Toward Net Zero Emissions: Some Experiences from the Netherlands

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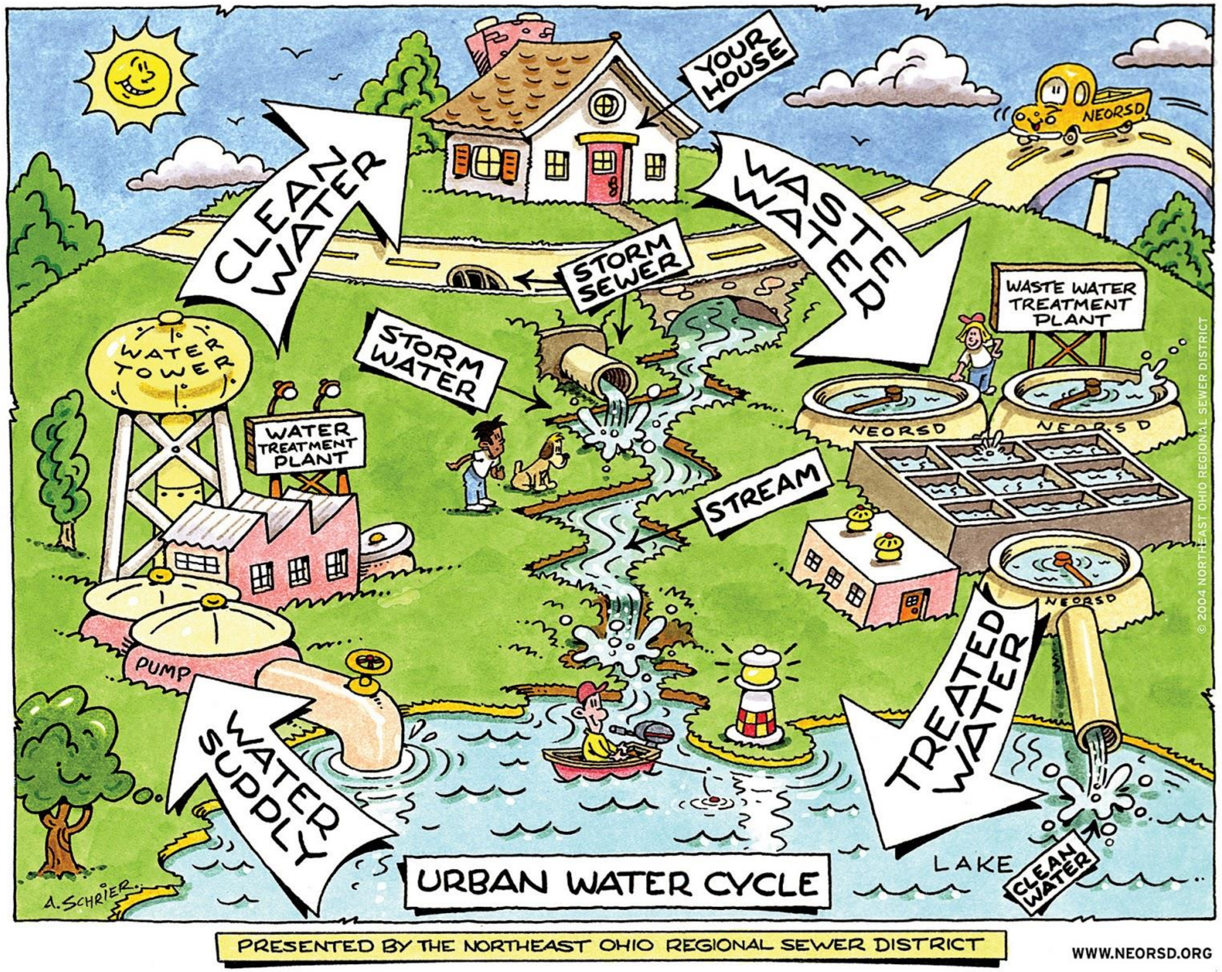
Urban Water Infrastructure

- Infrastructure covering the full urban water cycle
- Large and complex systems
- High value assets but low value of water
- Risk-averse sector with long innovation cycles
- Multiple stakeholders leading to complex decision making
- Multiple challenges



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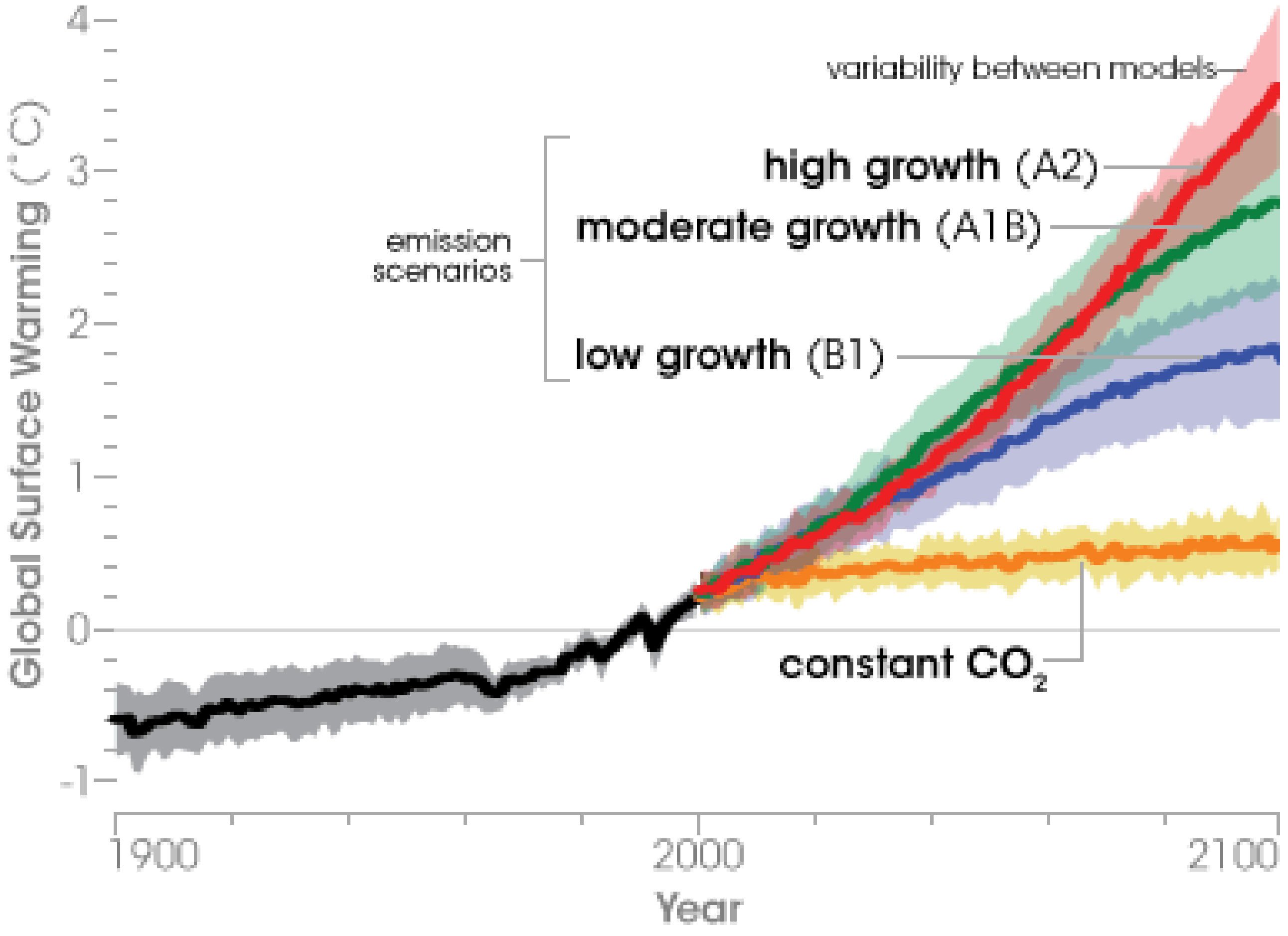
Challenges Facing Urban Water Infrastructure

