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MEMBER COUNTRY UPDATE: NORWAY

Judit Sandquist

SINTEF Energy Research

General update on biofuels in Norway

- Biofuels mandate
  - Norway has recently adopted an ambitious biofuels implementation plan, with **7% supply in 2017 gradually increasing to 20% by 2020**. Of which 1.5% and 8%, respectively, will be advanced biofuels. Right now, marine and aviation are exempted.
- Biofuels are mainly imported today.
- 90% of all biofuel is biodiesel (mainly rape), 10% is bioethanol (mainly corn)
- Norway has feedstock
  - At least 7 TWh of todays unexploited biomass can be converted to fuels. If the amount of usage increases, within sustainability limits, the potential of biofuels production can increase to 16 TWh. This is equivalent to 320 and 720 million liters diesel.

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Norwegian biofuel initiatives

- Borregaard: New bioethanol drying plant
  - Borregaard has invested in upgrading the ethanol produced to 100% (water free) to be able to access the low blends market. They will have a capacity to produce 20 million liters of 100% ethanol at the end of 2017.
- Statkraft/Silva Green fuels: Demo engineering
  - Assessed the available (30+) technologies
  - None of the technologies are mature enough to justify commercial deployment.
  - **The costs are frequently underestimated, critical technology elements are not highlighted and risk mitigation will be required**.
  - Silva Green Fuels will start the engineering of a 55-150 mill liters fuel/year demo plant in 2017, the chosen technology is not disclosed to the public yet.
- St1 is interested in setting up bioethanol production
  - Running demo in Kajanii

Norwegian biofuel initiatives

- Avinor:
  - Still no technical problems and all parts are satisfied. However there are some supply issues due to the low availability of the biojet.
- Quantafuel has a plastic to fuel technology,
  - However use of plastic waste is not considered renewable right now. I guess this will be similar issue as we had on flue gases. Quantafuel have a running demo in Mexico, and in Norway they are also looking at production fuel from biomass gasification on pilot scale. The gasification partner is not disclosed yet.
- Biozin:
  - Biozin is working on a technology that converts woody by products from the forest and timber industry to liquid hydrocarbon intermediates that can be directly processed in oil refineries. Currently producing hydrocarbon samples from own feedstock in the US.
- Biofuel Development + Westinghouse/AlterNRG/Kaidi
  - Investigating possibilities for pilot/demo plant in Norway. Kaidi has a running demo.

Small-scale biomass gasification

- First Norwegian small scale CHP based on gasification of locally sourced wood chips
- Located at Evenstad campus
- Produced by Volter
- Delivered by ETA Norge
- Start-up: 2016

