Sustainable wastewater treatment plants

Resource recovery oppotunities:

technologies and bottleneckes

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Wastewater treatment plants (**WWTPs**) **then and now**

Traditional perception (20th century)

Up to '30s

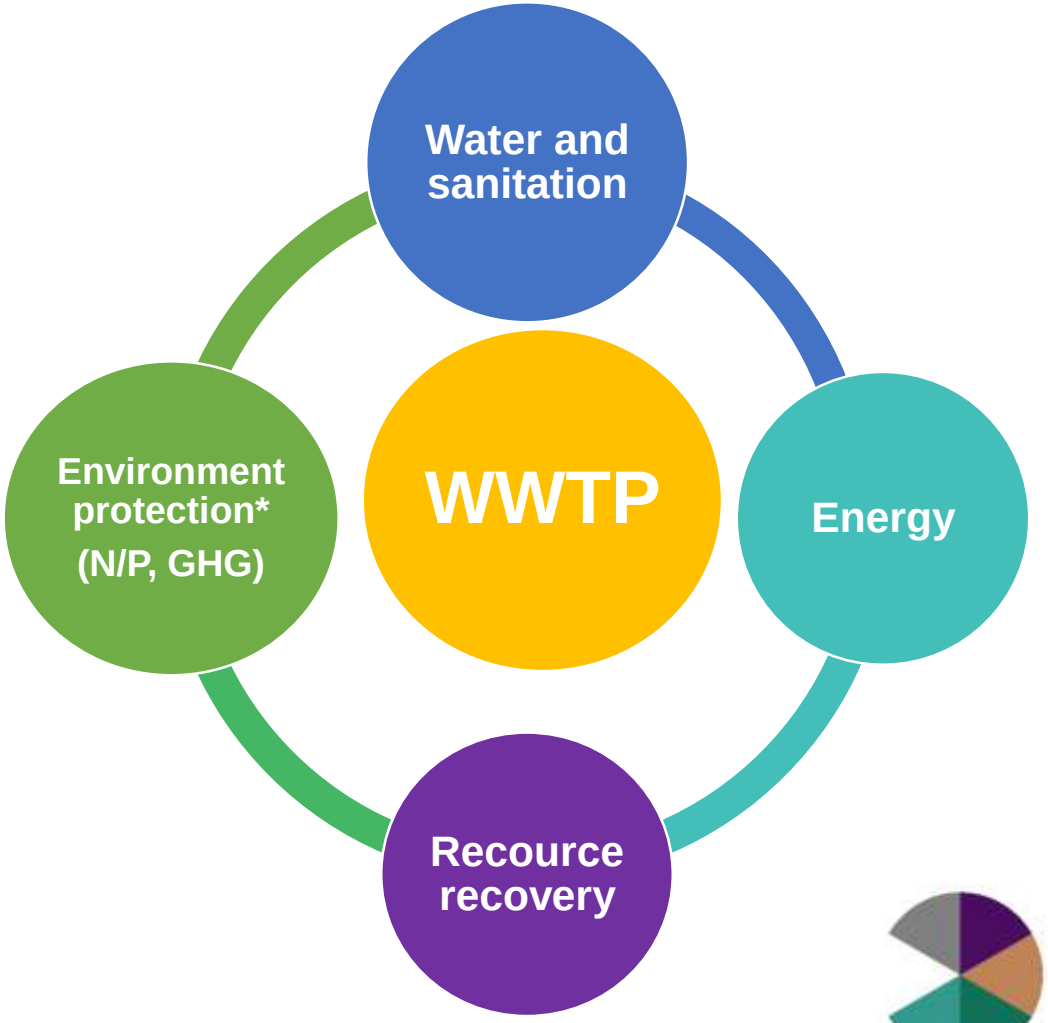
- **Sanitation and Water quality**
  Protection of inhabitants lived downstream of rivers from contagious diseases

'50-80s

- **Environmental protection**
  Concerns about eutrophication problems and the consistency of the surface water quality

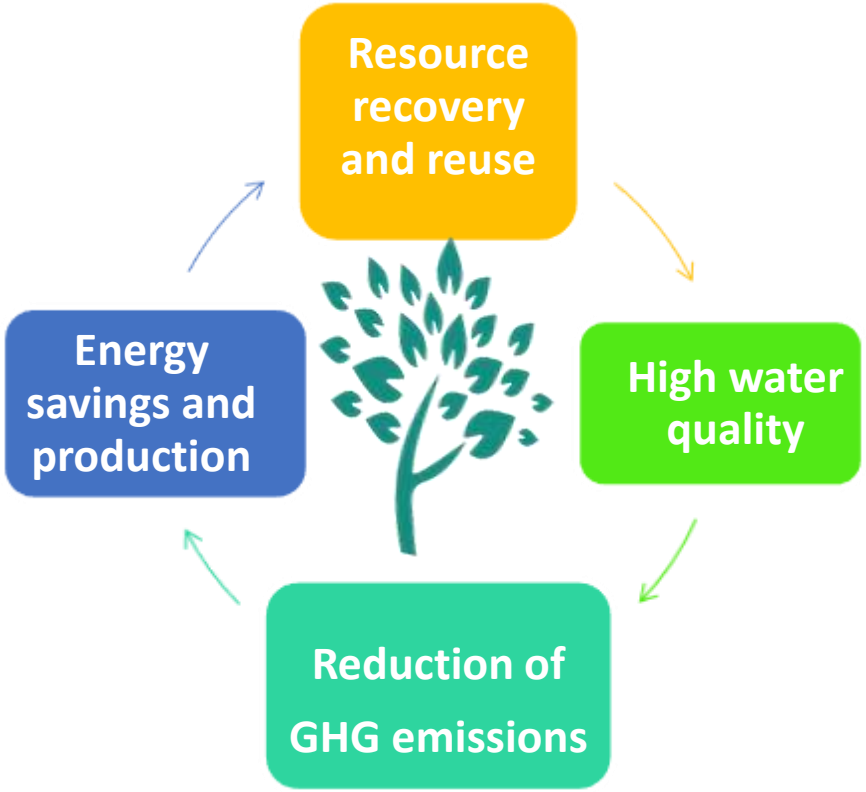
Read the article:
https://www.researchgate.net/publication/46148626_Wastewater_Management_through_the_Ages_A_History_of_Mankind

