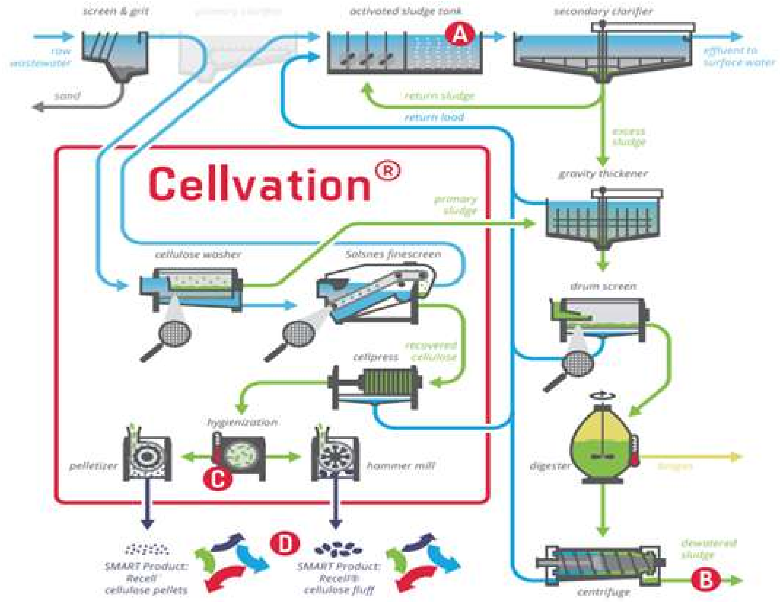
DESCRIPTION OF THE PROCESS

The CellPro technology is integrated into the pretreatment stage of a wastewater treatment plant, immediately after the influent passes through the bar screen. In the primary treatment phase, a dedicated Salsnes fine-sieve system extracts cellulose-rich screenings from the sewage stream in a separate, controlled step.

These screenings undergo a washing and refining process to remove contaminants and recover clean cellulose fibers. The resulting material is highly versatile and can be further processed depending on the intended application.

The cellulose fibers can be dried to produce lightweight cellulose fluff, compressed into durable pellets, or blended with bioplastics, such as PHA, to create strong and sustainable bio-composite materials.

Since the completion of SMART-Plant project, the technology has been further developed by CirTec BV in partnership with Giotto Water. CirTec developed a two-stage screening system, known as CellCap, consisting of an ingeniously designed drum screen (CellWash) and an improved rotating belt screen (IntenSieve) and it is now being used instead of the Salsnes system.



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ECONOMIC ASPECTS

- Up to 15% energy savings in aeration tanks.

ENVIRONMENTAL BENEFITS

- 20% reduction in CO_2 emissions.
- A real-life example of circular economy Recell®: a high-quality cellulose fiber for construction, paper, coatings, and sustainable chemicals.
- Cellulose fluff: usable in chemical and construction applications.
- Cellulose pellets: key material for bio-composites in furniture, decking, facades, and fencing.

BENEFITS FOR WASTEWATER TREATMENT PLANTS

- Up to 10% higher hydraulic capacity by reducing organic load.
- Up to 40% reduction in total suspended solids.

Contact

Ms. Marit van Veen
CirTec BV
https://www.cirtec.nl/sewer-mining-cellu-lose-recovery-2/
Email: m.vanveen@cirtec.nl

INTEGRATED ENERGY RECOVERY AT LIMOGES UWWTP

Limoges Metropole WWTP, France

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Limoges Métropole, responsible for sanitation services across the urban community since 2007, recognised energy consumption challenges at its main WWTP and initiated modernisation activities in December 2020.

The project integrated primary treatment infrastructure upstream of existing biological systems, enhanced anaerobic digestion capacity with dewatering equipment, and deployed real-time monitoring systems to enable data-driven operational optimisation across all treatment stages.

RATIONALE

In conventional WWTPs without primary treatment, all organic matter passes directly to energy-intensive biological treatment systems, creating unnecessarily high aeration demands and underutilised digester capacity with limited biogas production potential.

The Limoges modernisation project addresses this by capturing readily settleable organic material before biological treatment, reducing aeration loads while directing highly fermentable material to anaerobic digesters where it doubles biogas production compared to biological sludge alone.

DESCRIPTION OF THE PROCESS

To maximise energy performance, the project implemented three complementary strategies:

- Process redesign through primary treatment installation.
- Equipment optimisation including improved compressor performance and heat recovery from effluents for sludge digestion.
- Replacement of thermal dewatering and filter presses with latest-generation centrifuges.

These improvements collectively increase biodigester processing capacity and reduce oxygenation requirements in the biological treatment stage.
The station was equipped with a primary settling treatment system that increases sludge production and reduce the amount of pollution to be treated biologically in the secondary treatment system.

The settled material is added to the excess biological sludge (containing water-purifying microorganisms) in a digester. By allowing to produce more biogas, this reduces the final amount of sludge.

As the settled material from the primary treatment is much more fermentable than the biological sludge from the secondary treatment, biogas production is doubled.

To further support the processes, a dedicated energy performance monitoring dashboard was established. It tracks energy consumption per treatment stage, biogas production rates, and effluent flow and quality parameters, enabling continuous optimisation of operating conditions.

ECONOMIC ASPECTS

- CAPEX: €25.1 million (including €13.5 million of subsidies),
- OPEX: before €13.9 million; after €12.6 million.

SOCIAL BENEFITS

- Abandonment of labour and energy-intensive sludge dewatering processes.
- Reduction in operating costs (less electricity consumption, more sales of biogas) and enhanced control of the price of the service.

