Coproduction of biocarbon and biogas transportation fuel by combining pyrolysis and anaerobic digestion

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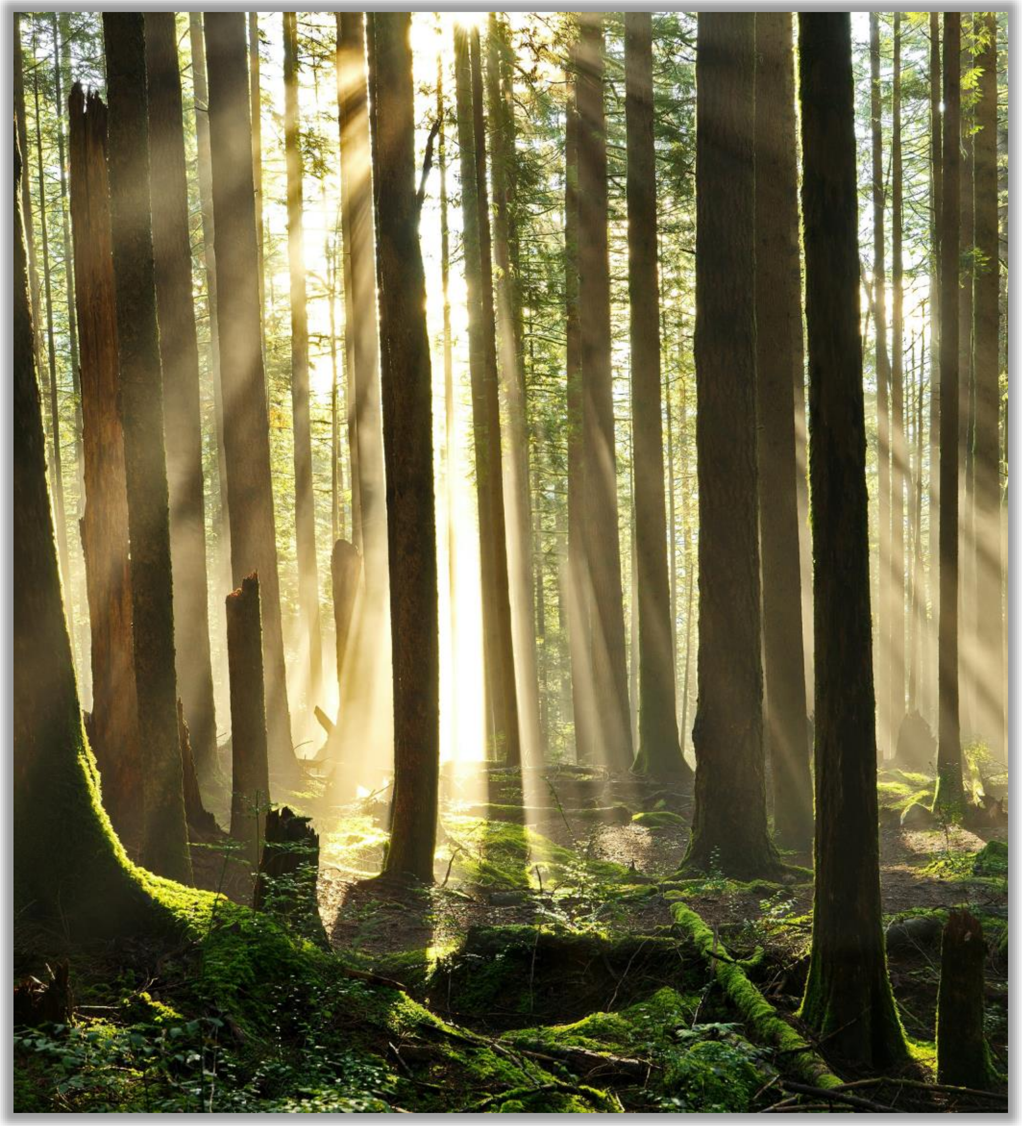
PFI

RISE PFI is part of RISE – Research Institutes of Sweden

Outline

- **Introduction**
  - About pyrolysis
  - Incentives for biobased and recycled carbon and oil products
  - Challenges and Possibilities
- **Smart Carbonisation with Byproduct Valorisation**
  - Strategy and ambitions
  - Aqueous condensate valorisation by anaerobic digestion
  - Organic condensate valorisation
- **Summary**



Introduction – About pyrolysis

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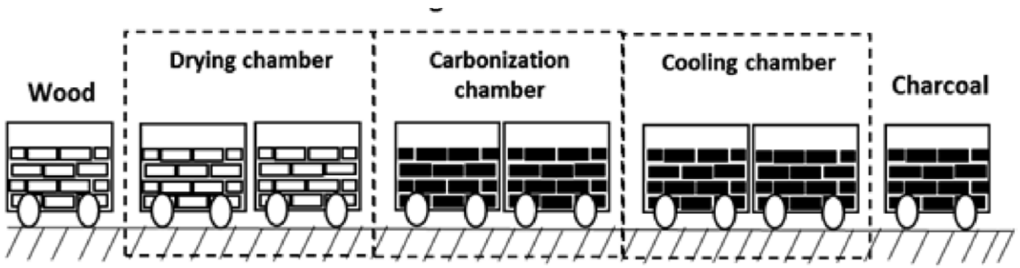
Mode		Conditions	Liquid	Biocarbon	Gas
Fast pyrolysis	**"Thermal Liquefaction"**	~ 500^{o}C, short vapor residence time ~ 1-2s	**75 %**	**12 %**	**13 %**
Intermediate pyrolysis	**"Carbonisation" and " Thermal liquefaction"**	~ 400^{o}C, long vapor residence time ~ minutes to hours	**45 %**	**30 %**	**25 %**
Slow pyrolysis	**"Carbonisation"**	~ 400^{o}C, long vapor residence time ~ hours to days	**35 %**	**35 %**	**30 %**

