IWA the international water association CLIMATE SMART UTILITIES

Climate Smart Futures- from Process Emissions to Planetary Boundaries

03/10/2023

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WEBINAR INFORMATION

- This webinar will be **recorded and made available "on-demand"** on the IWA Connect Plus platform, with presentation slides, and other information.
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- The opinions, hypothesis, conclusions or recommendations contained in the presentations and other materials are the **sole responsibility of the speaker(s)** and do not necessarily reflect IWA opinion.

WEBINAR INFORMATION

- **'Chat' box**: please use this for general requests and for interactive activities.
- **'Q&A' box**: please use this to send questions to the panelists.

(We will answer these during the discussions and in post-webinar materials.)

Please Note: *Attendees' microphones are muted. We cannot respond to 'Raise Hand'.*

AGENDA

CLIMATE SMART UTILITIES

- Welcome, introductions and overview of series

  Amanda Lake, Jacobs, (Moderator)

- LCA in wastewater treatment

  Eoghan Clifford, University of Galway

  Q&A

- LCA in energy and resource recovery upgrades, VARGA project

  Maria Faragó, Rambøll

  Q&A

- Case study – Sustainability as a driver for Aarhus ReWater

  Jacob Kragh Andersen, Envidan / Inge Halkjær Jensen, Aarhus Vand

  Q&A

- Introduction to the GHG white paper

  Amanda Lake, Jacobs, (Moderator)

- Closing remarks (Encouragement to engage)

MODERATORS & PANELISTS

CLIMATE SMART UTILITIES
the international water association

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Ireland

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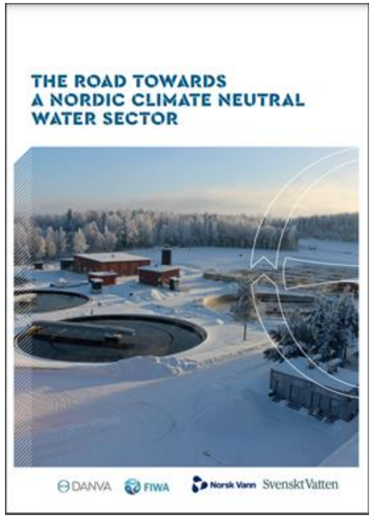
Rambøll
Denmark

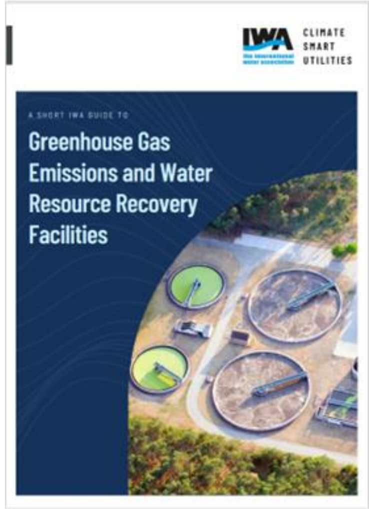
Inge H. Jenson
Aarhus Vand
Denmark

Jacob Kragh Andersen
Envidan
Denmark

OUR 2023 SERIES

the international water association CLIMATE SMART UTILITIES





LCA in wastewater treatment – an example in aeration

EOGHAN CLIFFORD, UNIVERSITY OF GALWAY

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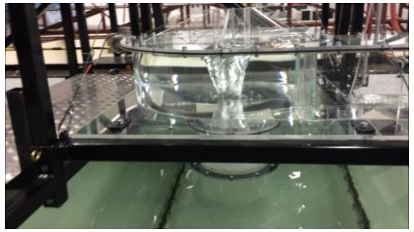
BACKGROUND

- Head of Civil Engineering in University of Galway
- Technical advisor to Vortech Water Solutions (spin-out from our research group)
- Process engineering in water and wastewater
- Academic and industry background
- Fundamental to applied (almost full-scale) research

OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

VorTech WATER SOLUTIONS



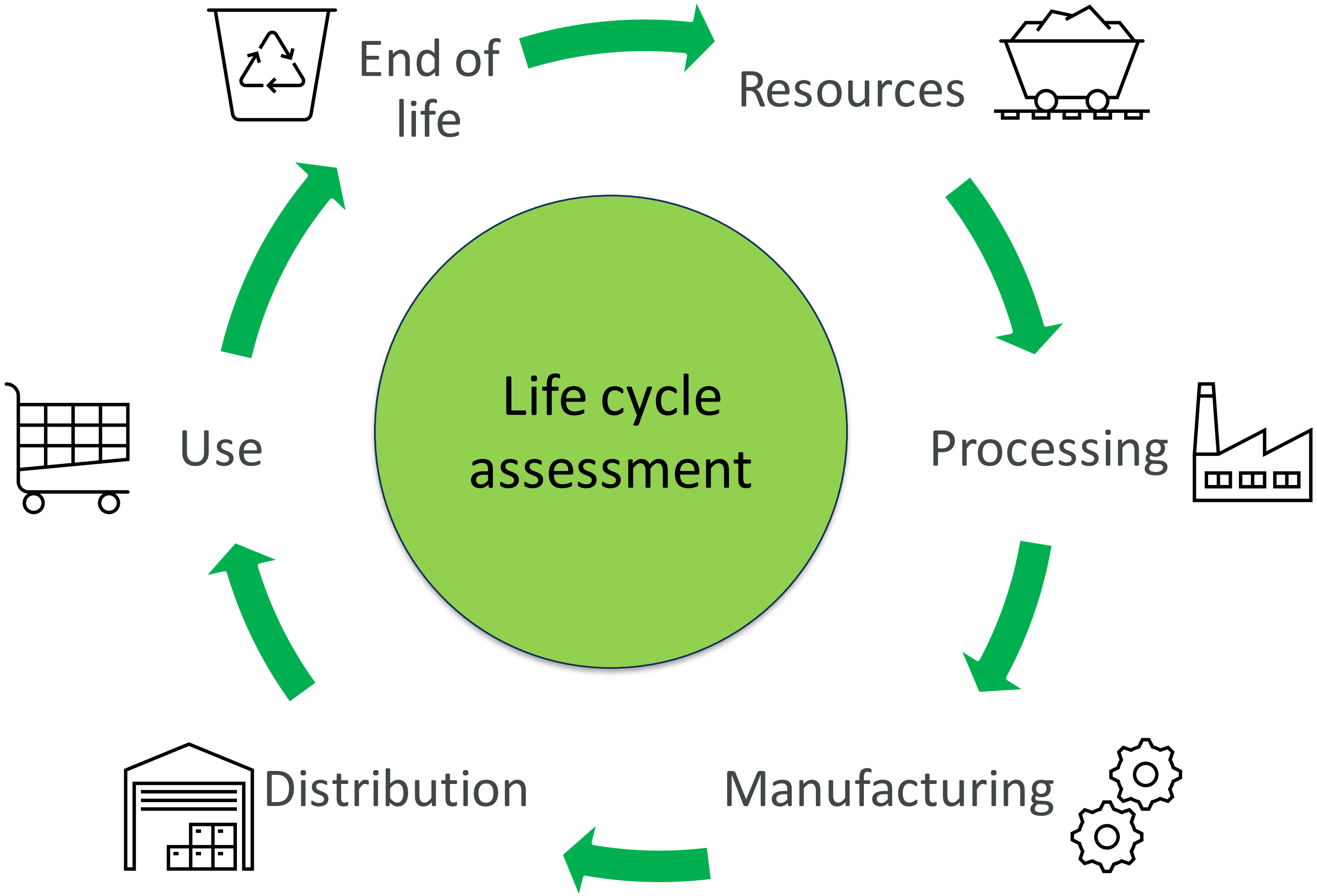


LIFE CYCLE ASSESSMENT

Life cycle assessment

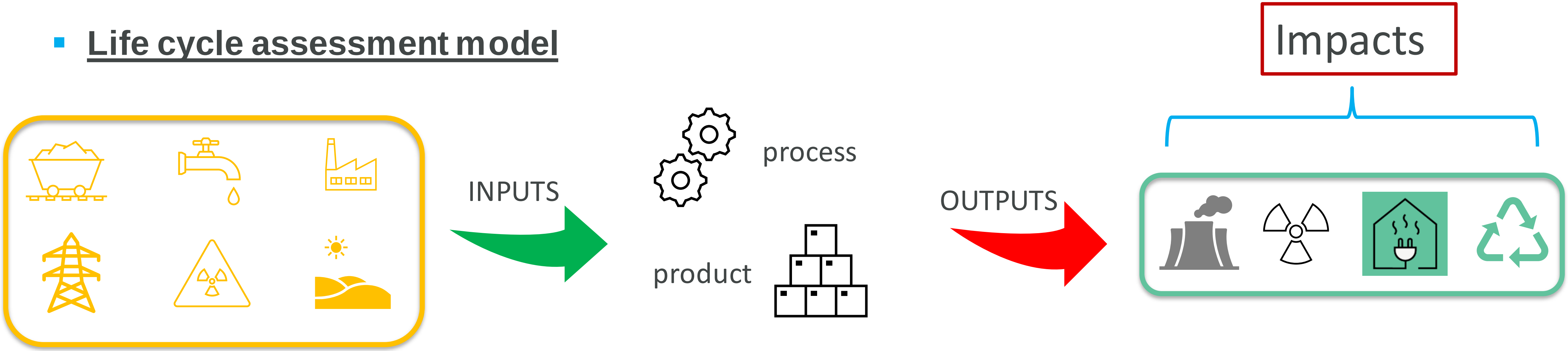
"A compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle."

ISO 14040

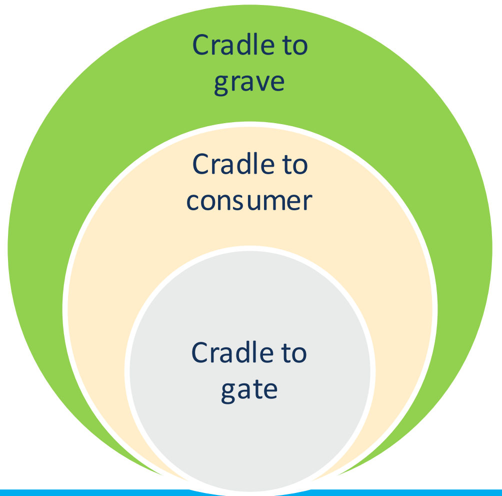


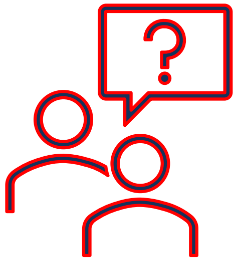
LIFE CYCLE ASSESSMENT

- **Life cycle assessment model**



- **Model boundary**





- **Functional unit**

Impacts per….

- 1 500 mL water bottle
- 1 km driven
- 1 kg O_2 entrained

DRIVERS FOR LIFE CYCLE ASSESSMENT

- Academic:
  - **Holistic** measurement of overall system/product impacts
  - Can drive innovation and mitigation
  - Evidence for policy
- Industry
  - Requirement at tendering stage (normally embodied carbon only)
  - Innovation and efficiency
  - Environmental credentials etc.
- Utility
  - Required for carbon reporting
  - Can drive green tendering processes
  - Can reduce whole life cycle costs and impacts

CHALLENGES WITH LIFE CYCLE ASSESSMENT

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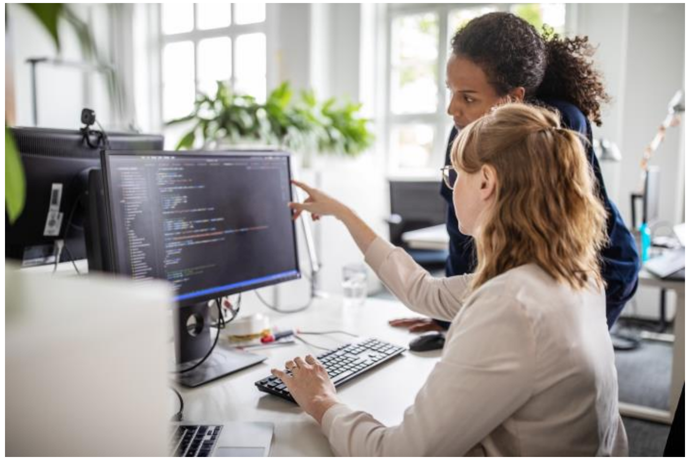
- BUT:

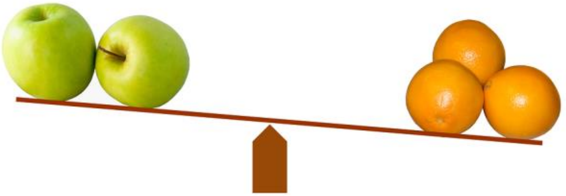


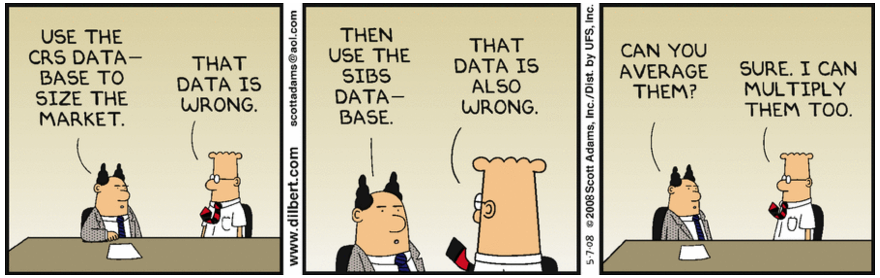
Messy / complex

Fair comparisons

Data

Expertise?





THIS STUDY

- Aeration a key component in wastewater treatment
  - Underpins most biochemical processes
  - Key for process control
  - Major energy consumer
  - Impacts wider WWTP emissions (e.g. N_2O)
- This study:
  - Part of an industry / academic collaboration
  - Developed LCA for an aeration product installed at a large WWTP
  - The first such study like this (as far as we know)..

