Guideline for API removal

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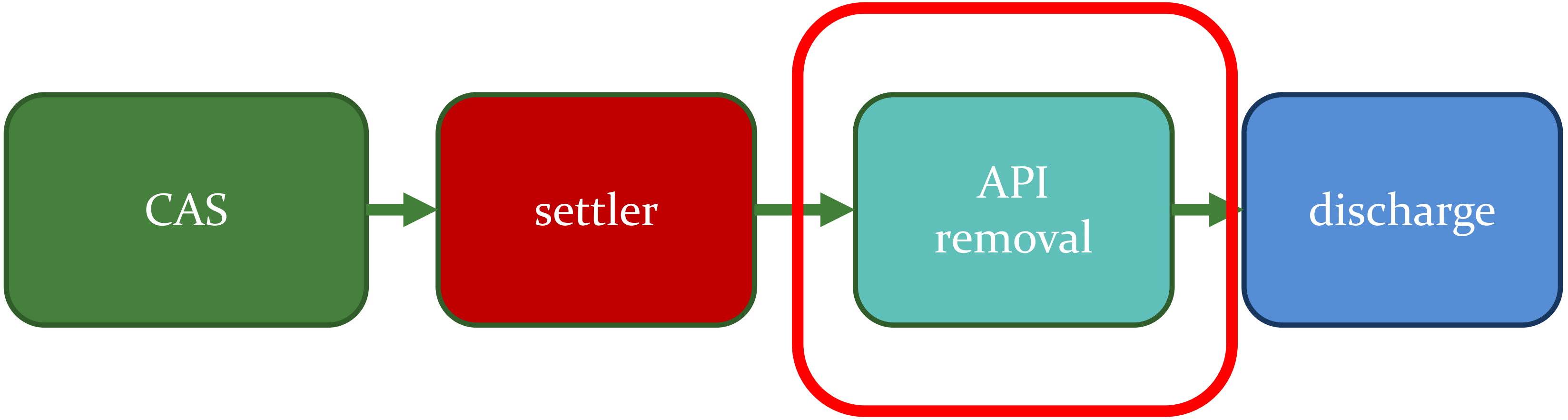
GoA 3.4 approach



