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ENERGY FORUM, AALTO UNIVERSITY

Enhanced Biogas Production in Municipal Wastewater Treatment

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Overview

Basics of wastewater treatment

Mass flows in the water cycle

Your own impact on the environment and the water cycle

Wastewater treatment plant (WWTP) as a large biotech facility

Zoom-in to some biochemical reactions and biotechnological processes

Energy self-sufficiency of WWTPs

Renewable methane as energy source

Ideas are needed

Nutrient release per capita – PE Person Equivalent

Average waste load – Dimensioning of the wastewater treatment plants

- Feed flow per day 400 l/(PE×d)

Your personal impact per year

- Solids 75 kg/(PE×a)
- Carbon 55 kg/(PE×a)
- Nitrogen 6 kg/(PE×a)
- Phosphorus 0.75 kg/(PE×a)

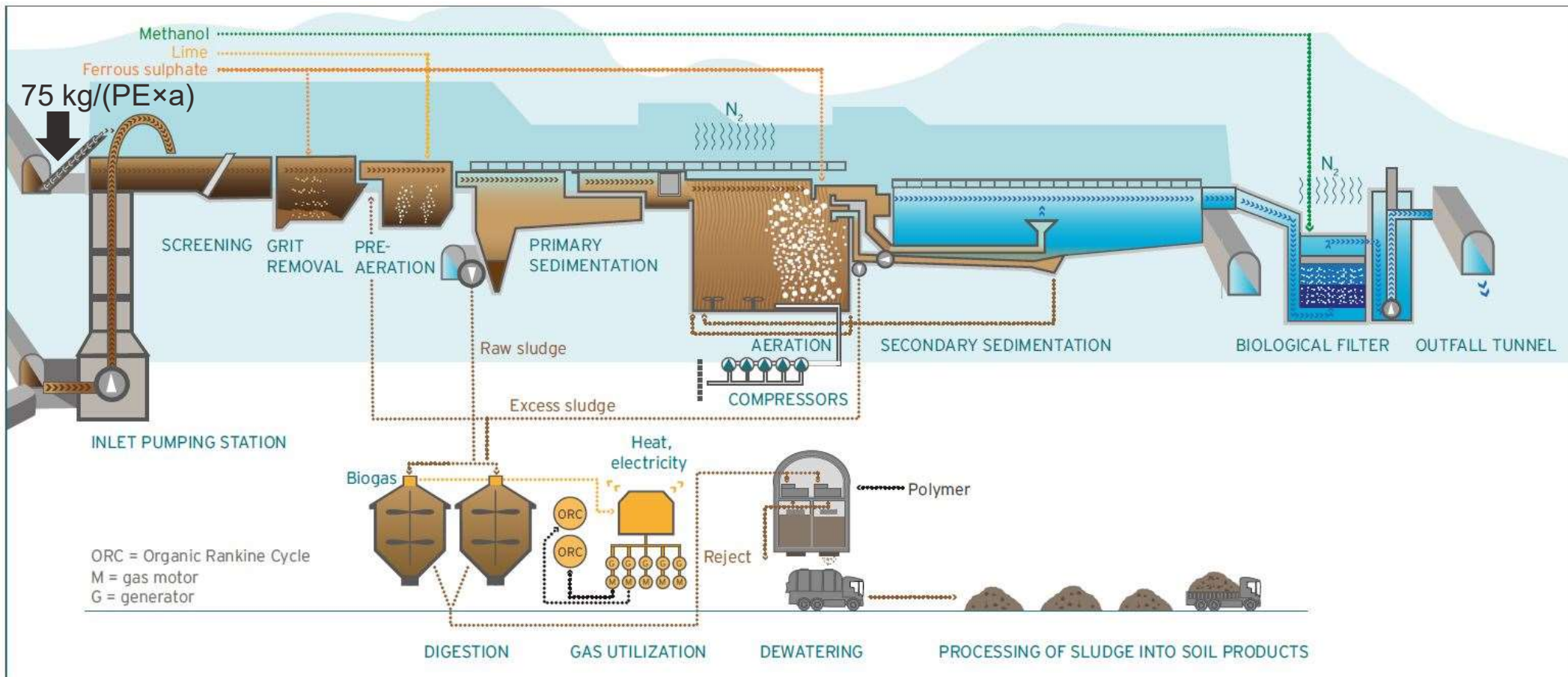
Environmental impact

Biochemical impact of the nutrients on the environment

- 1 g N → 14 g biomass
- 1 g P → 100 g biomass
- Phosphorus has by far the largest impact if released to the environment
- 1 g phosphorus can build up approx. 100 g biomass