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LIFE CYCLE ASSESSMENT OF AERATION IN A CASE-STUDY WWTP

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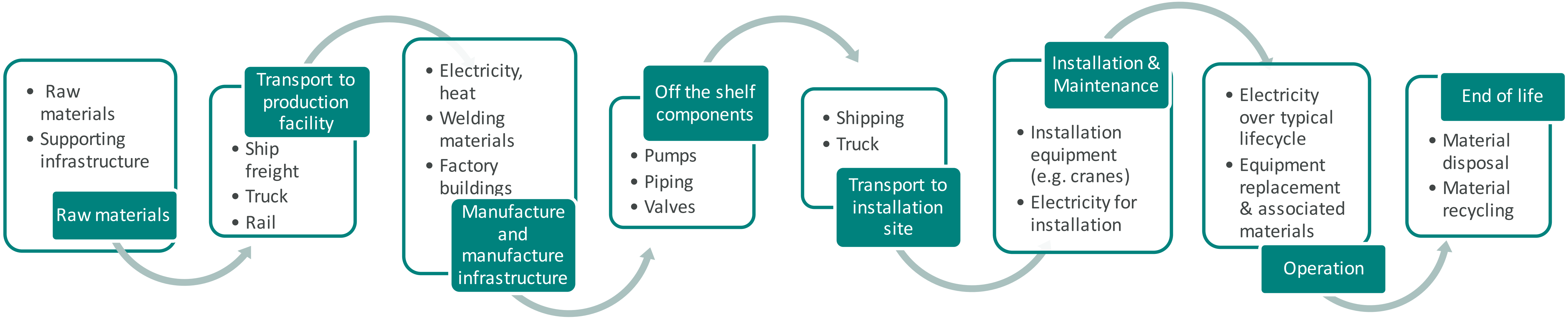
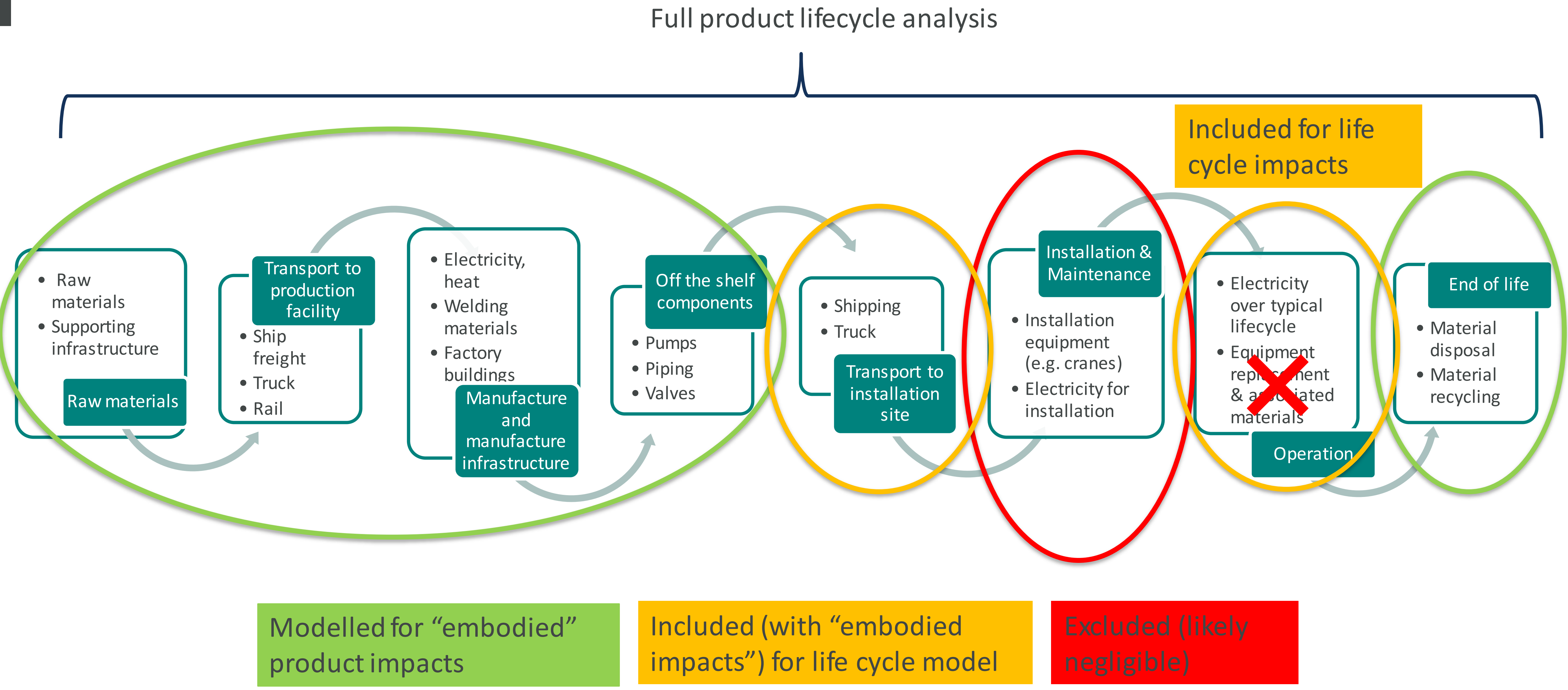
- Retro-fit of ~ 100,000 population equivalent wastewater treatment facility
- Utility required embodied carbon statement from supplier
- LCA carried out over product life cycle (using ecoinvent v3.9 & simapro)
- Non exhaustive list of product stages below



MODEL BOUNDARY



DATA, FUNCTIONAL UNIT & METHODOLOGY

Inventory data: Infrastructure, electricity grid carbon intensity & raw materials

Bespoke data: Bill of materials, data from equivalent sites relating to oxygen transfer etc.

Mixed sources: Transport (inventory + shipping route date), material properties

Functional units:
1 kg O_2 entrained in **wastewater** for a system operating for 40 years

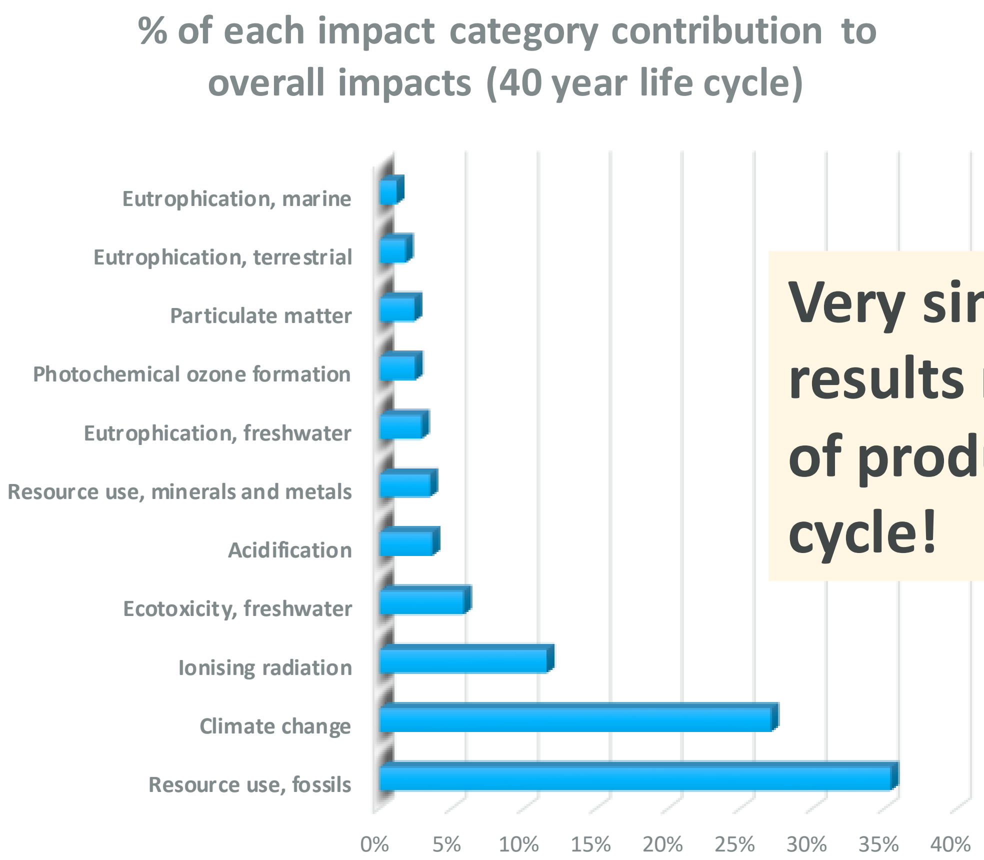
1 aeration product (to gate & operated over 40 years) treating for 200,000 PE

Methodology: EN15804 + A2 revision which covers Environmental Product Declarations of construction products (incl. use of CFF Annex C v2.1 – 2020).

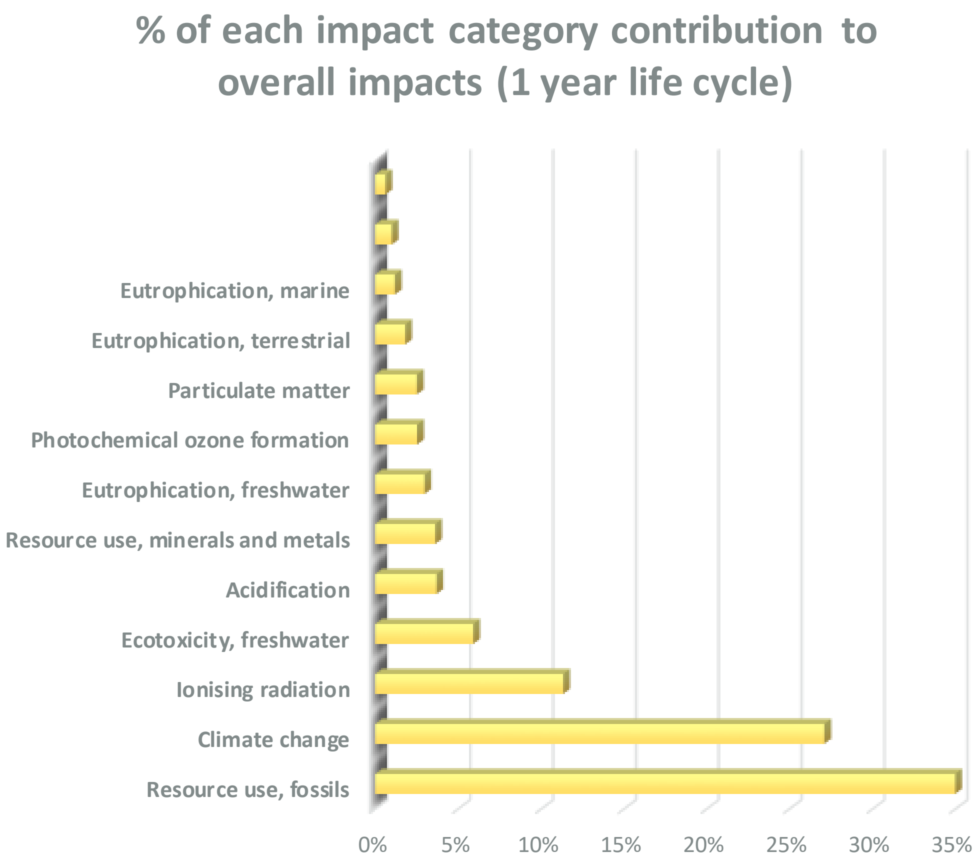
Data inputs and **model results** cross-checked using other sources as much as possible

RESULTS – CONTRUBITION OF IMPACT CATEGORIES TO OVERALL

- Overall life cycle impacts (40 year life cycle & 1 year life cycle)



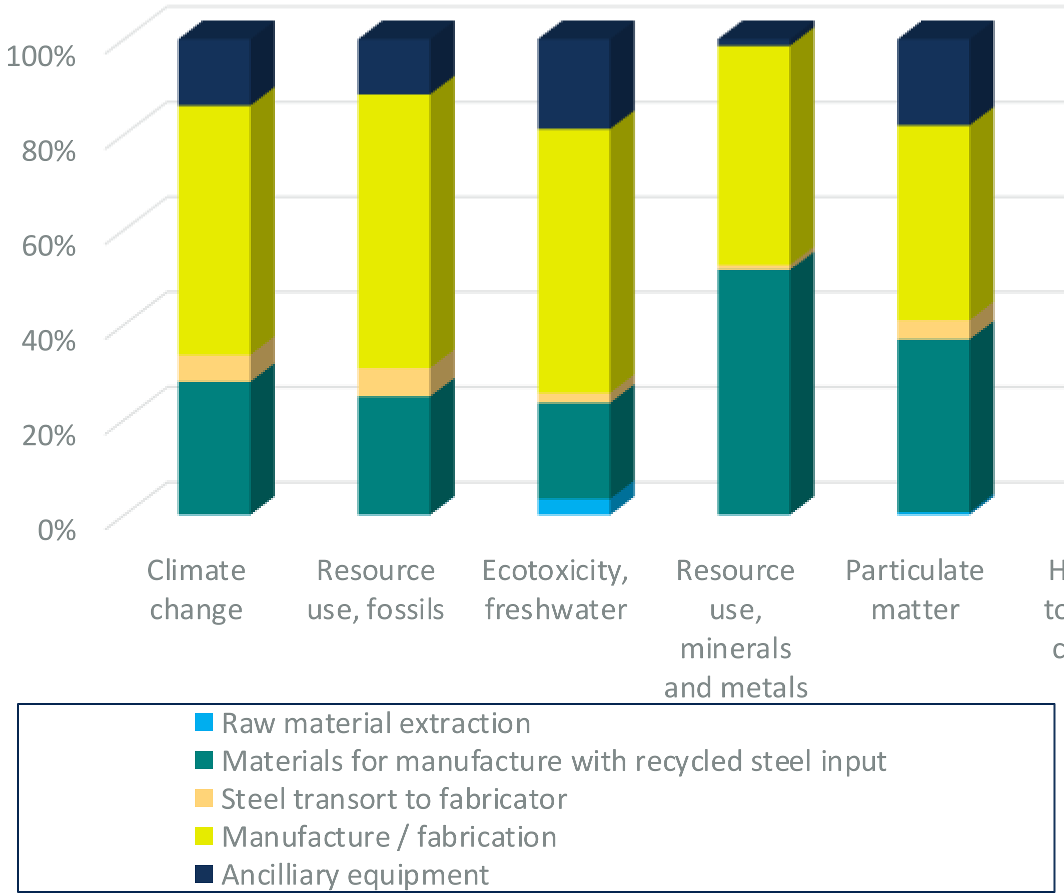
Very similar results regardless of product life cycle!



*** Impact categories contributing less than 1% of total not shown**

RESULTS – EMBODIED IMPACTS (CRADLE TO GATE)

- Impacts related to product manufacture and end of life



*** Impact categories contributing less than 5% of total not shown**

Product fabrication a key contributor

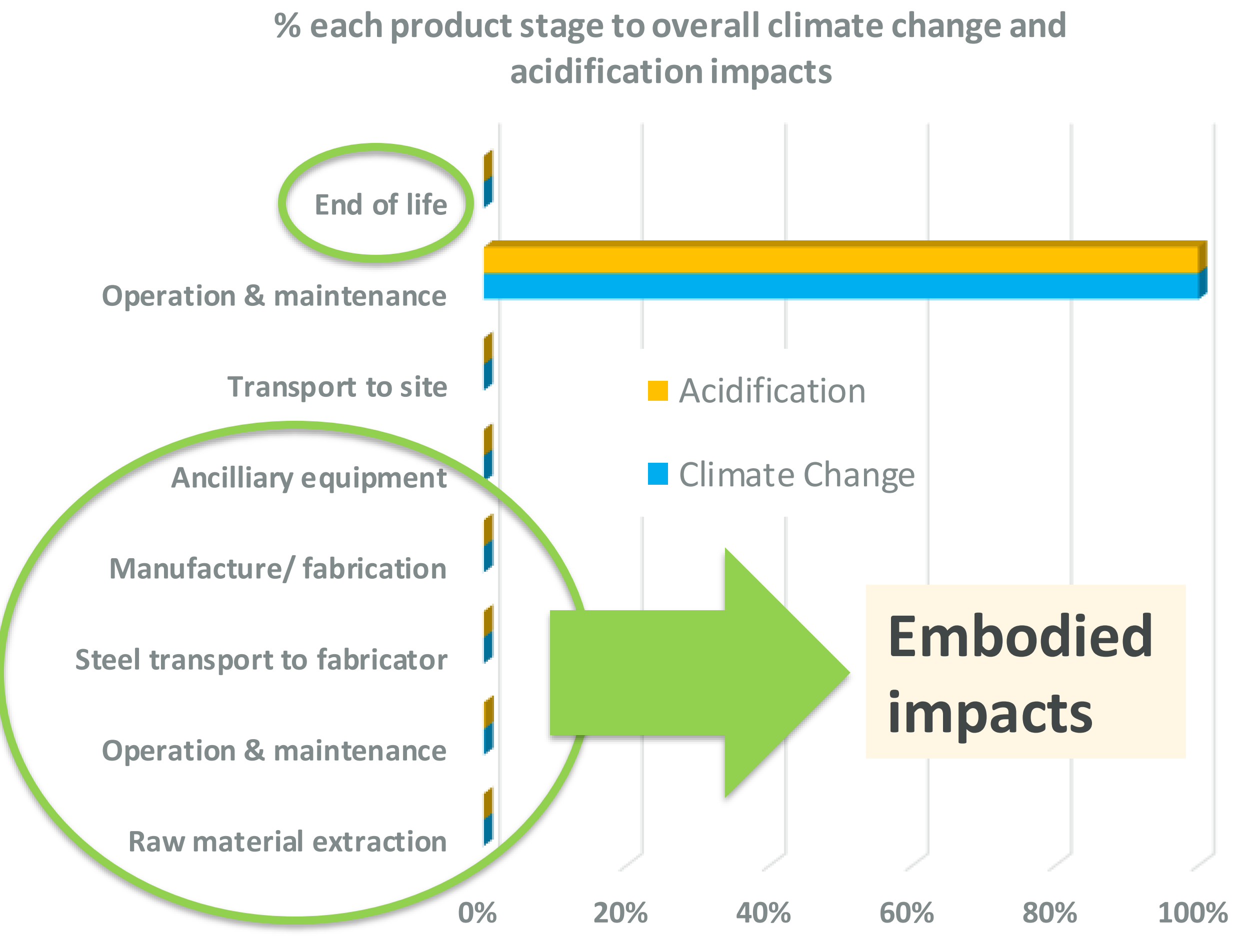
Steel production (key “offsets” due to recyclability at EOL)

Transport generally not significant (except acidification)

Very little data on “off the shelf” products

RESULTS – EMBODIED VS OPERATIONAL IMPACTS

- Contribution of each product stage to various impact categories



Operation accounts for virtually all impacts

Electricity mix is a key input variable

Oxygen requirements and transfer efficiency key input variables

RESULTS – FOCUS FOR IMPROVEMENT

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Analysis Stage	Importance	Data accuracy	Improvements
Raw material extraction			Low impact – inventory data only used
Materials for manufacture with recycled steel input			More bespoke data from steel forming
Steel transport to fabricator			Low impact and likely relatively accurate
Manufacture/fabrication			More be-spoke data would help
Ancillary equipment			Suppliers to model their products. Modelled as equivalent mass iron.
Transport to client			Low impact and likely relatively accurate
Operation / maintenance			High importance. Model future grid carbon intensity.
End of life			Improve data around recycling

CONCLUSIONS

- **Utilities**
  - Technology selection must favour efficient/flexible operation
  - Impact (& cost) modelling must be based on equivalent **SITE** data **(not clean water!)**
  - LCA can enable full impacts to be modelled over an entire life cycle
- **Industry**
  - Full impact analysis will be necessary (when, to what extent?)
  - Can and should drive innovation and efficiency
- Challenges
  - Ensuring like by like comparison at design/tender stage
  - Industry having in-house skills to do LCA
  - Quality control (data and models)

THANK YOU!

