IEA Bioenergy
Technology Collaboration Programme

Flexibility Provision from Biogenic Gases

A gasification perspective

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Task lead of IEA Bioenergy Task 33

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Task 33 - a global collaborative work force

If you have information that you want to share and to support the deployment of gasification, contact your national contact point.

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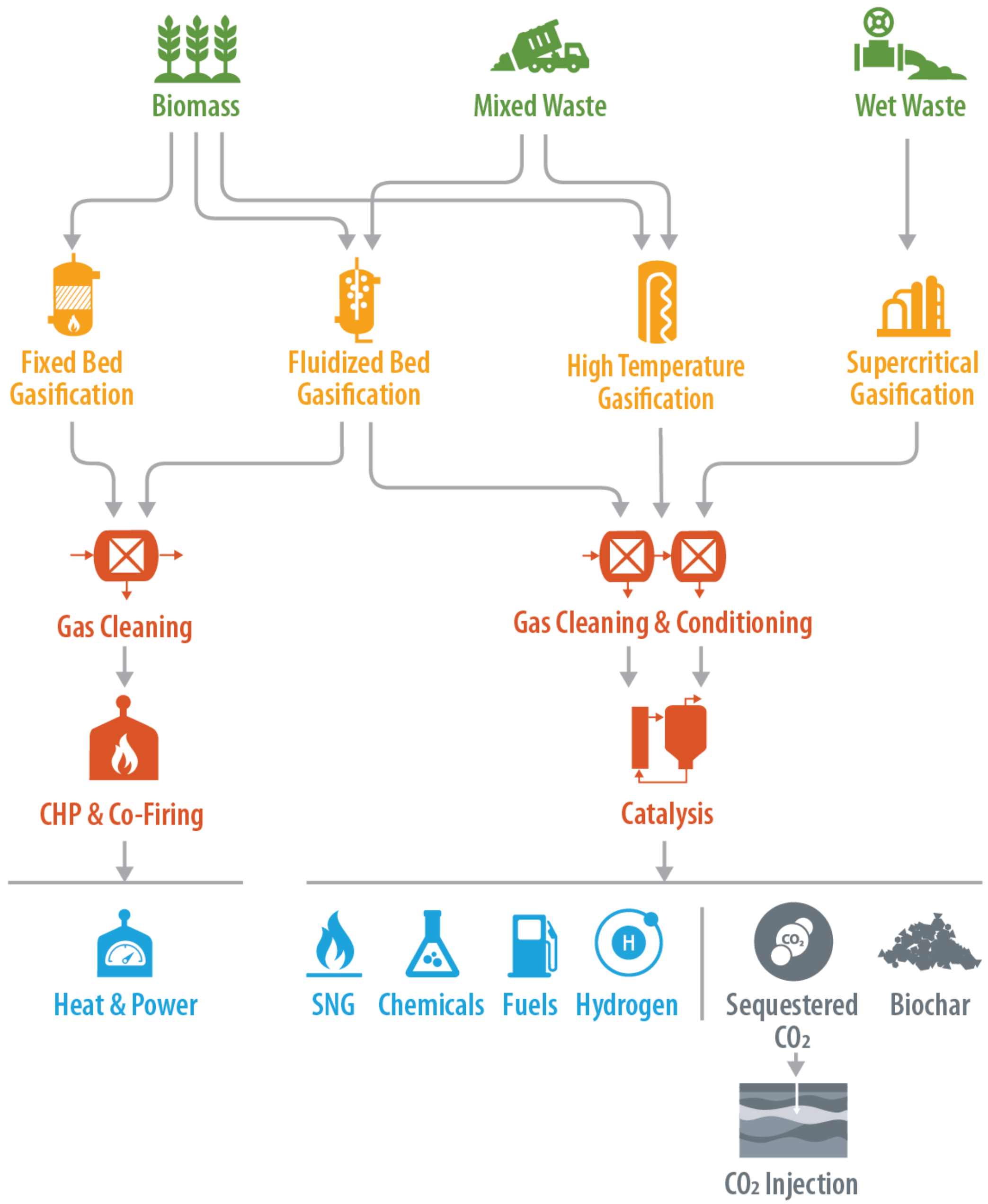
Gasification and applications

Flexibility

1. Feedstocks
2. Technology
3. Back-end applications
4. Production pathways
5. Intergration with other renewables
6. Negative emissions



Examples of production flexibility

- Green Gas production from gasification
- MeOH / DME production from gasification
- Diesel production from gasification