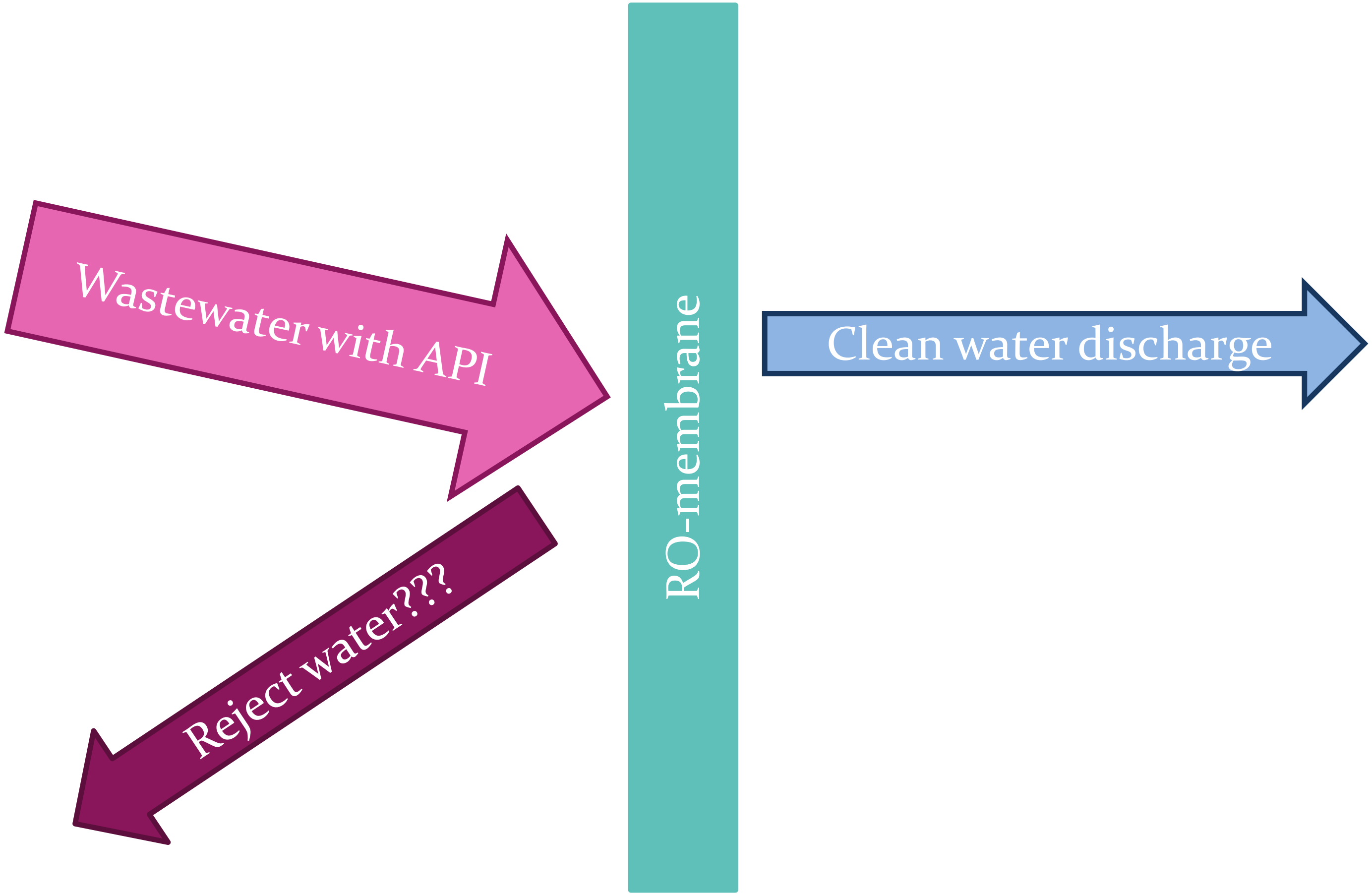
Technological overview

Category	Ozone	GAC	PAC	MBBR
API removal	++	++	++	o +
Technology maturity for API elimination	++	++	++	-
Complexity of operation	+	++	o	+
Reaction products from the water matrix	-	++	++	++
Transformation products or metabolites	-	++	++	-
Costs#	+	+	+	o
Energy usage in operation	-	+	o +	+
Carbon footprint	o	o	-	+
Space requirement	++	+	- ++	-
Compatibility to sludge usage in agriculture	++	++	-	++

There will not be "the best technology"

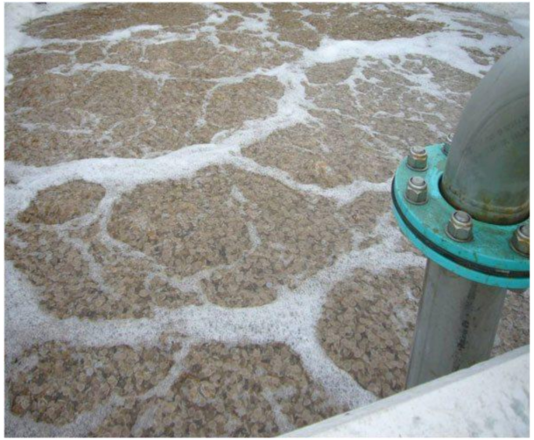
but decision support which is the best tech for me

