APPLYING A CONSEQUENTIAL APPROACH TO PROSPECTIVE LCA: REFLECTIONS AND EXPERIENCES

MASSIMO PIZZOL, 07 November 2022

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Contributors

- Pierre Jouannais (PhD, AAU, Microalgae tech) pijo@plan.aau.dk
- Maddalen Ayala Cerezo (PhD, AAU, Seaweed tech) mace@plan.aau.dk
- Juanita Gallego (PhD, AAU, Carbon capture tech) juanita@plan.aau.dk
- Maxim Tschulkow (Postdoc, U. Antwerp, Biorefinery tech): Maxim.Tschulkow@uantwerpen.be
- Ben Maes (PhD, U. Antwerp, Construction tech) Ben.Maes@uantwerpen.be
- Jorge Senan Salinas (Postdoc, Beta, Membrane tech) jorge.senan@uvic.cat
- Nils Thonemann (Postdoc, DTU, Emerging tech) niltho@dtu.dk

General reflections

POLISEMY OF ”PROSPECTIVE”

The term has multiple meanings

- Attributional LCA as retrospective: ”traces back” impacts and assigns according to normative rule. Looking into “what has contributed to this product”. **Rear-mirror.**

- Consequential LCA as prospective: Models consequences of decisions (that only happen in the future). Looking into cause-effects: “what happens when…”. **Front windscreen.**

- “Prospective” as “ex-ante”.
  Anticipate impacts of technologies that are emerging and not yet mature/at scale/marketed. Focus on the uncertainties in the assessment process.

Prospective LCA with consequential approach - which challenges?

- Actually…main issues due to uncertainty not to the approach as such
- All conseq. “features” apply to prospective system as well (constraints, subtitutions)
- Making a realistic model of a future reality is difficult (examples later)
- Lack of background databases another practical obstacle (people working on it)

What is the alternative?

- Assuming normative choices made today are valid in the future. **Questionable**.
- Placing yourself in the future only to “look back”. **Does it even make sense?**

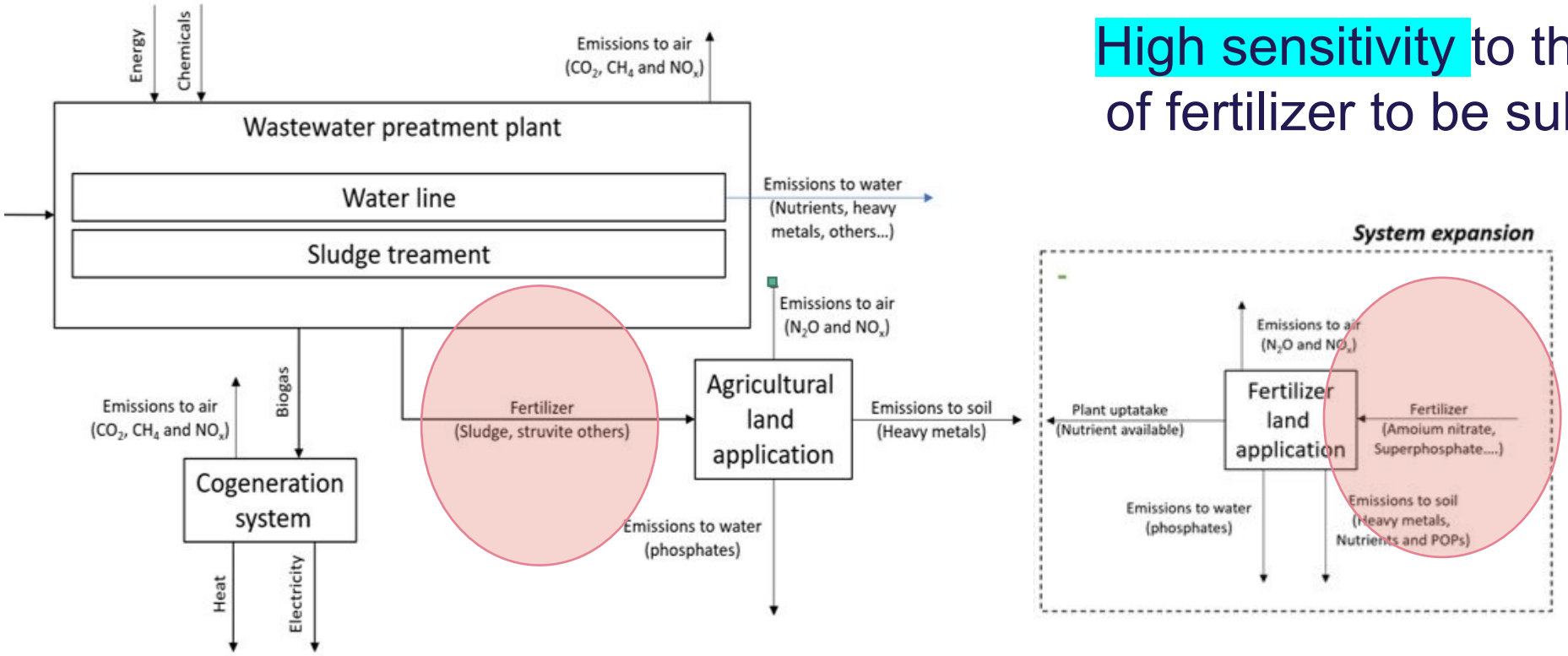
Examples from AAU research + collaborations

