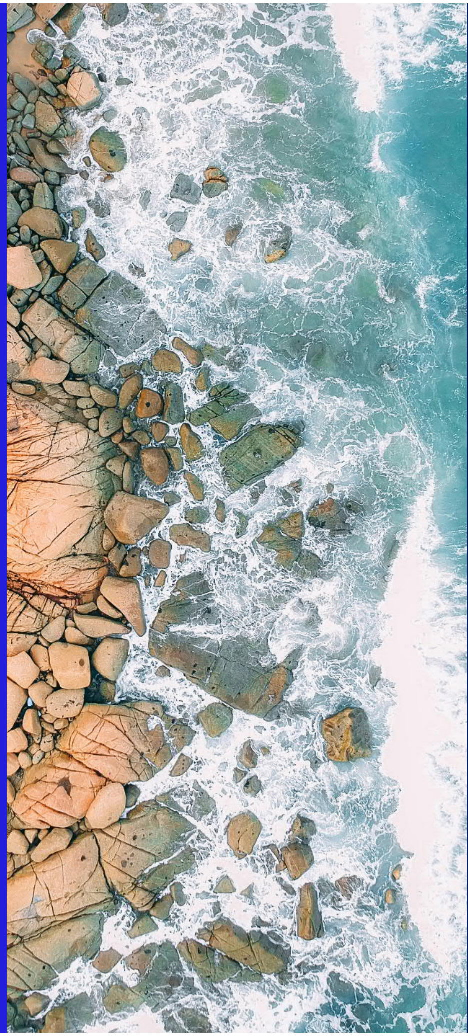
Net-Zero Roadmap: How Water Resource Recovery Facilities Contribute to the Overall Decarbonization Strategy

In the kNOW Webinar Series

September 15, 2021



Challenging today. Reinventing tomorrow.

Presenters

- Emma Shen
  Jacobs, Global Technology Lead for Wastewater Energy Optimization and Sector Decarbonization
- Jeff Carmichael
  Metro Vancouver, Division Manager, Business Development Group
- Per Henrik Nielsen
  VCS Denmark, Project Director
- Amanda Lake
  Jacobs, European Regional Wastewater Solutions Lead

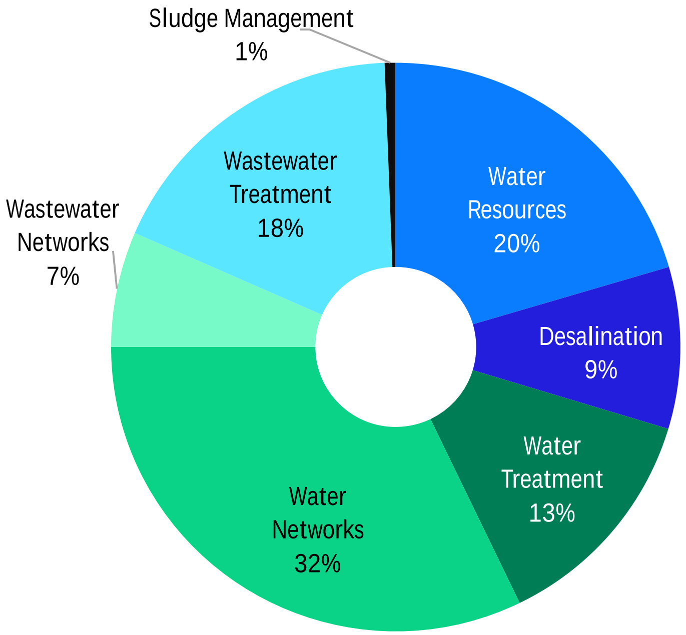
Latest Trends in Decarbonizing the Wastewater Sector

Emma Shen
Jacobs Global Technology Lead – Wastewater Energy Optimization and Sector Decarbonization

WRRFs Become Part of the Solution for Decarbonizing Our Future

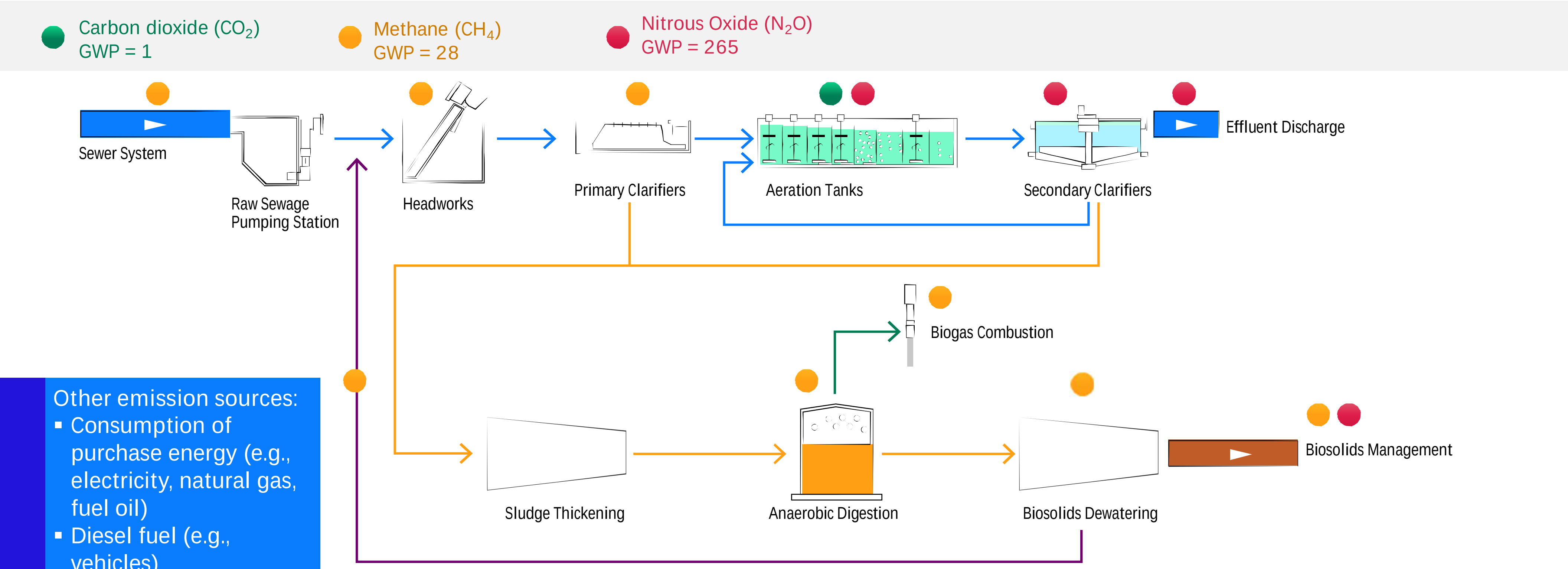
- Energy embedded in wastewater is almost five times the energy demand required for treating wastewater itself.
- WRRFs offer immense opportunities to reduce energy and carbon footprint through operational optimization and adaptation of innovative processes.
- (Beyond) Net-Zero WRRF is no longer just a vision for “utilities of the future”.

Energy Consumption Breakdown in Water Sector (GWI, August 2021)



Source: https://www.globalwaterintel.com/news/2021/32/is-net-zero-now-water-s-biggest-priority

GHG Sources at WRRFs



Other emission sources:

- Consumption of purchase energy (e.g., electricity, natural gas, fuel oil)
- Diesel fuel (e.g., vehicles)
- Refrigerants
- Chemicals

GWP: Global Warming Potential

Adopted from WEF Factsheet "GHG Sources and Sinks for WRRFs" (2021)

Energy Recovery from Biogas Should be the Baseline

- No biogas should be flared (wasted)!
- Combined heat and power (CHP) or renewable natural gas (RNG) – market driven

Biogas

CHP ←

- High carbon intensity for local power grid (e.g., coal, natural gas)
- High electricity cost
- Subsidies for renewable generation

CHP

- ✓ Electricity generation – typically enough demand onsite (offset)
- ✓ Heat reuse onsite

→ **RNG Production**

- Low carbon intensity for local power grid (e.g., nuclear or hydro)
- Carbon tax or incentives for GHG emission reduction

RNG Production

- ✓ RNG (biomethane) - grid injection or used as vehicle fuel
- ✓ Renewable heat onsite and offsite

Innovative Technologies to Boost Biogas Production

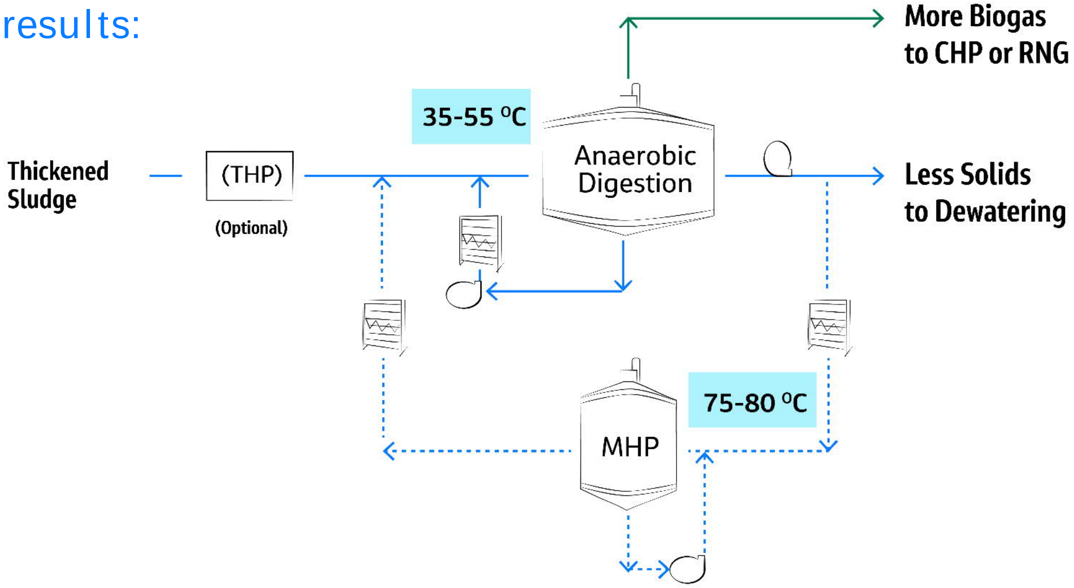
Micro Hydrolysis Process (MHP)

- Innovative anaerobic digestion technology developed by Jacobs in collaboration with Verde Technologies and Brigham Young University
- Use of Caldicellulosiruptor Bescii (C. Bescii), a hyper-thermophilic anaerobic bacteria, to hydrolyze cellulose and other recalcitrant biomass

Lab-scale and pilot testing show promising results:

- >70% volatile solids reduction
- 25% more biogas production
- 25% less biosolids generation
- Improved dewaterability

First full-scale implementation planned at the Clinton River WRRF (Oakland County, Michigan) after successful pilot



Converting Biosolids to Low Carbon Intensity Fuel

Pyrolysis – converting biosolids into gas (syngas), liquid (bio-oil) and biochar

Pyrolysis Equipment at Silicon Valley Clean Water WRRF (California)

Integrated Thermal Process (Fluid Lift Gasification™) at Morrisville Municipal Authority Facility (Pennsylvania)

Parry et al., 2020. *Circular Biochar Economy*. WEFTEC Connect

Sewer Thermal Recovery

Sewer - low-carbon, reliable source for heating and cooling

- Every 1 MGD of wastewater provides approximately 0.9 MW heating/cooling capacity (based on 5 °C deltaT)
- Offsets GHG emission from conventional natural gas heating/electrical cooling
- Reduces thermal pollution in waterways
- Scalable – from individual building to district energy system (DES) application

PIRANHA - small system serving 25 to 200 residential units (Courtesy: SHARC)

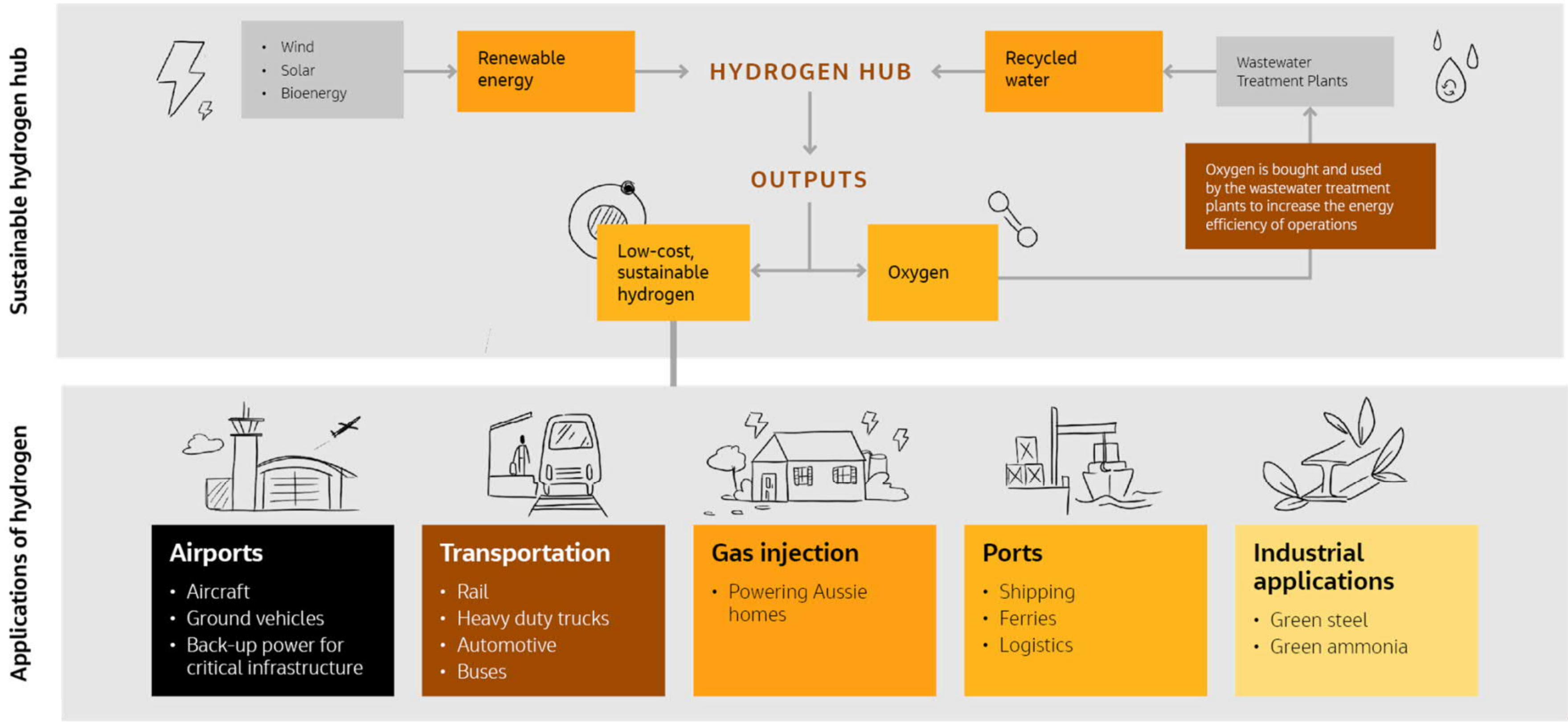
In-pipe heat recovery, applied with new installation or replacing sewers (Courtesy: Rabtherm)