ENHANCED BIOGAS PRODUCTION IN MUNICIPAL WASTEWATER TREATMENT

Helsinki, Viikinmäki, 800 000 PE (Person Equivalents)



Biological treatment step – Zoom-in on “Biology”

Two steps are necessary for nitrogen degradation

Nitrification (aerobic = oxygen consuming step)



Denitrification (anaerobic = lack of oxygen)

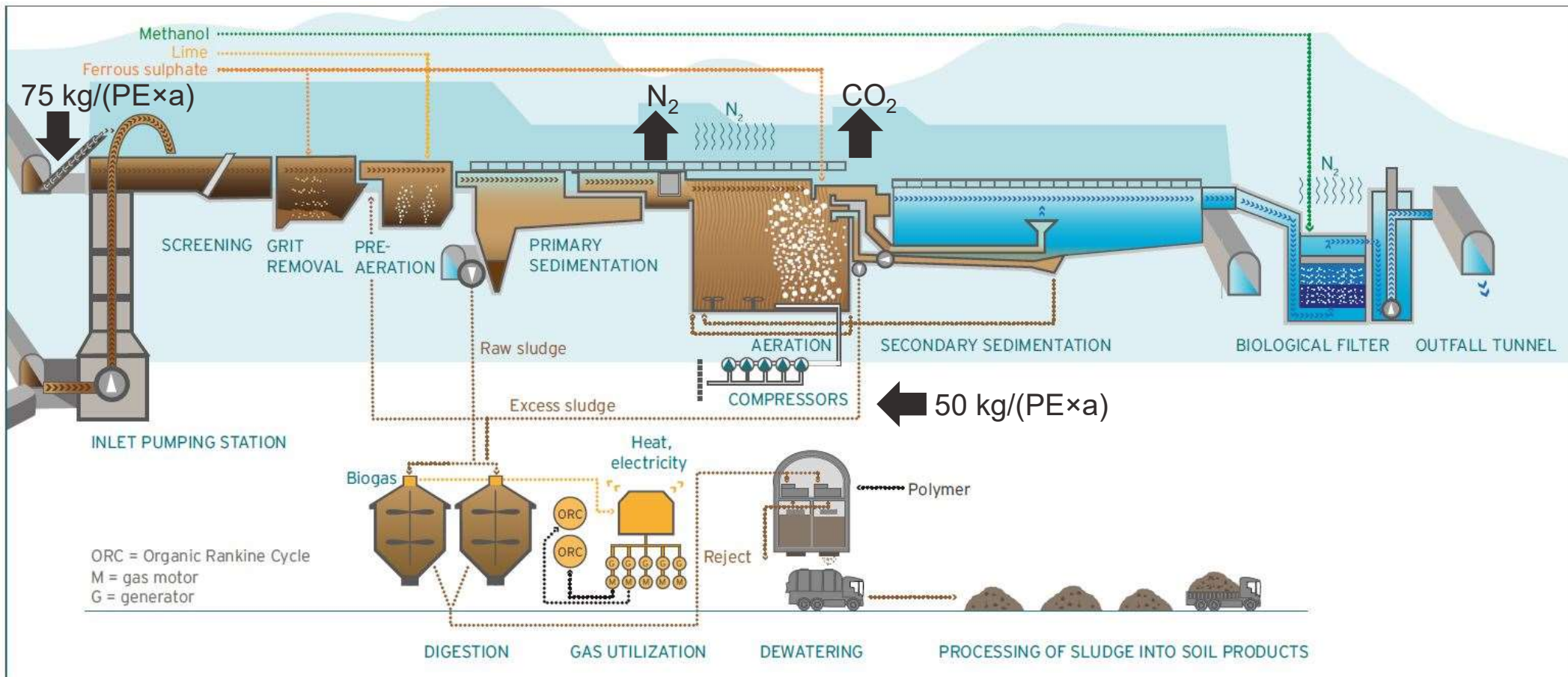


Nitrogen is released to the air. The result is microbial sludge with bound C and P