- Population growth and urbanisation
- **Climate change**
- Sustainability concerns
- Environmental issues
- Infrastructure deterioration
- Increased user expectations
- Other



Reduction of GHG Emissions: Amsterdam

- City's target is to reduce GHG emissions by 55% until 2030 and 95% until 2050 (relative to 1990)

- Waternet has set related targets and can contribute by several means:
  - improving operational energy efficiency
  - generating electricity onsite from renewable sources
  - optimising treatment processes
  - capturing fugitive emissions
  - Many other

- Different opportunities exist but come at different costs and benefits!

Image from pixabay.com

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GHG Reduction Opportunities

- Waternet identified 50 promising opportunities:
  - 25 within their own control
  - 25 other, wider opportunities
- Utility opportunities
- Wider opportunities:
  - Thermal energy
  - Water end use related
  - Life cycle opportunities

Table 1. GHG Emissions Abatement Opportunities

utility opportunities		wider opportunities	
ID	opportunity	ID	opportunity
S1-1	sludge drying with solar energy or residual heat	S3-1	use of calcite instead of garnet sand in drinking water softening
S1-2	CO_2 emissions from combustion plants are reduced by Building Management System	S3-2	use of a 5MW aquifer thermal energy storage in a data center
S1-3	sealing sludge digestion tanks	S3-3	use of surface water as a solar energy collector to regenerate aquifer thermal energy storage systems
S1-4	flue gas treatment of combined power-heat generators	S3-4	struvite recovery from wastewater
S1-5	burning of N_2O from the waterline in the furnace of the Amsterdam Waste-to-Energy plant	S3-5	use of thermal energy (heat) from wastewater to regenerate aquifer thermal energy storage systems
S1-6	burning of CH_4 from the waterline in the furnace of the Amsterdam Waste-to-Energy plant	S3-6	use of 20,000 shower heat exchangers in households
S1-7	optimization of the nitrification in the wastewater treatment plants to reduce N_2O emissions	S3-7	use of thermal energy (heat) from drinking water to regenerate aquifer thermal energy storage systems
S1-8	sealing sewers and use of recovered CH_4	S3-8	use of calcite garnets from drinking water softening
S2-1	side stream dosing of ozone in drinking water plants	S3-9	use of thermal energy (cold) from surface to regenerate aquifer thermal energy storage systems
S2-2	supply of drinking water to water distributor by frequency-controlled pumps	S3-10	use of CO_2 from the biogas upgrading process in drinking water treatment
S2-3	building of 5 3MW wind turbines	S3-11	use of thermal energy (cold) from drinking water to regenerate aquifer thermal energy storage systems
S2-4	shutting down water conditioning at Loenderveen drinking water pretreatment plant	S3-12	use of thermal energy (cold) from industrial water to regenerate aquifer thermal energy storage systems
S2-5	installation of 100,000 solar panels	S3-13	biogas production from glycol containing wastewater from Schiphol airport
S2-6	15 additional measures 2014 in the long term energy saving program	S3-14	sludge destruction and expansion of the biogas upgrading process at the Amsterdam West wastewater treatment plant
S2-7	7 additional measures 2016 in the long term energy saving program	S3-15	use of thermal energy (cold) from wastewater
S2-8	6 additional measures 2015 in the long term energy saving program	S3-16	use of thermal energy (heat) from drinking water to regenerate aquifer thermal energy storage systems
S2-9	5 additional measures 2013 in the long term energy saving program	S3-17	regeneration of an aquifer thermal energy storage at Schiphol airport with industrial water
S2-10	400 solar panels for heat production digestion and cooling panels	S3-18	supply of industrial water without dune passage
S2-11	more efficient aeration at WWTPs	S3-19	use of thermal energy from a drinking water transport main to recover an aquifer thermal energy storage
S2-12	production of drinking water and industrial water from wastewater effluent	S3-20	use lime instead of sodium hydroxide in drinking water softening
S2-13	shut down water circulation between drinking water reservoirs	S3-21	sustainable purchase of chemicals
S2-14	use of direct current instead of alternating current	S3-22	use of thermal energy (heat) from rainwater for room heating
S2-15	direct treatment of drinking water without dune passage	S3-23	regeneration of activated carbon onsite
S2-16	replacement of small polder sewers by large polder sewers	S3-24	use of grinders in households and production of CH_4
S2-17	replacement of small sewage pumping stations by large sewage pumping stations	S3-25	use of iron containing membrane concentrate instead of $FeCl_3$ in wastewater treatment plants

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Lam. K.L. and van der Hoek, J.P., (2020), "Low-Carbon Urban Water Systems: Opportunities beyond Water and Wastewater Utilities?", *Environmental Science and Technology*, 54, 14854-14861

Assessment of GHG Reduction Potential and Costs: Methodology

- **Marginal Abatement Cost** approach:
  - Estimate and plot **marginal abatement costs** (€/ton CO_2-eq) against **abatement potential** (kton CO_2-eq/year) for different opportunities
  - Prioritize opportunities based on their marginal abatement costs
- Cost based on annualised **CAPEX** and annualised **OPEX**
- Negative total annual expense indicates cost-effective options (net savings)