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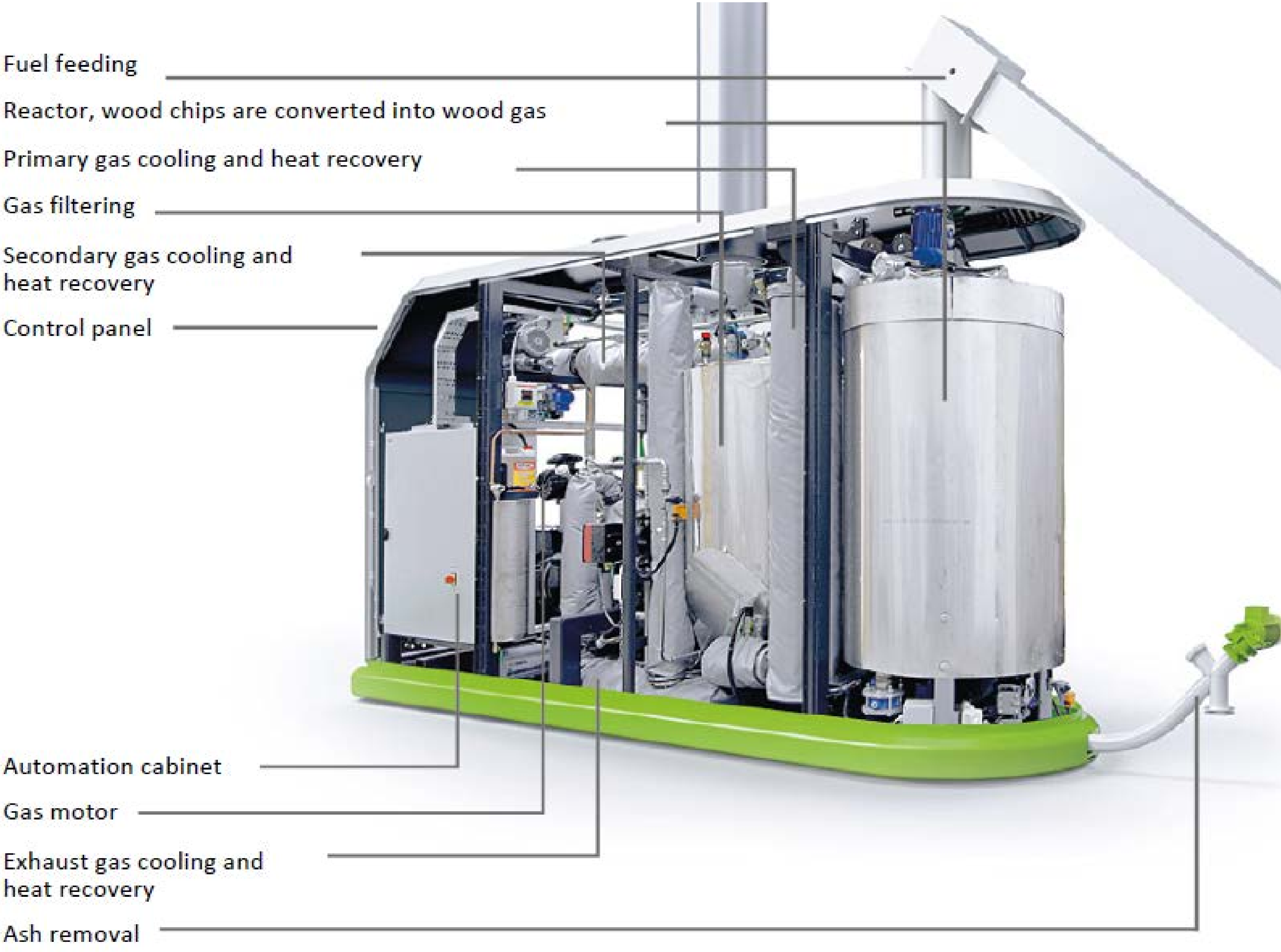
Stakeholders and project

- Technology supplier: ETA Norge
  - ETA Norge is a small company delivering complete technological solutions within bioenergy and solar. Primarily interested in new technological solutions in order to have the best possible environmental impact.
- The project
  - Statsbygg was responsible for the design of the new building → solar+bio+power production → bioCHP. Several CHP suppliers were contacted, an assessment on technological solutions as well as installation/maintenance easiness was conducted. Volter was chosen for the CHP due to their user-friendly design and good technical solutions.
- Experiences
  - Works VERY GOOD! The drawbacks compared to conventional wood chip boiler is the higher amount of ash as well as increased maintenance (weekly controls of the oil level, gas filter etc). They are working on utilization of the remainder carbon in the ash.
- Future
  - Good experiences and support (33%) from Innovation Norway may pave the way for further installations.

The CHP unit

- Volter 40
- Capable to produce:
  - 45 kW power
  - 100 kW heat
- Efficiency
  - 20% to power
  - 50% to heat
  - 70% total



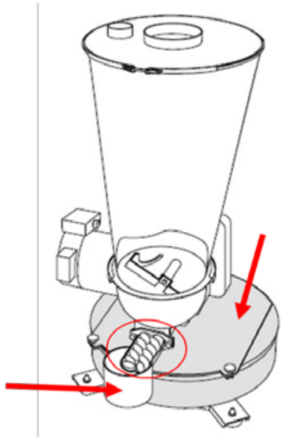
Gasification research

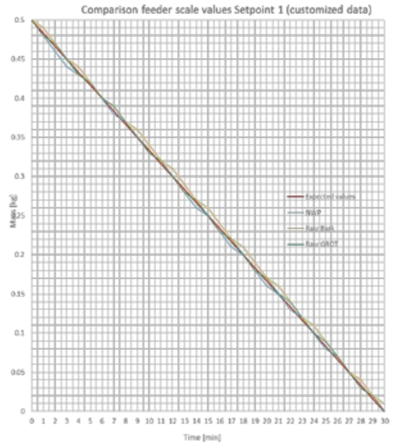
- The Norwegian Research Council is focusing on support for project utilizing forestry residues, side streams and wastes as feedstock. The research center for environmentally friendly energy on biofuels, Bio4Fuels had a successful kick-off 9-10th February.
- GAFT