ENVIRONMENTAL BENEFITS

- Better control of the quality of wastewater discharged into the environment.
- Reduction in sludge quantity to evacuate (-8% expected).
- Significant improvement of the carbon footprint of the plant, from 1,764 to 71 tonnes of CO2 per year.
- Significant improvement in energy performance.

Volume of Wastewater treated (17.5Mm3)	Before the project	After the project
Electricity consumption (GWh/year)	11.25	9.23
Gas consumption (thermal GWh/year)	9.3	0
Gas production (thermal GWh/year)	5.1	10


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Contact

Ms. Magalie Gady
Industrial Works Project manager
Limoges-Metropole WWTP
E-mail: magali.gady@limoges-metropole.fr

STRUVITE PRECIPITATION FROM FILTRATE OF SEWAGE SLUDGE

Braunschweig sewage treatment plant, Germany

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The P-Net project, led by TU Braunschweig, focuses on the controlled recovery of magnesium ammonium phosphate (struvite) through precipitation and crystallisation. Struvite, once considered an operational problem because it caused incrustations in pipes and equipment, is now being intentionally recovered to prevent blockages and to produce a usable phosphorus product.

The project aims to optimise this process so that the phosphorus content in digested sludge falls below the 2% limit required by the German Sewage Sludge Ordinance. This enables regional reuse of phosphorus in agriculture.

RATIONALE

Phosphorus is essential for food production, yet natural reserves are limited. German wastewater treatment plants produce around two million tonnes of sludge annually, containing about 60,000 tonnes of phosphorus. The formed crystals are then separated in a settling tank.

Larger crystals settle and can be collected, while smaller crystals are returned to the reactor to promote further growth. The final struvite product is usually dewatered, dried, and processed for use as a slow-release fertiliser.

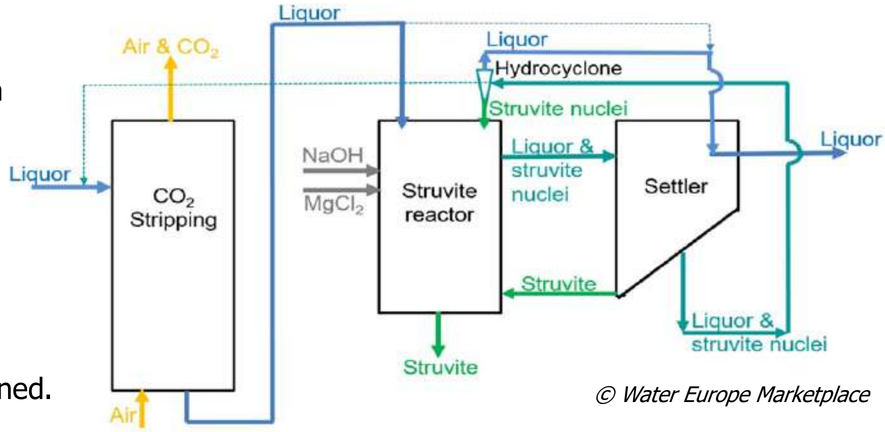
Historically, sludge has been incinerated or spread on fields, but with the 2017 amendment of the Sewage Sludge Ordinance, phosphorus recovery will be mandatory by 2029 and direct land application will no longer be allowed. P-Net supports this transition by turning sewage sludge from a disposal problem into a valuable resource through phosphorus recovery at the treatment plant itself.

DESCRIPTION OF THE PROCESS

As part of the phosphorus recycling process, biological P-remobilisation is done. Then the Filtrate from the centrifuge is used for struvite precipitation. It can also be carried out after anaerobic digestion, sometimes combined with additional hydrolysis to increase dissolved phosphate. To enable struvite formation, the pH is raised above 7.5. First, CO_2 is removed through air stripping. A magnesium source such as $MgCl_2$, MgO, or $Mg(OH)_2$ is then added. In the struvite reactor (a continuously stirred tank), magnesium, ammonium and phosphate react to form struvite crystals. Crystal growth is supported by mixing, retention time, and recirculation of fine crystals.

Technology requirements

- Dissolved phosphate concentration should be at least 50 mg PO4-P/L.
- Total suspended solids (TSS) and total solids (TS) should be below 600 mg/L and 2%, respectively.
- A molar ratio of Mg:N:P between 1:2:1 and 1:12:1 should be maintained.



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ECONOMIC ASPECTS

- The process applied at the Braunschweig sewage treatment plant was a full-scale demonstration rather than a permanent installation. The project calculations indicate that implementing this process for a wastewater treatment capacity of 20,000 population equivalent would require an estimated investment of approximately €960,000, which will produce around 36 tonnes of struvite per year.

ENVIRONMENTAL BENEFITS

- The recovered struvite is a slow-release fertiliser with a fertilising effect comparable to conventional mineral fertilisers.
- It has been approved by the EU for use in organic farming since 2023.
- It helps reduce dependence on imported phosphorus and supports circularity.
- Less energy requirement than conventional P-fertiliser production expected.