Architectural rendering for National Western Center (Denver, CO) – 3.8 MW sewer thermal DES under construction

Renewable Microgrid with Energy Storage

- Independent from a central grid, with local energy generation, storage and intelligent controls
- Renewable energy sources:
  - Solar
  - Biogas (cogen)
  - Hydrogen
- Key benefits for WRRFs:
  - Increases site resilience and redundancy
  - Reduces energy cost
  - Reduces GHG emissions
  - Might help build a local solar or hydrogen industry with new jobs

WRRF-Based Hydrogen Hubs



Jacobs Yarra Valley Water Whitepaper:
https://www.jacobs.com/sites/default/files/2020-06/jacobs-yarra-valley-water-towards-a-zero-carbon-future.pdf

metrovancouver | CLIMATE 2050

Metro Vancouver Climate Action

REGIONAL PLANS AND LIQUID WASTE SERVICES INITIATIVES AND PROJECTS

Jeff Carmichael
Division Manager, Business Development,
Liquid Waste Services

15 September 2021

metrovancouver

DRIVERS FOR CLIMATE ACTION

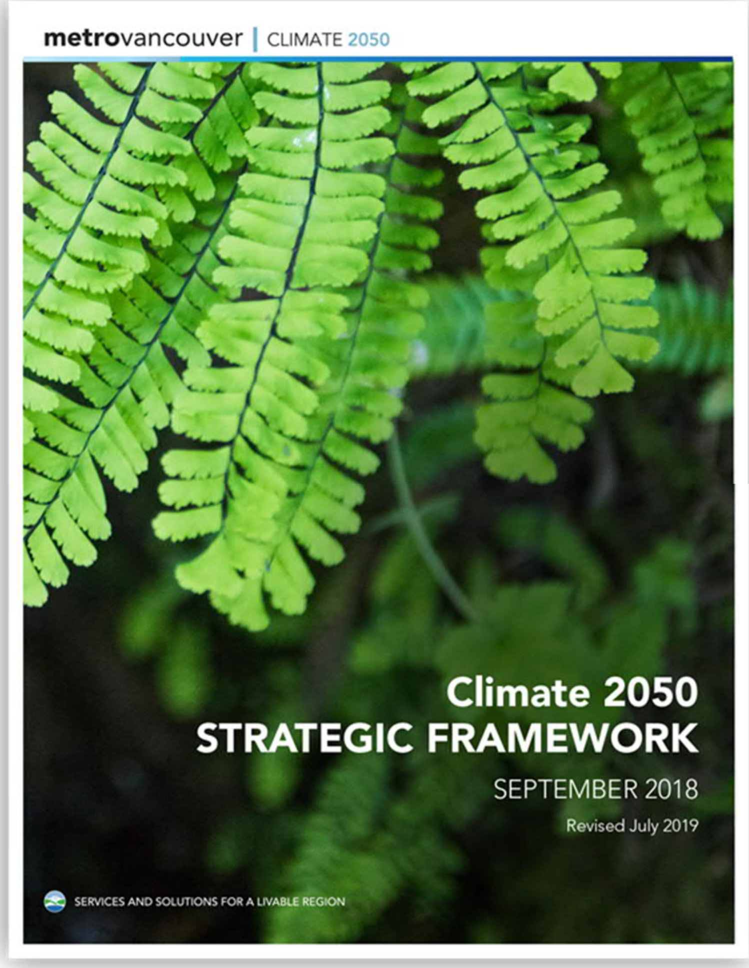
Climate 2050**:** Metro Vancouver demonstrates bold leadership in responding to climate change

- **Carbon neutral region** by 2050
- Infrastructure, ecosystems and communities are **resilient** to the impacts of climate change

Energy Management Policy

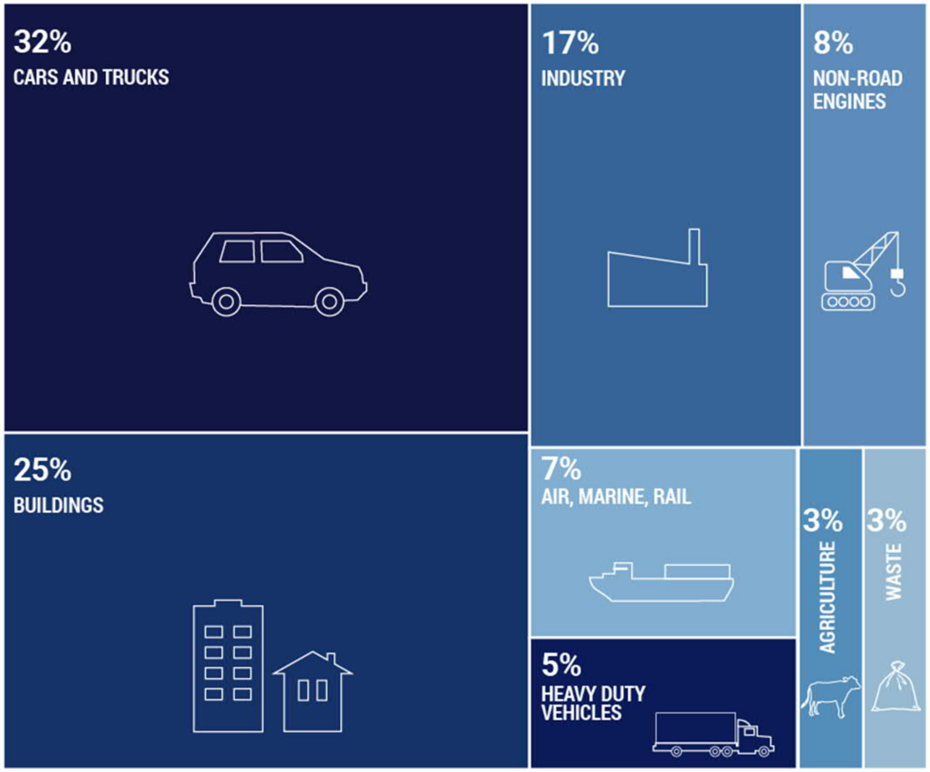
Board Strategic Plans

Liquid Waste Management Plan



CAUSES OF CLIMATE CHANGE

Regional greenhouse gas emissions



Dominated by vehicle and building emissions

Somewhat unique low-GHG hydroelectricity

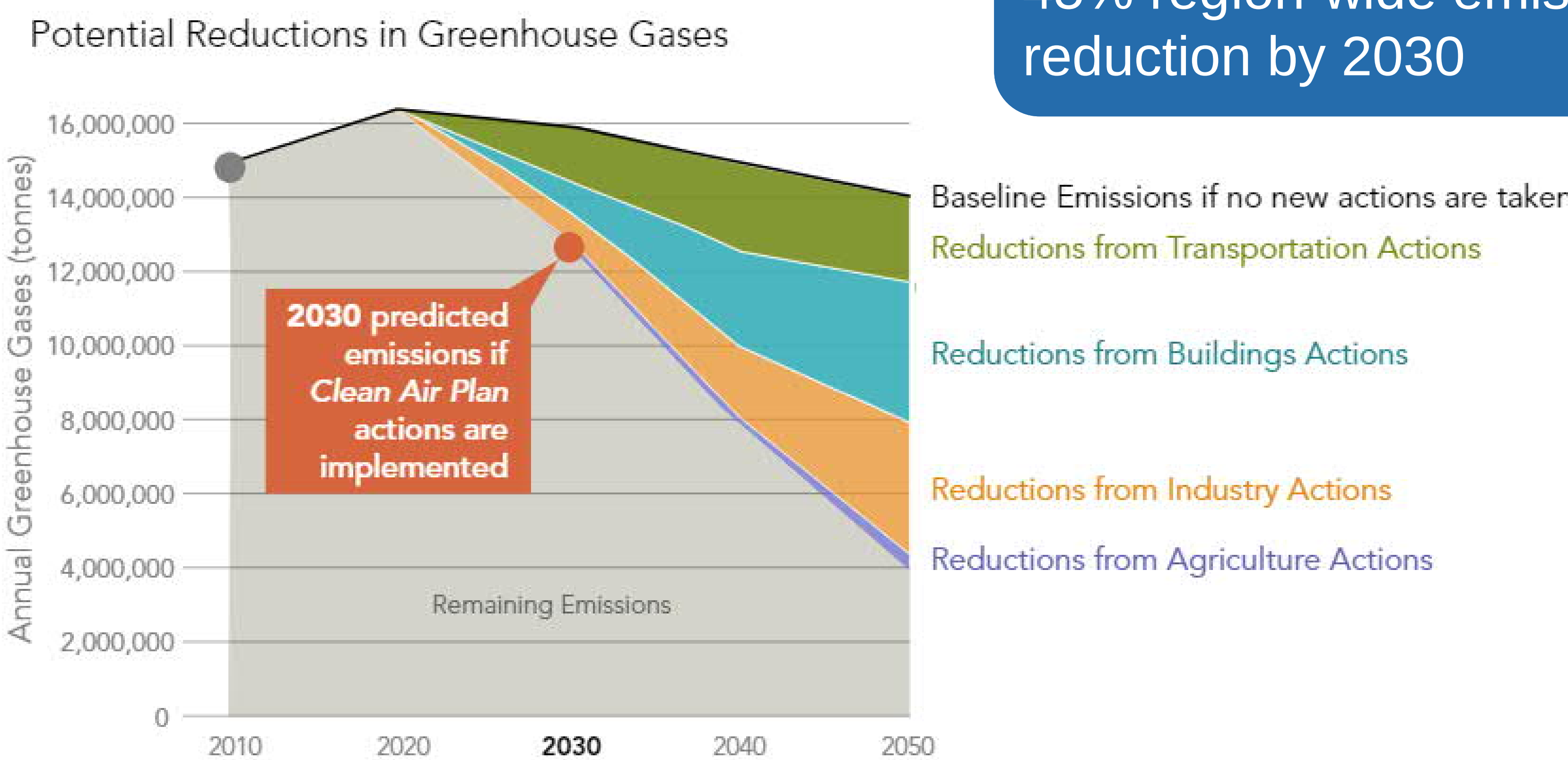
Non-energy related emissions are poorly understood, so not included in current reporting protocols.

ESTIMATED EMISSIONS IMPACT

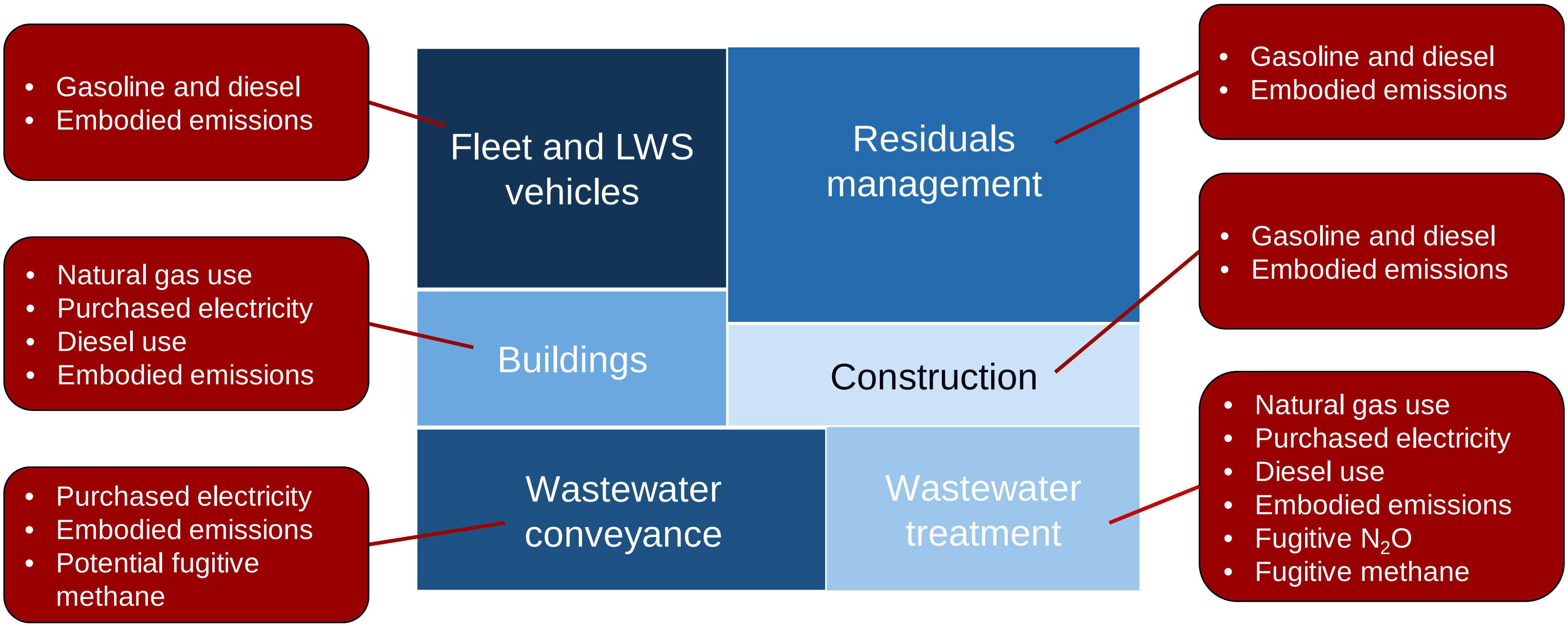
Greenhouse Gases

Goal:

45% region-wide emissions reduction by 2030



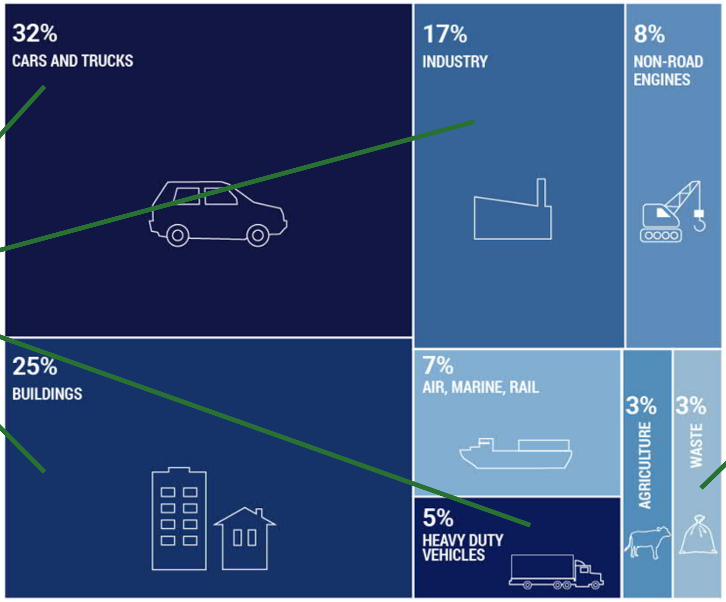
REDUCING LIQUID WASTE GHG EMISSIONS



USING LIQUID WASTE RESOURCES TO REDUCE REGIONAL EMISSIONS

Energy sources:

