MEMBER COUNTRY UPDATE: NORWAY

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SINTEF Energy Research

General update on biofuels in Norway

- The Norwegian blending obligation is currently **10 % biofuels**, of which **3.5% is advanced biofuels**. There are ambitions for increasing the biofuels share to 20% with 8 % advanced by 2020. The Government's ambition is to further increase the biofuels share to 40% by 2030.
- **For aviation, 1% biofuels share** is proposed from 2019. There is a major concern regarding the availability of aviation biofuels, especially in Europe.

- **Silva Green Fuel** has chosen Steeper Energy's HTL technology for their demonstration plant. The construction will be finished during 2019.
- **Biozin** (hydropyrolysis) is working on concept studies for their proposed demo plant
- **Gasification-related initiatives** are presented on separate slides

- Generally it is a concern how to comply with a very detailed European regulatory system and long-term regulatory uncertainties.

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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

- Status 2018: The feedstock quality is a challenge
- Developing a new reactor for pellets
- CHP is too expensive in Norway, due to low energy prices


Quantafuel
The biomass-to-liquid project
QUANTAFUEL

Currently plastic waste, biomass and non-captured natural gas are unused resources causing huge environmental and financial problems

Quantafuel's alternative hydrocarbon feedstock

Time-to-market

Plastic waste

- Global annual plastic production of >300 MT
- Only ~10 % reused
- ~60 % to landfills

Primary focus

Biomass

- US with ~100 million tonnes of wood waste
- All forestry with by-products
- Wood waste and return wood

Secondary focus

Natural gas

Market potential:

- Local diesel prod. from clean gas
- Associated gas (currently flared)
- Stranded gas

Not currently prioritised

Other hydro-carbon sources

- Crude oil
- Other oil products
- Coal
- Organic oil
- Food and other organic waste

Not prioritised

Source: BP, Eni, Wood MacKenzie, US DoE, Wikipedia

Quantafuel has initiated construction of first European plant and has an extensive project backlog

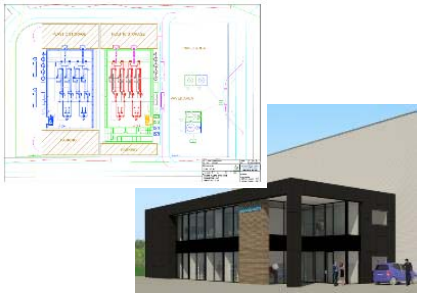
Attracting partners

Close cooperation with industry, investors & NGOs

- Investors in top-co, plants and R&D
- Industry with fuel players, recycling and others
- Strong support from gov. agencies, funds and NGOs [1)]

1st commercial plant

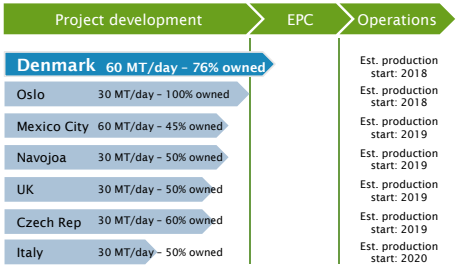
Skive officially opened and construction initiated



- Skive plant officially opened, with all agreements and approvals in place
- Equity investors in place, 60 % debt facility under way – in place this year
- Expected first oil Q3 2018

Market roll-out

Significant, firm project portfolio and demand



- 7 firm plant projects with 270 MT/day total capacity
- Company scaling delivery capabilities
- Next feedstock: bio jet fuel being developed with leading industry players