Modern perception



*Greenhouse gases, nitrogen/phosphorous

Could WWTPs turn to Water Resourse Facroties?



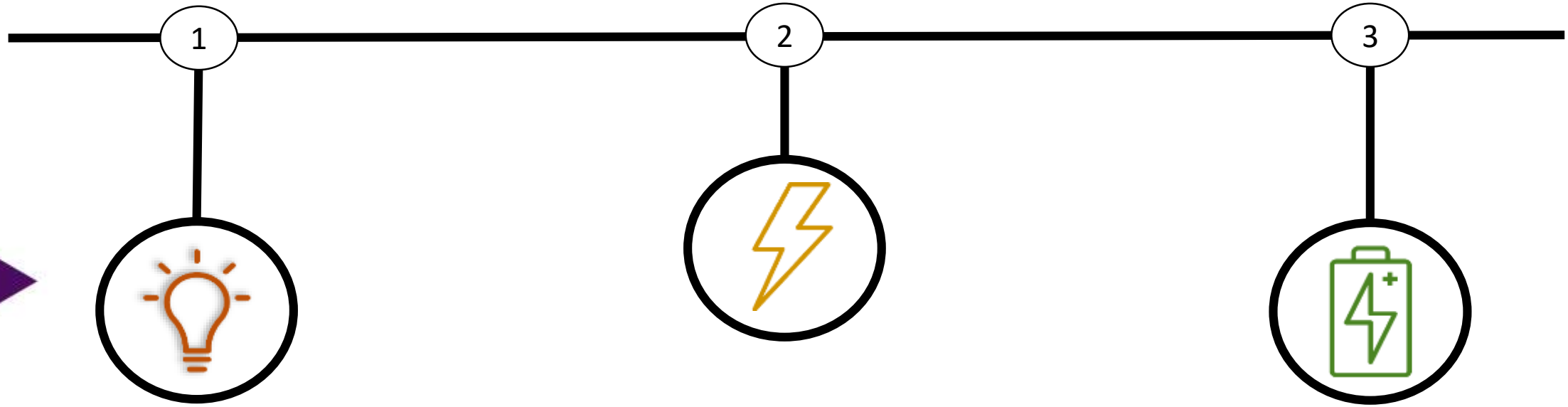
Potential resources from WWTPs

- Water recovery
- Energy recovery
- Nitrogen recovery
- Phosphorous recovery
- CO_2 recovery
- Cellulose recovery
- Volatile fatty acids (VFA)

Others:
Extracellular polymeric substances (EPS)
Polyhydroxyalkanoates
Single-cell protein (SCP)
Iron phosphate

Energy Consumption of Water Sector in EU

https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/water-energy-nexus-europe



Water sector is about 4%
of **total global** electricity consumption

25-40%
of WWTP operating costs is electricity

24.5 TWh/y
consumed by WWTPs in 2017
equal to electricity for
about 2 million households/year

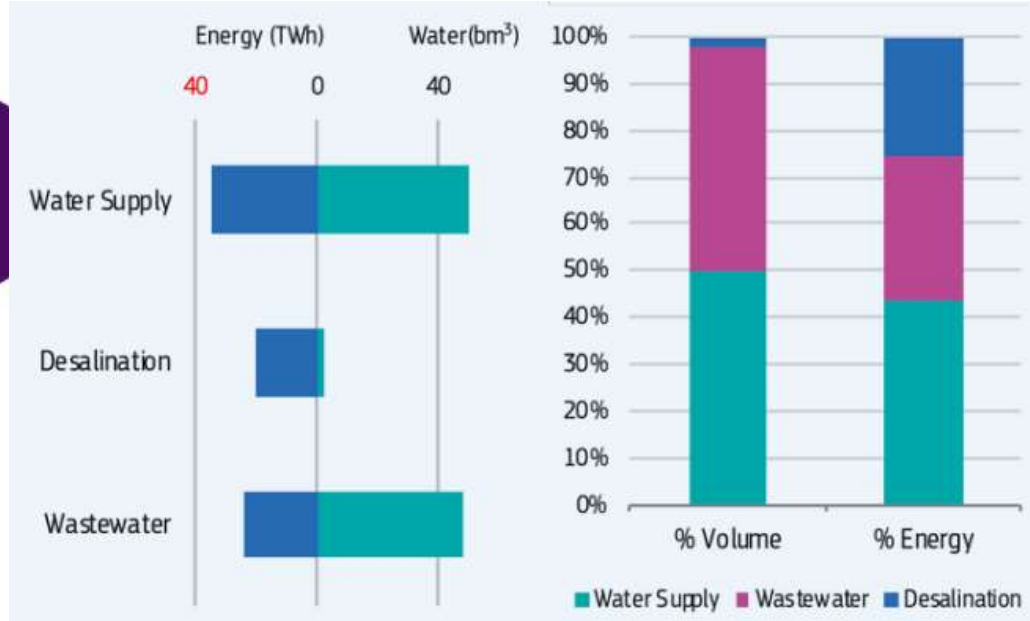
What can we do for savings?

