An Integrated Approach for Process Development and Assessment in the Framework of Bioprocesses for Sustainable Energy Transition

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2025 AIChE ANNUAL MEETING

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Outlines

1. Need for new frameworks

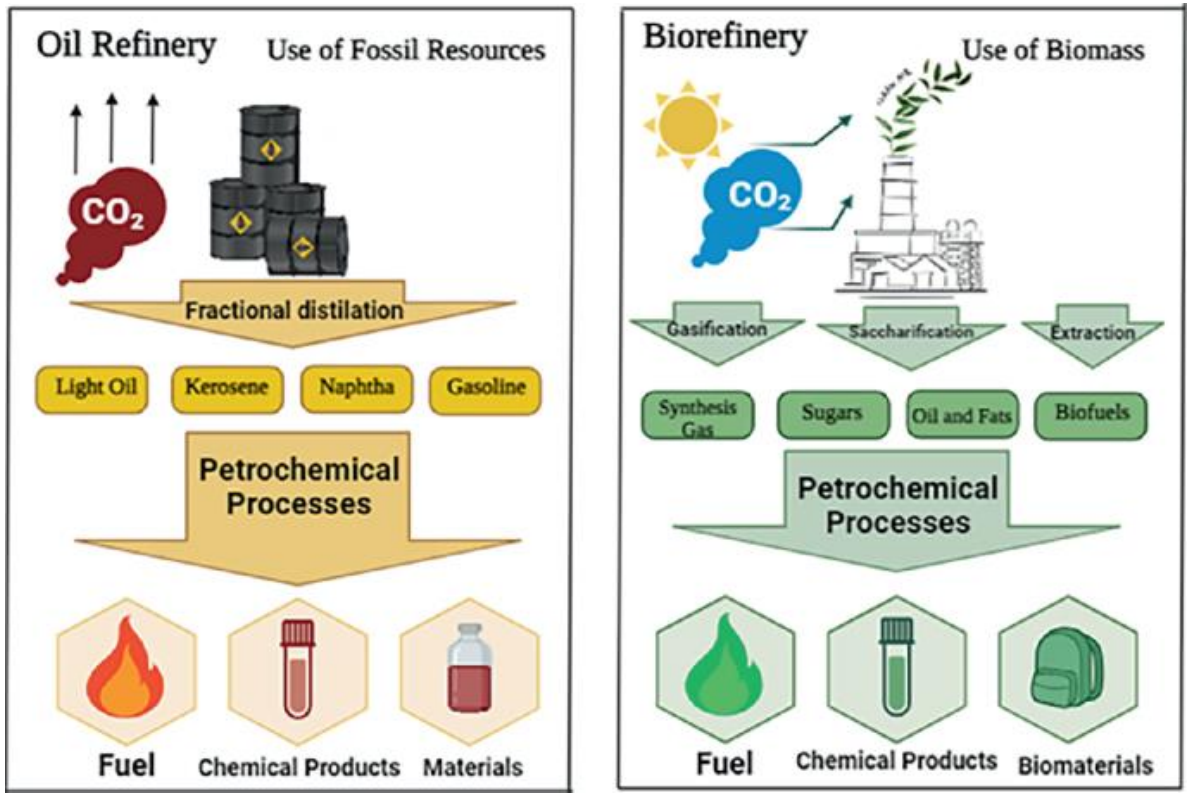
2. Case studies for two projects

3. Future applications

4. Lessons learnt and conclusions

Targets

- Replacing fossil fuels in synthesis of bulk chemicals and fuels
- Make the market of “alternatives” economically feasible



Source: Cavalcante et al. (2025). An Introduction to the Biorefinery. In: Production and Biorefining of Biocrude Oil: Current Status and Future Developments. Advances in Sustainability Science and Technology. Springer, Singapore.