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ELSEVIER
Journal of Cleaner Production
Volume 165, 1 November 2017, Pages 1529-1541

Design and implementation of a performance assessment methodology cognisant of data accuracy for Irish wastewater treatment plants

Edelle Doherty [a], Greg McNamara [b], Lorna Fitzsimons [b], Eoghan Clifford [a]

ELSEVIER
Science of The Total Environment
Volume 761, 20 March 2021, 144094

Review

Life cycle assessment of fish and seafood processed products – A review of methodologies and new challenges

Israel Ruiz-Salmón [a], Jara Laso [a], María Margallo [a], Pedro Villanueva-Rey [b], Eduardo Rodríguez [b], Paula Quinteiro [c], Ana Cláudia Dias [c], Cheila Almeida [d], Maria Leonor Nunes [d e], António Marques [d e], Antonio Cortés [f], María Teresa Moreira [f], Gumersindo Feijoo [f], Philippe Loubet [g], Guido Sonnemann [g], Andrew P. Morse [h], Ronan Cooney [i j], Eoghan Clifford [i j], Leticia Regueiro [k], Diego Méndez [k]...Rubén Aldaco [a]

Show more

Life Cycle Assessment of Waste Water Treatment Plants in Ireland

DOWNLOAD FULL TEXT PDF

Original scientific paper

Journal of Sustainable Development of Energy, Water and Environment Systems
Volume 4, Issue 3, pp 216-233
DOI: https://doi.org/10.13044/j.sdewes.2016.04.0018

Greg Mcnamara[1], Lorna Fitzsimons[1], Matthew Horrigan[1], Thomas Phelan[1], Yan Delaure[1], Brian Corcoran[1], Edelle Doherty[2], Eoghan Clifford[2]

[1] School of Mechanical Engineering, Dublin City University, Glasnevin, Dublin 9, Ireland
[2] Civil Engineering, College of Engineering and Informatics, National University of Ireland Galway, University Road, Galway, Ireland

Abstract
The Urban Wastewater Treatment Directive 91/271/EEC introduced a series of measures for the purpose of

ACKNOWLEDGMENTS:
FUNDERS, INDUSTRY PARTNERS AND PROJECT TEAM

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LCA in energy and resource recovery upgrades, VARGA project

MARIA FARAGÓ, LCA & SUSTAINABILITY SPECIALIST AT RAMBØLL

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ABOUT ME

BIOFOS

aarhusvand

VandCenterSyd

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RAMBØLL

LCA and Water Sustainability Specialist

Oct. 2022 - present

2019-2022

2017-2019

Research Assistant & member of the Innovation team at DTU Environment

DTU Technical University of Denmark

2017

MSc in Environmental Engineering,

Urban Water Systems management & LCA/Sustainability assessment

aarhusvand

POLITECNICO MILANO 1863

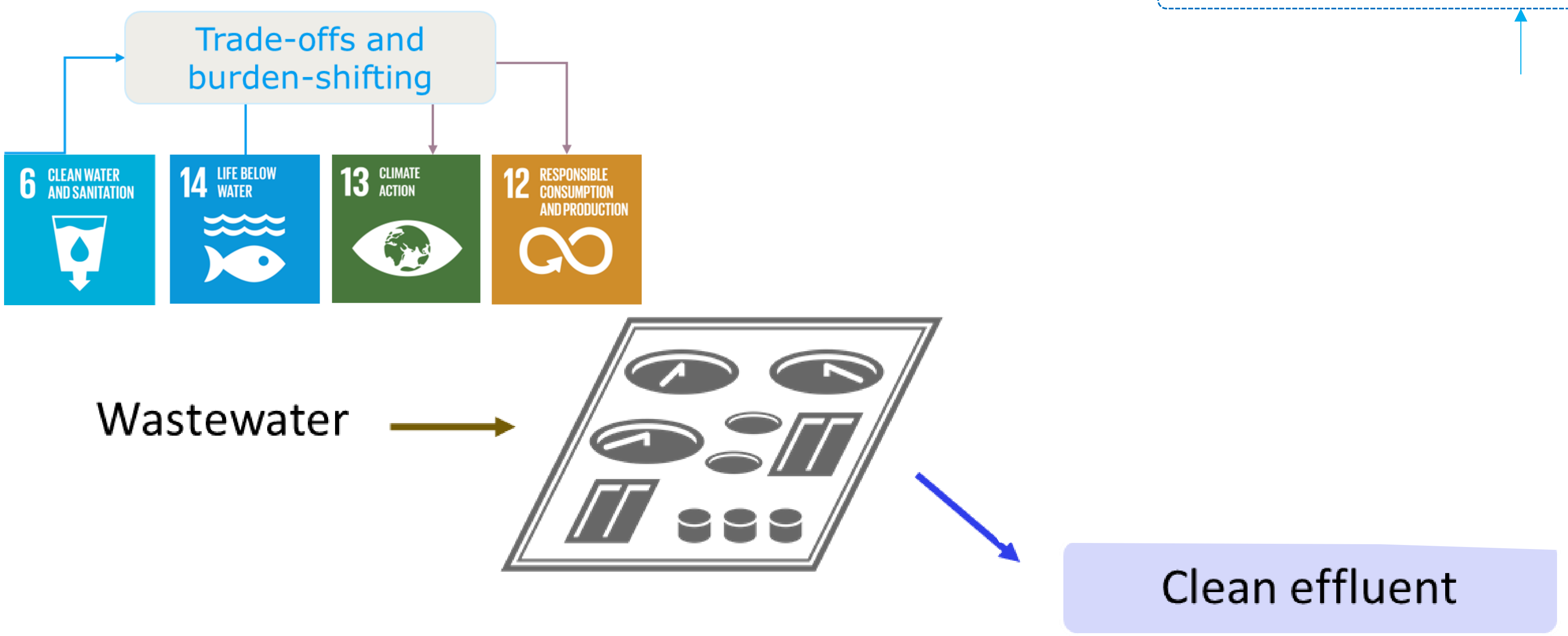
2013; 2015

BSc & MSc in Environmental & Land Planning Engineering

Planning and management of natural resources

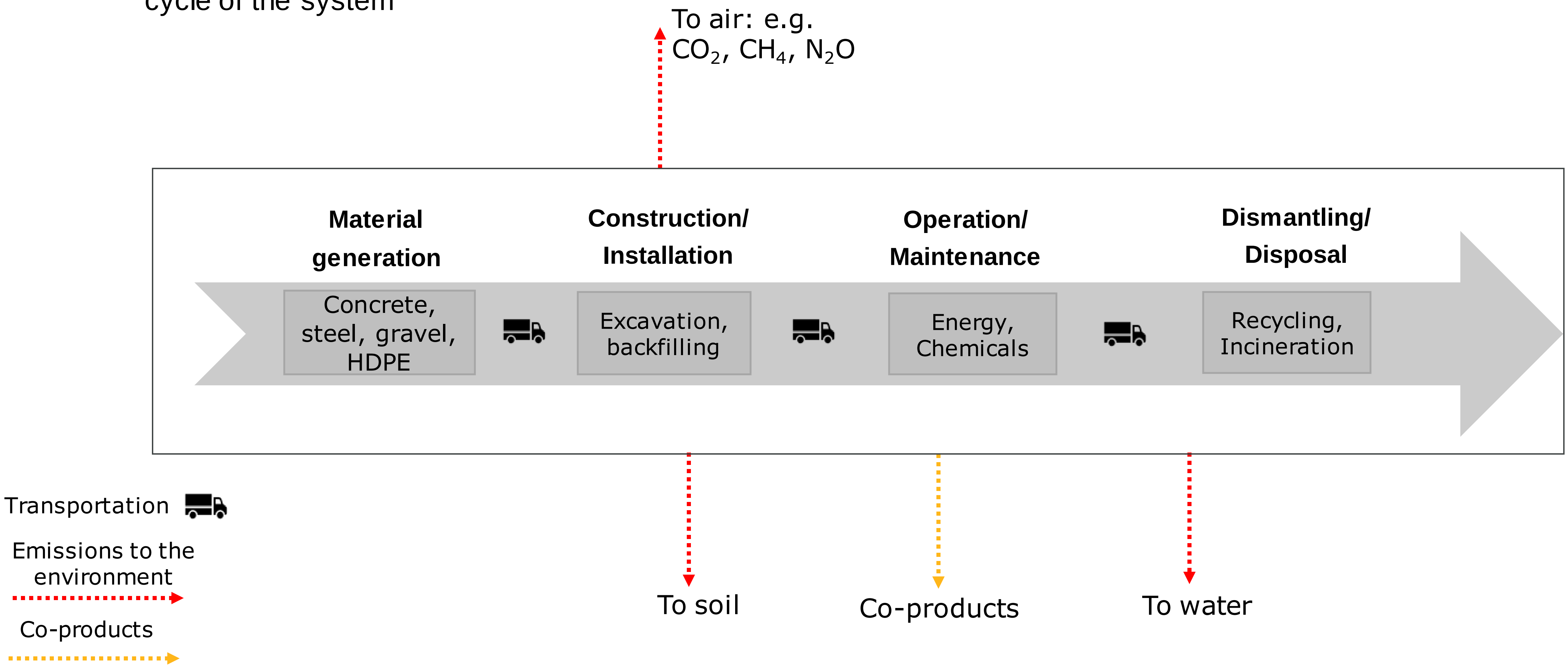
TRANSITIONING TO WATER RESOURCE RECOVERY FACILITIES

A CIRCULAR plant is not necessarily a SUSTAINABLE plant



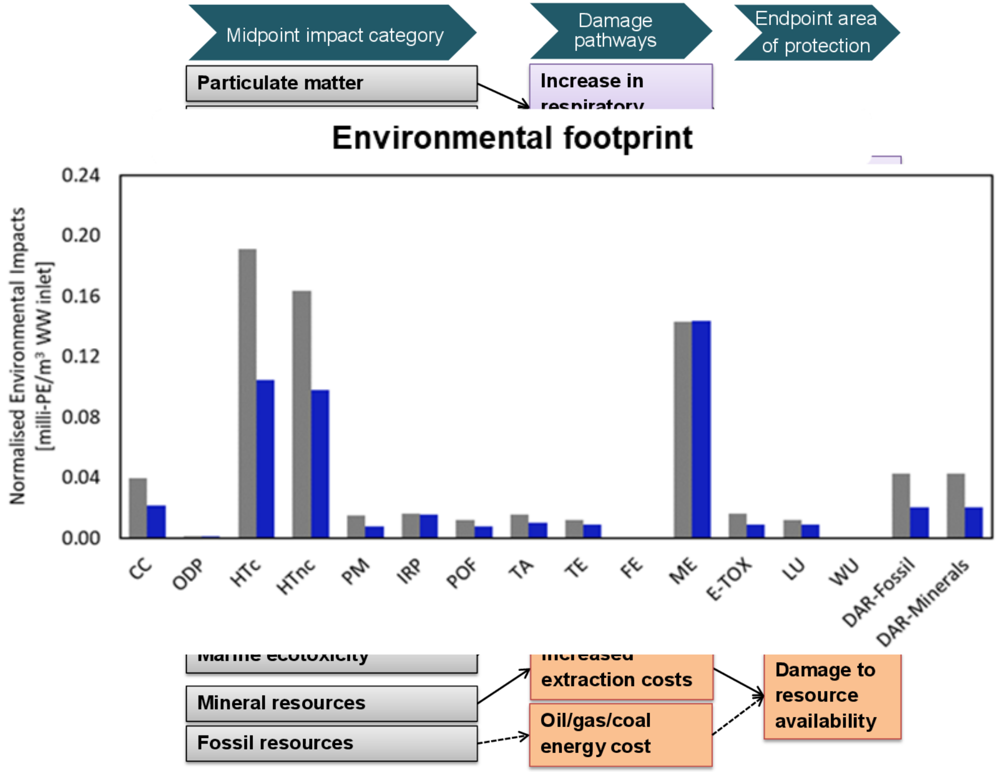
ENVIRONMENTAL IMPACT ASSESSMENT: LIFE CYCLE ASSESSMENT

Cradle to grave approach: Inventory of materials' consumption and emissions along the life cycle of the system