Gasification towards Green Gas

Biomass as feedstock → Gasification → Product gas

For the conversion of biomass to transportation fuels there is too less hydrogen and too much oxygen in the feedstock. $C_1H_{1,44}O_{0,66}$

Most fuels have composition

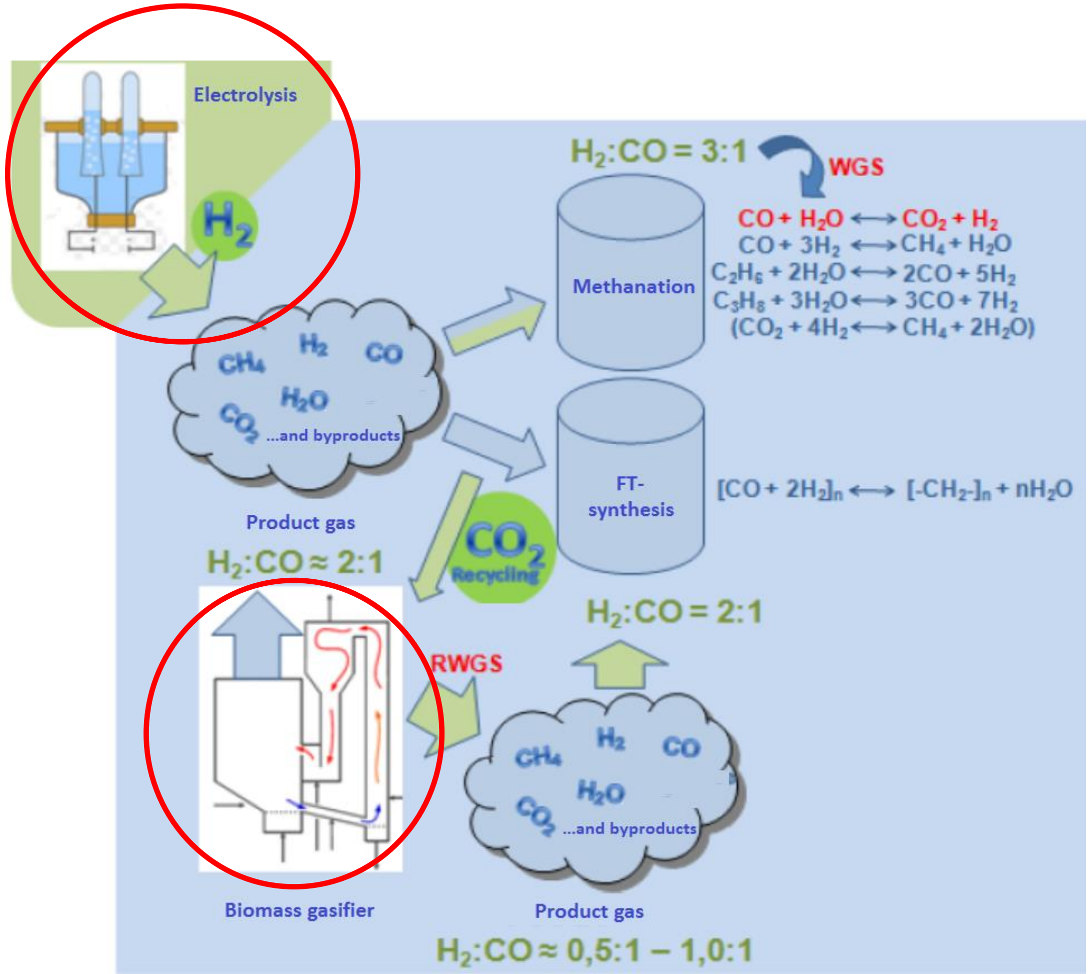
$-(CH_2)-$

This results in lower efficiencies compared to e.g. natural gas as a feedstock.

Compound		Air gasification Fixed bed	Oxygen gasification Entrained flow	Steam gasification Fluidized bed
CO	Vol. %	13-18	45-55	25-30
CO_2	Vol. %	12-16	10-15	20-25
H_2	Vol. %	11-16	23-28	35-40
CH_4	Vol. %	2-6	0-1	9-11
N_2	Vol. %	45-60	0-1	0-5
Calorific value	MJ/Nm^3	4-6	10-12	12-14

Source: A.V. Bridgwater, H. Hofbauer, S. van Loo: Thermal Biomass Conversion, 2009, ISBN 978-1-872691-53-4

Coupling thermal gasification with additional hydrogen from electrolysis



A system consists of dual fluidized bed steam gasifier and electrolyser for production of methane (PtG) or FT-products (PtL).