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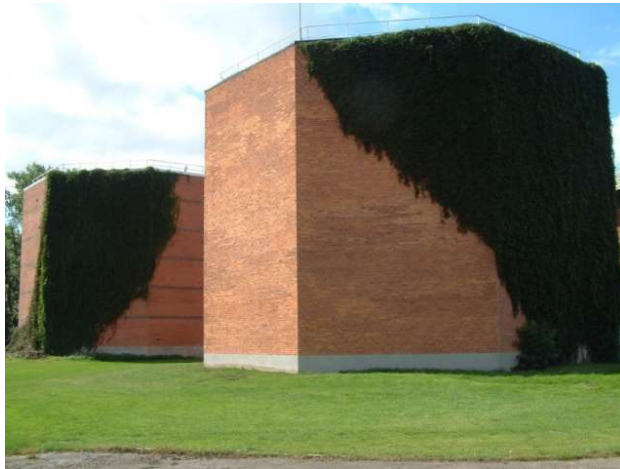
Anaerobic digesters are biotech reactors

Large reactors 1000 to 4000 m³

Residence time 15 to 25 days

Temperature 35 to 38 °C (mesophilic)

Gentle mixing



Anaerobic Digestion – Biotech in wastewater treatment

Main task: **Reduction** of the organic part → Disposal costs up to 300 EUR/t Dry Solids (DS)

Energy self-sufficiency of the wastewater treatment plant

Sludge feed to digestion: 52 kg/(PE×a) as solids

- 70-80 % organic matter in solids

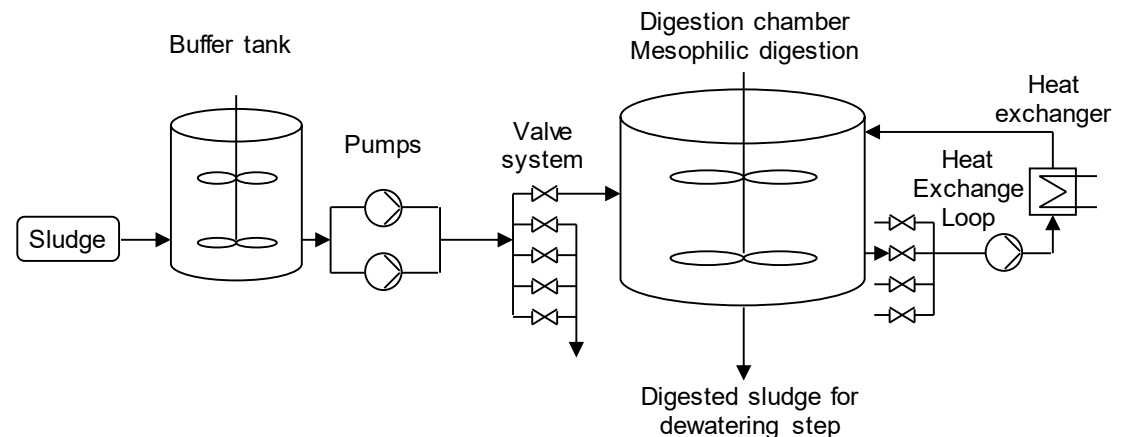


Sludge effluent: 25 kg/(PE×a) as solids

- 50-60 % organic matter in solids

Still, most of the organic matter is left

- It can be a raw material. Create new ideas for further use.