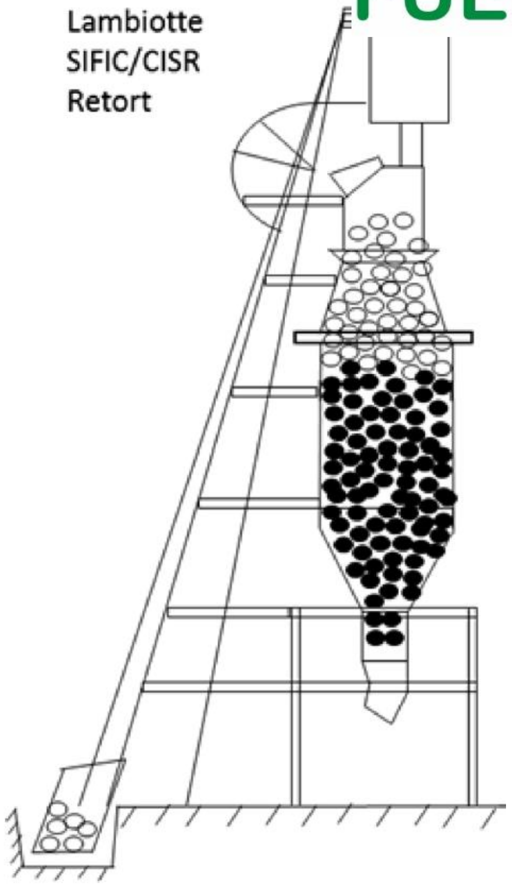
- Pyrolysis technology enables direct conversion of carbon rich organic feedstocks into hydrocarbon rich **carbon and oil products** that can replace use of virgin and fossil raw materials.

Introduction – Carbonisation

Carbonisation by slow pyrolysis

- Industrial carbonization process
- No utilization of byproducts
- Charcoal product yield is typically 30-35% on weight basis and 50-55% of carbon basis



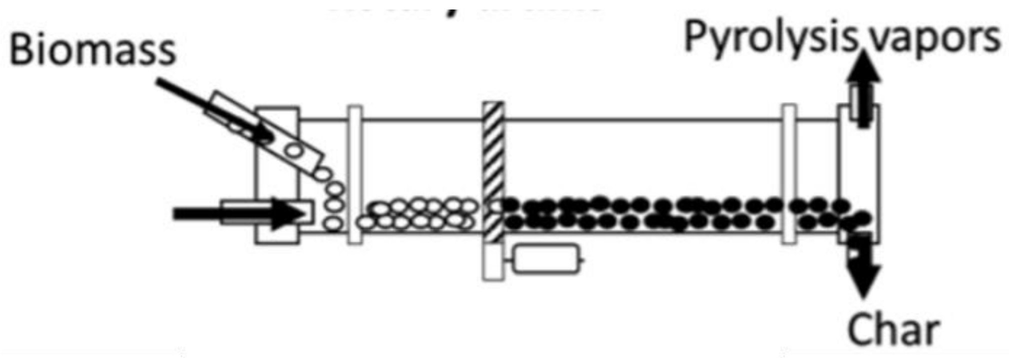


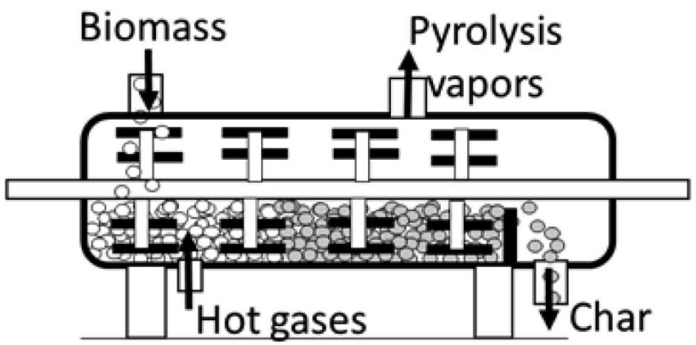
Introduction – Carbonisation and Thermal liquefaction

Intermediate pyrolysis

- Somewhat lower charcoal yield
- Possible to produce and utilize condensate byproduct

Aqueous condensate *Organic condensate*





Incentives – Reduced CO_2 emissions

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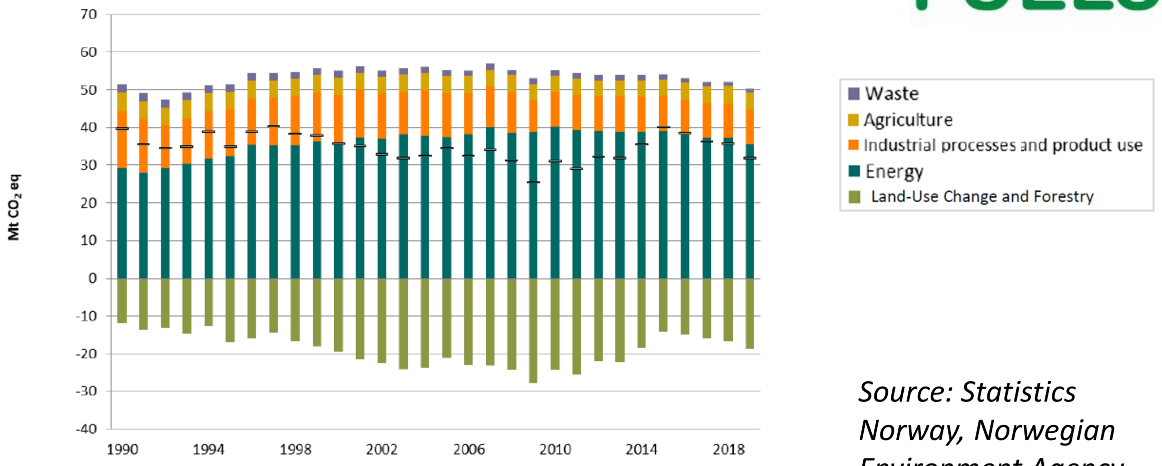
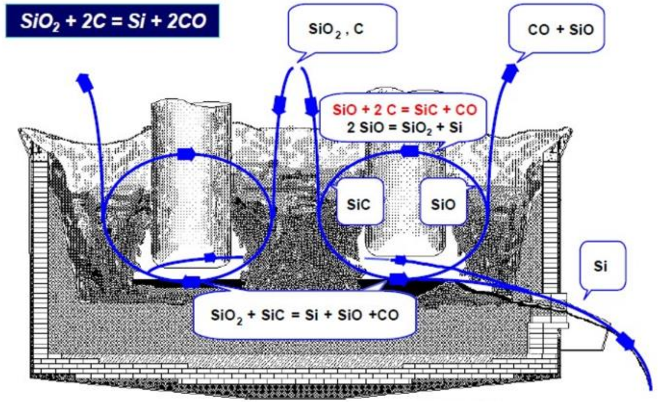
- Norway has committed 90-95% reduction in GHG emissions by 2050 (based on 1990 levels)
- Norwegian emissions in 2020: 50 Mtons CO_2
    - Oil and gas 12 Mtons
    - Process industry 12 Mtons
    - Road traffic 9 Mtons
    - Air and marine traffic etc 8 Mtons
    - Agriculture 4 Mtons
- Process industry
    - The metallurgical industry (5,6 Mtons) use large amounts of fossil carbon as reductant materials. In short term, replacement of fossil reductant materials with biocarbons is considered to be the only option for reducing GHG emissions from the industry

