Present vs Future: Wastewater Treatment Plant (WWTP) or Wastewater Resource Recovery Facility (WRRF)

University of Tartu

MARKUS RAUDKIVI

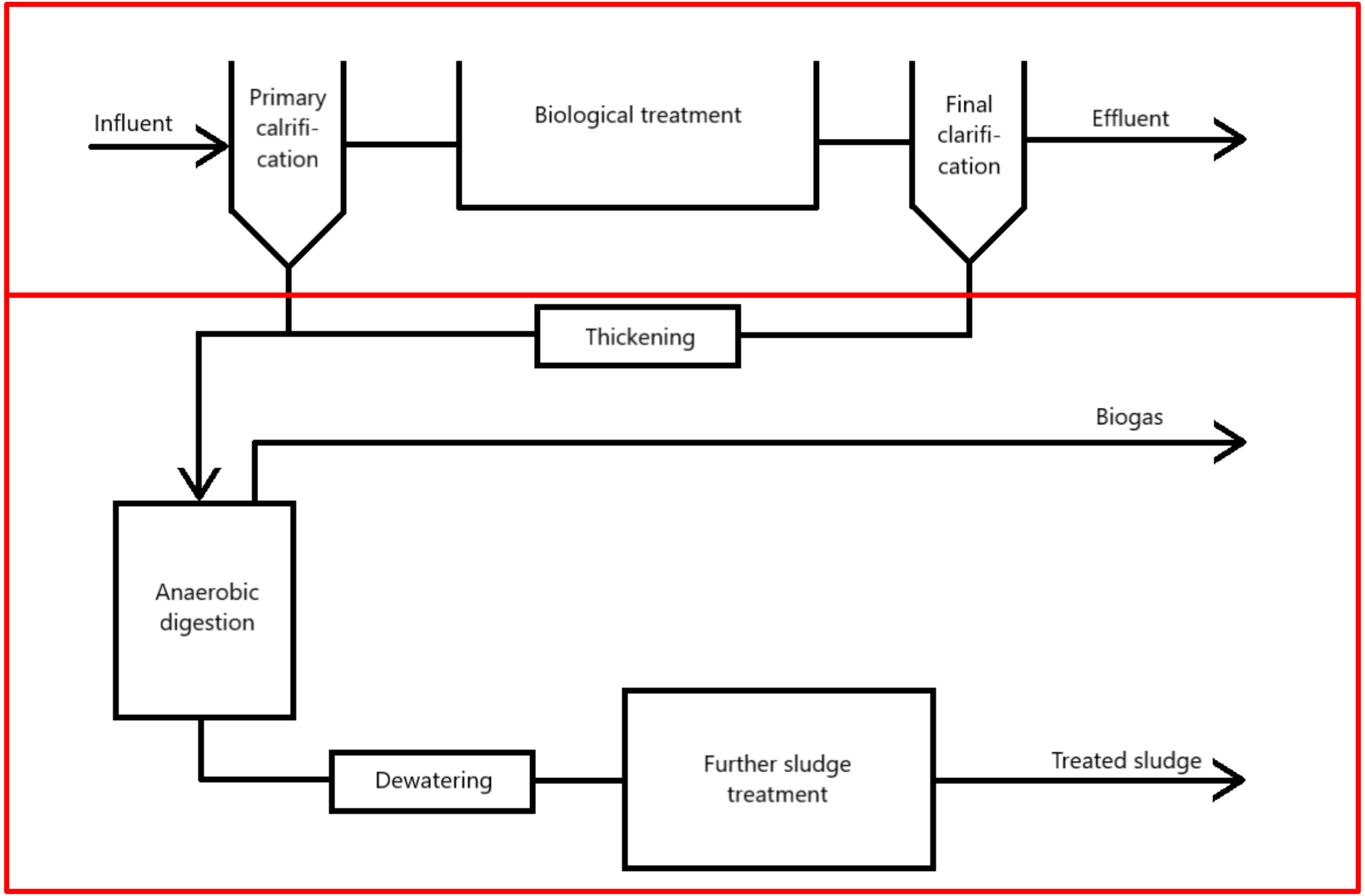