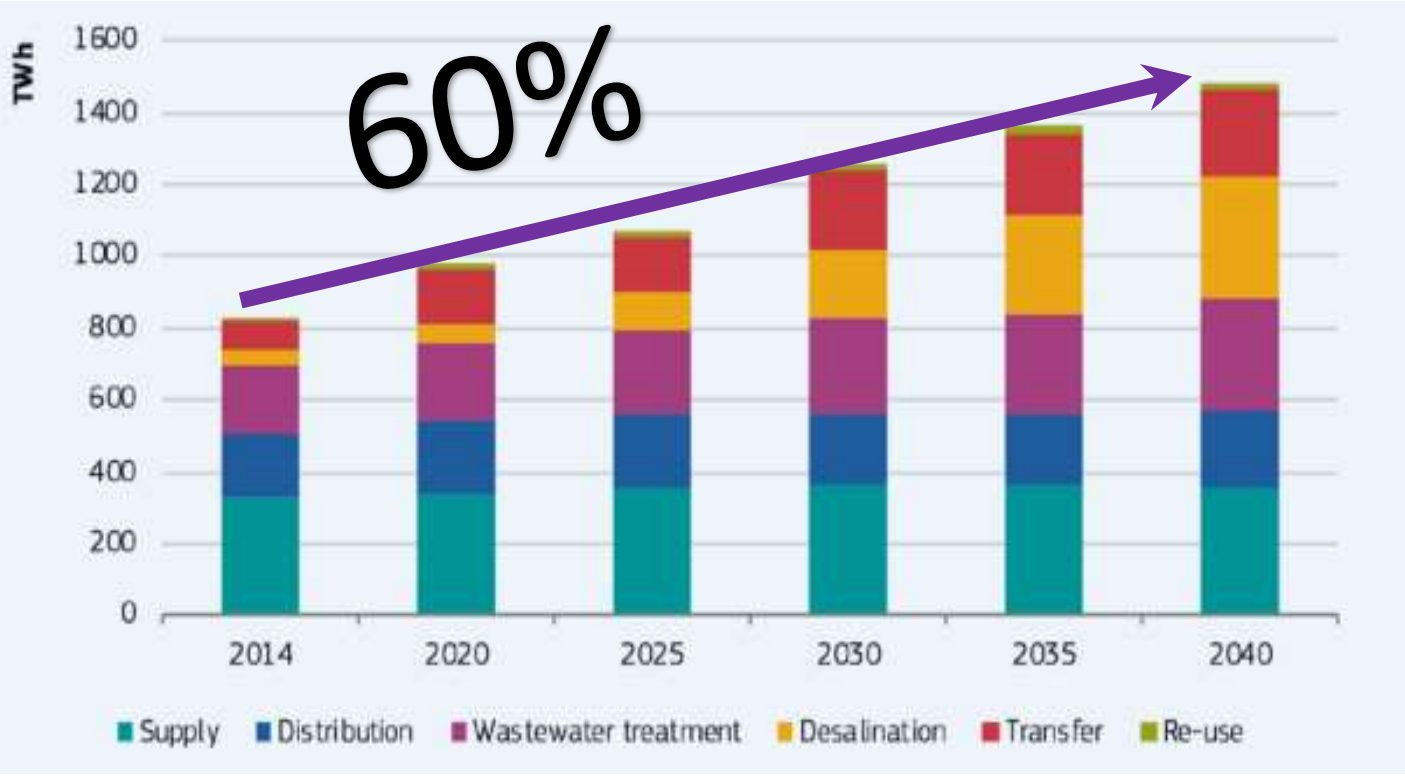
Water supply/distribution and wastewater treatment account for about 50 % each of the total energy demand of the urban water sector in Europe

(https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/water-energy-nexus-europe)

Energy needs for the different parts of the water sector in 2017

Reprinted from Magagna D., Hidalgo González I., Bidoglio G., Peteves S., Adamovic M., Bisselink B., De Felice M., De Roo A., Dorati C., Ganora D., Medarac H., Pistocchi A., Van De Bund W. and Vanham D. Water – Energy Nexus in Europe, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 03385-1, doi: 10.2760/968197, JRC115853 - **Fig.10**





By 2040, overall energy consumption of water sector is expected to increase by about 60%

Electricity consumption in the water sector by process.