- Pyrolysis technology enables severe cuts in GHG emissions by producing **biobased** and **recycled oil** and **carbon** which can replace use of fossil raw materials in process industry, transport and other sectors



Source: Statistics Norway, Norwegian Environment Agency



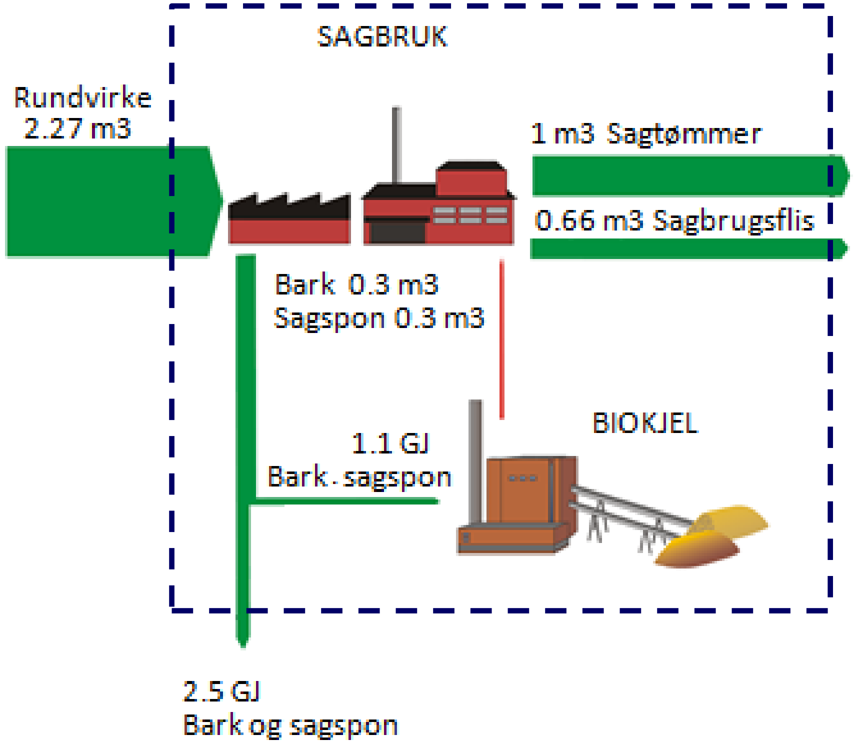
Production of SiFeSI alloys

Incentives – Circular economy

- A **circular economy** means that we must use resources more efficiently, **reduce** waste and increase **reuse** and **recycling** of materials in order to maintain materials and resources as long as possible.
- The development of an efficient circular economy is a necessity to reduce pressure on natural resources, create sustainable growth and to reach the EU's climate neutrality target for 2050.
- EU's directive for waste requires that 70% of construction waste and 65% of household waste is reused and recycled. In Norway, these goals for waste recycling are far from being reached:
    - Waste wood / construction waste: Most waste wood goes to direct incineration
    - Plastic waste: Only ~30% of plastic waste from packaging are re-used.
- Waste feedstocks like waste wood, plastic waste and sorted household waste has complex chemical composition and contain significant amounts of contaminants makes chemical recycling of these feedstocks particular challenging.
- Pyrolysis technology enables **chemical material recycling** of carbon rich organic waste feedstocks with complex chemical composition by direct conversion into hydrocarbon rich **oil and carbon products** that can replace use of virgin and fossil raw materials.

Incentives – Byproduct valorisation

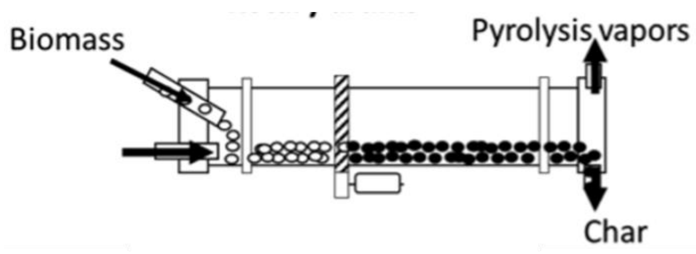
- Pyrolysis technology enables **increased value creation** and **better raw material utilisation** in wood processing industries by facilitating **decentralised conversion** of “**bulky” byproducts** from into **“energy dense” and transportable biocarbon or oil products**