PLATFORM BSR WATER

Interreg Baltic Sea Region

EUROPEAN UNION

EUROPEAN REGIONAL DEVELOPMENT FUND

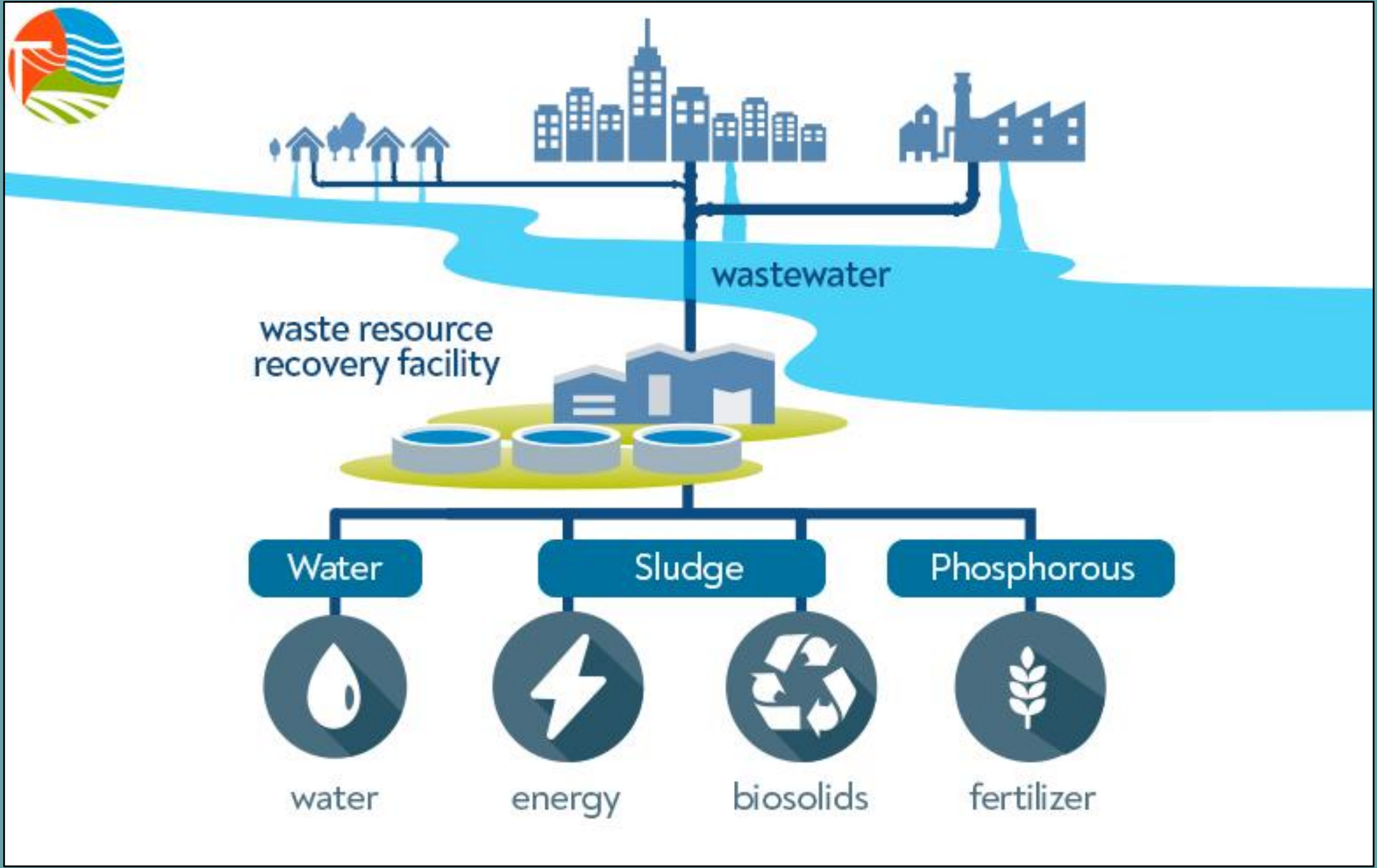
What is a wastewater treatment plant?