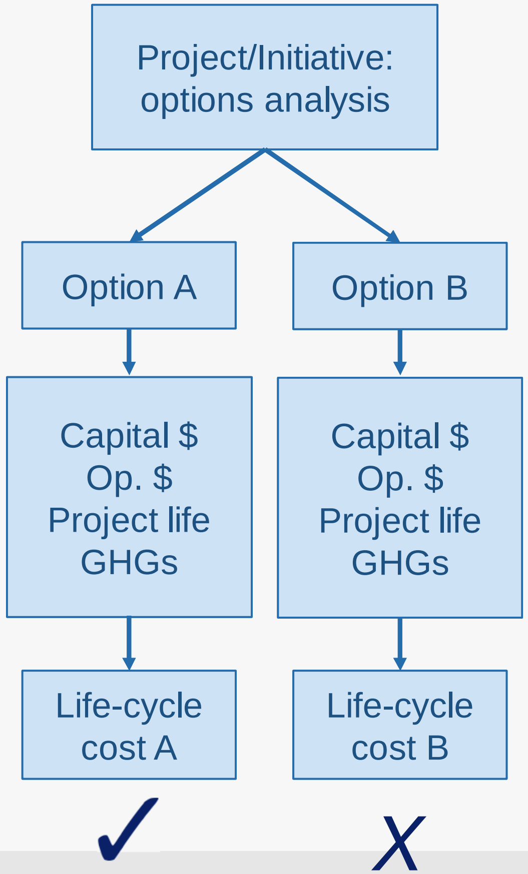
- Renewable natural gas
- Sewer / effluent heat
- Co-generation
- Biofuel
- Biosolids as fuel



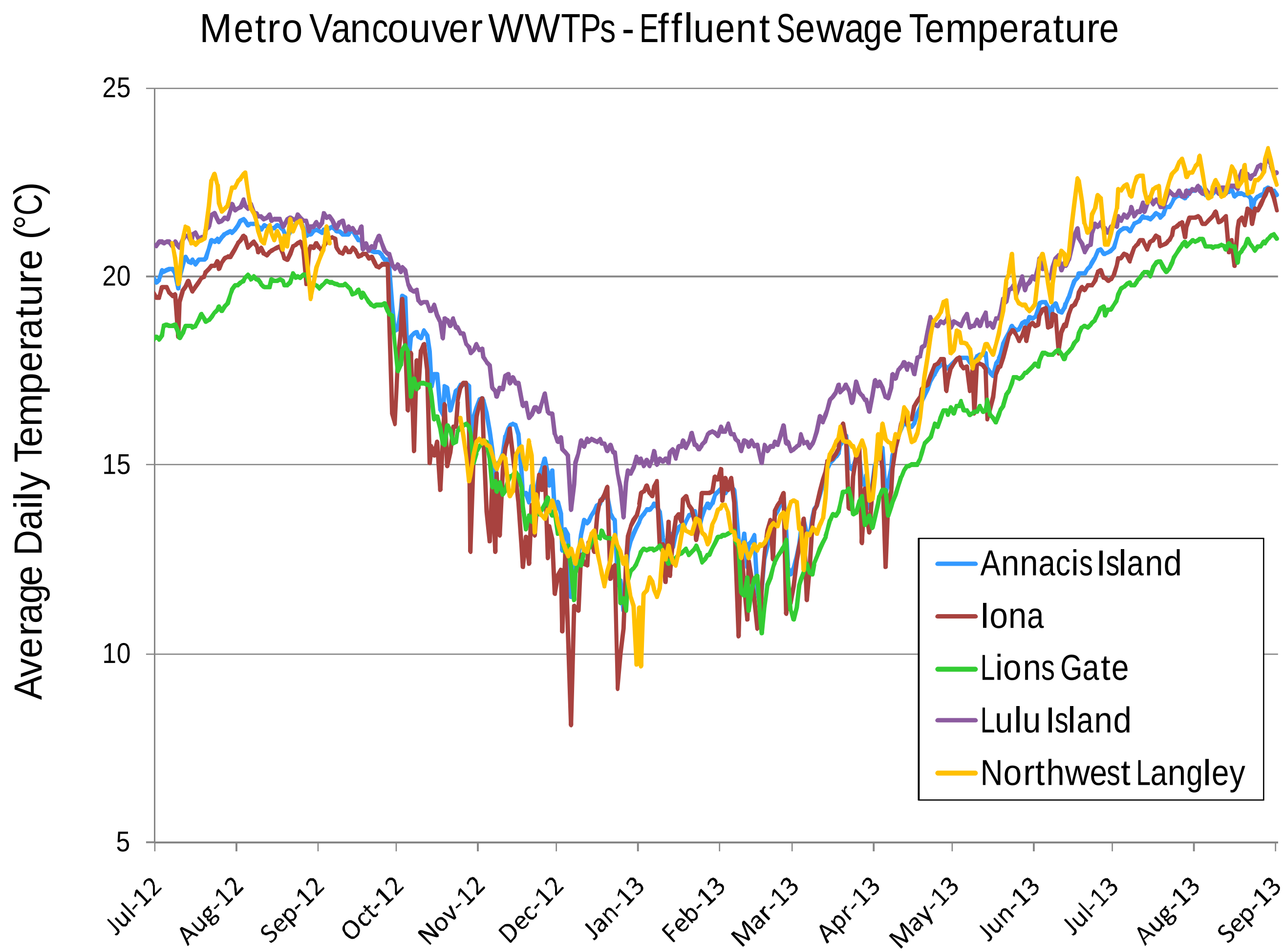
Biosolids as landfill cover and carbon sink

Action Protocol: Carbon Price Policy Methodology

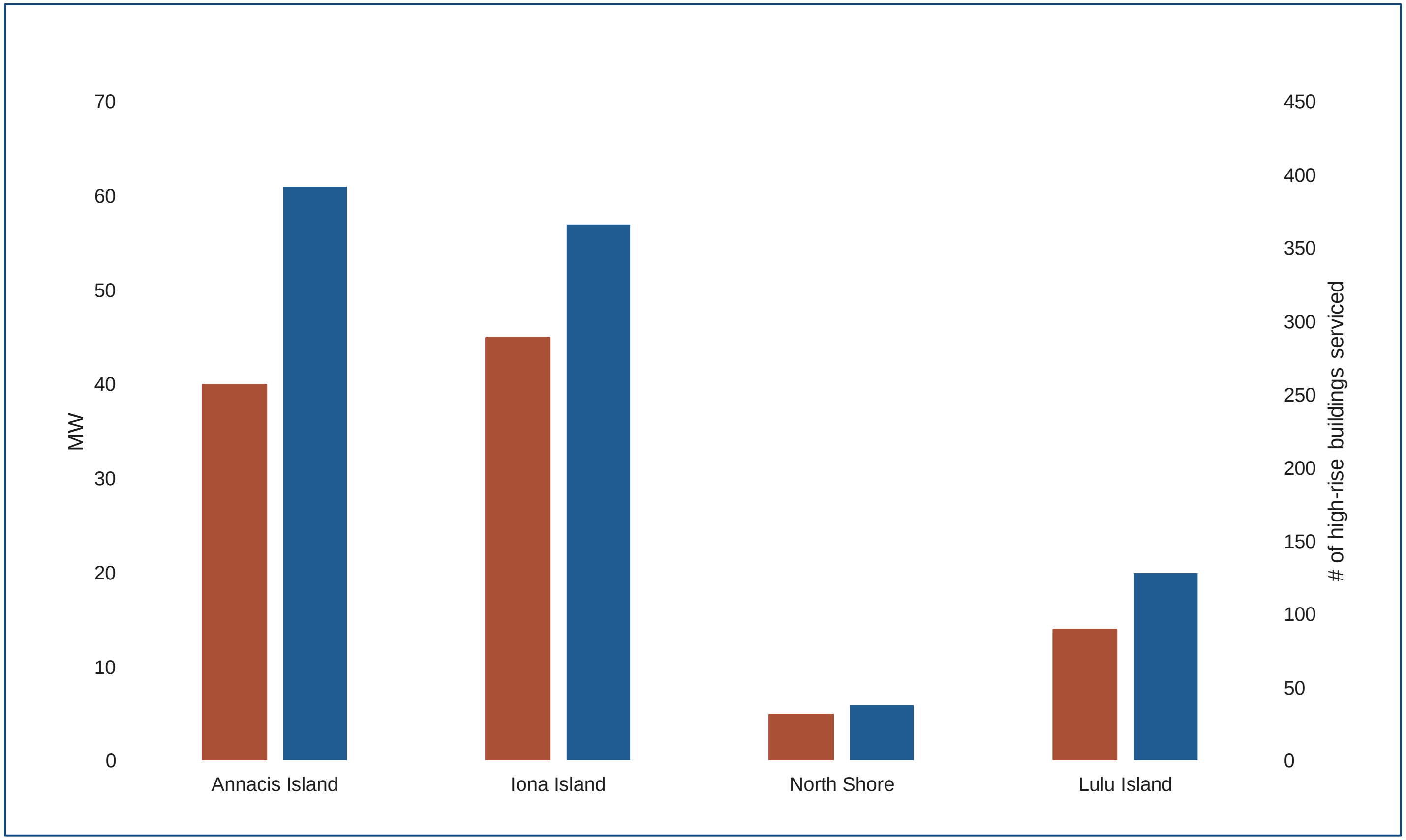
- Policy establishes a price ($150/tonne CO_2e) on applicable GHG emissions
- Value of GHGs associated with a proposed project or initiative can be calculated
- Intent to use Life Cycle Cost Analysis to quantitatively compare options
- Use process in place but no checks to ensure participation



SEWER HEAT INITIATIVES



SEWER HEAT: CURRENT AND FUTURE CAPACITY



Current capacity:
700 high rise buildings

Future capacity:
950 buildings

North Shore Effluent Heat project in design now

HIGH-EFFICIENCY AERATION

2020 and earlier activities

- Identified HEA technology w/ improved performance for energy use reduction
- Project funded under MV Sustainability Innovation Fund (SIF)
- Negotiated scope of work for demonstration testing at DC Water

2021 activities

- Execute contract for demonstration testing
- Design pilot facility modifications
- Procure fluidic oscillator and initiate construction

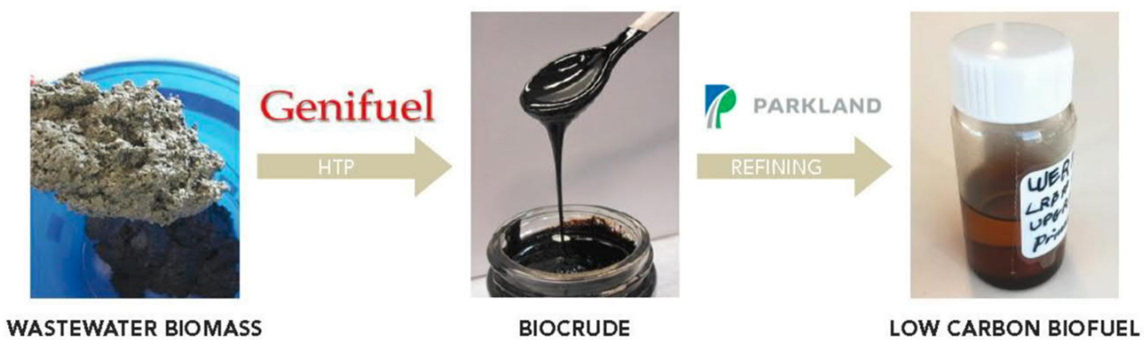
Future activities

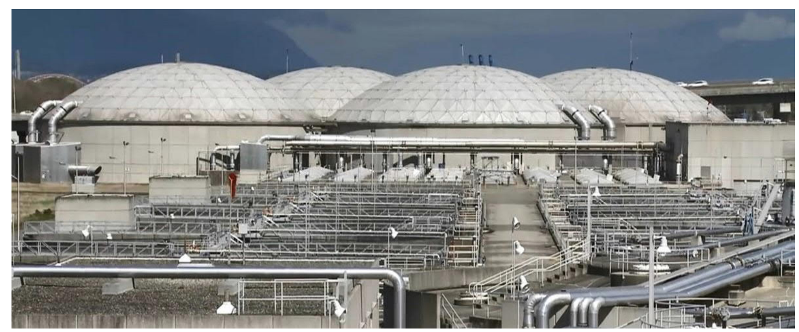
- Install and test Perlemax fluidic oscillator
- Complete WRF third-party independent assessment

HTL – PRODUCTION OF BIOFUEL

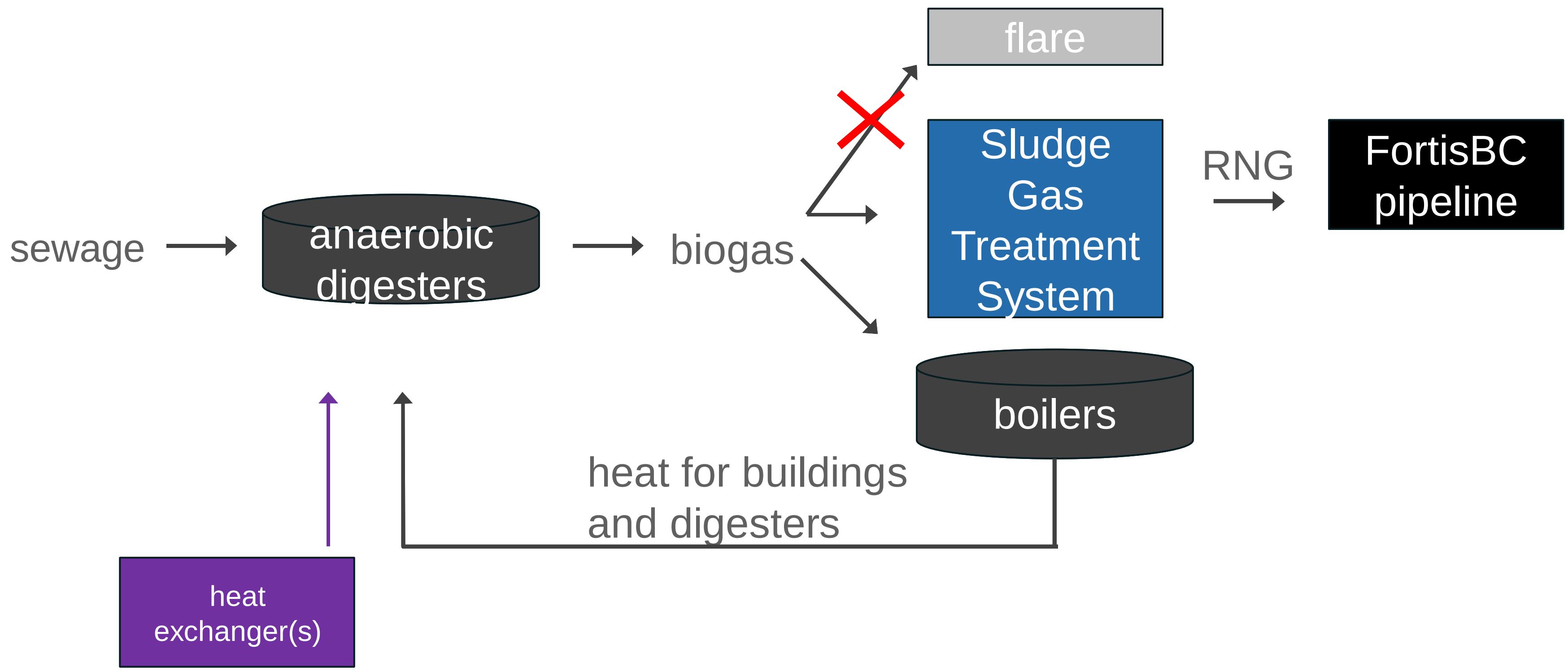
2021 activities
- Complete procurement for HTL unit design and fabrication
- Complete preliminary design of outside battery limits
- Continue work with Industrial Research Chair at UBC Okanagan to identify how to best integrate HTL into WWTP operations

