Silva Green Fuel

SGF – wood based bio-crude®

KLAUS SCHÖFFEL
CTO - SGF

Silva Green Fuel

- 100% subsidiary of Statkraft AS
- Owns and operates a demonstration plant at Tofte (Norway), with the aim of demonstrating HTL technology
- Development of a full-scale commercial plant is taking place in parallel
- 40 employees

Our Ambition:
Silva Green Fuel to become a leading producer of bio-crude oil based on HTL technology

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Key milestones since established in 2015

2015

- Silva Green Fuel established as a JV between Statkraft and Södra, and Statkraft acquired the Tofte industrial site from Södra

2017

- HTL technology selected, and investment decision to build a demo-plant to reduce the risk of scaling up from pilot plant to commercial scale

2019

- Construction of demo-plant at Tofte industrial site started

2021

- Demo-plant completed, **producing its first quantity of oil** December 9th 2021

2022

- 60-hour continuous run achieved
- DG1 full-scale plant

2023/24

- **7-day continuous runs achieved**
- +1,500 hours of oil production to date
- EU Innovation application submitted

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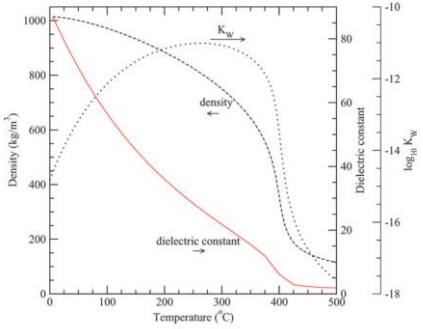
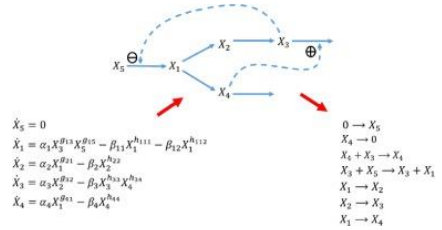
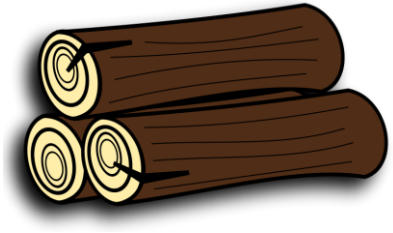
HTL: Challening the unkown





- T ≈ 373ºC
- P > 321 bar
- Capacity: 30 bbl/d



C, H, O

C, H

Never done before on that scale !

-H_2O

-CO_2

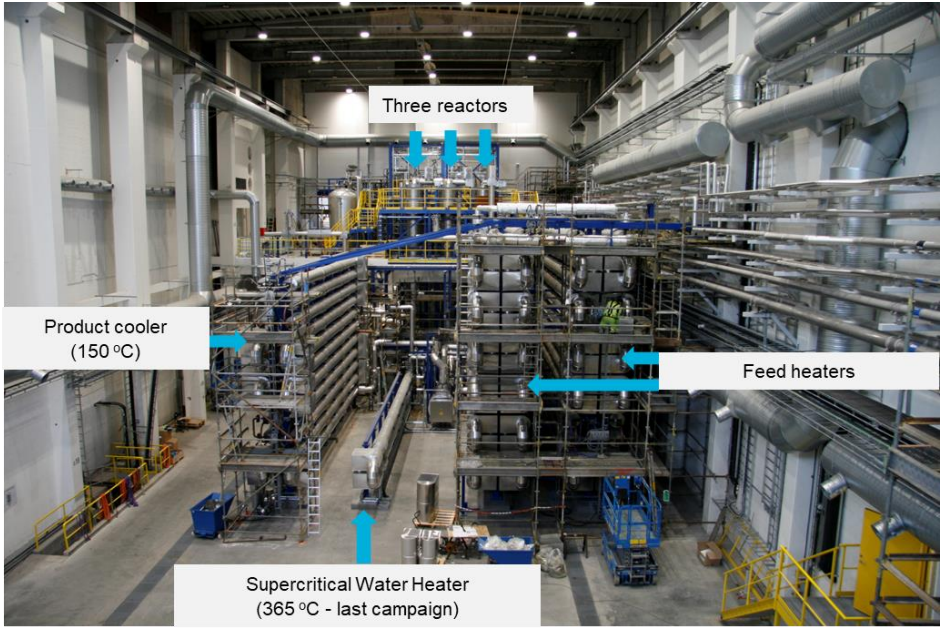
HTL-demo Tofte: world-wide 1st of its kind (5 t/d)