Emerging recycled membrane systems (INREMEM 2.0 project)

- Evaluate different hybrid recycled membrane systems for nutrient recovery in wastewaters (TRL 1-5)
- Technologies: Electrodialysis, Nanofiltration, Reverse Osmosis, Membrane Bio-reactor
- Biofertilisers: Sludge, Ammonium sulphate, N enriched effluent…

Modelling of recovered nutrients

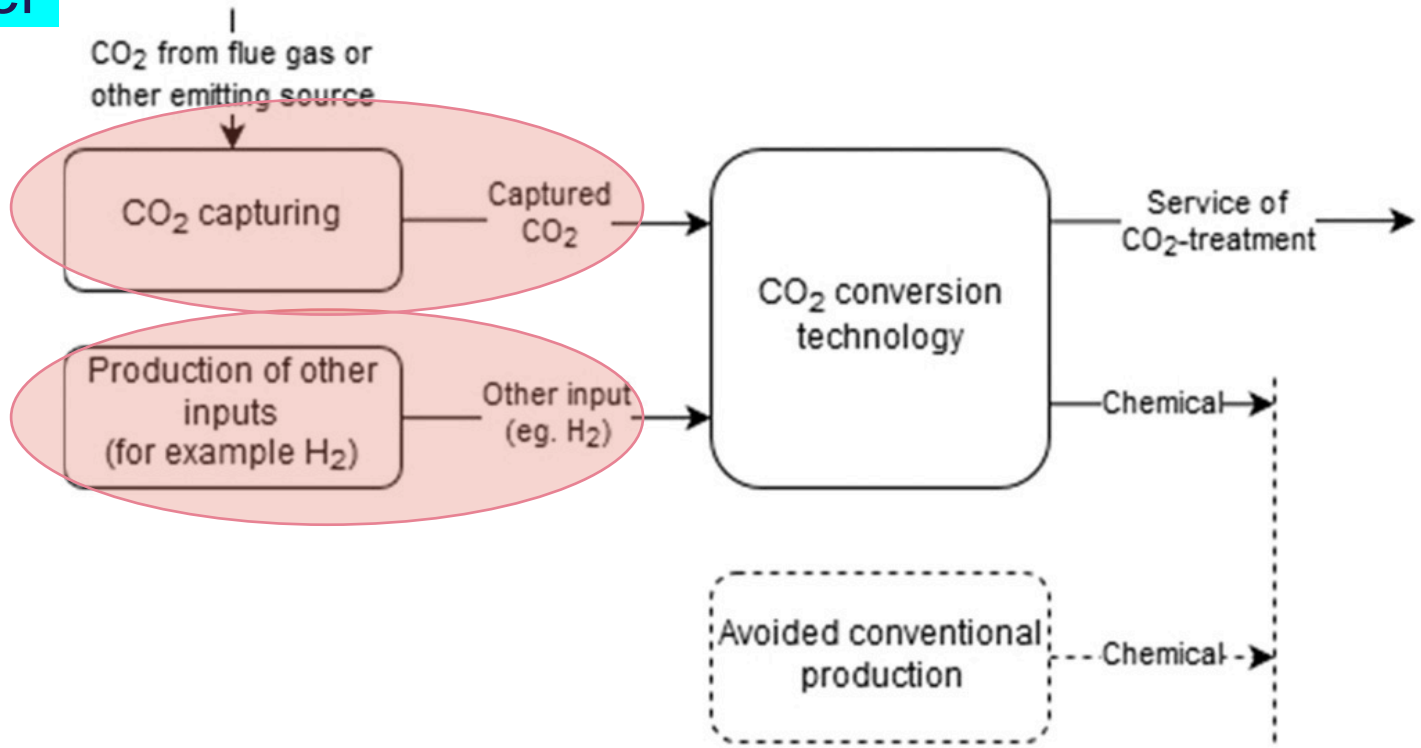
System expansion



High sensitivity to the choice of fertilizer to be substituted

Carbon capture and utilization
in the chemical industry