Future activities
- Construction, installation and testing of HTL pilot at AIWWTP
- Investigation of low carbon phosphorus and nitrogen compounds for use as fertilizer with UBC



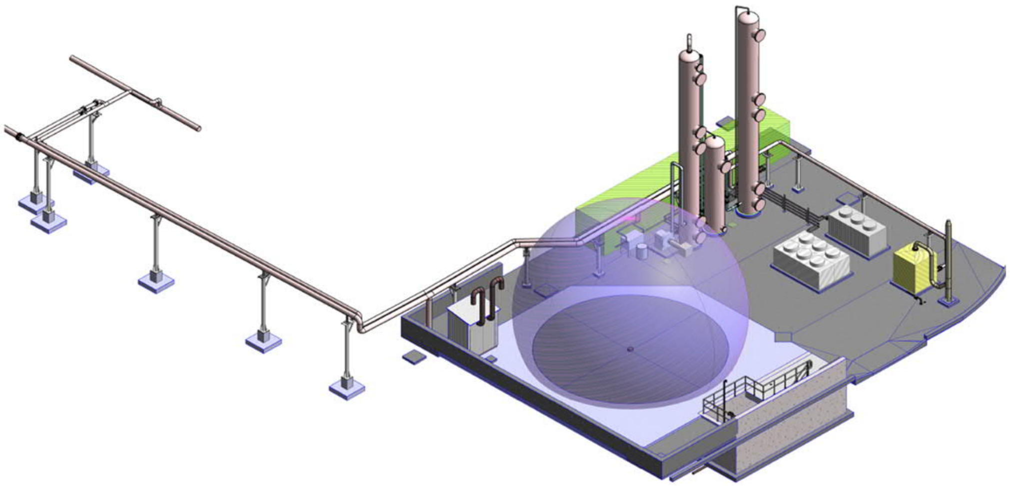


BIOGAS UPGRADING: CURRENT AND PLANNED SYSTEM

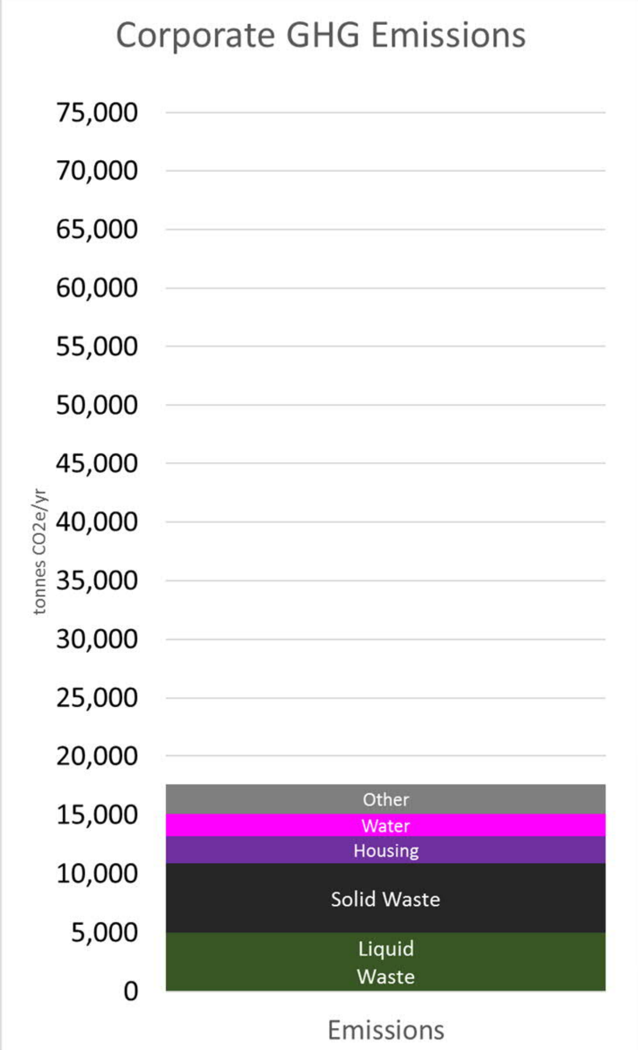


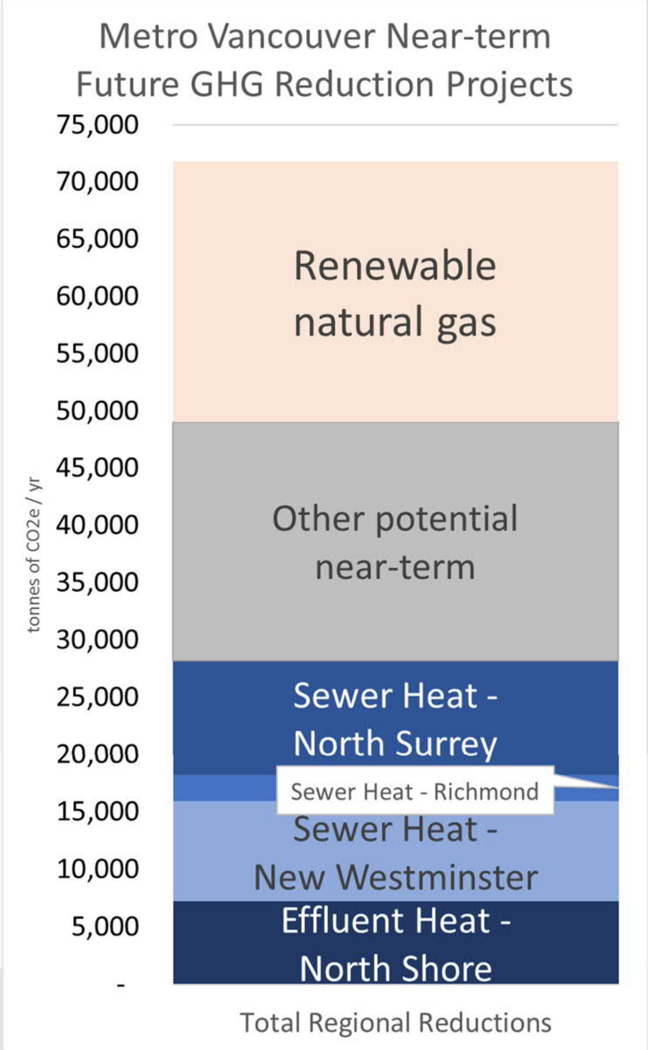
BUSINESS CASE ANALYSIS

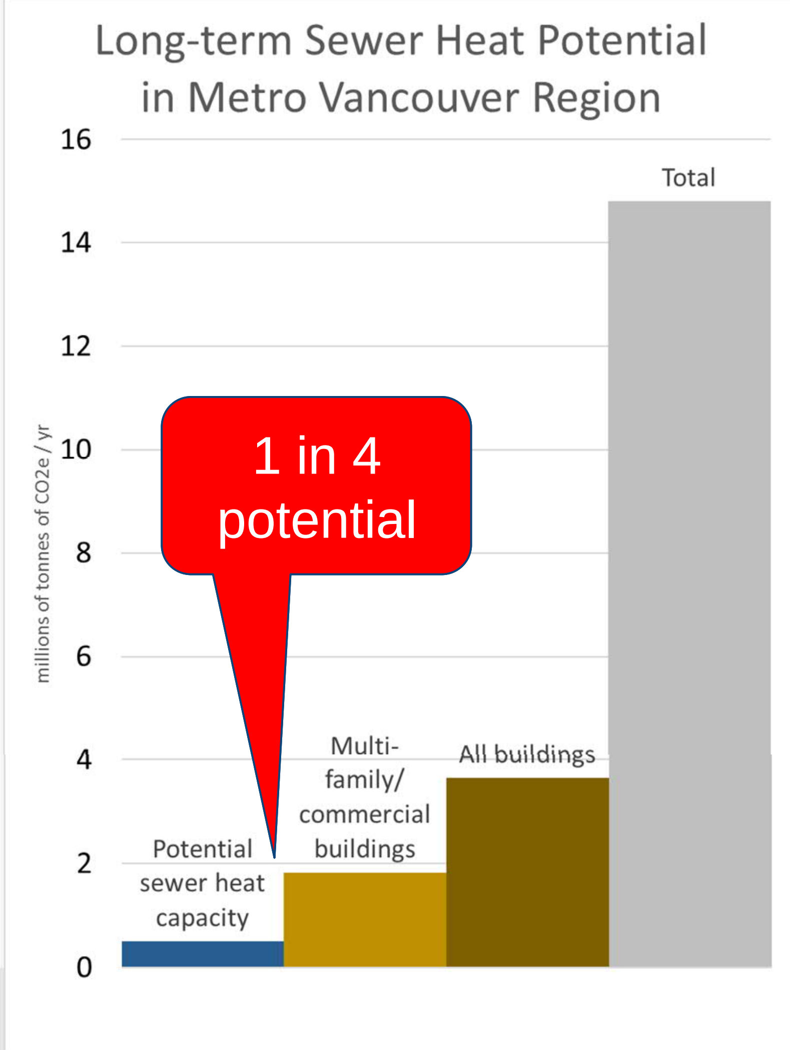
- 25-year equipment life
- Estimated $11M capital costs
- Initial RNG sales $630,000 /yr
- Initial O&M costs $150,000 /yr
- Carbon price policy benefits $380,000 /yr (average 2,500 tonnes CO2e per year)
- Positive business case and cash flow



GHG Reduction Potential







Thank you. Questions?

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SERVICES AND SOLUTIONS FOR A LIVABLE REGION

Beyond Energy Neutrality Program: Achieving Energy Independence in a Large Water Resource Recovery Facility

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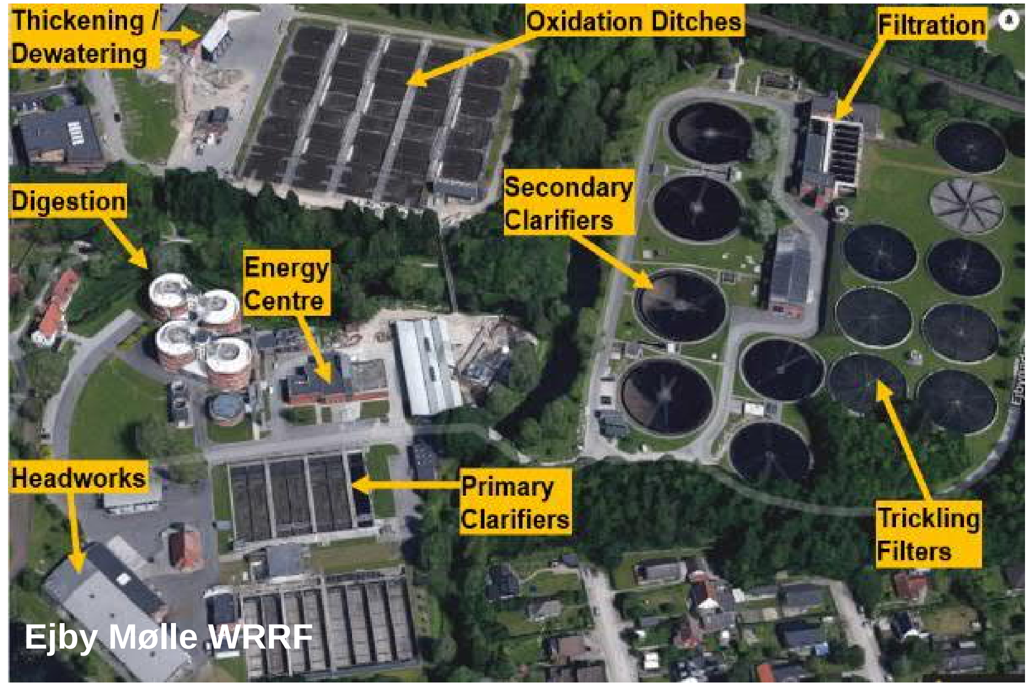
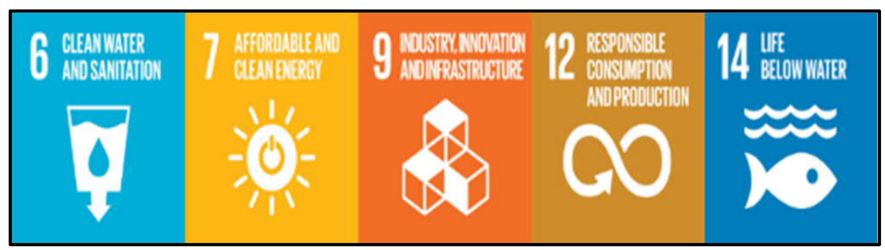
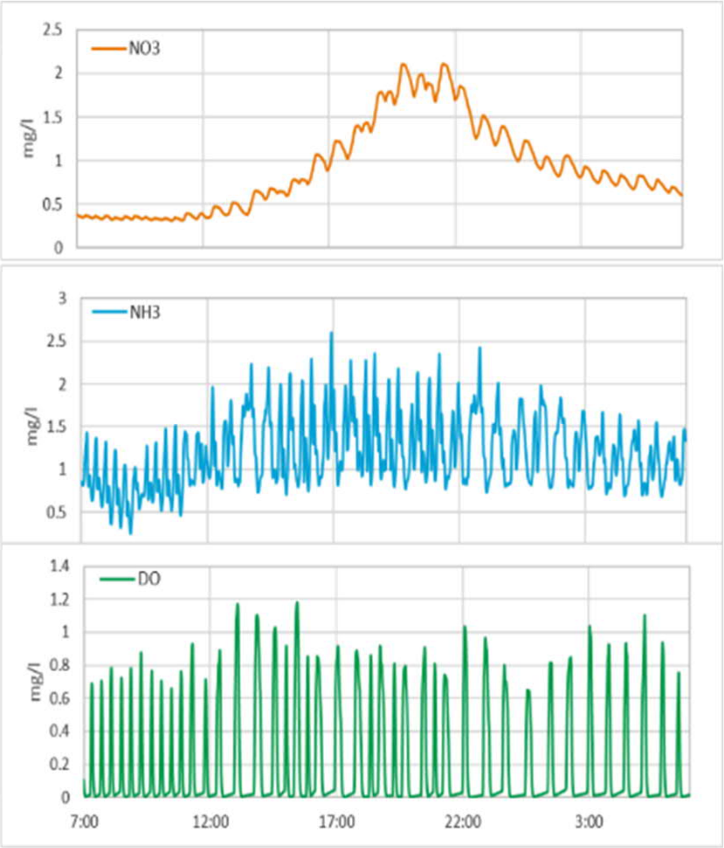
VCS Denmark
PRACTICAL WATER KNOWLEDGE

VCS Denmark
PRACTICAL WATER KNOWLEDGE





Ammonia-Based Aeration Control Played Key Role in Energy Optimization of BNR Process