Bioprocesses and CCU bottleneck

Intrinsically more complex feedstock

↓

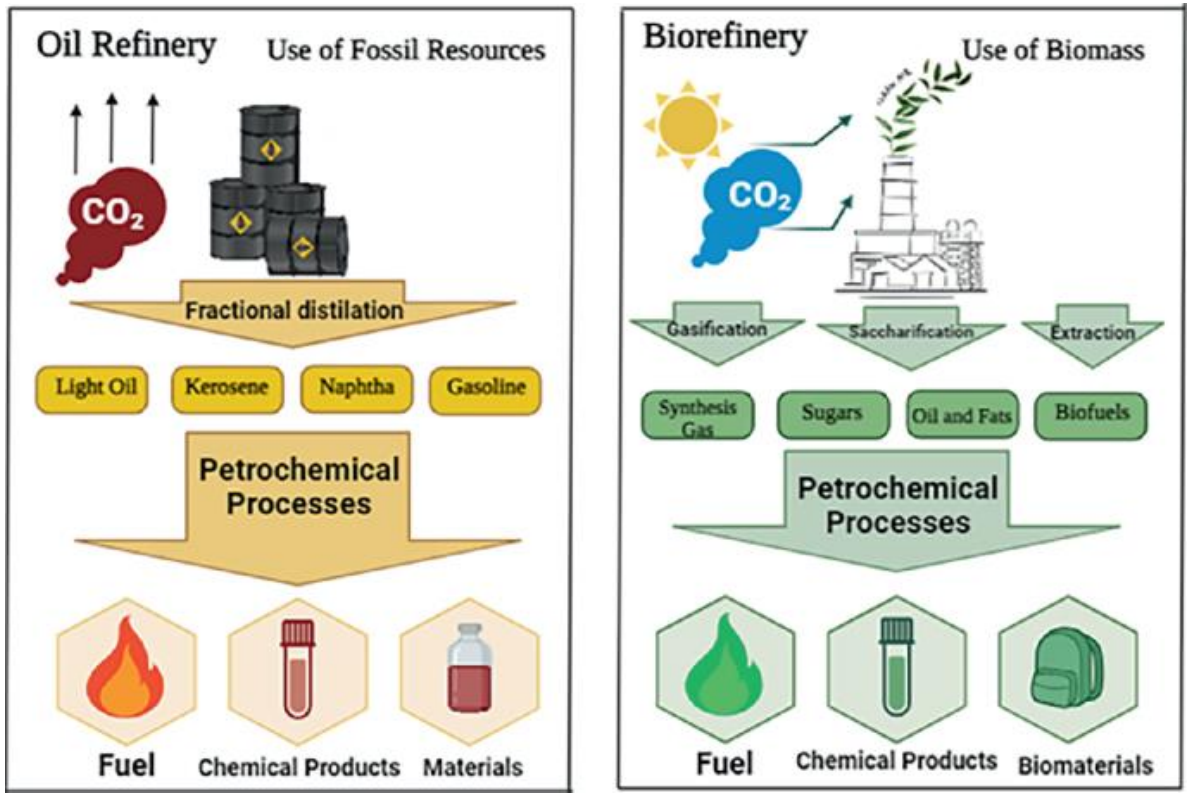
more complex process

and expensive consumable cost (H_2)

↓

higher costs (despite potentially better C-footprint)

Competitiveness becomes challenging



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Challenges… new needs

- Discontinuities in renewables
- New (unconventional) feedstocks
- Supply chain (need to build a new economic “ecosystem”
- Intrinsic lower TRL of alternatives compared to fossil-based benchmark

Need for:

- **New approach** to modelling and process design
- **More effective strategy** to speed up process development
- **Better integration between process design and assessment** to identify the most profitable “layout”
- New flow and way to exchange information

Need to go further beyond…

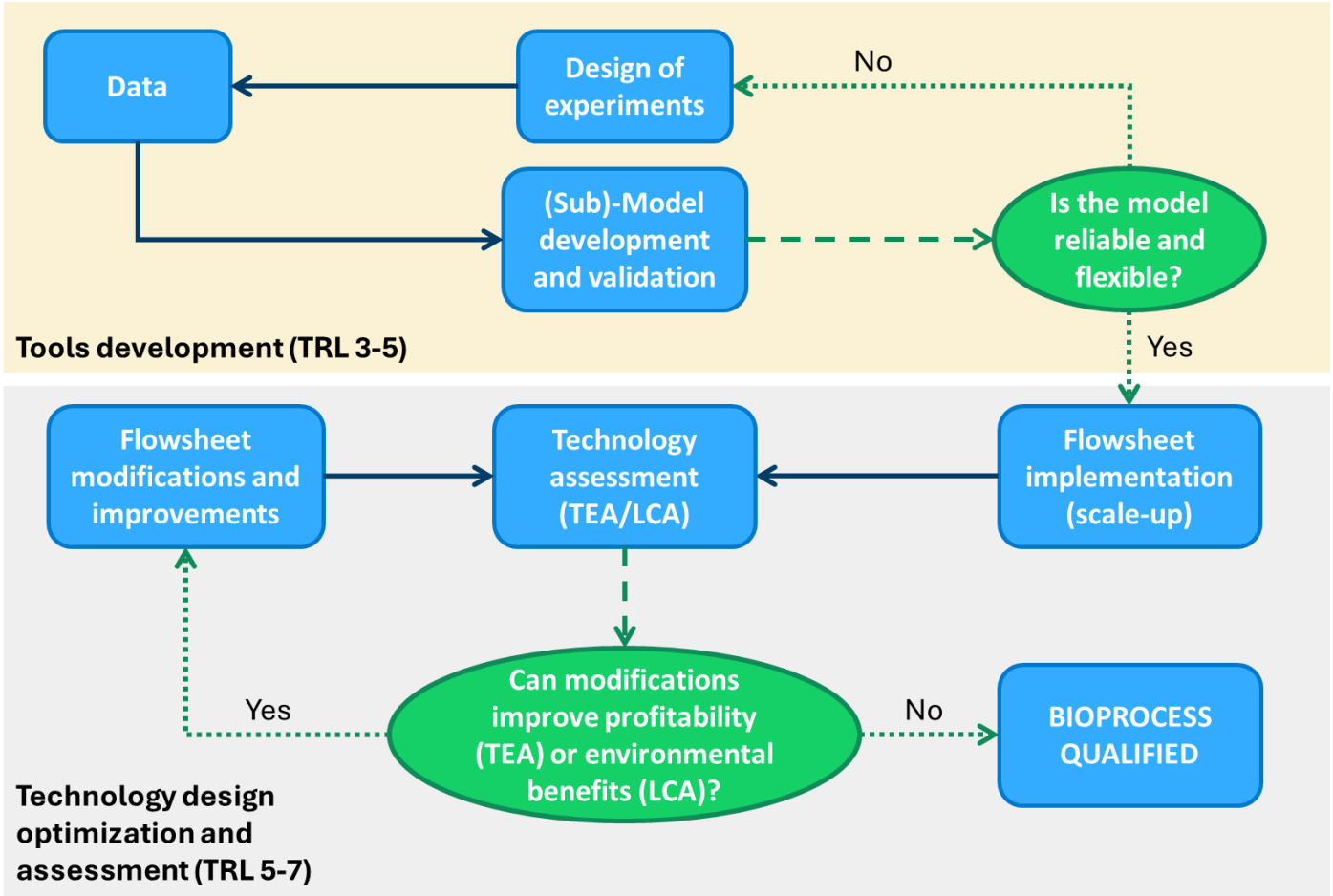
- Beyond the need for new modelling approaches to only accurately characterise the unit operations and predict the process KPIs

