Sustainable biofuels for aviation

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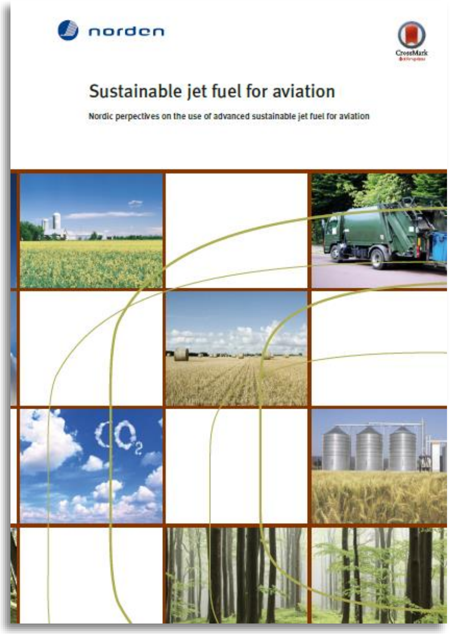
Sustainable jetfuel for aviation – Nordic perspectives on the use of advanced jetfuel for aviation

- Development process for sustainable jetfuel in the Nordic countries
- Contribution to GHG reduction and mitigation
- Current policies at Norwegian and EU level
- Promising technological pathways for production of sustainable jetfuel
- Norwegian initiatives for biofuels production and use
- Summary



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Development process for sustainable jetfuel in the Nordic countries

- Sustainable criteria
  - Greenhouse gas emissions
  - Direct and indirect land-use change
  - Nutrients
  - Pesticides
  - Biodiversity
  - Water usage
  - Generations of feedstock and biofuels

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Sustainability criteria – Greenhouse gas emissions (GHG)

- Non-CO_2 emissions at high altitute contribute significantly to globar warming
  - NO_x
    - Associated with combustion processes at high temperatures – contribution to ozone formation at lower atmosphere
    - Destroy methane in the atmosphere
  - Methane
    - Associated with agriculture and anthropogenic sources

- CO_2 emissions
  - Primary anthropogenic sources (combustion of fuels)
  - Combustion of biofuels is only CO2 neutral when using annual plants; use of biofuels is not CO2 neutral (GHGs associated with harvesting, processing, transport, use of non-annual plants)

Sustainability criteria – Direct and indirect land-use change

- Land use change (LUC)
  - Net increase in CO_2 emissions due to a decrease of carbon storage in the land as a result of a decrease of carbon rich vegetation (e.g. from forests to fields)

- Indirect land use change (iLUC)
  - Net increase in CO_2 emissions due to a shift in the use of a crop (e.g. from food to feedstock, with possible displacement of food production to other LUC-land areas)

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Sustainability criteria – Others

- Nutrients
  - Potential for eutrophication if P and N are leached from fields into lakes and streams
  - Recirculation of nutrients important when selecting feedstock and technological pathways
- Pesticides
  - Used to protect crops from pests; provide benefits such as improved crop yields and quality.
  - They have adverse effects on the environment and human health
- Biodiversity
  - Possibility to harm the ecosystem when utilizing land areas for feedstock
- Water usage
  - Important to consider both amount of water used in the production of biomass and the quality of water resources