Reverse osmosis was not considered

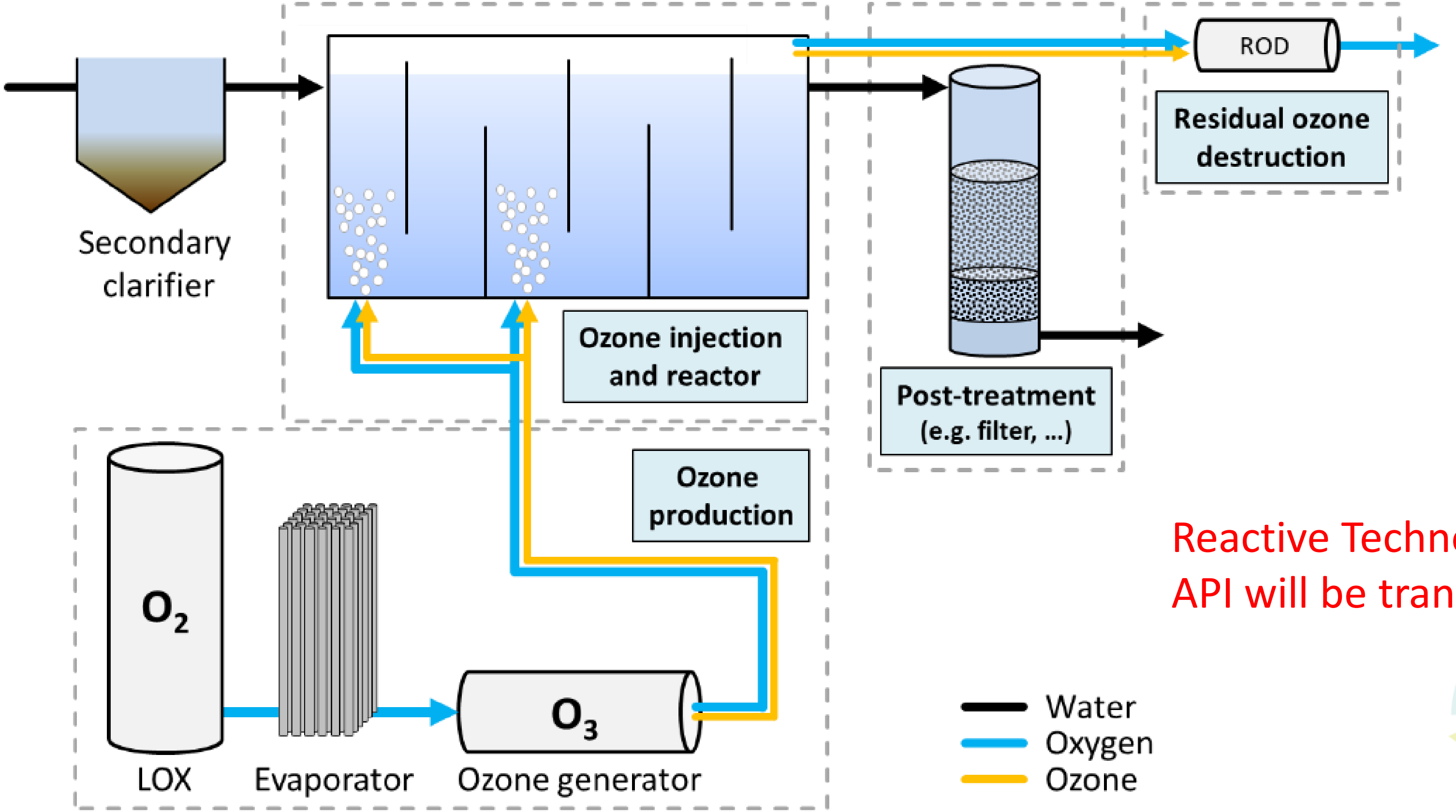


Modules of the guideline

WWTP fitness check → Feasibility study → Detailed planning → optimizing existing systems