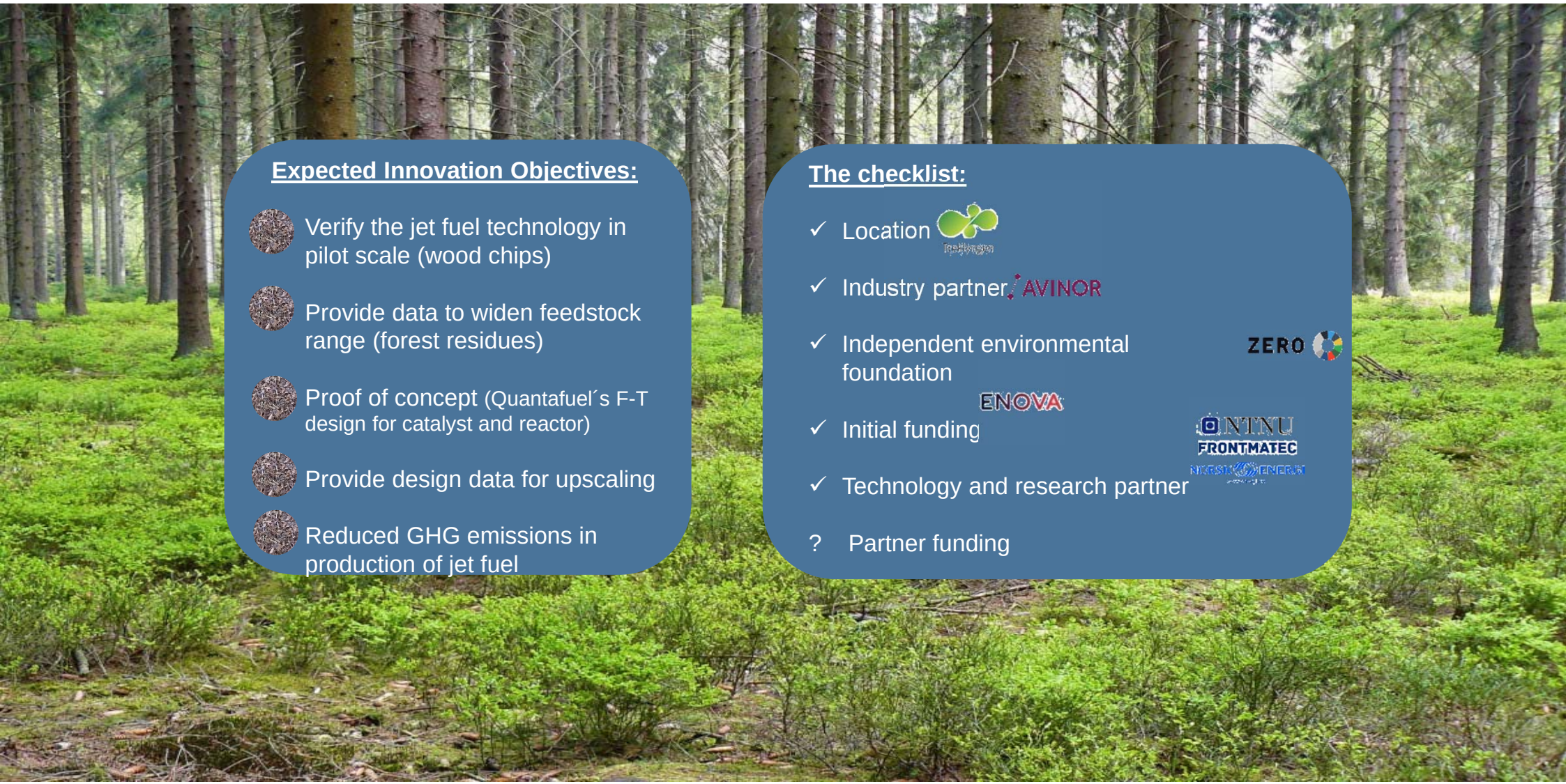
1) Including, but not limited to Skive kommune, Oslo kommune, Enova, Danmarks Grønne Investeringsfond, ZERO, WWF and more

Pilot scale demonstration and verification of Quantafuel's BtL technology

- Quantafuel has developed a proprietary BtL technology in lab scale and developed a system concept for a complete BtL process.
- The pilot plant will function as the first step (of two) in a pre-commercialization process. The verification of the technology and process will set the foundation for a demonstration scale, ie near-full-scale facilitiy.
- Preliminary capacity targets for full scale facilities are around 7 million liters of jet-fuel/year. The btL technology is planned further developed and commercialized in collaboration with leading aviation industry partners, as well as the norwegian scientific community.

QUANTAFUEL

Quantafuel´s Jet biofuel project



Expected Innovation Objectives:

- Verify the jet fuel technology in pilot scale (wood chips)
- Provide data to widen feedstock range (forest residues)
- Proof of concept (Quantafuel´s F-T design for catalyst and reactor)
- Provide design data for upscaling
- Reduced GHG emissions in production of jet fuel

The checklist:

- ✓ Location
- ✓ Industry partner AVINOR
- ✓ Independent environmental foundation ZERO
- ✓ Initial funding ENOVA
- ✓ Technology and research partner NTNU FRONTMATEC
- ? Partner funding

Introduction to the pilot project plan

- Basis:
  - In-house development of FT catalyst proven, in lab-scale, to have high selectivity and high yield within jet-fuel range
  - Lab-scale system verification
  - Process modelling and system configuration for full-scale plants
  - Potential found for high system efficiency, high selectivity and yield

- The jet-fuel pilot project
  - Verify Quantafuel's BtL technology in pilot scale
  - Produce jet fuel (20 l/h) from woody biomass

- Overall goals and results:
  - Verify sub-processes and overall process - proof-of-concept
  - Optimization of process parameters and process design aiming at:
    - Maximized yield and quality
    - Maximized system efficiency
  - Establish operational experience and operational data for all sub-systems and overall system under realistic, industrially relevant conditions
  - Establish design data for technology upscale to demonstration plant - close to full-scale commercial plant

- Expected Innovation Objectives:
  - Reduced greenhouse gas emissions in production and utilization of jet-fuel
  - Reduced production costs
  - Utilization of new energy carriers in jet-fuel production
  - New jobs in the forest and process industry


BioFuel
development
SUSTAINABLE ECONOMIC PRODUCTION OF
AVIATION BIOFUEL
FROM HOUSEHOLD WASTE
*
A CIRCULAR ECONOMY
*
COMBATING CLIMATE CHANGE BY REDUCING
THE GLOBAL GREENHOUSE GAS EMISSIONS