Carbonisation – Challenges and possibilities

Key challenges

- Product functionality
- Carbon product yields
- Profitability



Carbonisation – Challenges and possibilities

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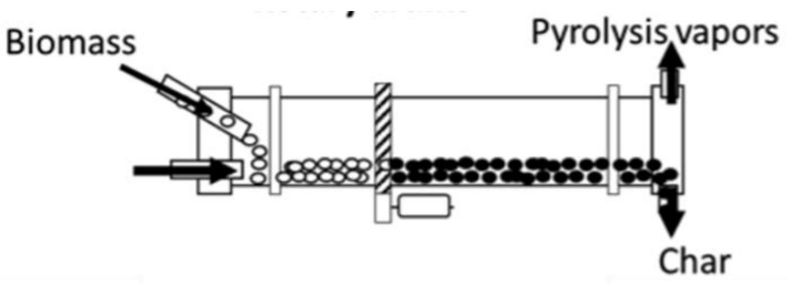
Key Challenges

- Profitability
- Carbon product yields
- Product functionality

Possibilities

- Very low product carbon yields in existing commercial biocarbon production
- Byproduct valorization
- Logistics
- Biocarbon product engineering
- Specialty biocarbon products
- Integration advantages



Biocarbon

Condensate byproducts

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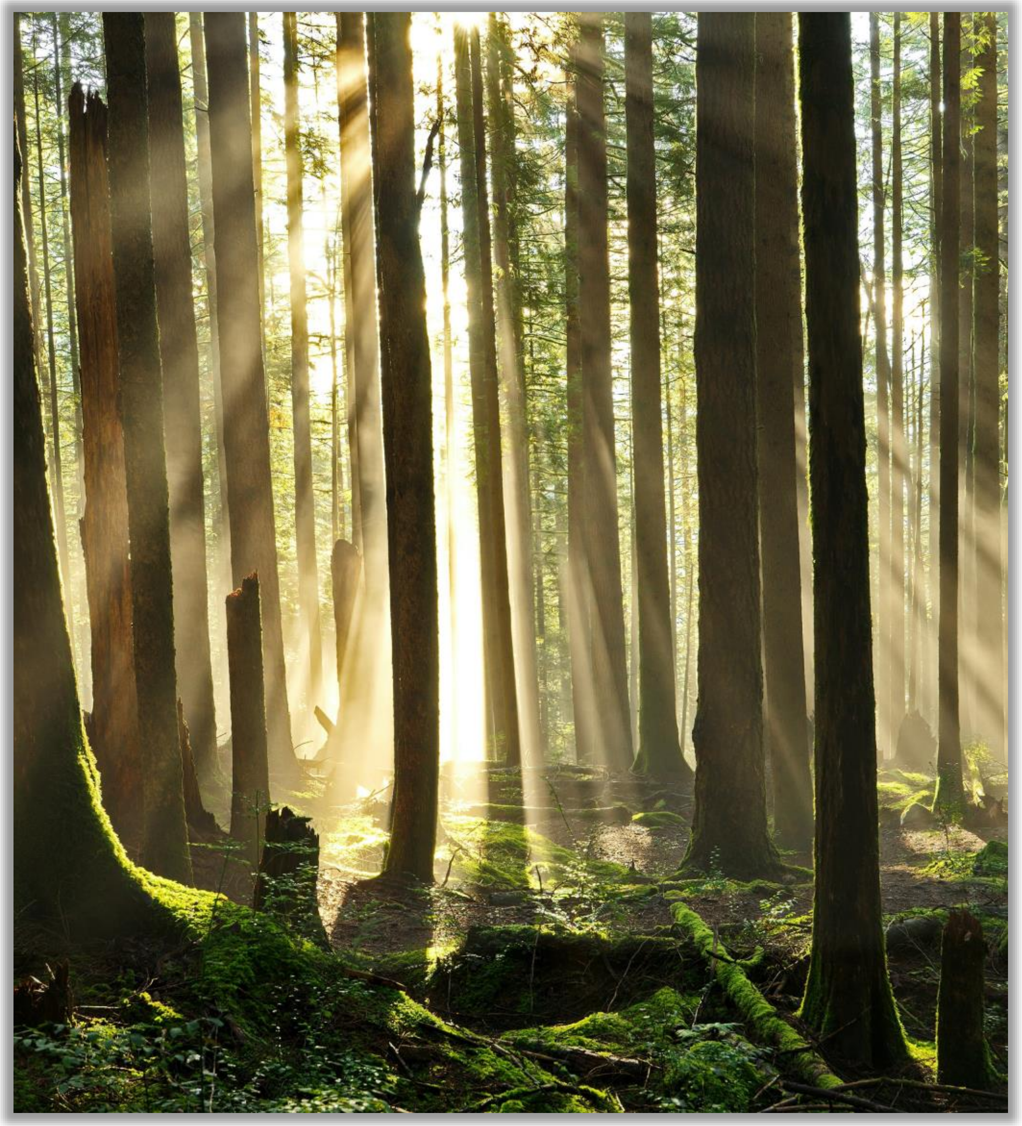
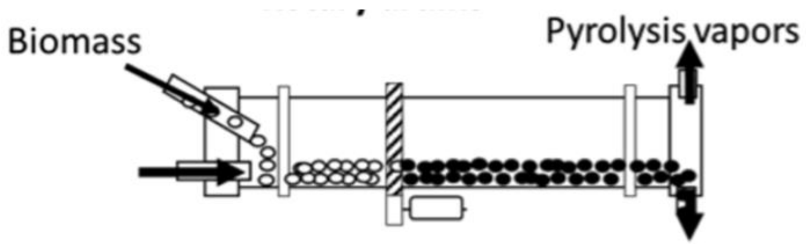


Smart carbonisation – Strategy and ambitions

Strategy

- Smart carbonisation by intermediate pyrolysis with byproduct valorisation
    - **Biocarbon** suitable for use in metallurgical industry
    - Anaerobic digestion of aqueous condensate for **biomethane** production
    - organic condensate upgrading into **Biofuel** or **Biobinder**