Ozonation process

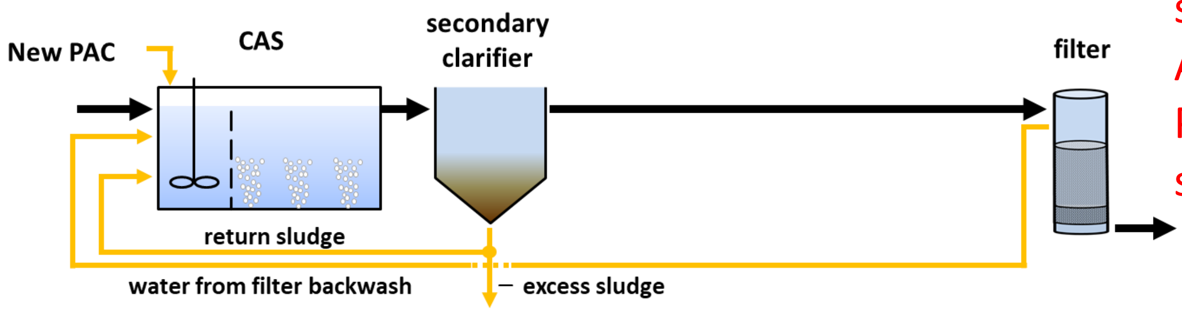


Reactive Technology:
API will be transformed

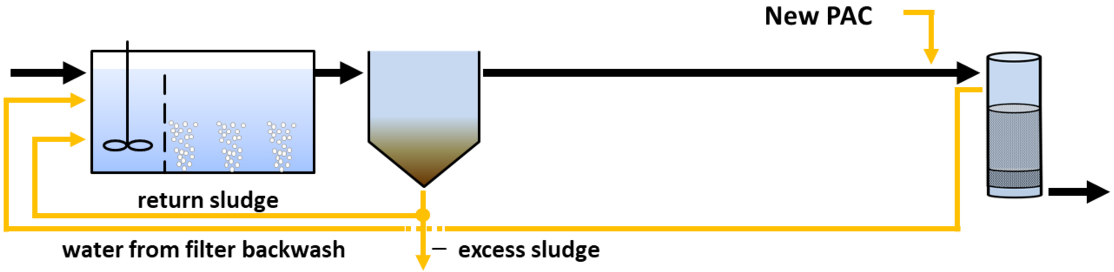
PAC process

Phase separation: APIs will be on PAC aka in the sludge

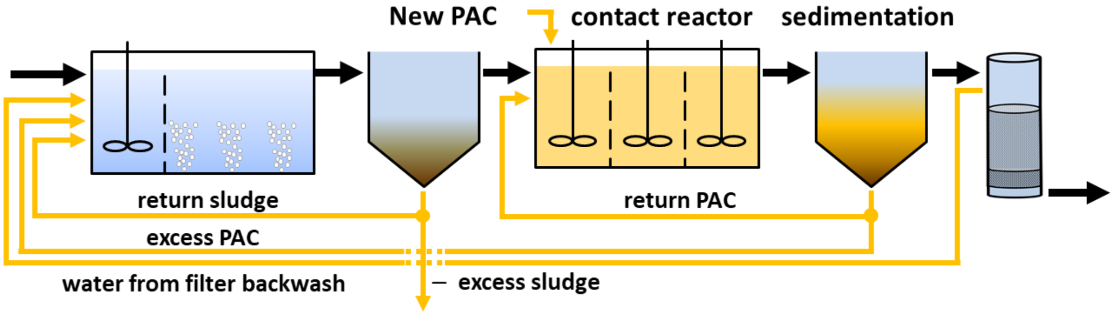
Simultaneous PAC dosage



PAC dosage prior to a filter

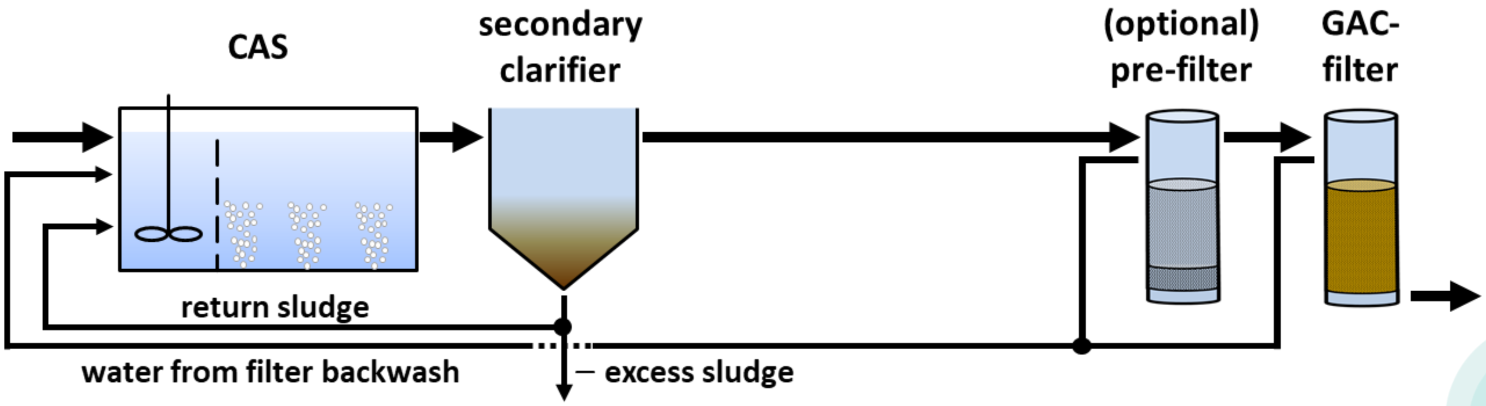


Separate PAC contact reactor (“Ulmer process”)

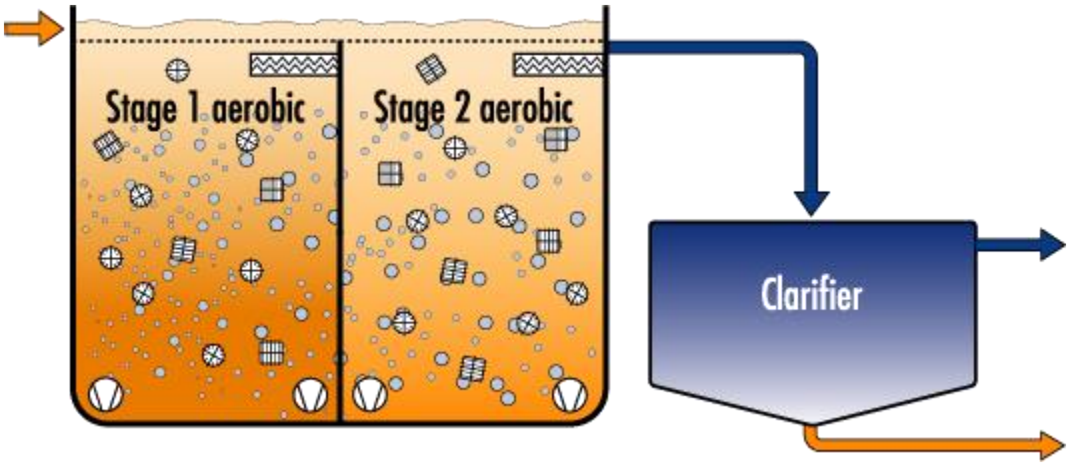


GAC process

Phase separation: APIs will be on GAC -> incineration



Moving Bed Biofilm Reactors



Reactive technology:

API will be:

a) Mineralised
b) Incorporated in biomass
c) Transformed

Strategy for implementing API removal

I WWTP fitness check:

Focus: Overview on whether certain technologies/approaches are excluded due to existing border conditions.

What to be evaluated:

- Target of AWWT (→ good ecological status of surface water or drinking water protection?)
- High bromide concentrations (→ O_3: bromate formation → source tracking) -> no O_3
- Nitrite peaks (→ O_3: impact on dosage relevance to be checked)
- Sludge disposal if on agricultural land no PAC (I,II)
- Suspended solids (→ potential impact on ozone dose, flushing of GAC filters)
- High DOC conc. (→ Share of industrial WW? → comparable to other WWTPs or more detailed evaluation (pilot/lab) necessary?)
- Local staff (→ "smaller" WWTPs → remote/robust operation possible?)

Should be possible with known /easily meassureable parameters

II Feasibility study

Focus/Output:

- Pre-evaluations (e.g. lab-scale tests for ozone, PAC/GAC)
- Monitoring / Screening (e.g. APIs, water quality parameters) according to chosen target of AWWT
- Design parameters of AWWT techniques
- Wrap-up: state of the art/knowledge on AWWT
- Technical concepts for different API removal technologies (e.g. assessment of required tanks sizes, energy demand and operational costs). Usage of either literature, similar WWTPs or results of the lab-scale tests.
- Evaluation/conclusion

III "Detailed planning"

- **Unusual API concentrations**, e.g., for WWTPs with large hospitals or pharmaceuticals industries within their catchment area.
- **Municipal WWTPs with high fraction of industrial wastewater**. In this case, piloting should be accompanied by a more detailed assessment on possible formation of toxic oxidation by-products and their removal during biological post-treatment.
- Depending on the overall expertise level of the utility, **a piloting phase** can also serve to build up know-how for up-coming operation of the full-scale unit. Early integration of WWTP staff into the planning process also improves the overall acceptance for the new technology.