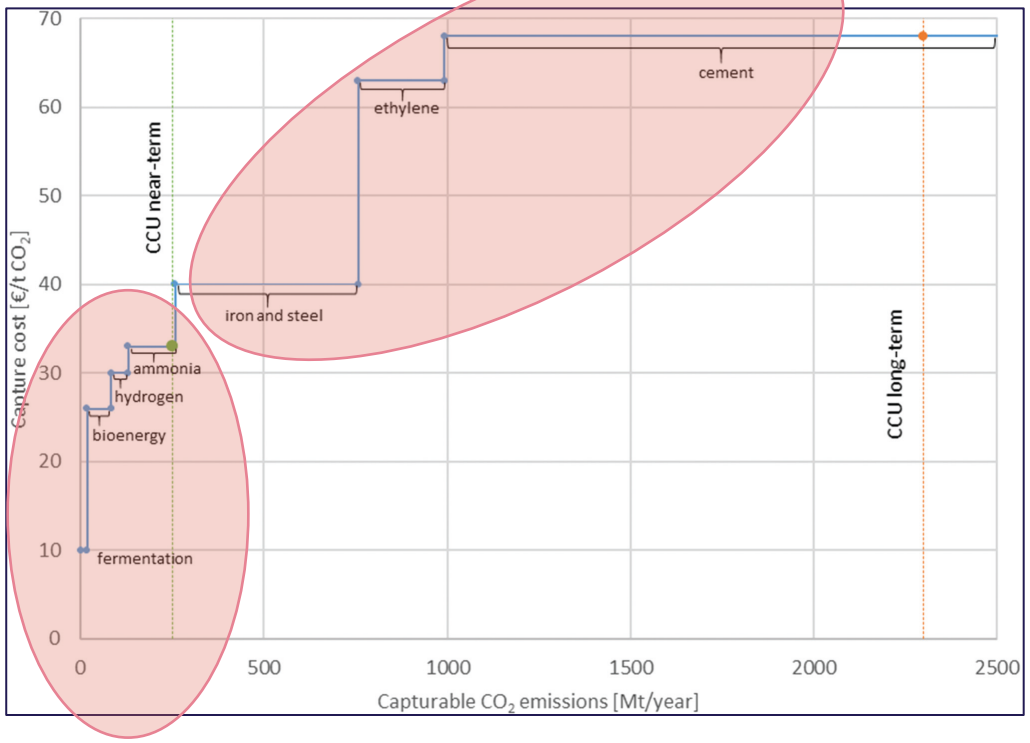
- Identification of marginal supplier for H_2, CO_2, and O_2
- Consideration of several conversion pathways



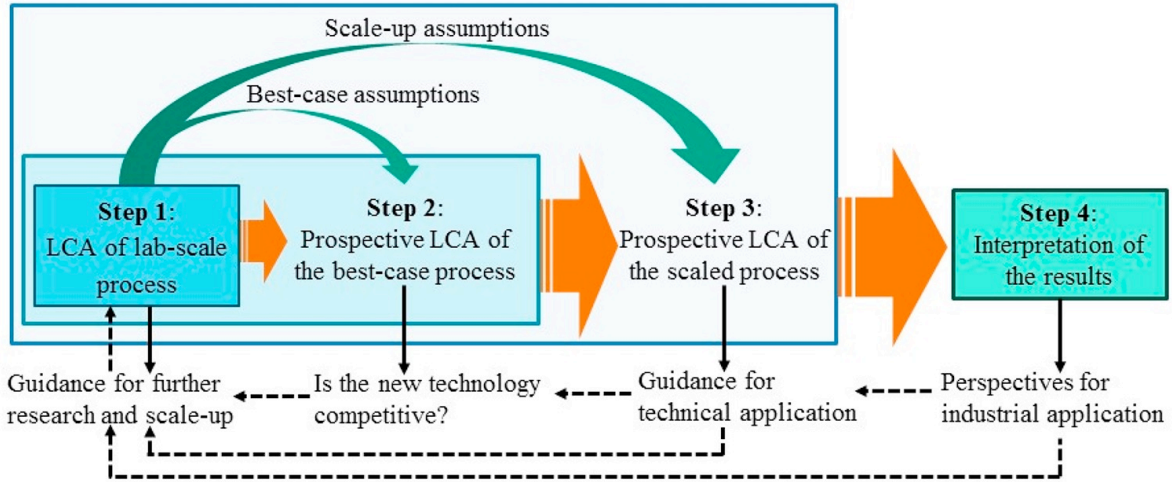
Thonemann & Pizzol (2019): Consequential life cycle assessment of carbon capture and utilization technologies within the chemical industry, DOI: 10.1039/c9ee00914k
Thonemann & Schulte (2019): From Laboratory to Industrial Scale: A Prospective LCA for Electrochemical Reduction of CO2 to Formic Acid, DOI:10.1021/acs.est.9b02944

