IEA Bioenergy Task33
Gasification of Biomass and Waste

Boosting the production of liquid biofuels through the addition of renewable hydrogen

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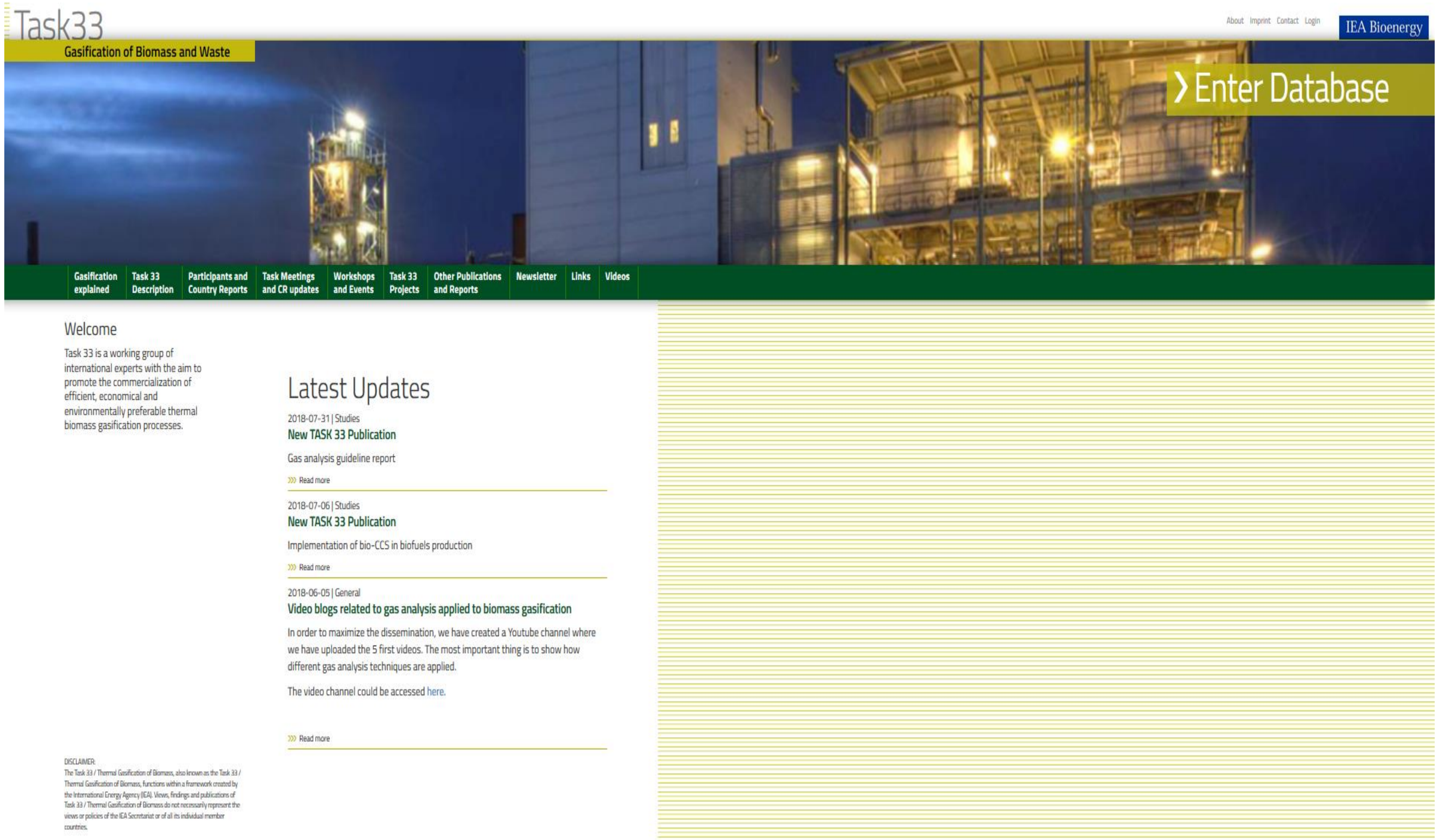