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Struvite Photo

BENEFITS FOR WASTEWATER TREATMENT PLANTS

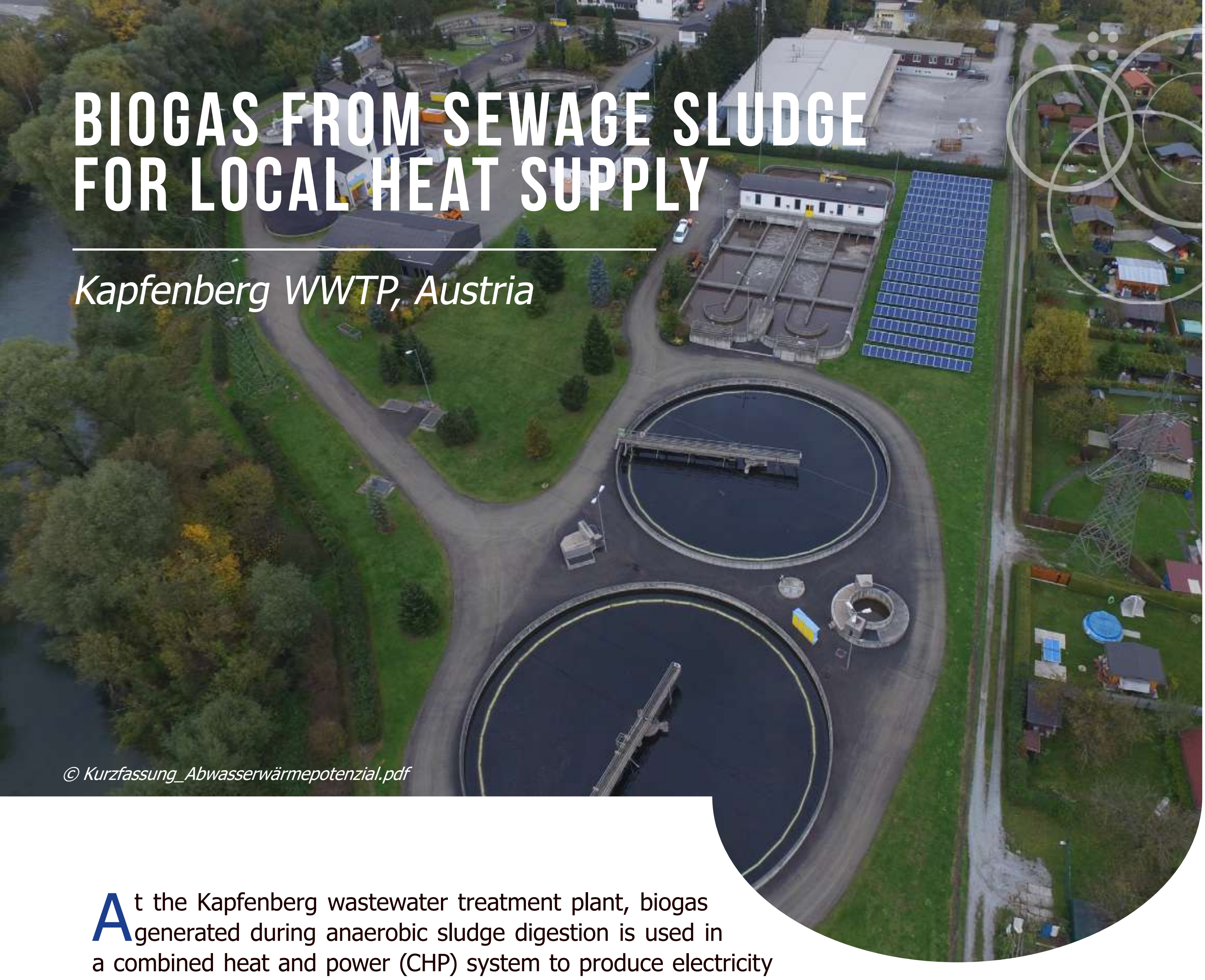
- Achieves high phosphorus recovery rates, with removal efficiencies of up to 95%.
- Prevents uncontrolled struvite deposits and reduces clogging in plant equipment.

Contact

Mr. Thomas Dockhorn
Technische Universität BraunschweigL
www.tu-braunschweig.de/en/isww
E-mail: t.dockhorn@tu-braunschweig.de

BIOGAS FROM SEWAGE SLUDGE FOR LOCAL HEAT SUPPLY

Kapfenberg WWTP, Austria



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At the Kapfenberg wastewater treatment plant, biogas generated during anaerobic sludge digestion is used in a combined heat and power (CHP) system to produce electricity and heat. This currently covers around 60% of the plant's electricity demand and more than 100% of its heat demand.

Previously unused surplus heat is now being supplied as CO_2-free heating to a new nearby residential quarter of 220 apartments. In addition, low-temperature heat from the treated effluent is being recovered to meet internal heating needs.

RATIONALE

To support climate-neutral cities, renewable and local heat sources such as wastewater are gaining increasing importance. Wastewater contains reliable thermal energy produced continuously wherever people live and work.

This combined use of low- and high-temperature heat represents a new approach to heat recovery at wastewater treatment plants and supports more efficient and sustainable energy use.

The integration into the local heat supply is being implemented in two phases:

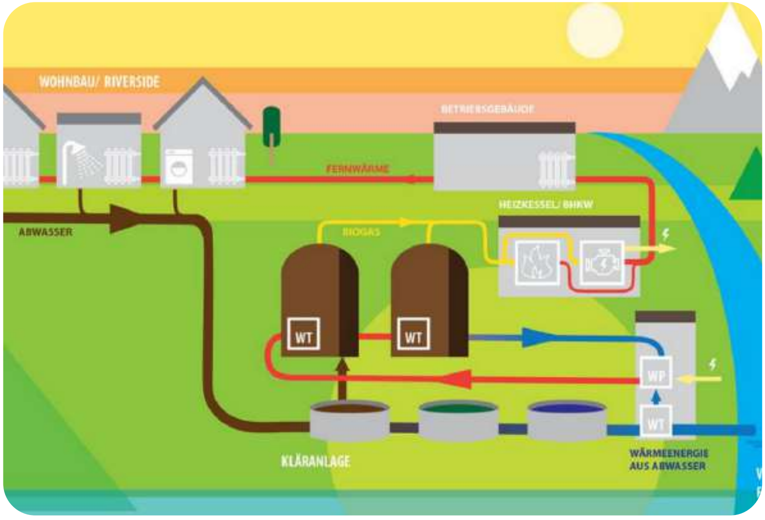
- Phase 1 (2019-2020): The plant is connected to the district heating network to export surplus heat generated in the CHP plant.