ID	Opportunity	Initial investments	Annualised CAPEX [1]		Annualised OPEX [2]			Total annual expense [3]	Assumptions [4]	Remarks
			Interest	Depreciation	Maintenance cost	Energy cost	Other operating cost			
S1-1	Sludge drying with solar energy or residual heat	6,980,000	174,500	465,333	139,600	404,000	-3,286,286 (a)	**-2,102,852**	DY:15, MC:2%	(a) Cost saving from less sludge disposal
S1-2	CO_2 emissions from combustion plants are reduced by Building Management System	55,000	1,375	1,375	275	-52,800 (a)	24,000 (b)	**-25,775**	DY:40, MC:0.5%	(a) Natural gas saving (b) Labour cost
S1-3	Sealing sludge digestion tanks	200,000	-	-	-	-	-	**-39,310 (a)**	-	(a) Overall expense estimation from internal assessment
S1-4	Flue gas treatment of combined power-heat generators	0	-	-	-	-	10,000 (a)	**10,000**	-	(a) Using an existing facility that was not operating
S1-5	Burning of N_2O from the waterline in the furnace of the Amsterdam Waste-to-Energy plant	4,000,000	100,000	100,000	20,000	-	-	**220,000**	DY:40, MC:0.5%	-
S1-6	Burning of CH_4 from the waterline in the furnace of the Amsterdam Waste-to-Energy plant	3,000,000	75,000	200,000	60,000	25,000	-	**360,000**	DY:15, MC:2%	-
S1-7	Optimization of the nitrification in the wastewater treatment plants to reduce N_2O emissions	300,000	7,500	20,000	6,000	-	-	**33,500**	DY:15, MC:2%	-
S1-8	Sealing sewers and use of recovered CH_4	614,625,000	15,365,625	15,365,625	3,073,125	-	-	**33,804,375**	DY:40, MC:0.5%	-
S2-1	Side stream dosing of ozone in drinking water plants	321,530	8,038	21,435		-124,847 (a)		**-95,373**	DY:15	(a) Aggregated OPEX cost from internal assessment
S2-2	Supply of drinking water to water distributor by frequency-controlled pumps	150,000	3,750	3,750	750	-31,600 (a)	-	**-23,350**	DY:40, MC:0.5%	(a) Purchased electricity saving
S2-3	Building of 5 3MW wind turbines	20,250,000	506,250	1,350,000	748,350 (a)	-3,613,500 (b)	-	**-1,008,900**	DY:15	(a) Internal communication (b) Purchased electricity saving
S2-4	Shutting down water conditioning at Loenderveen drinking water pretreatment plant	0	-	-	-	-	-45,000 (a)	**-45,000**	-	(a) Avoided purchases of caustic soda, CO2 and oxygen

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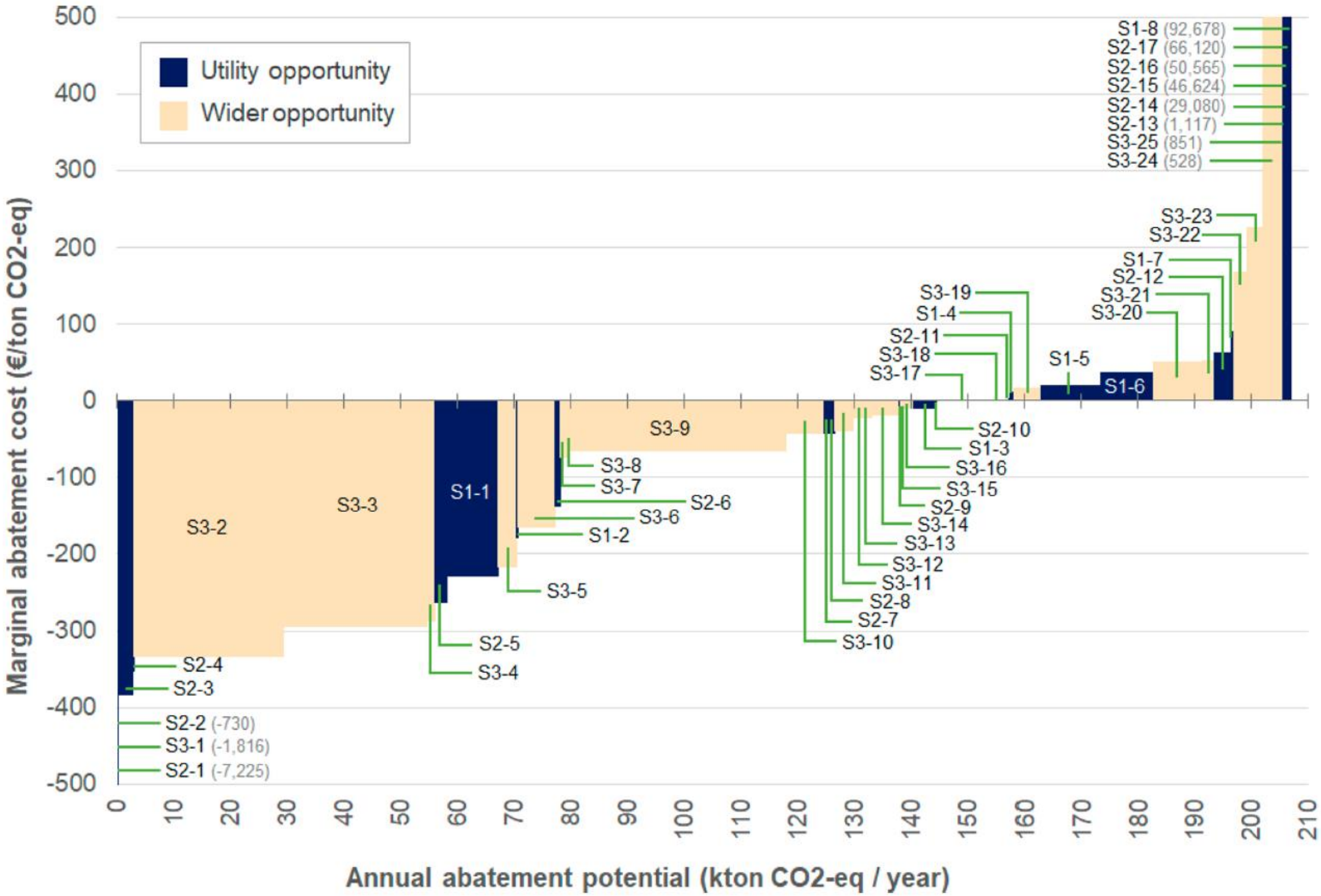
Assessment of GHG Reduction Potential and Costs: Results

- Most cost-effective **utility opportunities**:
  - building of five 3 MW wind turbines (S2-3)
  - installation of 100,000 solar panels (S2-5)
  - sludge drying with solar energy or residual heat (S1-1)
- However, total abatement potential of cost-effective **utility opportunities (21 kton** CO2-eq/year) is much smaller than the corresponding value for **wider opportunities (123 kton** CO2-eq/year)



