Bio4Fuels

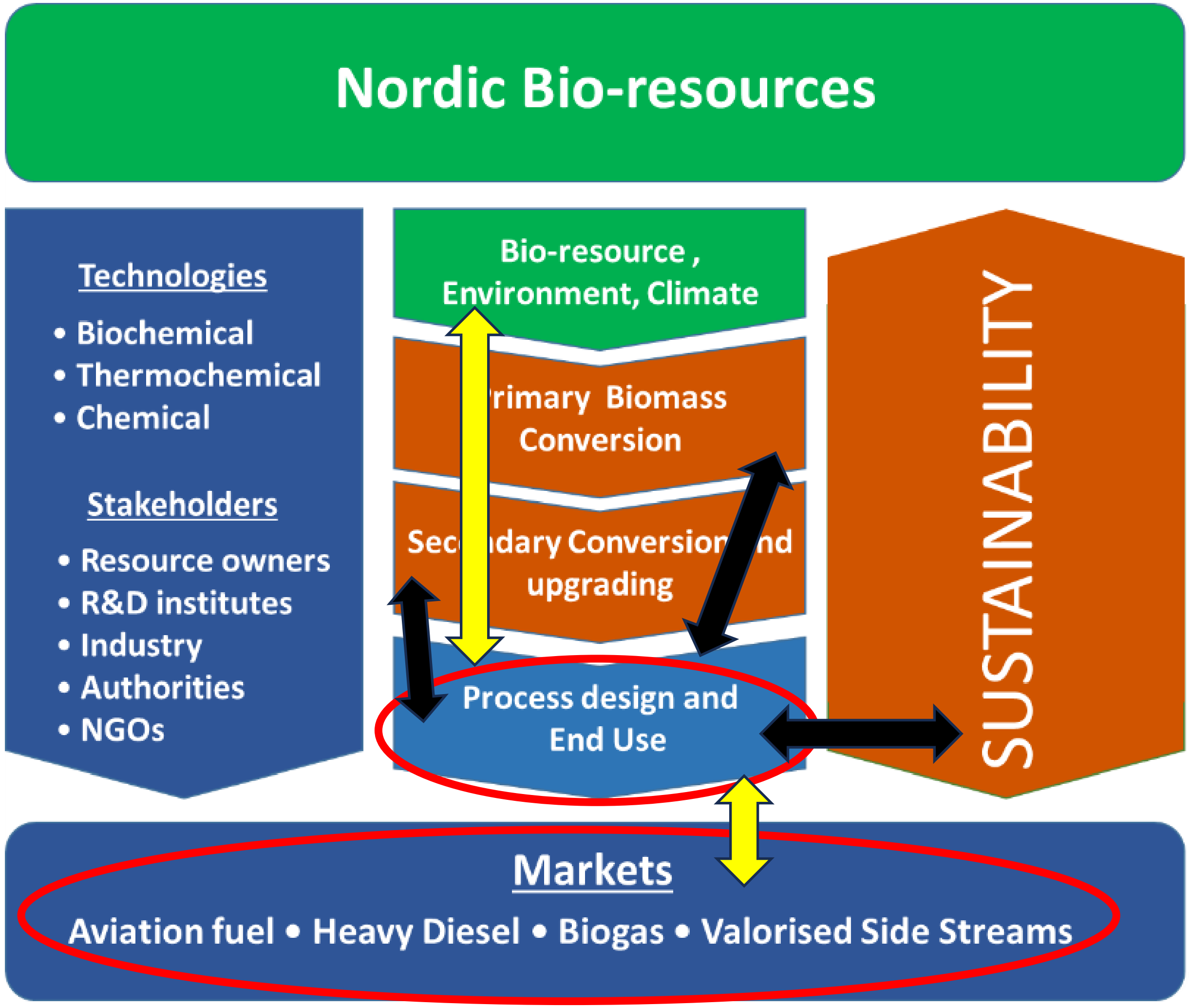
Norwegian Centre for Sustainable Bio-Based Fuel and Energy

SP 5 Process Design and End Use

Heinz Preisig, Terese Løvaas & **Bernd Wittgens**

Bio4Fuels Days, June 12 & 13. 2024, Helsinki Finland

Structure FME



SP4. Process design and End Use (B. Wittgens SINTEF MK)
WP4.1 Modelling Tool for Biorefineries (H. Preisig, NTNU)
WP4.2 Techno-Economic Eval. / Scale of Economy (B. Wittgens, SINTEF)
WP4.3 Preparing for Piloting and Up-scaling (K. Jens, HSN)
WP4.4 Product quality and End Use (T. Løvaas, NTNU)