Carbon capture and utilization
in the chemical industry

- Environmental cost curves for short (2030) and long-term (2050) time



- 4-step approach for prospective LCA and foreground data upscaling via:
  - Simulations
  - Technology expert knowledge



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Seaweed

Growing demand, constrained supply?

- Seaweed in new tech (plastic). How to identify marginal mix?
- Cannot use quantitative information (unreliable stats and missing scenarios).
- Need to include qualitative aspects (seaweed quality) and uncertainties (emerging cultivation tech).

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PlastiSea

Marginal suppliers
Of brown seaweed

Ayala, Thomsen, Pizzol . Using quantitative story telling to identify constraints in resource supply: The case of brown seaweed (submitted)
Ayala, Thomsen, Pizzol. Life Cycle Assessment of pilot scale production of seaweed-based bioplastic (submitted)

Steps in quantitative story telling

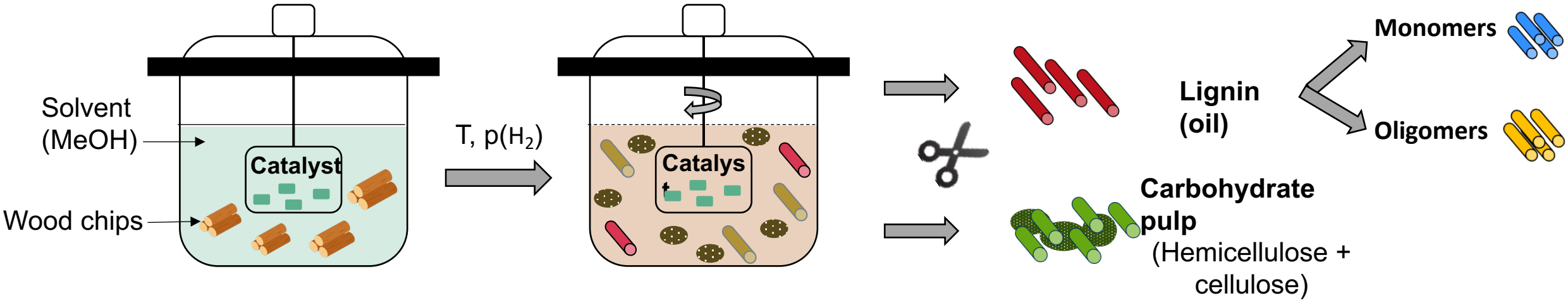
1. Identify narratives
2. Map actors
3. Quantify nexus relations
4. Link qualitative & quantitative
5. New narratives

Methods applied and output obtained

1. Literature review
   ↓
   Supply trends and shortlist of constraints
2. Networking, conferences, literature review
   ↓
   Shortlist of experts and interview guide
3. Interviews
   ↓
   Narratives on future seaweed constraints (qualitative)
4. Questionnaire
   ↓
   Expectation on future supply increments (quantitative)