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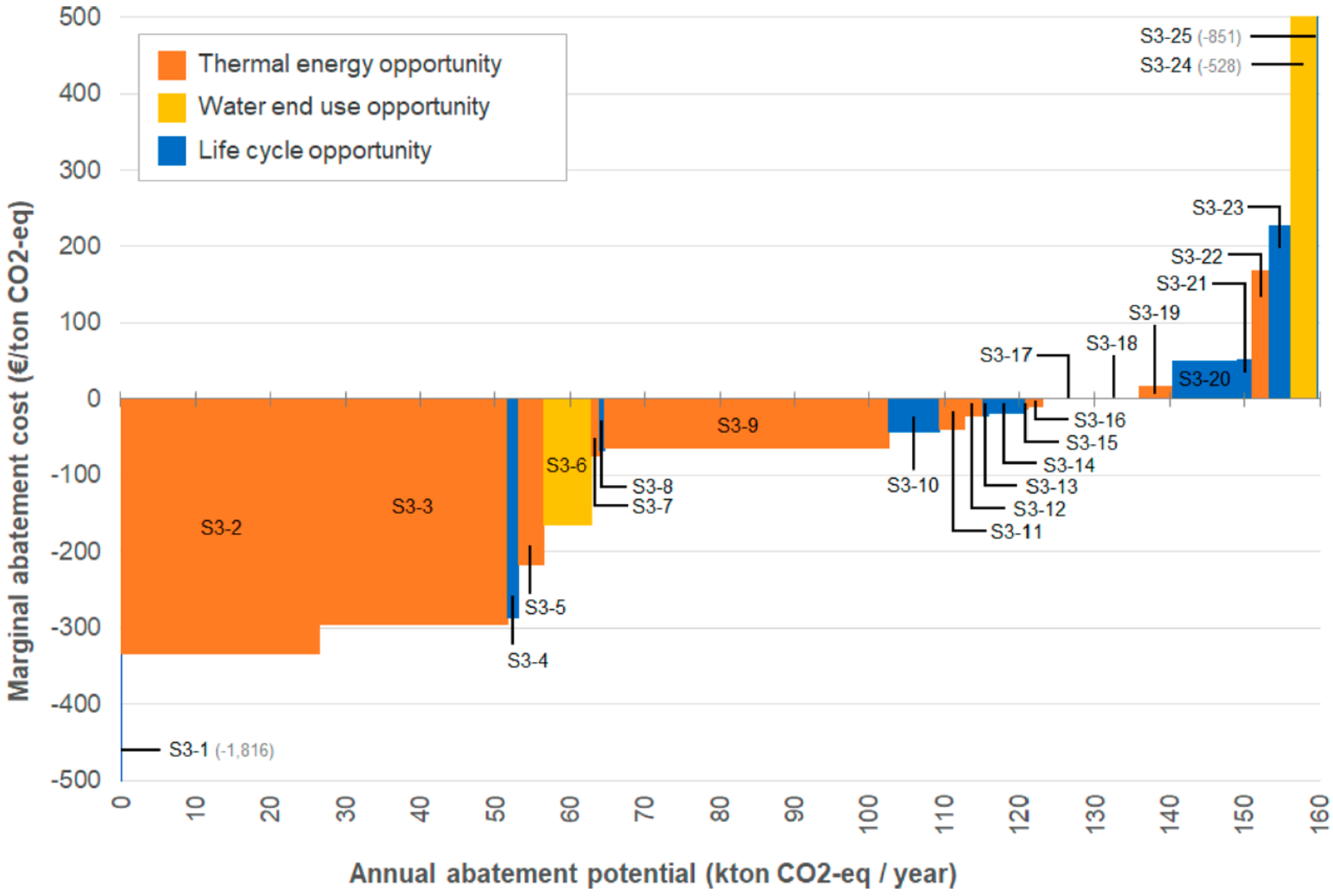
Assessment of GHG Reduction Potential and Costs: Results

- Most promising wider opportunities are **thermal energy** related:
  - use of 5 MW aquifer thermal energy storage in a data center (S3-2)
  - use of surface water as a solar energy collector to regenerate aquifer thermal energy storage systems (S3-3)

Water end use and **life cycle** based opportunities also have a lot of potential:
  - Use of 20,000 shower heat exchangers in households (S3-6)
  - Struvite recovery from wastewater (S3-4)