- Break the paradigm **from linear** (consecutive) **to iterative** (circular and continuous improvement)

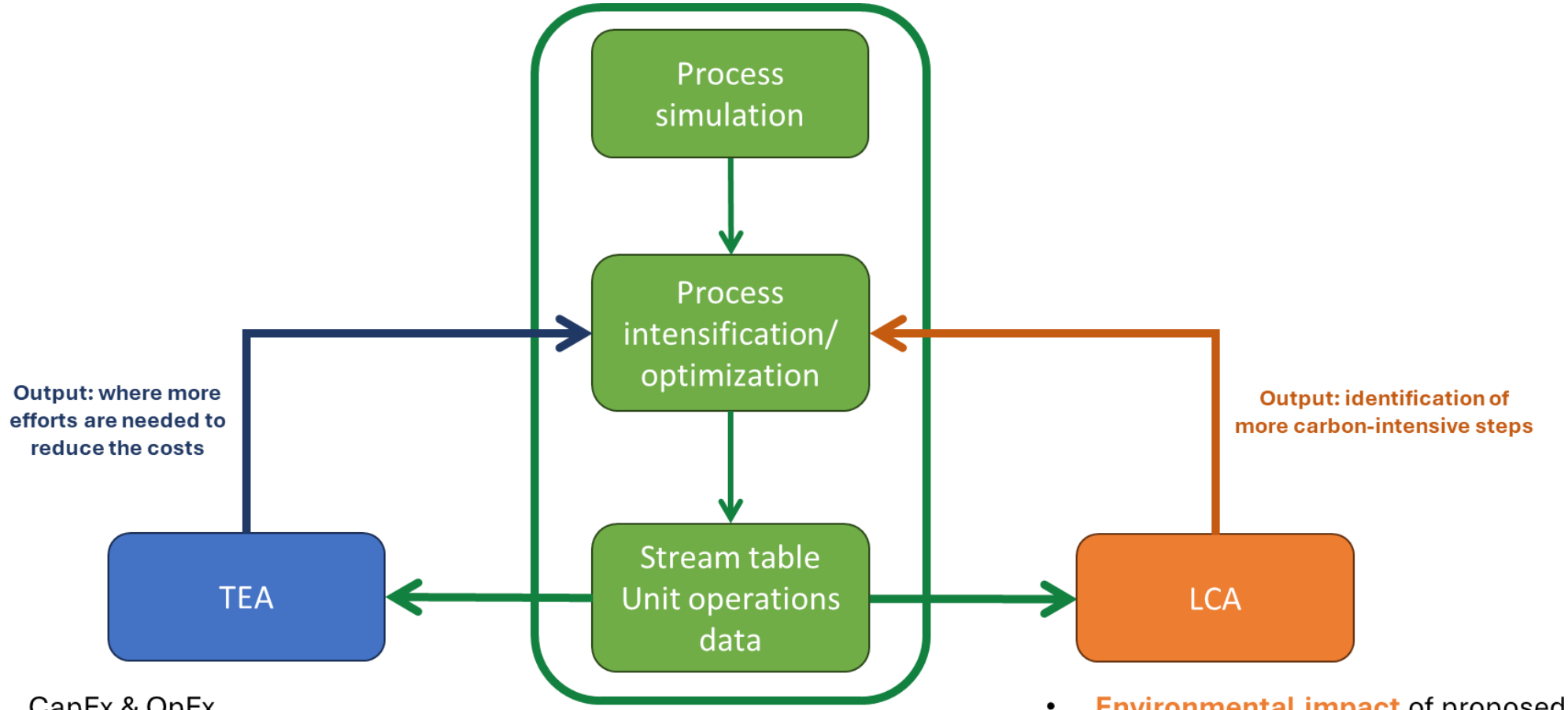
Process simulation → assessment

Process simulation ↔ assessment

Process development and assessment



What process assessment framework should include



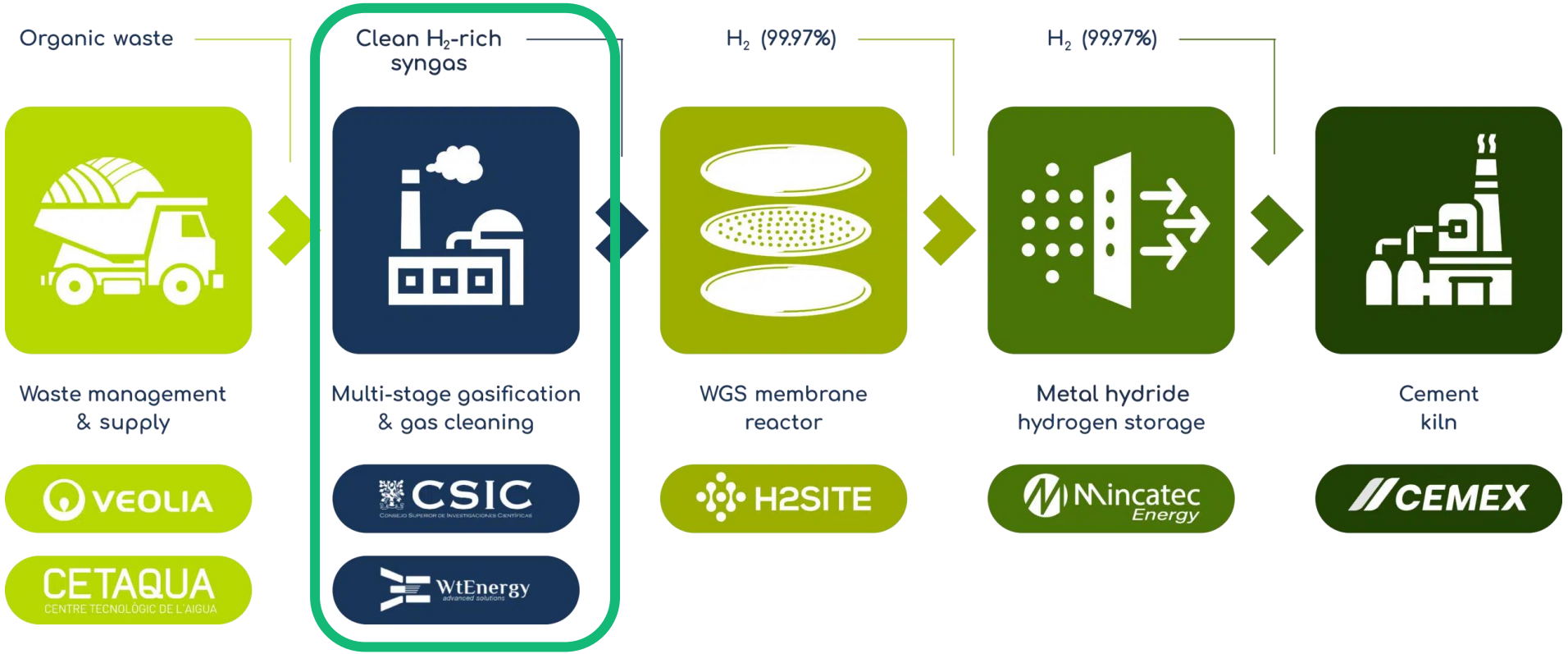
- CapEx & OpEx
- **Costs for all the supply chain**
- Economic **impact** of the proposed bioprocess
- **Selling price** to be competitive

Is carbon reduction feasible?

- **Environmental impact** of proposed solution
- **Carbon neutrality/mitigation** compared to existing technologies
- Full **supply chain** assessment