ENHANCED BIOGAS PRODUCTION IN MUNICIPAL WASTEWATER TREATMENT

Sludge is the end product of the wastewater treatment

Disposal costs per metric ton DS

- Sludge dry matter for disposal 25 kg/(PE×a)
- 200-300 EUR Incineration
- 150-200 EUR Composting, Disposal
- 100-150 EUR Agriculture



Methane formation process

A microbial consortium

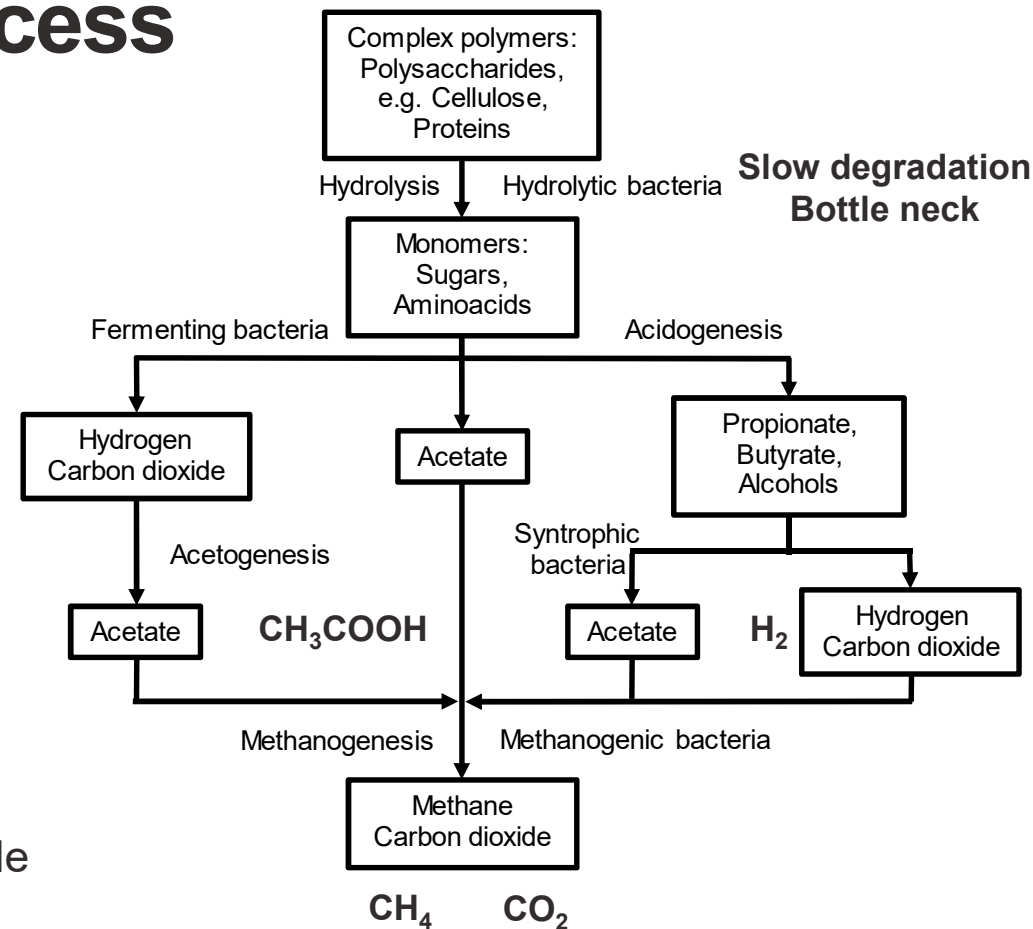
- A large number of different microbes
- Microbes are specialized on substrates

Biochemical mechanism

- Complex organic compounds are degraded
- Shorter units
- Monomers

Target

- Make the carbon-based nutrients bioavailable
- Produce energy for microbial metabolism



Biogas and Biomethane



Biogas

- Mix of 60 % methane, 40 % carbon dioxide and traces of hydrogen sulphide
- Can be used in Combined Heat and Power generation (CHP)



Biomethane

- Contains >95 % methane
- Upgrade: Stripping (= washing out) carbon dioxide and hydrogen sulphide by water
- Can be used in cars, buses, trains, gas grid



ENHANCED BIOGAS PRODUCTION IN MUNICIPAL WASTEWATER TREATMENT

Mass flows

Helsinki, Viikinmäki

Size: 800 000 PE (Person Equivalent)