Objectives

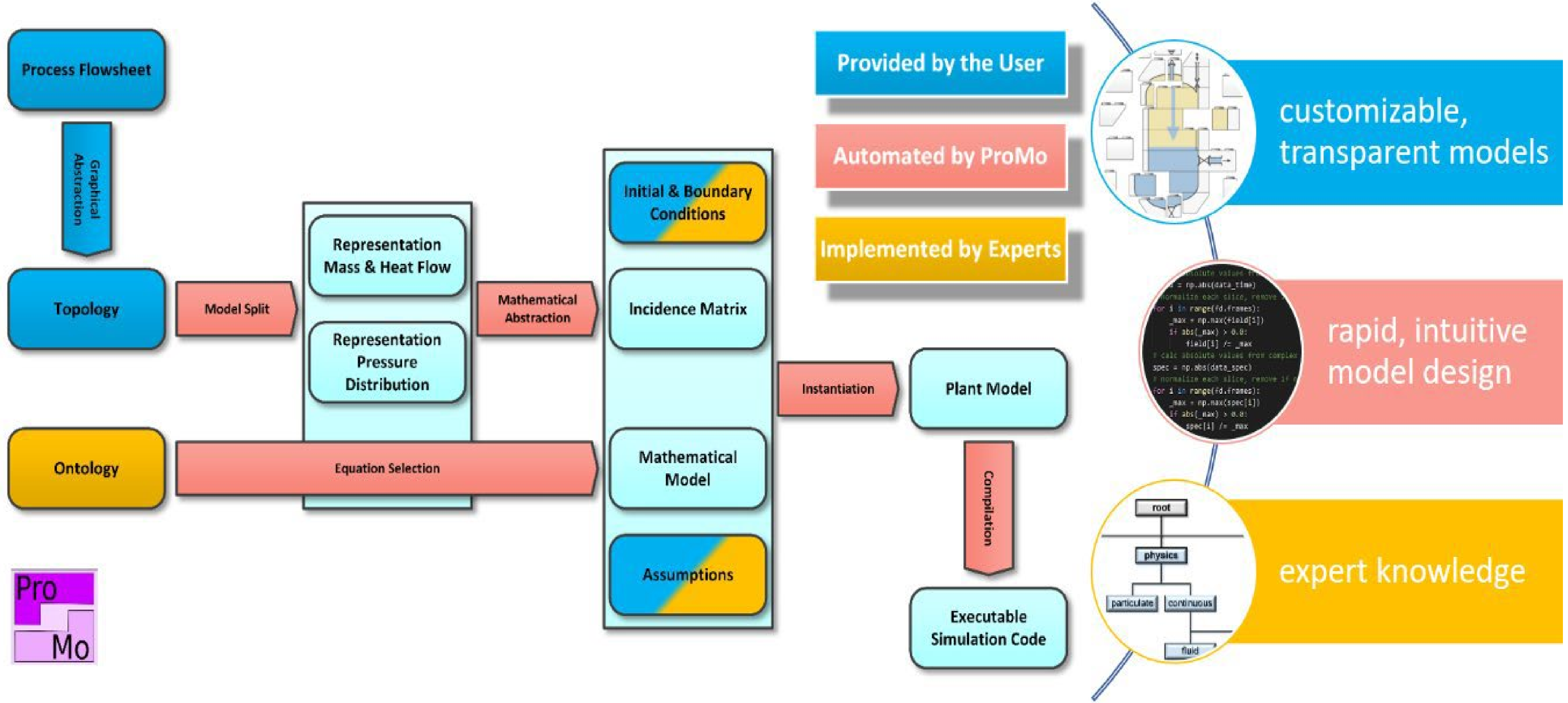
- Develop models to describe unit operation and use these as basis for new improved process design, potentially automize the model building and process design
- Fundamental sciene converted to commercial opportunities; more efficient processes and lower CAPEX/OPEX
- Evaluate current and new low carbon fuels under relevant combustion conditions, focus fuel conversion and emissions