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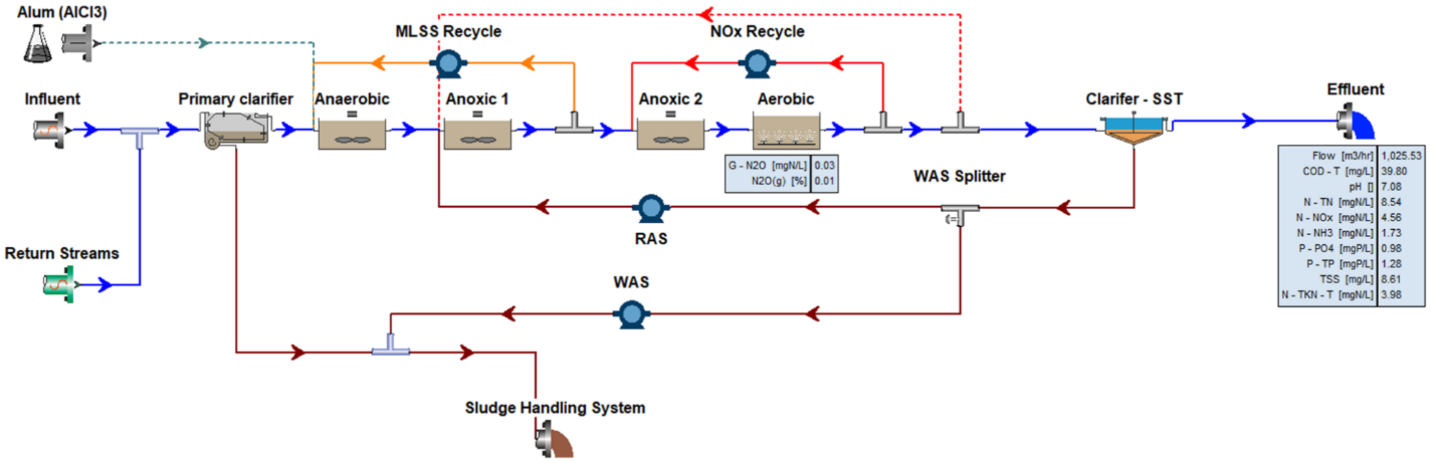
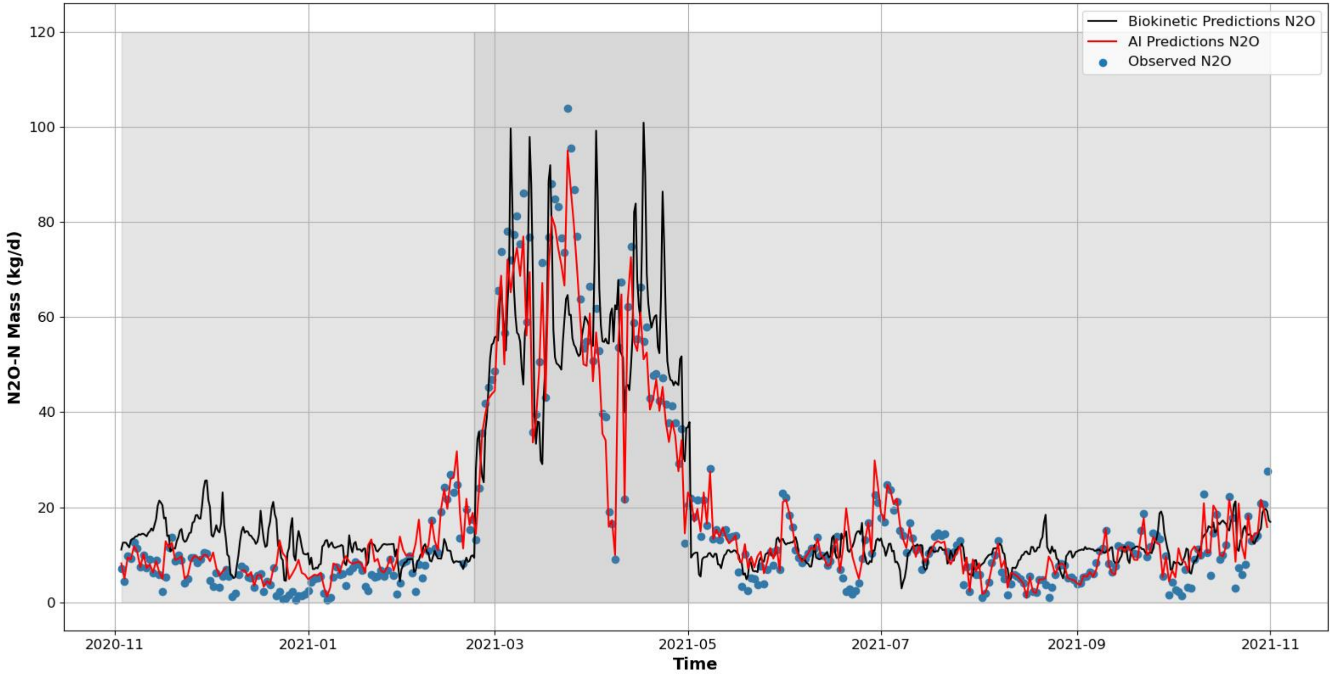
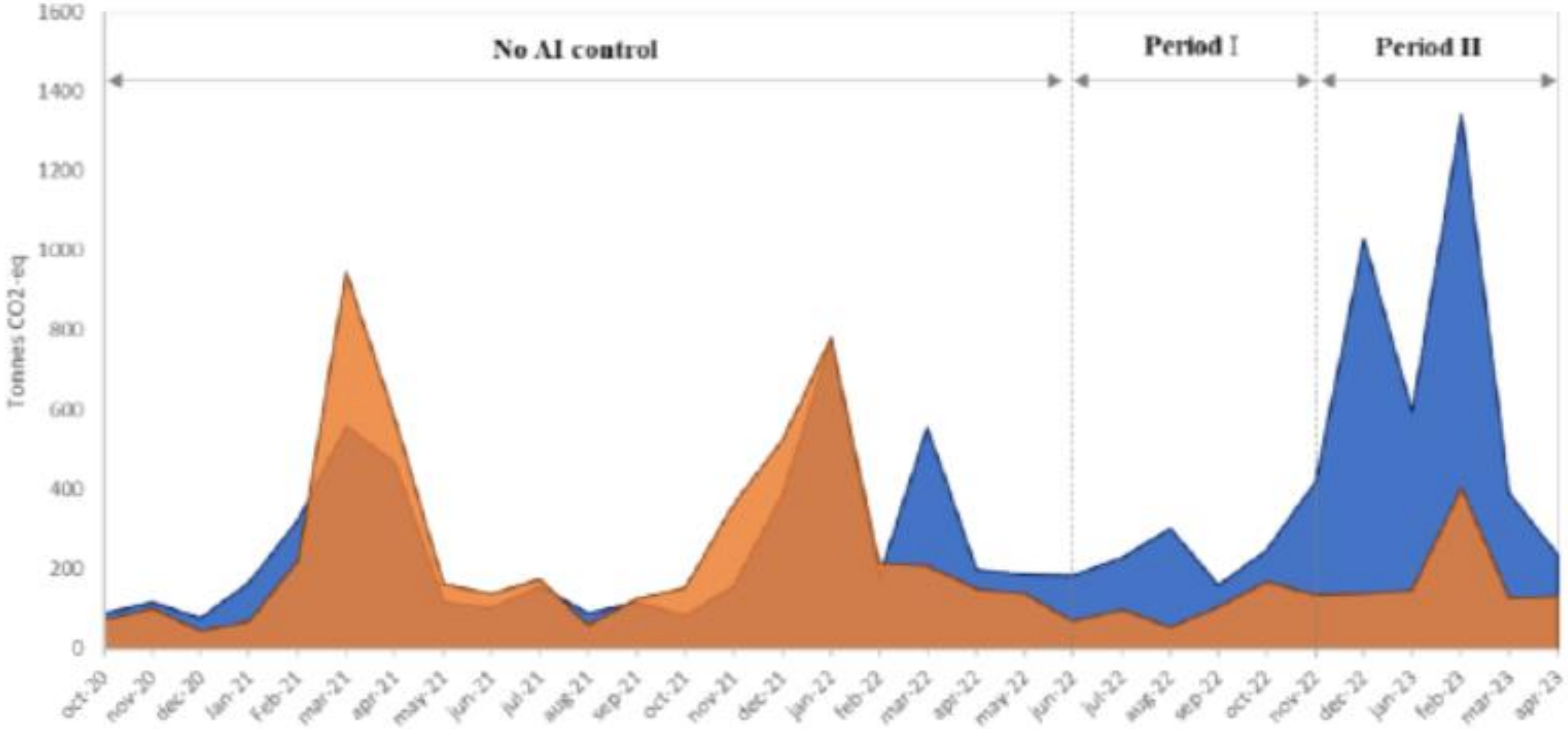
Reducing Nitrogen Emissions at WWTP

- Ongoing project with KWR and Waternet
- Case study: Amsterdam West WWTP
- Aim to reduce N_2O emissions (which are much more potent than CO_2 emissions)
- Need to be able to predict N_2O emissions first
- Process based models not working well
- AI/hybrid methodology





N_2O Emissions Reduction at Waternet



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Reducing GHG Emissions via Resource Recovery