COMMERCIAL FACILITY A & B

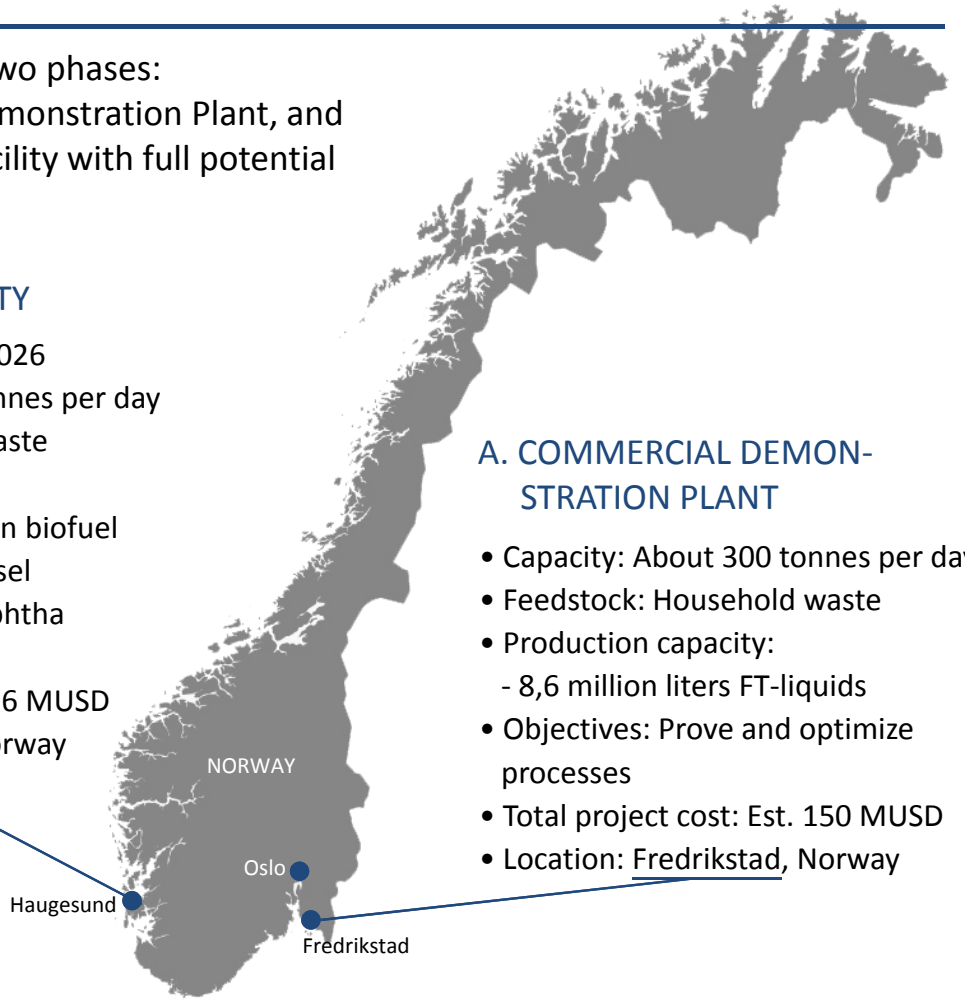
The project embraces two phases:

A. Commercial Demonstration Plant, and

B. Commercial Facility with full potential

B. COMMERCIAL FACILITY

- Operational start date: 2026
- Capacity: About 2000 tonnes per day
- Feedstock: Household waste
- Production capacity:
  - 50 million liters aviation biofuel
  - 10 million liters biodiesel
  - 12 million liters bionaphtha
  - 10.000 tonnes of LPG
- Total project cost: Est. 876 MUSD
- Location: Haugesund, Norway



A. COMMERCIAL DEMON-STRATION PLANT

- Capacity: About 300 tonnes per day
- Feedstock: Household waste
- Production capacity:
  - 8,6 million liters FT-liquids
- Objectives: Prove and optimize processes
- Total project cost: Est. 150 MUSD
- Location: Fredrikstad, Norway

