Strategies for production of jet-biofuels via EF gasification and FT Synthesis

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Bioenergy group at SINTEF Energy Research

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Local biomass

Wood logs

Wood chips, bark

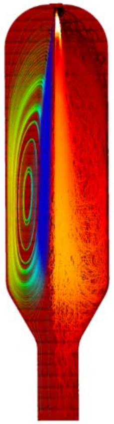
Organic MSW

Sludge

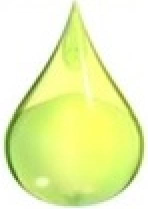
Digestates

Decentralized conversion to biocrude

$$y^{G}_{H_2O} < 10\%$$
$$\delta^{G}_{p} < 0.5\ \mathrm{mm}$$



Centralized upgrading liquid fuels in existing oil refinery

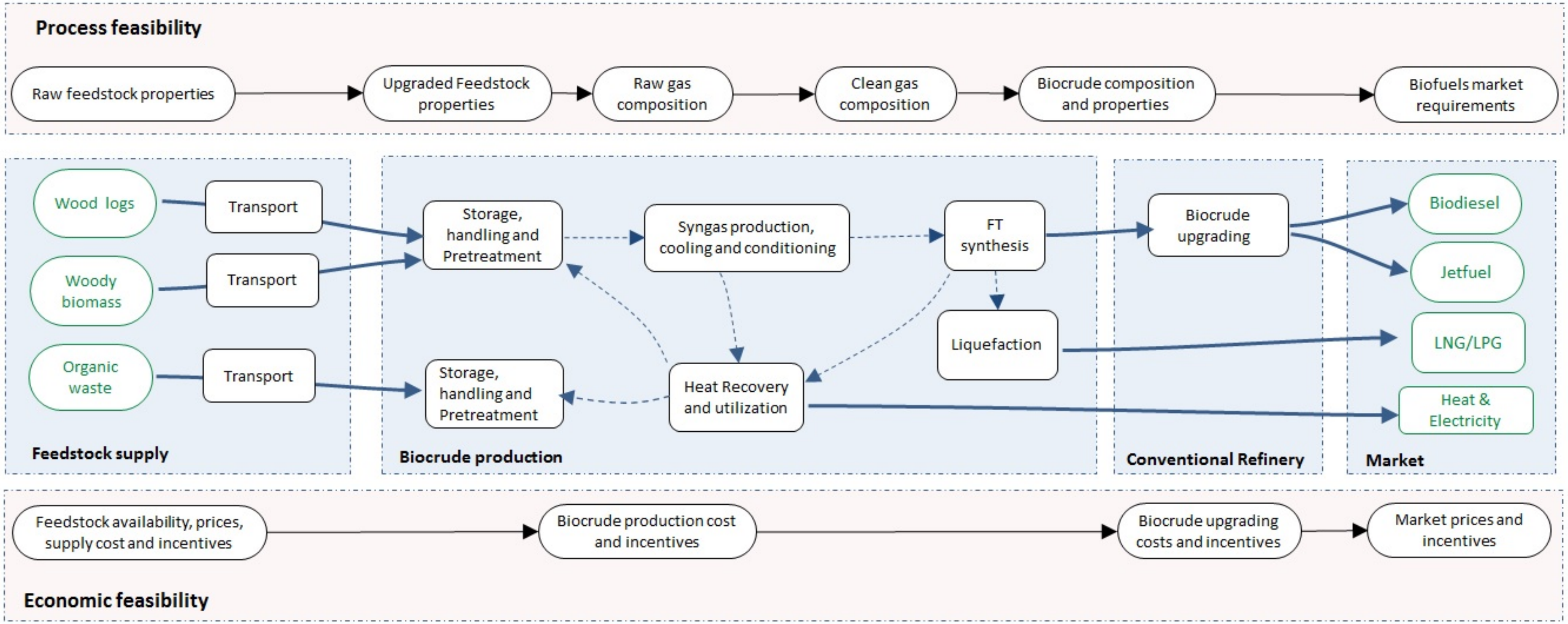


Norwegian biomass potential

Feedstock	Feedstock kTons/year	Jet biofuel GWh/year	Jet biofuel Mill. liters / year
Forest wood for logs and chips	1380	5175	542
Forest residues (thinnings, top and branches)	960	3600	377
Wood from cultivated landscape	210	862,5	90
Straw and cereal residues	225	1035	108
Sludge	4800	2925	306
MSW	1800	1120	117

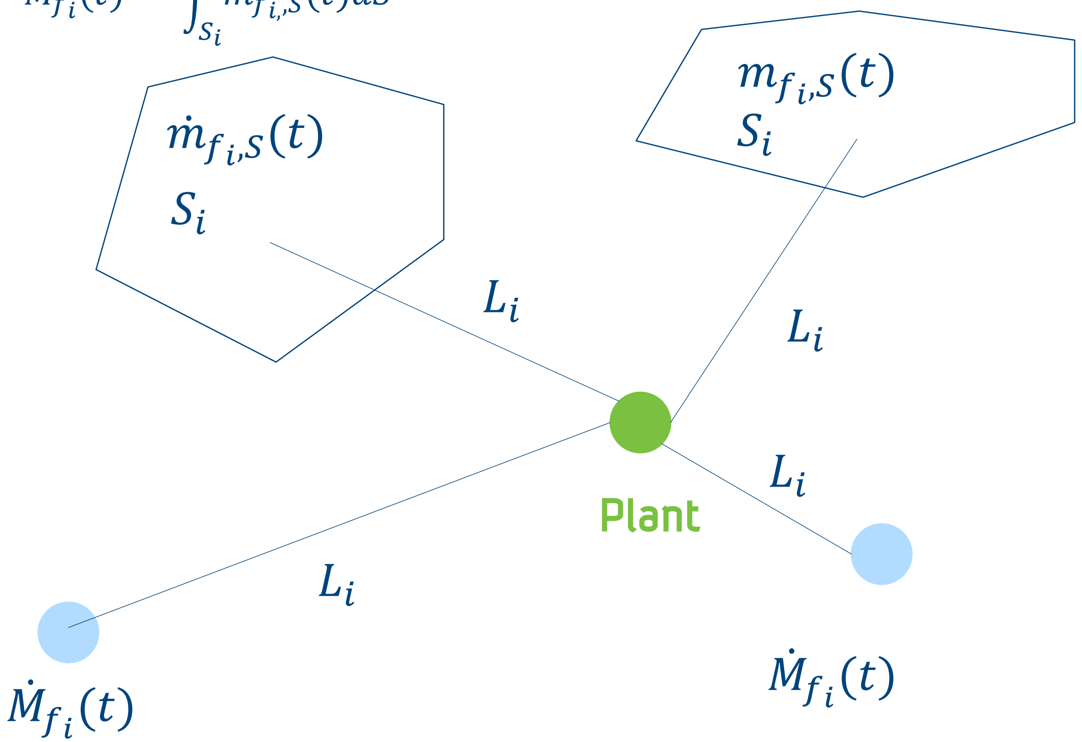
1.5 Millions liters / year Aviation Fuel
300% of total Aviation fuel in Norway
5% total consumption Aviation fuel in Europe