Prof. Heinz Preisig, NTNU

Sen. Adv. Bernd Wittgens, SINTEF

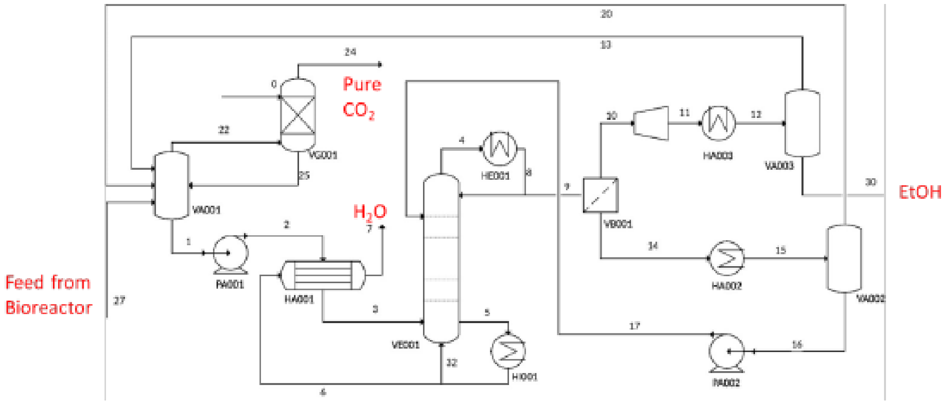
Prof. Terese Løvås, NTNU

Process Design: "Automated" Modelling of unit operations

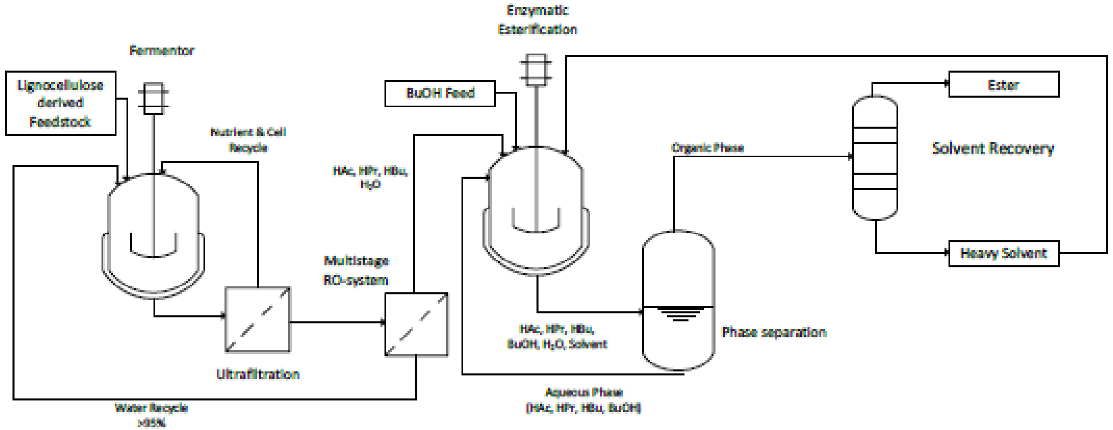


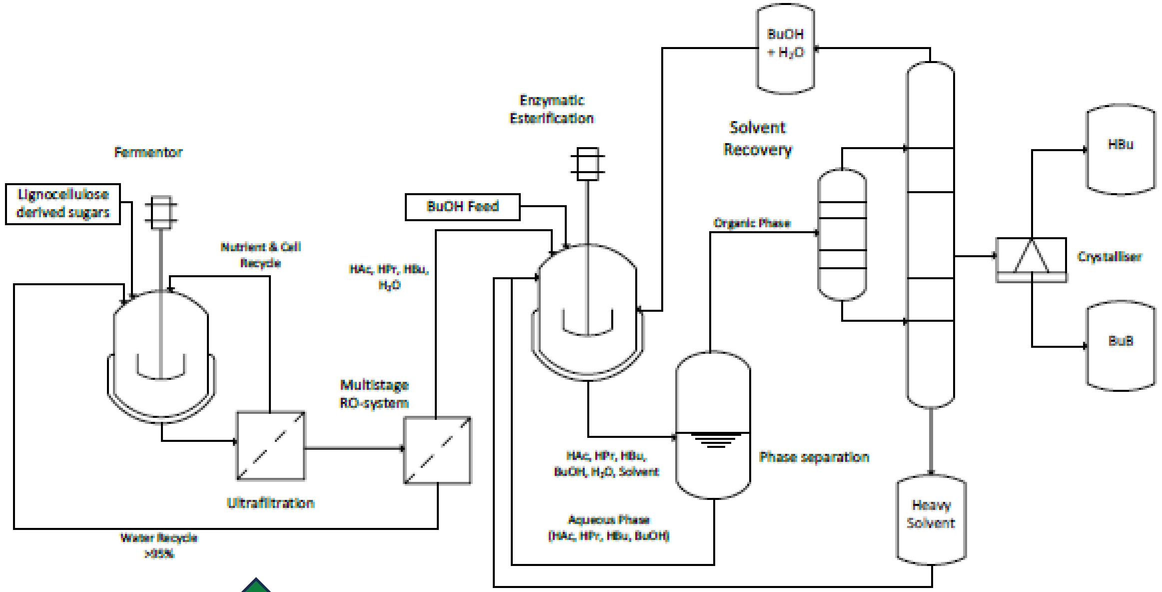
5.1 Process Design

A new process for ethanol recovery: 15% lower capital costs and 18% lower energy consumption. (EU Ambition)



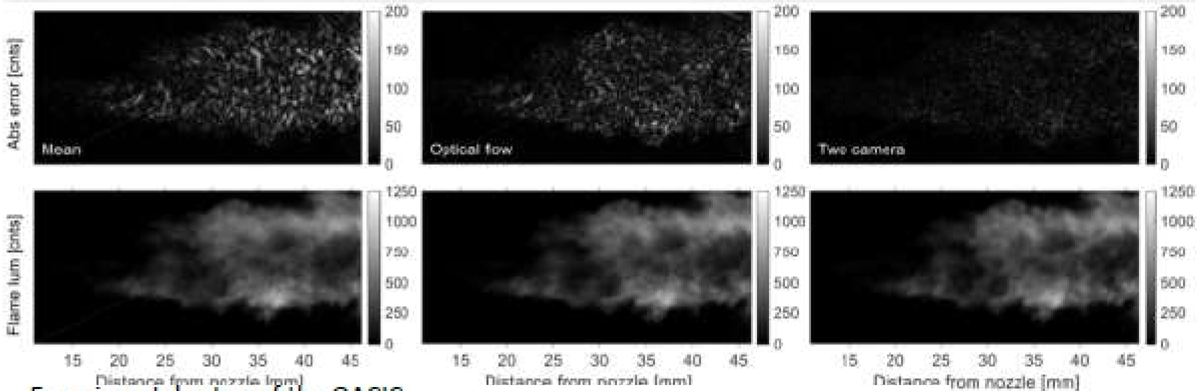
Process Development (ERANET BESTER)