- Phase 2 (2021-2022): Wastewater heat from the effluent is recovered to cover the plant's internal heat demand, freeing additional biogas heat for external supply during high-demand winter months.

DESCRIPTION OF THE PROCESS

At the Kapfenberg wastewater treatment plant, biogas is generated from sewage sludge through anaerobic digestion. This biogas is converted into electricity and heat using a combined heat and power (CHP) system.
The plant makes use of two heat streams:

- Low-temperature heat from treated wastewater is used for internal processes, such as maintaining digester temperatures.
- High-temperature heat from the CHP is redirected to the local district heating network, supplying nearby residential buildings with renewable heat.



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ECONOMIC ASPECTS

- **Phase 1:** Integration into district heating network
- Installation of district heating interface and heat exchanger, including control integration
- CAPEX: €46,000
- Annual income: €5,100
- **Phase 2:** Expansion to wastewater heat recovery
- Installation of wastewater heat exchanger and heat pump, adaptation of digester heat exchanger and construction of connecting pipelines
- CAPEX: €143,000
- OPEX: €26,000 per year
- Additional annual income: ~€19,600
- Natural gas savings: ~€17,000 per year

ENVIRONMENTAL BENEFITS

- Production of 896 MWh/year of renewable energy, with the heat pump requiring 212 MWh/year of electricity.
- CO_2 savings of approximately 239 tonnes per year.
- Supplies 100% of the housing estate's heat demand in summer and at least 50% in winter.
- Wastewater serves as a renewable, constant and reliable heat source.

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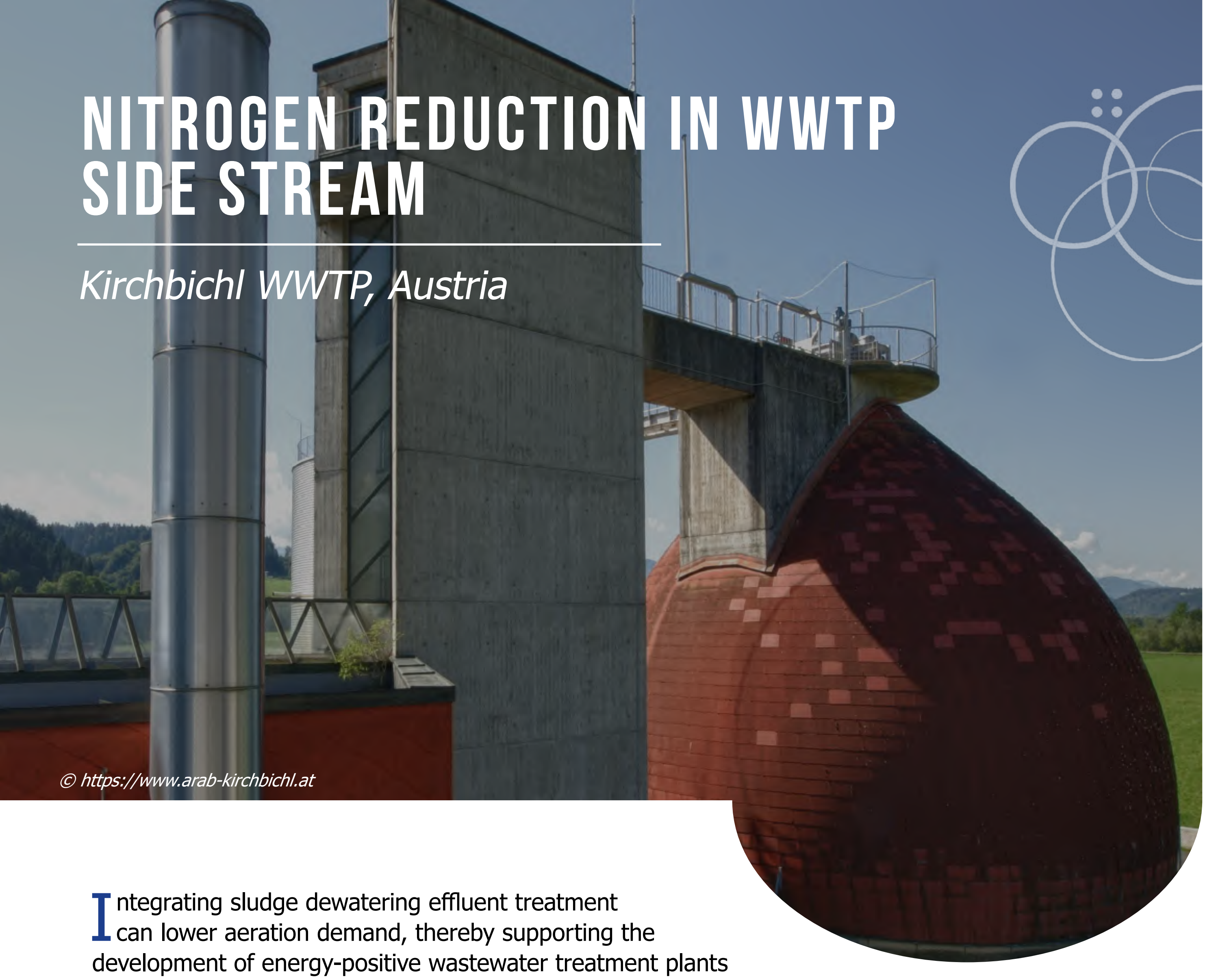
Contact