III "Detailed planning"

- Additional monitoring is recommended:

➢ To assess the variations of relevant parameter for the design (DOC, nitrite, TSS, min/max water flow). This monitoring helps to identify the need of more advanced online control e.g. in the case highly variable nitrite levels that can affect the ozonation efficiency, peaks in suspended solids that can affect post-filtration systems or the GAC filters.

➢ For ozonation only: In case of a bromide level of more than 150 µg/L at the potential ozonation influent was already identified during the fitness check and feasibility study, respectively, the bromate formation potential has to be assessing in more detail using either lab-scale or pilot-scale experiments. As, usually, no target value for bromate in WWTP effluents exists, exchange with the local water authority is required to agree on acceptable discharge limits. While the drinking water standard for bromate is 10 µg/L, for surface water to maximum annual average shall not exceed 50 µg/L .

➢ For ozonation only: In case the bromate formation potential is considered to be too high, a source tracking within the catchment area of the WWTP can help to identify hot spots for bromide emissions. Known source for bromide are waste incineration plants, thermal springs and infiltration of seawater in the sewer systems at coastal cities [3].

III "Detailed planning"

- Lab testing of ozonation can help to gather additional information on the local water quality, to derive more robust design parameters of the chosen AWT technique and can help to avoid long-term and costly piloting:

➢ The removal efficiency of different treatment technologies regarding specific APIs on which no or just little knowledge is available from pilot- or full-scale AWT plants

➢ For ozonation only: Lab-scale tests with a specific focus on the ozone decay at different boundary conditions (e.g. water quality, pH, water temperature) can be used to optimize reactor size and, thus, investment costs (see below). Lab-scale experiments can be conducted according to available literature[16]

III "Detailed planning"

For activation carbon: Adsorption tests for PAC dosing, while small-scale column tests (RSSCT) for GAC are established.