Participating countries

- Austria
- Germany
- Denmark
- Italy
- Netherlands
- Norway
- Sweden
- Switzerland
- USA

Task leader

Prof. Kevin Whitty

University of Utah, USA

Task 33 – actual projects

- SP1: Waste gasification
- SP2: Fuel pretreatment for gasification systems
- SP3: Biomass gasification for CCUS
- SP4: Biomass gasification success stories
- **SP5: Gasification-based hybrid systems**
- SP6: Hydrogen production via gasification
- SP7: Biomass and waste gasification status report
- SP8: Biomass gasification history and lessons learned
- SP9: Valorization of byproducts from small scale gasification
- SP10: Gas analysis report

Task 33 – actual projects

Gasification-based hybrid systems

Aim: Optimal utilization of renewable electricity surplus (solar- and wind energy) in combination with thermal biomass gasification for increase of production of gaseous and liquid fuels.

Gasification as a carbon source together with renewable hydrogen from surplus electricity for production of gaseous and liquid fuels.

-Power to Gas (PtG)

Focus on hydrogen and methane

-Power to Liquids (PtL)

Focus on FT products and methanol

Thermal biomass gasification as a source of carbon for electrofuels production

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

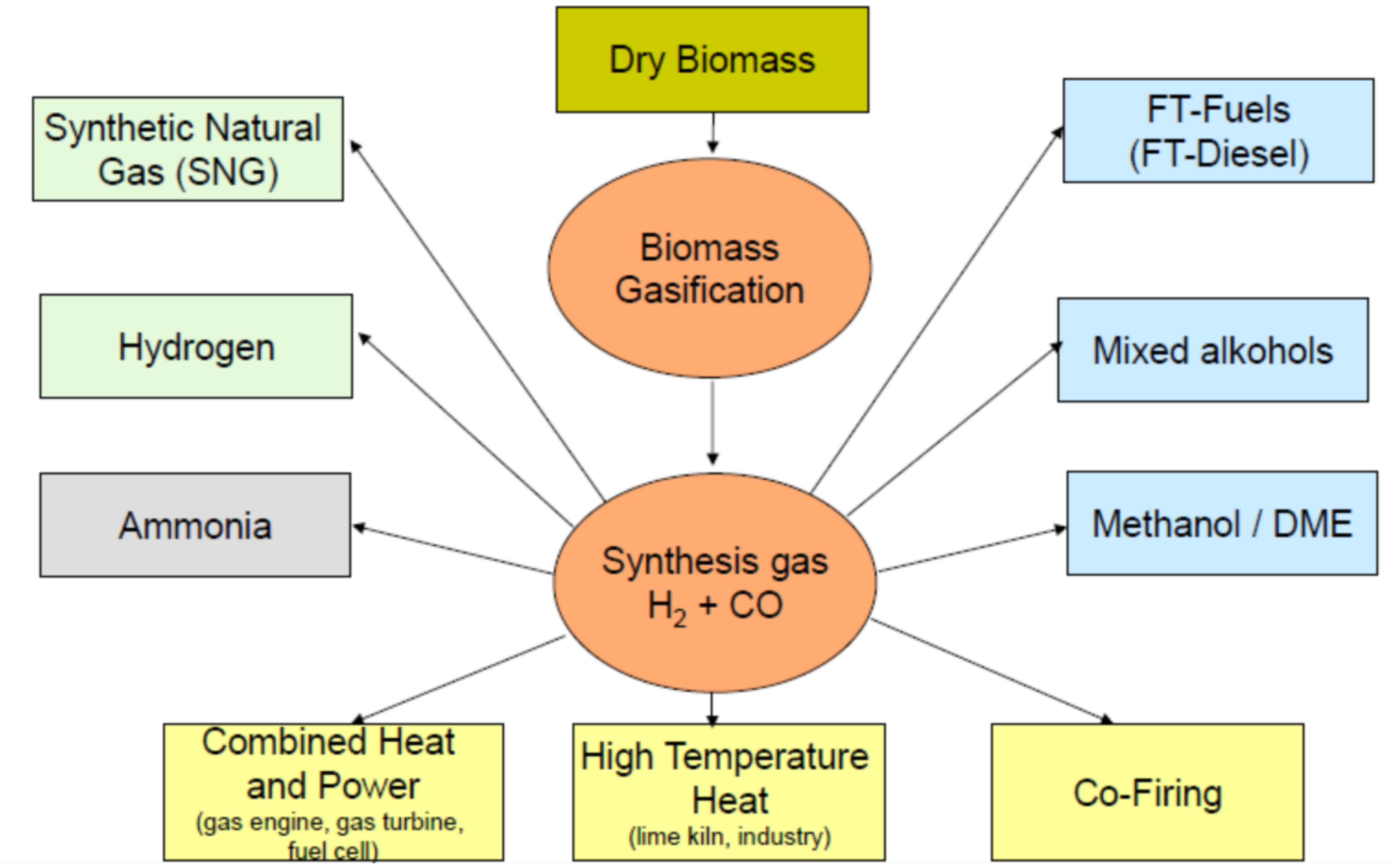
$-(CH_2)-$

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

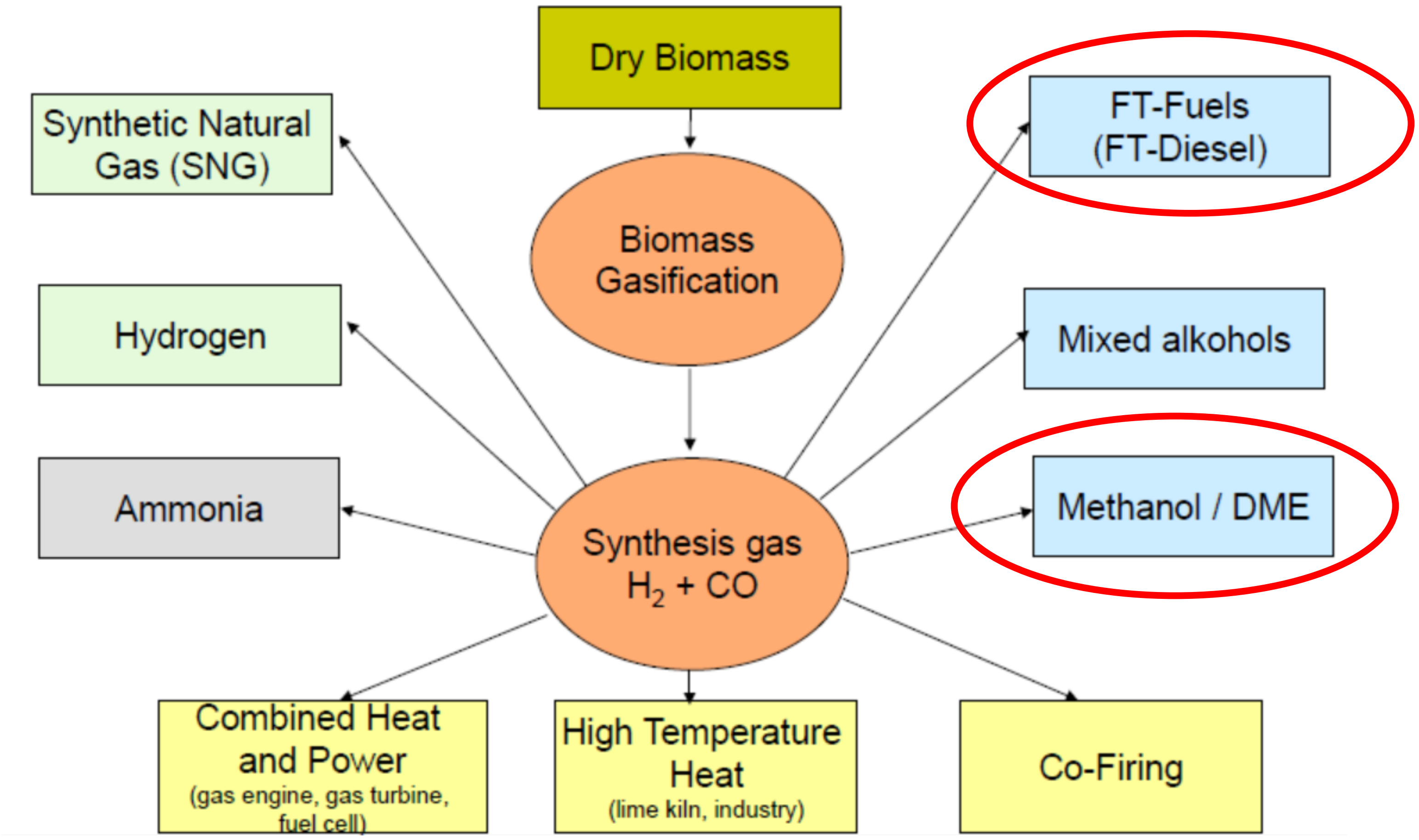
Compound		**Air gasification** Fixed bed	**Oxygen gasification** Entrained flow	**Steam gasification** Fluidized bed
CO	Vol. %	13-18	45-55	25-30
CO_2	Vol. %	12-16	10-15	20-25
H_2	Vol. %	11-16	23-28	35-40
CH_4	Vol. %	2-6	0-1	9-11
N_2	Vol. %	45-60	0-1	0-5
Calorific value	MJ/Nm^3	4-6	10-12	12-14