- EU Wider project (€11M) led by SINTEF, Norway (https://wider-uptake.eu)
- Brings together researchers, water utilities and private industries with the aim to find water smart solutions based on water resources recovery for circular economy
- Five case studies in Netherlands, Norway, Italy, Czech Republic and Ghana:
  - Most focused on more traditional wastewater reuse for different type of irrigations plus biochar / struvite
  - Dutch case study different and focused on resource recovery for the production of new bio-composite material

Dutch case study: New Biocomposite Material

Clippings from surface water management
- Reed
- Grass

Residuals from treatment (WTP and WWTP)
- Calcite
- Cellulose
- Other

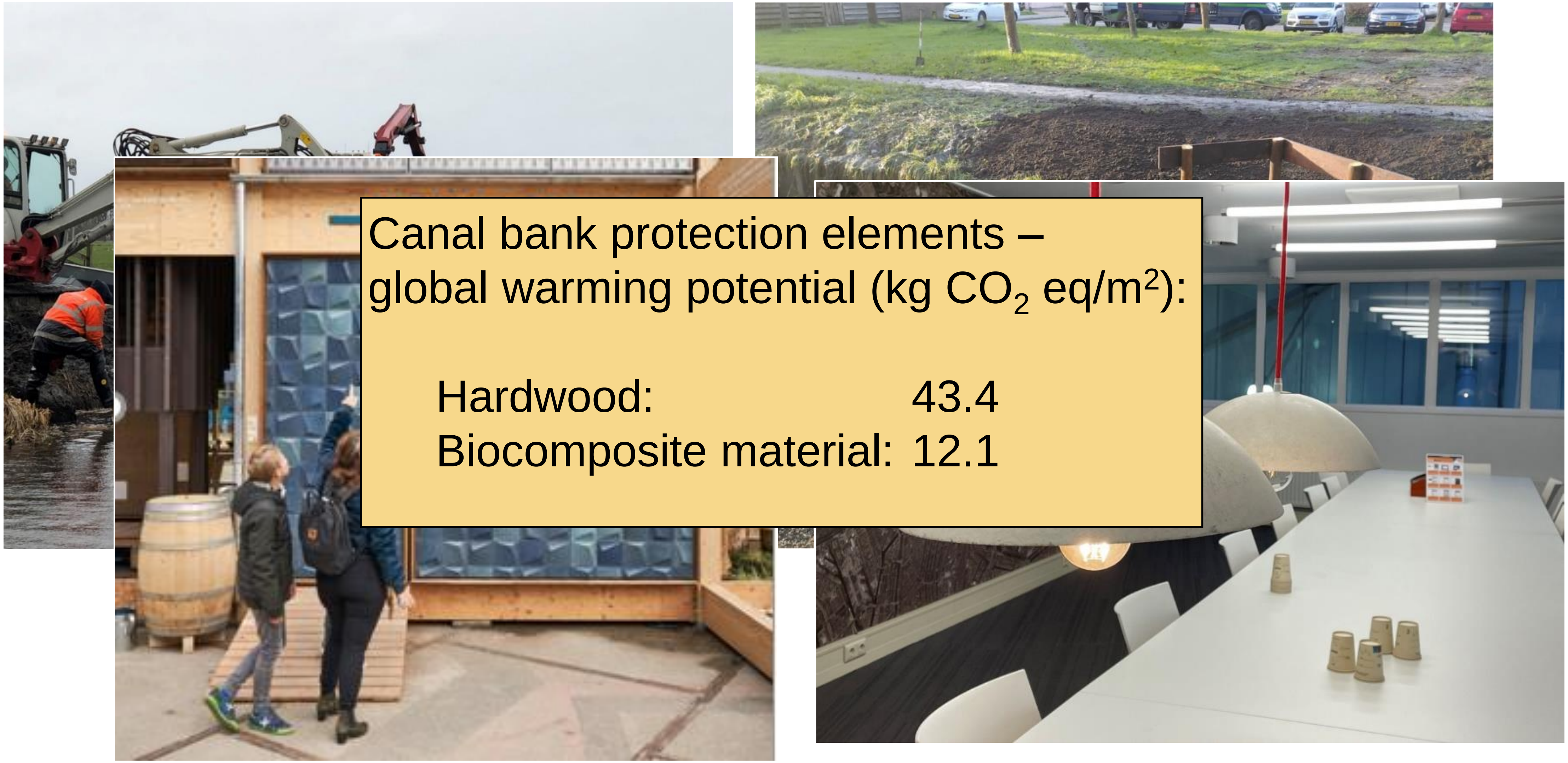
Agricultural by-products
- Bio-fillers

Bulk Moulding Compound Process:

Mixing and kneading fibres and fillers with added resin (and additives) into a dough.

Dough pressed into a mould under high temperature and pressure.

Biocomposite Material Applications



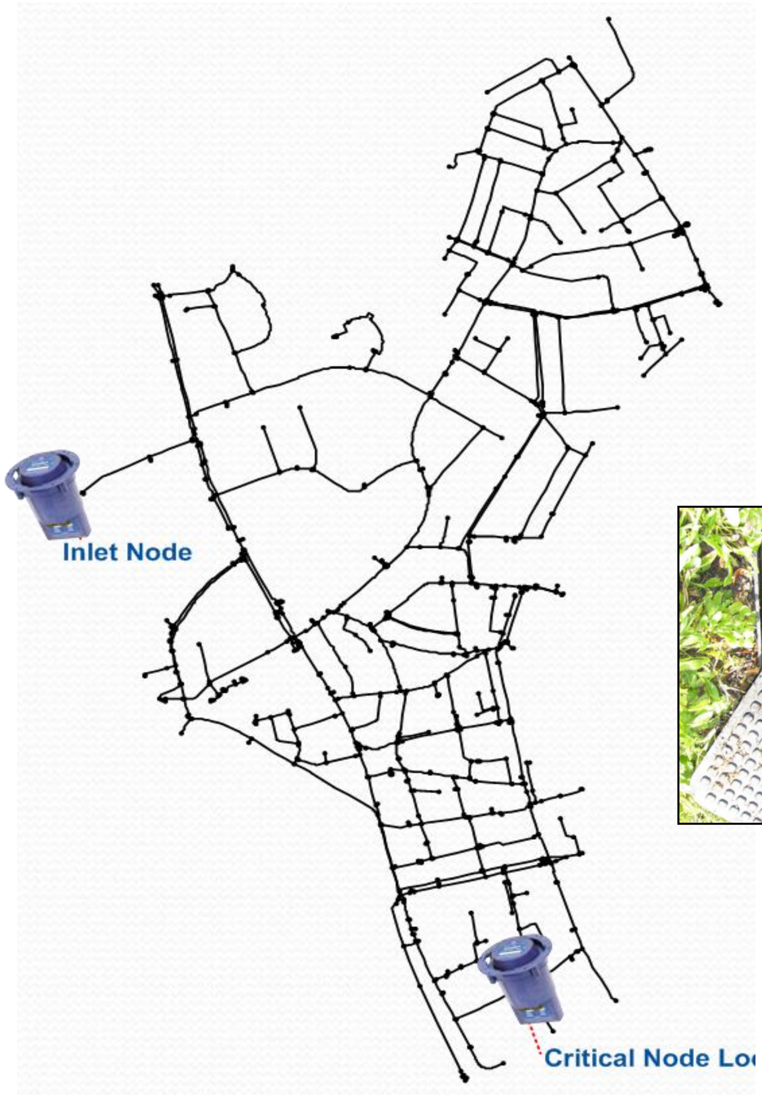
Canal bank protection elements –
global warming potential (kg CO_2 eq/m^2):