Other ongoing applications

Application in HYIELD



Picture credits: HYIELD Project webpage

Funded by the European Union

hyield

Clean Hydrogen Partnership

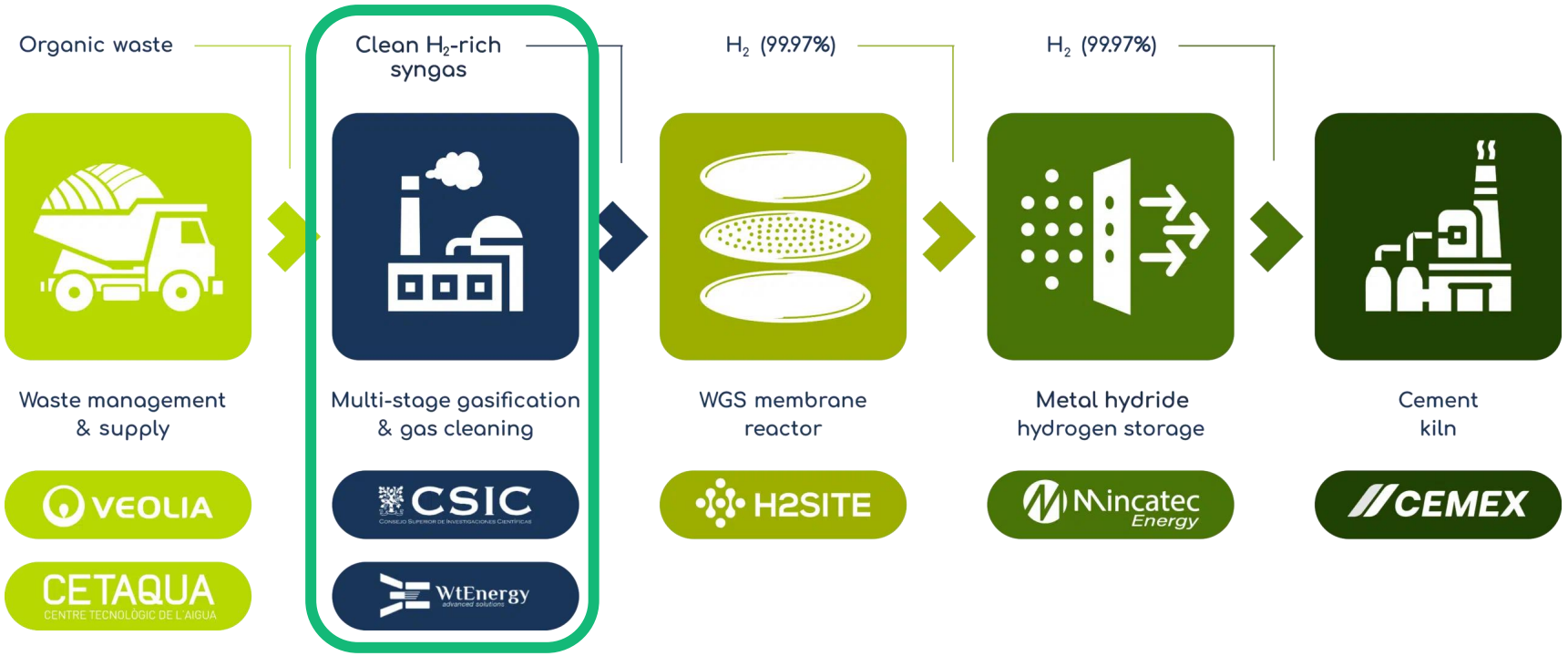
A novel multi-stage steam gasification and syngas purification demonstration plant for waste to hydrogen conversion