FROM CARBON FOOTPRINT TO A BROADER RANGE OF ENVIRONMENTAL INDICATORS

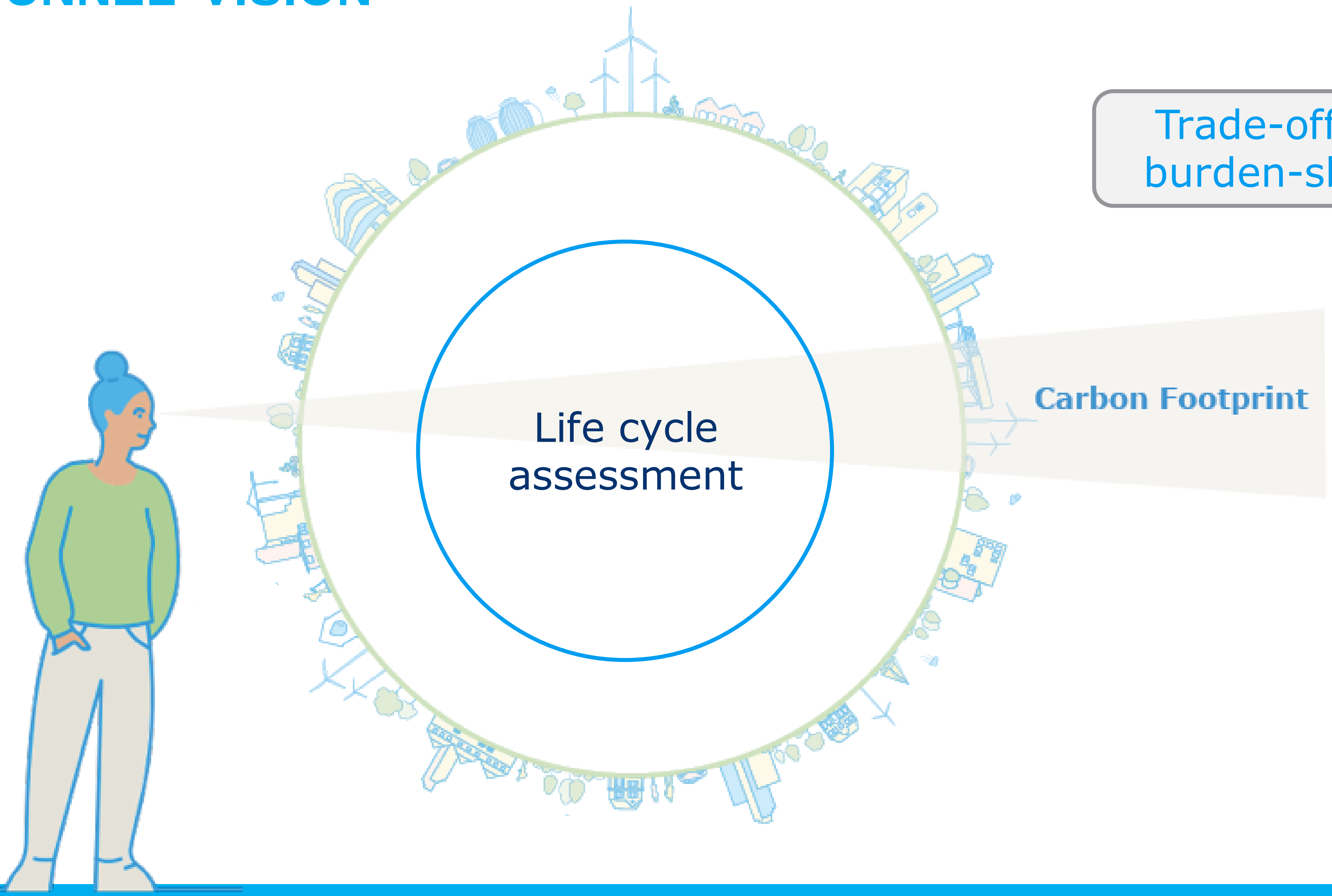
Cannot be used as a **single indicator** to track the environmental performance of WRRFs



Source: https://www.rivm.nl/en/life-cycle-assessment-lca/recipe

CARBON TUNNEL VISION

Trade-offs and burden-shifting



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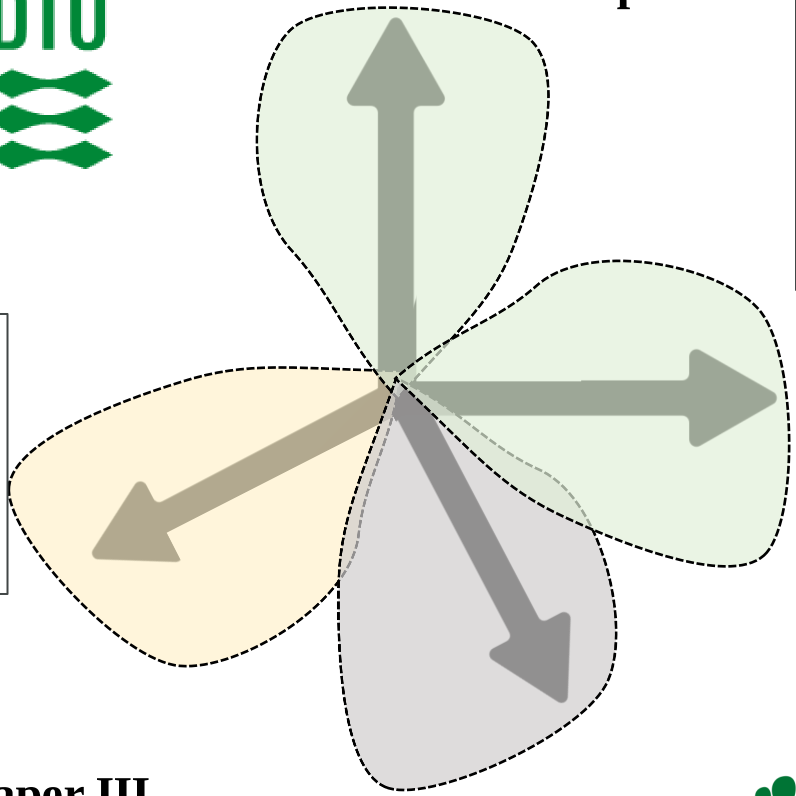

Paper I

Contents lists available at ScienceDirect
Journal of Environmental Management
journal homepage: www.elsevier.com/locate/jenvman
ELSEVIER
Research article

Challenges in carbon footprint evaluations of state-of-the-art municipal wastewater resource recovery facilities

Maria Faragò[a,*], Anders Damgaard[b], Morten Rebsdorf[c], Per Henrik Nielsen[d], Martin Rygaard[a]

Paper II

Contents lists available at ScienceDirect
Water Research
journal homepage: www.elsevier.com/locate/watres
ELSEVIER

From wastewater treatment to water resource recovery: Environmental and economic impacts of full-scale implementation

Maria Faragò[a,*], Anders Damgaard[b], Jeanette Agertved Madsen[c], Jacob Kragh Andersen[c], Dines Thornberg[d], Mikkel Holmen Andersen[e], Martin Rygaard[a]

Paper III

Environmental Science & Technology
pubs.acs.org/est
Article

Life Cycle Assessment and Cost-Benefit Analysis of Technologies in Water Resource Recovery Facilities: The Case of Sludge Pyrolysis

Maria Faragò,* Anders Damgaard, Ivana Logar, and Martin Rygaard

Paper IV

A multi-criteria sustainability framework to support decisions in technology choices in water resource recovery facilities

Maria Faragó[a], Anders Damgaard[b], Morten Rebsdorf[c], Martin Rygaard[a]*

- How can life cycle assessment (LCA) support decision-makers in selecting wastewater treatment and resource recovery technologies?

RETROFITTING AN EXISTING WWTP TO WRRF

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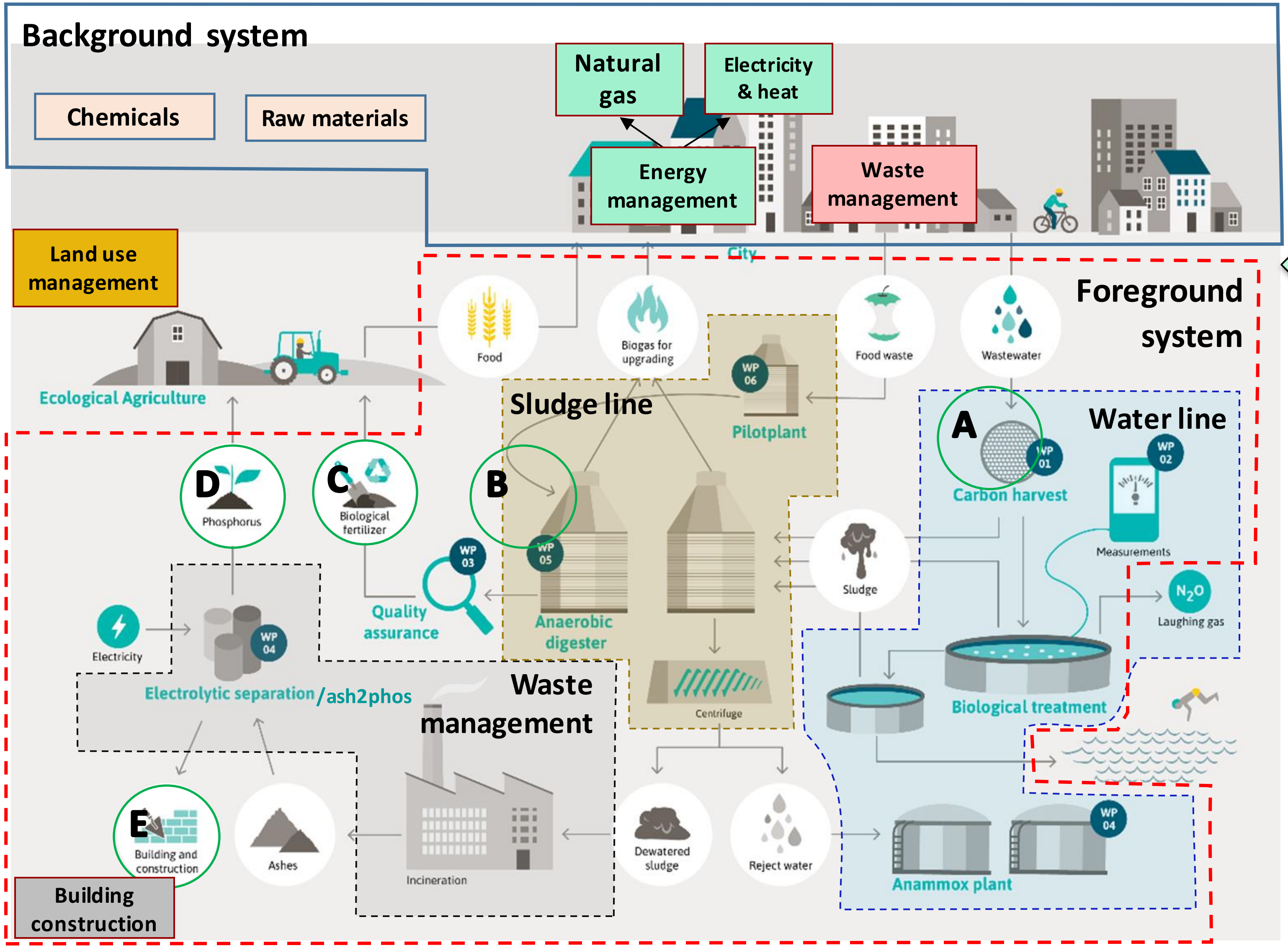
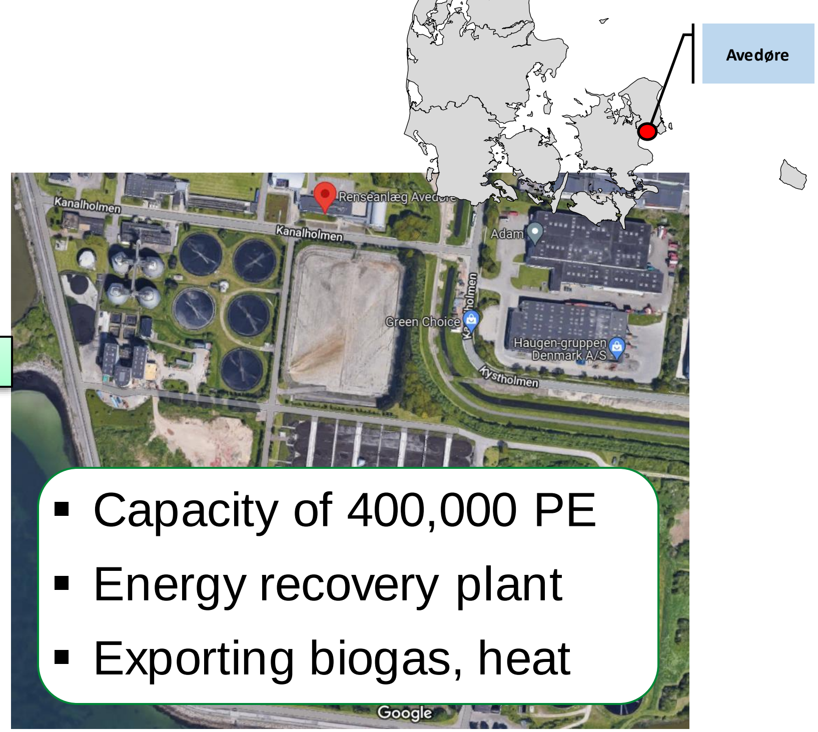


2025



- Capacity of 400,000 PE
- Energy recovery plant
- Exporting biogas, heat

- **Water line:** real-time measurement & control of N_2O, pre-filtration, anammox
- **Sludge line:** biogas upgrading + P2H
- **Waste management:** P, sand and chemicals recovery from sludge ashes

LCA OF RETROFITTING AVEDØRE WWTP TO A WRRF

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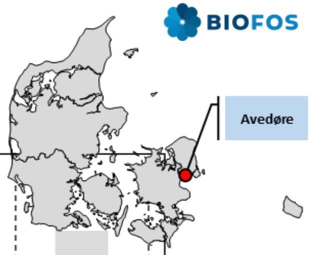
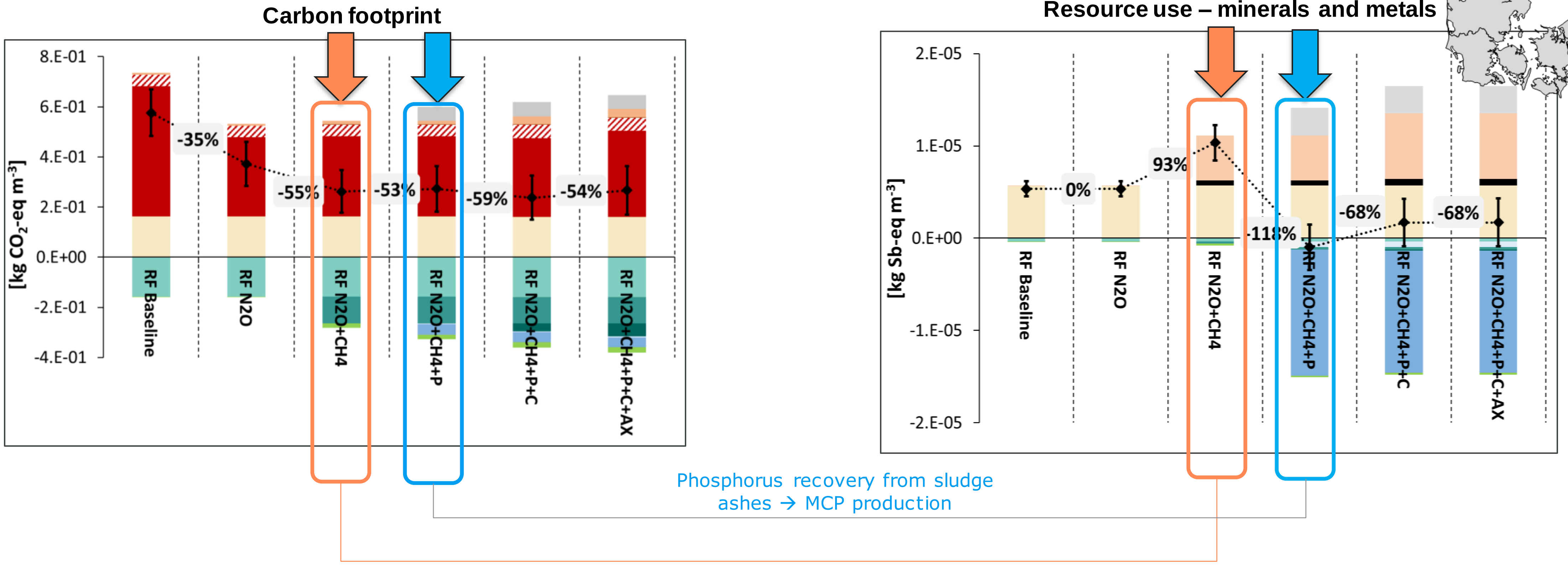