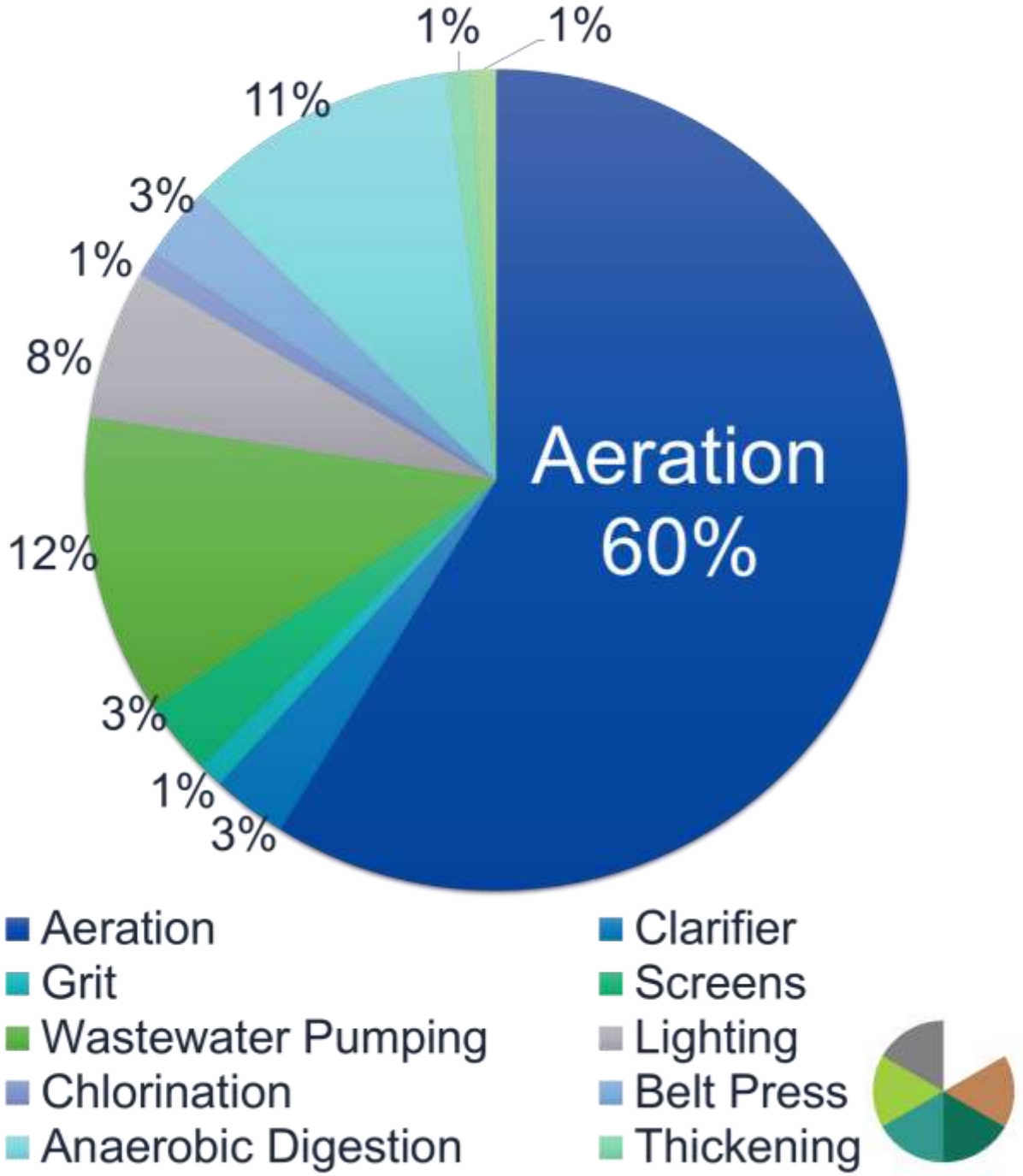
Reprinted from Magagna D., Hidalgo González I., Bidoglio G., Peteves S., Adamovic M., Bisselink B., De Felice M., De Roo A., Dorati C., Ganora D., Medarac H., Pistocchi A., Van De Bund W. and Vanham D. Water – Energy Nexus in Europe, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 03385-1, doi: 10.2760/968197, JRC115853 - **Fig.3**

The overall WWTP energy use

90 % of WWTPs in EU are small plants (< 50 000 PE).

They process only 31 % of the PE and absorb **42 %** of electricity use.

Mid- to very large-sized plants (>50 000 PE) process about 70 % of the PE with **58 %** of the total electricity use.



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PE - Population Equivalent means?

Ways for energy savings

Global energy demand is expected to grow by approximately 50% between 2010 and 2040, and fossil fuels will likely satisfy almost 80% of this

https://www.researchgate.net/publication/269463103_Production_and_use_of_biogas_in_Europe_A_survey_of_current_status_and_perspectives/figures?lo=1

The production of biogas by anaerobic sludge digestion

The most widely used energy recovery method applied worldwide

About 80% of the biodegradable COD fraction in the sludge can be converted into harvestable biogas in completely mixed reactors.

Methane
Other biofuels
Sludge incineration
Bioelectrochemical systems
Hydropower
Thermal energy