Total granted funding
€ 9 999 964

HORIZON-IA

Application in HYIELD

Funded by the European Union



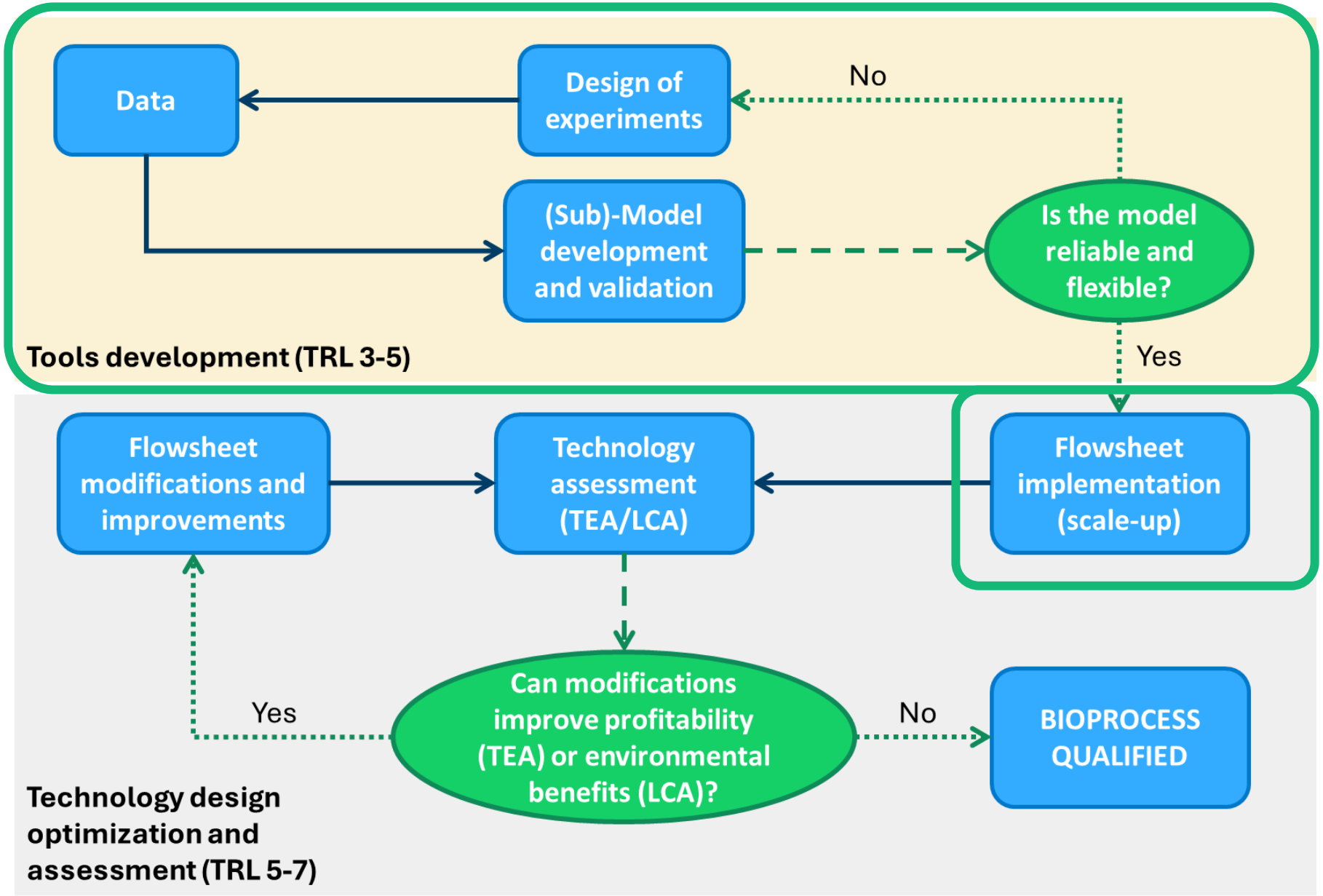
Picture credits: HYIELD Project webpage

MILESTONES & IMPACT

Expected impacts by 2040

- **72,000 tH2 / year** — GREEN HYDROGEN PRODUCTION
- **1.2 million tons** — WASTE TREATED
- **291,000 tCo2-eq / year** — GREENHOUSE GAS REDUCTION
- **2.19€ / kg** — LEVELIZED COST OF HYDROGEN
- **330** — JOBS CREATED