Feed flow: 102 million m³/a

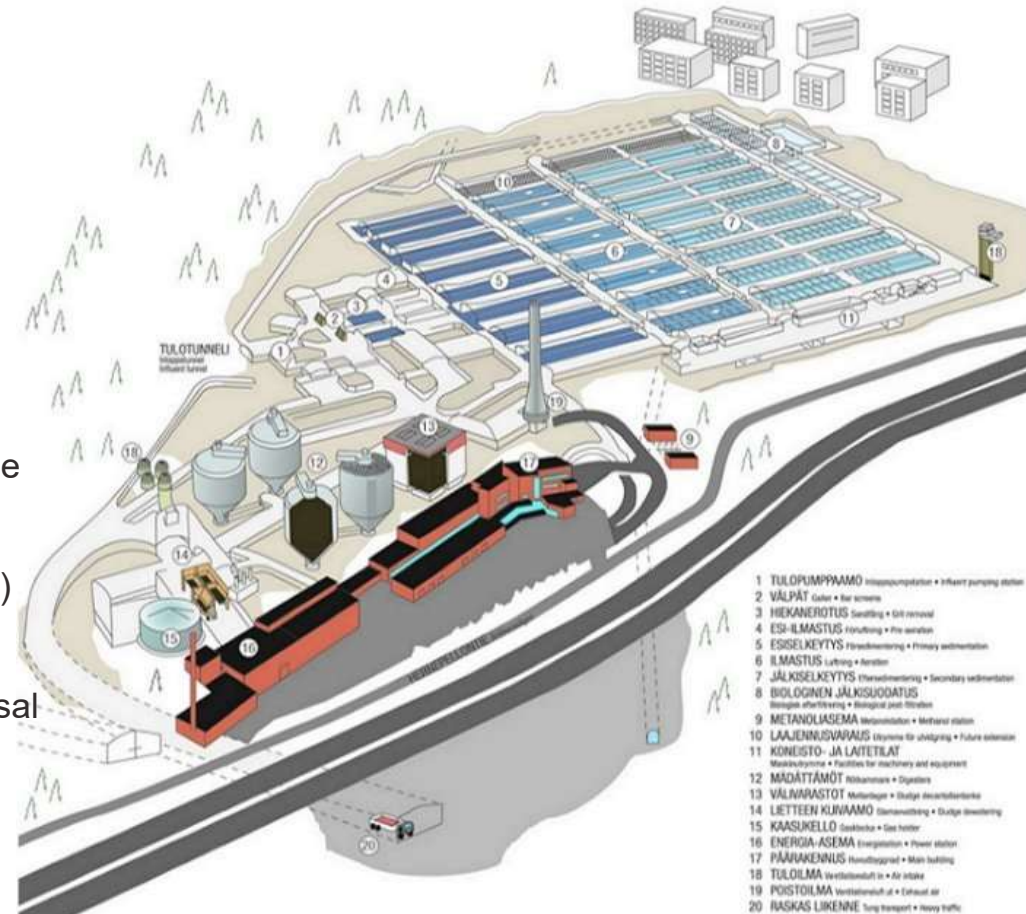
Biogas: 13.4 million m³/a
 → 17 m³/(PE×a) biogas
 → 10 m³/(PE×a) biomethane

Electric power production: 25 500 MWh/a (31 kWh/(PE×a))