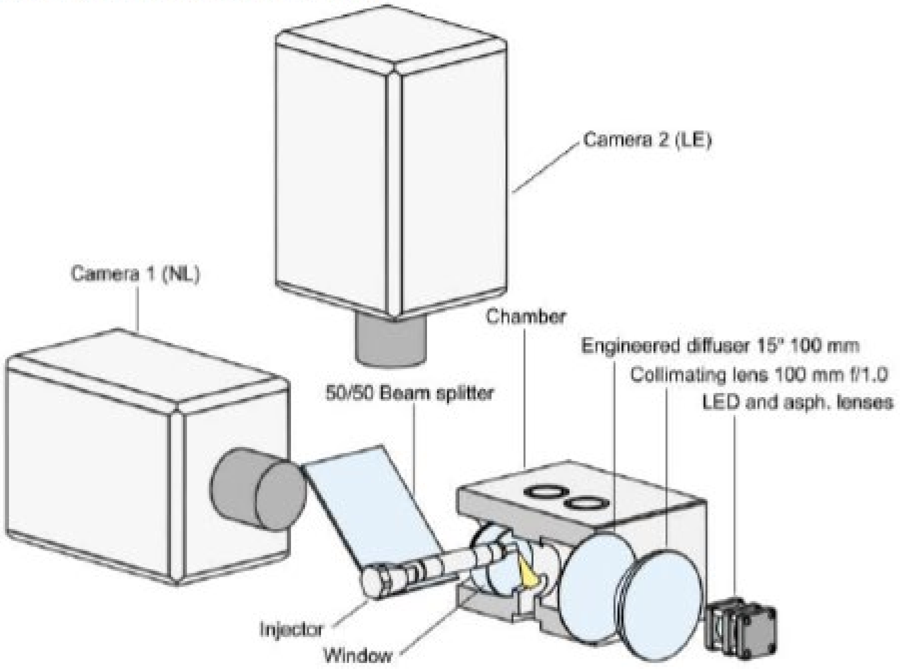


7

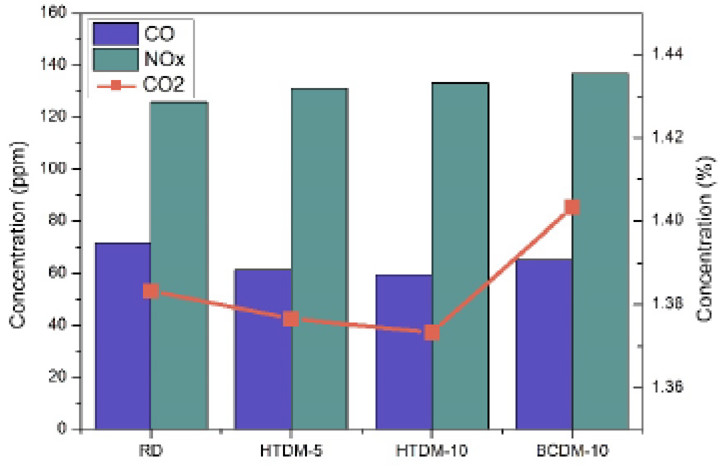
5.2 End Use (Experimental, Modelling and Optimization)

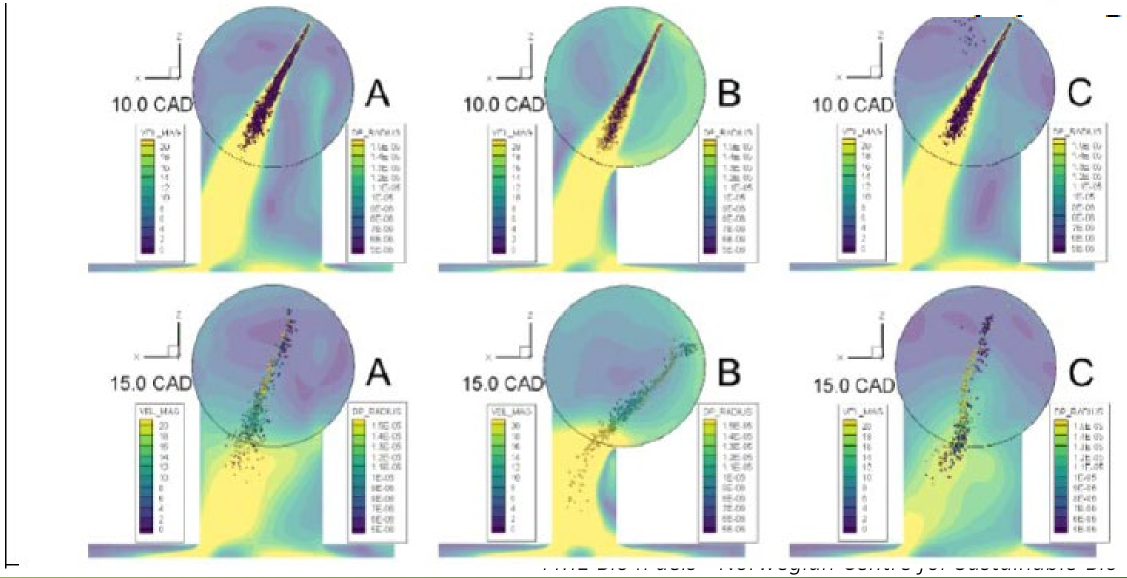


Experimental setup of the OACIC.