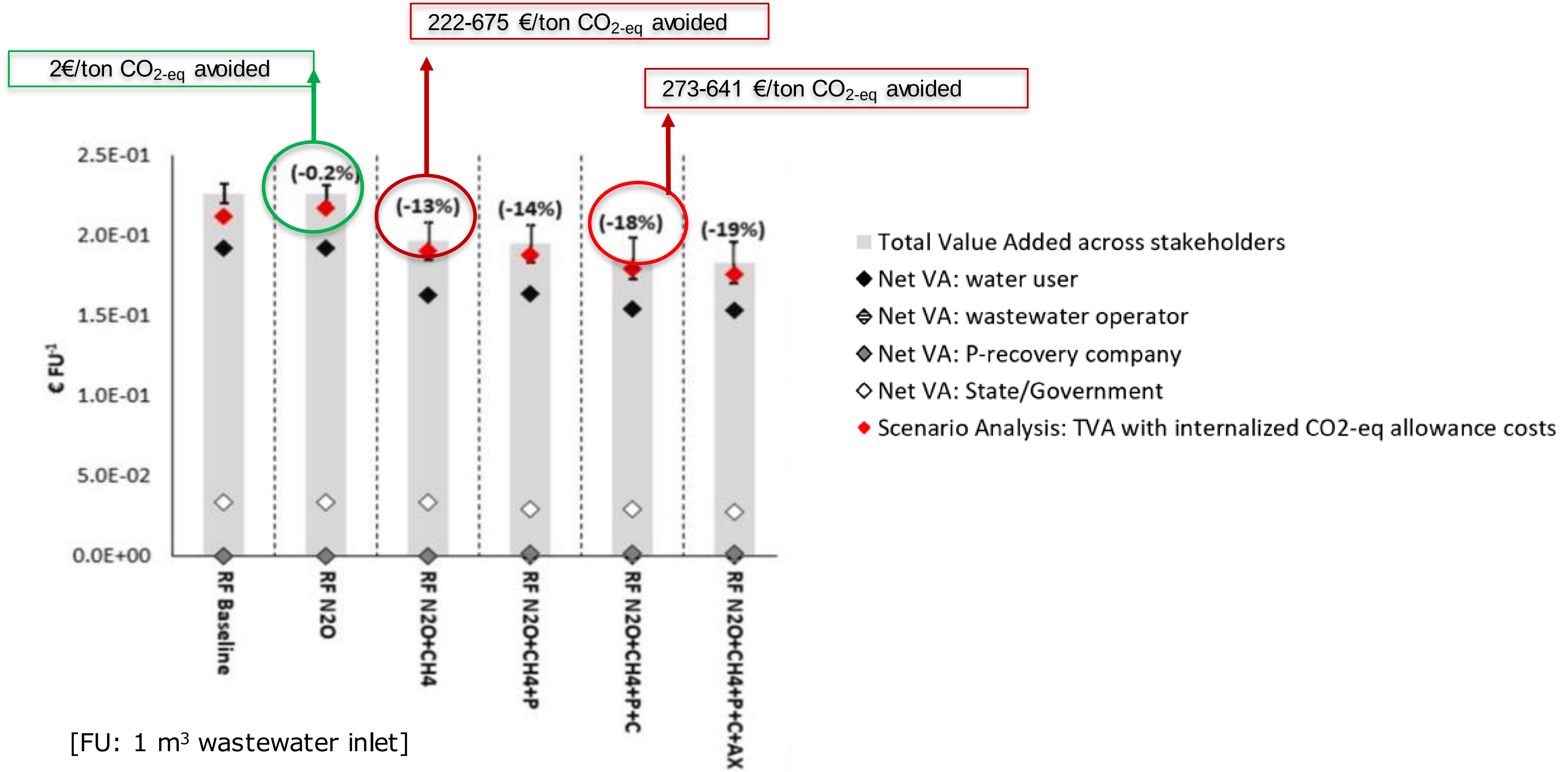
Phosphorus recovery from sludge ashes → MCP production

Hydrogen production
+ CO_2 from anaerobic digestion→ more biomethane

- Wastewater treatment: baseline operation
- GHG direct emissions: CH4
- GHG direct emissions: N2O
- P-recovery: other co-products substitution
- P-recovery: chemicals & electricity consumption, landfill and transp
- Materials: new infrastructures
- Others
- Discharge to sea: water pollution
- Biomethane --> Natural gas substitution
- Neomethane (P2H) --> Natural gas substitution
- Additional bio- and neomethane (pre-filtration)
- P-recovery: Monocalcium phosphate (MCP) substitution
- Heat substitution
- Net impacts

Source: Faragò, M., Damgaard, A., Madsen, J. A., Andersen, J. K., Thornberg, D., Andersen, M. H., & Rygaard, M. (2021). From wastewater treatment to water resource recovery: Environmental and economic impacts of full-scale implementation. *Water Research*, *204*, 117554.

ECONOMIC IMPACTS AND CO_2-ABATEMENT COSTS



[FU: 1 m^3 wastewater inlet]

- The TVA decreased with the implementation of resource recovery technologies by 19**%, <u>primarily due to the increase in operational costs (+70%)</u>** that counterbalanced **<u>the increase in revenue (+26%).</u>** The real-time measuring and control of N2O emissions was the cheapest technology.
- Internalising the CO_2-eq emissions did not significantly decrease the TVA in RF-Baseline suggesting that the current CO_2-eq allowance price is either too low or that wastewater operator should take further actions to reduce emissions.

CONCLUSIONS

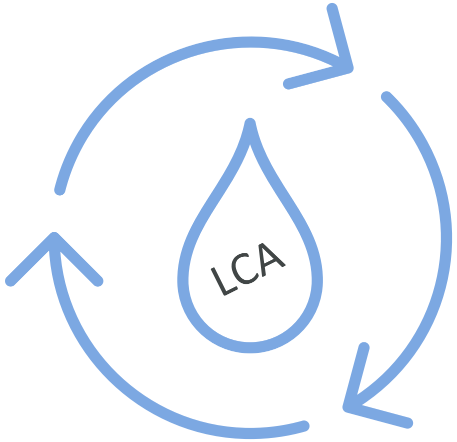
CLIMATE SMART UTILITIES

In general, **retrofitting** the existing Avedøre WWTP **to WRRF decreased the environmental impacts** with a few exceptions e.g. freshwater eutrophication

The **interplay of different types of technologies** was **the key to decrease impacts**: e.g. P2H+biomethanation, decreased climate change impacts while increased the demand of mineral resources. The increase in this category, was overcome by the implementation of P-recovery technology.

The **economic value** of the WRRF decreased by app. 20% compared to baseline. However, some technologies were cheaper than others. Especially **real-time monitoring and control of N_2O** did not significantly decrease the economic value and **was most effective to reduce direct GHG emissions** (up to 40%).

THANK YOU!



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SPECIAL THANKS GO TO ALL THE PROJECT PARTNERS AND THE DANISH ENVIRONMENTAL PROTECTION AGENCY FOR FUNDING THE VARGA PROJECT

Thanks to Rambøll for funding the time spent at the webinar and the preparation

Case study – Sustainability as a driver for Aarhus ReWater

JACOB KRAGH ANDERSEN, ENVIDAN / INGE HALKJÆR JENSEN, AARHUS VAND

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REWATER PROSPECTUS

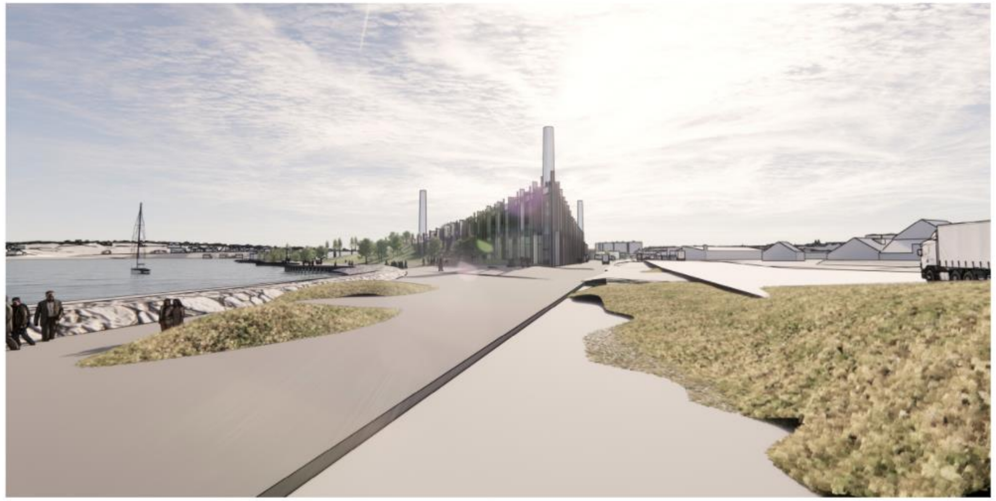
- New WRRF by 2028 - capacity 480.000 -> 600.000PE
- Three old WWTPs will be decommissioned
- Huge focus on resource recovery, sustainability and innovation

Aarhus ReWater

The World's Most Resource Efficient Wastewater Treatment Plant

Aarhus ReWater—a trailblazer in resource utilisation

A NEW RESOURCE AND WASTEWATER TREATMENT PLANT CLOSE TO MARSELISBORG WILL BE AN INTERNATIONAL TRAILBLAZER IN RESOURCE UTILISATION AND SUSTAINABLE TREATMENT OF WASTEWATER.



The plant, which is expected to be completed in 2028, will become known as Aarhus ReWater and replaces Marselisborg Wastewater Treatment Plant, which in a few years will have too little capacity to treat wastewater from a rapidly increasing number of citizens in Aarhus.

In addition to treating wastewater, the plant must produce surplus energy and utilise the resources in the wastewater. In future, it will also be possible to produce nutrients, proteins, food, chemicals, and essentials for the healthcare industry from wastewater.

With its location close to the city and the sea, Aarhus ReWater also becomes a beautiful landmark for everything we can achieve at Aarhus Vand.

Three visualisations of what the plant may look like.

READ MORE ABOUT AARHUS REWATER HERE

REWATER: PROJECT ORGANISATION

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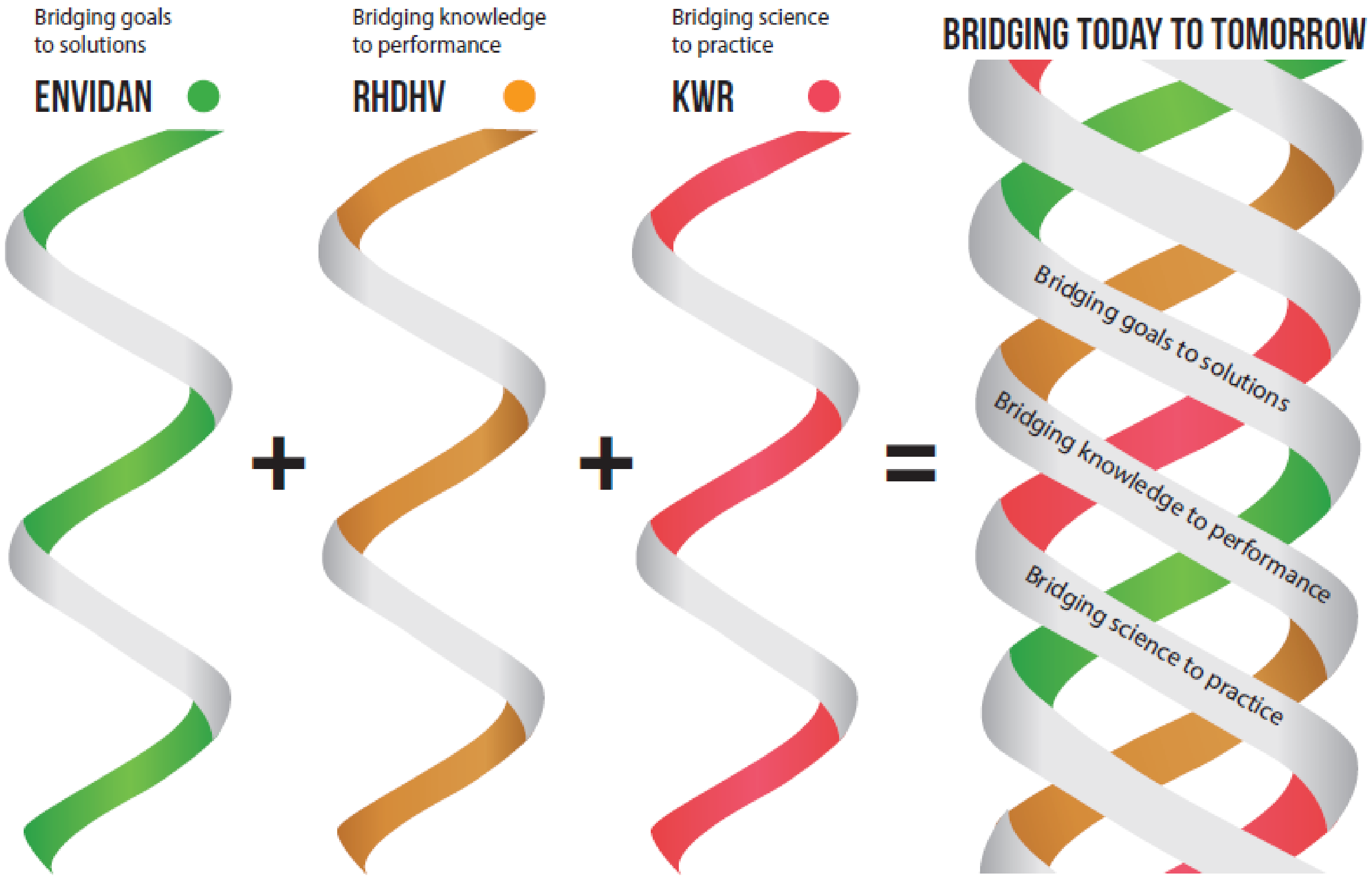
Envidan | Royal HaskoningDHV Enhancing Society Together | KWR



+ aarhusvand

+ AARSLEFF

Figure 1: Triple helix DNA - the process consortium's innovation partnership 'Bridging today to tomorrow.'

GUIDING STARS – TOWARDS 2060

Scenario: Stay Cool

Marselisborg Renseanlæg viser vejen for en energipositiv og klimaneutral vandsektor

Our promises

- Net energy production is pushed to the next level, creating more added value.
- All greenhouse gas emissions will be prevented and/or eliminated.
- Positive impact by implementation of solutions for cabon capturing concepts.

Scenario: Resourceful

Slam fra aarhusianske renseanlæg omdannes til næringsrig biokoks og aktivt kul

Our promises

- Application of technologies that will not downgrade or mix resources.
- Wastewater treatment is optimized for the production of valuable products.
- All outlets are valuable and this will be recognized by market and society.