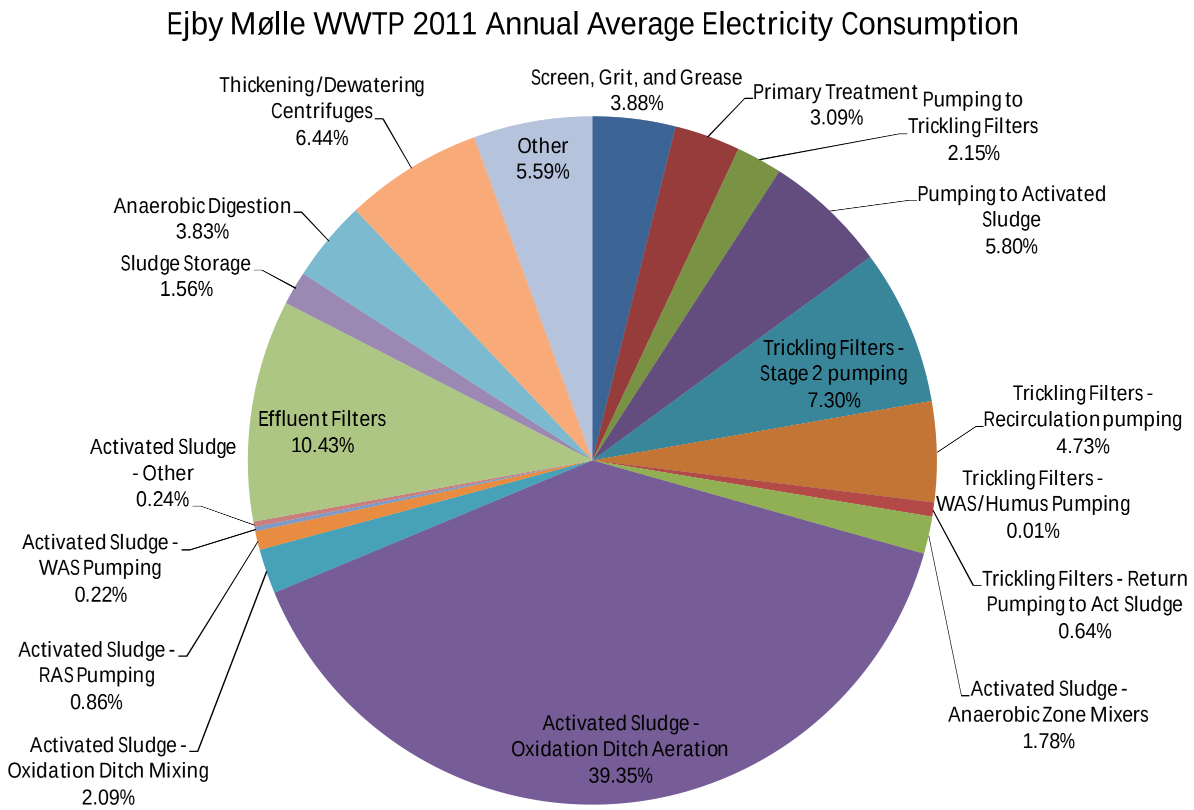


Maximizing Biogas Utilization

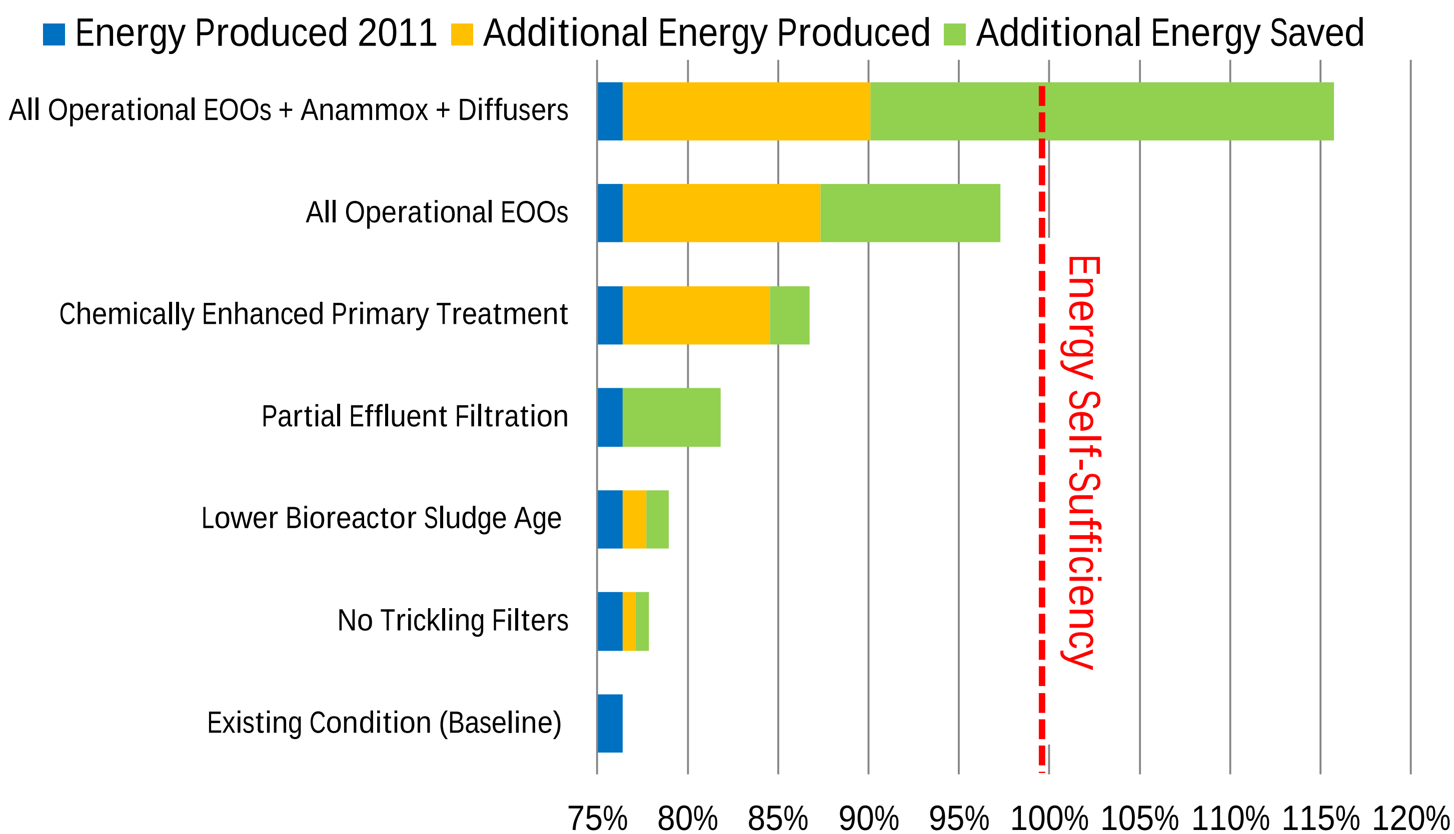
- Additional engine generation capacity fully utilized produced biogas
  - More electrical production
  - More heat recovered
- Reduced carbon footprint from flaring
- Carbon redirection

Beyond Energy Neutrality Program: Engaging Global Input for Collaborative Process Optimization at Ejby Molle

Detailed Historic Energy Consumption and Generation Data Key in Evaluating Optimization Opportunities

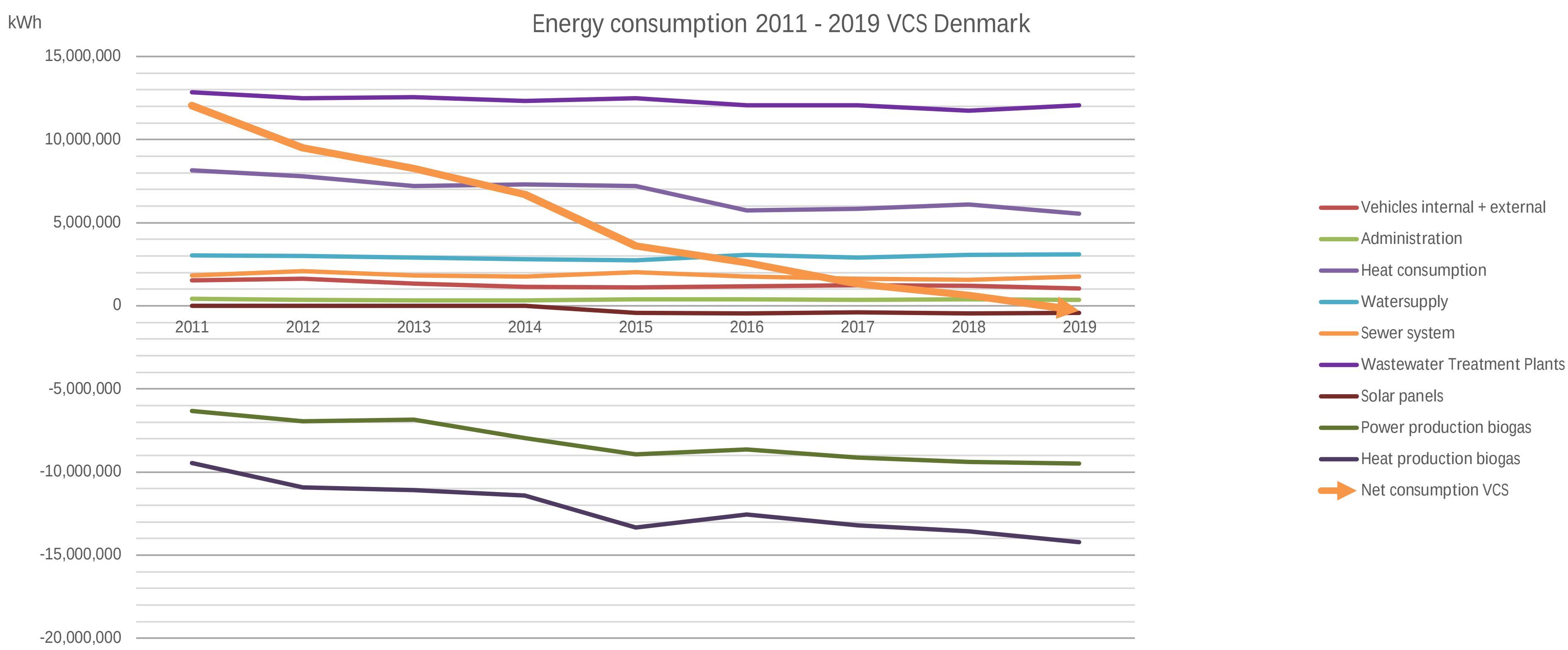


Readily Implementable Optimization Operational Modifications Showed Potential for Achieving Neutrality