Ambition

- Develop a smart carbonisation process which gives higher product yields on carbon basis as compared to the conventional slow pyrolysis carbonization process

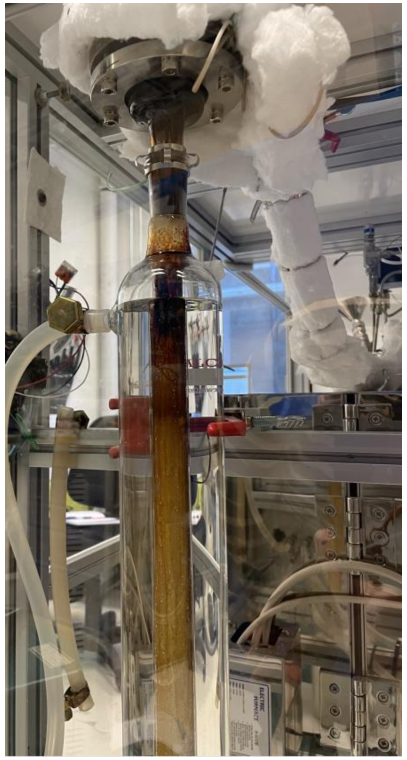
Biocarbon

Condensate byproducts

Smart carbonisation – Methods

Smart carbonisation by intermediate pyrolysis

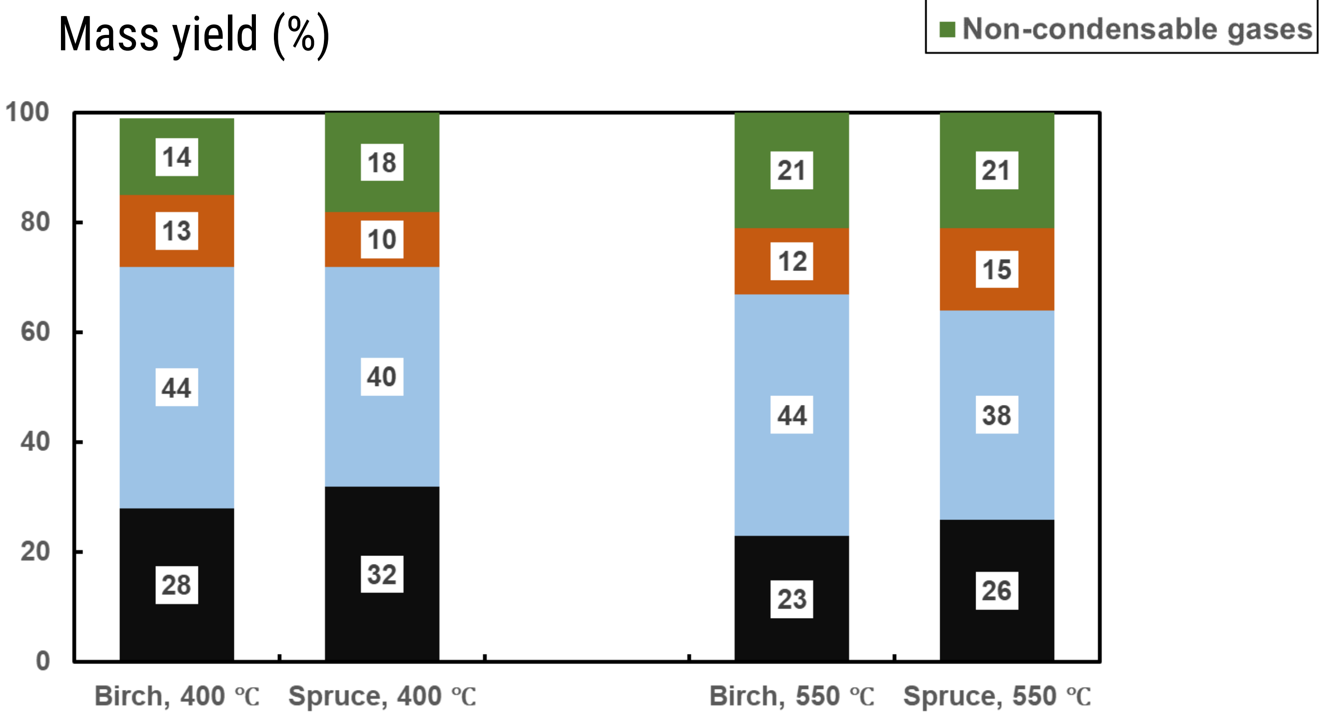
- Intermediate pyrolysis simulated in a modified batch pyrolysis reactor system
    - Two water cooled condensors and an electrostatic precipitator were applied in series for minimizing amount of non-condensable compounds
- Upscaled production in cooperation with pyrolysis technology supplier



Smart carbonisation– Product yields

Smart carbonisation by intermediate pyrolysis

- High temperature carbonisation process is required to obtain a biocarbon material suitable for metallurgical industry with high carbon content (FixC >90) and low amount of volatiles
- The biocarbon product yield for a high temperature carbonisation (550°C) of birch and spruce is only 23-26 Wt%
- Byproduct valorisation is even more important for a high temperature carbonisation process