Hardwood:	43.4
Biocomposite material:	12.1

Photos from NPSP

Leakage Reduction as Means of Reducing Carbon Emissions

- Water leaked needs to be pumped and treated – potential for substantial GHG emissions reductions
- Each m³ of leaked water is approximately 10 kg of CO_2 emissions (USA)
- Lots of water is leaking in many countries
- Project focused on reducing leaks by detecting bursts in a timely manner:
  - Aim: detect and locate bursts and equipment failure events and raise alarms in near real-time
  - Sensor data: pressures/flows transmitted to control room every 15 minutes
  - Data analytics type technology
  - Bursts/leaks can be prevented this way too



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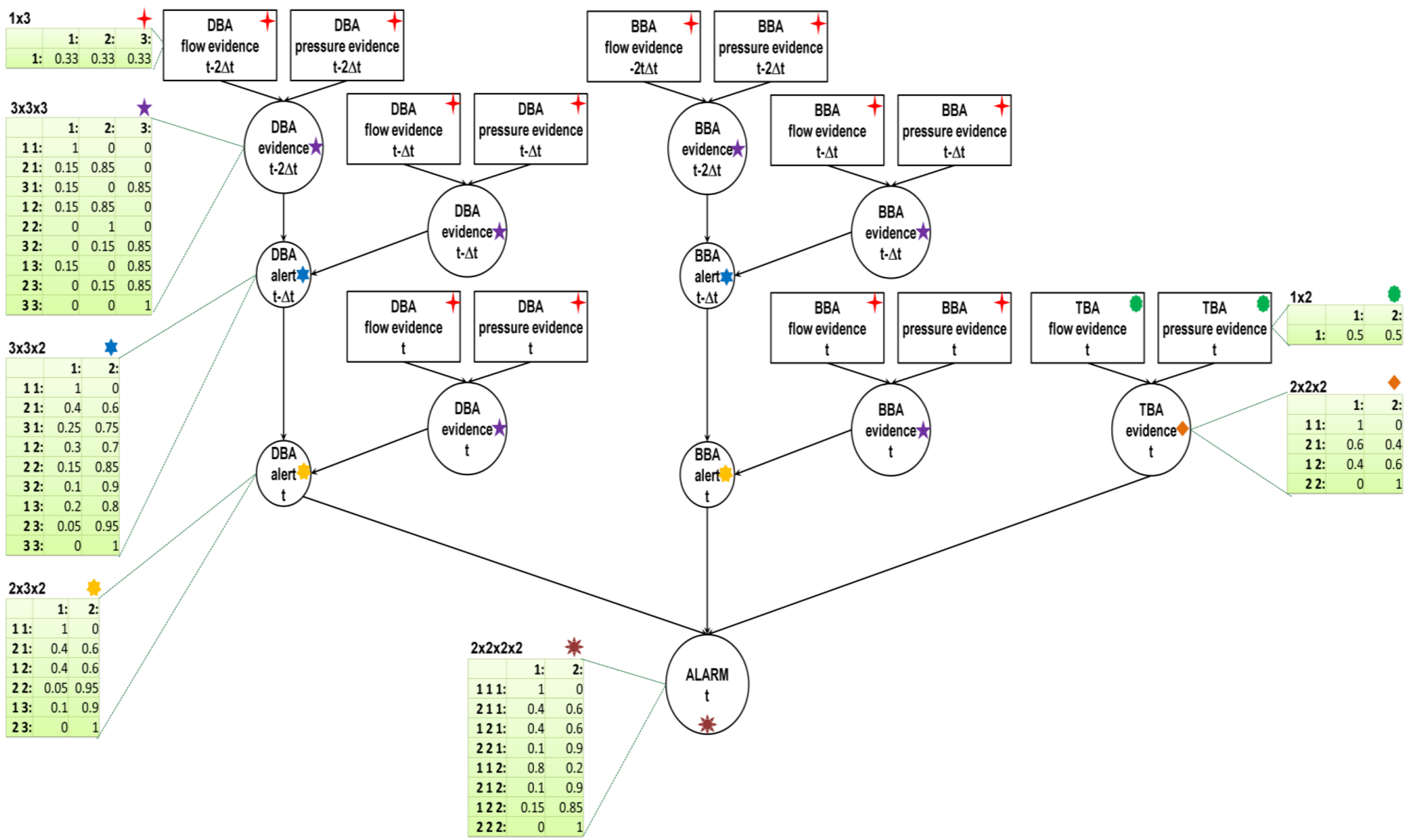
AI-based Methodology