Sustainability criteria – Generations of feedstock and biofuels

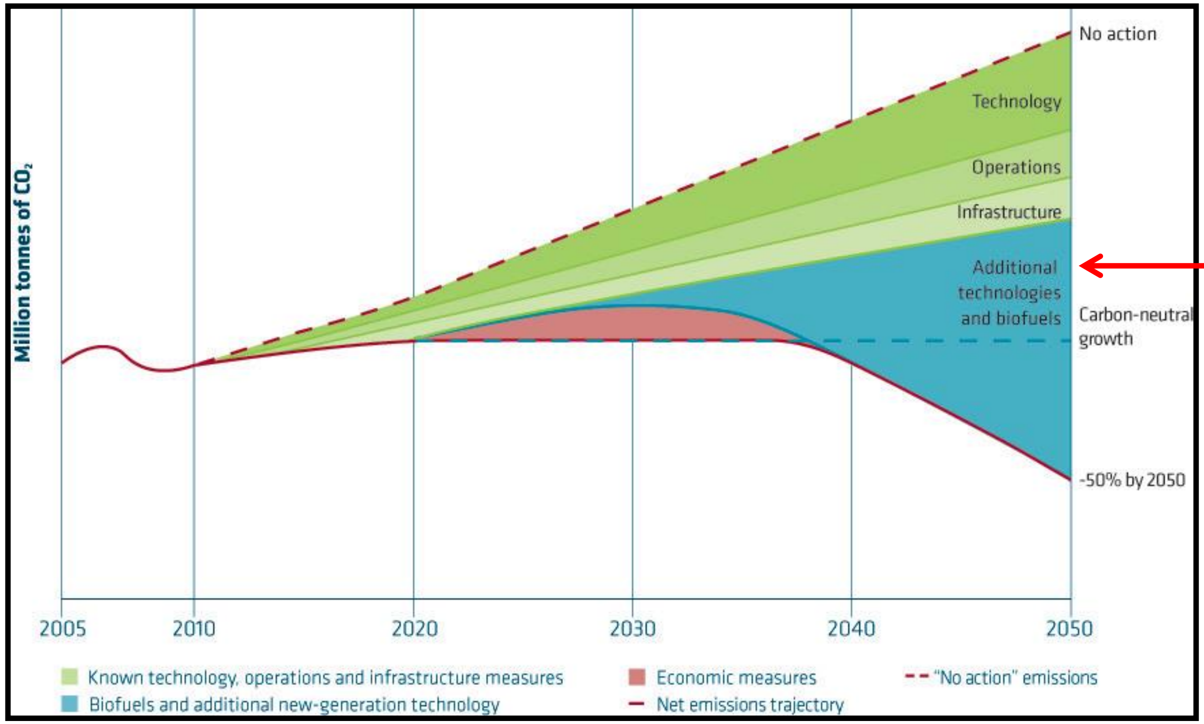
- 1st generation (1G): Food and feed crops 
  - Feedstock competing with food production (rapeseed, sugarcane, palm oil, maize,...)

- 2nd generatoin (2G, advanced biofuels): Lignocellulosic and waste materials
  - Exhibit zero (or low) LUC impacts (residues from agriculture and forestry, MSW,...)

- 3rd generatoin (3G): Micro-, macroalgae and engineerd feedstocks

- 4th generation (4G): Algae, microorganisms and microbes, which absorbed and convert CO_2 to biofuels

Contribution to GHG reduction and mitigation



RENEWABLE JET-FUELS NEEDED!

Source : Air Transport Action Group, 2013

- Improve fleet fuel efficiency by 1.5% per year from now until 2020
- Cap net emissions from 2020 through carbon neutral growth
- Halving net CO_2 emissions by 2050 based on 2005 emissions

Current policy frameworks - EU

- The European Emission Trading Scheme (EU ETS)
  - System of tradable allowances for companies, covering ~45% of the EU's GHG emissions
  - Each allowance gives the right to emit 1t CO_2 or the equivalent amount of N_2O and PFCs
  - "Cap and trade" principle; cap reduced over time, in alignment with the overall GHG targets of the participating partners
  - Aviation included since 2012: emissions from, to and within the European Economic Area (Norway included)
  - In the aviation sector, the cap has been provisionally set at 210 million aviation allowances per year → 5% below the average annual level of aviation emissions in the 2004-2006 base period.
  - The ETS carbon price was EUR 9/ton CO_2 in 2015. As of June 2016 it is EUR 6/t CO_2 (~10% of the current price of fossile jetfuel) → far below what is needed to incetivise emissions cuts

