Comparative Energetic Assessment of Integrated H_2- and CH_4-Production via Biomass Supercritical Water Gasification

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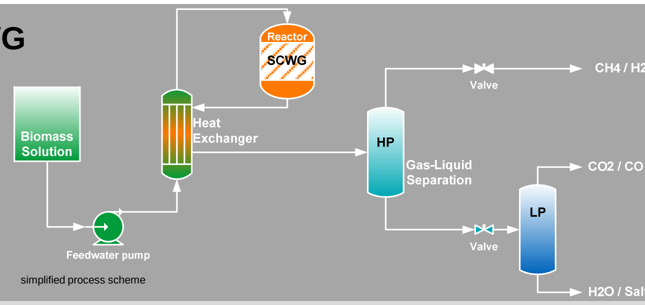
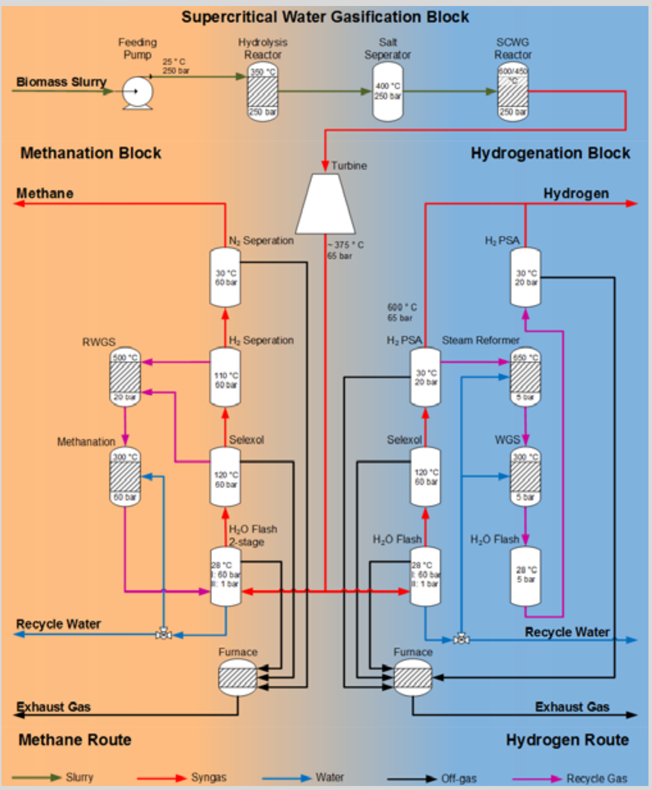
Introduction: Super Critical Water Gasification - SCWG

- p > 220 bars, T > 374 °C, no distinction gas/liquid
- Conversion of **wet biomass**
- T < 500 °C **high CH_4 yields**
- T > 500 °C **high H_2 yields**
- SCW is polar and **organics are dissolved**



simplified process scheme

Simulation model [1,2]



Biomass Input: Lipid extracted algae - LEA

Aquatic feedstock is considered as a future fuel source for 3rd generation biofuels due to its higher specific area yield and not being in competition with food production. Lipid extraction leaves a most by-product, LEA, that can be made use of by more rigorous treatment methods such as hydrothermal gasification. Composition of LEA [3]:

Proximate Analysis a.r. in wt.%		Ultimate Analysis daf, wt.%	
Volatiles	75.34	Carbon	50.99
Fixed Carbon	14.45	Hydrogen	7.44
Ash	4.59	Oxygen	33.59
Moisture	5.62	Nitrogen	7.49
		Sulphur	0.49

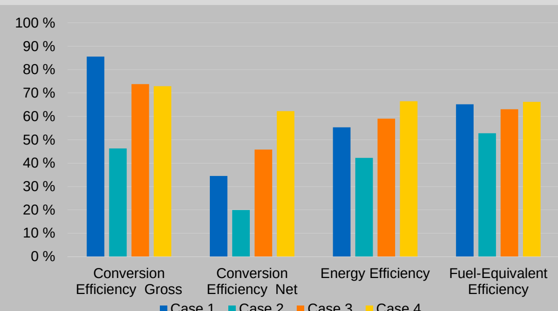
Simulated Cases

Basic Pinch Analysis suggested that neither of the base cases was thermodynamically self-sufficient and required substantial amounts of processing fuel. For higher in-situ energy recovery, in the case of H_2 production the secondary production, and in the case of CH_4 production power extraction was excluded.

	Case 1	Case 2	Case 3	Case 4
Product	H2	H2	CH4	CH4
Slurry solid content	5 wt.%	5 wt.%	18 wt.%	18 wt.%
SCWG temperature	600 °C	600 °C	600 °C	450 °C
Power production	Yes	No	Yes	Yes
Gas Recycle	Yes	No	Yes	Yes

Results & Conclusions:

- Energy efficiency could be as high as 0.48 and 0.57 for H_2 and CH_4.
- H_2/CH_4 formation is mostly influenced by the solid content.
- Flash separation is enhanced by higher water content.
- CH_4 yield is highest at 450 °C but at lower C conversion, which would require either high catalyst load or long reaction times.
- District heating integration could increase energy efficiencies substantially.
- In Finland CH_4 price is ~1.35 €/kg, H_2 6-15 €/kg. At ~10 €/kg, the turnover of H_2 production would equal CH_4 production's.



Future Work:

- Optimise H_2 production at higher solid content and CH_4 production at lower temperature by experiments and calculation.
- Economic feasibility study and life cycle assessment for different feedstock with focus on black liquor.
- Planning towards a SCWG pilot plant.

References: [1] Magdeldin M, Kohl T, Jarvinen M. Process modeling, synthesis and thermodynamic evaluation of hydrogen production from hydrothermal processing of lipid extracted algae integrated with a downstream reformer conceptual plant. Biofuels 2016:7(2);97-116.

[2] Magdeldin M, Kohl T, De Blasio C, Jarvinen M. Heat Integration Assessment for the Conceptual Plant Design of Synthetic Natural Gas Production from Supercritical Water Gasification of Spirulina Algae. ECOS - The 28th Int. Conf. on efficiency, cost, optimization, simulation and environmental impact of energy systems 2015,¨Jun 26 – Jul 3, Pau, France.

[3] Phyllis2, database for biomass and waste, https://www.ecn.nl/phyllis2, Energy research Centre of the Netherlands.

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