Highlights from the GAFT project

Feedstock physical & chemical properties

- Ash melting properties
  - ✓ Melting behaviors of ashes from individual fuel and fuel mixtures
  - ✓ Investigation of ash melting mechanisms
- The effect of particle properties on feeding stability
  - ✓ Test of feeder
  - ✓ Test of project fuels
  - ✓ Effect of particle properties on feeding stability (i.e., programmed feeding rate *vs* measured feeding rate)





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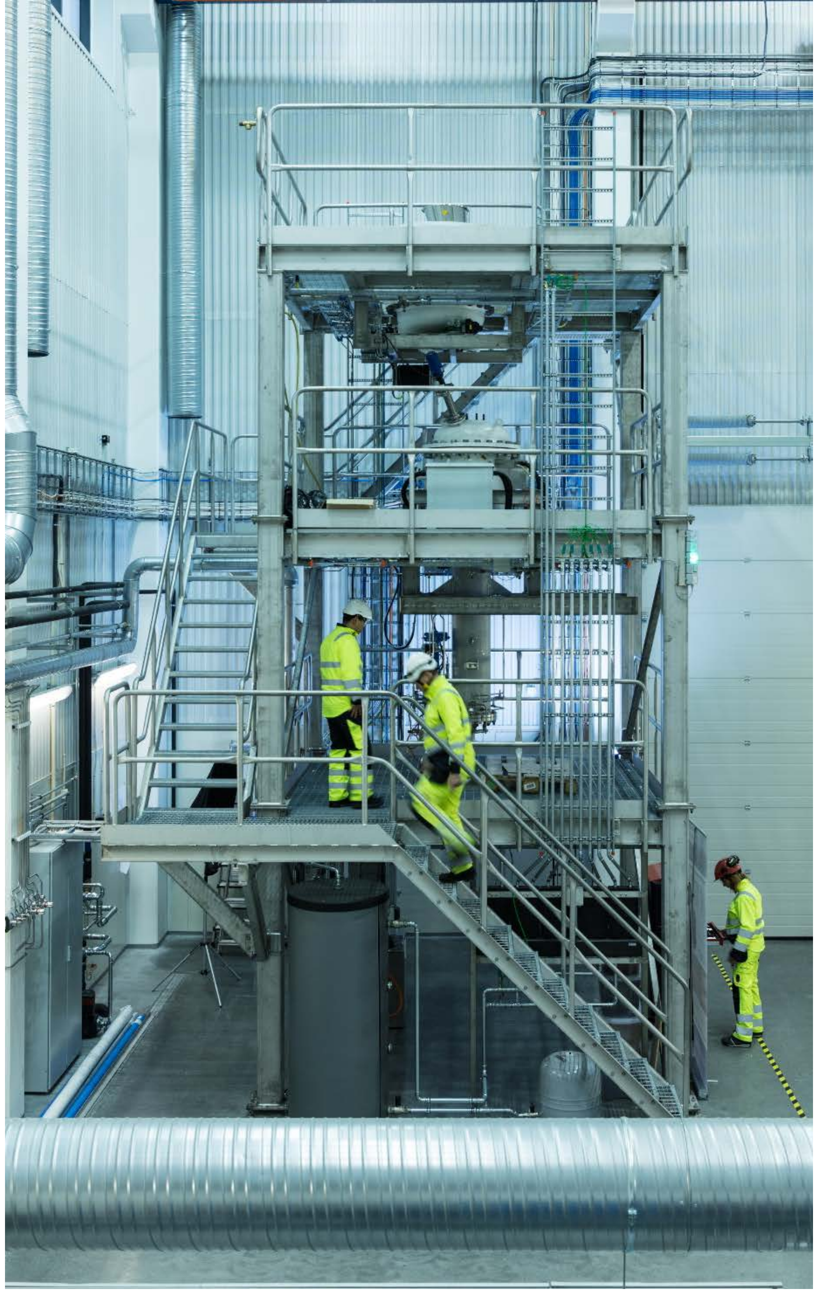
Current status of gasifier installation and the NorBioLab infrastructure project