During the steam gasification a gas with H_2 : CO = 2 ratio is produced, but for methanation a gas with ratio H_2 : CO = 3 is necessary, it means further hydrogen from electrolyser is needed.

Advantage:

Coupling the thermal gasification of biomass with hydrogen from electrolysis can doubled the production of renewable fuels in comparison if only product gas from gasification is used.

Advantages of biomass gasification integration into PtG (SNG is the product)

- Total carbon exploitation from biomass can be more than doubled
- Higher overall process efficiency (larger product yield and possibility of heat integration)
- O_2 from electrolysis can be used for gasification
- By adding hydrogen from electrolysis, the use of the water-gas shift reaction can be avoided
- Large H_2 storage can be avoided
- By non-available surplus electricity, the methanation can be operated with synthesis gas from gasification only

Energy flow/energy conversion/mass yeld (Methane via steam gasification)

- Configuration:
- - Steam gasification
- - Alkaline electrolyzer

	No additional hydrogen	With additional hydrogen
Methane output	63,7 MW	140 MW
Mass yield	193 $kg/tonne_{dry}$	370 $kg/tonne_{dry}$

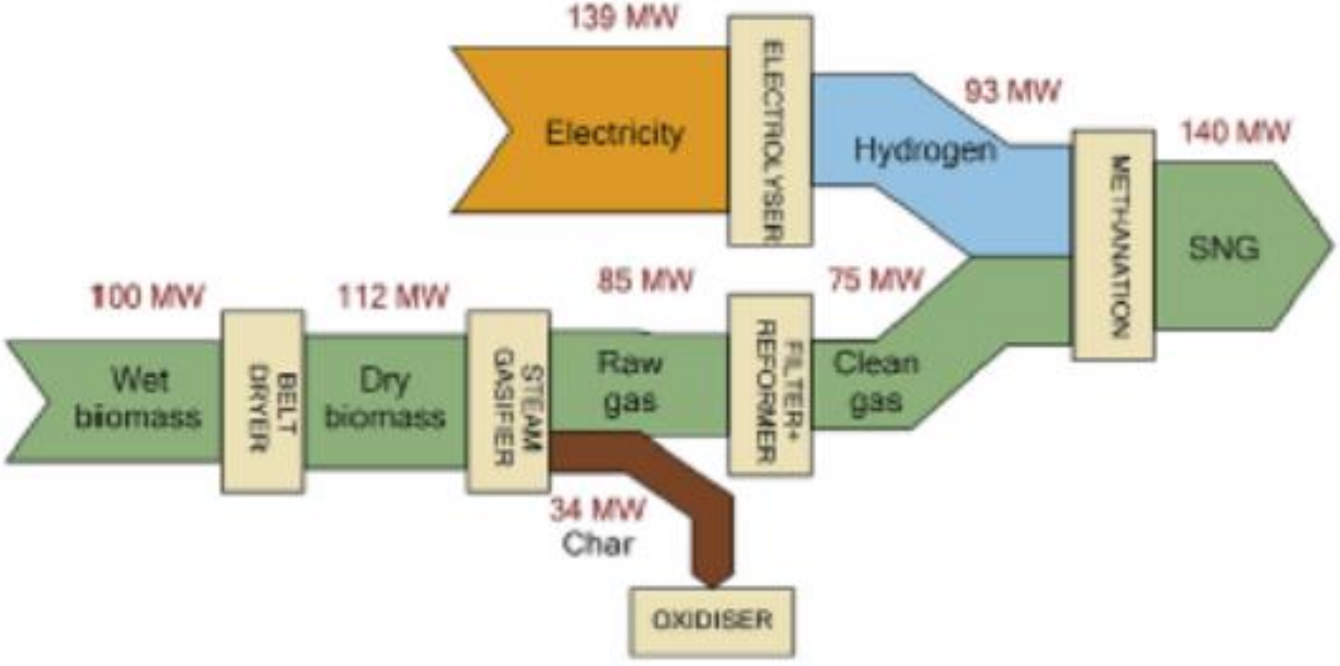
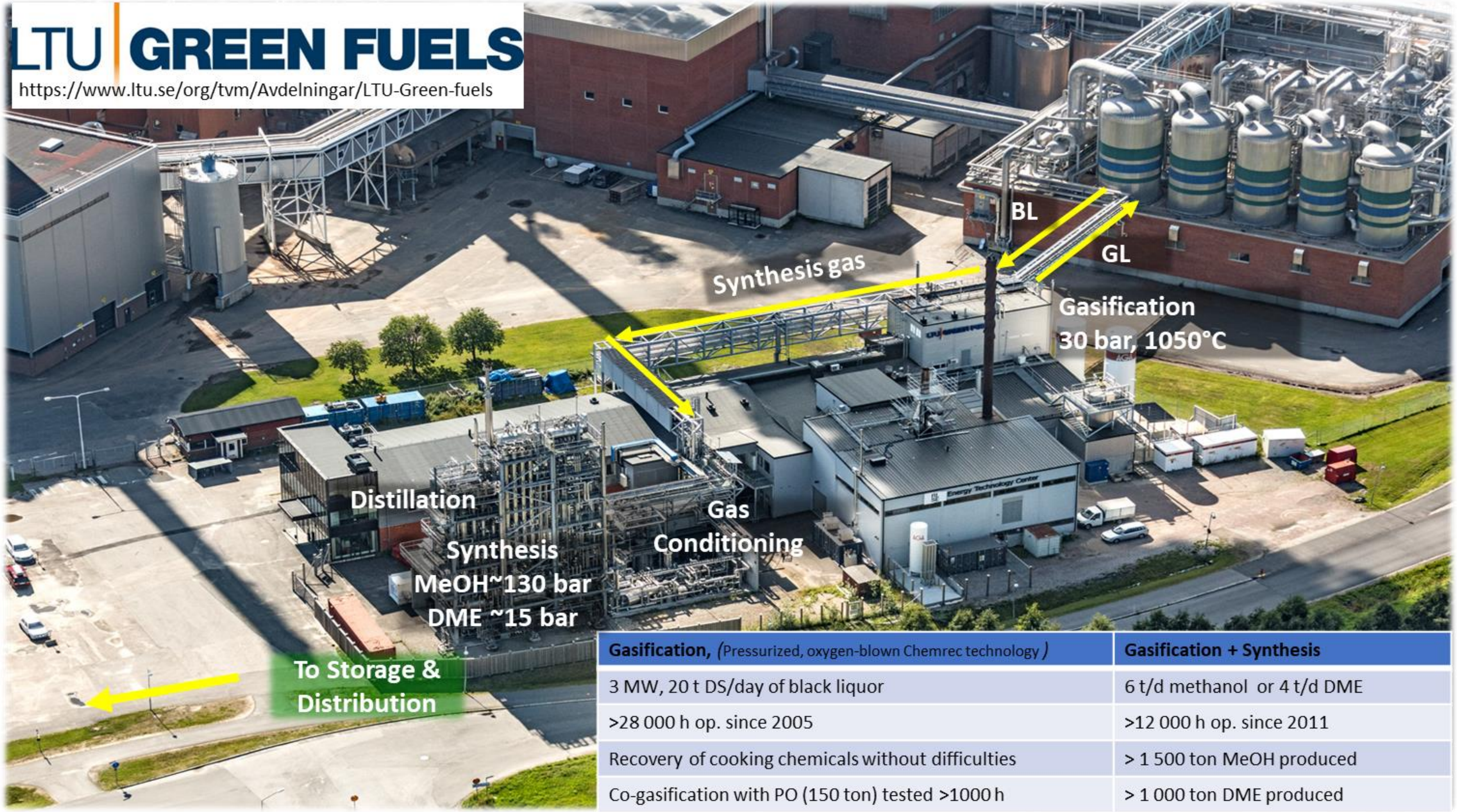