Value-Chain Model



Feedstock Supply

$$\dot{M}_{f_i}(t) = \int_{S_i} \dot{m}_{f_{i},S}(t)\,dS$$



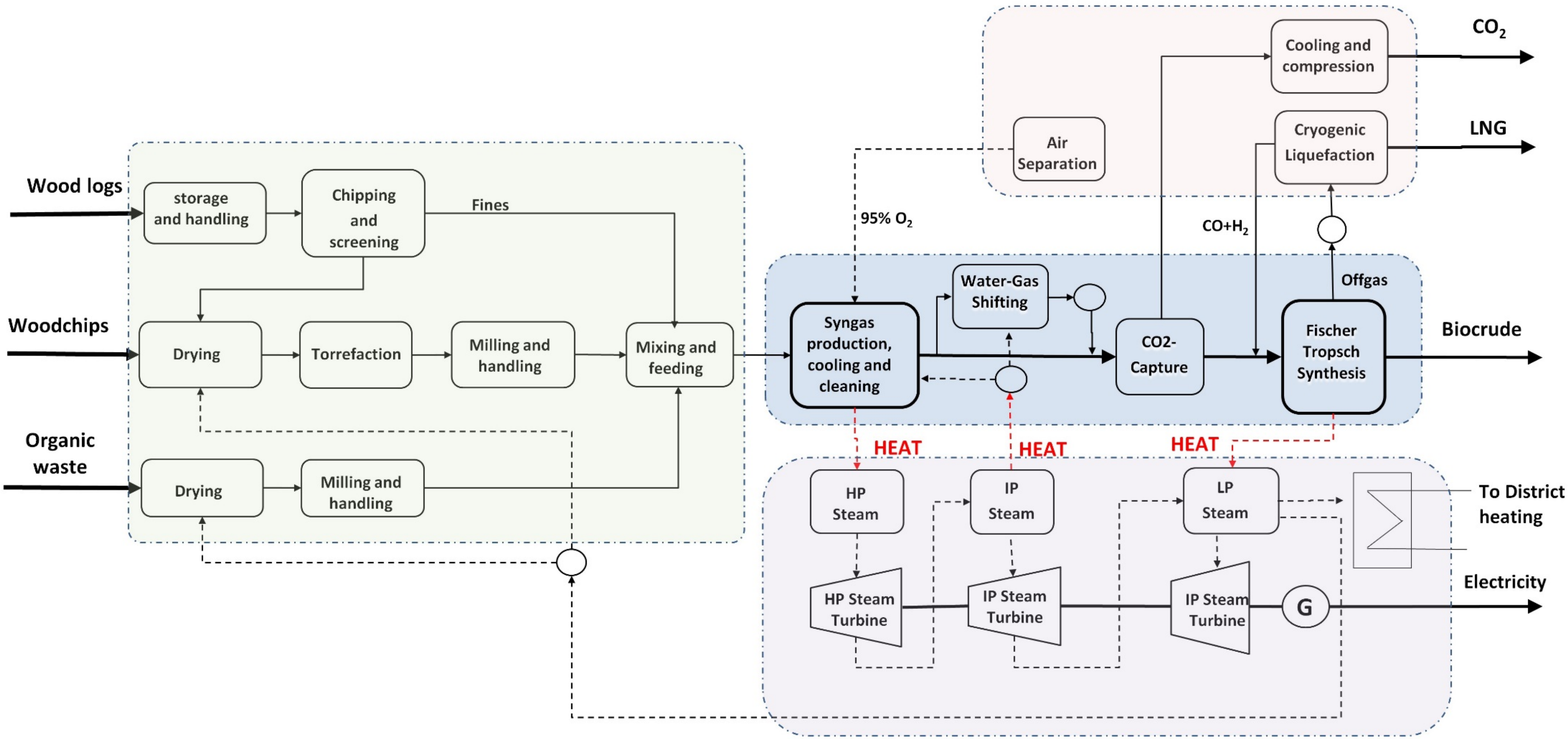
Feedstock supply cost

$$C_{f_i,T} = \left(M_{f_i,T}/\rho_i\right)\left[c_{pr,f_i} + c_{tr,f_i} + c_{tr,L_i}L_i\right] \qquad M_{f_i,T} = \int_T \dot{M}_{f_i}(t)\,dt$$