Optical Accessible Compression Ignited Chamber (OACIC)





Dissmination in relation to Bio4Fuels (5.1.1)

1. Pujan, R. & Preisig, H. A.; Systematic Modelling of Flow and Pressure Distribution in a Complex Tank; *ESCAPE30,* **2020**
2. Pujan, R.; Nitzsche, R.; Koechermann & Preisig, H. A.; Modelling Ontologies for Biorefinery Processes - A Case Study; *ESCAPE 30,* **2020**
3. Pujan, R. & Preisig, H. A. Systematic Modelling of a Butanol Fermentation equipped with in-situ Gas Stripping; *VENICE20 8TH INTERNATIONAL SYMPOSIUM ON ENERGY FROM BIOMASS AND WASTE,* **2020**
4. Pujan, R. & Preisig, H. A.; Systematic Modelling of Flow and Pressure Distribution in a Complex Tank; *Computers & Chemical Engineering,* **2021***,157*
5. Pujan, R. & Preisig, H. A.; Systematic Modelling of Transport Processes across Interfaces; *Computer Aided Chemical Engineering,* **2021**
6. Pujan, R.; Sengupta, P. & Preisig, H. A.; Systematic Modelling of Distillation Columns based on Topologies and Ontologies; *Computer Aided Chemical Engineering 49:865-870,* **2022**
7. Pujan, R. & Preisig, H. A.; Systematic Biorefinery Modelling with ProMo; *Young Energy Researchers Conference 2022,* **2022**
8. Pujan, R. & Preisig, H. A.; Biorefinery modelling is in tatters, and here is why; *PROCEEDINGS OF THE 34 rd European Symposium on Computer Aided Process Engineering (ESCAPE34),* **2022**
9. Pujan, R. & Preisig, H. A.; Into the Valley of Death Rode the Green Transition; *PROCEEDINGS OF THE 33 rd European Symposium on Computer Aided Process Engineering (ESCAPE33),* **2023**
10. Pujan, R.; Sabahi, S. K. & Preisig, H. A.; Systematic Modelling of Nanofiltration Processes; **2023** (unpublished)
11. Pujan, R & Preisig, H A; Survey of Bioprocessing Modelling (in preparation)
12. Gautam, V.; Rodriguez-Fenrandez, A. & Preisig, H. A.; A Cloud-based Collaborative Interactive Platform for Education and Research in Dynamic Process Modelling; *PROCEEDINGS OF THE 33 rd European Symposium on Computer Aided Process Engineering (ESCAPE33),* **2023**
13. Preisig H., Peter Klein. & Horsch, M. T.; Topology-Based Construction of Business-Integrated Material Modelling Workflows; *PROCEEDINGS OF THE 32 nd European Symposium on Computer Aided Process Engineering,* **2022**,1237-1242
14. Preisig, H. A.; Documenting Models Comprehensively Using a Minimal Graphical Language; *Computer Aided Chemical Engineering 49:1021-10026,* **202**
15. Preisig, A.; Hagelien, T.; Rusche, H.; Abtahi, N.; Belouettar, S.; Klein, P. & Konchakova, N.; Ontologies In Computational Engineering; *WCCM-ECCOMAS2020,* **2021**
16. Preisig, H. A.; Ontology-Based Process Modelling-with Examples of Physical Topologies; *Processes,* **2021***, 9*

Dissmination in relation to Bio4Fuels (5.1.2)