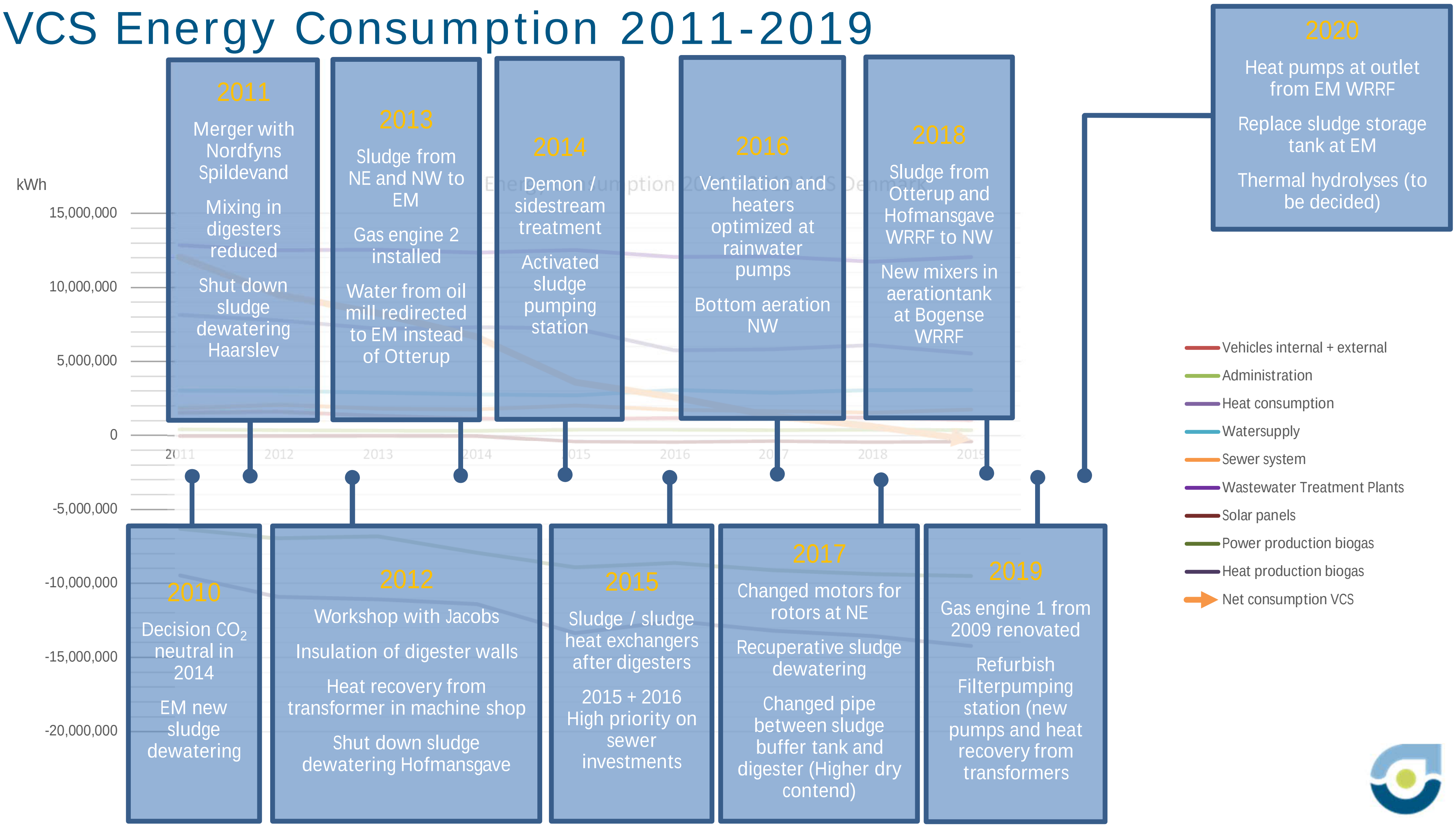


Implementing Several EOOs Achieved Energy Self-Sufficiency by the End of 2013

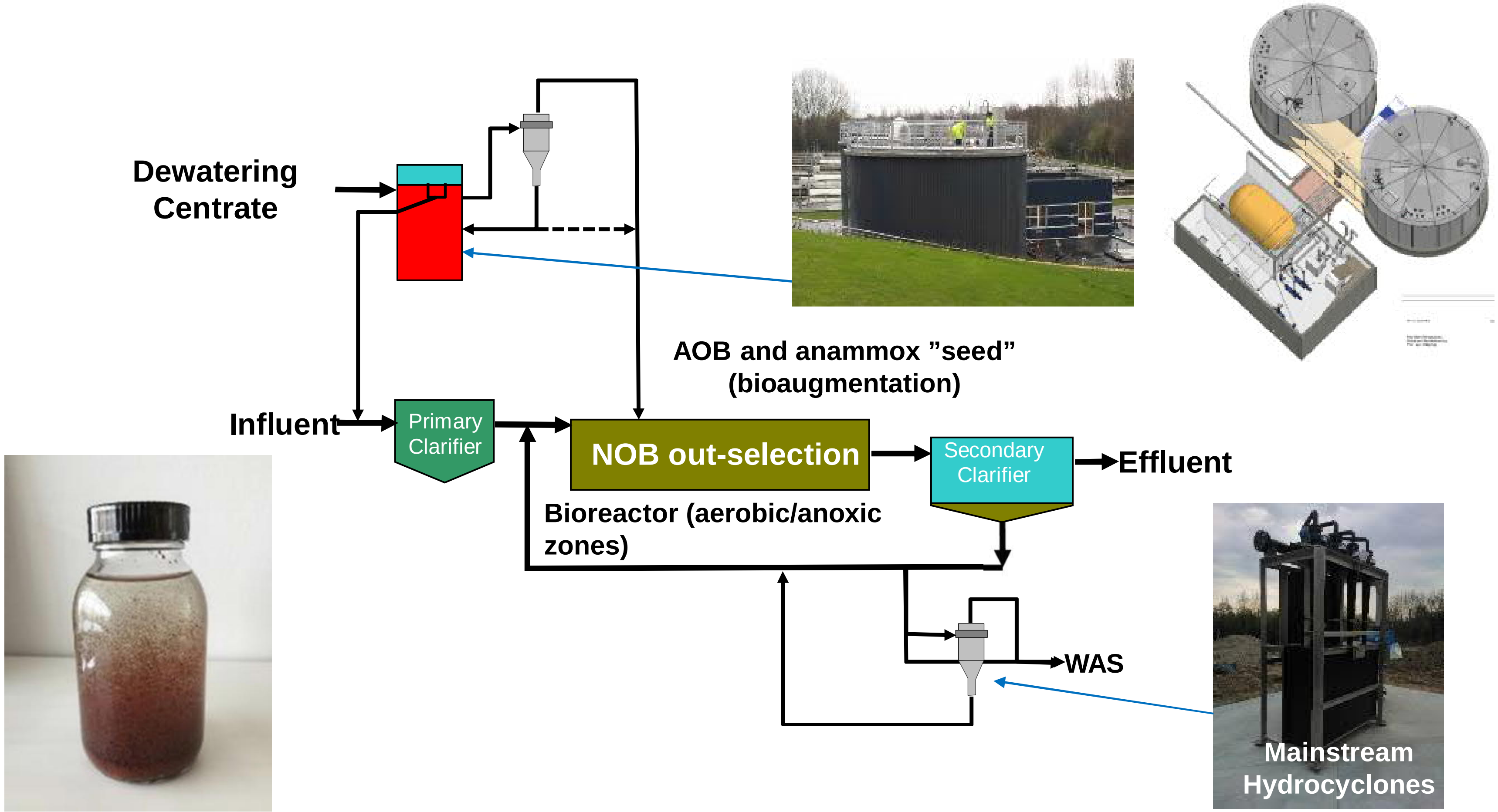
VCS Energy Consumption 2011-2019



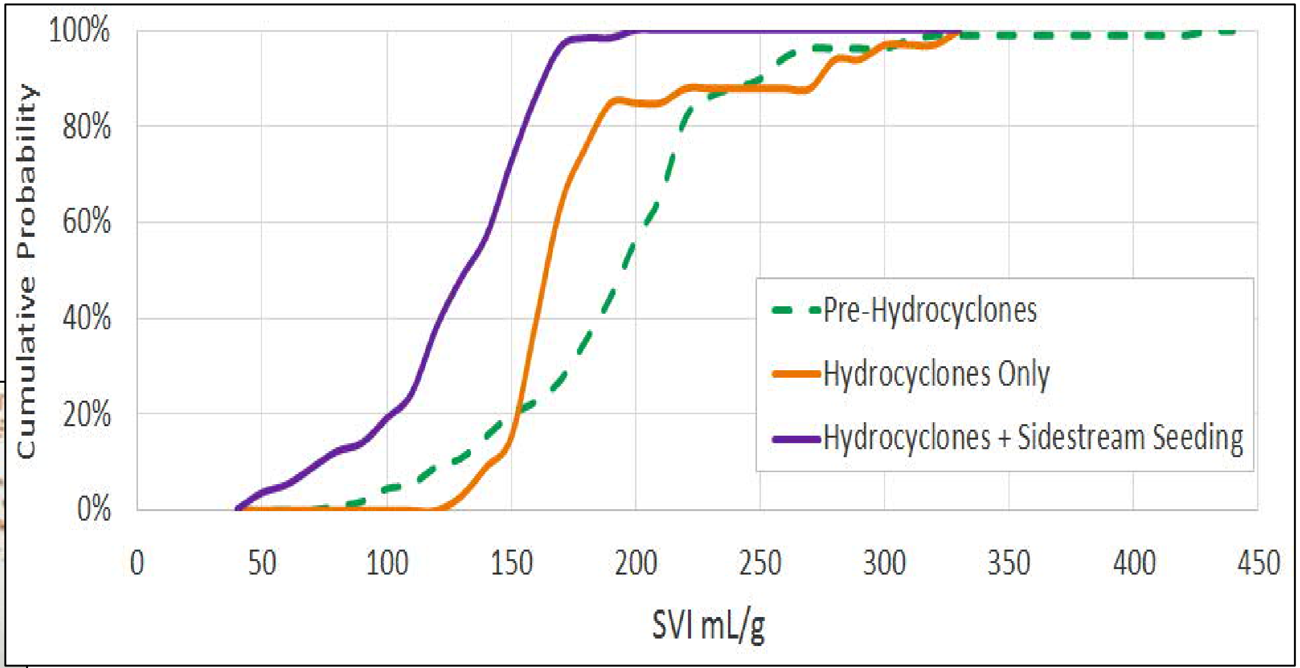
VCS Energy Consumption 2011-2019



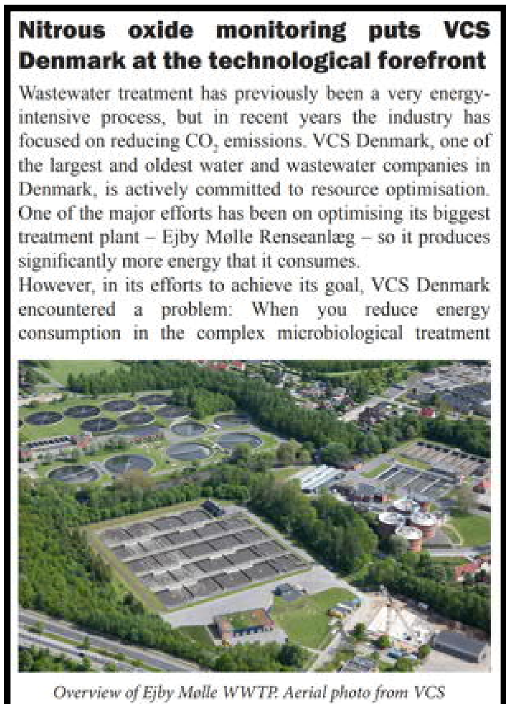
Leveraging Deammonification for Both Sidestream and Mainstream Nitrogen Control



Induced Granulation and Sidestream Bioaugmentation Improved Sludge Settleability



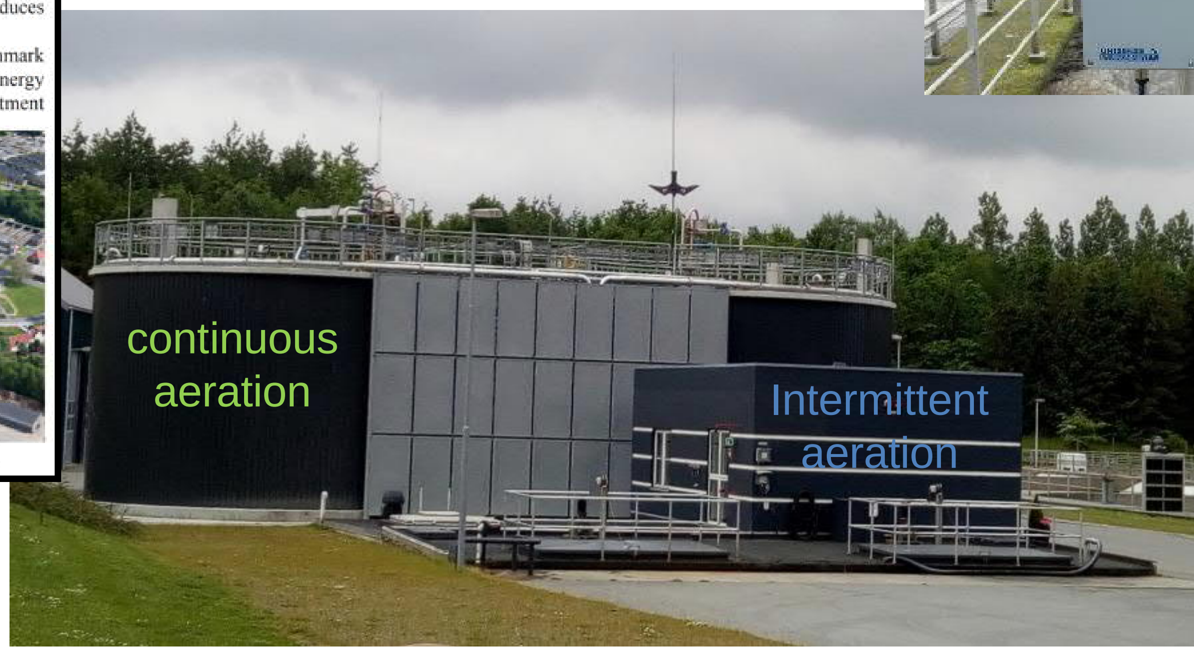
It's Not Energy Reduction at the Expense of the Environment: N2O Probe Development and Application

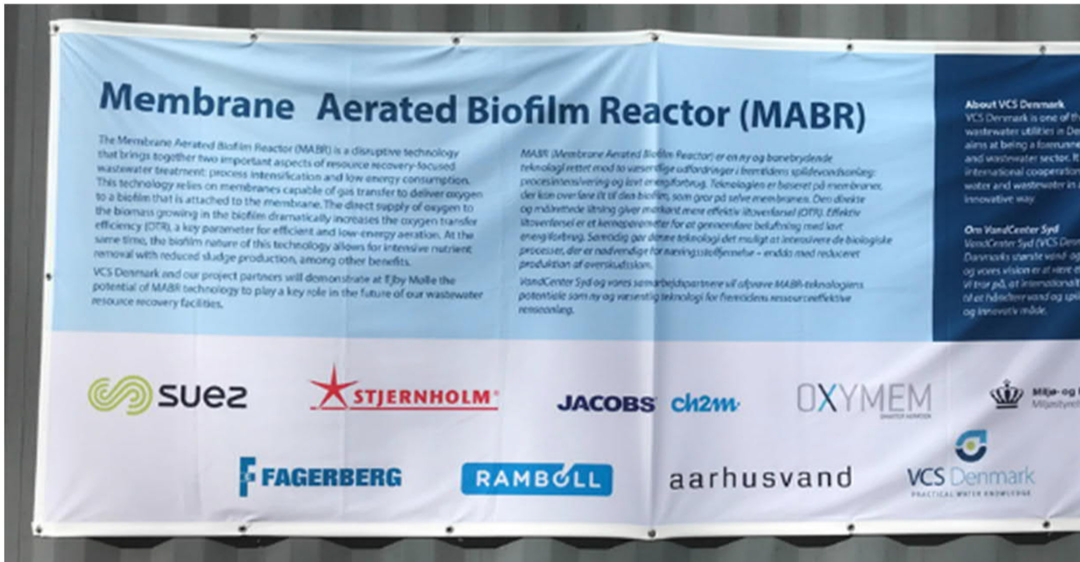


Nitrous oxide monitoring puts VCS Denmark at the technological forefront

Wastewater treatment has previously been a very energy-intensive process, but in recent years the industry has focused on reducing CO_2 emissions. VCS Denmark, one of the largest and oldest water and wastewater companies in Denmark, is actively committed to resource optimisation. One of the major efforts has been on optimising its biggest treatment plant – Ejby Mølle Renseanlæg – so it produces significantly more energy that it consumes.
However, in its efforts to achieve its goal, VCS Denmark encountered a problem: When you reduce energy consumption in the complex microbiological treatment

Overview of Ejby Mølle WWTP. Aerial photo from VCS





Further Developing Emerging Technologies: MABR Demonstration

Jacobs

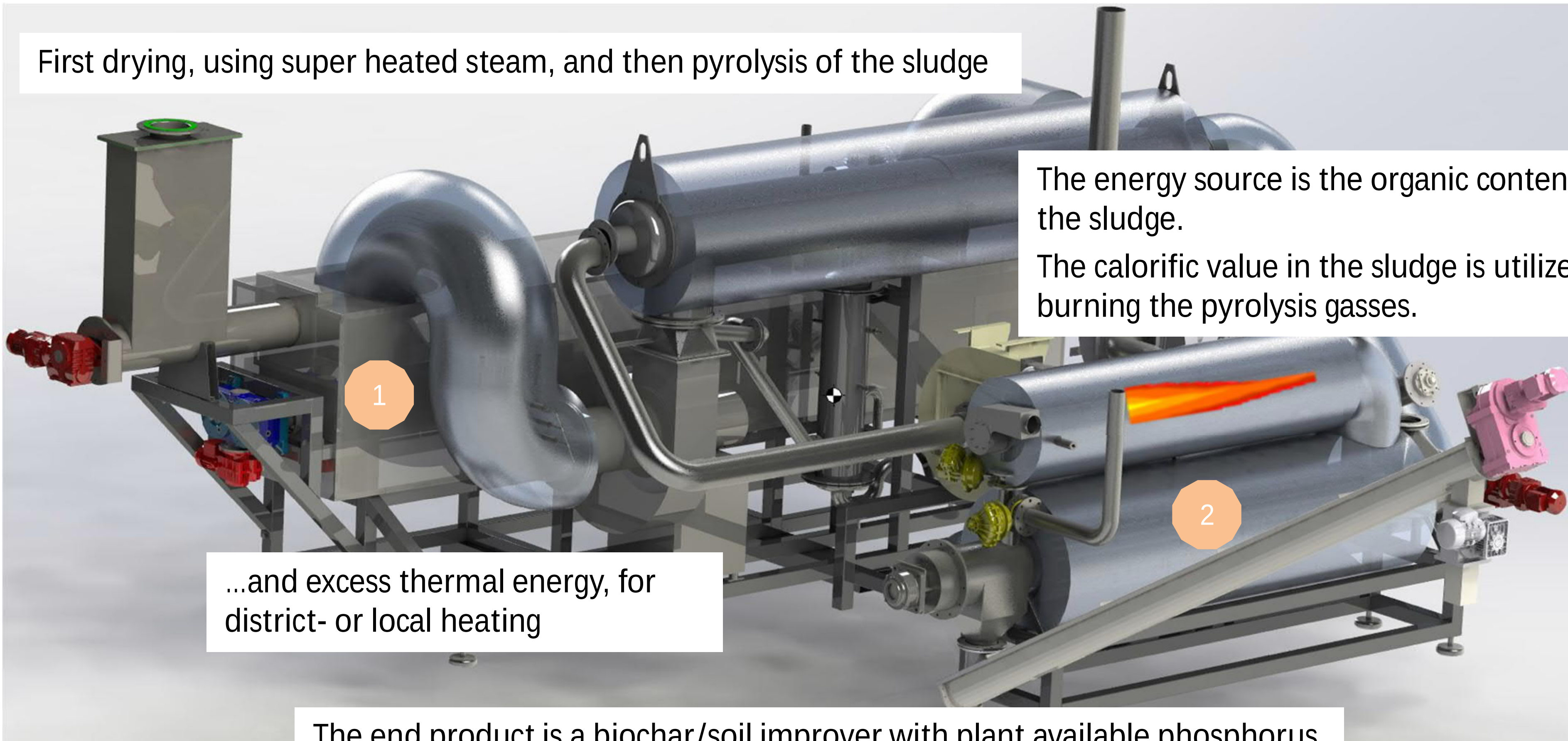
aarhusvand

OXYMEM

suez

What About Biosolids?