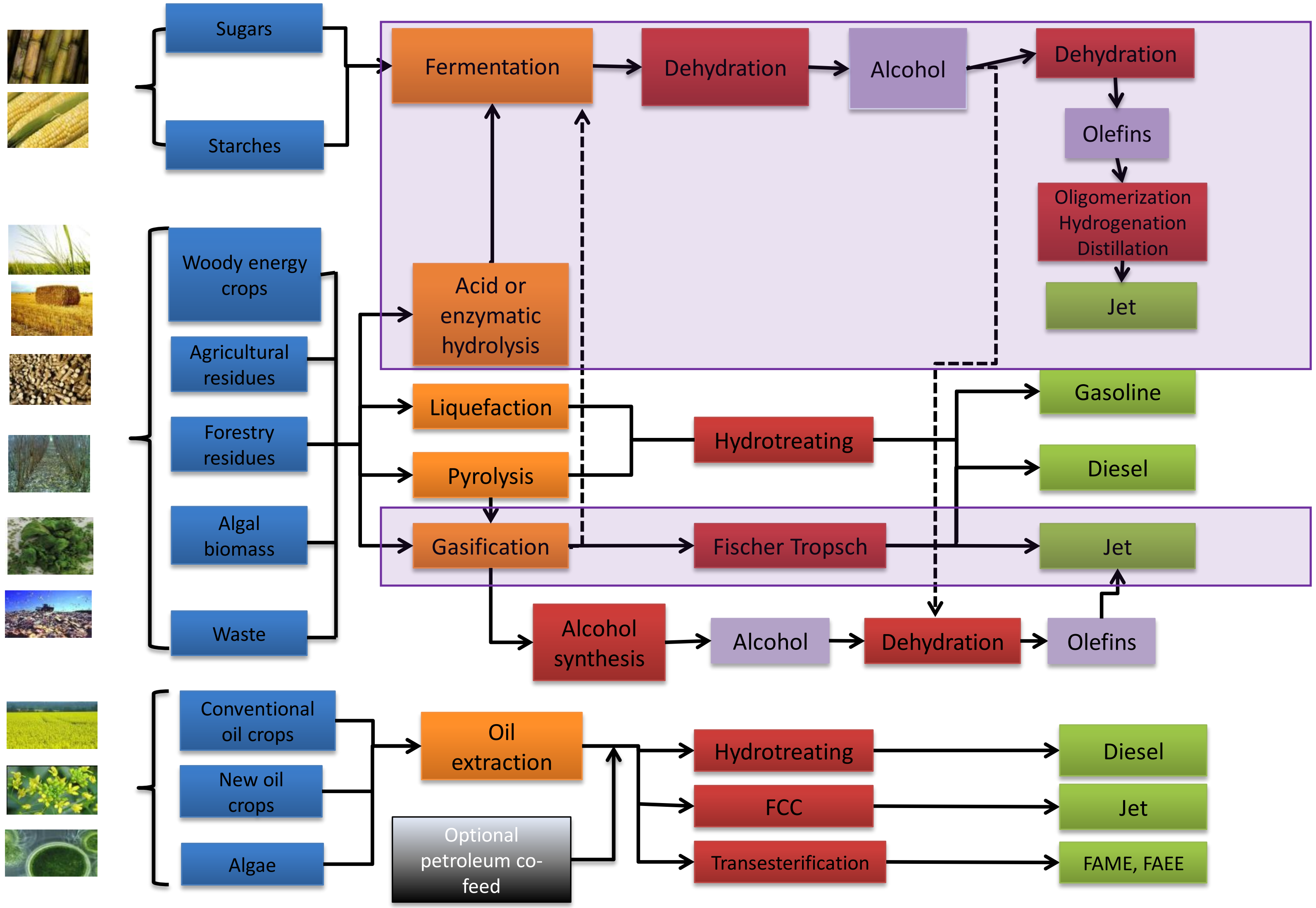
Current policy frameworks - Norway

- Norway has a target of a 67.5% share of Renewable Energy Sources (RES) of gross final consumption of energy by 2020, including a 10% share of RES in energy for transportation

- The Norwegian Government has just agreed on increasing the share of biofuels in diesel and gasoline from 5.5 to 7% in 2017 and it shall reach 20% by 2020. All biofuels sold in Norway should be sustainable.

- Biofuels are exempted from CO_2 tax. However the aviation sector is subject to CO_2 tax, landing charges and the EU ETS.

Promising technological pathways for production of sustainable jetfuel



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Promising technologies– certification of sustainable jetfuel pathways

Table 12: ASTM certification of sustainable jet fuel pathways

Pathway	Certification status	Feedstock
Fischer-Tropsch (FT)	✓ 50% blend	Any biomass or carbon source
Hydroprocessed esters and fatty acids (HEFA)	✓ 50% blend	Vegetable oils, animal oils, and any other bio-oils containing tri-glycerides
Synthetic Parafinic kerosene (SIP)	✓ 10% blend	Any sugar containing feedstock
Alcohol to Jet (AtJ) (BASED ON ISOBUTANOL)	✓ 30% blend	Any sugar containing feedstock
FT synthetic kerosene with aromatics (FT-SKA)	under review (100% blend)	Any biomass
Hydroprocessed depolymerized cellulosic jet (HDCJ)	under review	Lignocellulosic
HEFA+	testing (as annex to HEFA, around 10% blend)	Same as HEFA
AtJ synthetic kerosene with aromatics (AtJ-SKA)	testing (100% blend)	Same as AtJ
Catalytic hydrothermolysis (CH)	testing	Vegetable oils, animal oils, and any other bio-oils containing tri-glycerides
Hydrothermal liquefaction (HtL)	-	Any biomass
Pyrolysis to jet (PtJ)	-	Any biomass
Power to liquid (PtL)	-	Concentrated CO_2
Microbial Conversion of CO_2	-	Concentrated CO_2