1. F. Bisotti, M. Gilardi, O. T. Berglihn, R. Tschentscher, V.G.H. Eijsink, A.Várnai, B. Wittgens, 2024. From laboratory scale to innovative spruce-based biorefinery. Note I: Conceptual process design and simulation. Computer Aided Chemical Engineering, 53, 2449-2454. Link - 201Bisotti.docx (live.com)
2. M. Gilardi, F. Bisotti, O. T. Berglihn, R. Tschentscher, V.G.H. Eijsink, A.Várnai, B. Wittgens, 2024. From laboratory scale to innovative spruce-based biorefinery. Note II: Preliminary techno-economic assessment – link 231129112323904 Gilardi.docx (live.com)
6. M. Gilardi, F. Bisotti, O. T. Berglihn, R. Tschentscher, V.G.H. Eijsink, A. Várnai, B. Wittgens, 2023. Soft modelling of spruce conversion into bio-oil through pyrolysis – Note I: steam explosion and LPMO-activated enzymatic saccharification. Computer Aided Chemical Engineering, 52, 757-762. https://doi.org/10.1016/B978-0-443-15274-0.50121-9
7. F. Bisotti, M. Gilardi, O. T. Berglihn, R. Tschentscher, L.D. Hansen, S.J. Horn, A. Várnai, B. Wittgens, 2023. Soft modelling of spruce conversion into bio-oil through pyrolysis – Note II: pyrolysis. Computer Aided Chemical Engineering, 52, 769-774. https://doi.org/10.1016/B978-0-443-15274-0.50123-2
8. Preisig, H.A., B. Wittgens; Thinking Towards Synergistic Green Refineries; Energy Procedia, Vol 20, pp. 59-67, https://doi.org/10.1016/j.egypro.2012.03.008, 2012
9. Preisig, H. and B. Wittgens; Thinking towards synergistic green refineries, Energy Procedia, Vol. 20, Pages 1-414 (2012)
10. F. Bisotti, M. Gilardi, O.-T. Berglihn, R. Tschentscher, V.G.H. Eijsink, A. Várnai, B. Wittgens; From laboratory scale to innovative spruce-based biorefinery. Note I: Conceptual process design and simulation. Oral presentation at ESCAPE-34, Florence (Italy), June 2024.
11. M. Gilardi, F. Bisotti, O.-T. Berglihn, R. Tschentscher, V.G.H. Eijsink, A. Várnai, B. Wittgens; From laboratory scale to innovative spruce-based biorefinery. Note II: Techno-economic assessment. Oral presentation at ESCAPE-34, Florence (Italy), June 2024.
12. M. Gilardi, F. Bisotti, O. T. Berglihn, T. Rücker, T. Brück, B. Wittgens, 2024. Modelling of biomass-to-X: challenges and strategies. Oral presentation at ICONBM-24, Palermo (Italy), May 2024.
13. Gilardi, M., F. Bisotti, O.-T. Berglihn, R. Tschentscher, V.G.H. Eijsink, A. Várnai, B. Wittgens; Soft Modelling of spruce conversion into bio-oil through pyrolysis: Note I - Steam explosion and LPMO-activated enzymatic Saccharification, ESCAPE, Athens Greece, June 2023
14. Bisotti, F., Gilardi, M., O.-T. Berglihn, R. Tschentscher, V.G.H. Eijsink, A. Várnai, B. Wittgens; Soft Modelling of spruce conversion into bio-oil through pyrolysis: Note II - Pyrolysis Modelling, ESCAPE, Athens Greece, June 2023
15. Rücker T., O.T. Berglihn, B. Wittgens, and S. Weging; Valorization of Norway Spruce (Picea Abies) Residues-Extraction and Analysis of Phenolic Constituents, EUBCE, Bologna Italy, June 2023
16. T. Rücker, T. Pettersen, B. Wittgens, S. Weging, O.T. Berglihn; Advanced analysis of high value-added products from a pilot scale lignin depolymerisation plant; GREEN – Natural resources, green technology & sustainable development, September 2022
14. Wittgens, B.; Bester: Process Scaling and demo-plant Concept; presented at Webinar: Role of synthetic biology in Circular economy: BESTER project's lessons; June 2021
15. Wittgens, B., T. Pettersen, O.T. Trygve Berglihn; Review of Design Guidelines for Biorefinery Separation Systems; EUBCE 2019, Lisbon, Portugal
16. Wittgens, Bernd; Biofuel Production – Potential for Marine Biomass; presented at Bellona Seminar. Sustainable biomass in the Nordics – How should we farm the Ocean; Oslo, https://bellona.no/event/sustainable-biomass-in-the-nordics-how-should-we-farm-the-ocean November 2019
17. Horn, S. J., R. Astrup, B. Wittgens, D. Akporiaye; Derfor forsker vi for morgendagens biodrivstoff; Dagbladet; https://www.dagbladet.no/kultur/derfor-forsker-vi-for-morgendagens-biodrivstoff/67455940; Apr. 2017
18. Steinsmo, U. et. al.; Arena Skognæringen Trøndelag; https://arenaskog.no/wp-content/uploads/2017/04/unni-steinsmo-- skognringa-som-viktig-del-av-den-sirkulre-konomien--betydningen-av-forskning-og-utvikling-for--utnytte-mulighetene-.pdf, Apr.2017
19. Horn, S. J., R. Astrup, B. Wittgens, D. Akporiaye; Nærmere en Løsning for Biodrivstoff; Aftenposten; https://www.aftenposten.no/viten/i/E8g5a/-Narmere-en-losning-for-biodrivstoff, Mar. 2017
20. O. T. Berglihn, B. Wittgens, D. Akporiaye; Biofuels Research at SINTEF; Presented at: UN Seminar on Sustainable Energy Transported; https://www.sintef.no/en/latest-news/un-seminar-on-sustainable-energy-transport-hosted-by-sintef/ SINTEF, Trondheim Oct. 2016.
21. K. Asheim et.al.; Bærekraftig Biodrivstoff et avgjørende Klimatak; https://www.zero.no/wp- content/uploads/2016/05/berekraftig-biodrivstoff-et-avgjoerende-klimatiltak-1.pdf; ZERO, 2016
22. Wittgens, B. and H. Preisig; Hvorfor lever Olje-økonomien videre?, https://gemini.no/2016/06/haltende-hamskifte/; 2016
23. Wittgens, B. and H. Preisig; Haltende Hamskifte, Dagens Næringsliv, 2016, https://www.dn.no/meninger/debatt/2016/06/16/2143/Teknologi/haltende-hamskifte/