Influent
Primary calrifi-cation
Biological treatment
Final clarifi-cation
Effluent
Thickening
Biogas
Anaerobic digestion
Dewatering
Further sludge treatment
Treated sludge

Major shift in paradigm

WWTPs around the world are currently going through a major change, driven by climate change, circular economy and advancements in technology:

- From energy consumers to energy or biofuel providers to municipality
- Producers of valuable substrates, such as fertilisers
- Treated wastewater is seen as a resource and considered for reuse
- WWTP is a place where public health can be monitored by continuous analysis of specific biomarkers



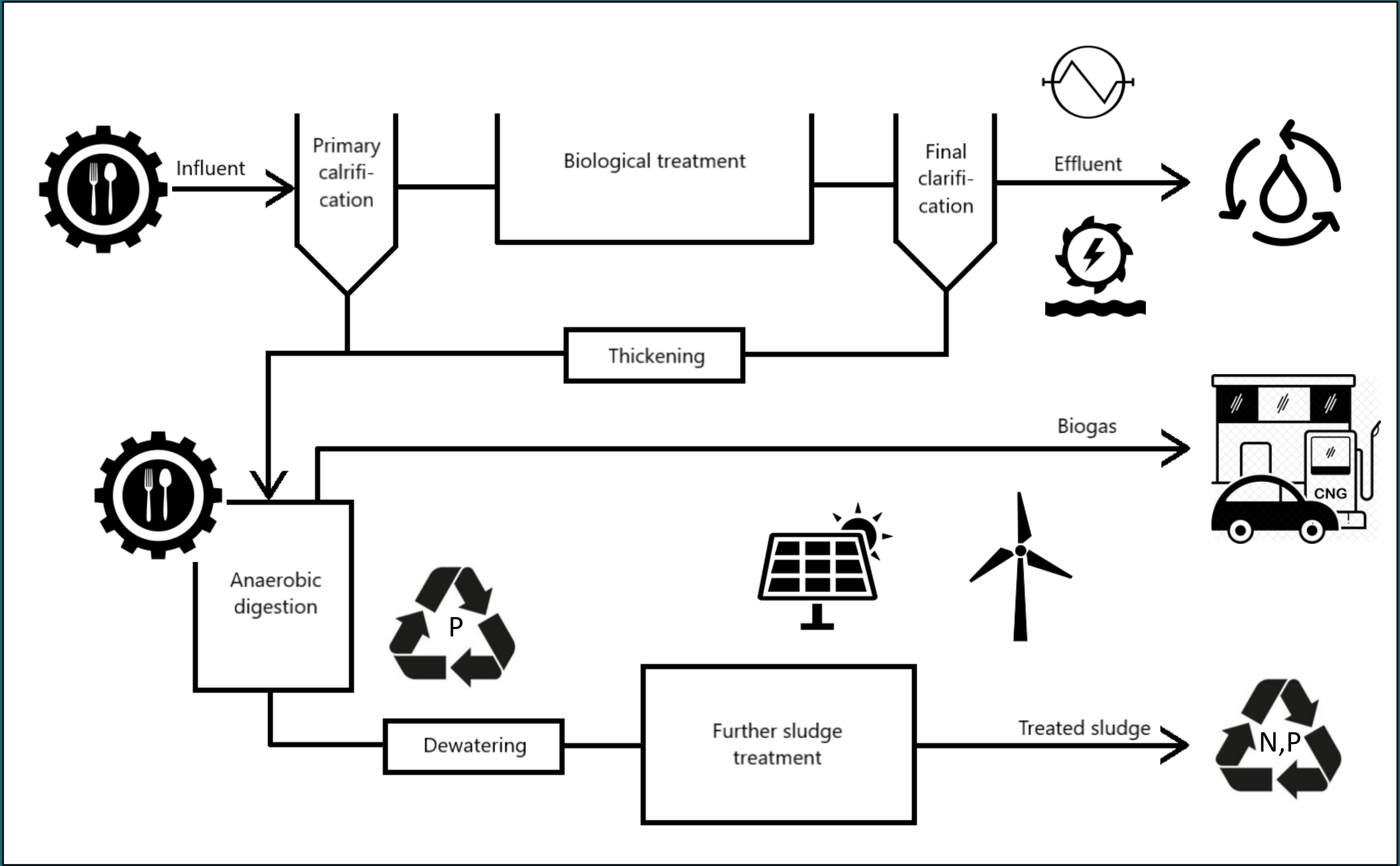
Source: The World Bank, "Wastewater? From Waste to Resource", www.worldbank.org/wastetoresource