Technology provider`s pilot plant in Aalborg

PURPOSE

- De-risking
- Testing core technology
- Basis for Scale up
- System integration
- Selection of materials
- Handling of side-streams and water

Scale-up: X 100



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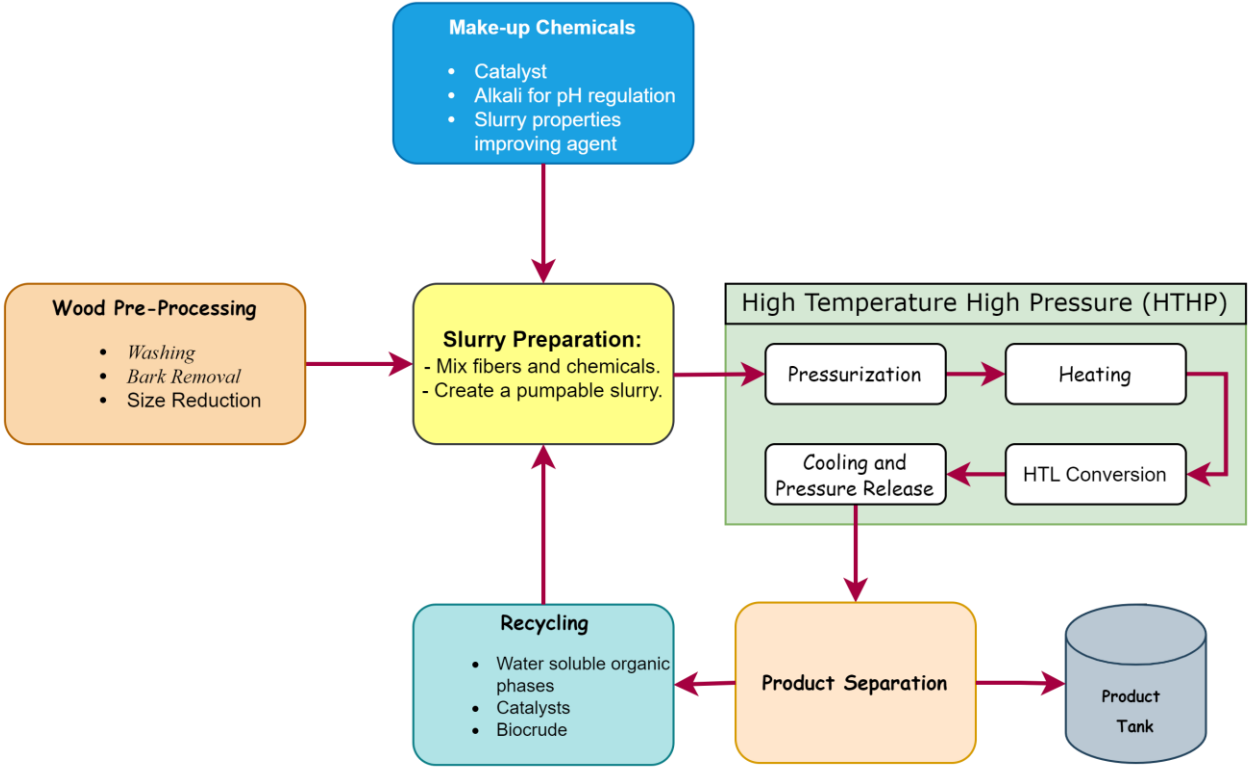
HTL at SGF Demo plant in Tofte



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Demo-plant set-up: mini “full-scale” plant

- The demo-plant is set-up like a “full-scale” operation including all relevant side streams and processes you would have in a full-scale production, including a control room providing 24/7 observation and surveillance

Key operational KPIs[1)]:

Oil produced:	• Net quantity of >119 tonnes of bio-crude oil
Number of runs	• 58 test campaigns
Total hours in production	• >1,550 oil-producing hours
Longest runs	• 7 days

The world’s first continuous biofuel demo-production using HTL technology

1) KPIs as of June 2024

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Experiences Gained Operating the Demo Plant

Positive Findings
Proof of wood conversion chips to high quality oil
Able to tune oil quality by operating parameters
Demonstration in operational environment (TRL7) of several specially designed systems

Major Process related Set-backs
Corrosion findings
Fouling of high temp conversion equipment

Technical issues solved
Leakages in high pressure seals
High pressure slurry pump
Pumping of main and intermediate products
Interphase detection in oil/water separators
Tuning of thermal oxidizer

Other learnings
HSE activities for a HTHP chemical plant
Operator training of 5 shifts
Fixation of operating parameters during test campaigns

Major Process Related Setbacks (I): Fouling

C39: Severe Fouling

- Fouling in reaction systems limited operational hours & consistent oil quality
- SGF solved this by extensive testing & development

K56: Stable Heat transfer

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Major Process Related Setbacks (II) - Corrosion

- Pipe Rupture in in HP feedheater system
- Significant material loss through Corrosion in first part of FH
- Erosion-Corrosion mechanism: Solid particles (biomass, coke, salts), corrodents (acetates, formats, CO2, chlorides..)
- Construction Material P91 steel not appliable
- Critical part (first 65 meters) now replaced with resistant material
- First campaign with new HX system successful (no corrosion detected)

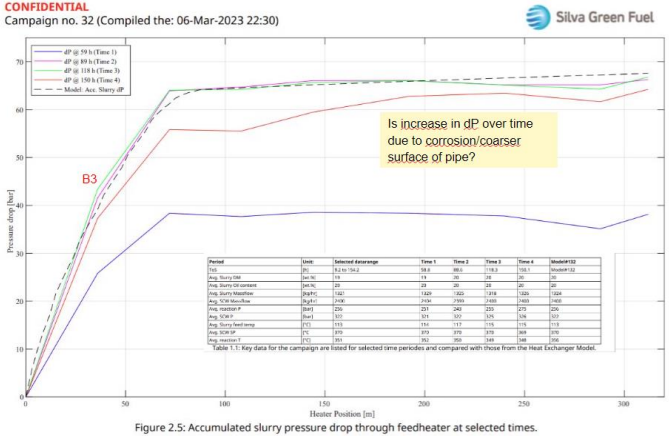

Figure 2.5: Accumulated slurry pressure drop through feedheater at selected times.

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SGF Demo Plant at a Glance

- SGF is steadily solving the issues by dedicated development
- Next milestone: 1000h campaign

Demo Plant Figures
Location
3482 Tofte, Norway
Operators at Demo:
25 (5 shifts)
Total Campaigns:
57
Longest Campaign
1 week (172h)
Acc. Hours on Slurry:
1550h
Produced Oil (netto)
119 ton

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Upgrading of HTL biocrude

HTL-Process → Oil/Water Separation → De-mineralization → Hydro-treatment

Demo

In collaboration with external partner

Analysis	Unit	P0254 washed (biocrude Nov 2020)
Water	wt%	0.65
Density @15°C from calculation	kg/m3	1083
Density @70°C from measurement		1046
Kinematic Viscosity @ 20°C	cSt	
Kinematic Viscosity @ 40°C		
Kinematic Viscosity @ 50°C		3740
Kinematic Viscosity @ 70°C		
Kinematic Viscosity @ 100°C		70
Carbon	wt% (wet basis	79.9
Hydrogen	wt% (wet basis	8.66
Oxygen	wt% (wet basis	11.36
Nitrogen	wt% (wet basis	0.0905
Sulfur	wt% (wet basis	0.0147
Metals	wt% (wet basis	0.0317
Total CHONS + metals	wt% (wet basis	100.1
Distillation yields		
IP-180°C (aqueous phase)	wt%	1.0
IP-180°C (organic phase)	wt%	0.9
180-350°C	wt%	29.2
350°C+	wt%	68.9
NMR 13C		
Carboxyl or carbonyl bond	wt%	3
Aromatic C-O bond	wt%	7
Aromatic C-C bond	wt%	24
Aromatic C-H bond	wt%	15
Methoxyl-Aromatic bond	wt%	0
Aliphatic C-C bond	wt%	51

