Economic Optimization of Integrated Nutrient and Energy Recovery Treatment Trains Using a New Model Library

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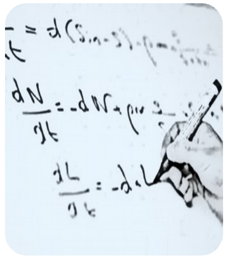
Outline of the presentation

Introduction



Nutrient recovery model (NRM) library

Treatment train optimization

Take-home message

INTRODUCTION

The nutrient paradox

Nutrient excesses
 Environment

Environmental pollution

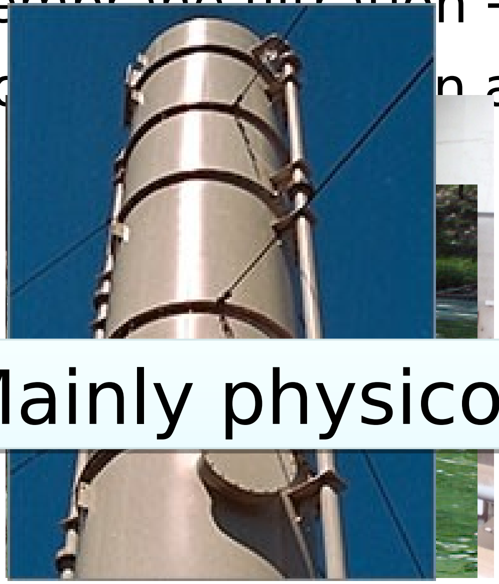
Increasing demand for
chemical fertilizers

Nutrient depletion (P, K)

How to produce more food and energy with less pollution?

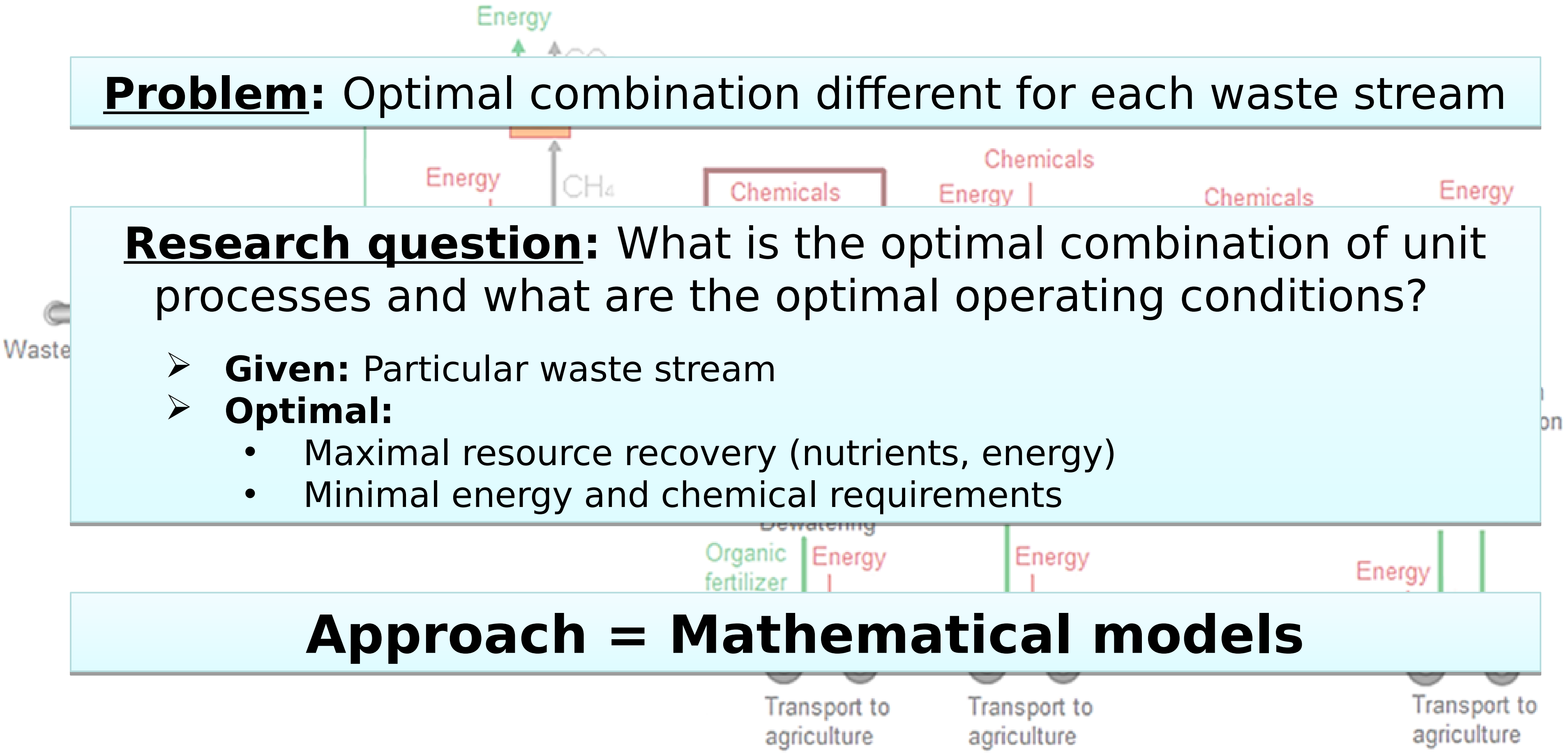
Nutrient recovery from (digested) waste: A potential sustainable and cost-effective solution