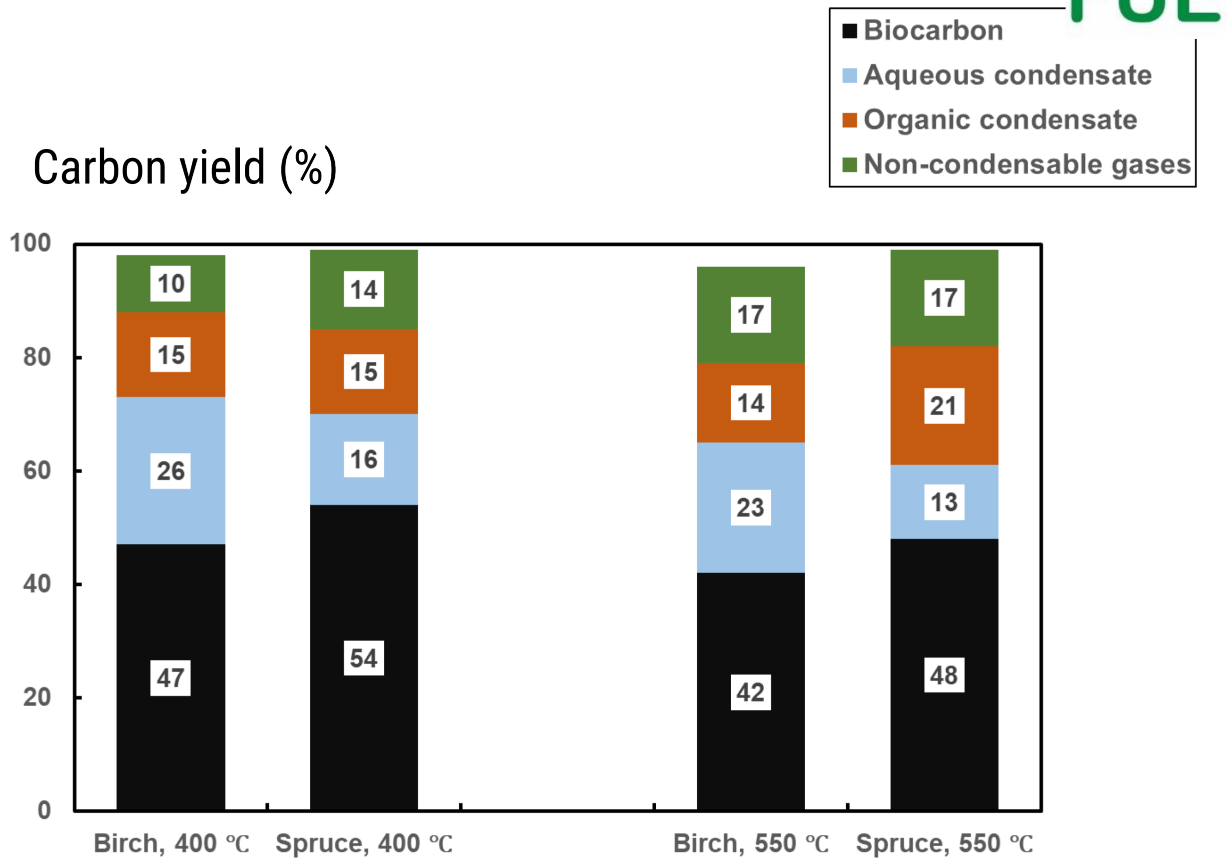
van der Wijst, C., Ghimire, N., Bergland, W. H., Toven, K., Bakke, R., and Eriksen, Ø. (2021). "Improving carbon product yields in biocarbon production by combining pyrolysis and anaerobic digestion," BioResources 16(2), 3964-3977.

Smart carbonisation – Product yields

Smart carbonisation by intermediate pyrolysis

- On carbon basis, the biocarbon product yield for high temperature carbonisation of birch and spruce wood is 42-48%
- Byproduct product yield on carbon basis:
    - Aqueous condensate: 13-23 C%
    - Organic condensate 14- 21 C%
    - Non-condensable gases ~17% C%

- Significant higher carbon product yields can be obtained if the carbon material in aqueous and organic condensates can be valorised



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Smart carbonisation – Anerobic digestion of aqueous condensate

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Anaerobic digestion of aqueous condensate

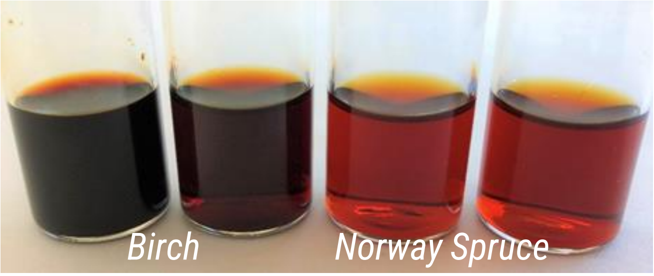
- Cooperation with University of South-Eastern Norway (USN)
- Syringe batch reactors and an AMPTS II test system were applied to evaluate production potential, kinetic and stoichiometric data for biochemical methane
- PhD thesis: Nirmal Ghimire "Methane production from lignocellulosic residues“.

Ghimire N. "Methane production from lignocellulosic residues", PhD thesis, University of South-Eastern Norway Faculty of Technology, Natural Sciences and Maritime Studies, 2021

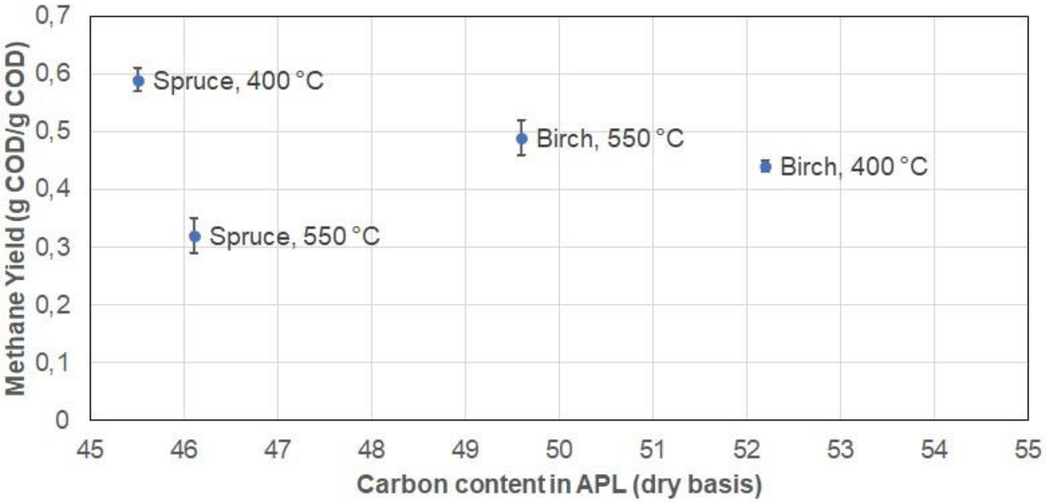
Smart carbonisation – Anaerobic digestion of aqueous condensate