Dissmination in relation to Bio4Fuels (5.3)

1. Kohansal, Komeil; Sanchez, Eliana Lozano; Khare, Shivang; Bjørgen, Karl Oskar Pires; Haider, Muhammad Salman; Castello, Daniele; Løvås, Terese; Rosendahl, Lasse Aistrup; Pedersen, Thomas Helmer. (2023) Automotive sustainable diesel blendstock production through biocrude obtained from hydrothermal liquefaction of municipal solid waste. *Fuel*
2. Khare, Shivang; Bjørgen, Karl Oskar Pires; Kohansal, Komeil; Haider, Muhammad Salman; Castello, Daniele; Pedersen, Thomas Helmer. (2023) New Renewable Hydrothermal Liquefaction (HTL) Biofuel: A Combustion and Emissions Study in an Optical Engine. *Energies*
3. Lewandowski, Michal; Netzer, Corinna; Emberson, David; Løvås, Terese. (2021) Numerical investigation of glycerol/diesel emulsion combustion in compression ignition conditions using Stochastic Reactor Model. *Fuel*
4. Lewandowski, Michal; Netzer, Corinna; Emberson, David; Løvås, Terese. (2020) Numerical investigation of optimal flow conditions in an optically accessed compression ignition engine. *Transportation Engineering*
5. Bjørgen, Karl Oskar Pires; Emberson, David; Løvås, Terese. (2020) Combustion and Soot Characteristics of Hydrotreated Vegetable Oil Compression-Ignited Spray Flames. *Fuel*
6. Bjørgen, Karl Oskar Pires; Emberson, David; Løvås, Terese. (2019) Optical Measurements of In-Flame Soot in Compression-Ignited Methyl Ester Flames. *Energy & Fuels*
7. Bjørgen, Karl Oskar Pires; Emberson, David; Løvås, Terese. (2019) Diffuse Back-Illuminated Extinction Imaging of Soot: Effects of Beam Steering and Flame Luminosity. *SAE technical paper series*

Note: Peer reviewed papers only

Summary

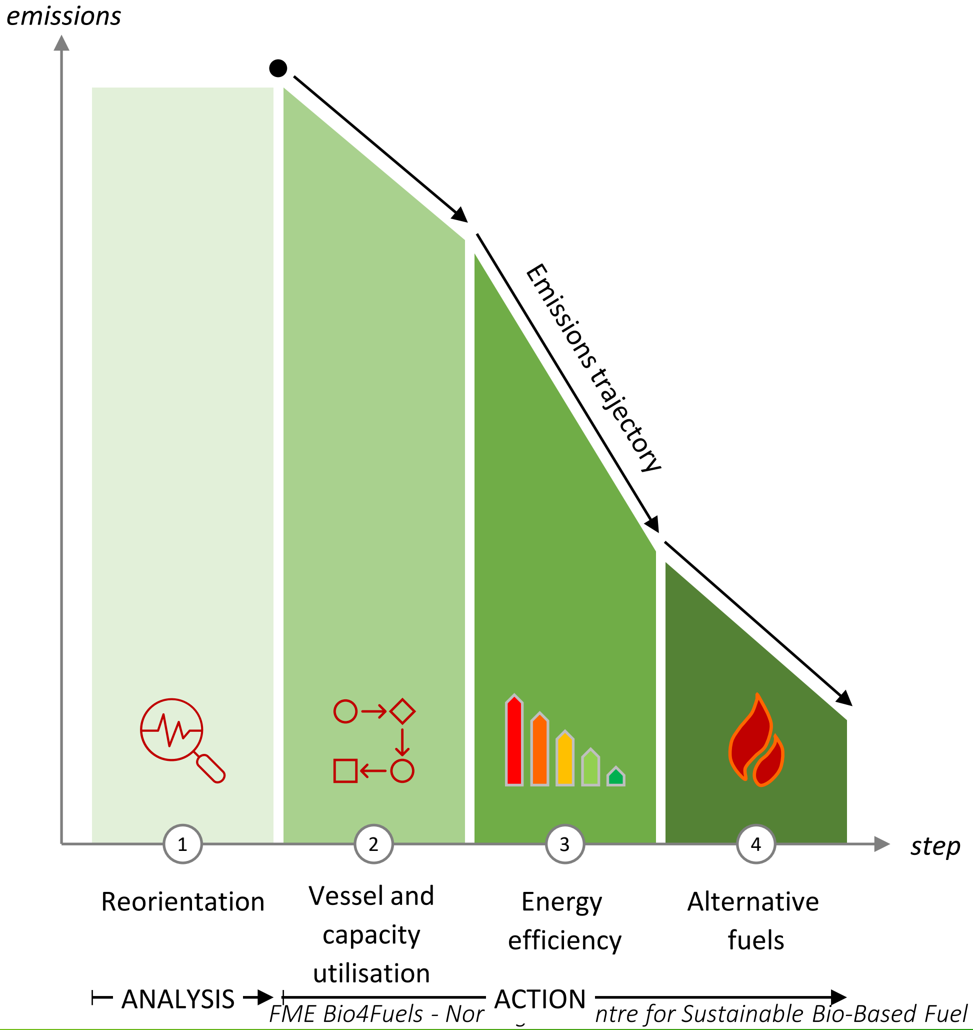
- 8 years of interdisiplinary activity
- Step learning curve to model
    - Biochemical converison kinetics and operational conditions
    - Separation is complex for most birefinery processes (thermochemical and biochemical)
    - Strong integration of experimental and modelling needed
- Comprehensive spin-off projects developed

