



# A framework for resilient plant and digital twin design for water and wastewater technologies

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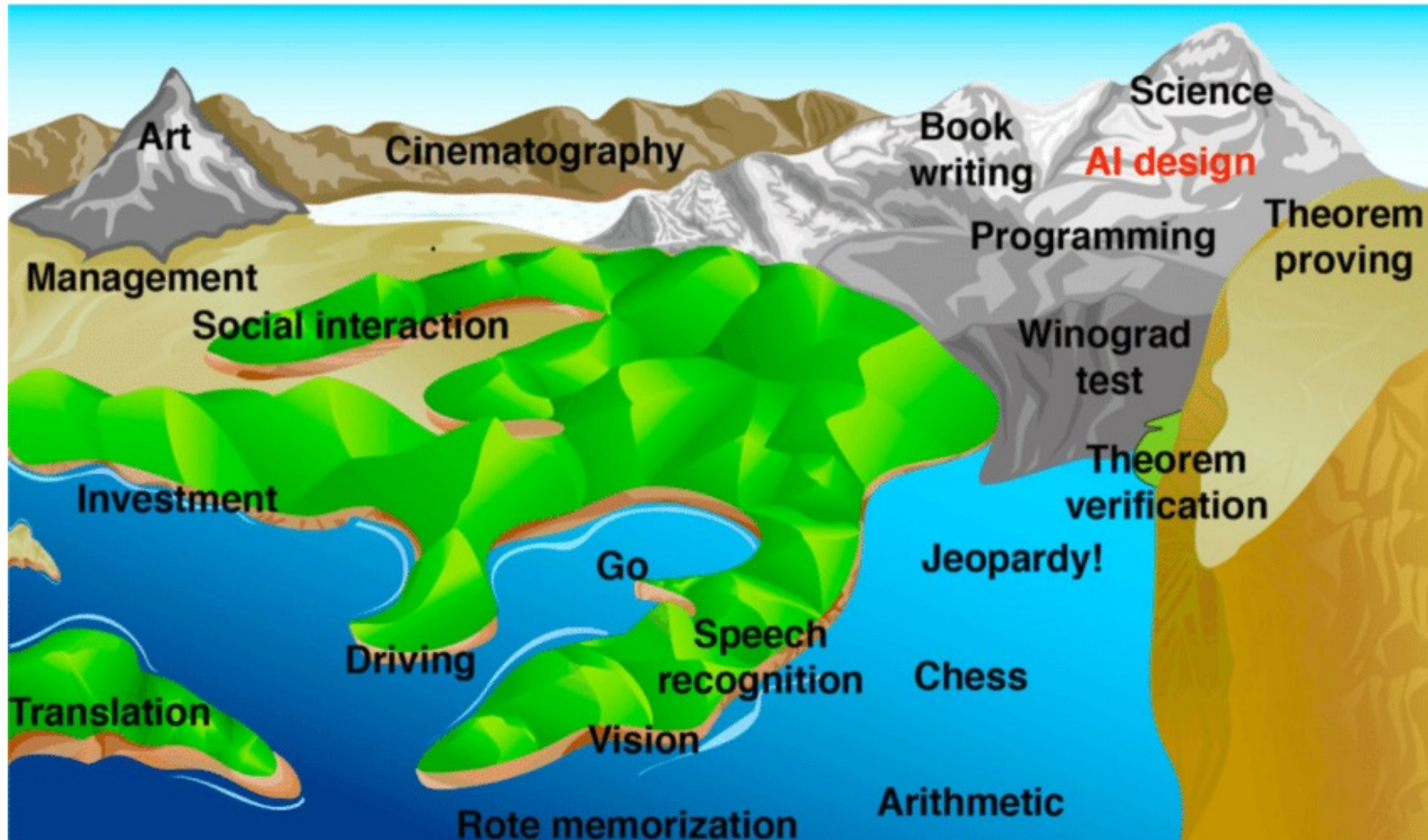
AIWW, Arena, 8/11/2023