The levels of change

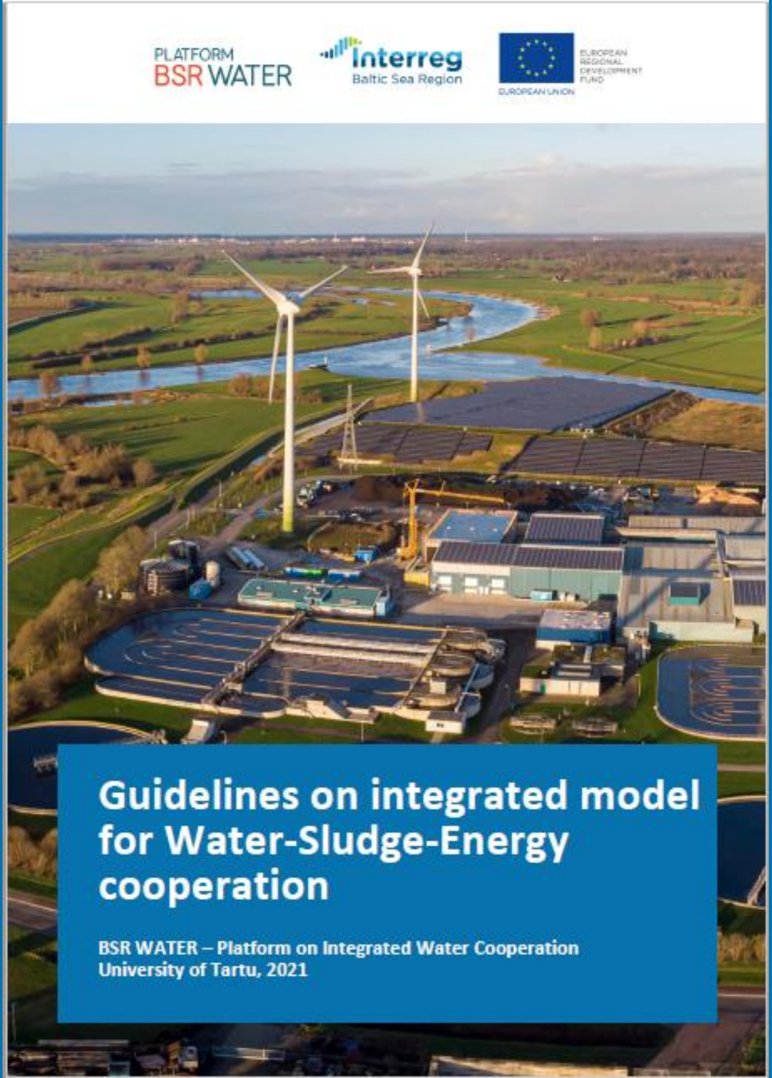
1) Energy neutrality/positivity – good maintenance and operation of the technology, efficient biogas production, renewable energy production

2) Climate neutrality – reducing the GHG emissions from processes, production of renewable energy and biofuels with climate positive balance

3) Resource recovery – investments into effluent and nutrient recovery and reuse, circular economy-based approaches, production of secondary raw materials