Reductive catalytic fractionation (RCF) process

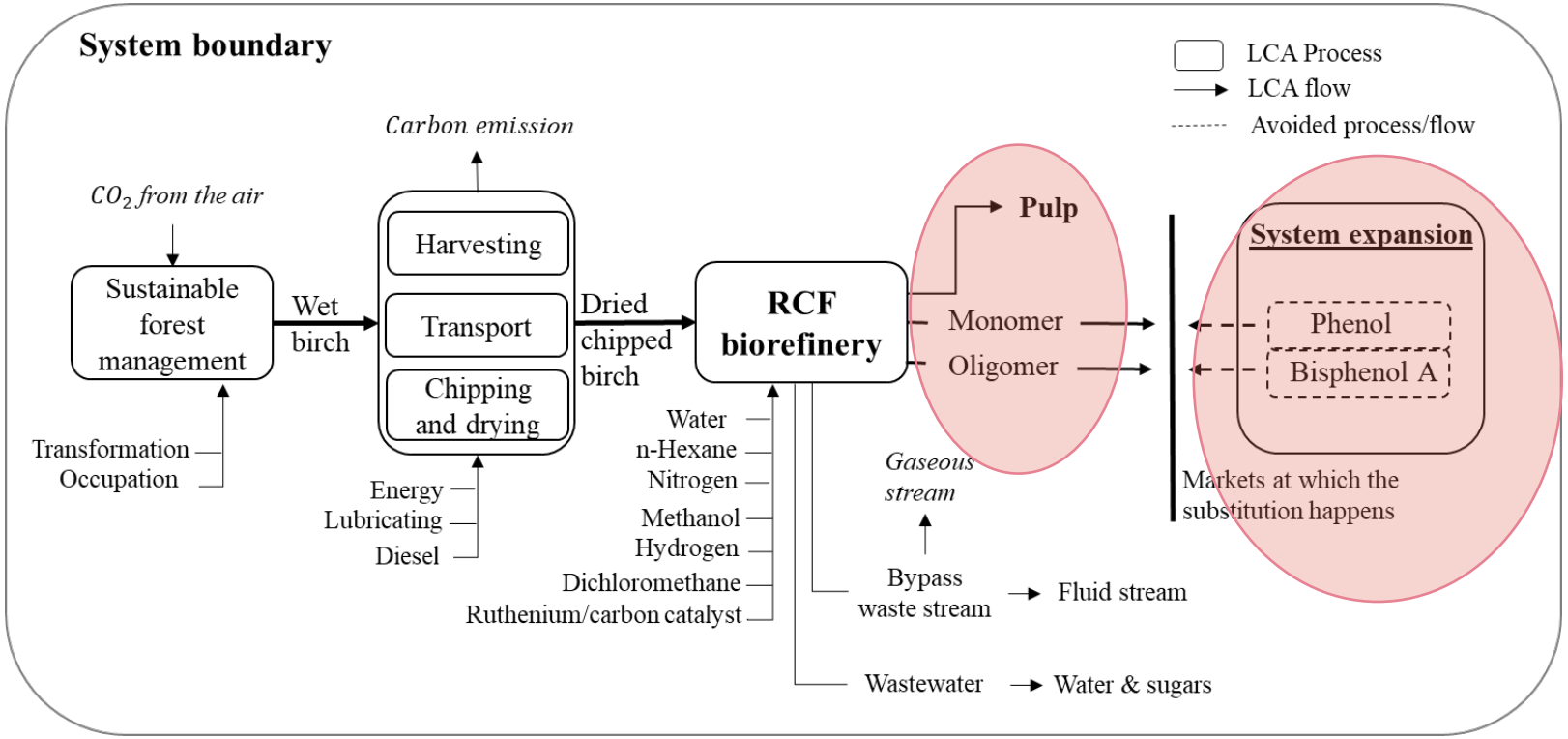
Lignin valorization tech.



What are environmental consequences of RCF implementation and its lignin-first valorization strategy?