Today's program

- **FOCUS: Process Design and End Use.** Chair: Bernd Wittgens, SINTEF
  - 11:00 – 11:10 *SP Leader introduction*, Bernd Wittgens
  - 11:10 – 11:35 *Fuel transition strategies to achieve real emissions reductions in shipping*, Anders Valland, Sintef Ocean
  - 11:35 – 12:00 *Modelling of an integrated biorefinery for spruce valorization and preliminary Techno economic assessment*, Matteo Gilardi, SINTEF Industry

A Valland: Fuel transition strategies to achieve real emissions reductions in shipping

- The presentation will cover the
- Current situation in global maritime shipping and
- Gap's between ambitions and actual state of affairs.
- Examples on performance of biofuels in engine tests compared to fossil fuels
- Strategy for how to move shipping towards the targets set by the IMO

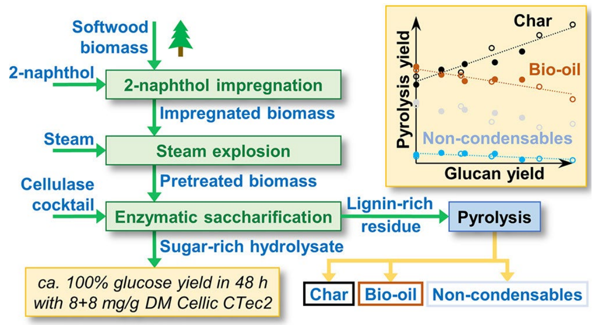


M. Gilardi: Modelling of an integrated biorefinery for spruce valoriation and preliminary TEA (From lab-scale to industrial facility)

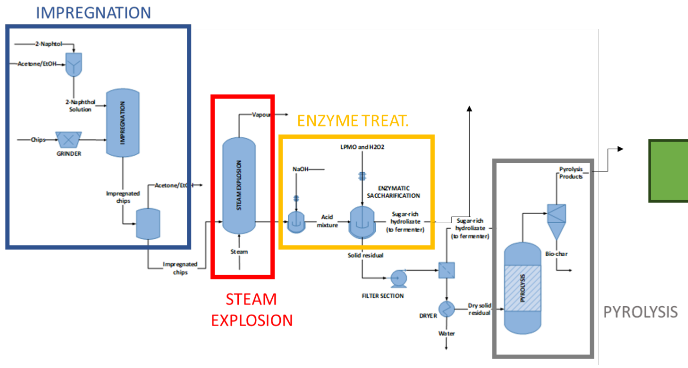
BIO4 FUELS

We target process **design and scale-up** of a **biorefinery for the valorization of spruce chips**:

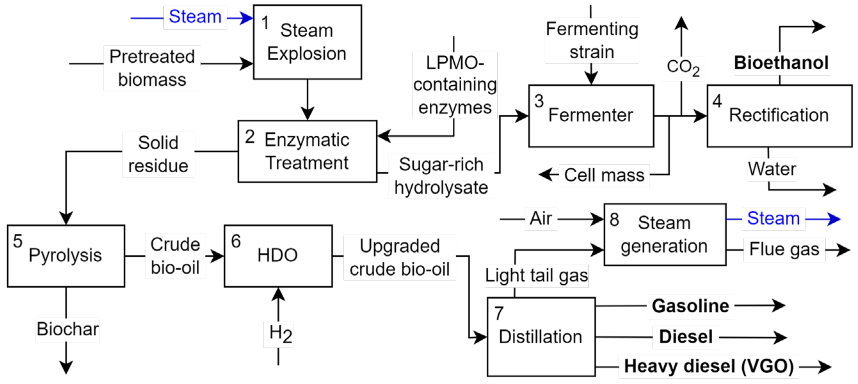
- Remove lab-scale steps that cannot be replicated on an industrial scale
- Identify missing steps and **design a comprehensive process**
- Identify a feasible and **valuable path** to **convert biomass into added-value chemicals**



1. Tested lab-scale concept



2. Translation into a feasible industrial plant



3. BFD completed with missing steps/units

Bio4Fuels

Norwegian Centre for Sustainable Bio-Based Fuel and Energy

fme.bio4fuels@nmbu.no

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway

*Ontology: How entities are grouped into basic categories and which of these entities exist on the most fundamental level.