BiOFuel development

PRODUCTION PROCESS

Proven technology with a high degree of innovation

1 Feed-stock
Pre-treated household waste (RDF, MSW) imported from UK

2 Gasifi-cation
Breakdown of waste into molecules under high temperatures

3 Syngas
A gas consisting of Carbon Monoxide/CO and Hydrogen/H2

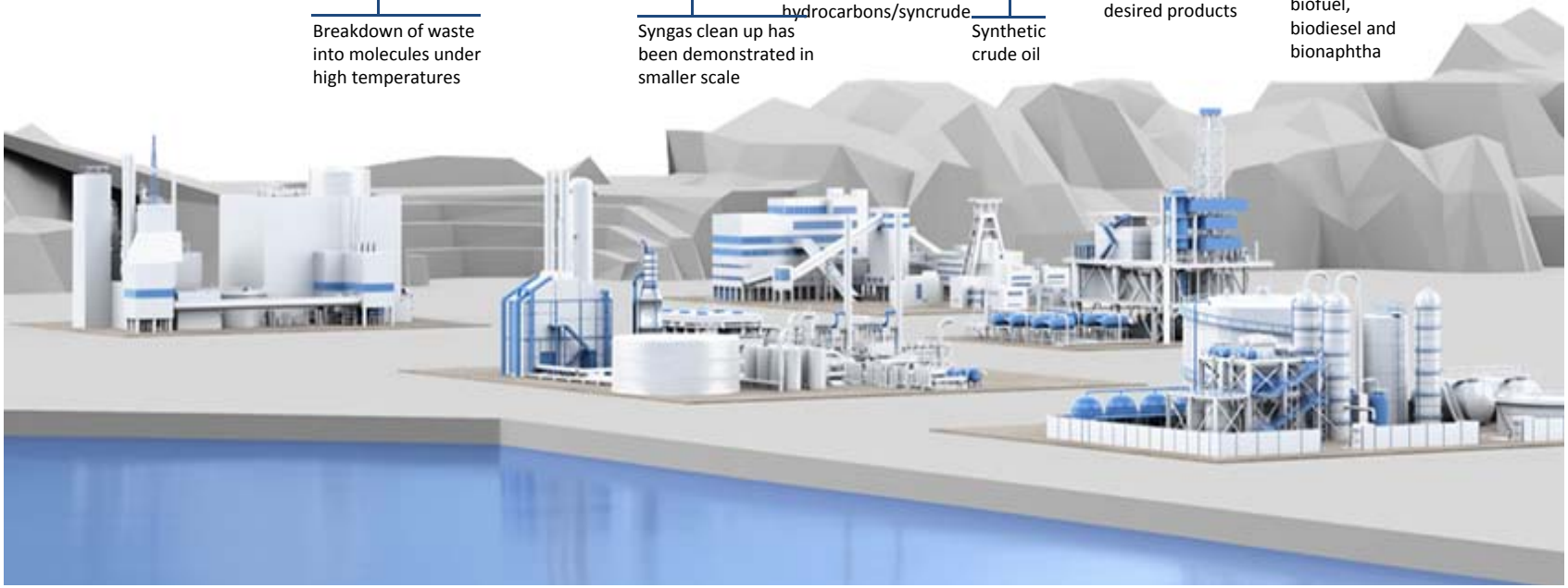
4 Purifi-cation
Syngas clean up has been demonstrated in smaller scale

5 FT-process
A chemical process converting syngas to liquid hydrocarbons/syncrude

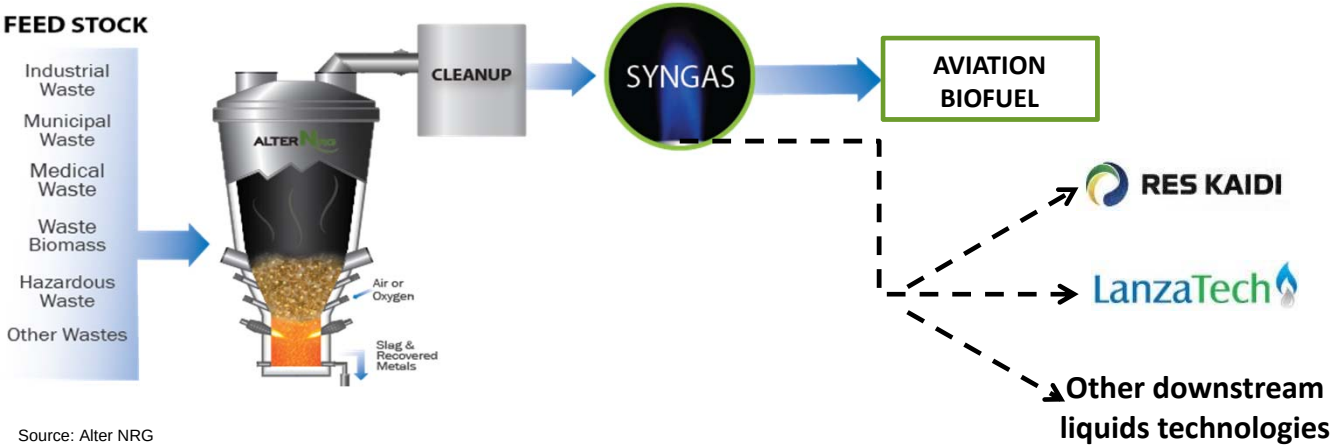
6 Syn-crude
Synthetic crude oil

7 Refining
A chemical process that converts the synthetic crude oil to desired products

8 Synthetic fuels
Aviation biofuel, biodiesel and bionaphtha



TECHNOLOGY PROVIDERS – WORLD LEADING



Source: Alter NRG

- **Alter NRG** is a Canadian company that develops and/or owns projects using ***Westinghouse Plasma Corporation (WPC)*** gasification technology
  - 30 years+ of research and development. USD 2 bn+ invested in projects/technology.