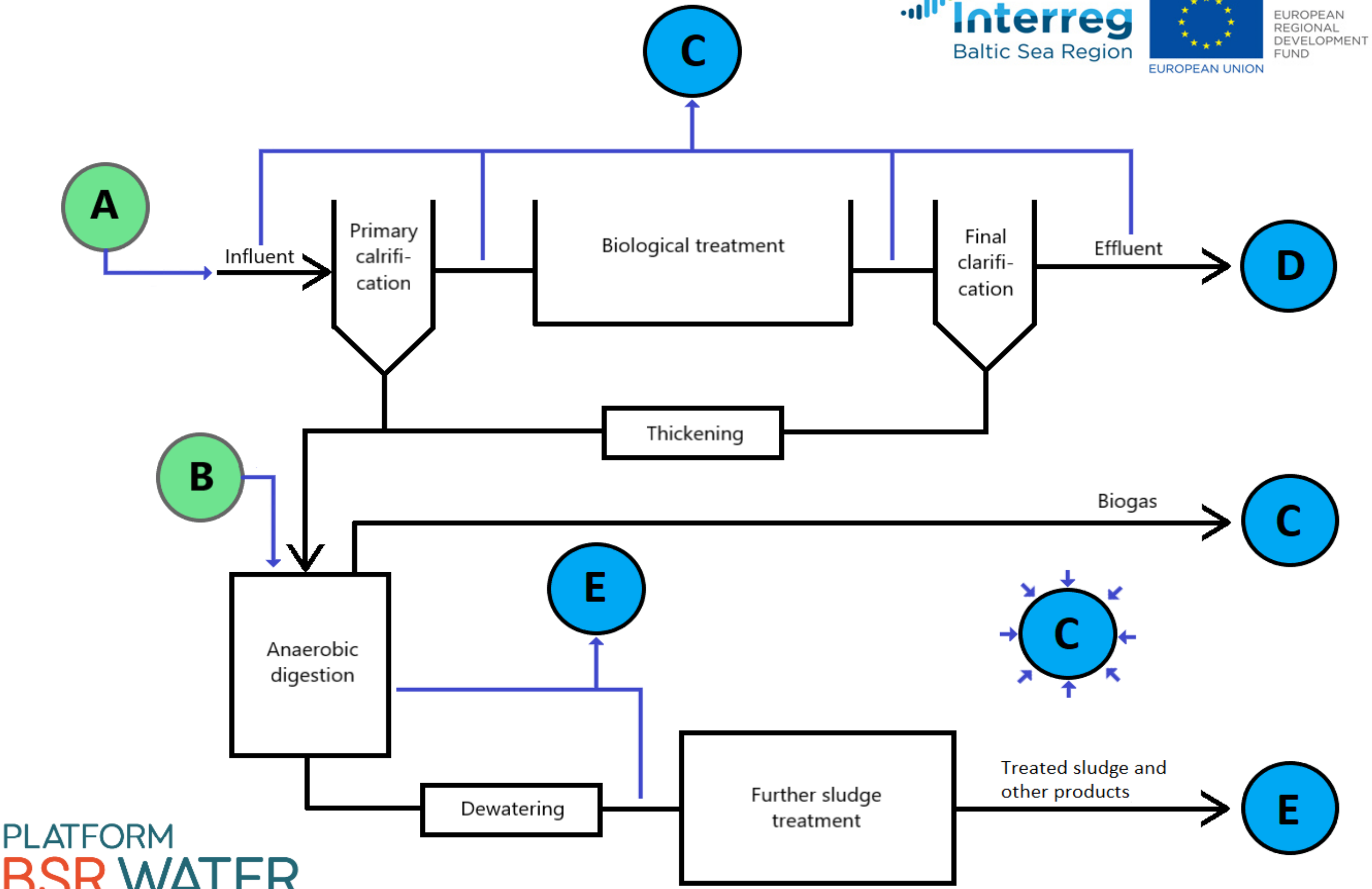
Source of the graphics: Google



GoA 4.3

Guidelines on integrated model for Water-Sludge-Energy cooperation

- Published on the 13th of September
- One of the deliverables of the BSR WATER project (GoA 4.3)
- The document outlines various options to move towards becoming a WRRF, chances for cross-sectoral cooperation and potential investments to consider.



Points of Cooperation:

A – influent

B – biodegradable material to digester

C – energy and fuel produced

D – effluent for reuse

E – treated sludge, fertilisers or other materials

3.1.3. Recommendation A.3 – Accepting wastewater with high easily degradable organic content from industrial sources (food industry)

Recommended for:

- WWTP with anaerobic digestion or anaerobic treatment of wastewater;
- Smaller WWTPs struggling with biological nitrogen treatment due to low organic carbon content in the influent.

Description:

For a WWTP with biogas production, higher incoming easily degradable carbon can directly result in higher biogas production, in turn making energy neutral or even energy positive wastewater treatment plant operation a possibility. Food residues might however increase the maintenance needs of some of the equipment and therefore indirectly increase maintenance costs.