Here we are

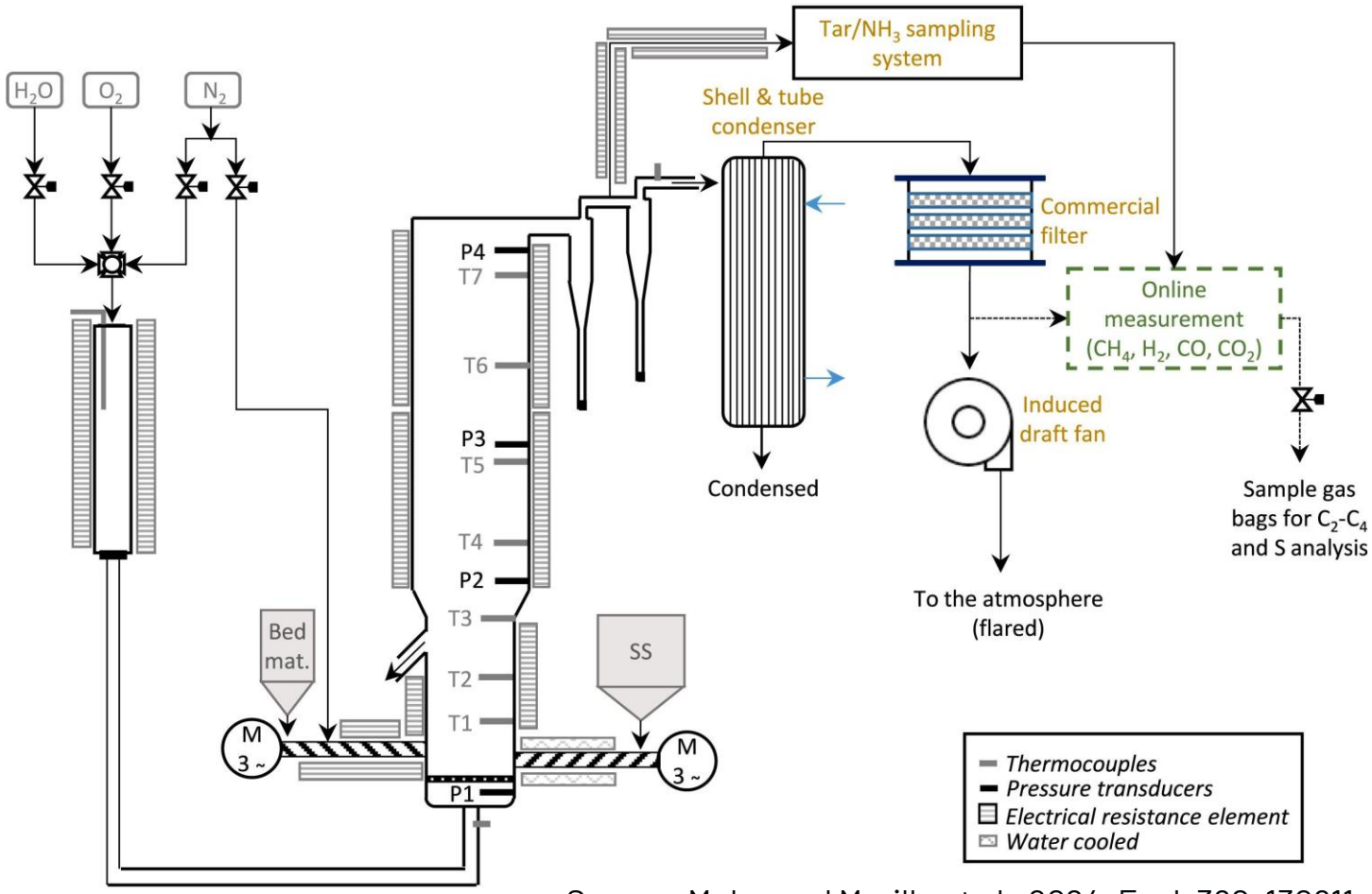

Data
Design of experiments
No
(Sub)-Model development and validation
Is the model reliable and flexible?
Yes
Tools development (TRL 3-5)
Flowsheet modifications and improvements
Technology assessment (TEA/LCA)
Flowsheet implementation (scale-up)
Yes
Can modifications improve profitability (TEA) or environmental benefits (LCA)?
No
BIOPROCESS QUALIFIED
Technology design optimization and assessment (TRL 5-7)

Pilot data

- The gasification model will be **validated** on **exp data** collected from the **30 kW_{th} pilot plant** at IBC-CSIC

- **Different operating points** will be tested by changing temperature, SC, and ER to screen a wide domain to **industrially relevant conditions**