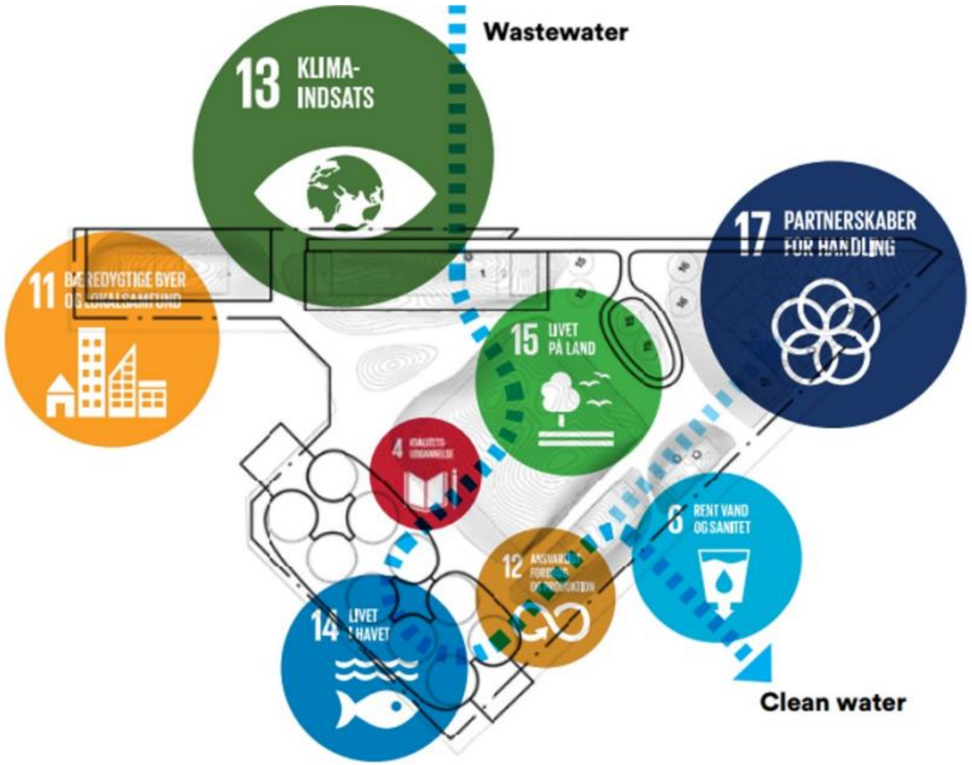
Scenario: Valuing Water

Our promises

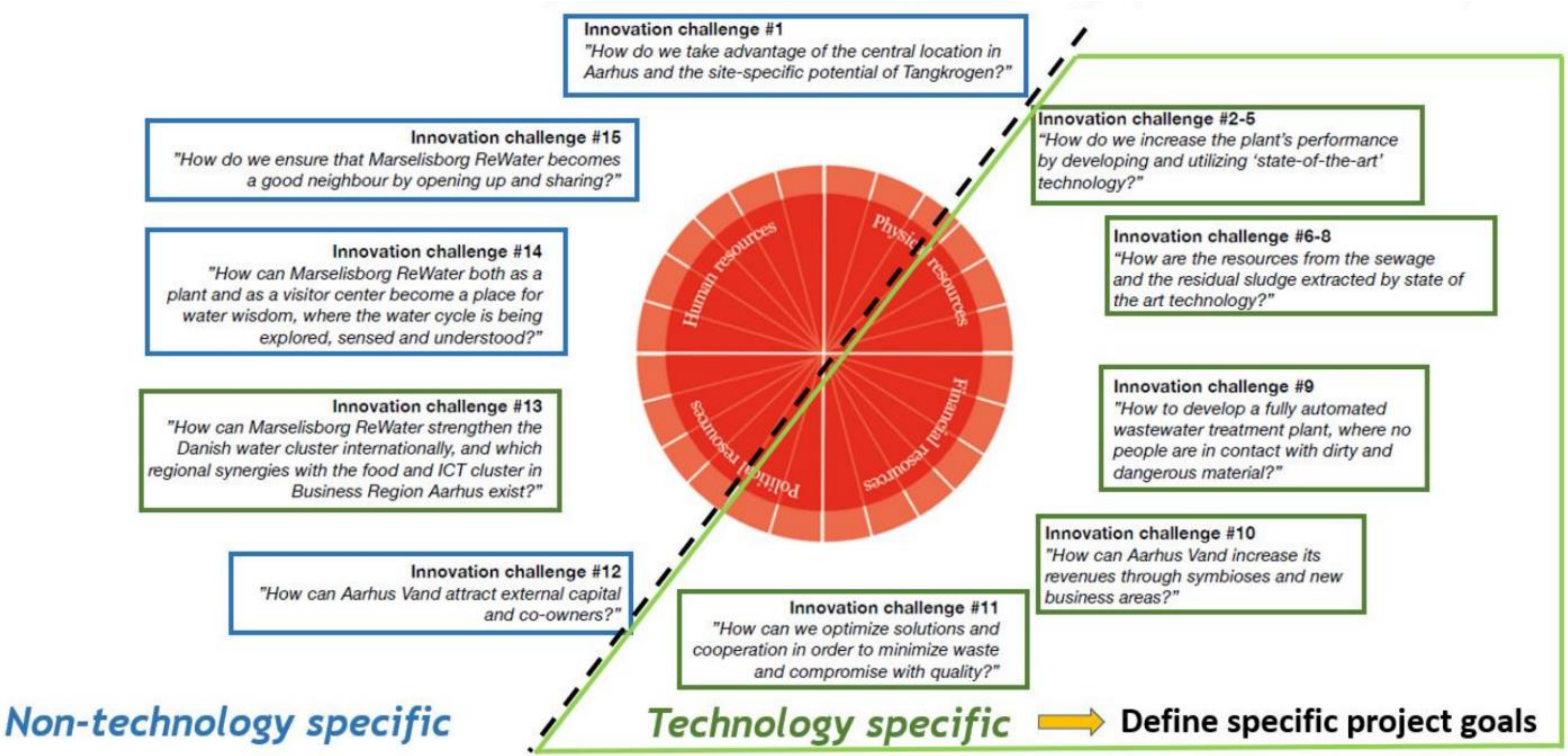
- Improve the quality of ecosystems with a positive impact on biodiversity.
- Taking full responsibility to minimize impact of the city on receiving waters.
- Continuous exploration for finding ocassions for water reuse from effluent.

Photos: WWW.aarhusvand.dk/cases/spildevand/marselisborg-renseanlaeg

SUSTAINABILITY – UNSDG AS A STARTING POINT

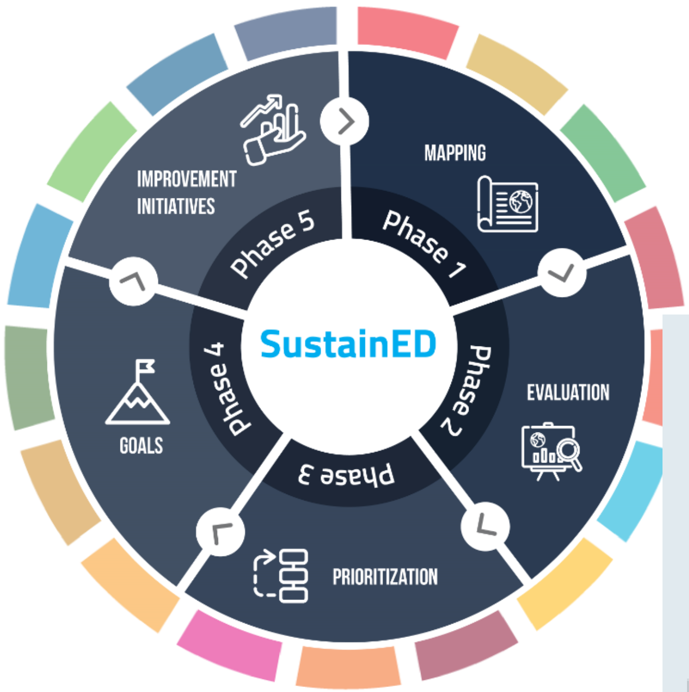


INNOVATION CHALLENGES

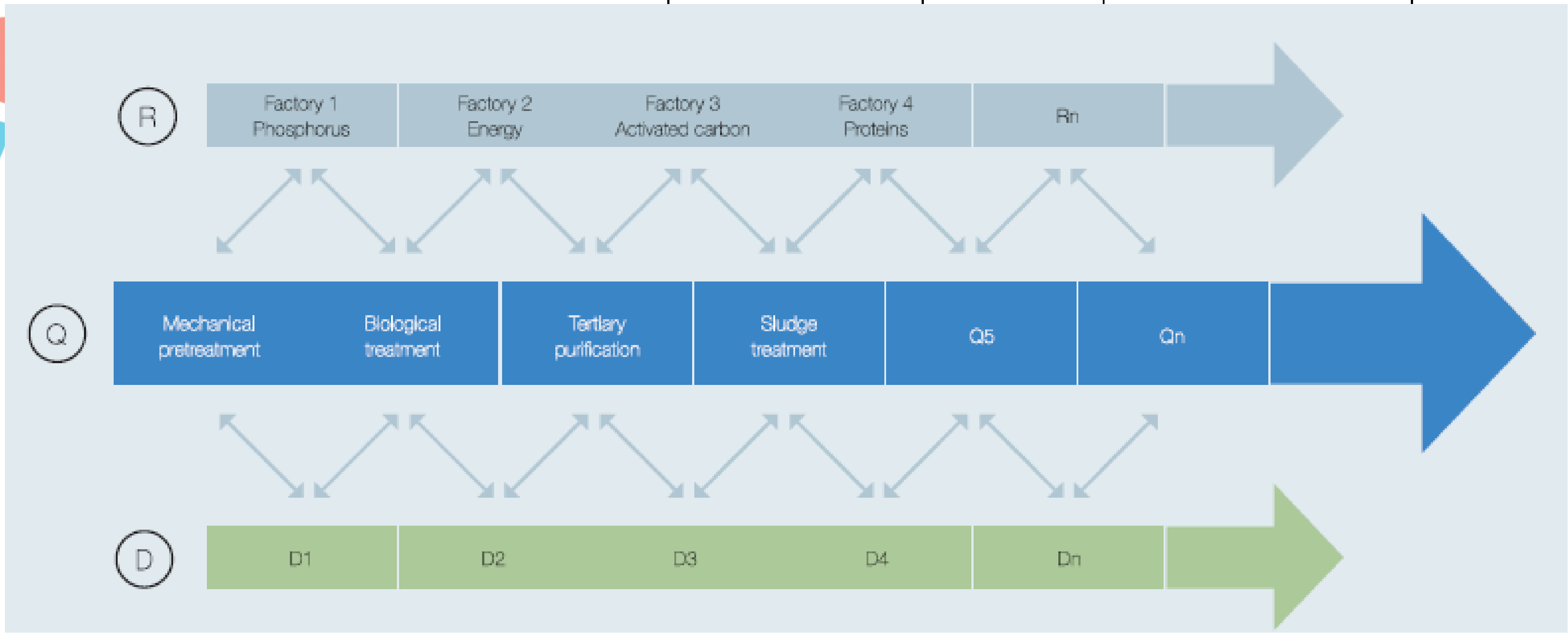


SETTING GOALS BEFORE SELECTING TECHNOLOGIES

IWA the international water association — CLIMATE SMART UTILITIES

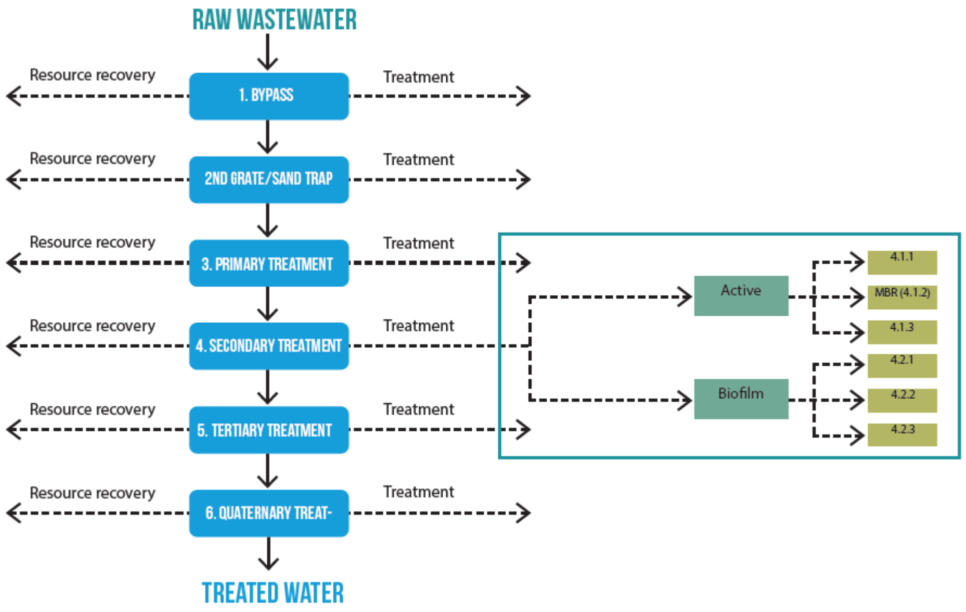


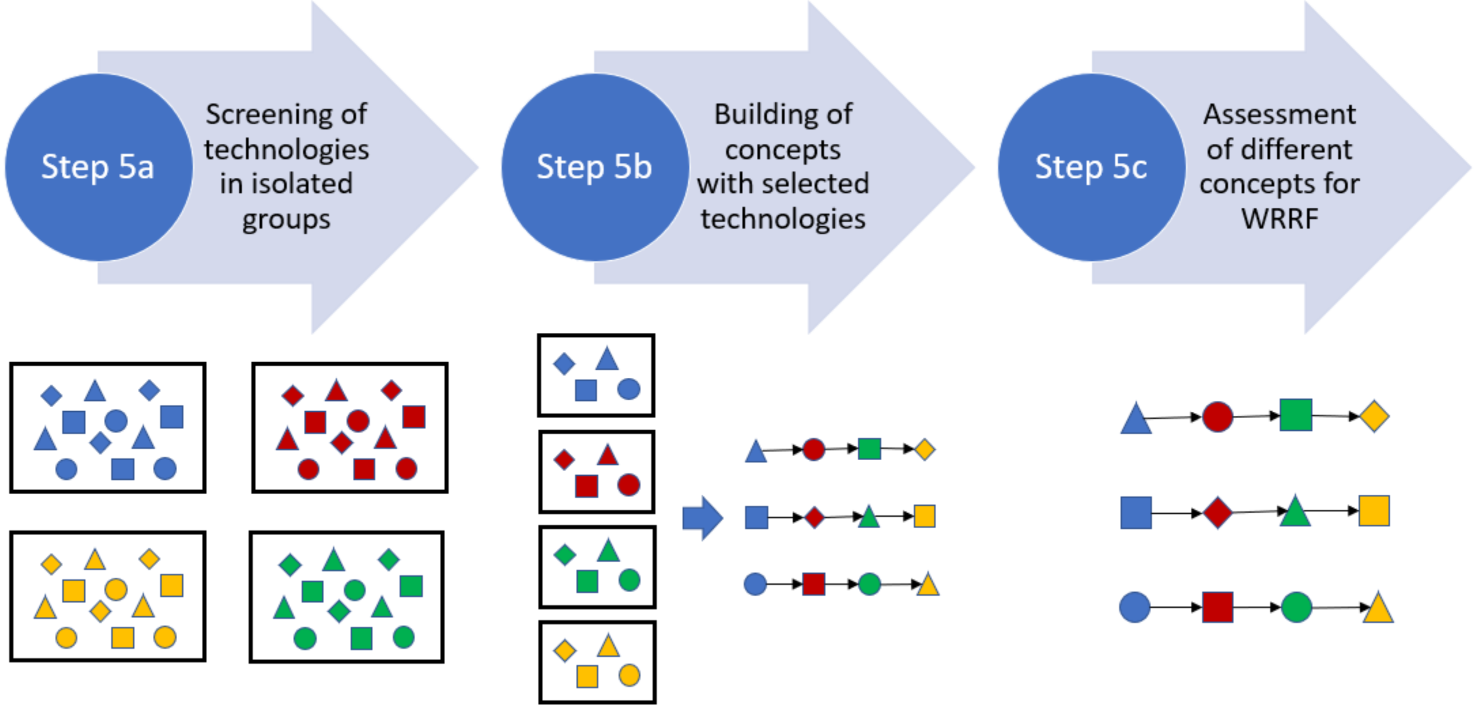
UN-SDG	UNSDG sub-goal	Innovation Challenges, AAV ReWater	ReWater specific project goals
13 CLIMATE ACTION	**#13.2** Integrate climate change measures into national policies, strategies and planning	#4 How do we achieve energy and CO_2 neutrality in the water cycle throughout Marselisborg's catchment?	**Operation phase:** #4.1: Energy neutral Marselisborg catchment (= xxx % net energy for ReWater). Operational phase. #4.2: CO2 neutral Marselisborg catchment (= xxx % net CO2 for ReWater). Operational phase.