Continuous demineralization process verified on Lab-scale & Pilot-scale

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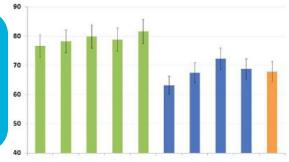
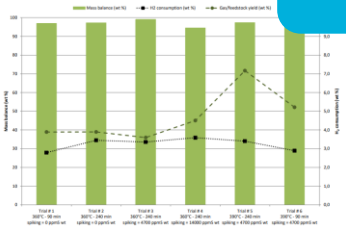
Upgrading: Development Method

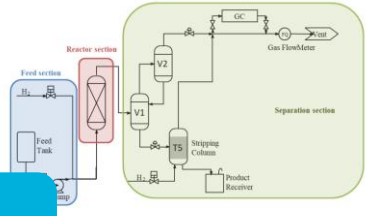
Screening of commercial HT catalysts (Batch)



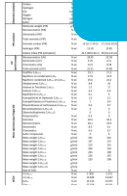
Optimizing process conditions (Batch)



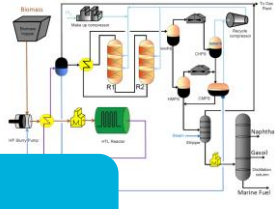
Continuous testing (FB-pilot)



Fractionation and Analysis



TEA



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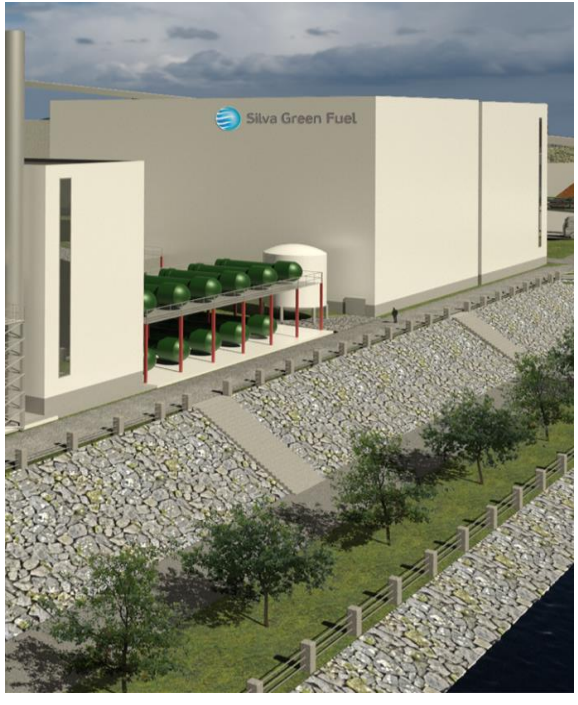
Promising results from continuous pilot-scale upgrading

- 1200 hrs cont operation (HTL-oil)
- Wt% O: < 0.1 % (11.4)
- D15 = 0.9001 kg/l (1.083)
- H/C = 1.62 (1.30)

Boiling Range [ºC]	Cut	Wt%
C5-180	Naphtha	15
180-350	Middle Distillate	57
350-540	Vacuum Gas Oil	23
540+	Vacuum Residue	5

SGF – Strong business case for first commercial plant

Status on development	• PID expected in Q1 2025, followed by FID in Q1 2026 • Full-scale plant completed by YE 2028
Site access	• Zoning plan by Asker municipality
Water and energy requirement	• Annual water consumption of 8.2 million m^3 • Annual electricity consumption of 235 GWh
Feedstock required and logistics	• Yearly consumption of ~630k m^3 fub
Oil produced (p.a.)	• Yearly production of 100k tonnes
By-products produced	• 90k tonnes of biogenic CO2 • 5k tonnes hydrogen
Land/ size required	• Full-scale plant of 60k sqm – all available at Tofte



Thank you for your attention !

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