Wasserverband Mürzverband
https://www.muerzverband.at/wasserverband/
E-Mail: office@muerzverband.at

NITROGEN REDUCTION IN WWTP SIDE STREAM

Kirchbichl WWTP, Austria



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Integrating sludge dewatering effluent treatment can lower aeration demand, thereby supporting the development of energy-positive wastewater treatment plants (WWTPs). At the two-stage WWTP Kirchbichl, the focus is on optimising nitrogen removal by coupling nitritation in the dewatering effluent with denitritation in the first-stage activated sludge tank. The process was introduced in 2015.

RATIONALE

Sludge dewatering liquor (SDE) carries a significant ammonium-nitrogen load, accounting for approximately 15–20% of the total nitrogen entering the WWTP. When SDE is recycled directly to the activated sludge tank, it increases the aeration demand for treatment.

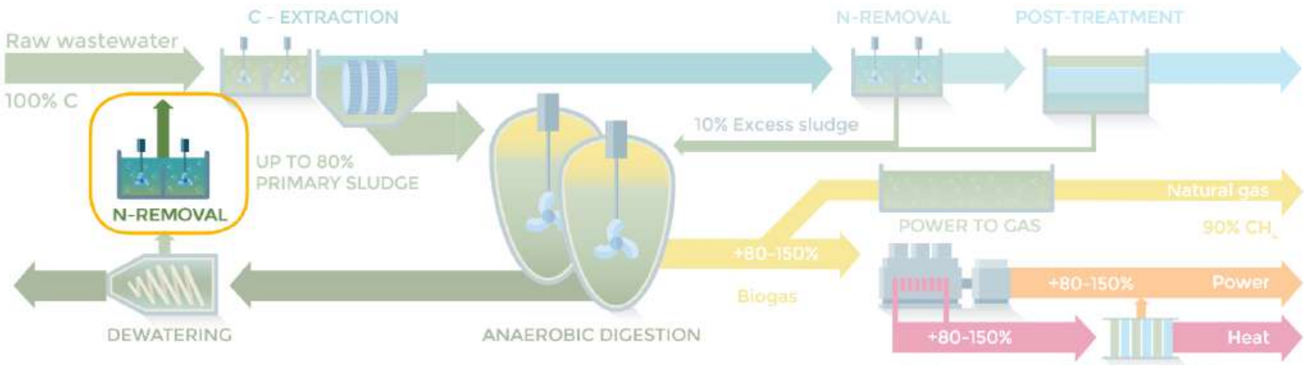
At Kirchbichl, nitritation is applied as side stream process before returning dewatering liquor to the main line. The resulting nitrite contains chemically bounded oxygen, which can be utilised for organic carbon removal in the first treatment stage, thereby reducing the overall aeration requirement.

DESCRIPTION OF THE PROCESS

Kirchbichl is a two-stage activated sludge plant using the patented HYBRID process. HYBRID process was implemented 2010 and offers significant energy benefits by reducing overall aeration demand and increasing energy recovery through biogas utilisation in CHP systems.

In the first stage, an activated sludge tank with a high COD load extracts a larger share of COD from the wastewater compared to single-stage plants, generating surplus sludge for digestion.

The second stage, operated at a higher sludge age, facilitates nitrification and denitrification. Nitrogen removal can be optimised by recirculating part of COD from the first stage. These advantages have been demonstrated at several large-scale WWTPs. Energy efficiency has been further improved by integrating sidestream nitritation for treating ammonium-rich sludge dewatering effluent. The nitrite produced is then reintroduced into the first stage, enabling denitritation instead of denitrification. This approach saves COD, which can be redirected to enhance biogas production or improve TN removal in plants with low TN/COD ratios. Additionally, sidestream nitritation lowers operating costs due to better conditions for ammonium oxidation compared to mainstream treatment (higher oxygen transfer rates).
While sidestream nitritation combined with mainstream denitritation is nearly as energy efficient as sidestream anammox (oxygen demand ≈ 1.5 g O_2/g N removed), nitritation offers more stable operation and lower investment and control costs.



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ENVIRONMENTAL BENEFITS

- Lower greenhouse gas emissions: Reduced aeration demand and more efficient nitrogen removal decrease electricity consumption, cutting indirect CO_2 emissions from the WWTP's energy use.
- Enhanced renewable energy generation: Saving COD for digestion boosts biogas yield and CHP recovery, increasing on-site renewable energy and supporting energy-positive operation.
- Improved nutrient management: Optimised nitrogen removal in two-stage treatment reduces nitrogen discharge to receiving waters, helping prevent eutrophication and protect aquatic ecosystems.

ECONOMIC ASPECTS

The process reduces aeration energy demand in the main treatment line, cutting electricity costs. By converting ammonium to nitrite and coupling this with denitritation in the first-stage activated sludge tank, nitrogen removal becomes more efficient while lowering carbon demand.