Accepting easily biodegradable carbon sources could also be feasible for smaller WWTPs with low BOD concentrations in their influent and additional methanol dosing for denitrification. In this case, small industries with lower flow rates are especially good, as too high incoming BOD can result in high secondary sludge production and create problems in sludge treatment.

Important parameters and potential effects:

- BOD and the BOD/COD ration describing biodegradability
    - Higher biogas production – with higher incoming BOD, both more primary and secondary sludge can be produced, increasing sludge mass transported to digestion and therefore biogas production as well.
    - For WWTP with too low organic carbon in the influent, accepting industrial high BOD influent can reduce or eliminate the need for external organic carbon addition via methanol dosing. This can also increase the efficiency of biological phosphorus and nitrogen removal and result in a cleaner effluent.
- Volume and redundancy of digesters
    - Accepting more organics means higher sludge production, therefore digesters need to have spare volume that can be used. In longer terms, building additional digesters could be feasible, while the stable industrial inflow and long-term agreements might be needed in case of new investments.
- Concentration of nutrients (nitrogen, phosphorus)
    - High additional N concentration can increase the aeration energy and potentially methanol dosing (depends on how much organics is taken out with primary sludge), resulting in higher expenses.
    - High additional P concentration can increase the need for chemical phosphorus precipitation, increasing expenses to precipitation chemicals such as FeSO4 and Al2(SO4)3.
- Hazardous components, such as heavy metals, different organic pollutants, pharmaceutical residues, microplastics etc
    - can deem the treated sludge unusable, create environmental harm, bring the need for tertiary treatment in order to get the effluent clean,

    - can cause inhibitions to biological treatment or digestion, lower the efficiency and increasing financial costs. In very bad cases, severe inhibition can destroy biological treatment and result in very high effluent nutrient concentrations, bringing forth high environmental fees and potential fines.

Financial feasibility:

Financial feasibility will mainly come from increased biogas and energy production and from lower electricity bills. Additional influent will of course increase the costs of treatment and influent from the food industry can also significantly increase maintenance costs of equipment. In most cases, the practice is very cost-beneficent and should result in fast financial feasibility, with no high return times on investment. Some additional information should be considered:

- Financial feasibility of higher biogas production depends greatly on the biogas utilisation. Using CHPs with high electricity production ratios can increase the feasibility greatly, as smaller amounts of electricity need to be bought from the network or could even be sold back if the circuit is developed to accept electricity from distributed generation.
- While upgrading biogas to biomethane still in most calculations loses money compared to electricity production; gas-powered public transportation can be supplied with the biomethane. This is often a political decision (EU green transportation goals), while with good financial compensation measures in place, can also bring positive financial effect to the WWTP.

Example: Grevesmühlen WWTP in Germany

4.1.6. Recommendation C.6 – Producing hydropower from wastewater

Recommended for:

- WWTP with different elevations from the catchment area or receiving water body;
- WWTP trying to achieve energy/climate neutral or positive operation.

Description:

Although hydropower generation in WWTPs is not very common at the moment, research around Europe has shown that there is potential in the technology. This rise is interest is mainly due to new micro-turbines, which can be used in various location, both in the WWTP or in the sewage network. As hydropower generation from natural sources has seen many setbacks lately do to their negative effects to the aquatic ecosystems, power generation from the sewage networks has no such concerns. There might even be benefits to wastewater treatment such as increased dissolved oxygen concentrations with a smart use of the technology [16]. As more hydropower is produced at higher load times, the technology also matches peak demands very well [17].

The actual feasibility and profitability of the technology still greatly depends on the natural elevation of the region. Both upstream (before the WWTP, in the sewer network) and downstream (between WWTP and the receiving water body) small-scale hydropower generation is possible if the elevation difference between two points is enough. Although this elevation difference (also called "head") should be as high as possible, small-scale systems with heads as low as 4 meters can already be feasible [17]. Country-wide assessments and profitability calculation methods relying on satellite data have been developed for Spain [18] and Switzerland [17], which could also be adapted to the northern regions.