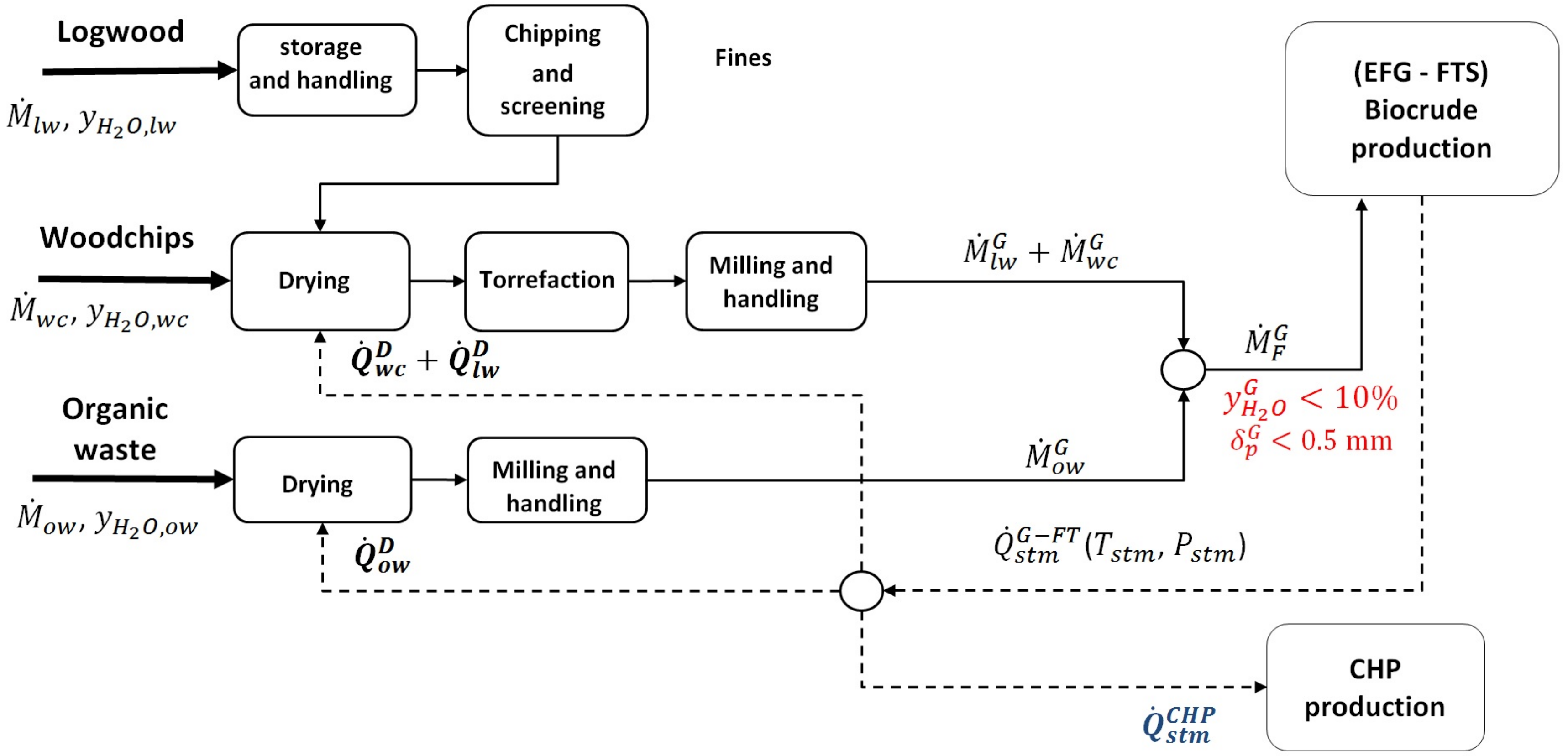
Feedstock Supply

Input fuel	Birch, raw	Birch, torrefied (at 275 °C for 30 min)	Digested sludge
Volatiles (% wt. dry)	89.43	77.14	48.9
Fixed carbon (% wt. dry)	10.35	22.64	9.3
Ash (% wt. dry)	0.22	0.22	41.8
LHV (MJ/kg dry)	18.42	19.29	9.3
C (% w/w)	48.62	55.55	31.6
H (% w/w)	6.34	5.77	3.66
O (% w/w)	44.9	38.5	19.1
N (% w/w)	0.09	0.13	3.88
S (% w/w)	0.05	0.05	-*

Bio-crude production (co-processing & co-production)



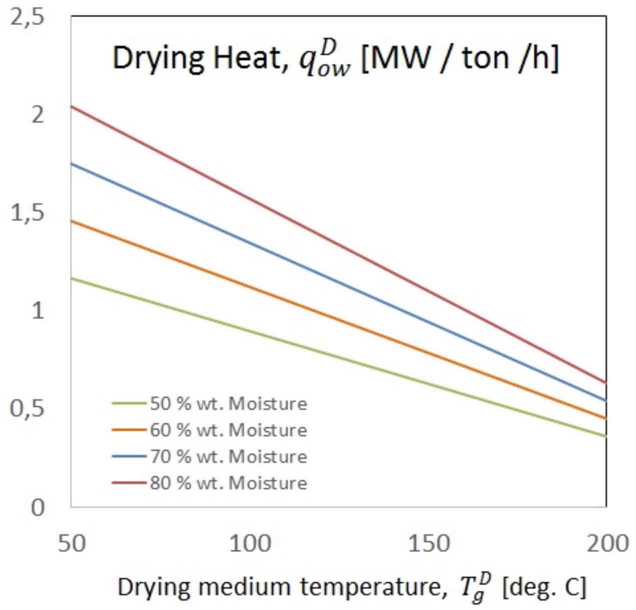
Bio-crude production (pretreatment)

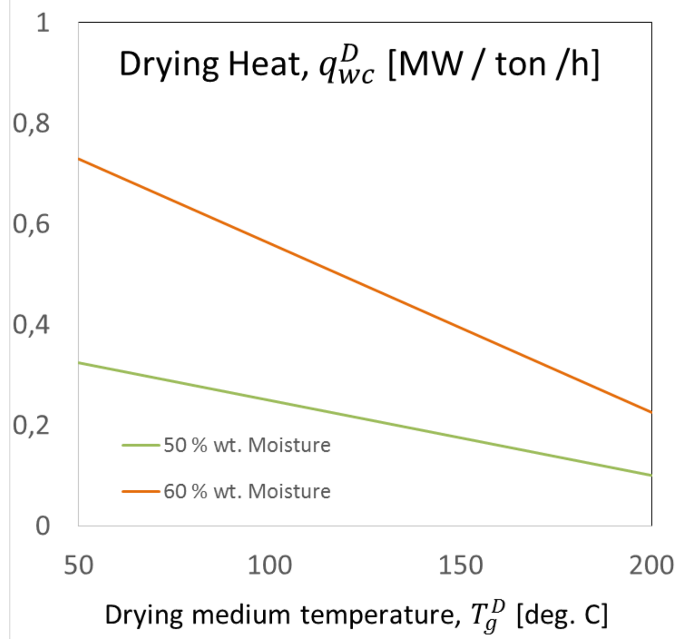


Bio-crude production (pretreatment)

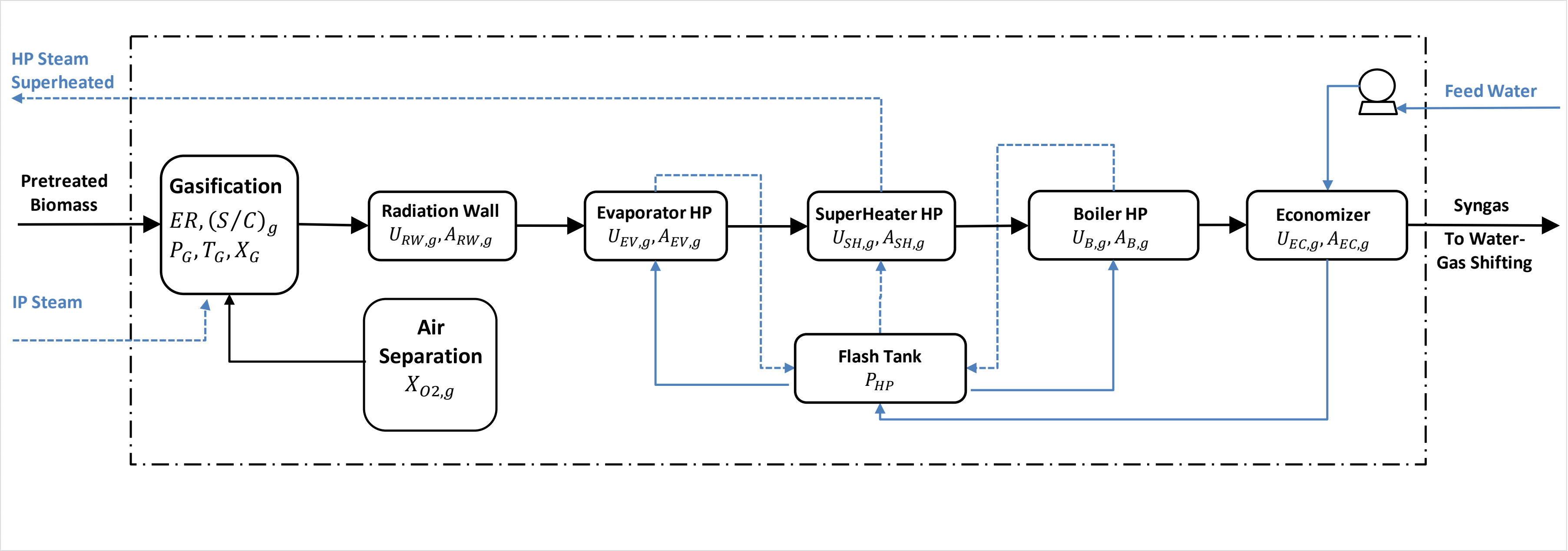
Dryer Technology	Band	Rotary	Steam Rotary	Fluidized Bed	Pneumat Steam
Feed	Sawdust, shavings, woodchips	Sawdust, bark, woodchips	Sawdust, woodchips	Woodchips	Sawdust bark, fore residues
Feed Flow (ton/h dry)	8-9	6-7	5-6	9	25
Inlet moisture (% wt.)	50-60	50-60	50-60	50-60	50-60
Outlet moisture (% wt.)	10-15	10-15	10-15	10-15	10-15
Drying medium	air, flue gas (90-120 C)	air, flue gas (250-400 C)	steam 6-10 bar	steam 3-26 bar	steam 7-26 bar
Drying capacity (tons H_2O / h)	10	7-8	6-7	5-40	25
Energy consumed (GJ/ton H_2O)	4-5	4-5	3-4		2-3