Fig.: Energy flow for methane (SNG) with hydrogen addition

Source: I. Hannula: Energy 104

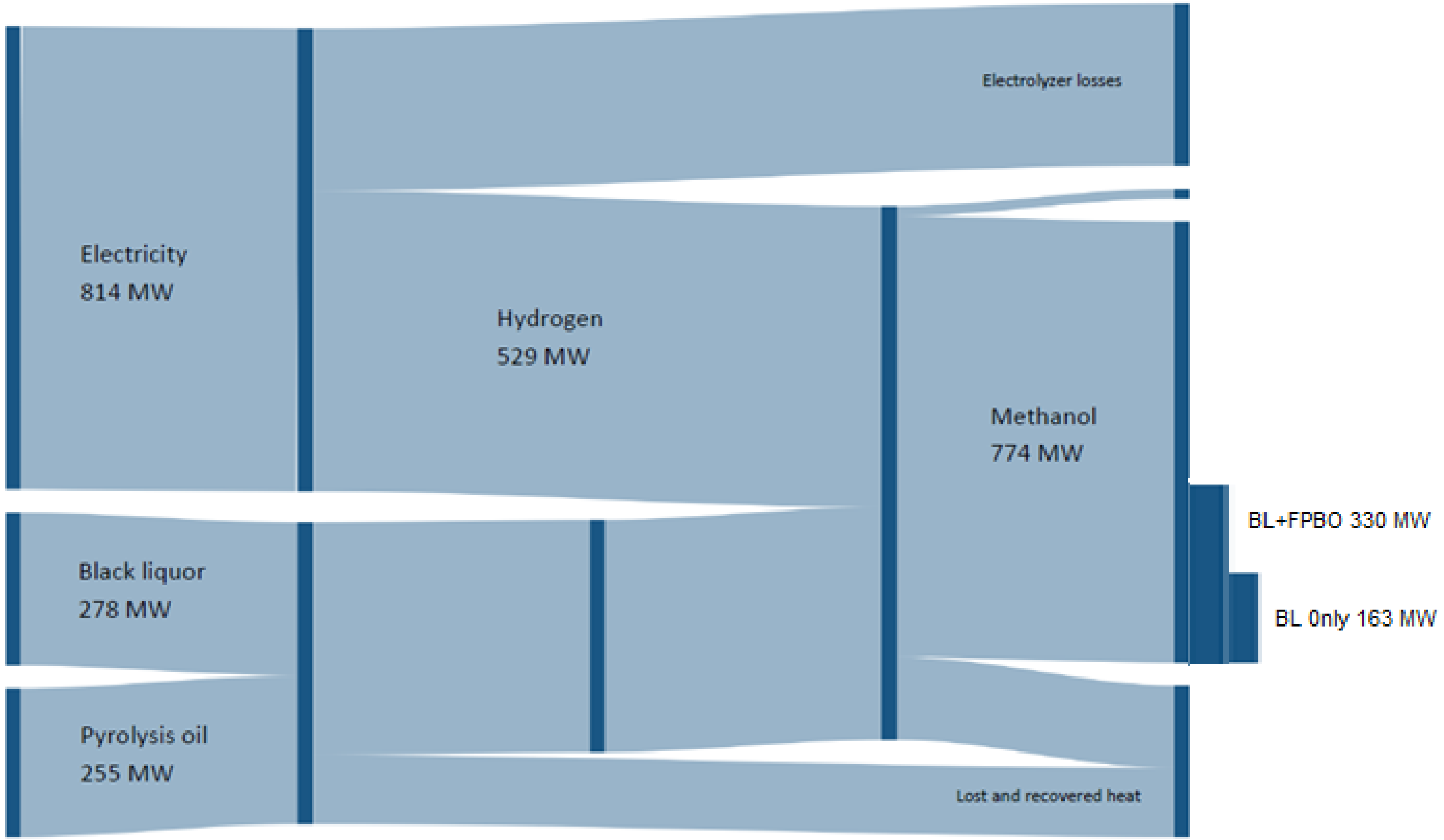
LTU Green Fuels plant → production of MeOH and DME



Gasification, *(Pressurized, oxygen-blown Chemrec technology)*	Gasification + Synthesis
3 MW, 20 t DS/day of black liquor	6 t/d methanol or 4 t/d DME
>28 000 h op. since 2005	>12 000 h op. since 2011
Recovery of cooking chemicals without difficulties	> 1 500 ton MeOH produced
Co-gasification with PO (150 ton) tested >1000 h	> 1 000 ton DME produced

- Complete plant for black liquor gasification and synthesis of methanol and DME
- Long term testing between 2011 and 2016
- The methanol and DME was used in heavy duty trucks and ind. processes