**Wim Audenaert, PhD, Eng**

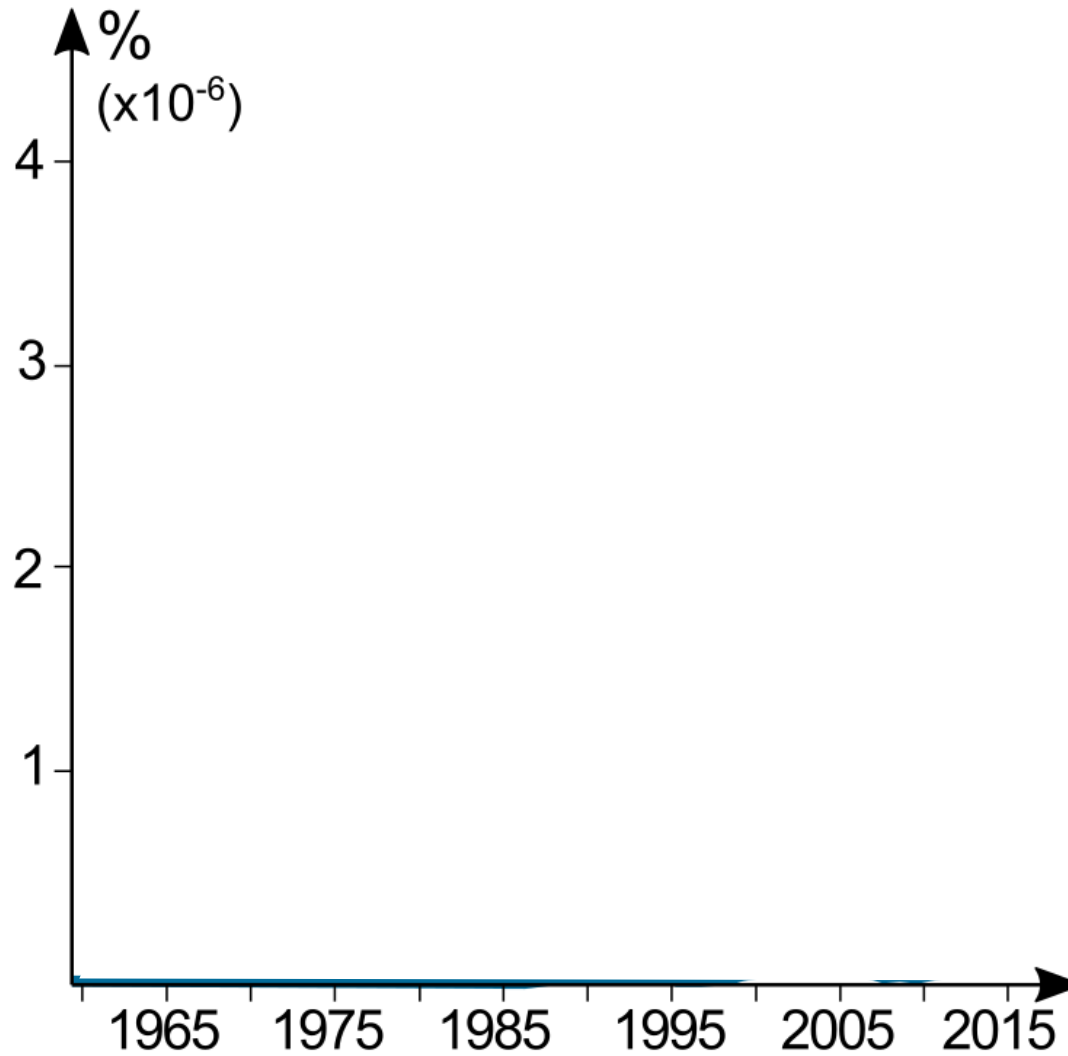
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# What is a digital twin?