Bio-crude production (pretreatment)





Gasification and Syngas Cooling



Fuel Power = **150 MW**

Pressure = **25 bar-g** (sensitivity analysis)

O2-enrichment = **95%**

Range of Equivalence Ratio = **0.2-0.4**

Outlet Syngas Temperature:

- Lower limit **1300 C** (ash melting point)
- Upper limit **1600 C** (constraints in materials)

Syngas Temperature to WGS = **160 deg. C**

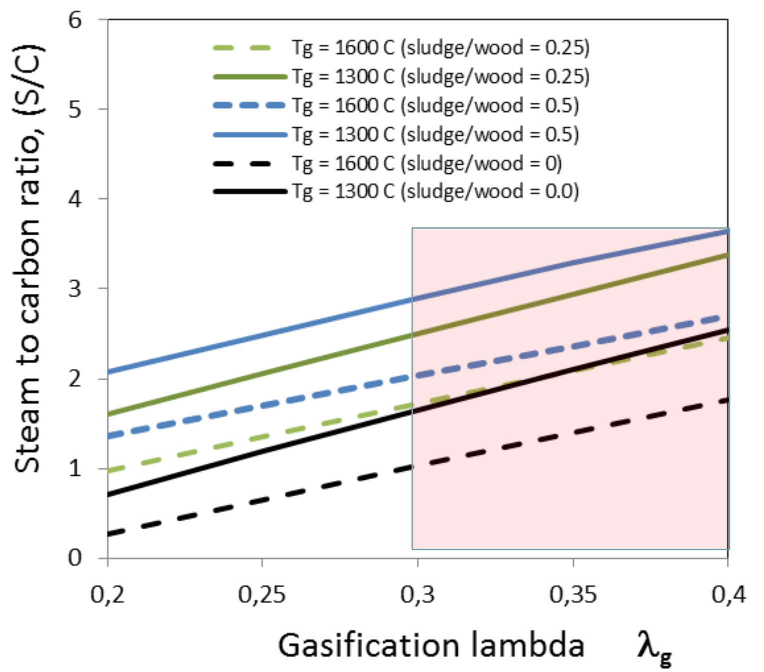
Feed water temperature = **105 deg. C**

HP Superheated Steam: **80 bar-g , 550 deg. C**

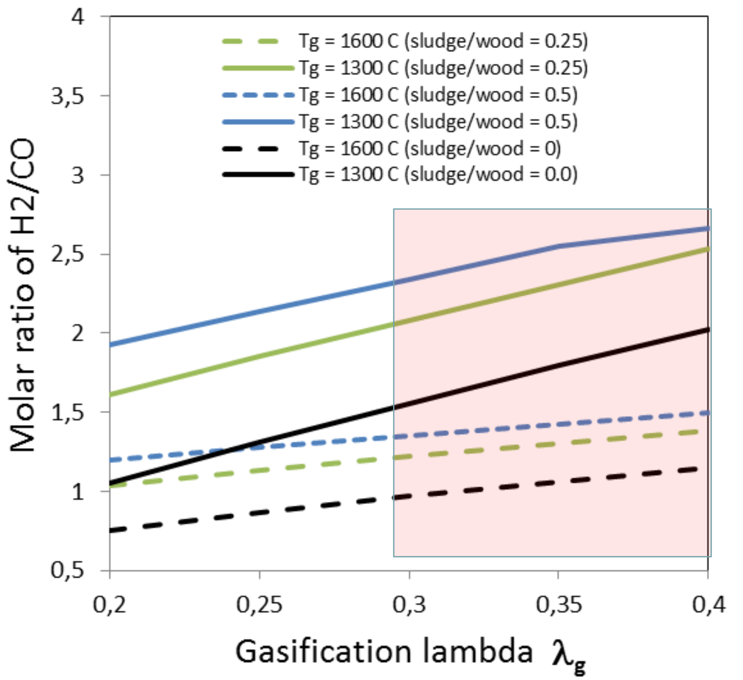