Combination of electrolysis and biomass gasification



Marginal efficiency H_2 to MeOH

$$\eta = \frac{(774 - 330)}{529} = 83.9\%$$

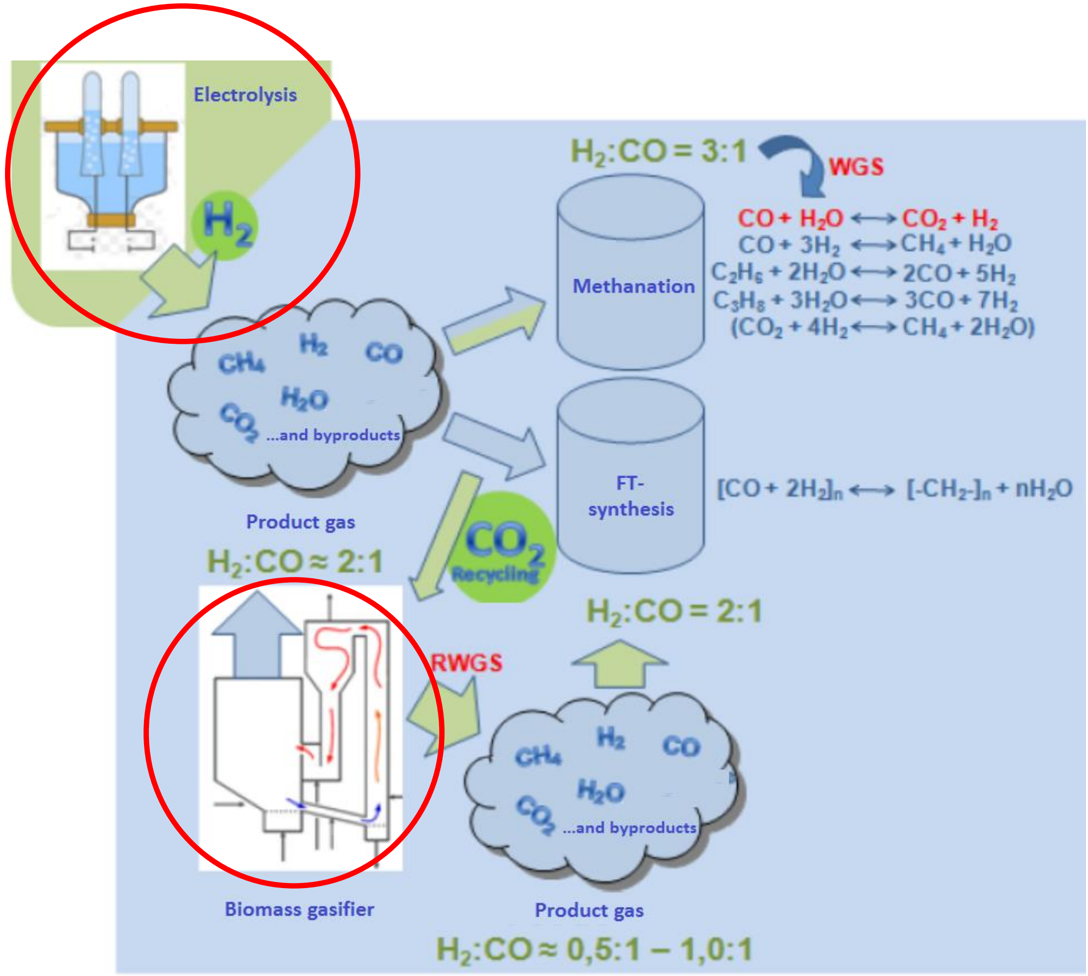
Power efficiency:

$$\eta_{el} = \frac{(774 - 330)}{814} = 54.5\%$$

Yield increase:

$$\Delta\dot{m} = \frac{(774 - 330)}{330} = 134\%$$

Power to Liquids (FT products)



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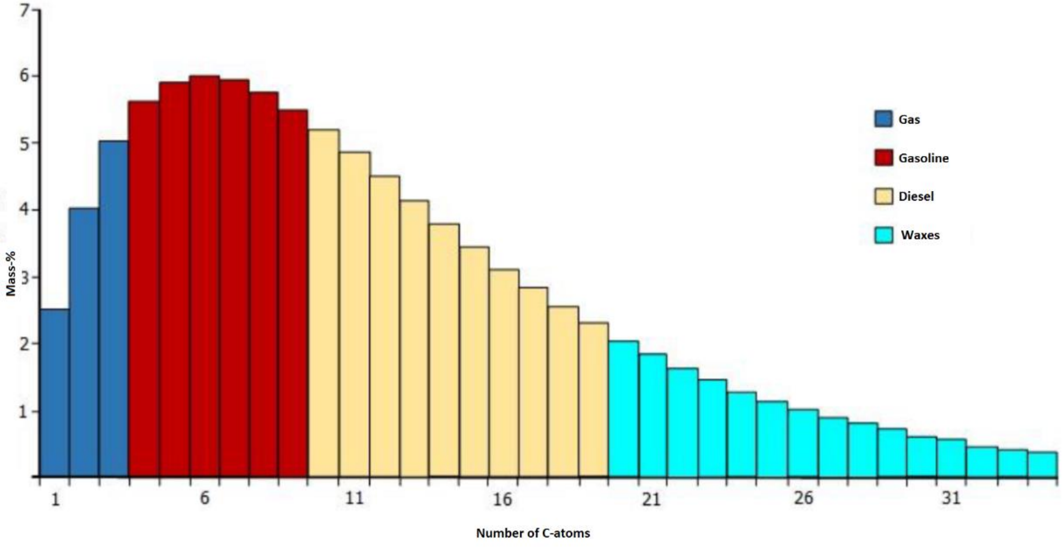
A system consists of two bed steam gasifier and electrolyser for production of methane (PtG) or FT-products (PtL).