# Hans Moravec's landscape of human competence



# The use of the word 'digital twin'



Compiled by Wim Audenaert, AM-Team.com  
Source: google Ngram

A digital twin predicts  
what cannot be measured  
based on  
what can be measured

AM-Team definition

# Some examples of what 'cannot be measured'

Leaks in drinking  
water network

Membrane  
fouling



Pump condition

Micropollutants

Carbon footprint  
(incl N<sub>2</sub>O)

Source: Cranfield University  
<https://www.cranfield.ac.uk/centres/centre-for-water-environment-and-development/nature-based-solutions-for-water-and-land-management>



# How is a digital twin built?

# The two big groups of tools

## **Mechanistic models**

**Based on known physics, chemistry and biology**

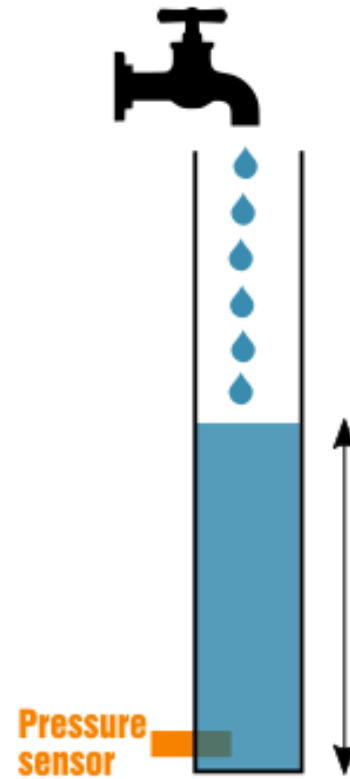
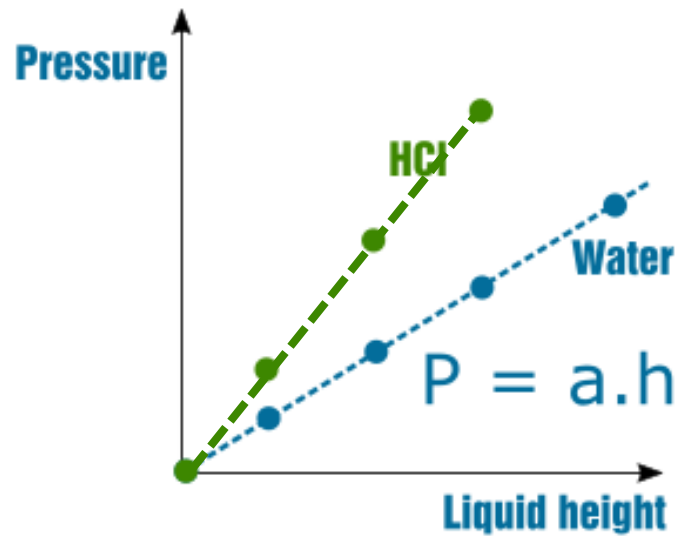
## **Hybrid models**

## **Data driven models**

**Based on (lots of) data  
Statistical models, AI, ...**

## SIMPLE EXAMPLE: HYDROSTATIC PRESSURE

### Data driven



### Mechanistic

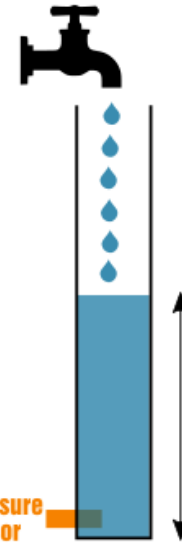
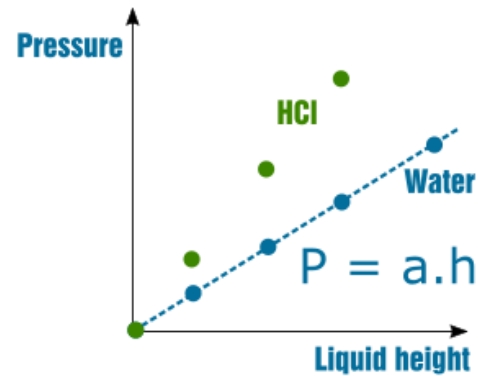
$$P = \rho g h$$