- Precipitation → struvite, calcium phosphates
- Ammonia stripping → NH_3
- Acidic air scrubbing → ammonium sulphates
- Membrane filtration → H_2O, N-K concentrates
- Bi[illegible]n and harvest → biomass
- …



⇒ Mainly physicochemical unit processes !

Potential flow diagram of a biorefinery for nutrient and energy recovery

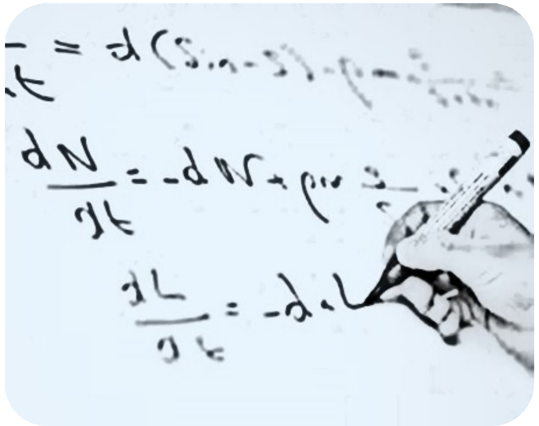


<u>Problem</u>: Optimal combination different for each waste stream

<u>Research question</u>: What is the optimal combination of unit processes and what are the optimal operating conditions?

- **Given:** Particular waste stream
- **Optimal:**
  - Maximal resource recovery (nutrients, energy)
  - Minimal energy and chemical requirements