Gasification and Syngas Quench

EF Gasification - Operational Limits

Steam / Carbon

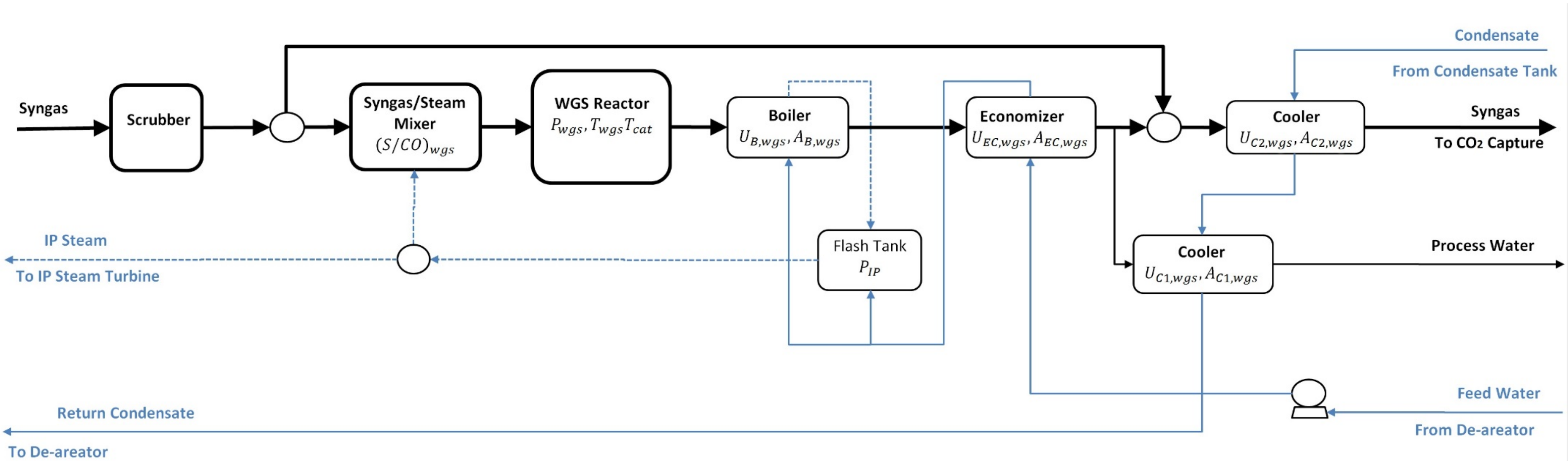


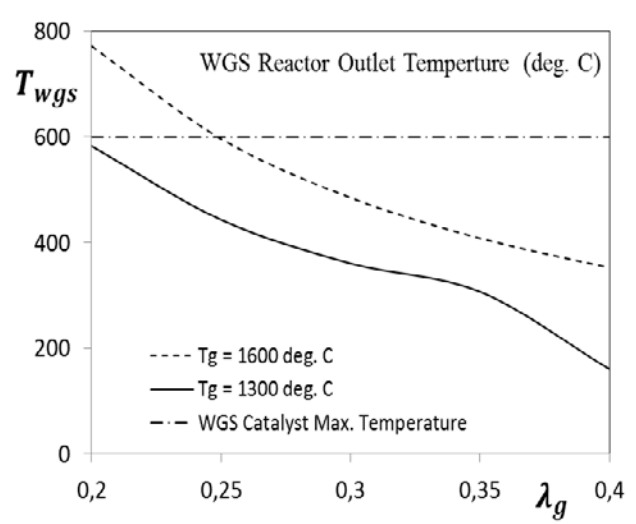
H2 / CO



- ✓ Temperature limits: 1300 – 1600 deg. C

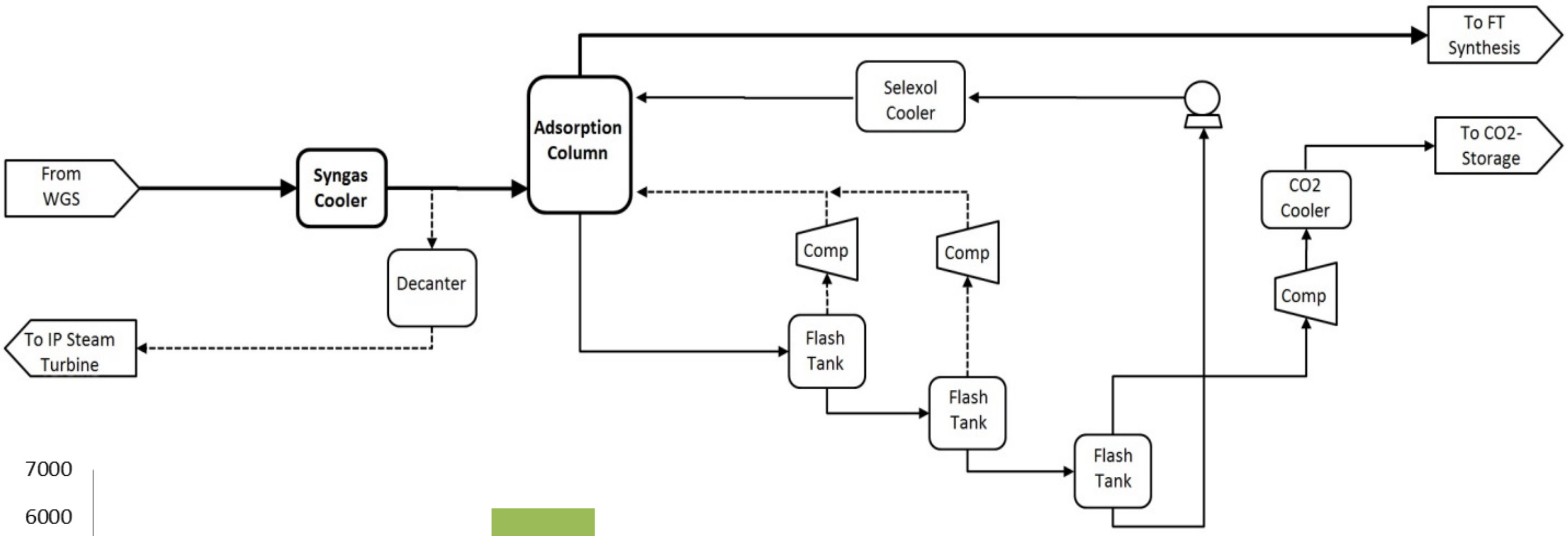
Water-Gas Shifting (WGS)

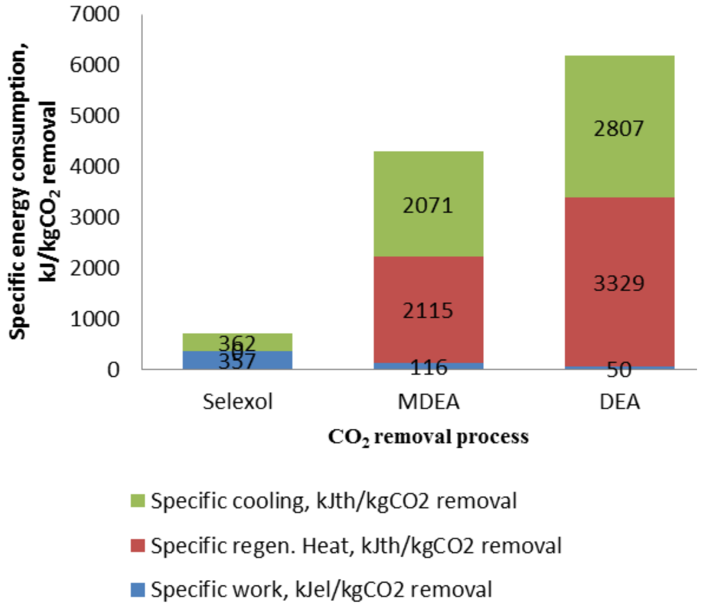




Adiabatic WGS
Maximum Catalysts Temperature = **600 deg. C**
S / CO = **1.2**
IP Steam Generation (**saturated, P=25 bar-g**)
Inlet Syngas Temperature to CO2-Capture = **95 deg. C**