$$\rho_{\text{Water}} = 1 \text{ g/mL}$$

$$\rho_{\text{HCl}} = 1.2 \text{ g/mL}$$

## SIMPLE EXAMPLE: HYDROSTATIC PRESSURE

Data driven



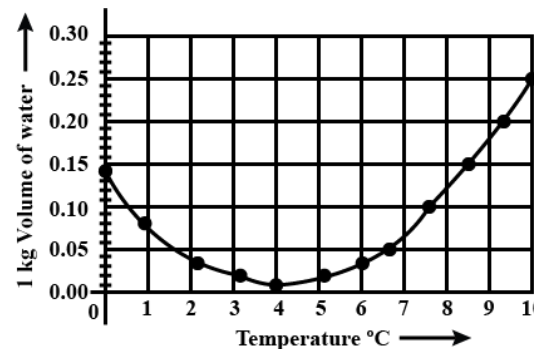
Mechanistic

$$P = \rho g h$$

$$\rho_{\text{Water}} = 1 \text{ g/mL}$$

$$\rho_{\text{HCl}} = 1.2 \text{ g/mL}$$

Hybrid



$$P = \rho g h$$

In a mechanistic model, (most of) the model parameters have a physical, chemical or biological meaning

## Data driven

You don't need to understand a lot. Especially handy for very complex systems for which lots of data is available.

Model application is rather narrow. The model can only be used to handle situations it was trained for.

## Mechanistic

You need sufficient understanding to build the model. Not so easy for very complex systems.

Model application is wide. You can conduct 'what-if' scenarios by varying parameters and variables. Data needs are limited.

# Where data-driven today is successful



Lots of data (quantity)



Good data (quality)



Complex system

# Such a 'situation' it was not trained for: mixing

## ■ A coffee cup and a bioreactor

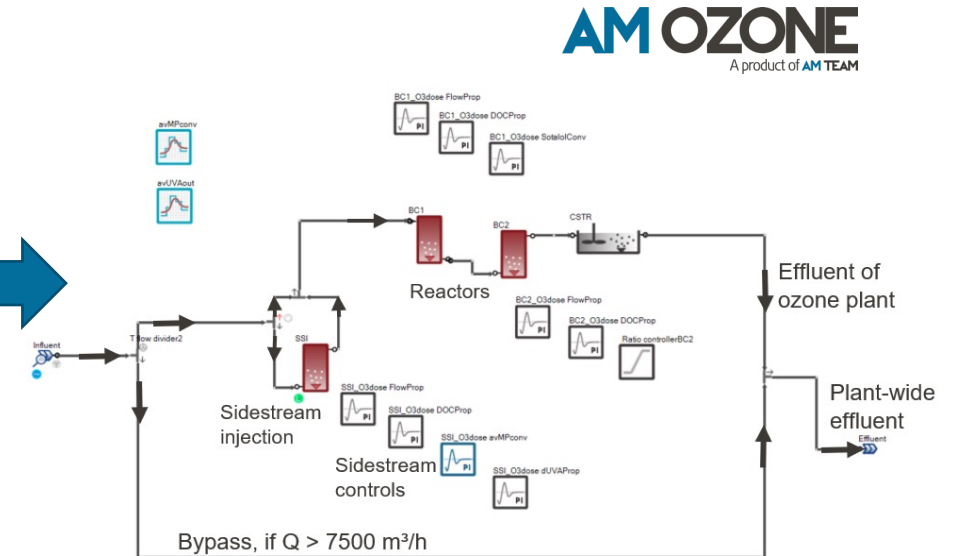


# Example: micropollutants

# Virtual piloting



Reality  
(*WWTP Eindhoven*)