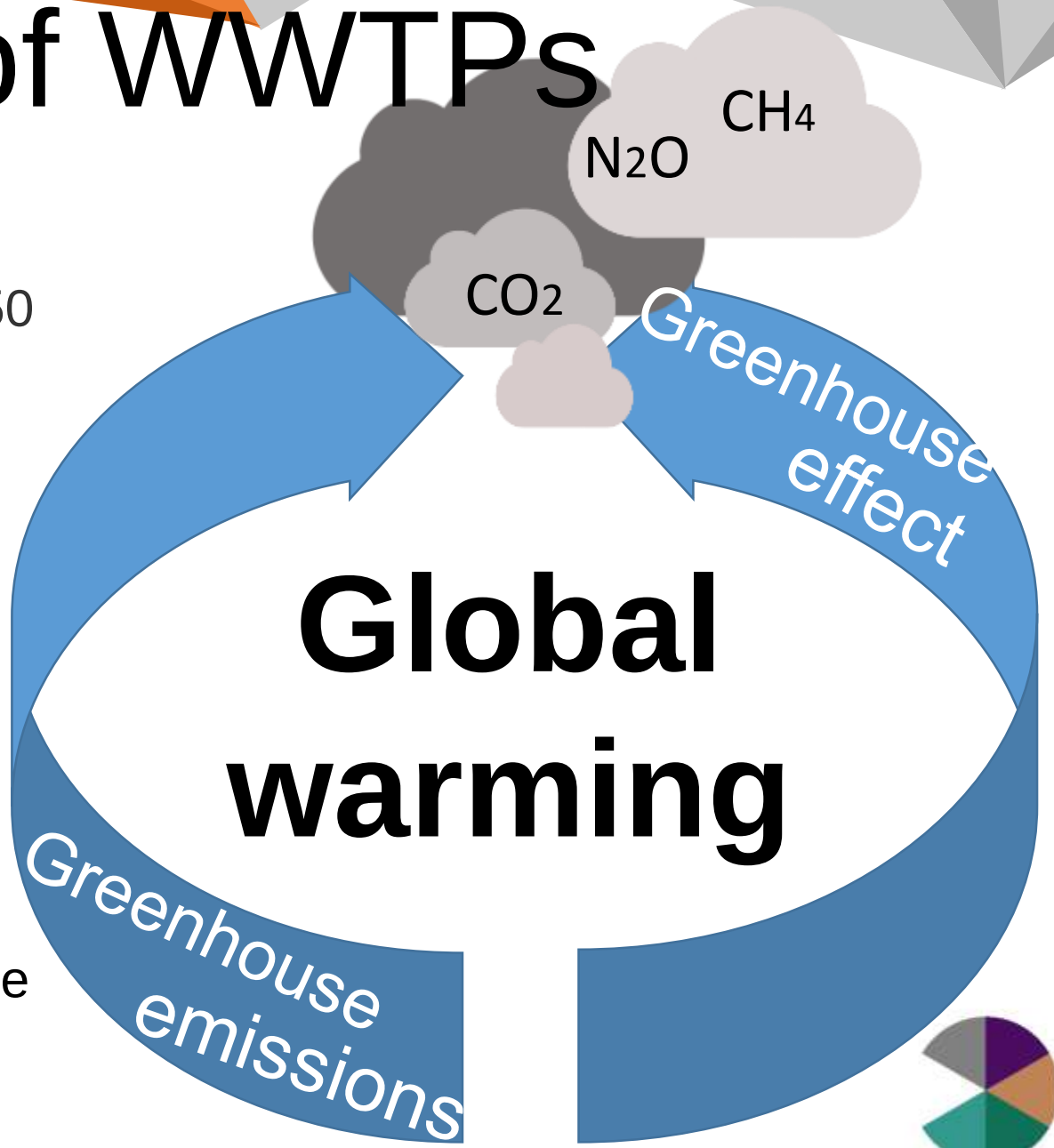
Carbon Footprint of WWTPs

Goal of Finland – 80% emissions reduction by 2050

Temperature increase above 1.5 degrees will affect extinction of species, risk of limit water and food supply

Can cause political instability, conflicts and migration worldwide

WWTPs produce GHG emissions and have a huge impact on global warming



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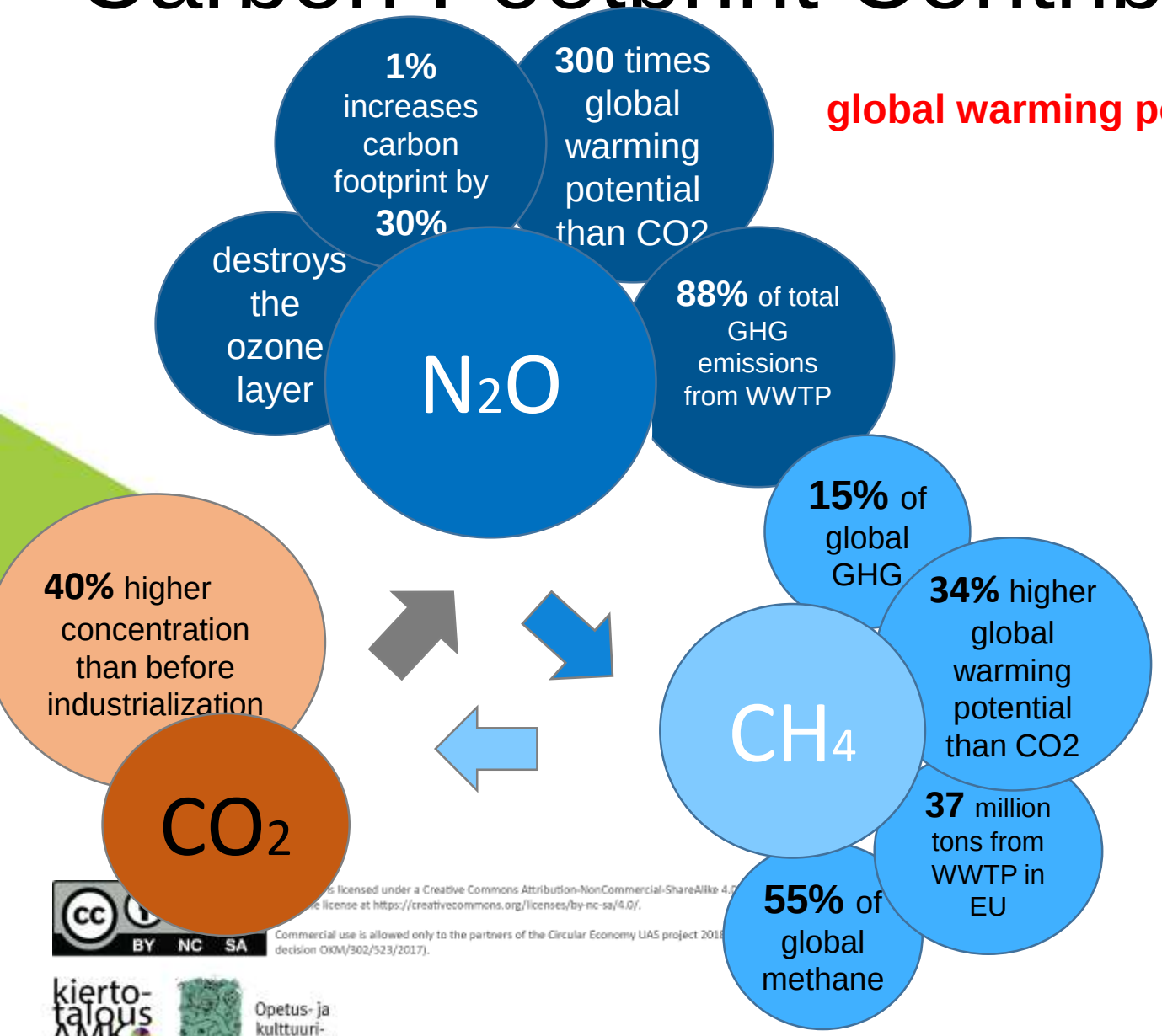
Carbon Footprint Contributors of WWTPs