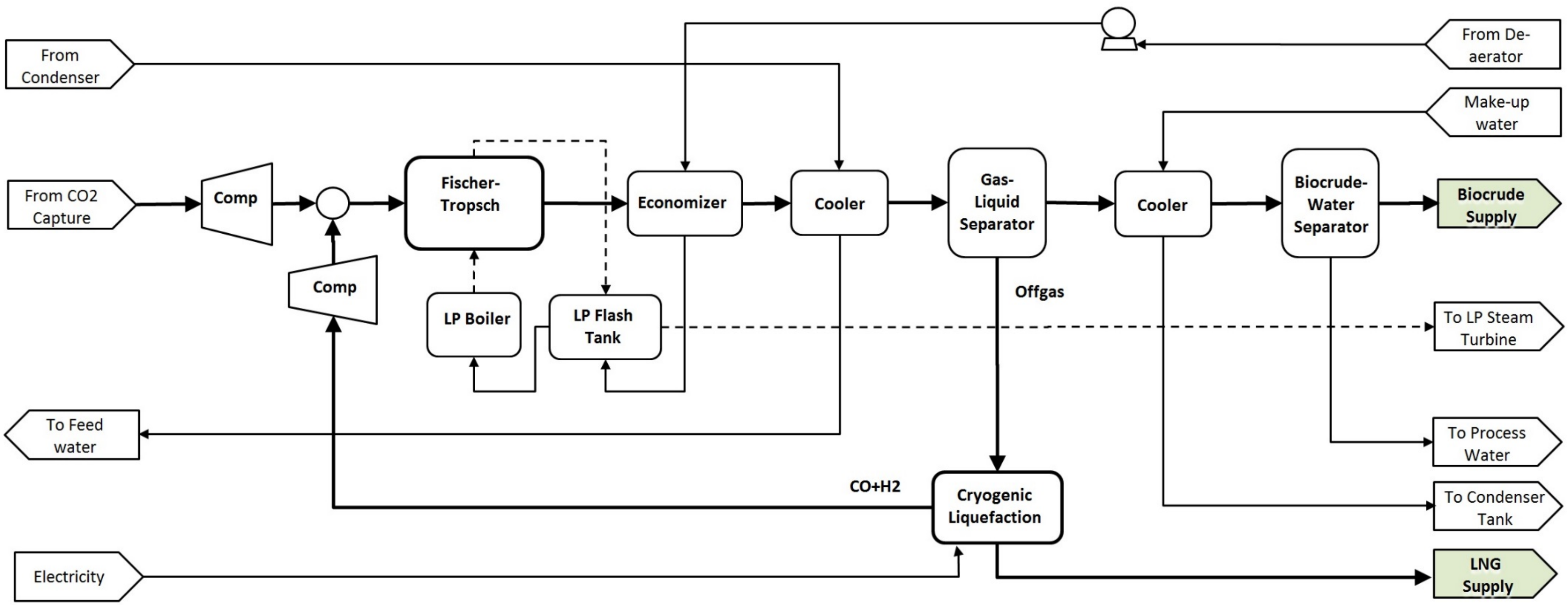
Selexol CO_2 Capture and Compression





- ✓ CO_2 concentration (18 % to 25%) suitable for selexol operation
- ✓ Other reason is cost of electricity is cheaper under Norwegian conditions

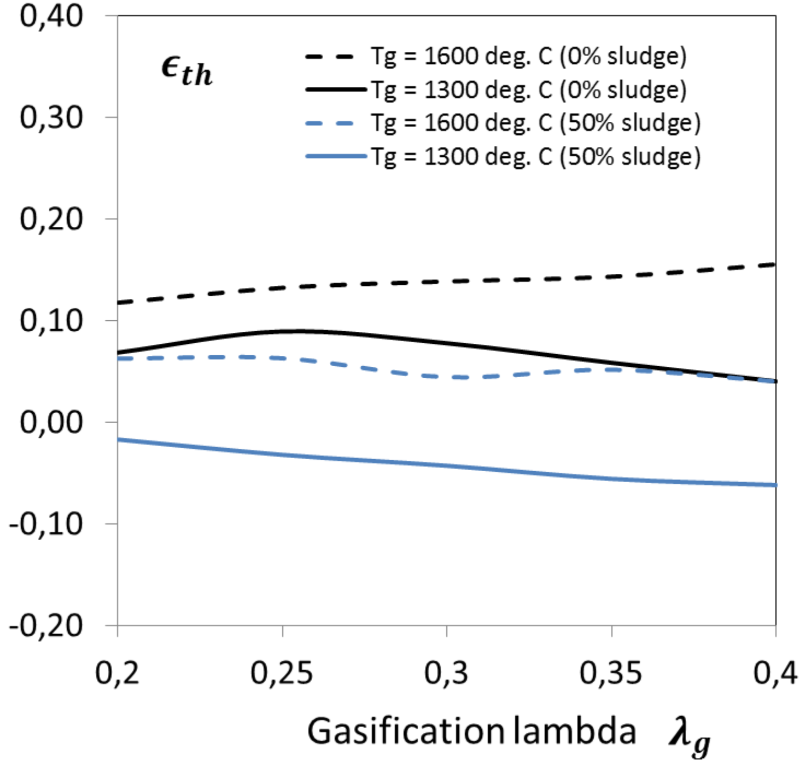
Fischer-Tropsch



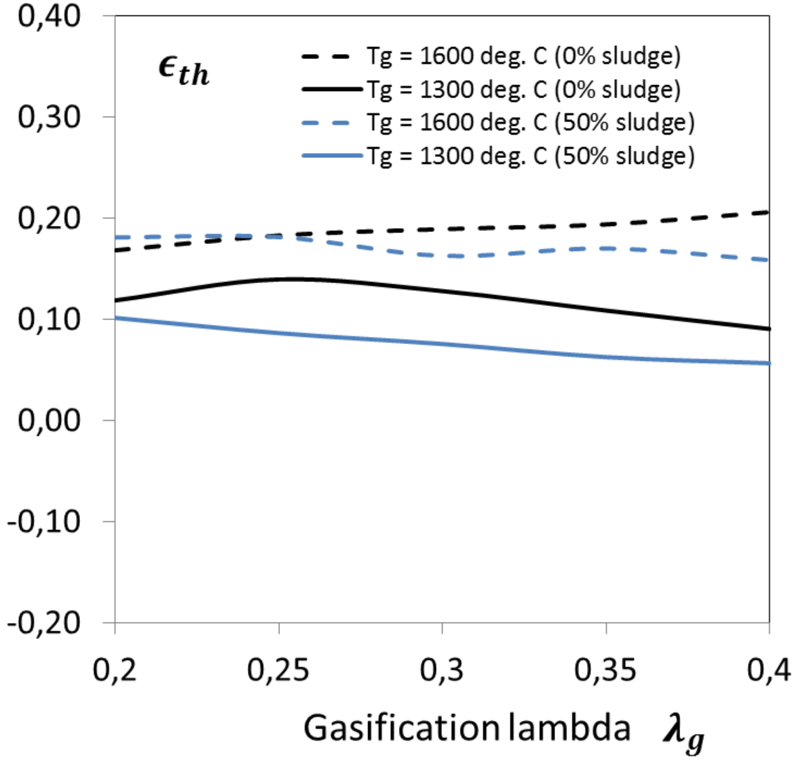
Inlet H2/CO ratio = **2.2**
FT Reactor: **250 deg. C (Bubbling Column) 25**
FT Reaction Progress: **40% - 80 % (sensitivity analysis)**
FT Product Selectivity: **α-Olefin Re-adsorption Product Distribution Model (ORPDM)**
Gas/Liquid Separation: **95 deg. C**
Biocrude/Water Separation: **35 deg. C**
LP Steam Generation: **10 bar-g, saturated**

Bio-crude production (thermal efficiency)

Sludge to log wood ratio: 0% - 50%
Wood log with 60% moisture
Dewatered sludge with 60% moisture