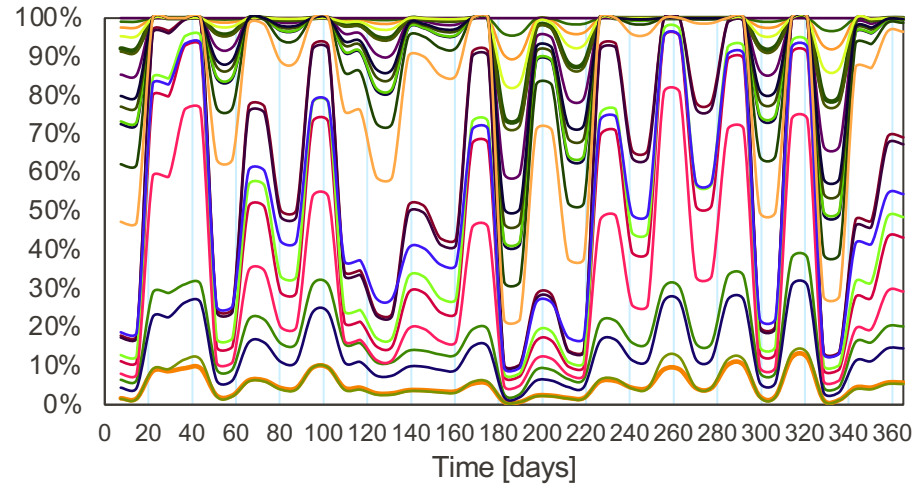
Virtual reality  
(*Ozonation*)