RCF targets several novel high-value products

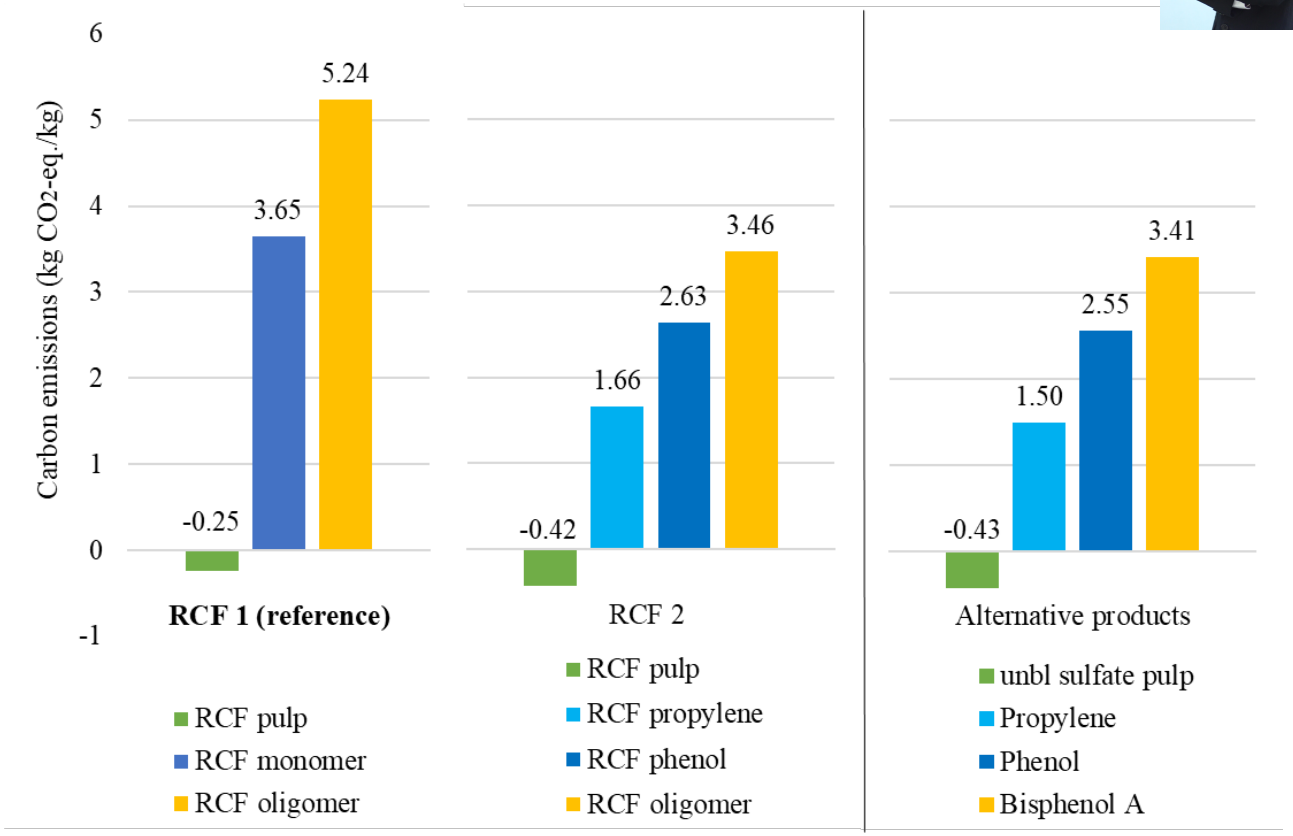
Joint production: pulp, monomer, and oligomer.



Functional unit: “1 kg of RCF pulp (monomers, or oligomers) at the RCF-biorefinery gate in 2022, produced in Belgium”.

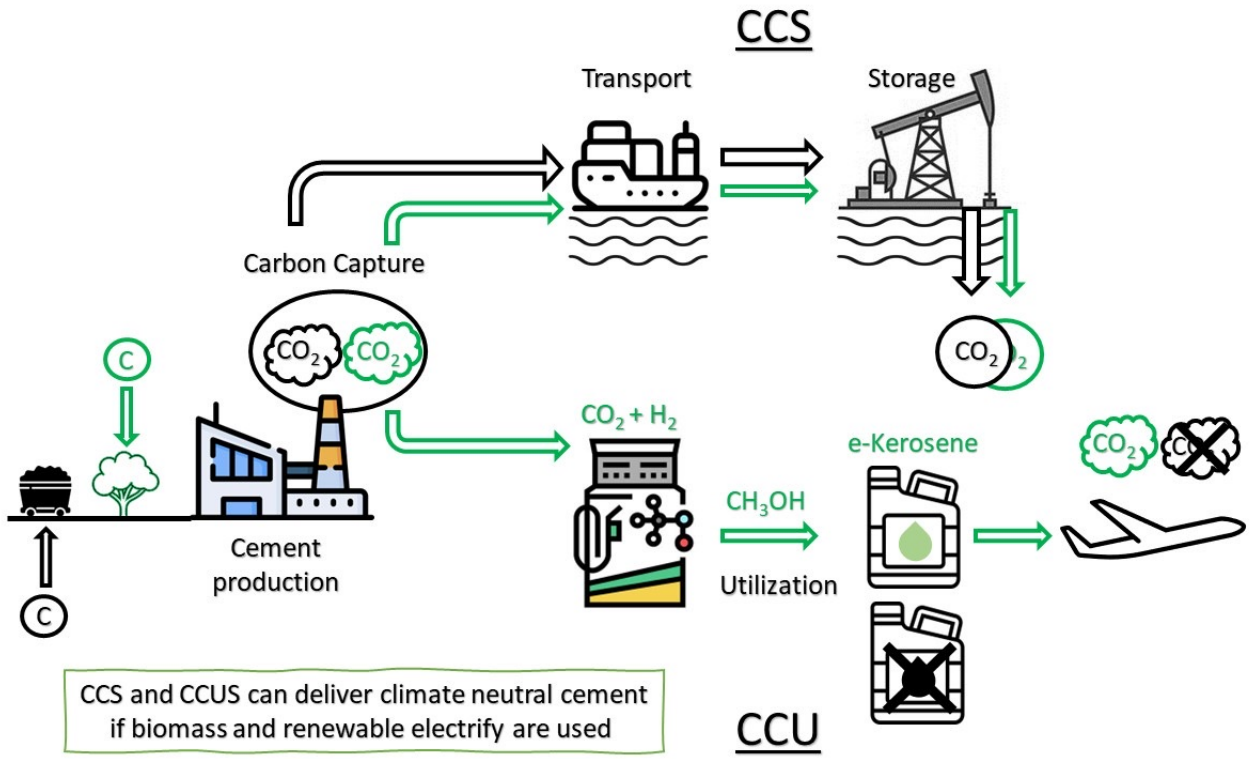
Modelling challenges
Biorefinery multifunctionality