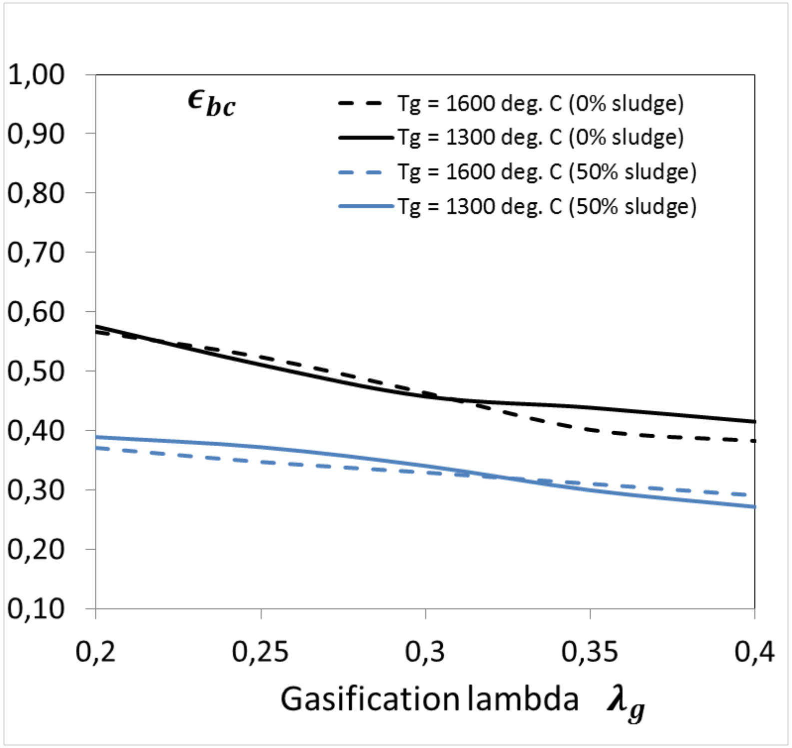


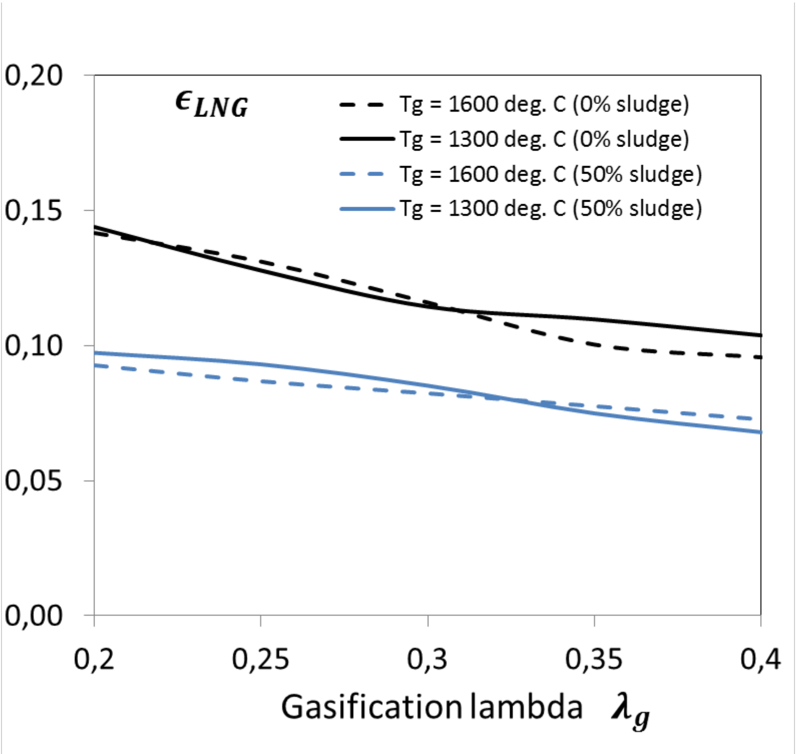
Drying: steam 150 deg. C



Drying: steam 200 deg. C

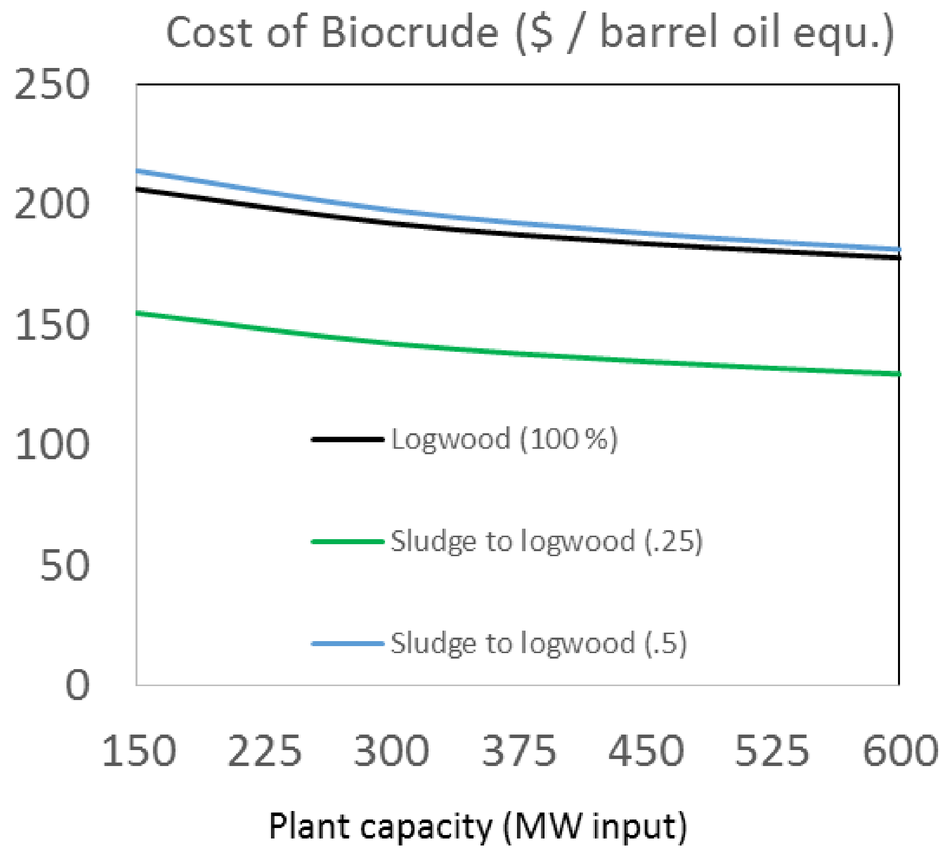
Bio-crude production Efficiency





Sludge to log wood ratio: 0% - 50%
Wood log with 60% moisture
Dewatered sludge with 60% moisture
Drying: steam 150 deg. C