- **RES Kaidi** is a US renewable and alternative energy technology and engineering services company. The Fischer Tropsch technology of RES Kaidi generates valuable fuels, chemicals and other products starting with a variety of feedstocks.
  (Alter NRG and RES Kaidi are owned by Sunshine Kaidi New Energy Group)

ALTER NRG Westinghouse Westinghouse Plasma Corporation RES KAIDI KAIDI

BiOFuel development

KAIDI – A MAJOR CHINESE RENEWABLE ENERGY COMPANY

- Builds, owns and operates a portfolio of power plants
- Turns for more than USD 8 billion
- The company produces more than 1400 MW of electric power
- Are going to build more than 3000 MW for the next 5-7 year period in China
- EPC competence - has been responsible for more than 200 projects
- Has shown expertise in hydropower, wind power and concentrated solar energy
- Technologies in removing sulfur, wastewater treatment and gas purification
- Fischer-Tropsch technology (Iron and Cobalt Catalysts)


Biomass. Fujian, China


Biomass. Anhui, China


Biomass. Anhui, China


Biomass. Hubei, China


Water. Nanbuhe, China


Water. Yunnan, China


Wind. Pinglu, China


EPC. Mao Khe, V.Nam


EPC. Quảng Ninh, V. am


EPC. Hai Duong, V.N-


EPC. Henan, China

ALTER NRG

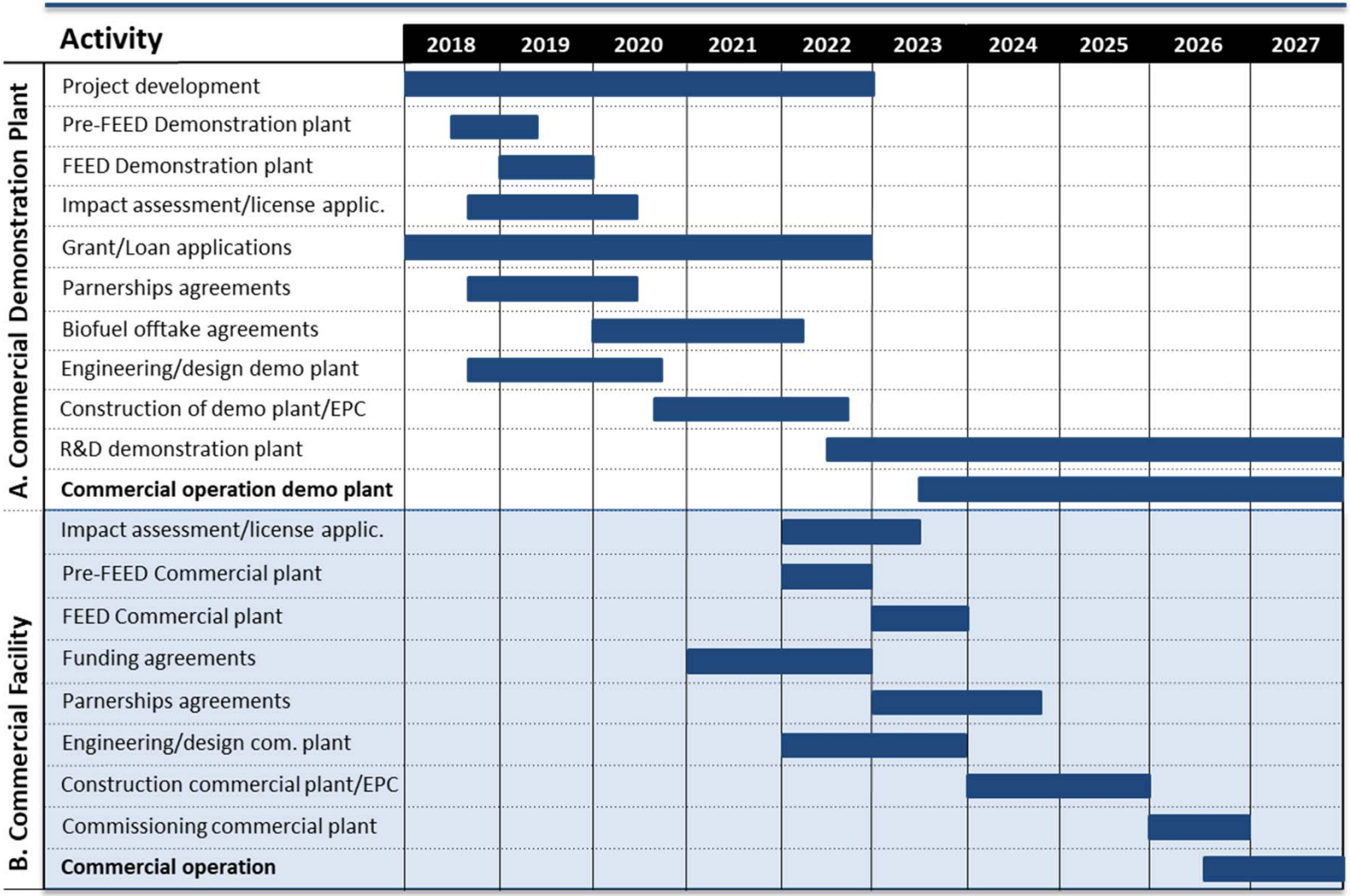
Westinghouse
Westinghouse Plasma Corporation