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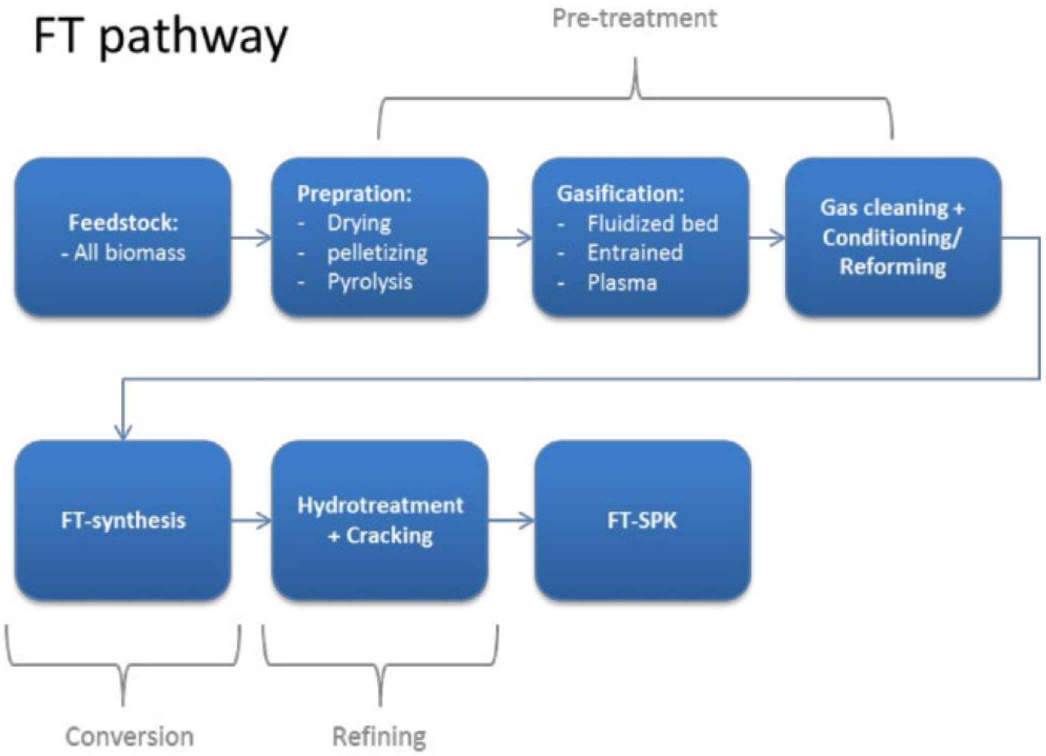
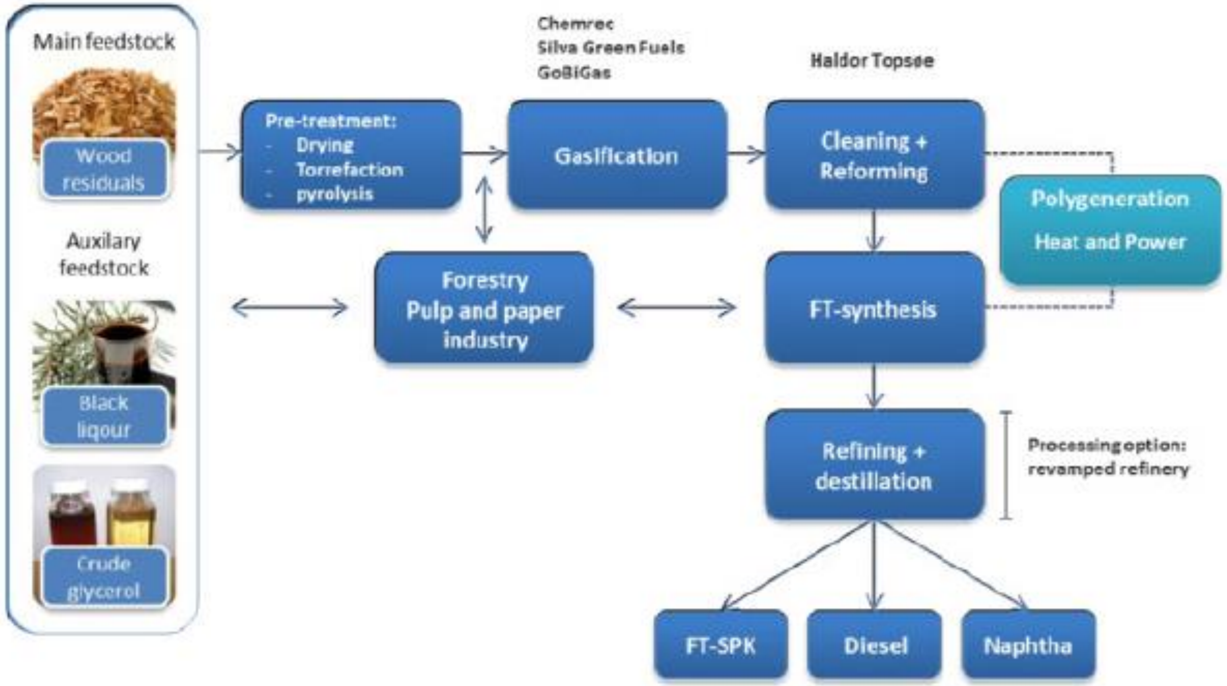
Production of sustainable jetfuel – Gasification to Fischer-Tropsch