global warming potential is...?

Greenhouse Emissions from Typical WWTPs

A decrease of GHG emission at any of these stages can contribute to sustainability

Pumping and heating power – CO_2
Aeration power – CO_2
Chemicals – CO_2
Anoxic and aerobic treatment – CO_2 and N_2O
Sludge treatment – CO_2 and CH_4
Sludge disposal – CO_2 and CH_4

Extra task: Think on ways of solving the problem!

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Resource recovery: water reclamation and reuse

The main driver for the reclamation and reuse:

- **water scarcity of freshwater distribution;**
- **climate change-related water stress.**

Around *99 wt%* of the matter contained in wastewater is *WATER*

Imperfection **of water treatment procedures causes the present of residual concentrations of organic *micropollutants*: pharmaceuticals, polychlorinated biphenyls (PCPs), microplastics, nanoparticles, pathogens, and pesticides**

Need of advanced treatment technologies:

- **filtration,**
- **disinfection,**
- **advanced oxidation processes.**

Q: what is more profitable for water supply:
Desalination
long distance fresh-water transfer
Reclamation and reuse

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Resource recovery: water reclamation and reuse. Real cases.

Choose one case and read the source

Catalan Water Agency

https://www.researchgate.net/publication/5492393_The_water_reclamation_and_reuse_project_of_El_Prat_de_Llobregat_Barcelona_Spain

Singapore, NEWater project

https://www.pub.gov.sg/watersupply/singaporewaterstory re

Windhoek, Namibia

https://www.sciencedirect.com/science/article/abs/pii/0273122396004039

Tokyo's Shinjuku district

https://www.gesui.metro.tokyo.lg.jp/business/pdf/6-3_2008.pdf

Torreele facility

https://youtu.be/fAnpZb30ecA
http://www.demoware.eu/en/demo-sites/torreele

Resource recovery:
Nutrient recovery and reuse technologies

drivers

Nitrogen

- Consume about 1-2% of global energy by Haber-Bosch process
- Essential for food production

Phosphorus

- No substitution in crop growth
- Depletion in 50-100 years
- 2,3% annual demand increase

Potential:

to satisfy up to **50%** of the ***global*** N market

to increase P market diversity

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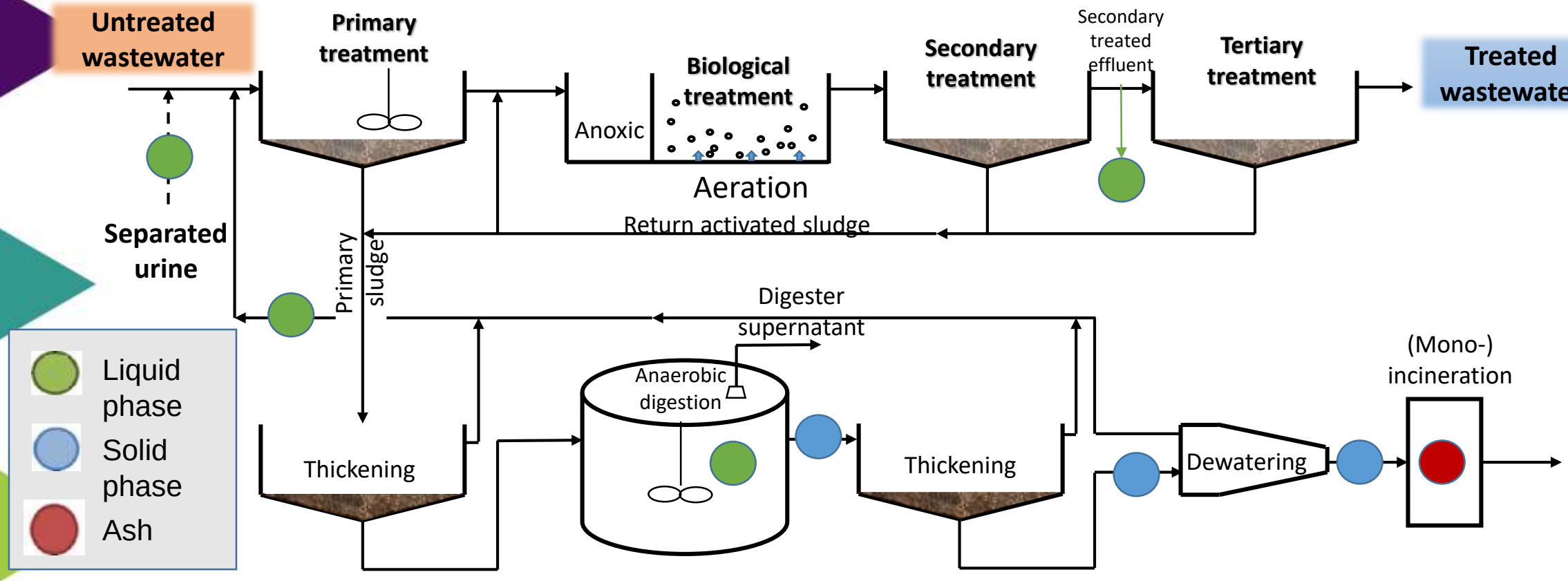
Typical Wastewater Treatment Plants Scheme*