Anaerobic digestion of aqueous condensate

- For Birch, about 50% of dissolved organic compounds in aqueous condensate converted to biomethane
- For spruce wood, 30-60% of dissolved organic compounds in aqueous condensate converted to biomethane, depening on severity in the pyrolysis process
- Codigestion with other substrates is favorable as conversion rate for aqueous scondensate is quite slow



Aqueous condensate samples from carbonization of Birch and and Norway Spruce



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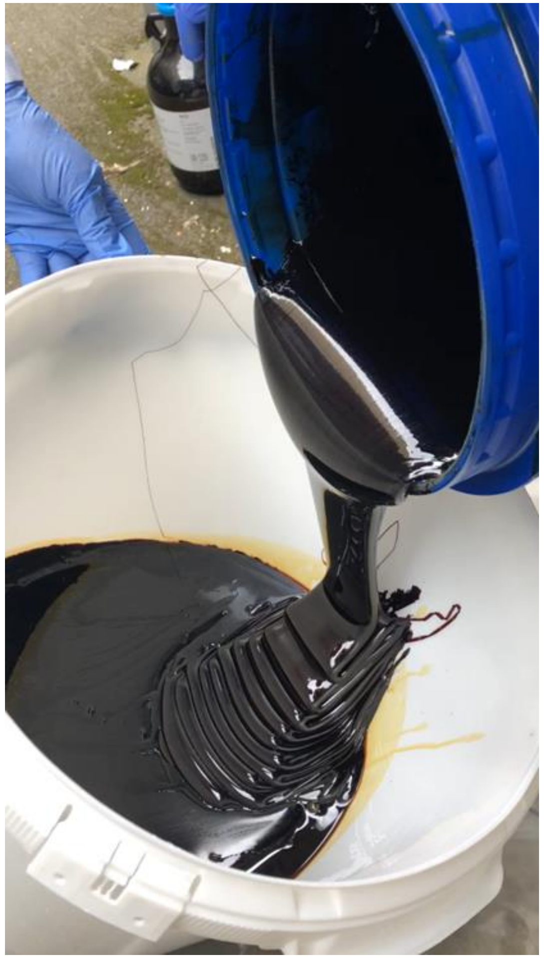
Smart carbonisation – Valorisation of organic condensate

Condensate characteristics

- High energy density (LHV) 25- 28 GJ/t
- Water content: ~ 10%
- Oxygen content (wt%, d.b): 23%
- High viscosity 100-400 CSt (50°C)

Application

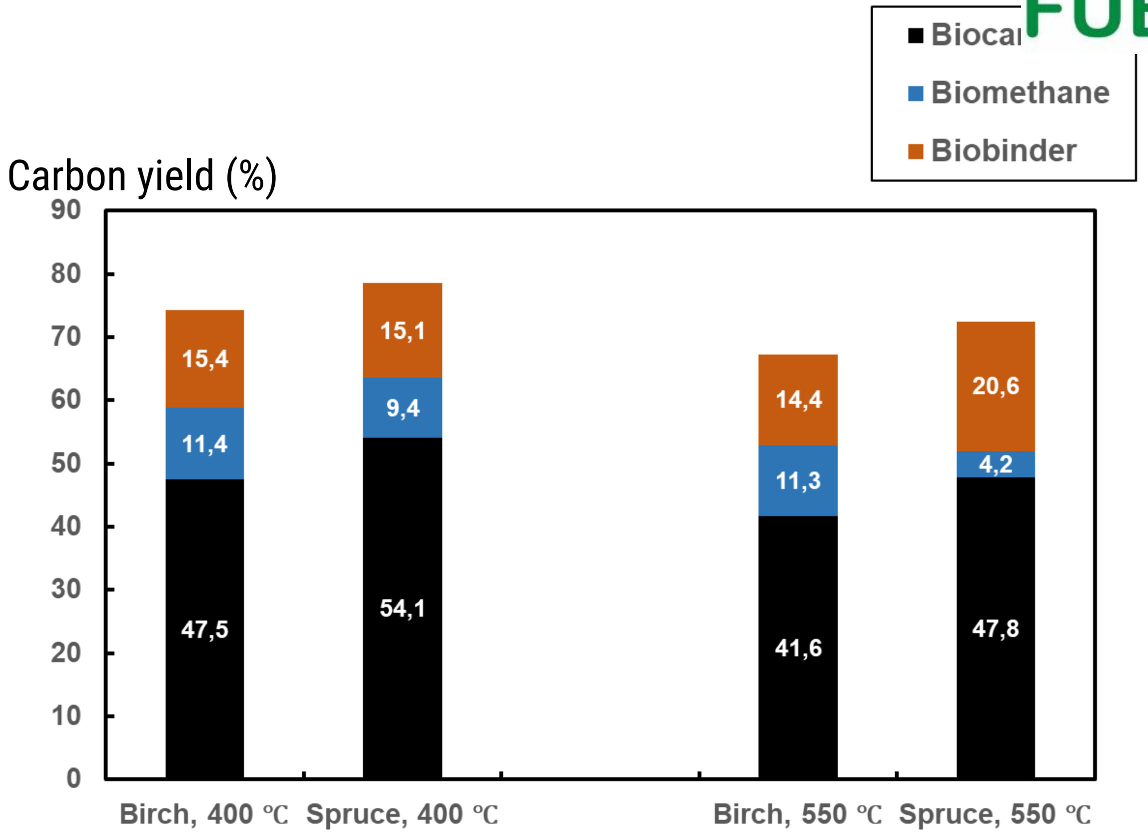
- Transportation fuel: To extensive upgrading needed for using the biocrude as transportation fuel
- Renewable heating fuel: High viscosity and acidic groups does not allow use in existing burners
- Solid biofuels: Suitable for use as binder in soild biofuels
- Biobinder: Stabilisation gives a biobinder with attractive properties which may replace fossil bitumen binders in various applications