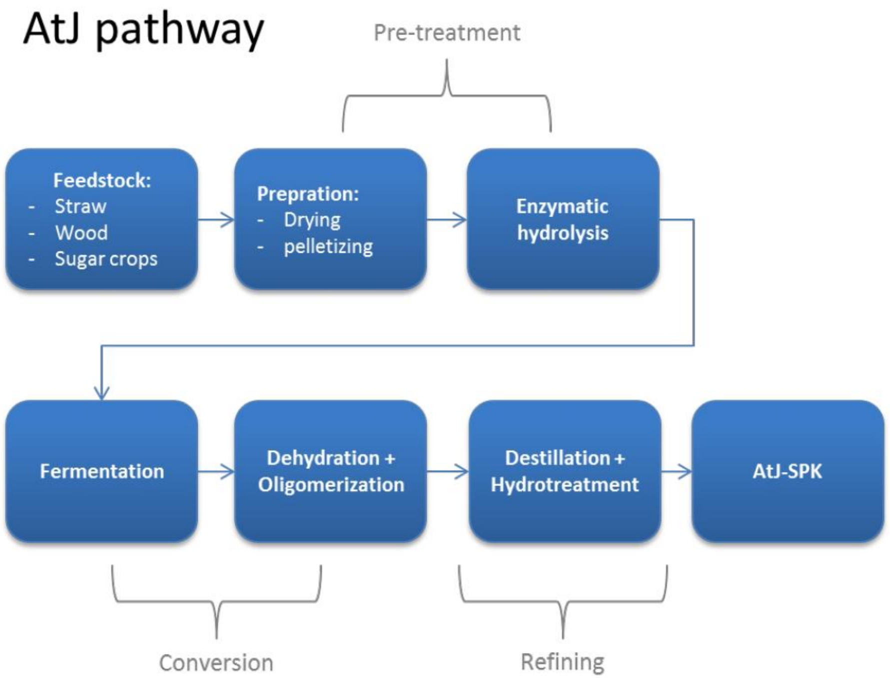
- The first technology to be certified for biojetfuel
- There is no commercial production of FT-SPK using biomass yet