During the steam gasification a gas with H_2 : CO = 2 ratio is produced, which is optimal for FT-synthesis.

By FT synthesis is the usage of additional hydrogen from electrolyser a little bit different. The principle is based on CO_2 recycling, it means, the inert CO_2 will not be released to the atmosphere, but it will serve as an additional fluidizing agent in the gasification unit as a carbon source for further reactions with hydrogen from electrolysis.

From synthesis gas to FT products

- Synthesis gas – H2 and CO mixture
- For FT synthesis necessary ratio H2:CO = 2:1



- Surplus carbon in product gas is not used in the syntesis process, as there is not enough hydrogen for the conversion

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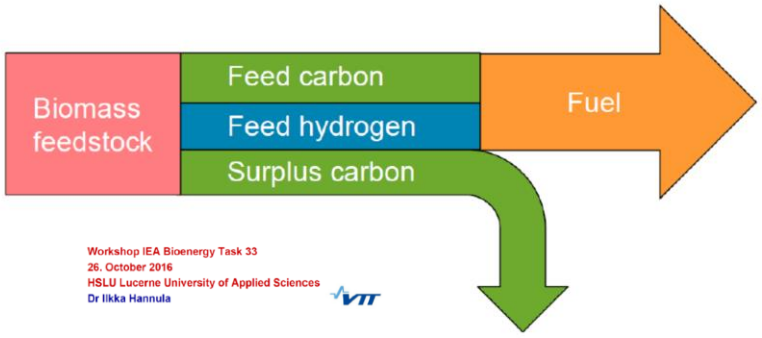
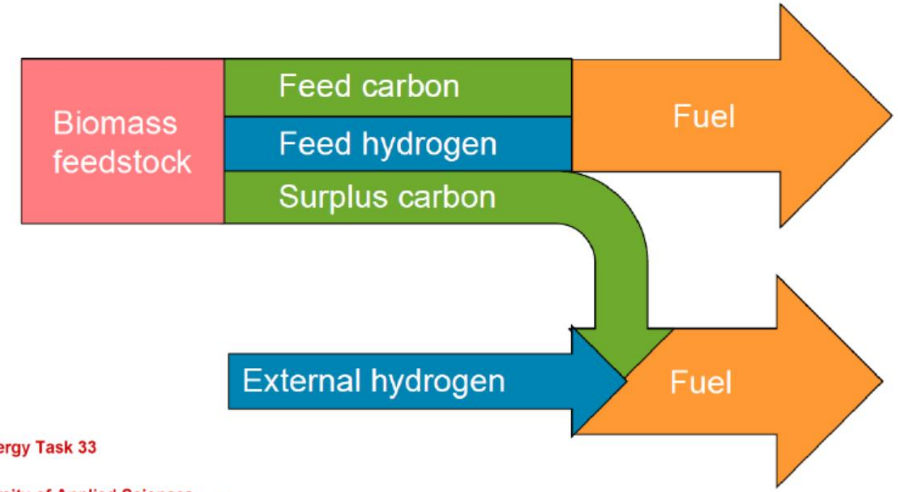


Boosting the production with external hydrogen - Fischer Tropsch products



Workshop IEA Bioenergy Task 33
26. October 2016
HSLU Lucerne University of Applied Sciences
Dr Ilkka Hannula

Using of additonal (external) hydrogen the FT products amount could be doubled

Advantages:

- Conversion of surplus electricity and surplus carbon to high valuable products
- Higher carbon utilization
- Biomass acts as base load (8000 oph/y possible), no start-stop operation, only load change