IBC-CSIC 30 kW_{th} BFB gasification pilot

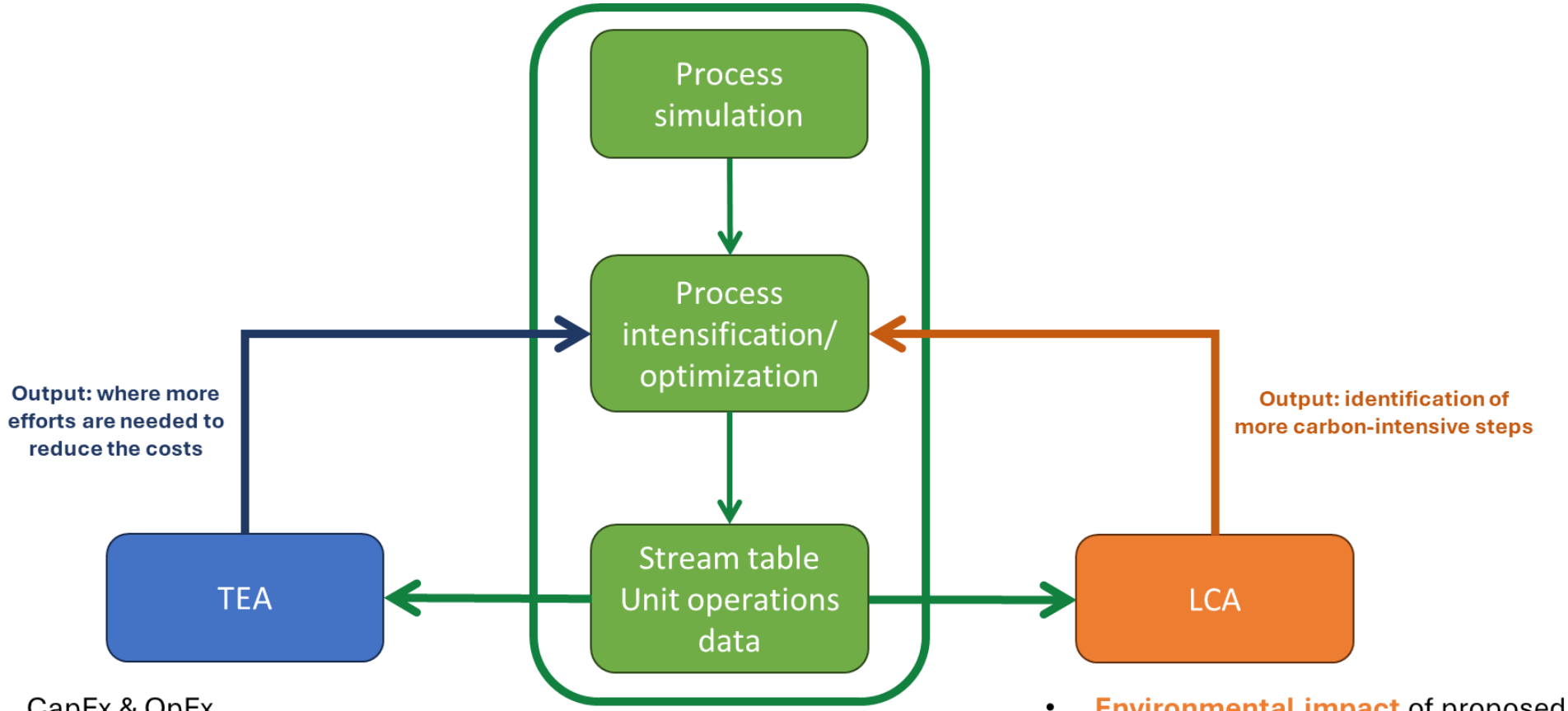


Source: Moles and Murillo et al., 2024, Fuel, 360, 130611

Lessons learnt

- Bioprocesses (including biorefining) are rather complex process
- Conventional linear approach is not sufficient to assess the technology and support/speed up their development, improvement, and deployment
- New framework are needed where process simulation – TEA – LCA are fully integrated to balance profitability and sustainability
- Biotechnologies need several experts (biologist, chemical engineers, economist/business developers, and industrial final users) sitting at the same table