Production of sustainable jetfuel – Promising scenario Gasification/FT



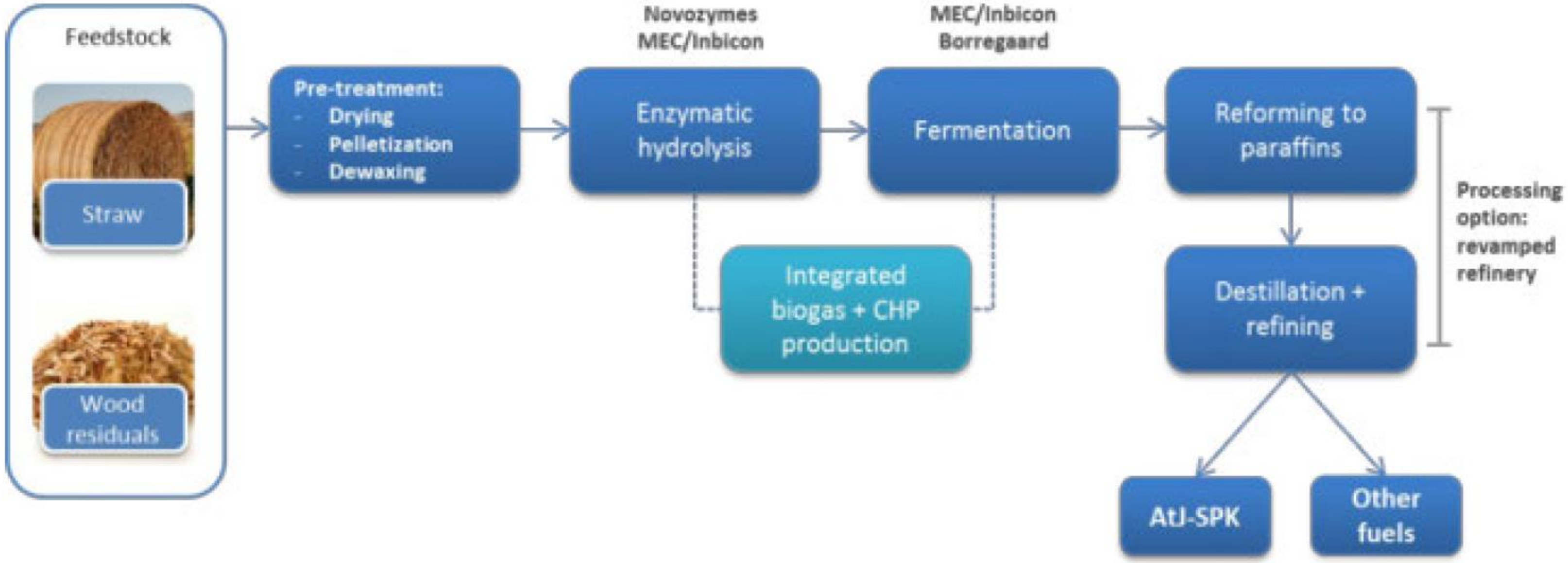
- Wood residues are largely available among the Nordic countries
- Close connection to the forestry and pulp-and-paper industry and infrastructure
- Technology and know-how within gasification

Production of sustainable jetfuel – Alcohol-to-Jet (AtJ)



- Technology expected to be certified in 2016
- Most promising pathway: biomass-sugars-**isobuthanol**-biojetfuel
- GEVO commercializes production of isobuthanol-based jetfuel from forestry residues. Alaska Airlines has successfully tested this jetfuel (first commercial flight to use a fuel blend made from woody biomass)

Production of sustainable jetfuel – Promising scenario AtJ



- Straw and wood residuals are largely available among the Nordic countries
- Nordic competences within hydrolysis and fermentation technologies

Norwegian initiatives for biofuels production and use

- **Biozin**: production of biojetfuel, biodiesel and biogasoline from forestry biomass with own patented technology
- **Treklyngen**: 2 major initiatives for biofuels production
  - **St1 and Cellunolix** ® technology: bioethanol from forestry biomass and waste
  - **"Norwegian wood"** with Elkem, Avinor and Vardar: production of biojetfuel
- **Silva Green Fuel:** production of biodiesel either drop-in or blend-in/co-refining
- **Quantafuel:** BtL as main focus with own Fischer-Tropsch technology and plastic waste as feedstock

- **Avinor:** From January 2016 OSL became the world's first hub to offer jet biofuel to all airlines on a commercial basis

Summary

- Sustainability criteria play a key role in biofuels deployment
- Need for long-term good policy frameworks
- Impossible to choose a winner technology
- High risk - There is no commercial technology for production of advanced biofuels production…few good examples and many unsuccessful stories
- Up-scaling is costly (valley of death)
- Quite a few initiatives – interest for production of biofuels from Norwegian biomass feedstocks

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Teknologi for et bedre samfunn