The installed power of the turbines in WWTPs is usually around a few hundred and few thousand kW, while small systems with as low as 13 kW have been built [17]. As the turbine size and number is very well scalable, this recommendation should not be too much size-dependant and could be profitable for both very small and very large WWTPs. They might be especially useful for small rural areas with a centralised WWTP in more mountainous regions (Sweden).

Financial feasibility:

Similar to solar and wind power, the hydropower investment cost has decreased within the last few decades, greatly decreasing the baseline of profitability. Still the main factors when calculating financial feasibility are the elevation difference and the total load (installed power). With lower loads and elevations, the installation cost of a small-scale hydropower station might be between 1500-6000 €/kW, while with higher loads and elevations the cost might be significantly smaller, being in the range of 200-800 €/kW [19]. As with all energy production feasibilities, the payback rate of the investment also depends on the local energy market and overall prices.

Although a payback period for hydropower installation in the WWTP is very difficult to calculate and varies the most compared to wind and solar, payback times such as 6 – 10 years should be considered for high-potential cases [20].

4.3.3. Recommendation E.3 – Extraction of phosphorus from sludge incineration ashes

Recommended for:

- Large WWTPs with the sludge incineration technology.

Description:

Phosphorus recovery from sewage sludge ash (SSA) is a very promising new approach, with potentially highest P-recovery efficiencies compared to other nutrient recycling approaches [27]. These various technologies however, such as wet chemical, thermo-chemical or electro-chemical extraction, are all only applicable in very large WWTPs. There is also a possibility for a centralised nutrient recovery facility, which could be fed with the ash from multiple large WWTPs – compared to sludge, ash is much more compact and can be transported with lower costs [28]. Sewage sludge ash has high overall phosphorus concentrations, usually between 5 to 11%, while in some cases up to 20% [27]. With rising concerns for micropollutants, nutrient recovery from SSA can reduce those risks as almost all organic pollutants are completely degraded during incineration. Although SSA have potential to be used directly, further extraction processes are usually recommended due to high heavy metal concentrations and low bioavailability of phosphorus in the ash.

Compared to struvite precipitation and other nutrient recovery methods from sludge and wastewater, the phosphorus recovery technologies from SSA are not as mature yet as full-scale applications require huge investments and carry significant risks [28]. Still, there is a number of promising applications currently being developed such as TetraPhos®, Ash2Phos®, EcoPhos® and PHOS4Green for wet-chemical extraction; AshDec® for thermo-chemical extraction; RecoPhos® for thermo-electrical extraction [29]. More specific information about nutrient recovery from sewage sludge ashes can also be found in another publication produced by the BSR WATER project, called the Palette of Solutions for Nutrient Recycling in the Baltic Sea Region [30].

Financial feasibility:

Although the phosphorus recovery from ashes can possibly take place in-situ at the WWTP, centralised phosphorus extraction facilities are slowly being developed, to which WWTP incineration ashes can be given away or sold to. This lowers the amount of material needed to be landfilled and decreases overall costs – potentially even gaining new revenue from the sale of the ashes (could be problematic based on local legislations). At the moment the recycled phosphorus products are in market competition with rock-based phosphate products and in most cases financial feasibility can't be reached due to low primary phosphorus prices. This also resulted in the first larger company using SSA to recover phosphorus declaring bankruptcy in 2012 [31]. In order to support P-recycling, changes in legislation, public opinion and/or market behaviour are needed to alleviate the risks currently tied to full-scale P-recycling investments.

Barriers and obstacles

Though the move towards a sustainable Europe is viewed as a priority today, circular economy, energy and resource recovery are mostly still just slogans

- EU/local level legislations cannot change overnight
  - Lack of information of business models, difficult to support
  - Water tariff laws in place to protect the customers – change needs careful consideration
- Investment costs into renewable energy are significant
- Secondary raw material production is risky – primary raw materials are often cheaper
  - No current support on the market, financial feasibility is questionable and unstable
- Public perception still a problem

Thank you!

CONTACT

Markus Raudkivi
Project coordinator
University of Tartu
markus.raudkivi@ut.ee

www.bsrwater.eu

PLATFORM BSR WATER

Interreg Baltic Sea Region

EUROPEAN UNION

EUROPEAN REGIONAL DEVELOPMENT FUND