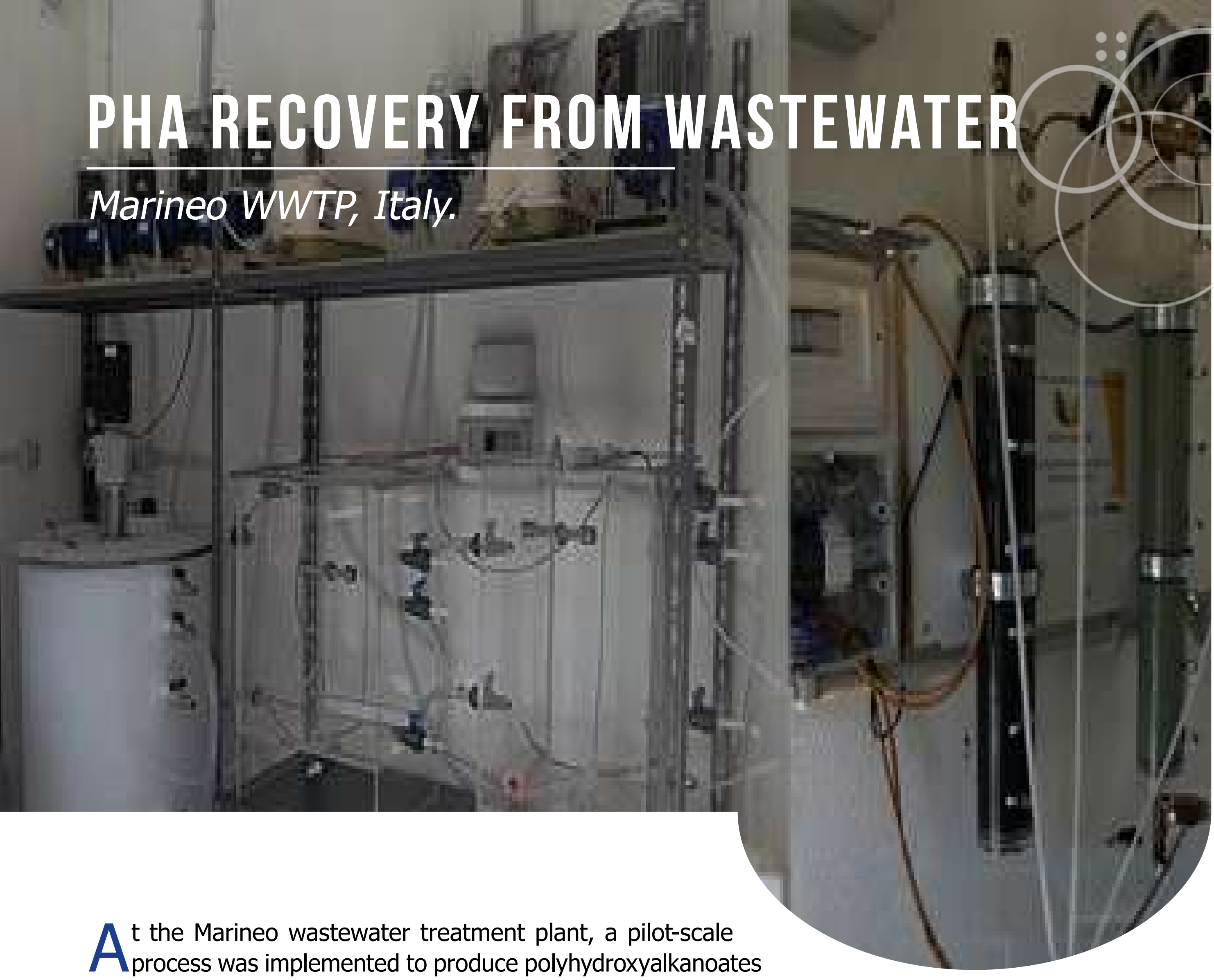
This saves COD for anaerobic digestion, resulting in higher biogas yield and increased energy production, delivering both reduced operating costs and improved energy recovery.

Contact

ARAB GmbH
http://www.arab-kirchbichl.at/
Email: ara@arab-kirchbichl.at

PHA RECOVERY FROM WASTEWATER

Marineo WWTP, Italy.



At the Marineo wastewater treatment plant, a pilot-scale process was implemented to produce polyhydroxyalkanoates (PHA) from sewage sludge using a dedicated diversion line.
The demonstration proceeded without operational constraints, and all key steps including fermentation, biomass selection and PHA accumulation performed as expected. These results highlight the feasibility and scalability of the approach and its potential to support the transition of wastewater treatment plants into resource recovery facilities.

RATIONALE

The growing demand for plastics, especially in packaging, has intensified environmental concerns due to their long degradation time. PHAs, a family of biodegradable bio-polyesters, offer a sustainable alternative to petroleum-based plastics, as they have similar properties to polypropylene and low-density polyethylene.

Excess sludge is fermented in a 210 L fermenter, and the resulting VFA-rich liquid is recovered using a membrane bioreactor (MBR) with hollow-fiber membranes. This VFA stream is then fed to the accumulation SBR, where microorganisms convert it directly into PHA. The process is operated continuously via dedicated control software. The system has an output potential of up to 50-80% of microbial cell dry weight, demonstrating a strong potential for resource recovery.

DESCRIPTION OF THE PROCESS

The Marineo WWTP operates a conventional activated sludge process, including pretreatment (sieving and degritting), biological treatment in two parallel combined basins, settling, filtration and UV disinfection.