FROM SINGLE TECHNOLOGIES TO CONCEPTS

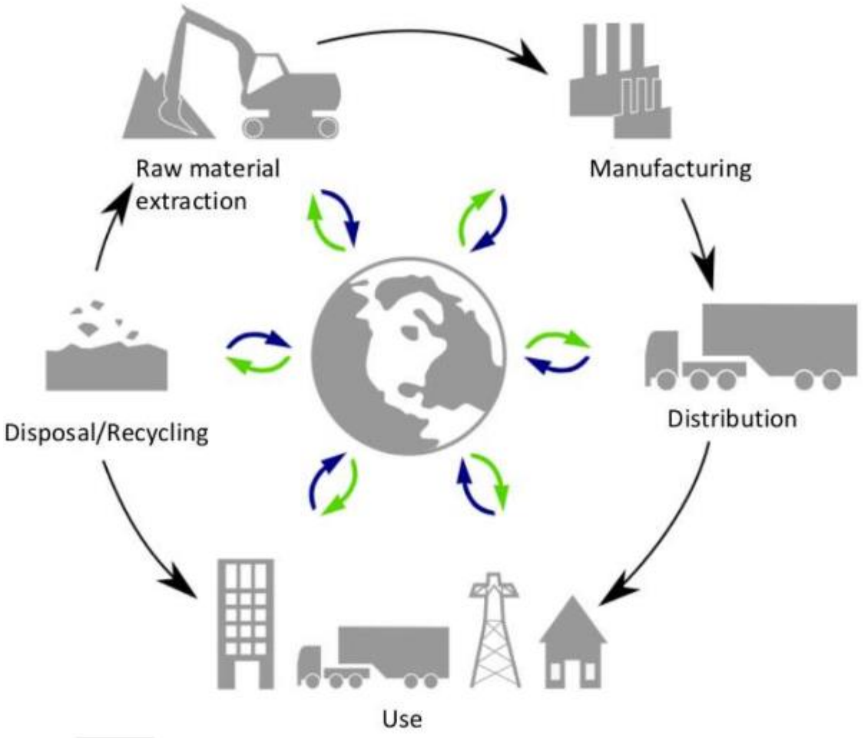
BAT-catalogue

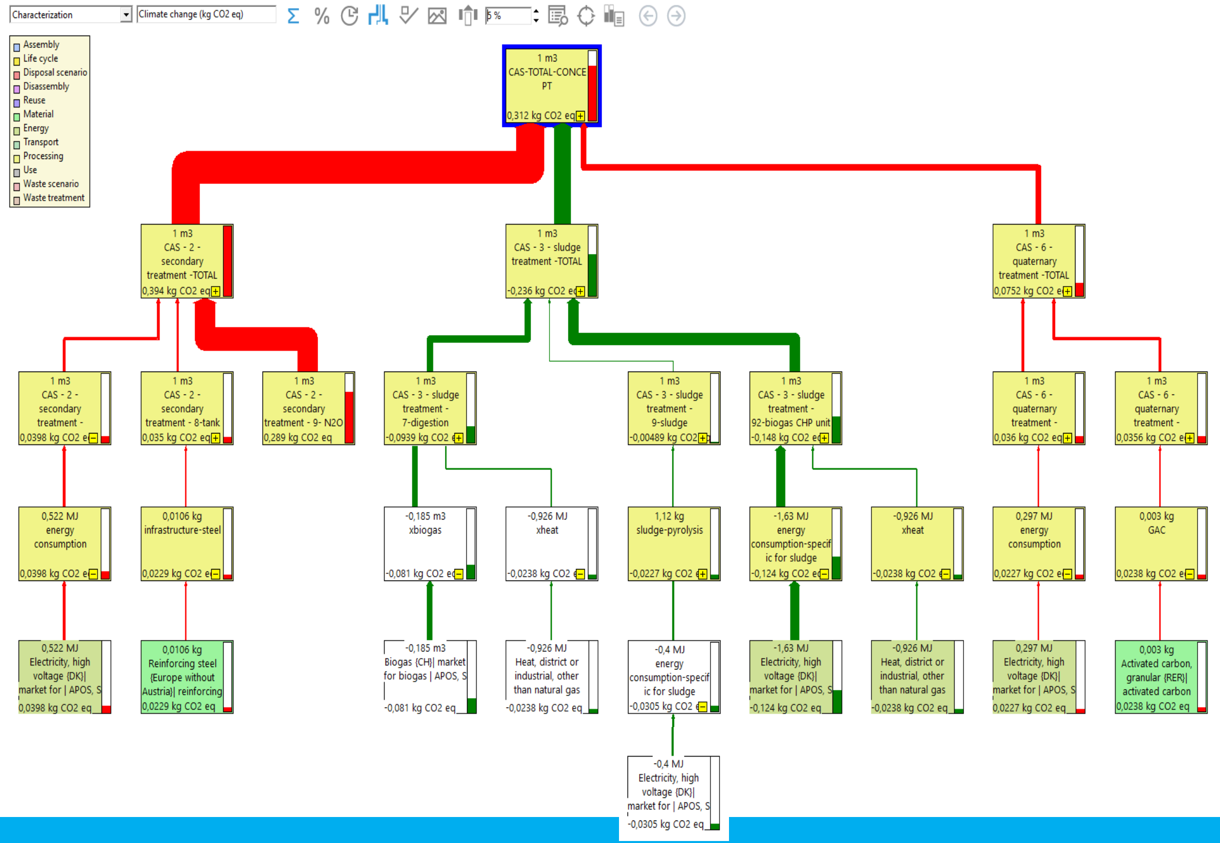




LIFE CYCLE ASSESSMENT (LCA)

- Holistic and standardised method for assessing the environmental load throughout the entire lifetime of a product / technology / system
- Decision supporting tool





MULTICRITERIA ANALYSIS (MCA)

- Concepts evaluated by MCA, including criteria on:
  - Environmental sustainability (LCA)
  - Economical sustainability (TOTEX)
  - Social sustainability
  - + more technical criteria

- Next phase will focus on:
  - Green areas
  - Wetlands
  - Covered plant with vegetation on the roof
  - Health and safety

Criteria		Normalized score (0-1)				Weight (%)	Result = Weight x Normalized score			
	Concept	BL*	A	B	C		BL*	A	B	C
Environment	Better treatment than discharge limits									
	Eutrophication potential									
	Depletion of resources									
Climate change										
Resource recovery potential										
Economy										
Complexity										
Adaptability, Modularization, and Flexibility										
Total										

BREEAM CERTIFICATION

- A holistic sustainability assessment framework, measuring sustainable value in 8 categories and validating this performance with third-party certification
- ~250 criteria to be evaluated

WPA-v6.0 (PA - Int)

CEEQUAL® delivered by bre

MENT - PRE-ASSESSMENT SPREADSHEET VERSION 6

Doc No: CS216-0.0

Date: 01-10-2019

ReWater

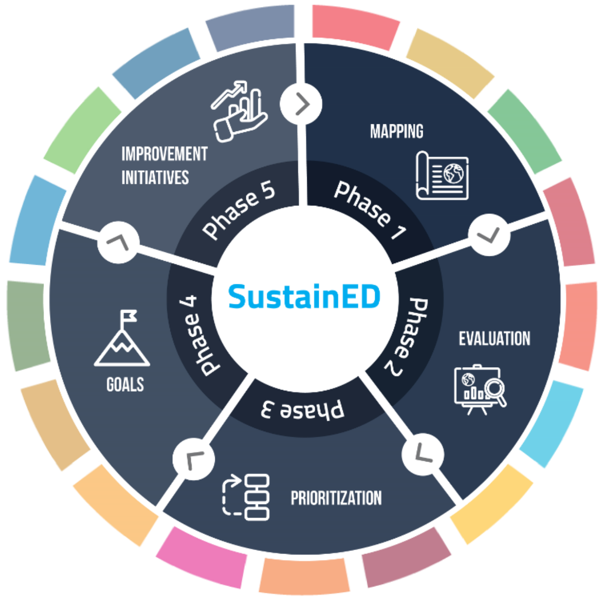
rmation Sheet along with all other background information

Section and Ques No.	Section Titles & Criteria	Scope Out?	Initial Assess. Score as at dd/mm/yy	Evidence for scores awarded or reason for scoping out	Potential Score Still to Come	Evidence Required to achieve Potential Score	Potential Final Score
Section 1 - Management							
1.1.1	The project team has actively considered the principles of sustainable development in the planning, design, and construction of the project.	FIXED	35	• AAV and HLA framework with SDG • Material from workmeetning 01			35
1.1.2	The project team has actively adopted a sustainability-driven approach to the development of the construction management plan for the project.	FIXED	11				11
1.1.3	The selection process for (i) the principal Designer, (ii) the principal Contractor, and (iii) the key sub-contractor(s) included past environmental and social performance as one of the evaluation criteria.	N	12				12

SUSTAINABILITY (LANDSCAPE)

SUMMARY + WAY FORWARD IN REWATER

- Utilities set focus on sustainability upfront
- Work systematic and holistic with sustainability during project execution:
  - Spent time on setting specific project goals (ambitious but realistic)
  - Acknowledge the iterative process selecting technologies fulfilling the specific project goals
  - Use a multicriteria analysis for evaluating concepts (LCA, TOTEX etc.)
- Consider certification scheme like BREEAM
- Resource recovery
- **Aarhus ReWater:** next design phase still full focus on sustainability, innovation and resource recovery



THANK YOU!

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ACKNOWLEDGMENTS:

WHITE PAPER: GREENHOUSE GAS EMISSIONS AND WATER RESOURCE RECOVERY FACILITIES

International Water Association | The Source | IWA Connect Plus | IWA Publishing

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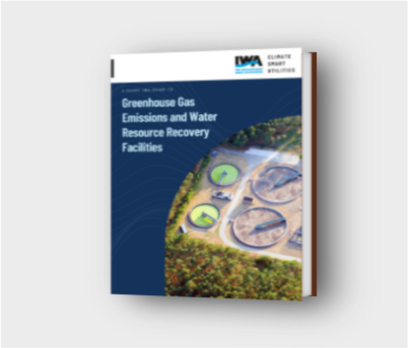

DOWNLOAD PUBLICATION

SEPTEMBER 25, 2023 IWA Climate Change Environment Wastewater

Climate Smart Utilities: Greenhouse Gas Emissions and Water Resource Recovery Facilities

IWA is pleased to present a new short guide on Greenhouse Gas Emissions and Water Resource Recovery Facilities produced by the IWA Climate Smart Utilities GHG sub-group.

As humanity faces the looming challenges of global heating and irreversible tipping points such as increasingly frequent and record-breaking heatwaves and flooding, it is crucial for the water sector to accurately establish baselines and effectively reduce its greenhouse gas emissions (GHG). These actions are integral to global efforts aimed at achieving the critical objective of limiting global warming to within 1.5 degrees Celsius above pre-

Download at https://iwa-network.org/publications/greenhouse-gas-emissions-and-wwrfs/

WITH HUGE THANKS TO CONTRIBUTORS!

the international water association CLIMATE SMART UTILITIES

- **With thanks to contributors:**

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- **IWA Secretariat team**

  Benedetta Sala, Brenda Ampomah, and Charles Joseph

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IWA the international water association CLIMATE SMART UTILITIES

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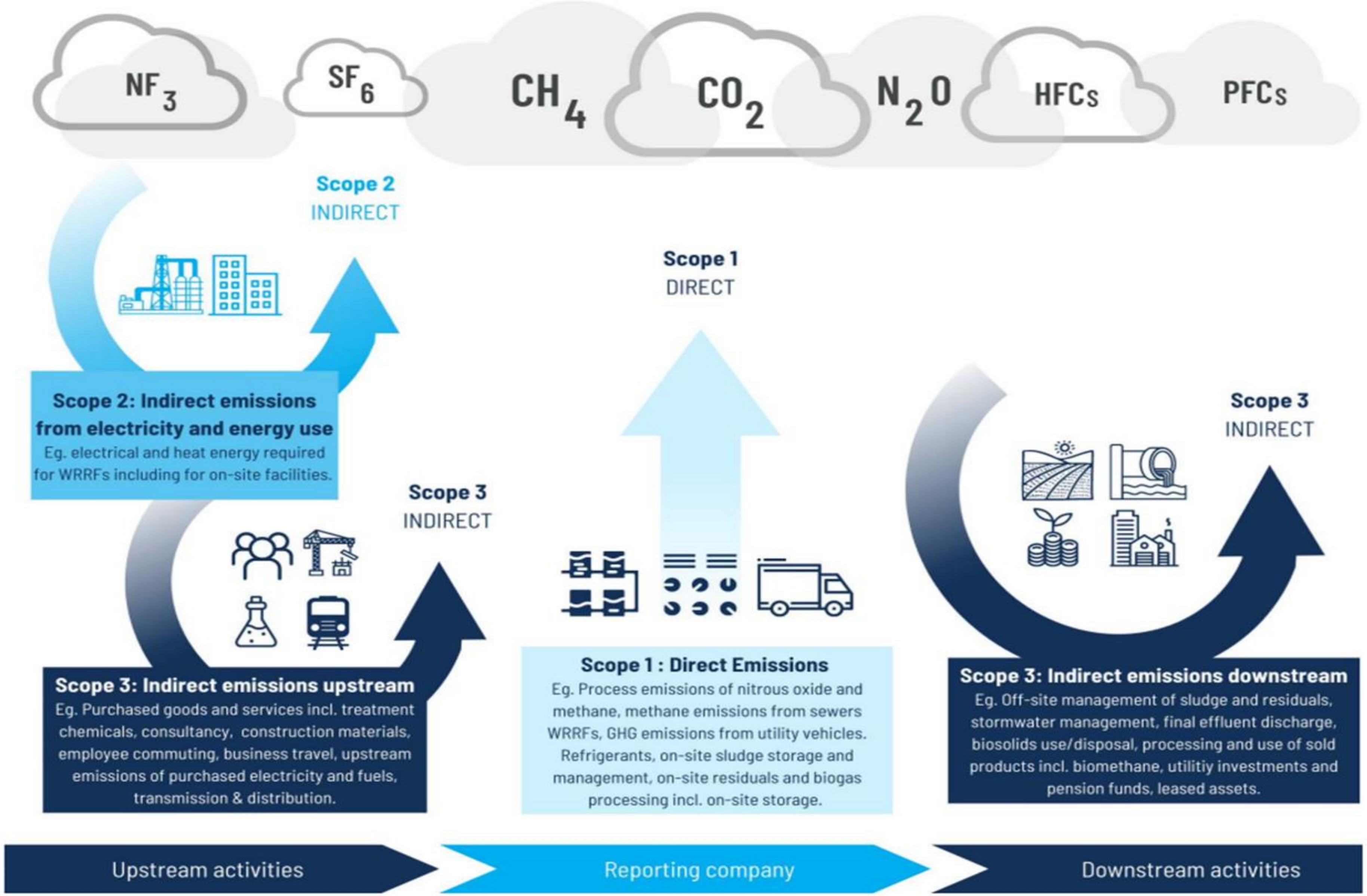
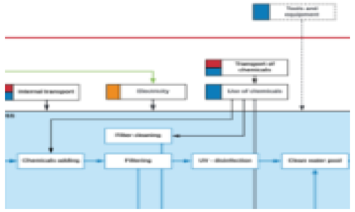


CLIMATE SMART UTILITY-BERGEN WATER

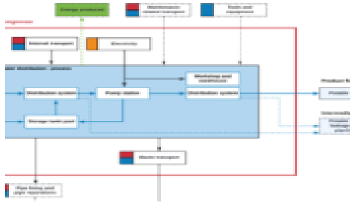
the international water association CLIMATE SMART UTILITIES

- Bergen Water - International Water Association (iwa-network.org)