RES KAIDI

KAIDI

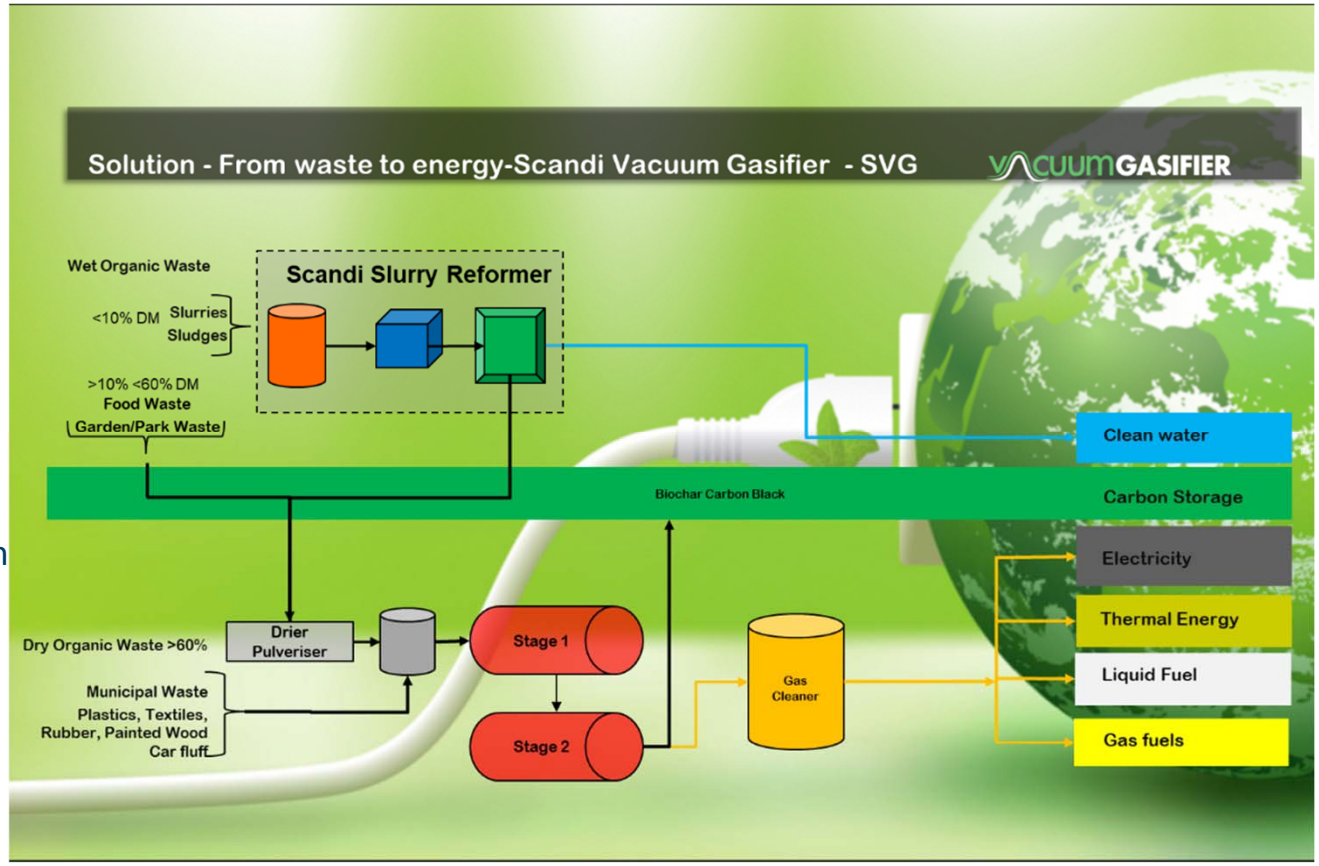
BiOFuel development

ESTIMATED TIME SCHEDULE



Scandi Energi

- 4 projects in Norway
- 3 projects (1 contract) in Turkey
- **Drier** supplied with residual heat from the gasifier for the drying of feedstock to a level of 85% dry matter.
- **Vacuum Gasification:** The first stage of gasification is under a partial vacuum to reduce the formation of tars and oils.
- **Steam Gasification** The biochar, oils/tar and gas are passed to the second gasifier where the injection of steam enhances the cracking of remaining hydro-carbons.
- **Gas Cleaning** cyclonic filter first to remove any ash and char particles before being quenched. The cooled gas is cleaned in a water scrubber and then dried through a series of venture filters that dry and remove any remaining particles.