- Mechanical installation is finalized
- Electrical installation is finalized
- Stress test, loss of power, loss of process air
- Water cooling system have been tested
- Control system is in final phase, testing
- Test of propane burner system
- Project is roughly 2 quarters behind original schedule



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Upcoming activity

- Pressure and leakage test; entire reactor system (8 bar, N2 atmosphere)
- Drying of reactor and testing of heating and cooling system (600 °C, pressure sweep from atmospheric to 8 bar, N2 atmosphere), disassembly and inspect
- Heating of reactor to max temperature (ca. 1400 °C, pressure sweep from atmospheric to 8 bar, N2 atmosphere), disassembly and inspect
- Atmospheric biomass combustion
- Atmospheric biomass gasification with oxygen enrichment

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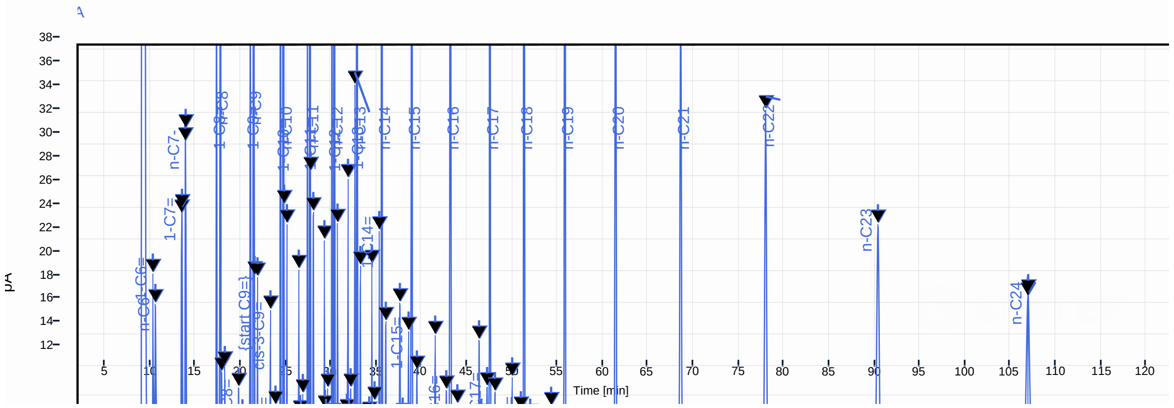
FT synthesis

- Catalyst screening completed, wax phase analyzed
- Effect on catalyst performance of varying conditions (syngas composition, temperature, pressure and residence time) in a lab scale fixed-bed reactor.
- Catalyst performance will be verified for selected conditions in in-house microchannel reactor, demonstrated to have beneficial properties for small scale GTL reactors.
- Kinetic model



Value chain analyses – Workshop, March 2017

Objectives

- Realistic view on the economy of biofuels production

  - Possibilities and limitations of the value chain model
  - Identify and quantify the technological risks and mitigation
  - Define plausible market and regulatory scenarios (30 years)

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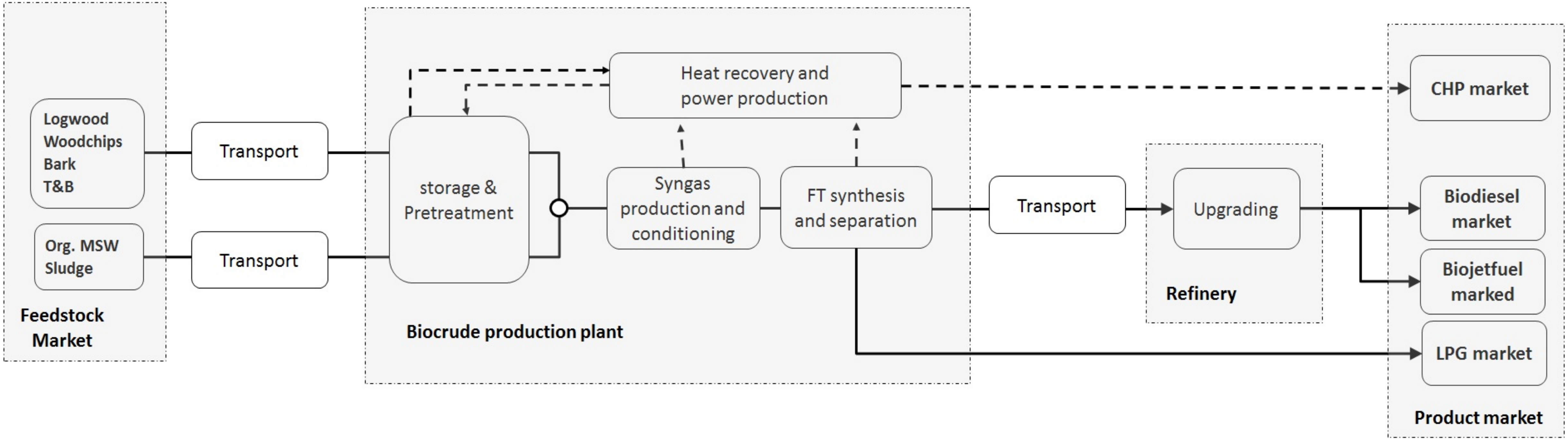
Value chain model