- Determining and dependent co-product **not clear nor static** (similar market trends) → analysis from multiple perspectives
- Uncertainty about alternative counterpart that will be replaced (substitution) on the market in the future!



Carbon capture in cement production
Explorative technological scenarios

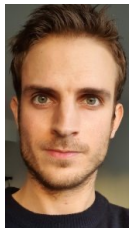
- Business as Usual, CCUS, CCS
- Year 2020, 2030 and 2050
- Electrical boiler heat, gas boiler heat, heat pump
- Use of alternative fuel in diff %
- PA +3.5°C and >1.5°C



Davila, Sacchi, Pizzol. Preconditions for CCUS to deliver climate neutrality in cement production (In preparation)

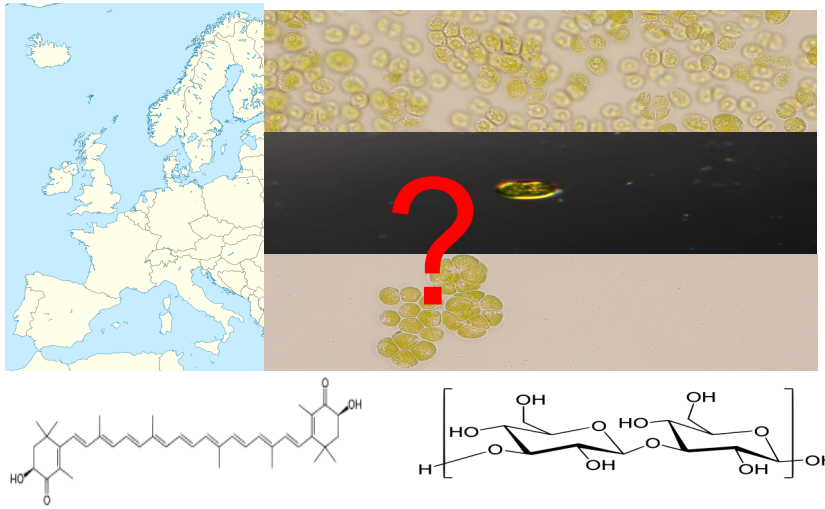
Challenges and solutions

1	Market for alternative fuel hard to predict and forecast, modelling effects of increase supply of these (constrained) materials main issue (high sensitivity)	Look for best available practice, explain in detail assumptions, avoid modelling “burden free”
2	Modelling the capture plant (data scarcity as tech hasn´t been implemented yet in this sector)	Use concept studies & data from cement plant flue gas as best proxy. Use experimental data from pilot plants for limited parameters since the scale is different
3	Modelling other parts of the value chain of low TRL (scarce data on transport, injection in a depleted oil gas and utilization)	Partner with engineering companies that know the processes and can provide good approximations. E.g. for liquefaction, transport and injection processes
4	Identify marginal technology to substitute co-products (excess heat as a form of district heating for the city)	Rely on projections and forecast from the utilities company, if not possible, from official reports about energy systems
5	Forecasting cement production and CO_2 emissions by 2050	Strong collaboration with industrial partner, access to assumptions behind projections and decarbonizing roadmap. Use data from trusted sector clusters
6	Many projections available for 2030 but not for 2050	When direct modelling of 2050 not possible, assume that values are the best approximation for the year 2050