Approach = Mathematical models

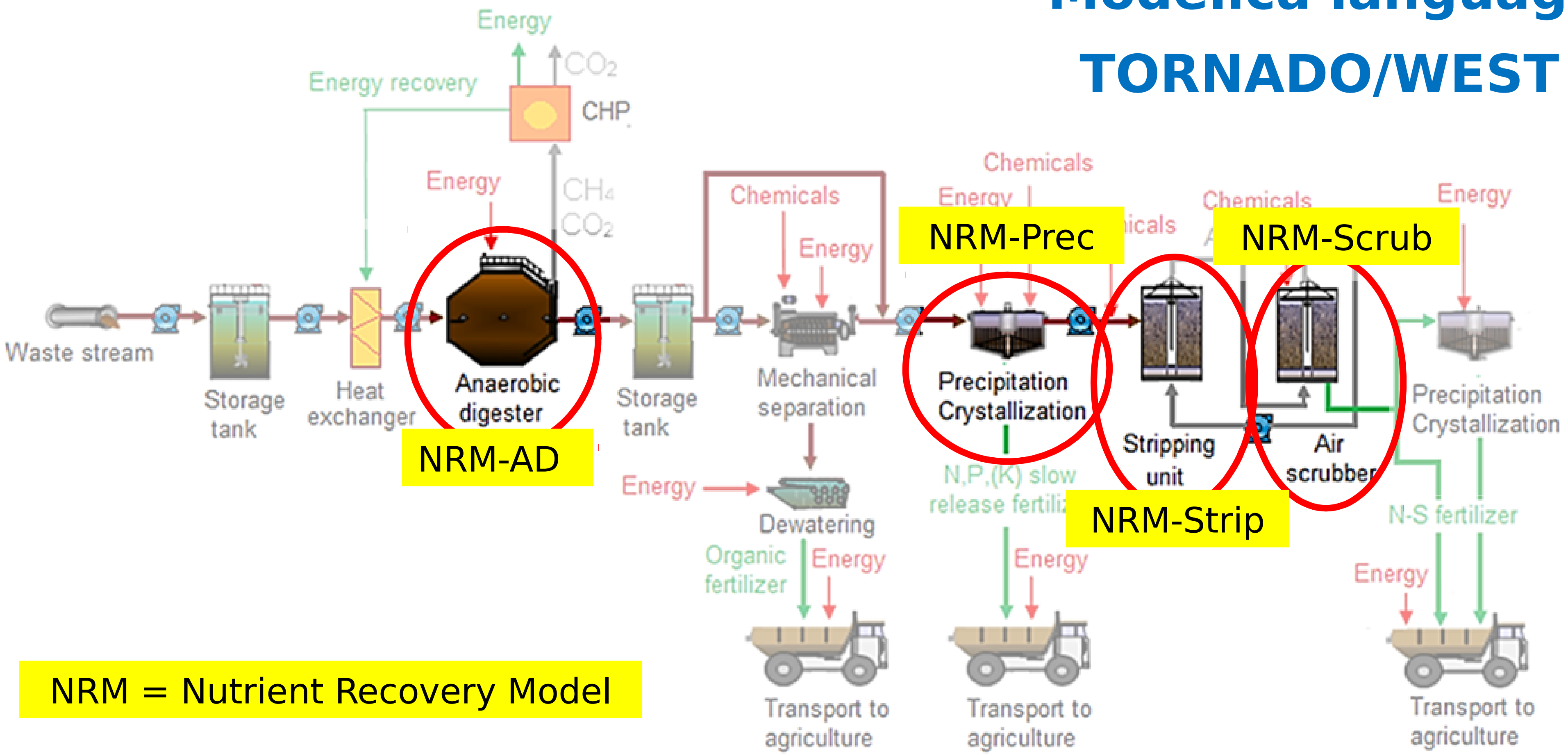


Nutrient recovery model (NRM) library

Generic nutrient recovery model (NRM) library

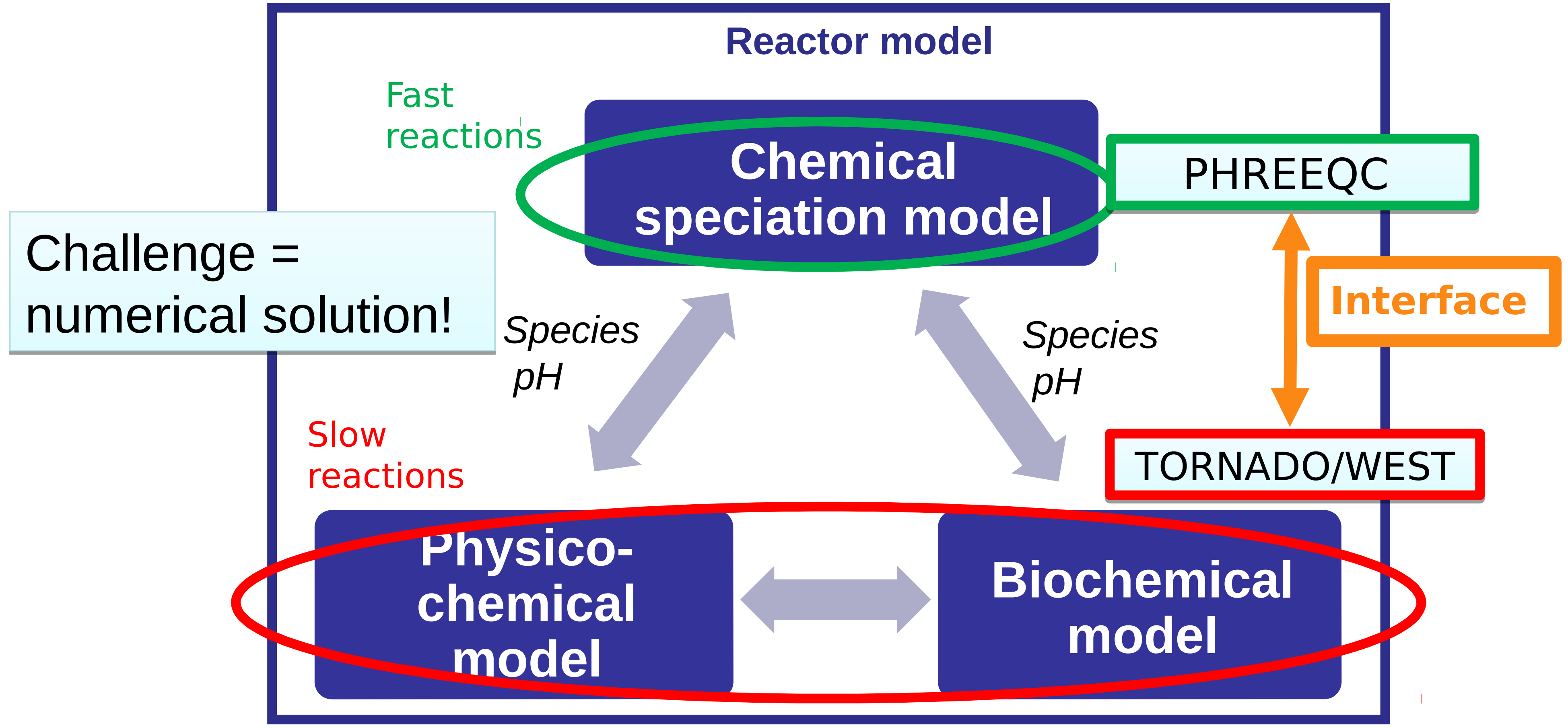
Modelica language

TORNADO/WEST



NRM = Nutrient Recovery Model

Combined three-phase physicochemical-biological models



TREATMENT TRAIN OPTIMIZATION

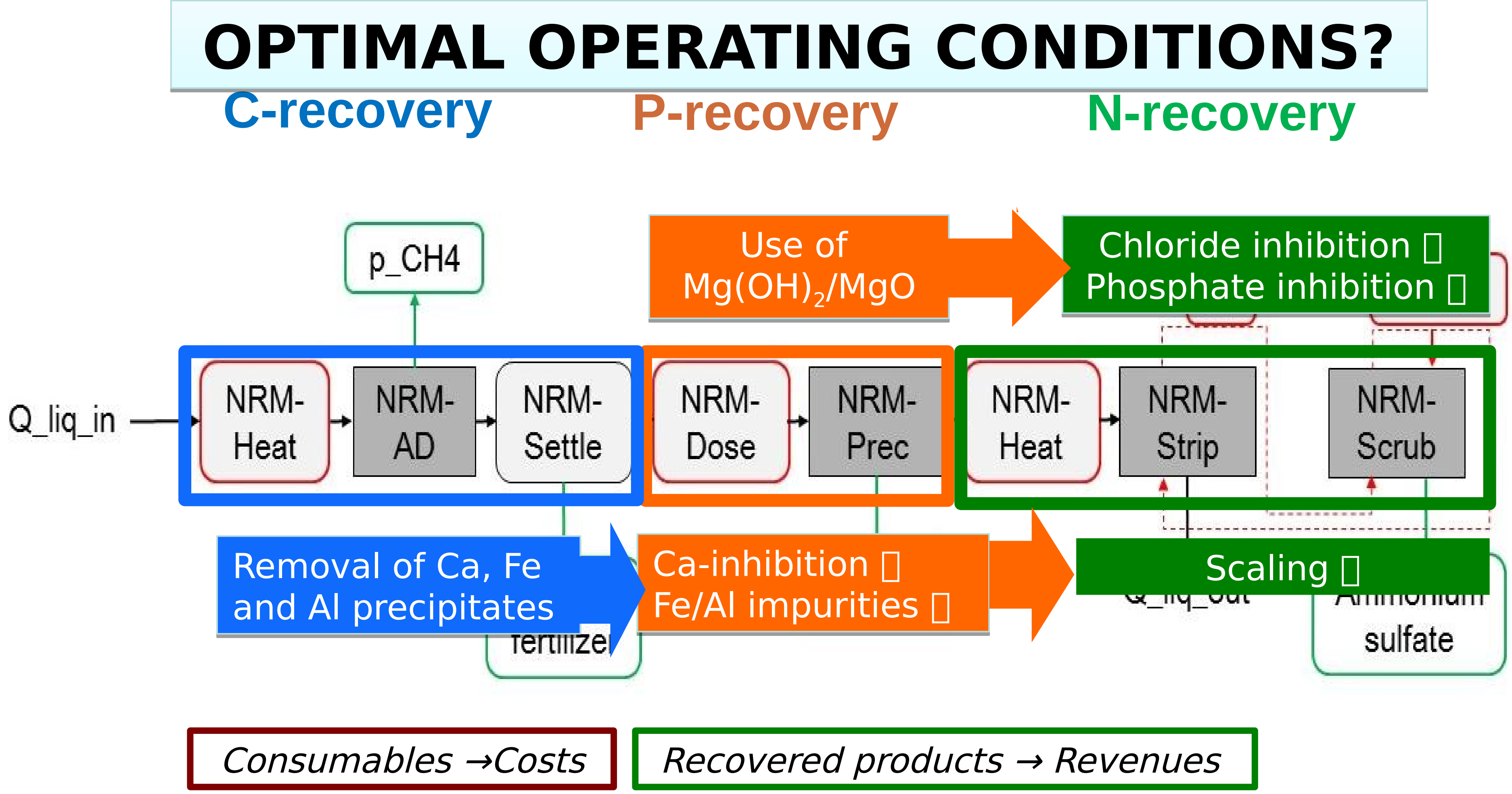
Global sensitivity analysis (GSA)

- Selection of factors with the highest impact on model outputs (= objective for further study)
  - Input waste stream characteristics
  - Kinetic model parameters
  - Process operational parameter
  - ....

↓ *Acquired understanding*

Optimal treatment train configuration

Treatment train configuration
Target = struvite + ammonium sulfate



MAXIMIZE

MINIMIZE

Treatment train optimization

Treatment train optimization: Economic analysis

Variable costs & revenues

- Heat requirements worst & best case
- Chemicals
- Electricity
- Maintenance, material & labor costs
- Biogas production   electricity and heat
- Fertilizer marketing worst and best case
- CO_2 emission reduction credits: 15 $ ton^{-1}

Capital costs

- Technology providers
- CAPDET software

Treatment train optimization: Economic analysis

Optimized Biorefinery

Financial benefits:

~ variable costs:

5 \$ m^{-3} manure y^{-1}

90 \$ ton^{-1} solids y^{-1}

~ variable + capital costs:

2 \$ m^{-3} manure y^{-1}

40 \$ ton^{-1} solids y^{-1}

Subsidies

Heat balances

ZeroCost-Biorefinery (pay-back time: 7 years)

Take-home message

Main conclusions

- Generic nutrient recovery model (NRM) library created and validated

- Global sensitivity analysis
  - Identification of interaction between processes
  - Optimal treatment train configuration