Smart carbonisation – Product yields

Smart carbonisation by intermediate pyrolysis

- Smart carbonisation with coproduction of biomethane and biobinder from condensate byproducts gives significant higher product yields on carbon basis than traditional carbonisation
- For low and high temperature carbonisation of wood feedstocks, about 74-79% and 67-73% of the wood feedstock carbon material was converted into biocarbon, biomethane and biobinder
- Carbon losses are due to non-condensable gases and unconverted organics in aqueous condensate



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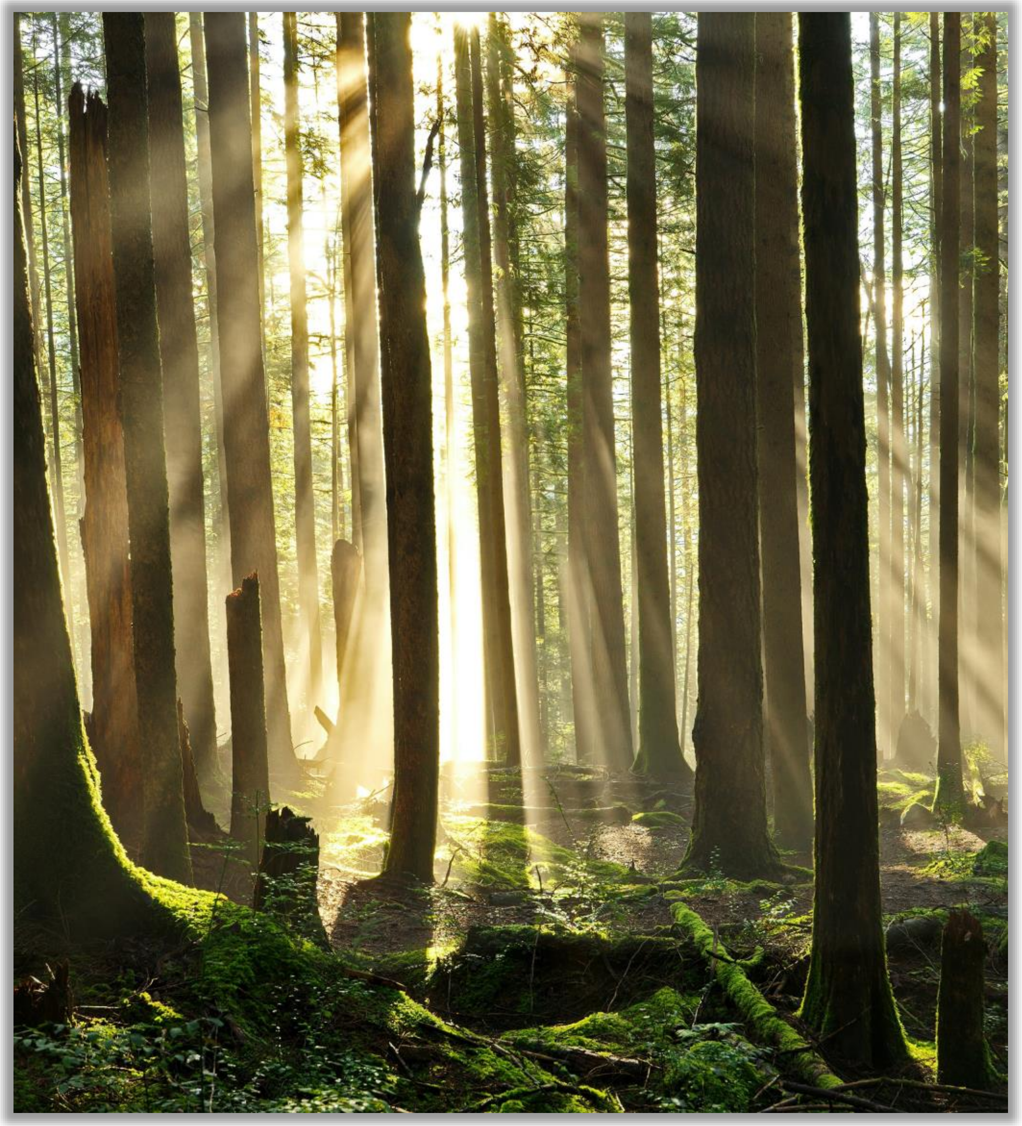

Summary

- Pyrolysis technology enables direct conversion of biobased and recirculated carbon rich organic feedstocks into hydrocarbon rich carbon and oil products that can replace use of virgin and fossil raw materials. The technology can enable i) severe cuts in GHG emissions by replacing fossil carbon and oil products process industry, transport and other sectors ii) material recycling of carbon rich waste feedstocks which are burnt today and iii) byproduct valorisation from wood industry and agriculture
- Smart carbonisation with coproduction of biomethane and biobinder from condensate byproducts gives significant higher product yields on carbon basis than a conventional slow pyrolysis carbonisation process
- Results suggests that the aqueous condensate byproduct from wood carbonisation is suitable as co-substrate for biomethane production by anaerobic digestion and that the organic condensate byproduct can be upgraded into a biobinder suitable for biocarbon agglomerates etc
- For a low and high temperature carbonisation process , about 74-79% and 67-73% of the wood carbon material was converted into biocarbon, biomethane and biobinder respectively.

Thank you!

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