Microalgal cultivation technology
based on unknown strain

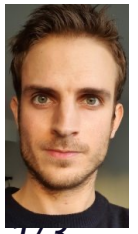
- Very high uncertainty, and **multi-dimensional** (geographical, technological, biological)
- How to model the substitution performed by the co-produced biomass if we do not know the final strain, location and ratio between co-produced biomass and functional unit?



AquaHealth

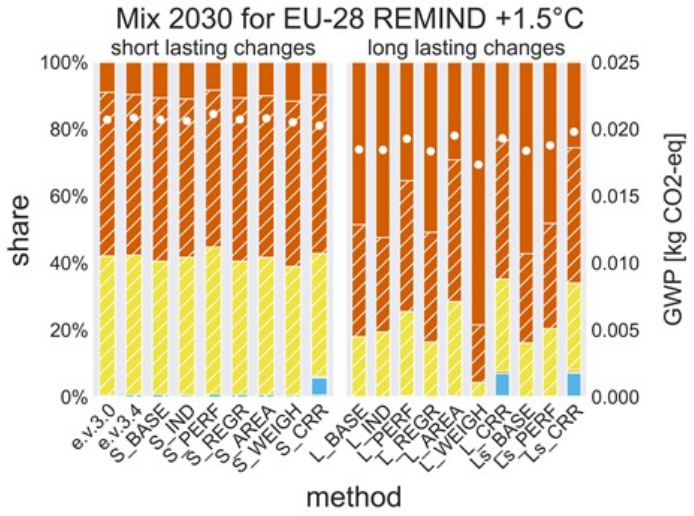
Jouannais, P. *et al.* (2022) 'Stochastic LCA Model of Upscaling the Production of Microalgal Compounds', *Environmental Science & Technology*.
Jouannais, P. and Pizzol, M. (2022) 'Stochastic Ex-Ante LCA under Multidimensional Uncertainty : Anticipating the Production of Undiscovered Microalgal Compounds in Europe'.

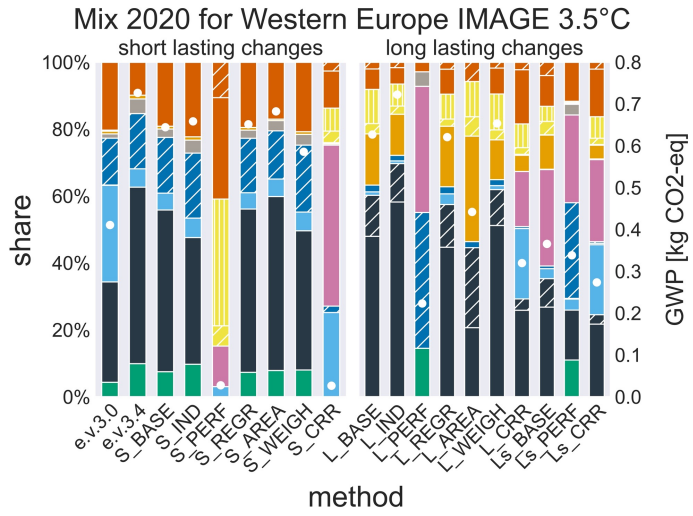
- Identify potential pathways based on local conditions and strain characteristics
- **Uncertainty propagation** assign probabilities to each pathway
- **Parameterization** of model Lipid content affects productivity, nutrient input, biogas yield, feed substit..
- Anticipate **obligatory properties** based on current practices in the emerging sector
- **Optimization algorithm** to find substituted fish feed ingredients



Consequential background

- Premise-based (IAM projectsion)
- Weidema's 4-step approach
- Calculate the marginal mix
  - Several techniques to determine the time interval
  - Several techniques to meassure growth to determine the marginal supplier





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Maes et al. (Submitted)

Concluding remarks

Wrap-up

- Main issue is uncertainty not the conseq. approach
- But indeed specific challenges for conseq. studies
- Overview of solutions + work in progress. Get in touch to know more

massimo@plan.aau.dk

@m_outreach

@ALIGNED_HE ALIGNED project www.alignedproject.eu

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