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Scandi Energy – pilot test

- Test at the OSB Industry Park in Adana, Turkey
- Feedstock: 20% sewage sludge from a nearby waste water treatment plant and 80% RDF from the Adana Municipal waste plant.
- The gas produced had the following composition:

Element	Vol %
H_2	13.50
CO	18.20
CH_4	23.80
C_2H_4	12.50
CO_2	32.00
	100.00

← no steam under this pilot test

- The gas had a heating value of 20,310 kJ/m^3

Char composition:

Element	% w/w
Carbon	25.20
Hydrogen	0.50
Nitrogen	0.65
Sulphur	1.43
Ash/Inerts	74.10
Oxygen Calculated	- 1.50
	100.38

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GASIFICATION AT SINTEF







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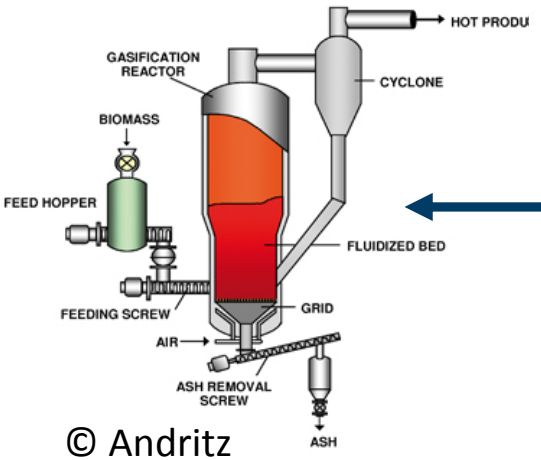
Visions

- To develop a new biomass gasification technology which can operate at peak cold gas efficiency without ash related issues
  - Feedstock should have an influence on overall process performance but not on operation

- To gain fundamental understanding about underlying phenomena which can enable this

The ash challenge



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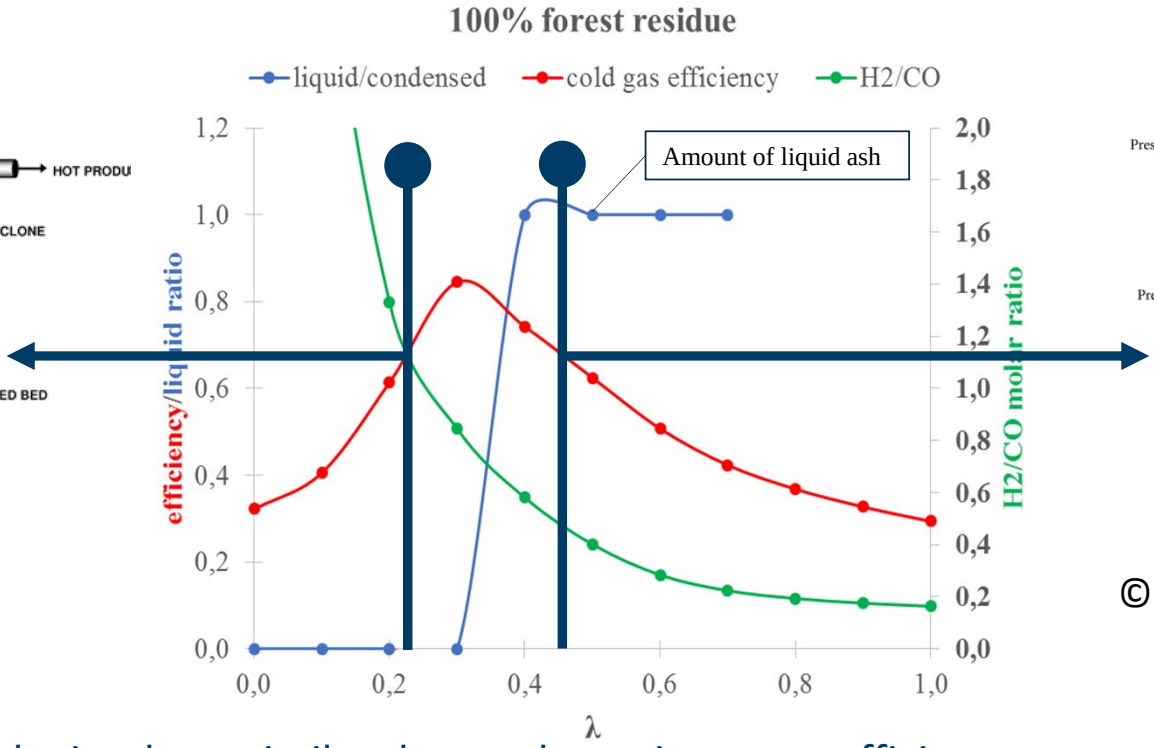

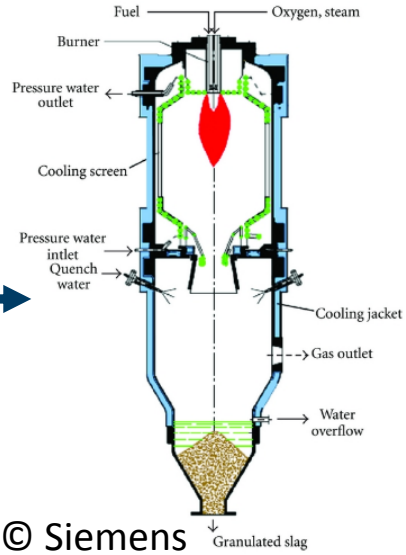

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- The two technologies have similar thermodynamic energy efficiency
- None of them can be operated at optimal energy efficiency, in the sticky slag window