For PHA production, a dedicated diversion line was added consisting of:

- A fermenter to convert excess sludge into volatile fatty acids (VFA)
- A sequencing batch reactor (SBR1) to enrich PHA-accumulating microorganisms
- A sequencing batch reactor (SBR2) for PHA accumulation

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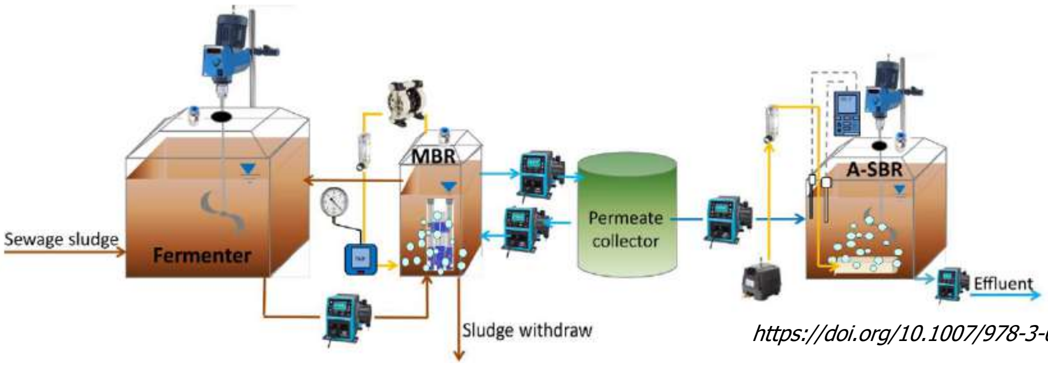


https://doi.org/10.1007/978-3-031-63353-9_6

ENVIRONMENTAL BENEFITS

- Biodegradable plastics: PHA can be broken down naturally by microorganisms, reducing plastic pollution.
- Sustainable alternative to conventional plastic with low environmental impact.
- Transforms wastewater treatment from a linear waste disposal process into a circular resource recovery system.

ECONOMIC ASPECTS

While the system successfully demonstrated technical feasibility with PHA yields of 50-80% of microbial cell dry weight, the technology has not yet been successfully implemented at full commercial scale. Further development is needed to assess complete economic viability, including capital costs, operational expenses, and market integration.

BENEFITS FOR WASTEWATER TREATMENT PLANTS

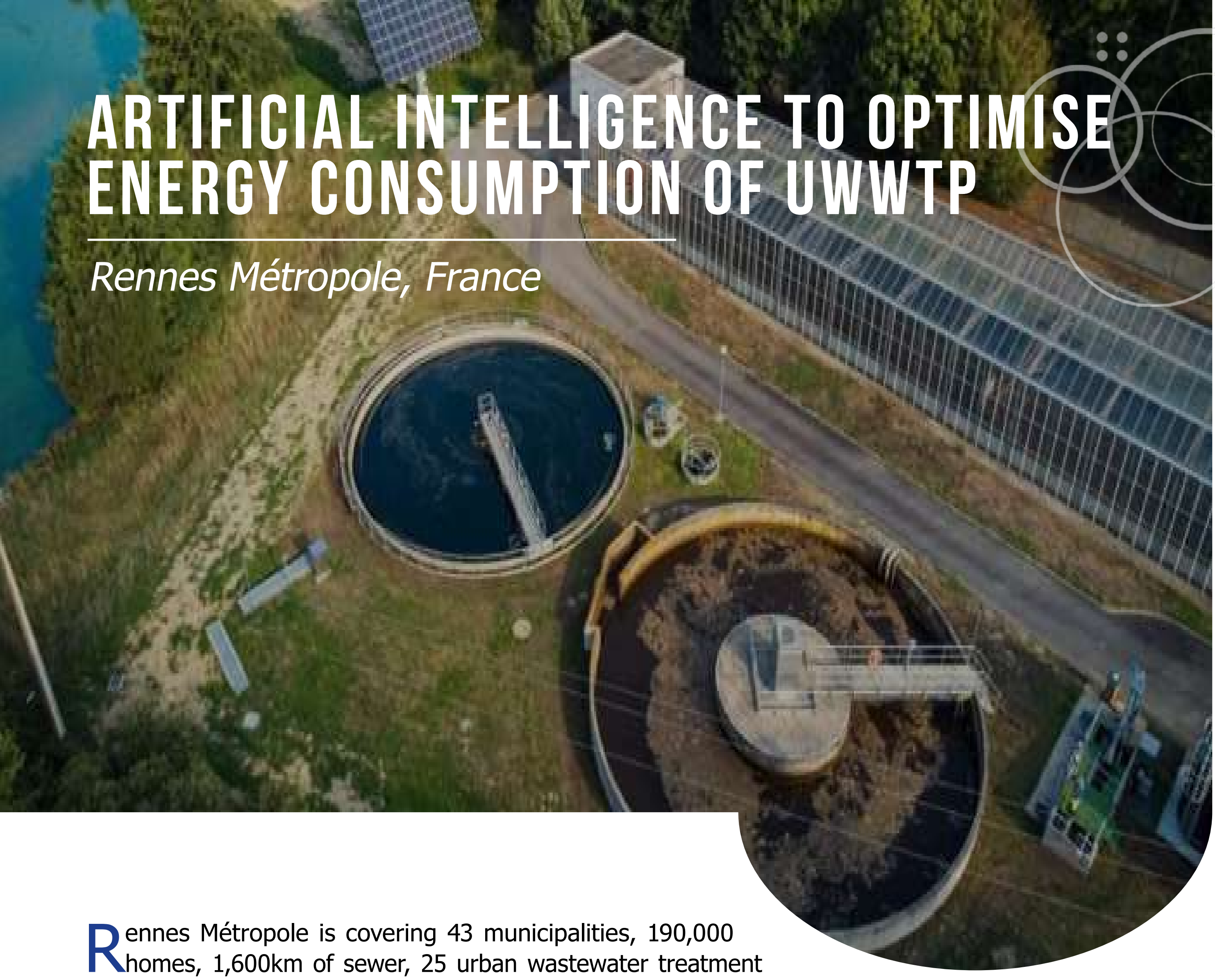
- Lower sludge disposal costs due to reduced sludge volumes.
- Revenue from PHA sales could partially offset wastewater treatment operational costs.