Dry sludge: 19 000 t/a → 24 kg/(PE×a) → Costs for disposal

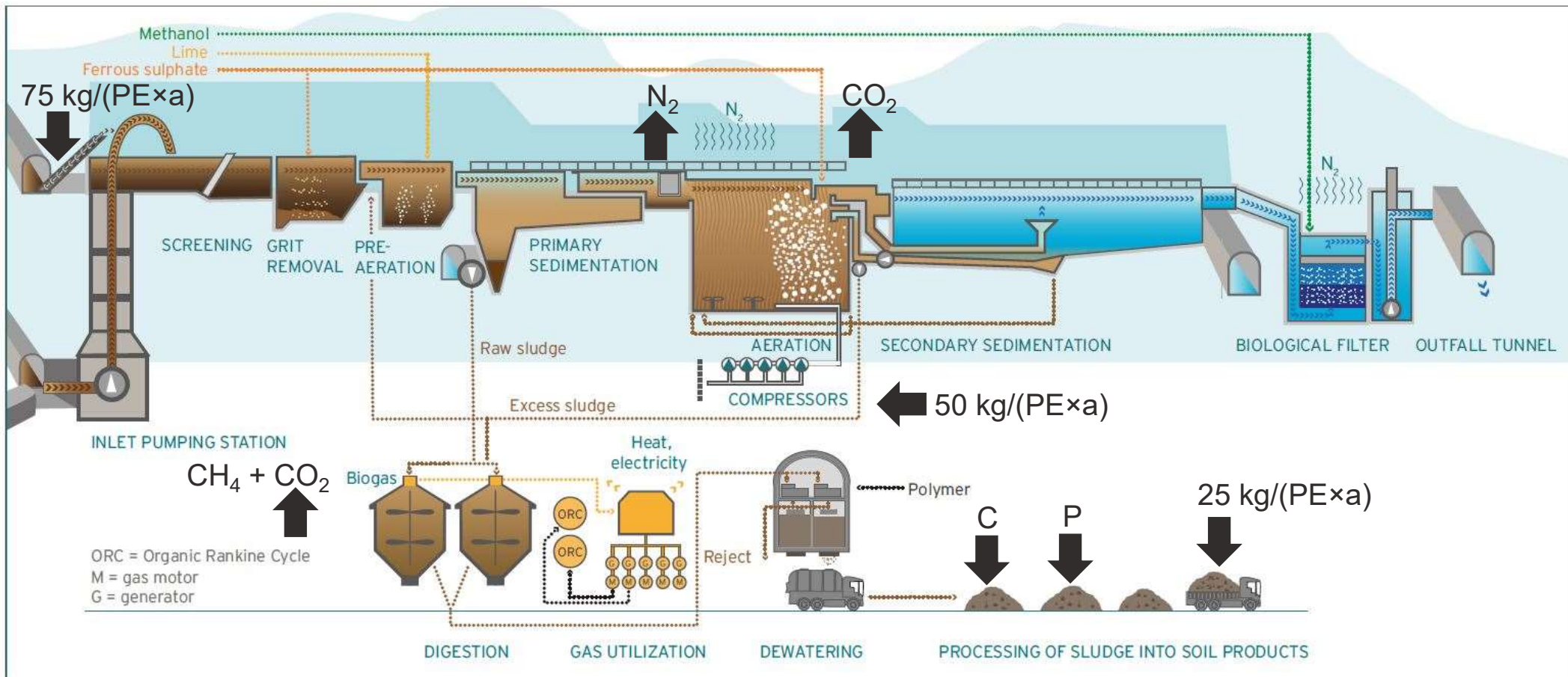
Wet sludge (28 % TS) for disposal: 65 000 t/a (180 t/d)

Viikinmäen jätevedenpuhdistamo
 Avlopprensingsverk • Wastewater treatment plant



ENHANCED BIOGAS PRODUCTION IN MUNICIPAL WASTEWATER TREATMENT

Helsinki, Viikinmäki, 800 000 PE (Person Equivalents)



ENHANCED BIOGAS PRODUCTION IN MUNICIPAL WASTEWATER TREATMENT

New ideas are needed

Use the remaining 25 kg/(PE×a) → Lower disposal costs

Make the **biogas yield** more effective → Increased income

- Many digesters are suboptimal

Biorefinery – Produce other material than methane

- Hydrogen has much higher energy content
- Hydrogen is much more versatile

Produce **bio-based building blocks**

- Monomers for bio-based and biodegradable plastics

Value from waste

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Sources and further reading

Kemira Handbook: About Water Treatment

- Free Download <https://www.kemira.com/insights/water-handbook-2020/>

YouTube: Polymers in Wastewater Treatment:

- <https://www.youtube.com/watch?v=TKAHZECfXok>

Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (DWA)

- Many publications: <http://de.dwa.de/>

DESTATIS: <https://www.destatis.de/DE/Startseite.html>

European statistical office, EUROSTAT: <https://ec.europa.eu/eurostat/web/main/home>

International Water Association, IWA: <http://www.iwa-network.org/>

Viikinmäen jätevedenpuhdistamo: <https://www.hsy.fi/>

European Sustainable Phosphorus Platform: <https://phosphorusplatform.eu/42-r-d-projects/514-p-rex>

The End – Maybe not ...

Thank you for your attention

Kiitos mielenkiinnostanne

Tack för ert intresse

Questions? – Kysymyksiä? – Frågor?