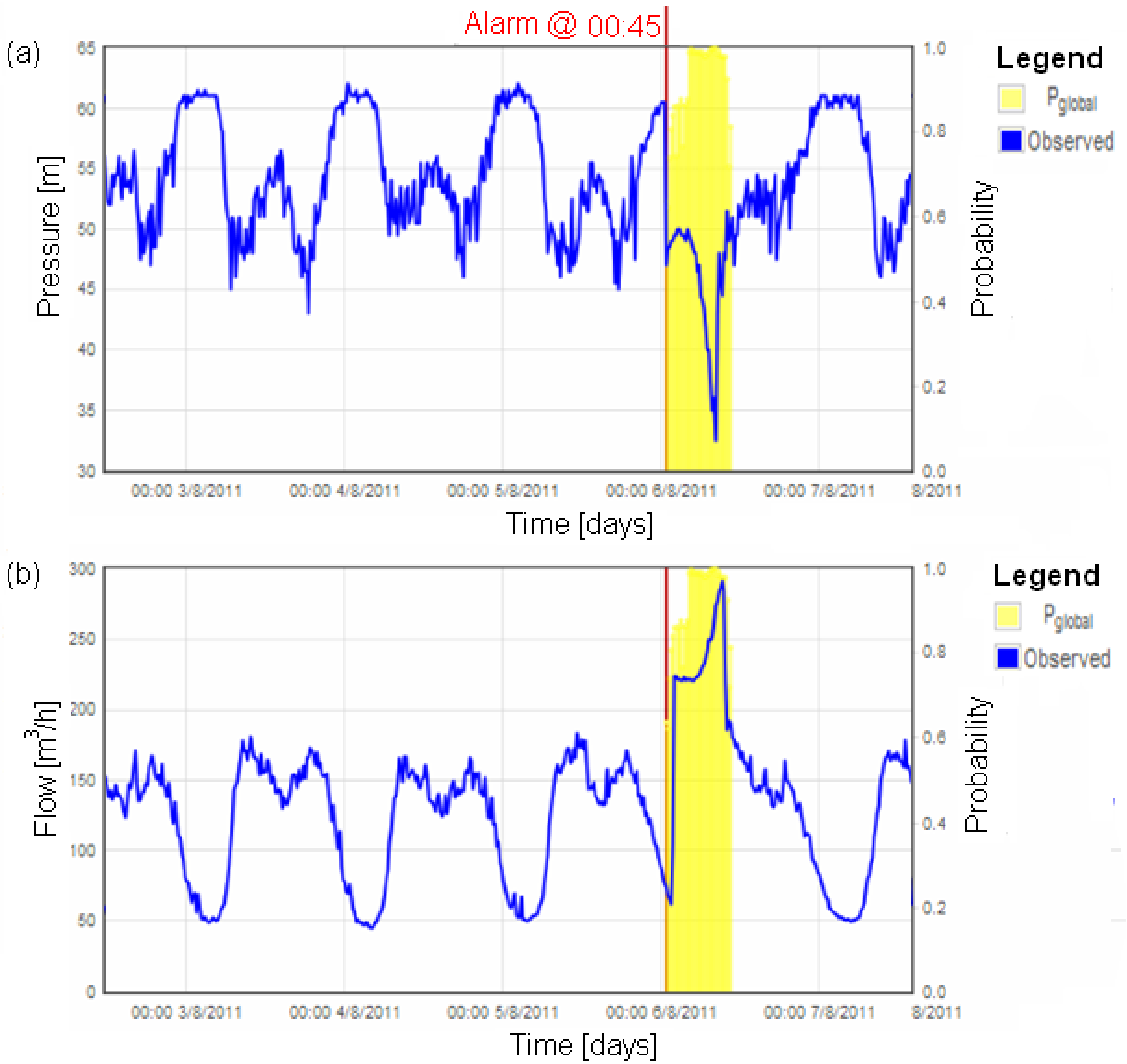
Key steps:

1. Predict sensor signals for near future assuming no burst/other events
2. Collect evidence about a potential failure event taking place
3. Process evidence and raise an alarm (if necessary)

Re-train periodically as new confirmed events become available



Example



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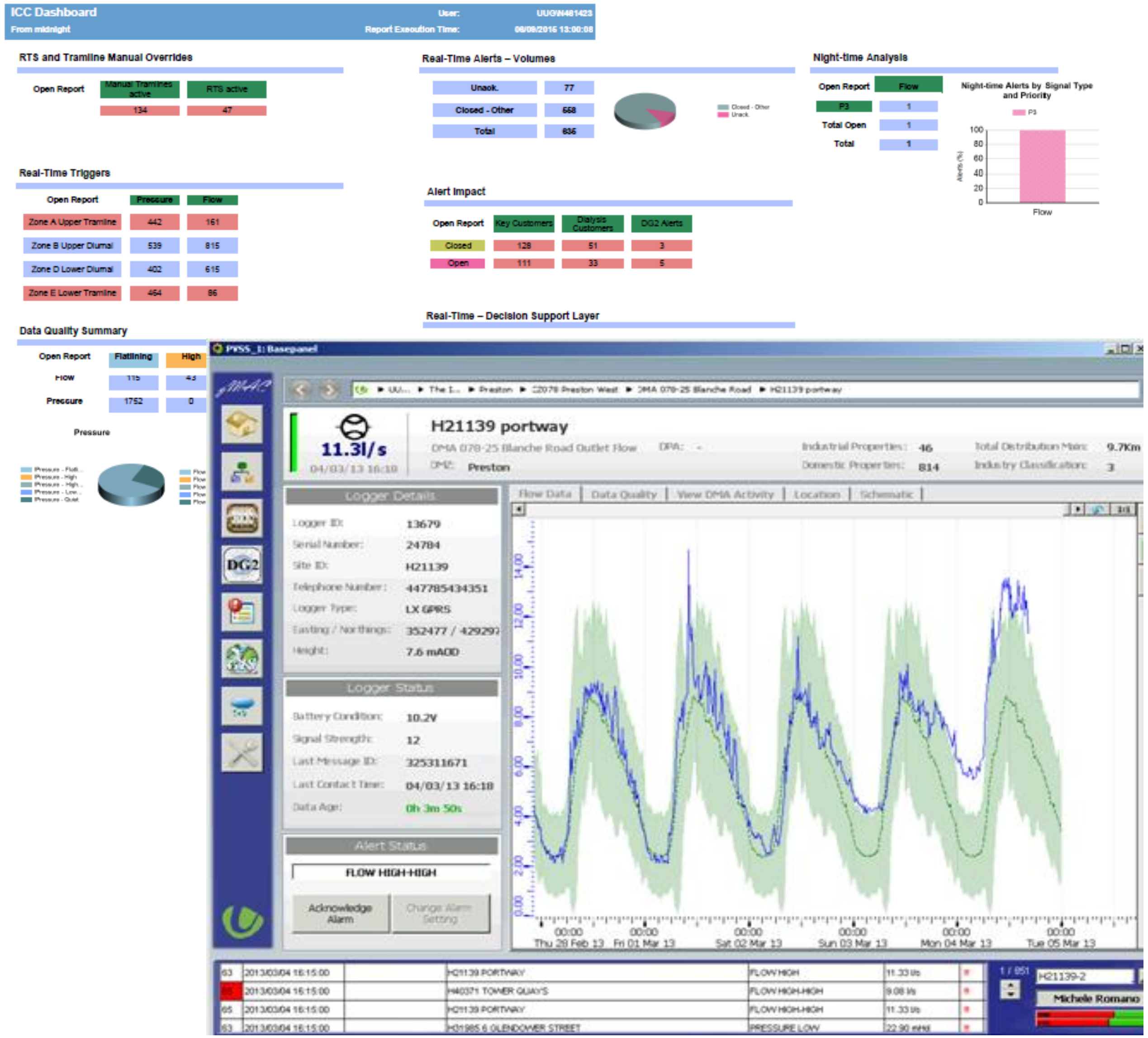
Commercial Solution

- Elements built into a commercial solution
- Successfully tested and validated, enables fast and reliable detection
- Used companywide since 2015 processing data from 7,000+ sensors
- Major operational cost saving and carbon emissions reduction



Summary

- Reducing GHG emissions remains a challenge for water industry and wider society
- Still need to develop innovative new technologies and solutions (although many already exist)
- Need to carefully prioritize the emissions reduction technologies and solutions
- We all have a role to play in getting closer to net zero future!

Thank you for your attention!

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