Contact

Mr. Giovanni Sciortino
AMAP S.p.A
https://www.amapspa.it/
Email: giovanni.sciortino@amapspa.it

ARTIFICIAL INTELLIGENCE TO OPTIMISE ENERGY CONSUMPTION OF UWWTP

Rennes Métropole, France



Rennes Métropole is covering 43 municipalities, 190,000 homes, 1,600km of sewer, 25 urban wastewater treatment plants treating 28 million m3 of wastewater. They are responsible for the entire small water cycle including sanitation. In the recent period, they decided to take over all sanitation services previously managed by private companies under a common public management model. On the other hand, the Métropole committed itself to reduce its greenhouse gas emissions by 50% by 2030.

Within this context, Artificial Intelligence (AI) has been identified as a key enabler to improve energy efficiency, optimise process control, and support the integration of renewable energy sources. AI-based supervision allows wastewater treatment plants to dynamically adapt operations to real-time process conditions, while maintaining treatment performance.

RATIONALE

Wastewater treatment represents a significant energy consumption of the Métropole. Reducing energy demand and shifting to solar energy offers a substantial opportunity to decrease the greenhouse gas emission.

The main objectives were therefore to improve wastewater treatment, reduce energy use and increase solar energy self-consumption. To test the approach of using AI for this, Rennes Métropole partnered Purecontrol, a local SME proposing AI based solutions.

DESCRIPTION OF THE PROCESS

Five treatment plants, ranging in size from 5,500 to 360,000 PE, have been modelled with digital twins. These plants were equipped with a set of sensors to monitor inlet flow rate, oxygen sensor, redox, recirculation volume, and other parameters. Programmable logic controllers (PLCs) were used to manage aeration pumps, and an AI-based supervision was used.

The AI system combines process data (PLCs, sensors, rules) and contextual data on weather, energy pricing and mix and variations in wastewater generation, to maintain or enhance treatment performance while providing alarms, fault detections and reduction of energy use. The key principle is for the AI to reconstitute a virtual ammonium sensor and predict its evolution for the coming day. The tool then controls the aeration cycles according to the evolution of the simulated ammonium load to apply the most efficient aeration cycle scenario. This allows to:

- Precisely adjust aeration times to incoming loads thereby reducing the operating time;
- Optimise activation during off-peak hours thereby lowering the energy cost;
- Stabilise the discharge quality, thereby allowing better regulatory compliance.

At one of the plants (5,500 PE), equipped with two solar trackers, the AI system was further extended to optimise solar energy self-consumption. By analysing weather forecasts and historical production data, AI predicts solar output and aligns plant energy demand with on-site energy generation.

ENVIRONMENTAL BENEFITS

- Better quality of wastewater discharged into the environment.
- Improvement in energy performance (1,200 MWh/y saved).
- Improvement of the carbon footprint with 41 tonnes of CO_2eq avoided per year.
- 30% reduction in Nitrous oxide emissions.

ECONOMIC ASPECTS

The solution required low Capex because it relies on non-intrusive data collectors, edge devices and remote supervision. Low installation fee and subscription-fee, calculated according to the use case, type and size of the site to be managed.

Savings of €214,800 in energy costs annually, compared to pre-2020 consumption levels.

15% reduction in aeration time and 5% in energy use.

BENEFITS FOR WASTEWATER TREATMENT PLANTS

- Improved management of the system with enhance supervision, automatic control of the process and ease of the technical management.
- Optimisation of aeration process.
- Maximisation of self-consumption of solar energy.
- Dedicated interactive dashboards and alert system, including energy performance monitoring.
- Enhanced control of the price of the service.

Contact

Ms. Enora Delanoë
Communication manager
Email: enora.delanoe@purecontrol.com

Funded by
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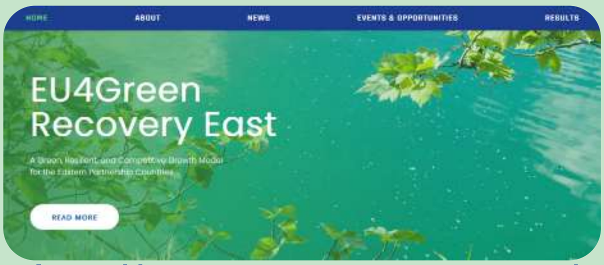
EU4GREEN RECOVERY EAST

EU BEST PRACTICES ON WASTEWATER TREATMENT

This Regional Reference Catalogue has been developed under the EU4Green Recovery East programme to showcase innovative practices in energy-efficient and climate-resilient wastewater treatment from across the European Union.

It is designed to serve as a strategic planning tool and source for countries to work toward modernising their wastewater infrastructure and advancing their environmental and climate objectives.

For updates and resources, visit the EU4Green Recovery East website, your country's EU Delegation website or the EU Neighbours East website.



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March 2026