80% cost saving  
90% time saving  
Testing freedom

# The Wervershoof DT

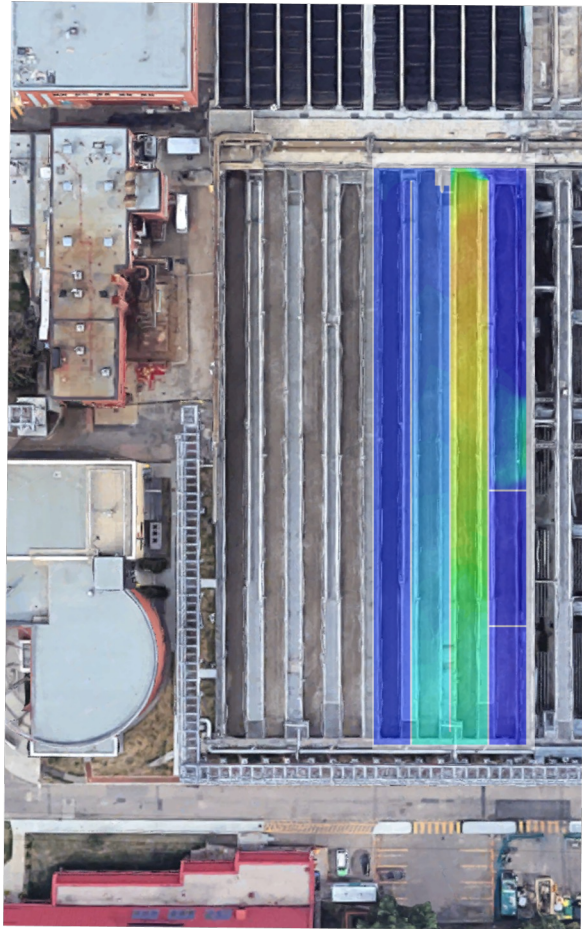


## Kinetics: BrO<sub>3</sub>, O<sub>3</sub>, HO\*, MP's in real-time

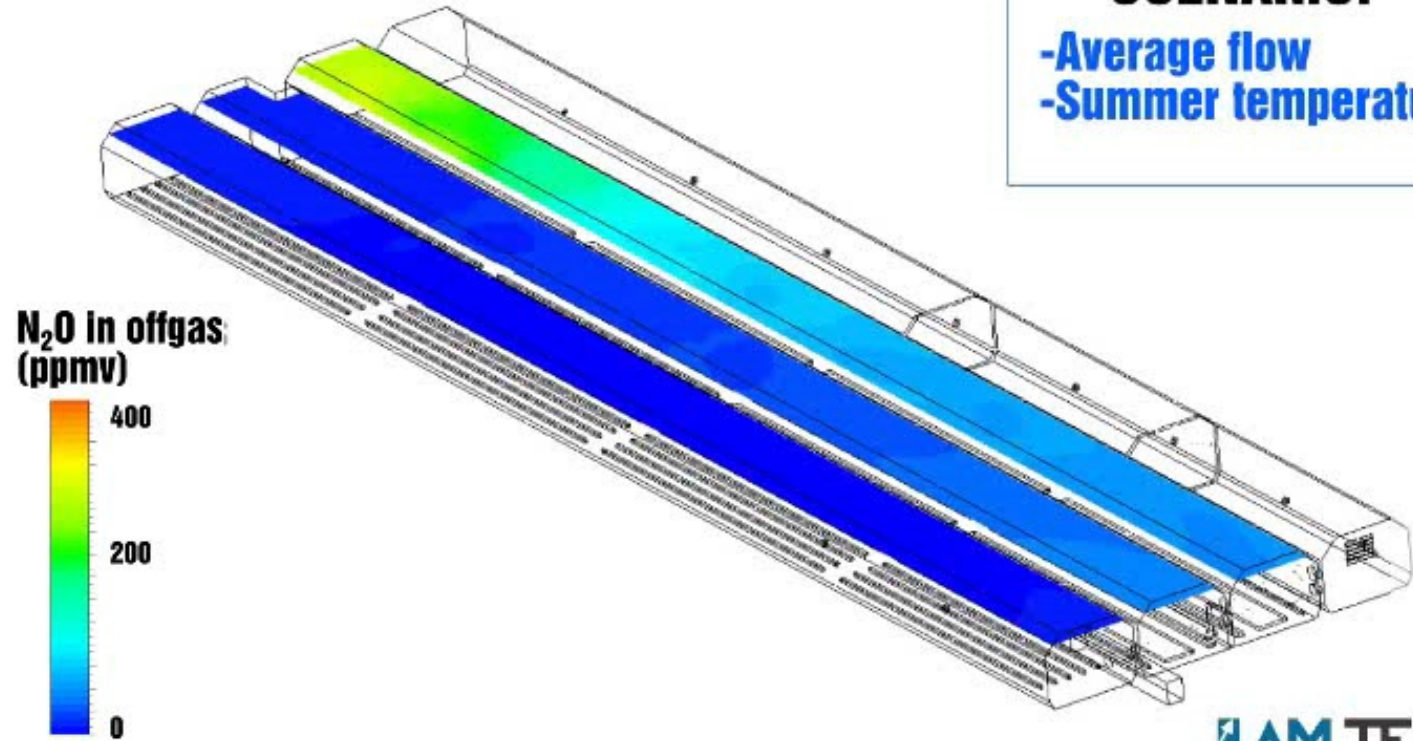


# Example: N<sub>2</sub>O

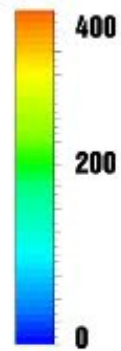
# 'One factor at a time' change for N<sub>2</sub>O



**SCENARIO:**  
-Average flow  
-Summer temperature



**N<sub>2</sub>O In offgas (ppmv)**



**Total N<sub>2</sub>O emission:**  
**232 kg CO<sub>2</sub>/d**  
**Offgass      Effluent**  
**96.7%      3.3%**



# Conclusions

# Benefits of digital twins



- AI: from hype to sustainable trend
- Mechanistic models: largely underused for digital twin purposes
- The future will likely be hybrid

Thanks for listening!

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