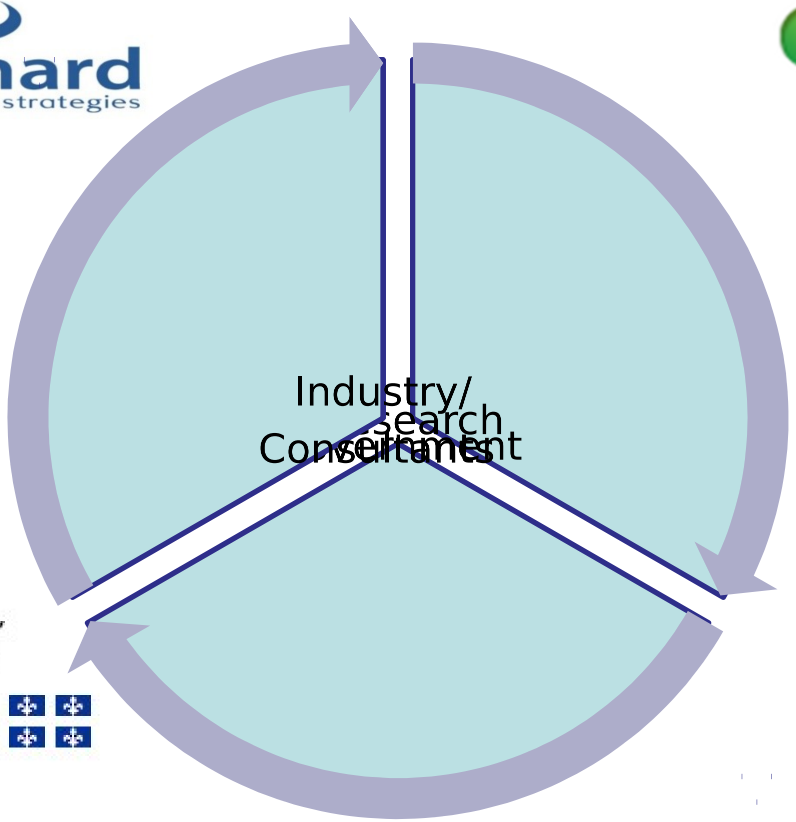
- Model-based treatment train optimization
  - Valuable tool for evaluation of project feasibility
  - Key factors for design of nutrient and energy recovery facilities:
    - subsidies
    - fertilizer marketing potential
    - heat balances

Perspectives: Development of a decision-support tool for optimization of holistic organic waste valorization chains

Primodal
Earth Essential Technologies

Chamard
environmental strategies

VIRIDIS
environnement



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Further reading

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Model-based optimisation and economic analysis to quantify the viability and profitability of an integrated nutrient and energy recovery treatment train

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In order to hasten the implementation of optimal, cost-effective and sustainable treatment trains for resource recovery from biowaste, a new nutrient recovery model (NRM) library has been developed and validated at steady state. It includes physico-biochemical mathematical models for anaerobic digestion, struvite precipitation and ammonia stripping and absorption as ammonium sulfate. The present paper describes the use of the NRM library to establish the operational settings of a sustainable and cost-effective treatment scenario with maximal resource (nutrients and biogas) recovery and minimal energy and chemical requirements. Under the optimised conditions and assumptions made, potential financial benefits for a large-scale anaerobic digestion and nutrient recovery project treating 2700 m^3/d of pig manure were estimated at US\$2·8–6·5/m^3 based on net variable cost calculations, or an average of ~\$2/(m^3 year), equivalent to \$40/(t total solids year), over 20 years in the best case when also taking into account capital costs. Hence, it is likely that in practice a full-scale zero-cost biorefinery for nutrient and energy recovery from manure can be constructed. As such, this paper demonstrates the potential of the NRM library to facilitate the implementation of sustainable nutrient and energy (biogas) recovery treatment trains for biowaste valorisation.

Questions ?

Modelling is a must for optimizing the value chain!

« Nothing is lost,
Nothing is created,
Everything is transformed »

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