We are here…



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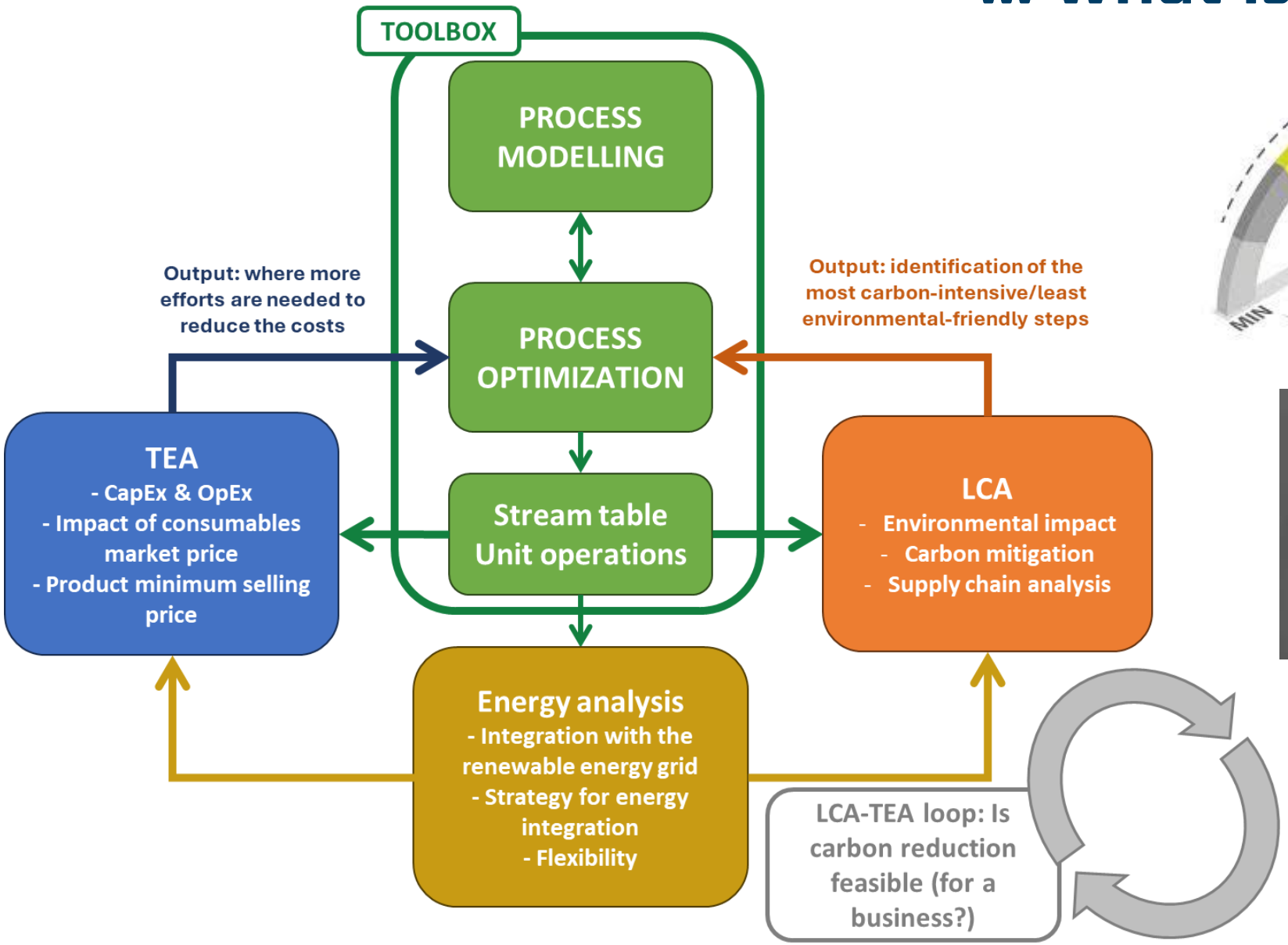
… what is our plan



Acknowledgements

VALUABLE

hyield

Clean Hydrogen Partnership

SAUNA

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Acknowledgements

BIO4 FUELS
Agreement 257666

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

The Research Council of Norway

Norwegian Centre for Environment-friendly Energy Research

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