First drying, using super heated steam, and then pyrolysis of the sludge



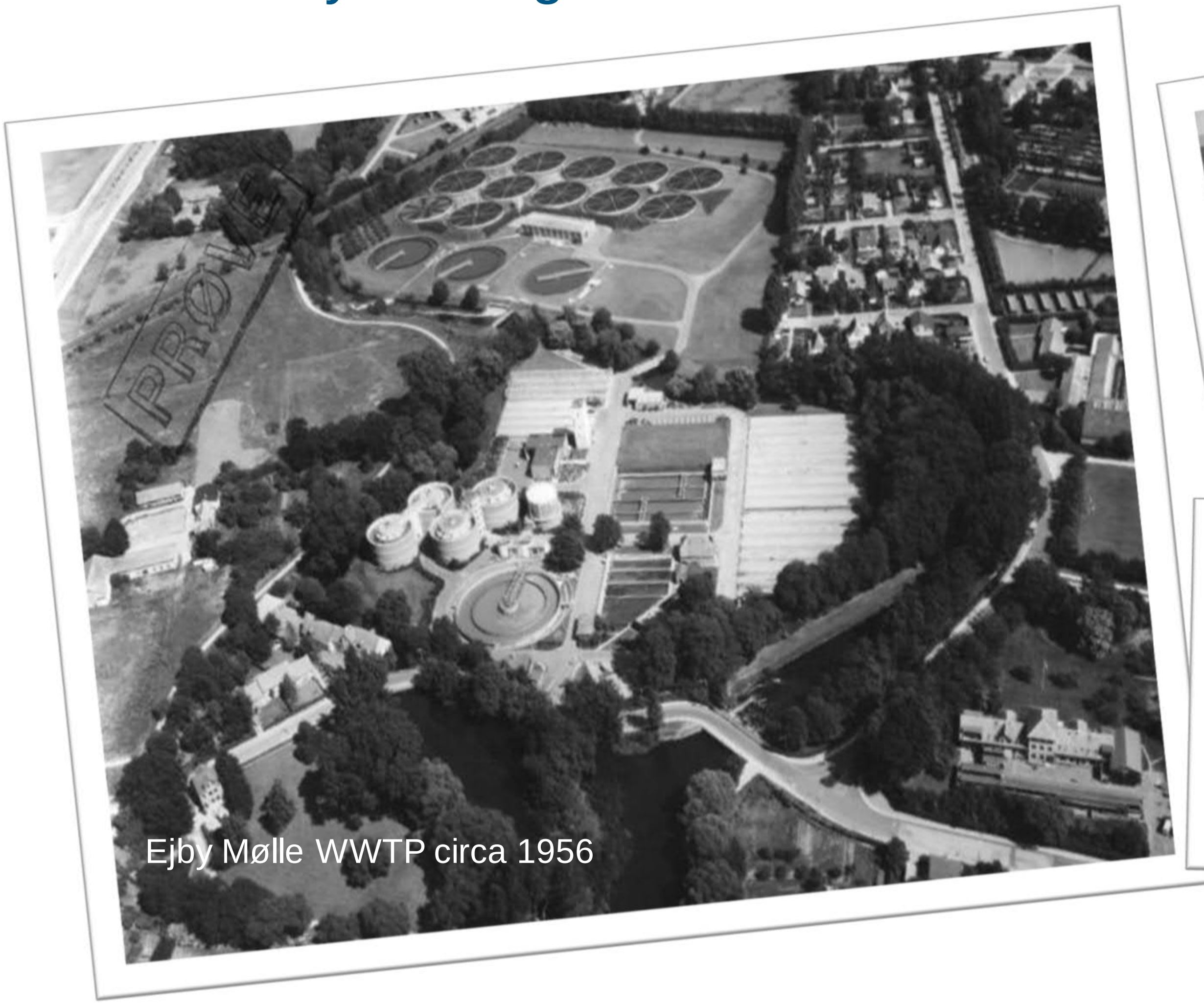
The energy source is the organic content in the sludge.

The calorific value in the sludge is utilized by burning the pyrolysis gasses.

...and excess thermal energy, for district- or local heating

The end product is a biochar/soil improver with plant available phosphorus, and can be processed into activated carbon (filter material)

Summary Thoughts and Conclusions



Ejby Mølle WWTP circa 1956

Decarbonisation in the UK

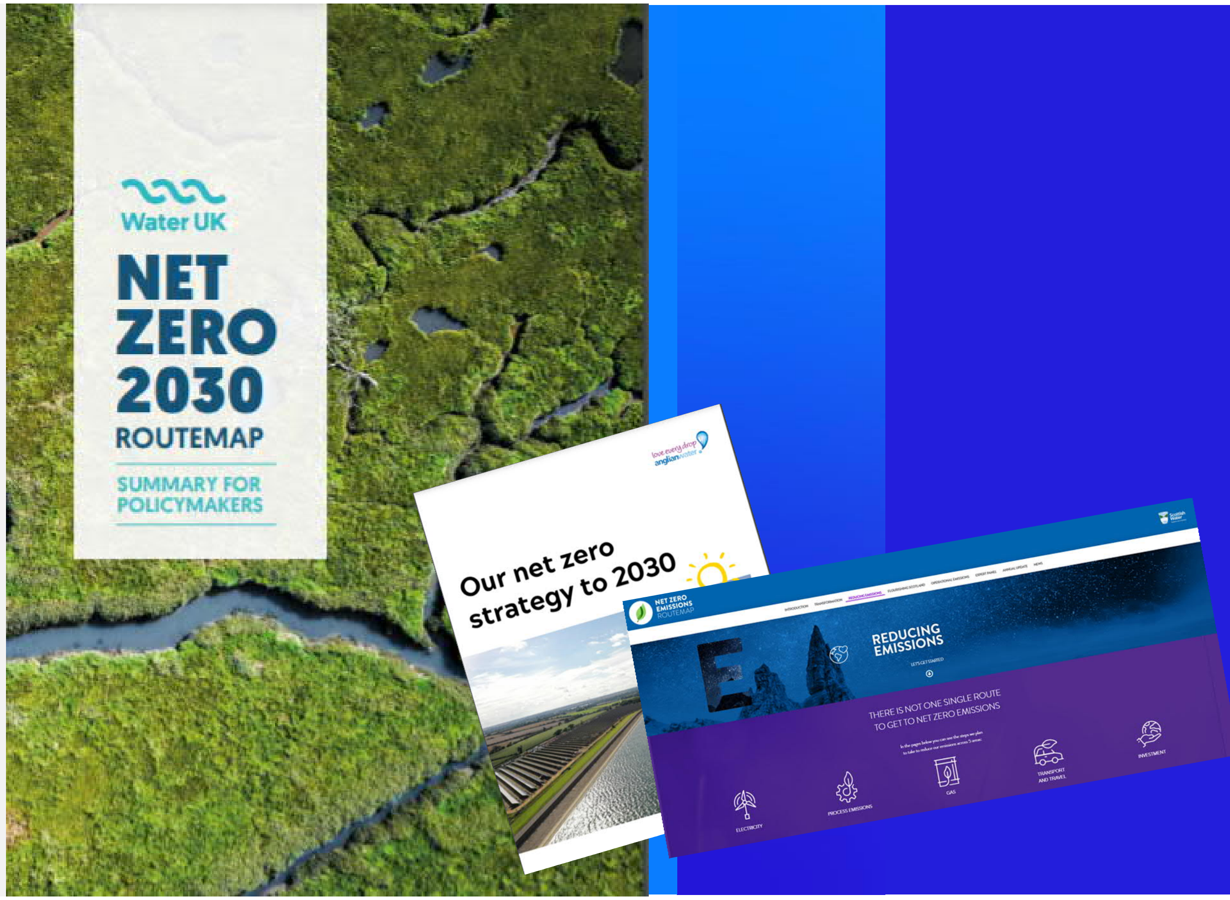
Amanda Lake
Jacobs European Regional Wastewater Solutions Lead

Decarbonisation in the United Kingdom

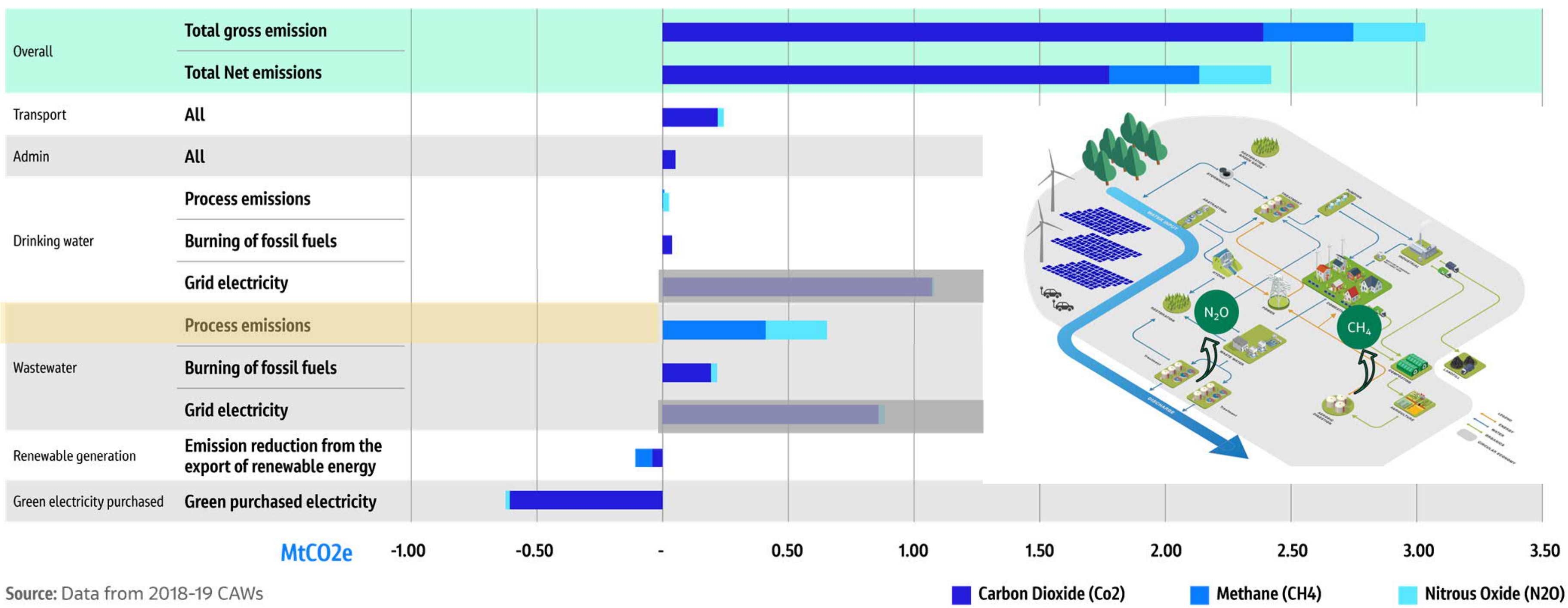
2019
- Pledge to net zero 2030

2020
– 2030 Net zero routemap

2021
– Individual company net zero routemaps

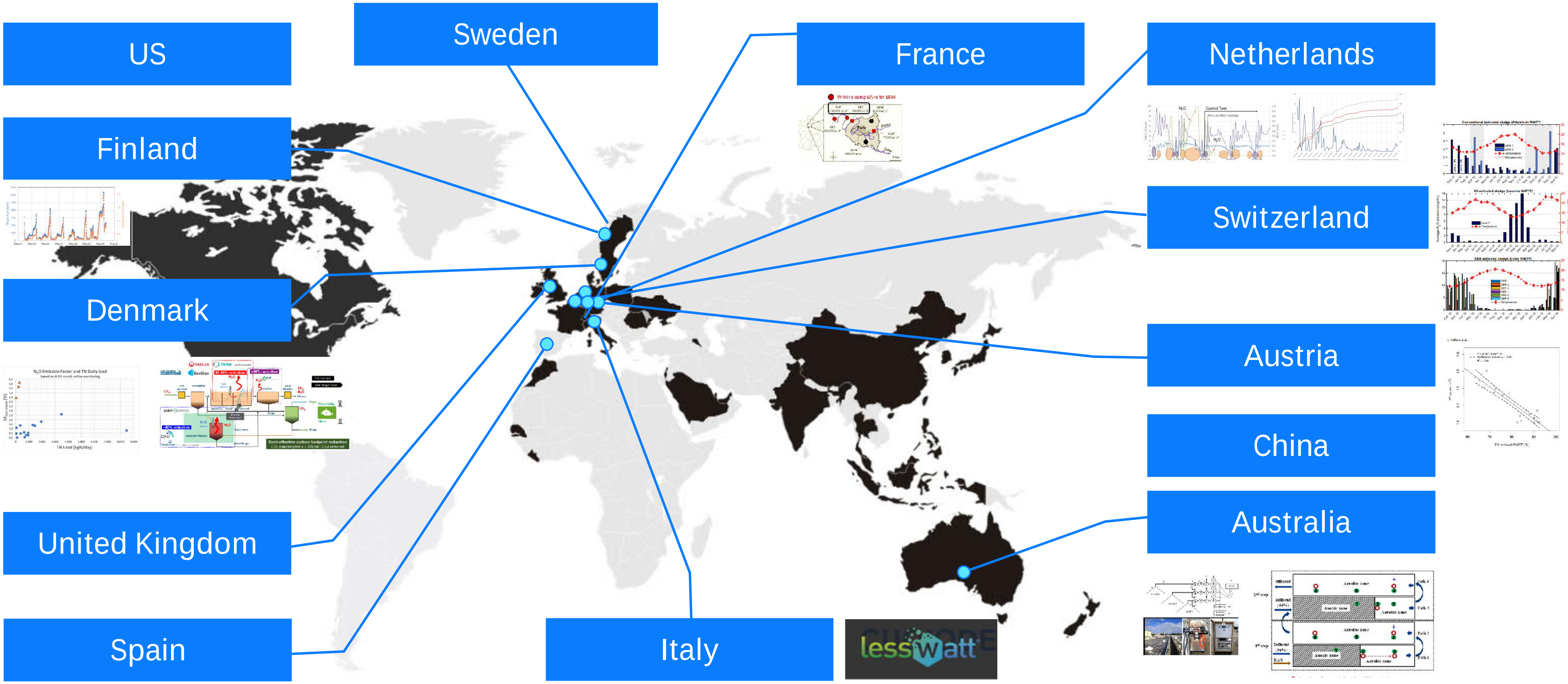


Importance of Scope 1 Process Emissions

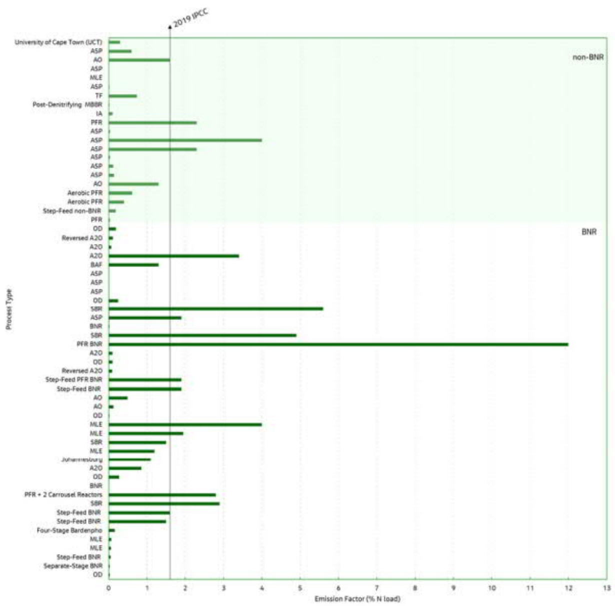


Source: Data from 2018-19 CAWs

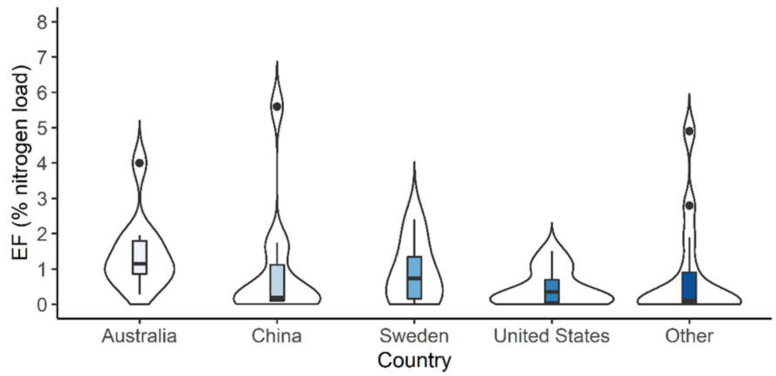
Global Industry and Research Efforts to Date