Advantages of the FT liquids

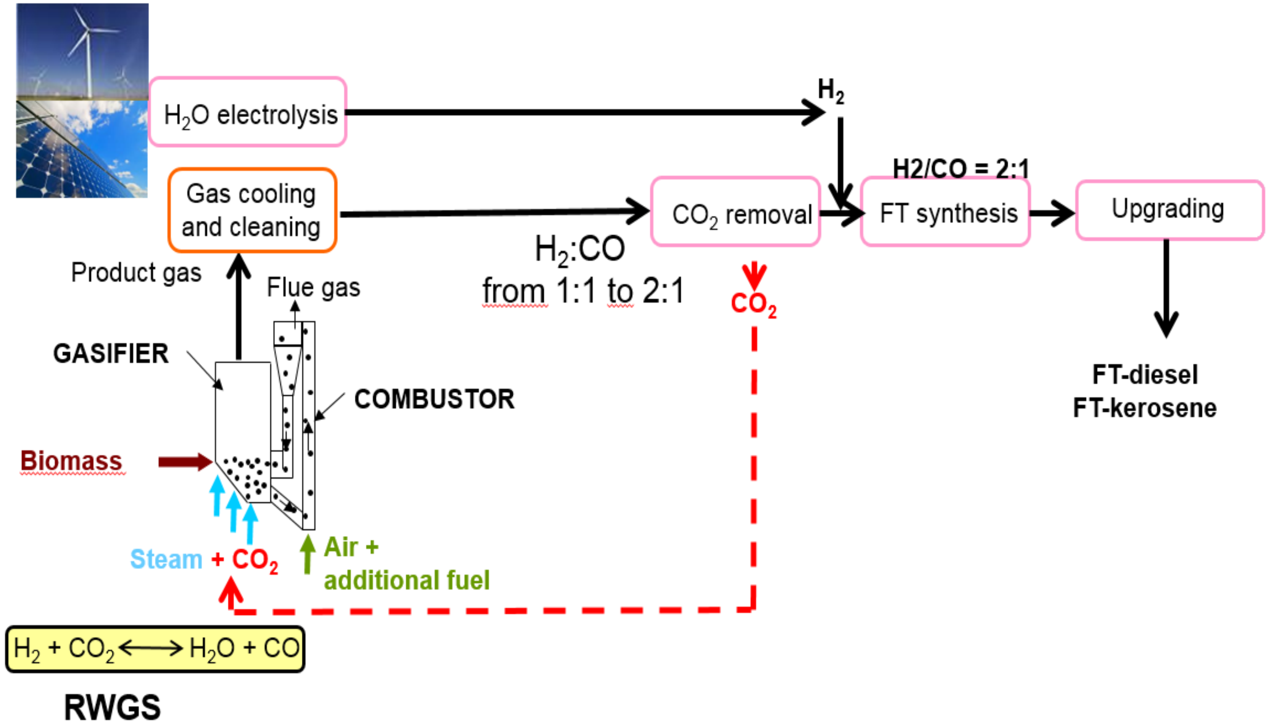
- As a synthetic fuel, PtL offers improved combustion with fewer pollutants, which makes it attractive for production of e.g. aviation fuels.

- While methanol-based biodiesel must be blended with petroleum-based diesel, renewable diesel can fully substitute it – and renewable jet fuel is accepted in 50% blend in aviation, at least in Europe.
- In aviation today, only jet fuels from FT process have already satisfied all tests for being used as drop-in fuels.
- FT-based pathway has been approved for use in commercial aviation in blends of up to 50% with conventional jet fuel (Schmidt et al., 2018).

Conventional diesel fuel (left) and F-T ultra pure diesel (right)

PtL project (FT liquids) WindDiesel

- Advantages of this concept:
- As the H2 should come from excess electricity, the Winddiesel plant that is based on biomass gasification and Fischer Tropsch synthesis can be operated in its main parts with high annual operating hours.
- The addition of H2 from excess electricity brings a surplus in product yield and conversion rate of the used biomass but is not necessary for the synthesis process.



Base case:

- 100 MW Biomasse
- 0 MW Wind
- 49 MW FT-Product
- Carbon Conversion: 0.31

Maximum Windenergy

- 100 MW Biomasse
- 67 MW Wind electricity
- 88 MW FT-Product
- Carbon Conversion: 0.53

The additional CO_2, which is used as a fluidizing agent together with steam causes the shift of H_2 : CO ratio in favor of CO, thus the ratios between 0,5:1 and 1,9:1 can be achieved.

Microsoft Word - 13003-BB006a01_Publizierbarer_endbericht_Winddiesel_klienIF.doc

Summarizing the flexibility in different systems

	Green Gas	MeOH	FT-products
Biomass input	100 MWth	100 MWth	100 MWth
Product yield	64 MW_{SNG}	62 MW_{MeOH}	49 MW_{FT}
Power consumption for the addition of H_2	139 MW_{el}	153 Mw_{el}	67 MW_{el}
Product yield	140 MW_{SNG}	145 MW_{MeOH}	88 MW_{FT}

CH_4 --$|CH_2|_n$--

1. Various upcoming pathways can generate flexibility
2. Both from a management of molecules as well as heat (from electrolyzers)
3. The power needed to maximize all carbon for a medium sized gasification plant is significant

With limited H_2 available the utilization perhaps is best towards SAF?

Concluding with an actual project in the pipeline

Enerkem SUNCOR PROMAN Hydro Québec Investissement Québec Canada Québec

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