Cost of Biocrude Production

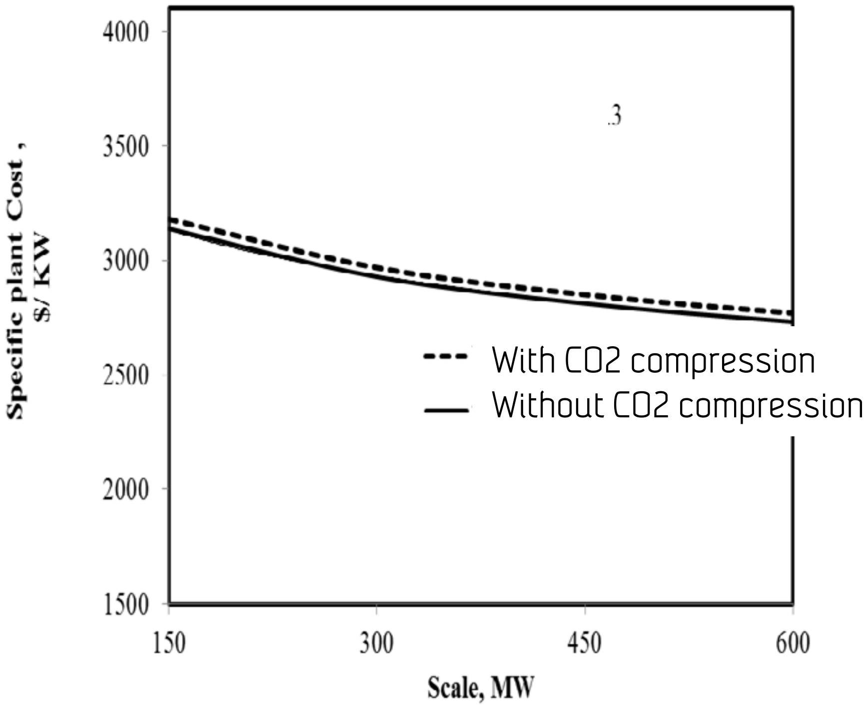


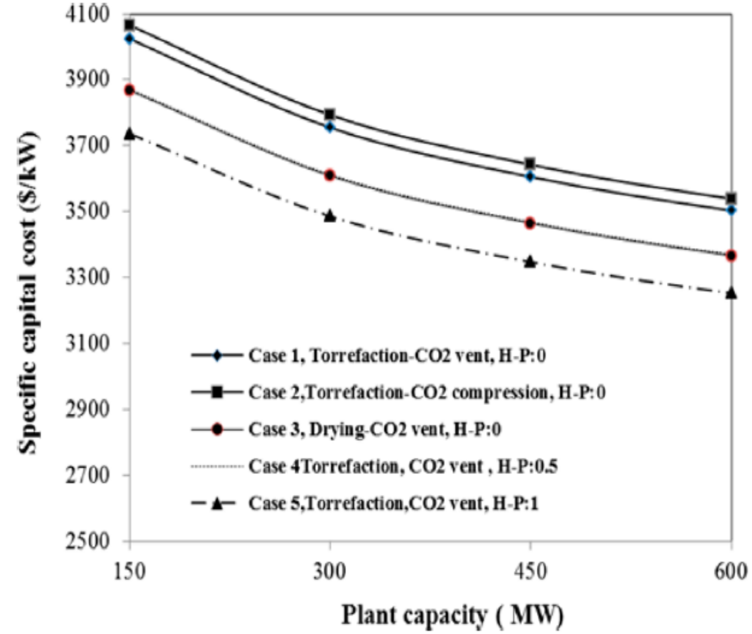
Wet Log: 60% moisture and 200 NOK/m3
Dewatered sludge: 60% moisture, Gate fee 500 NOK/ton wet
LNG price: 15 $/GJ LNG price

- There is an optimal sludge to wood ratio for minimum production cost

Bio-crude production

Plant investment cost ($/kW)





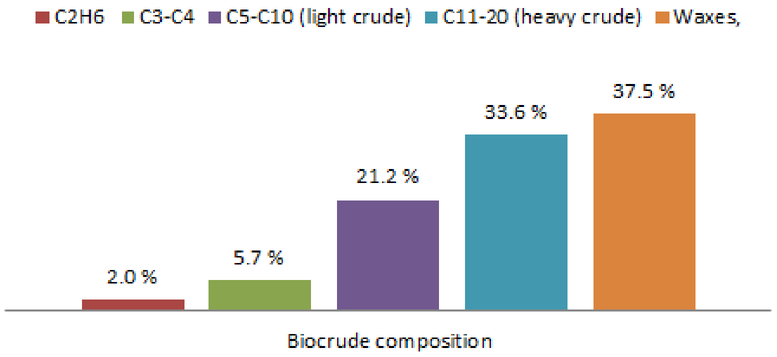
Co-processing with sludge
Co-production of LNG

Co-production of CHP

Biocrude upgrading

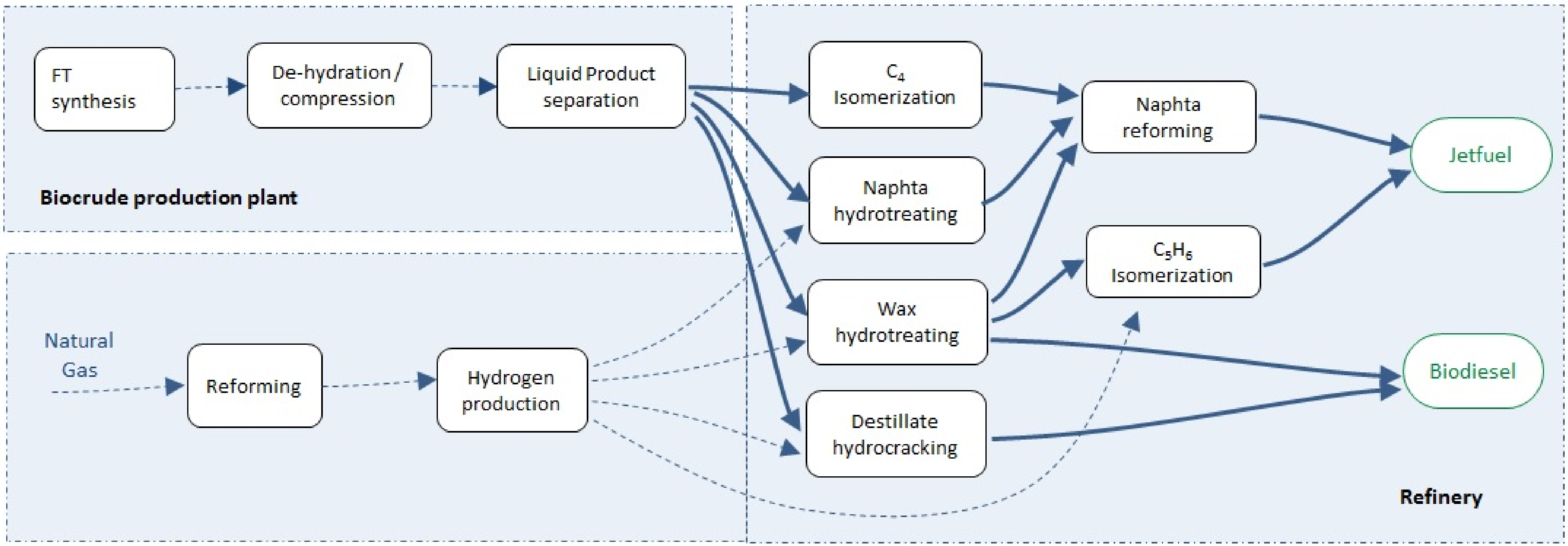
FT- biocrude composition

Heating value, h_g^G (MJ/kg)	
Elemental composition, x_i (% mol.)	C, O, H, N, S
Carbon number distribution, y_{C_n} (% wt.)	Wax (>C_{20}), Middle destillate (C_{12}-C_{19}) Naphta (C_5-C_{11}) LPG (C_2-C_3) Light gases: CO, H_2, CH_4
Functional groups distribution, y_j (% wt.)	Paraffines, Olefines Aromatics Oxygenates



Biocrude upgrading

Refinery processes



- ✓ Diesel / jet-fuel ratio will be evaluated

Coming…

- ✓ Integrate experimental process results for EFG and FT
- ✓ Improved process integration in EFG+FT route
- ✓ Decentralized feedstock pretreatment
- ✓ Upgrading in refinery processes
- ✓ H2 production in the EFG+FT route and partial biocrude upgrading

Thank you!

Comments or questions?

Bio-jetfuel production from woody biomass (comparison of routes)