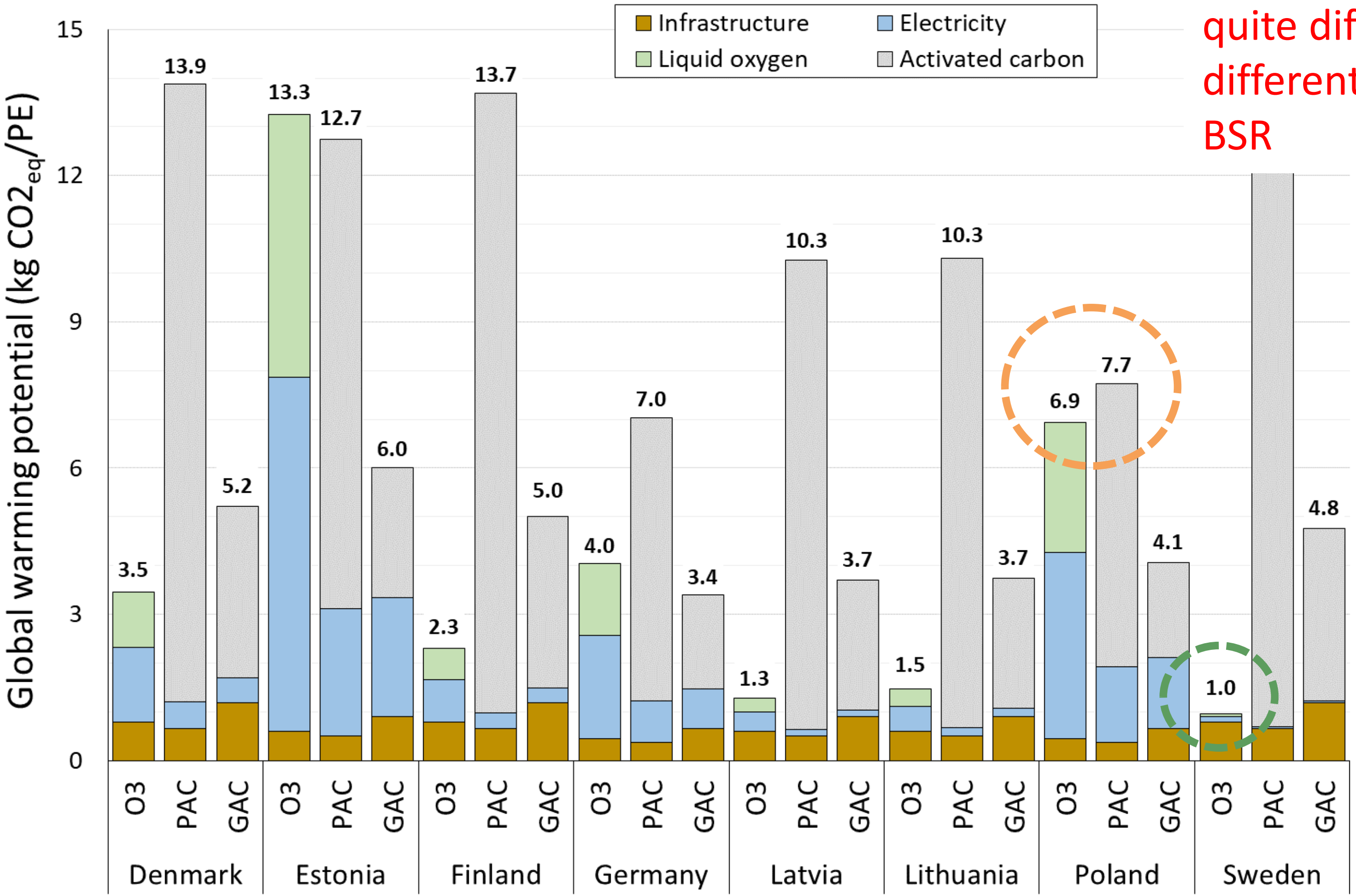
Usage of modelling for detailed planning: Based on the daily flow-pattern and changes in water quality more detailed design parameter should be derived:

- For Ozonation: Min./max. and average ozone production capacity and oxygen demand should be assessed to define the number of ozone generators (plus redundancy back-up), the sizing of the liquid oxygen storage and to update the cost of operation already estimated during the feasibility study. To ensure complete reaction of ozone in the water phase before leaving the ozone reactor the minimum hydraulic retention time (HRT) needs to be assessed. For ozone reactors with standard design (i.e. existing plants) a minimal HRT of 20 min is recommend. When targeting short HRT lab testing on ozone consumption velocity (see above) and a validation of HRT computational fluid dynamics is the gold standard. Current status is a minimum HRT of 12 min at 0.5 mgO3/mg DOC (WWTP Aachen, Germany).
- For PAC: The average daily PAC dosing need to be determined based on flow and average DOC background to size the PAC storage (> 1 week storage capacity at least) and to update the cost of operation already estimated during the feasibility study
- For GAC: Out of the maximum design flow the required filter are can be derived but needs to cross-validated by the suspended solids loading to the filter. If suspended solid loading to the GAC filter is the limiting hydraulic factor, a pre-filtration (e.g. microsieve, pile-cloth filtration) can help to minimize the investment cost for the GAC filter.

IV Optimising existing systems /Operations

- For oznonation: monitor bromate formation -> bromide source tracking, bromate formation suppression, bromate reduction by post-treatment // in case bromide levels are rising, unexpected high bromate formation occurs.
- High variations of API elimination -> monitor API elimination process more often via surrogate parameters, check for disturbances such as nitrite present in water (ozonation), bad PAC quality,

Specific global warming potential (GWP)



Sources of electric power are quite different in the different sub regions of the BSR

Ozonation:
- electricity production (low gCO_2/kWh)

Ozone preferred:
- Scandinavia, Latvia, and Lithuania

GAC preferred :
- Poland, Estonia

Ozone/GAC similar:
- Germany

preliminary

Questions?

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