Time and **space** resolution

Parametric: Feedstock market and supply, process and costs of technology, biofuels/co-products market, financial conditions, incentives, policy frameworks

Constraints: available feedstock, operational limits of the technology

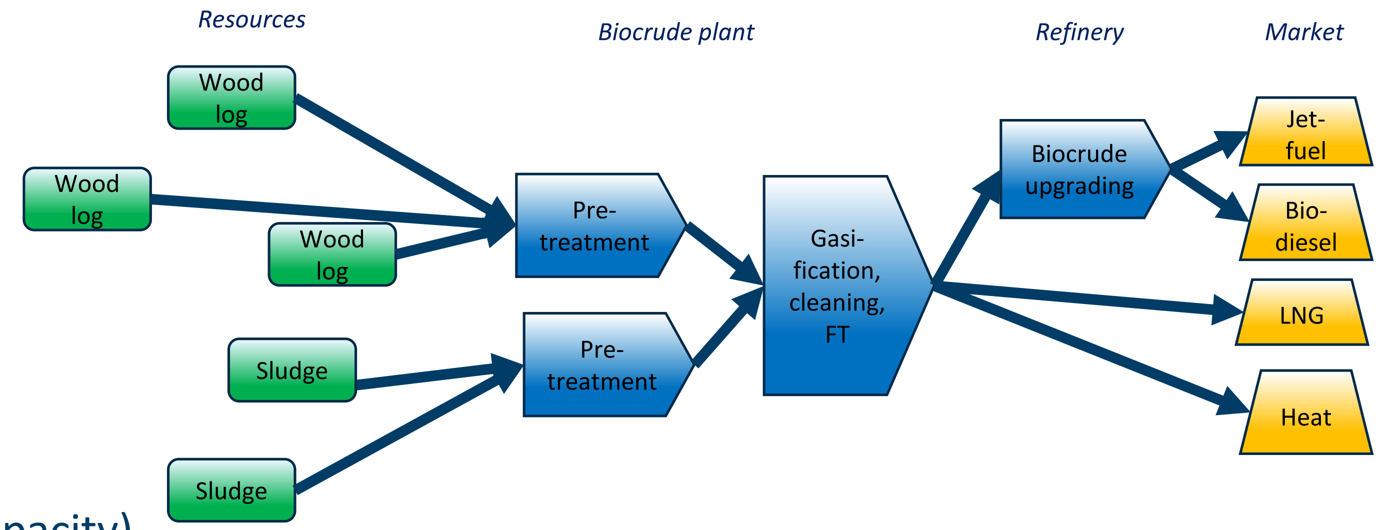
Summary and additions

- The single largest operational and technological risk is directly coupled to ash management when large fuel flexibility is desired
- Gas composition can be predicated well with thermodynamic equilibrium models
- Fluctuations in gas composition can be directly correlated to the fuel feeding system
- It has already been successfully demonstrated that fuels with high sulfur and alkali content can be gasified and the syngas cleaned
- Several technologies exists to remove particulates

Economic optimization model

Optimisation goal:

- Maximize net present value of the value chain
  - Investment costs
  - Plant operation costs
  - Transport costs
  - Purchase Costs
  - Income from sales



Decision variables:

- Technology investment (processes, capacity)
- Input of biomass (location, amount, mix)
- Market deliveries

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Optimisation model characteristics

- takes all parameters into account and calculate best solution for given scenario
- Can handle uncertainty systematically through stochastic programming
  - E.g. market prices and demand

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