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The projects

- GAFT - Gasification and FT-Synthesis of Lignocellulosic Feedstocks
  - Norwegian competence building project with industry
  - Experiments in, and modelling of the complete value chain, from biomass and waste to FT-products
  - Gasification and synthesis experiments
  - Value chain analysis
  - CFD modelling
  - 2015-2018, 20 MNOK

← Mid-term evaluation with good results

- GASPRO
  - Fundamental research project
  - Experiments and modelling of gasification processes
  - CFD modelling; from DNS to RANS
  - Supported by small and larger scale experiments
  - 2017-2022 16.5 MNOK

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The projects

- Bio4fuels
  - Norwegian centre
  - WP2.1 Gasification
  - 50% fundamental research (thermodynamic modelling and small scale experiments) , 50 % applied research with industrial relevance (gasification experiments)
  - Focus: ash
  - 2017-2024, 8 MNOK
- Flash
  - Predicting the FLow behavior of ASH mixtures for production of transport biofuels in the circular economy
  - Fundamental research, focus: ash
  - 2018-2021, 9.9 MNOK

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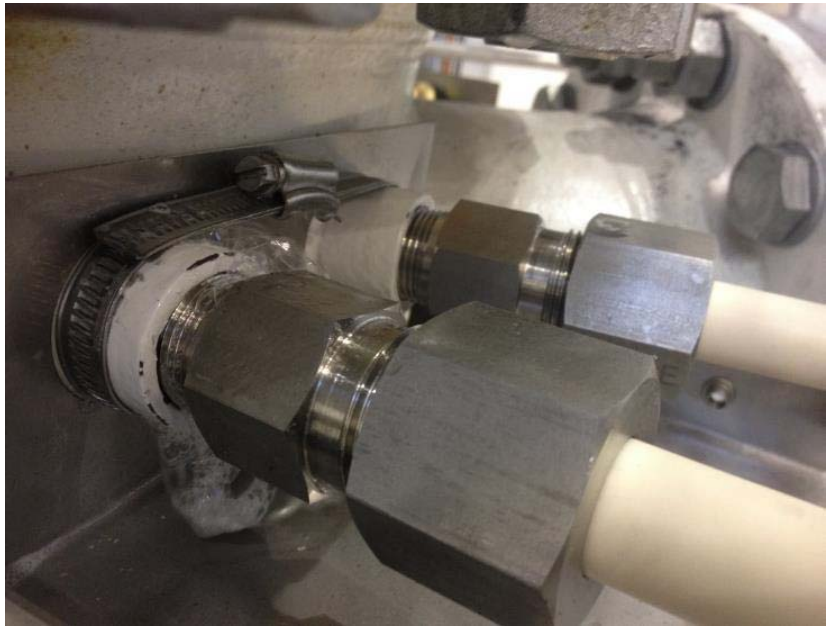
Current status of gasifier installation and the NorBioLab infrastructure project

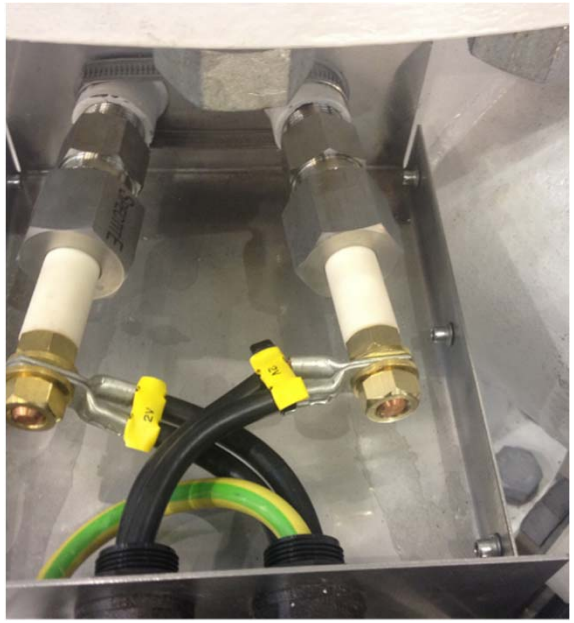
- Mechanical installation is finalized
- Electrical installation is finalized – remains final doc.
- Stress test, loss of power, loss of process air is finalized
- Water cooling system have been tested
- Onsite HSE – finalized
- Test of propane burner system - finalized
- Control system is finalized – remains final doc.
- Project is roughly 4 quarters behind original schedule

GAFT NorBioLab SINTEF

Ongoing activity

- Pressure and leakage test; entire reactor system (8 bar, N2 atmosphere)





Upcoming activity

- 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
  - Gasifier will be operated atmospherically at 15kW
  - Fuel: stem wood (campaign I), Ecopro residue (Campaign II)
  - Temperature will be roughly 1200 °C for stem wood
  - Temperature will be roughly 1000 °C for Ecopro residue

Summary of the research activities

- Experiments are focused on using waste and bi-products as fuel, not "conventional" biomass
- CFD-modelling covers DNS on a particle level to RANS on reactor level
- The thermodynamic modeling focuses on predicting viscosity/flow behavior
- Fundamental experiments to support the modeling activities

Technology for a better society