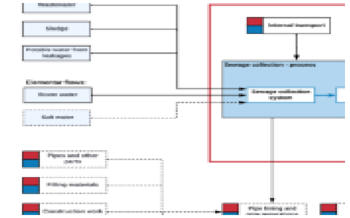
Carbon footprint 1

Product System Water Treatment



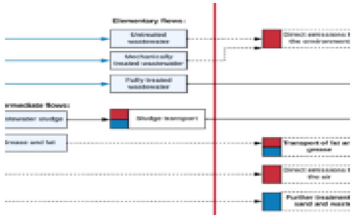
Carbon footprint 2

Product System Water Distribution



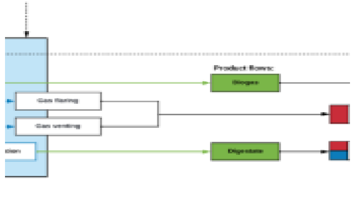
Carbon footprint 3

Product System for Sewage Collection



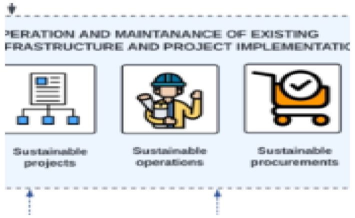
Carbon footprint 4

Product System for Sewage Treatment



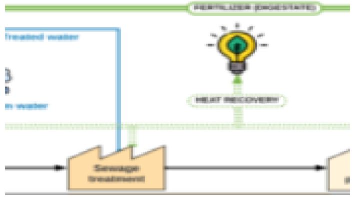
Carbon footprint 5

Product System for Biogas Production



Processes

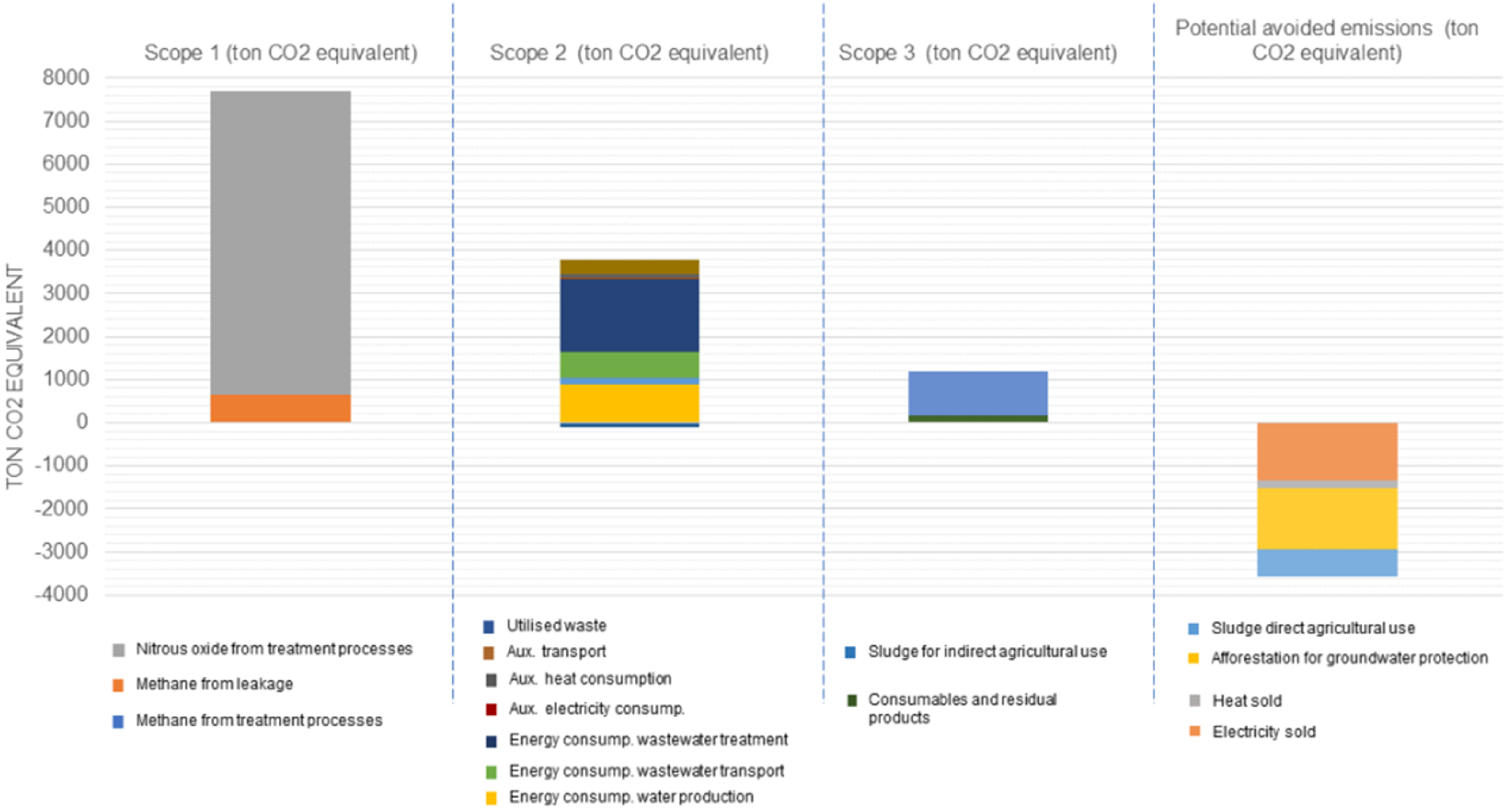
Climate & Energy



Product Value Chain

Climate & Energy

CLIMATE SMART UTILITY-AARHUS VAND



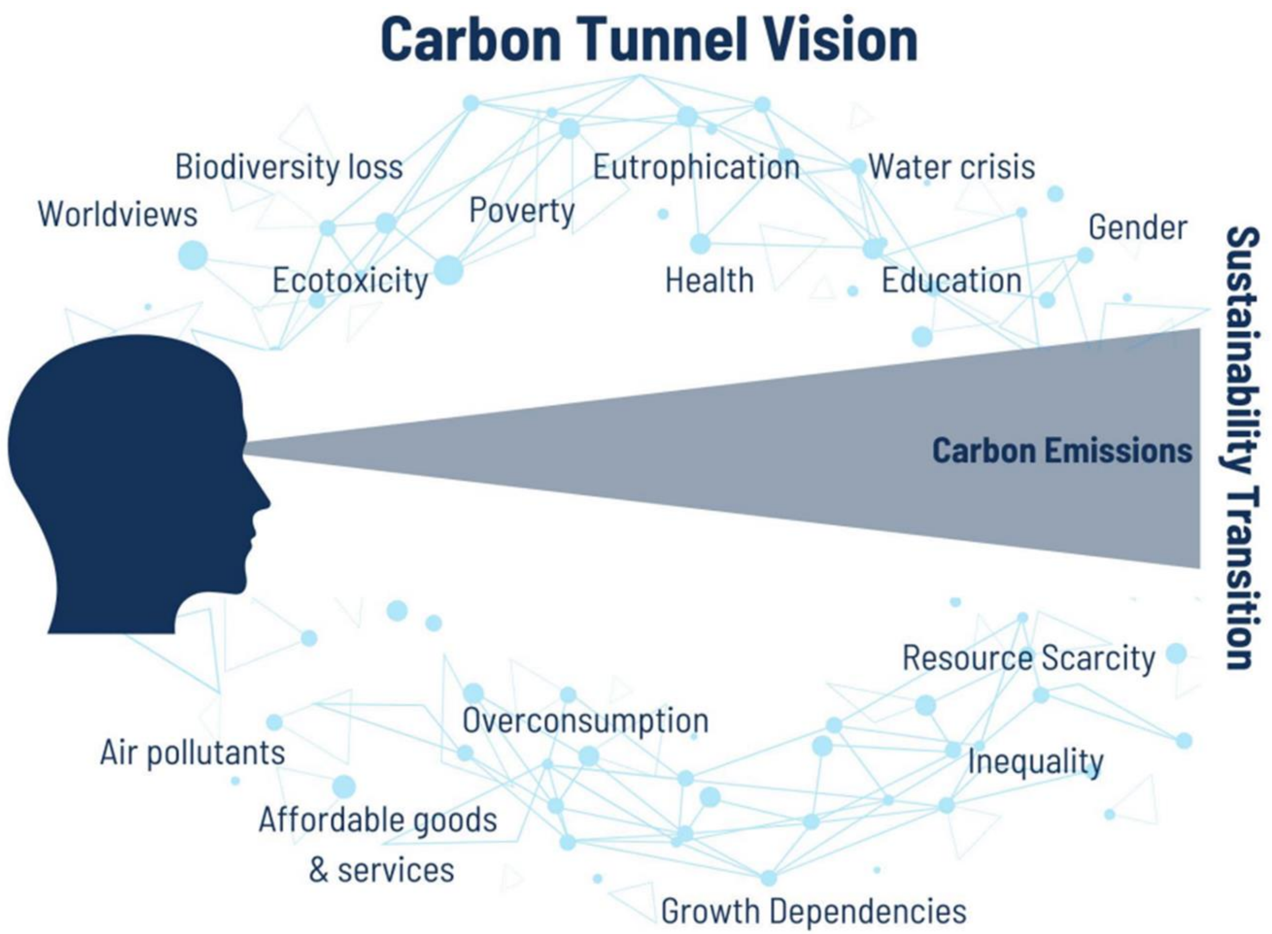
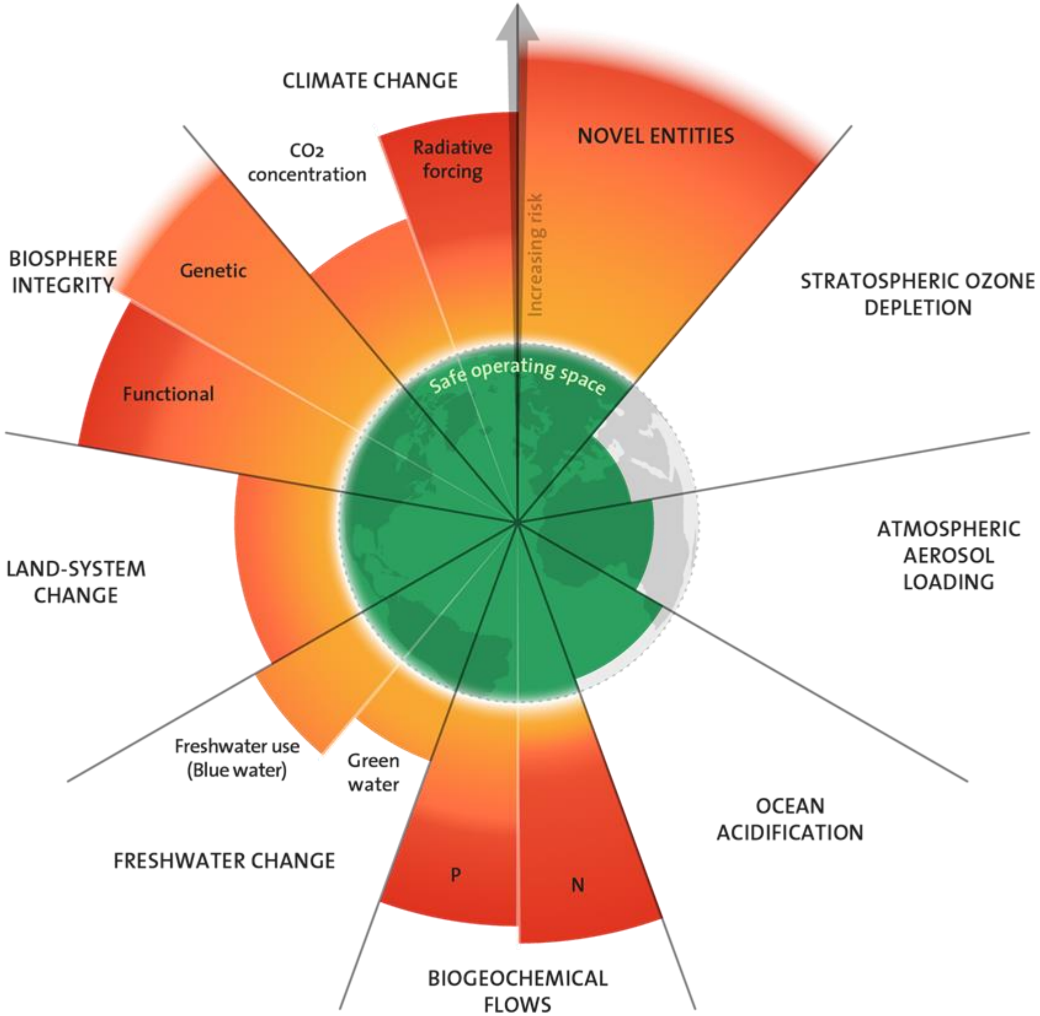


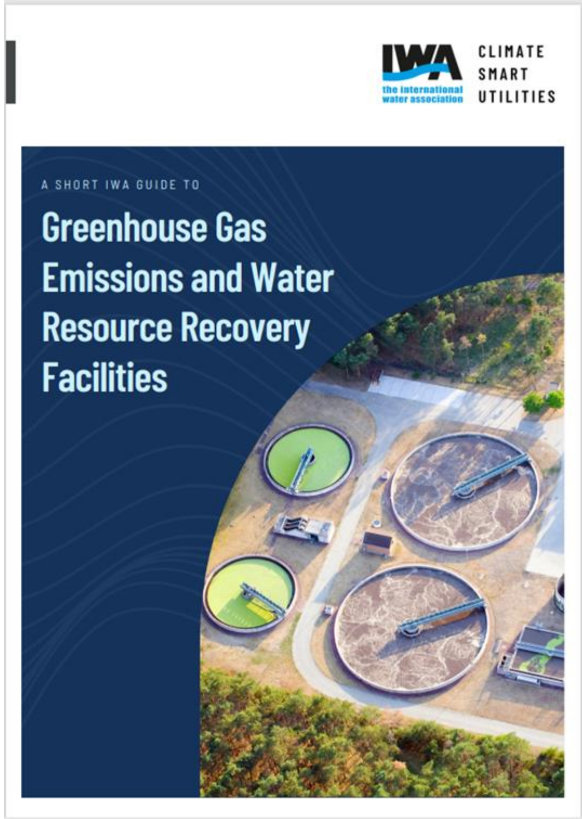
Figure 5: Risks of Carbon Tunnel Vision - adapted from figure by Jan Konietzko (Cognizant, 2021)

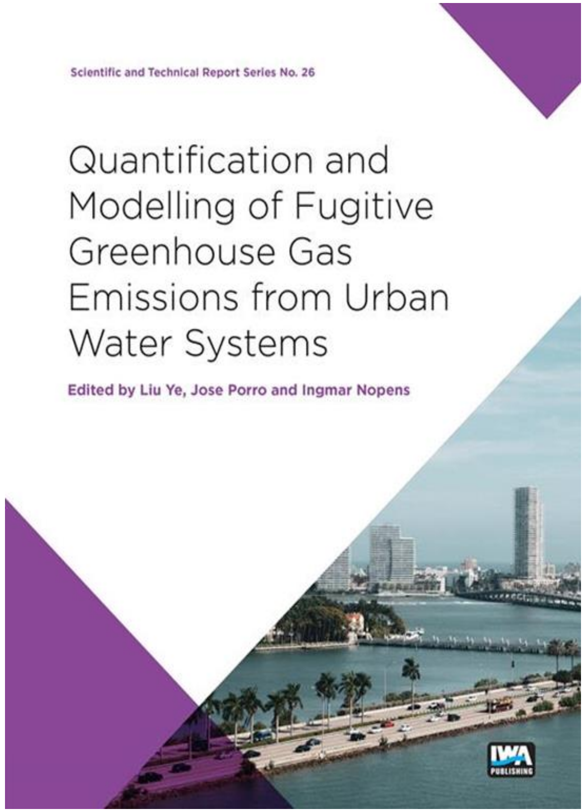
FROM PROCESS EMISSIONS TO PLANETARY BOUNDARIES

- https://www.stockholmresilience.org/research/planetary-boundaries.html



THANK YOU FOR YOUR CLIMATE ACTION TODAY





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CLIMATE SMART UTILITIES

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PHD OPPORTUNITY

- IHE Delft Institute for Water Education (and the University of Amsterdam) is offering a fully funded 4-year position in the field of **Financing Climate-Resilient Water Utilities.**
- The PhD project on will focuses on the ability of water utilities to become climate resilient.
- Nakuru Water and Sanitation Services Company (NAWASSCO) and the Addis Ababa Water and Sewerage Authority (AAWSA)
- The Application Deadline: 1 November 2023.
- For more information https://join.un-ihe.org/vacancy-publication/phd-candidate-in-financing-climate-resilient-water-utilities

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