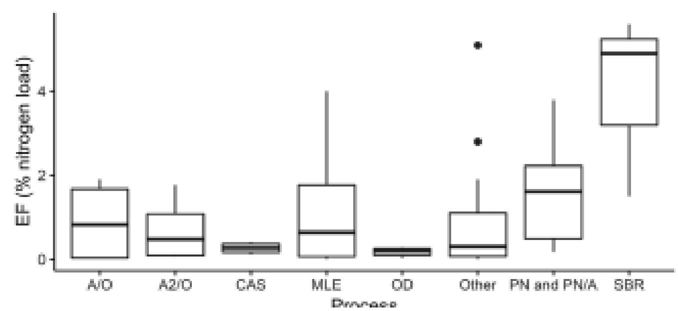


What We Know So Far



(Vasilaki et al. 2019)





IWA PUBLISHING
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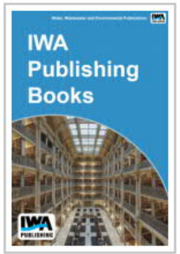
Quantification and Modelling of Fugitive Greenhouse Gas Emissions from Urban Water Systems

Editor(s): Liu Ye, Jose Porro, Ingmar Nopens



With increased commitment from the international community to reduce greenhouse gas (GHG) emissions from all sectors in accordance with the Paris Agreement, the water sector has never felt the pressure it is now under to transition to a low-carbon water management model. This requires reducing GHG emissions from grid-energy consumption (Scope 2 emissions), which is straightforward; however, it also requires reducing Scope 1 emissions, which include nitrous oxide and methane emissions, predominantly from wastewater handling and treatment.

The pathways and factors leading to biological nitrous oxide and methane formation and emissions from wastewater are highly complex and site-specific. Good emission factors for estimating the Scope 1 emissions are lacking, water utilities have little experience in directly measuring these emissions, and the mathematical modelling of these emissions is challenging. Therefore, this book aims to help the water sector address the Scope 1 emissions by breaking down their pathways and influencing factors, and providing guidance on both the use of emission factors, and performing direct measurements of nitrous oxide and methane emissions from sewers and wastewater treatment plants. The book also dives into the mathematical modelling for predicting these emissions and provides guidance on the use of different mathematical models based upon your conditions, as well as an introduction to alternative modelling methods, including metabolic, data-driven, and AI methods. Finally, the book includes guidance on using the modelling tools for assessing different operating strategies and identifying promising mitigation actions.

A must have book for anyone needing to understand, account for, and reduce water utility Scope 1 emissions.

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Pages: 200

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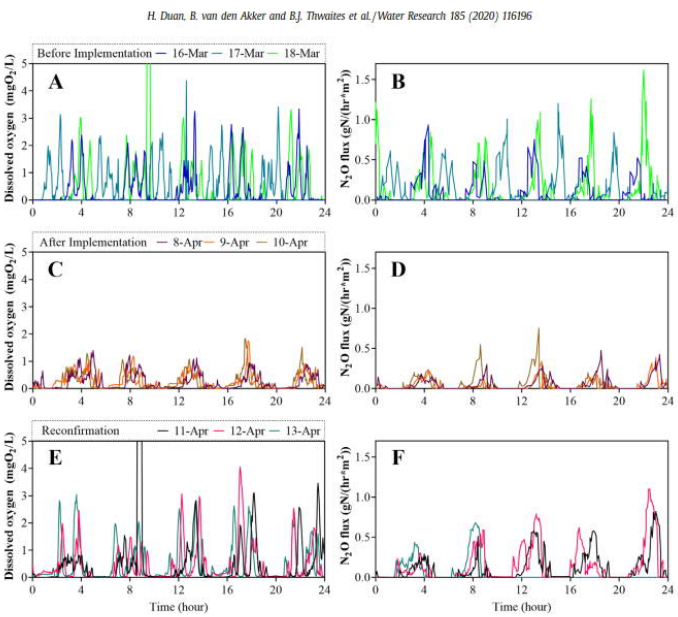
Member price: £67 / €83 / $100

eBook:
Standard price: £89 / €111 / $134
Member price: £67 / €83 / $100

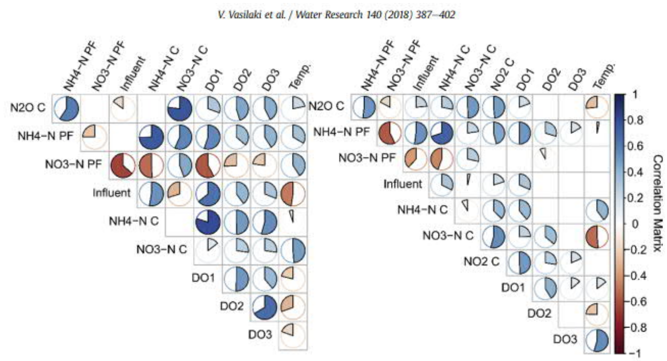
Mitigating Nitrous Oxide Emissions

Duan et al. (2020)



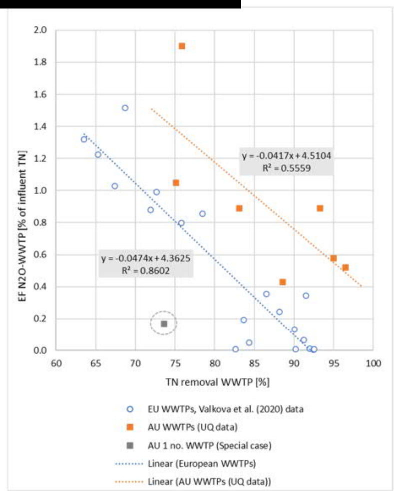
Full scale modelling and mitigation

Vasilaki et al. (2018)



Investigating drivers and solutions

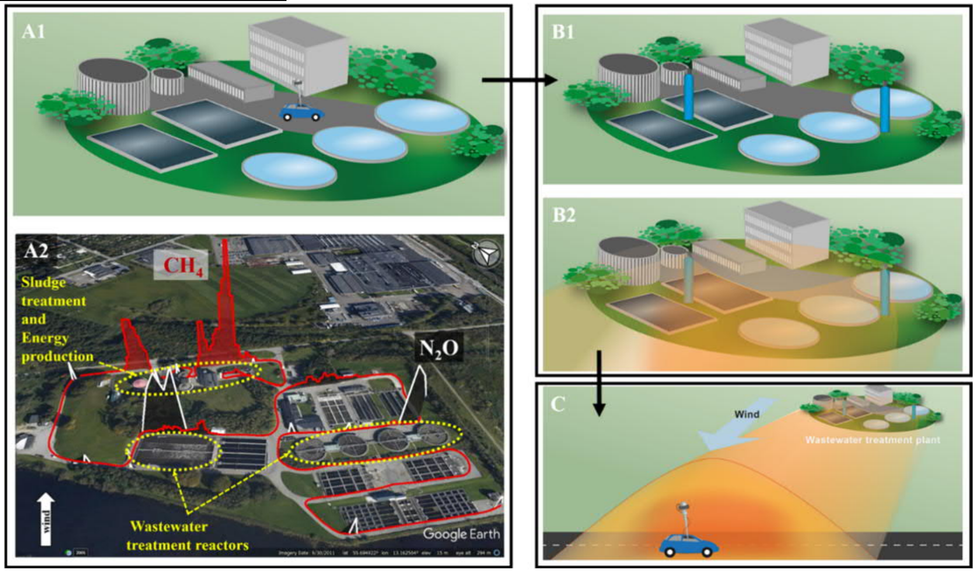
De Haas & Ye (2021)



Evolution in industry emission factors

Mitigating Methane Emissions

Delre et al. (2017)



Off site characterisation

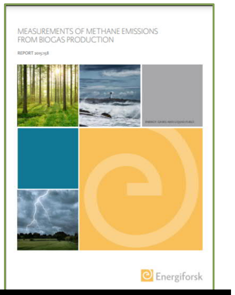
On site mitigation

APPENDIX 1. LEAK DETECTION RECORD
– CO-DIGESTION PLANT AND WASTEWATER TREATMENT PLANT

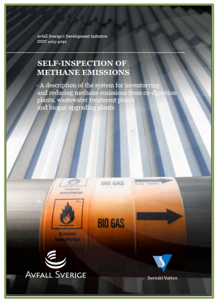
1. Potential emission object	2. Was methane leakage detected? YES	NO	3. Enter measurement (if any)	4. Specify type of action
DIGESTER				
Safety valve				
Water trap and collection tank				
Dynamic valves				
Static valves				
Roof				
In the sealing strip of hatches on the roof (e.g. manhole)				
Transition between wall and roof				
Overflow channels				
BIOGAS RESIDUE STORAGE VESSEL				
Safety valve on biogas residue tank				
Water trap on biogas residue tank				
Dynamic valves on biogas residue tank				
Static valves on biogas residue tank				
Roof on biogas residue tank (especially if it is a concrete roof)				
In the sealing strip of hatches on the roof				

Avfall Sverige (2019)

DBFZ (2019)



Holmgren et al. (2015)



EvEmBi

Voluntary action for GHG emissions control in the biogas sector

Emerging Approaches

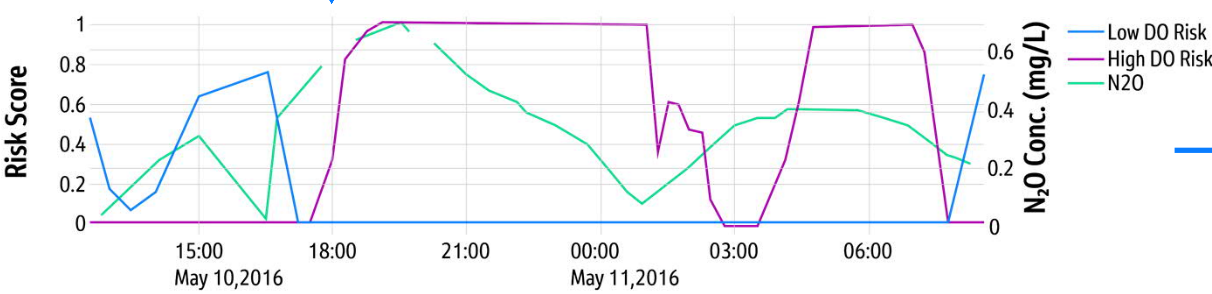
Knowledge Base

Courtesy Cobalt Water Global

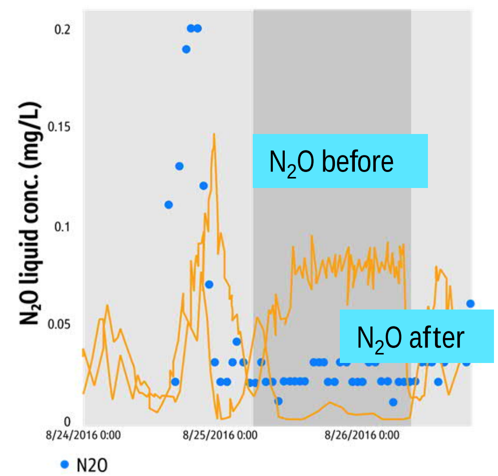
Process/ Condition	Operational Parametr/ Condition	Variable	Pathway No. (from figure 1)	References linking operational conditio to N_2O risk
Nitrification	High No_2	No_2	3	Kampschreur et al. 2009; Foley et al., 2010; Ahn et al., 2010; GWRC, 2011
	Low DO	DO	3	Kampschreur et al. 2008; Kampschreur et al. 2009;
	High DO	DO	1, 2	Ahn et al., 2010, Chandran et al., 2011, Law et al., 2012, Peng et al., 2014

Peer reviewed literature

Risk Assessment



Mitigation



Challenges and Opportunities

- Monitoring methods
- Cost benefit of mitigation
- Collaboration for climate action

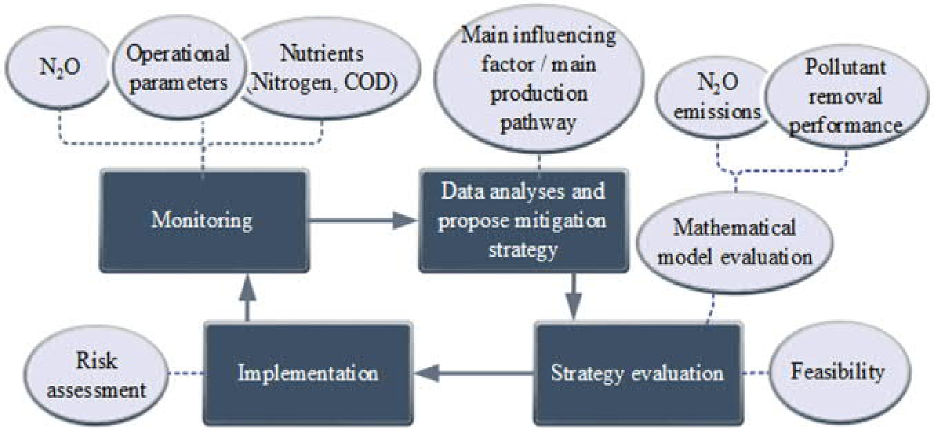


Fig. 7. Proposed standard approach for mitigating N_2O emissions from full-scale WWTPs.

Duan et al. (2020)

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Q&A

Thank You

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