Potential points for nutrient recovery at different stages of treatment process

Extra task: Find three ongoing EU projects on NP recovery



*More info from L. Egle, H. Rechberger, J. Krampe, and M. Zessner, *Science of The Total Environment*, vol. 571, pp. 522–542, 2016.

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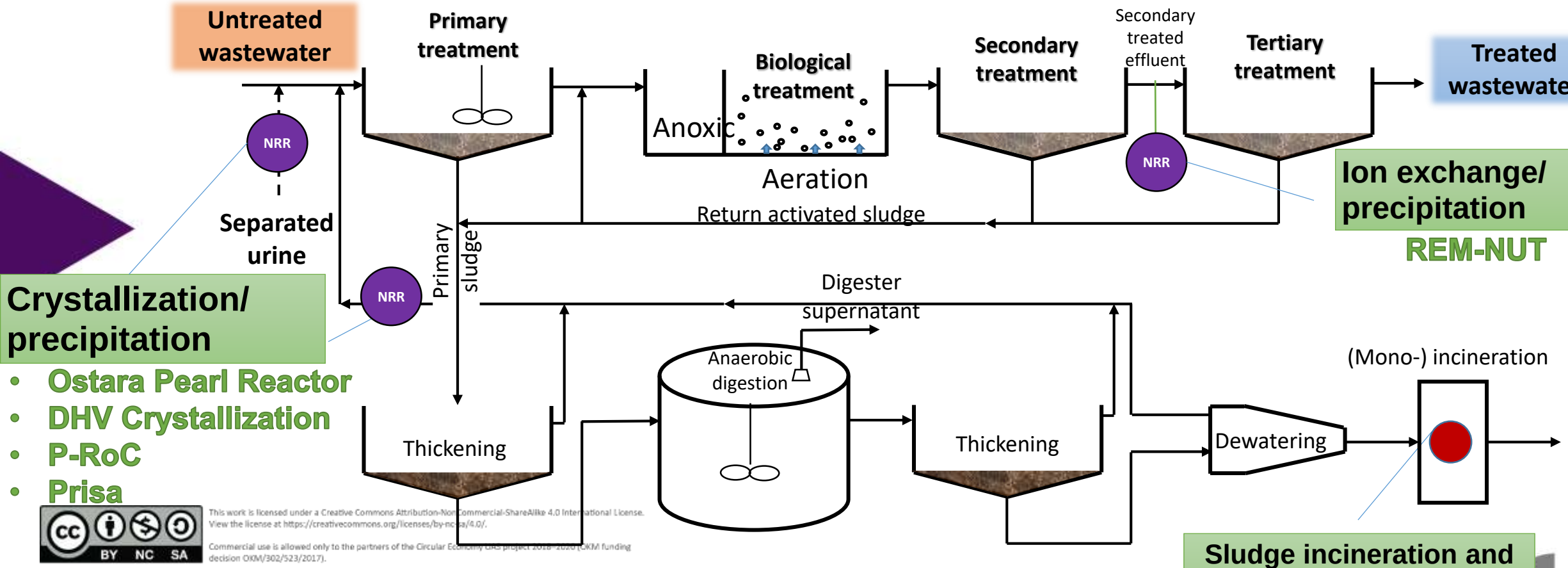
Emerging technologies: Nutrient recovery and removal (**NRR**)

Criteria

- High rate P/N recovery
- Low energy consumption
- Low GHG emission



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Benefits vs. Bottlenecks

+

Energy savings due to less aeration

+

N/P recovery

+

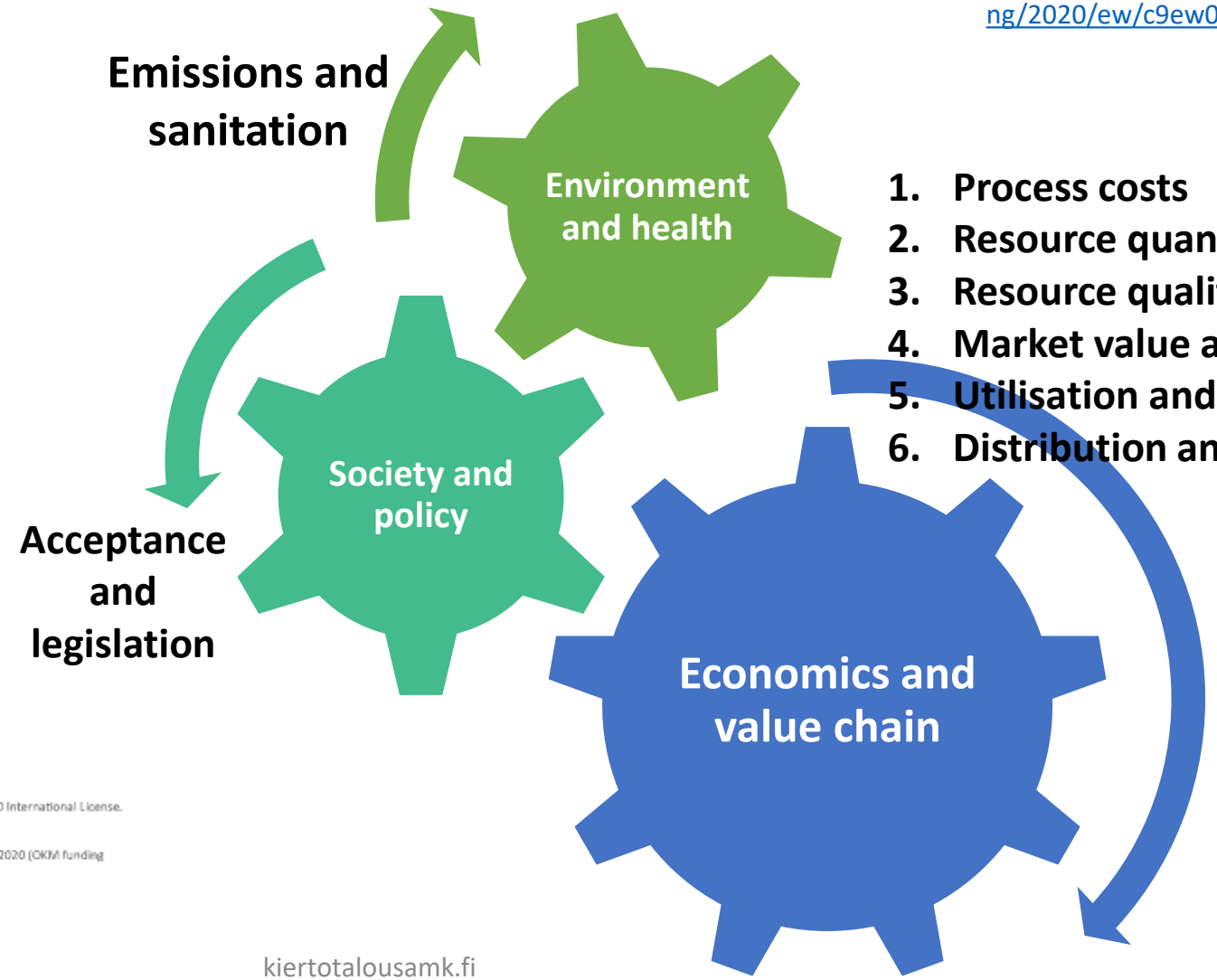
Operational costs reduction

+

GHG emission reduction

Read more about problems with emerging technologies implementation

https://pubs.rsc.org/en/content/articlelanding/2020/ew/c9ew00905a#!divAbstract



1. Process costs
2. Resource quantity
3. Resource quality
4. Market value and competition
5. Utilisation and application
6. Distribution and transport

Conclusions:

- Waste water is an invaluable resource that should be included into circular economy concept and utilized in the future.
- The market potentials of recovered resources (water, energy, fertilizer, VFA, and etc.) are substantial. The most precious resource contained in municipal wastewater is the **water** itself.
- Although significant number of technologies for the recovery of resources from wastewater have been examined by the researchers, only few of those have ever been implemented in full scale mode due to technical immaturity and legislation bottlenecks.
- Attracting of public funding bodies, promotional programmes, and policy agencies is needed to overcome legislation and acceptance barriers. The higher effluent quality requirements established in the future would also increase water reuse and resource recovery opportunities, promoting circular economy actions.

Literature:

1. G. Lofrano and J. Brown, “Wastewater management through the ages: A history of mankind,” *Sci. Total Environ.*, vol. 408, no. 22, pp. 5254 – 5264, ***2010***, doi: https://doi.org/10.1016/j.scitotenv.2010.07.062. https://www.researchgate.net/publication/46148626_Wastewater_Management_through_the_Ages_A_History_of_Mankind

2. Magagna D. et al. Water – Energy Nexus in Europe, Publications Office of the European Union, Luxembourg, ***2019***, ISBN 978-92-76- 03385-1, doi: 10.2760/968197, JRC115853. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/water-energy-nexus-europe

3. J. M. Lema and S. Suarez, Eds., *Innovative Wastewater Treatment & Resource Recovery Technologies: Impacts on Energy, Economy and Environment*. IWA Publishing, ***2017***.

4. L. Egle, H. Rechberger, J. Krampe, and M. Zessner, “Phosphorus recovery from municipal wastewater: An integrated comparative technological, environmental and economic assessment of P recovery technologies,” *Sci. Total Environ.*, vol. 571, pp. 522–542, ***2016***, doi: 10.1016/j.scitotenv.2016.07.019. https://www.sciencedirect.com/science/article/pii/S0048969716314656

5. P. Kehrein, M. van Loosdrecht, P. Osseweijer, M. Garfí, J. Dewulf, and J. Posada, “A critical review of resource recovery from municipal wastewater treatment plants – market supply potentials, technologies and bottlenecks,” *Env. Sci Water Res Technol*, ***2020***, doi: 10.1039/C9EW00905A. https://pubs.rsc.org/en/content/articlelanding/2020/ew/c9ew00905a#!divAbstract

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1 op:n Sustainable wastewater treatment plants. Resource recovery oppotunities: technologies and bottleneckes

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