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

Synthesis gas utilization

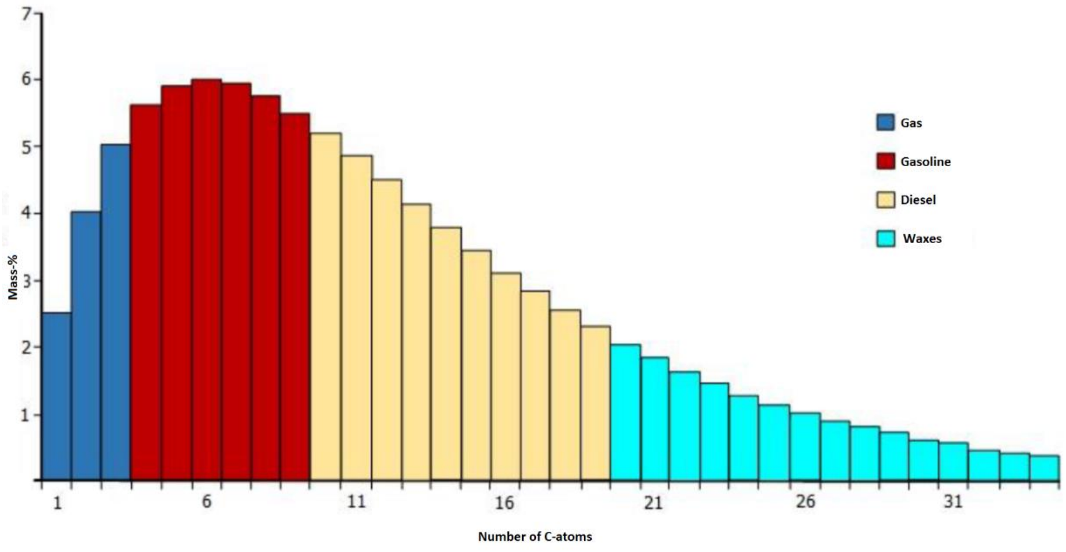


Synthesis gas utilization



From synthesis gas to FT products

- Synthesis gas – H_2 and CO mixture
- For FT synthesis necessary ratio H_2: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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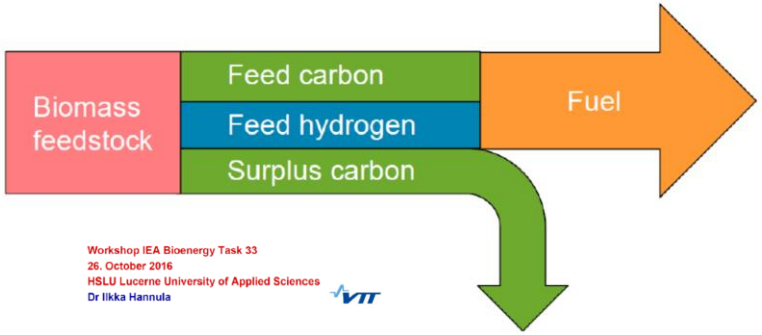
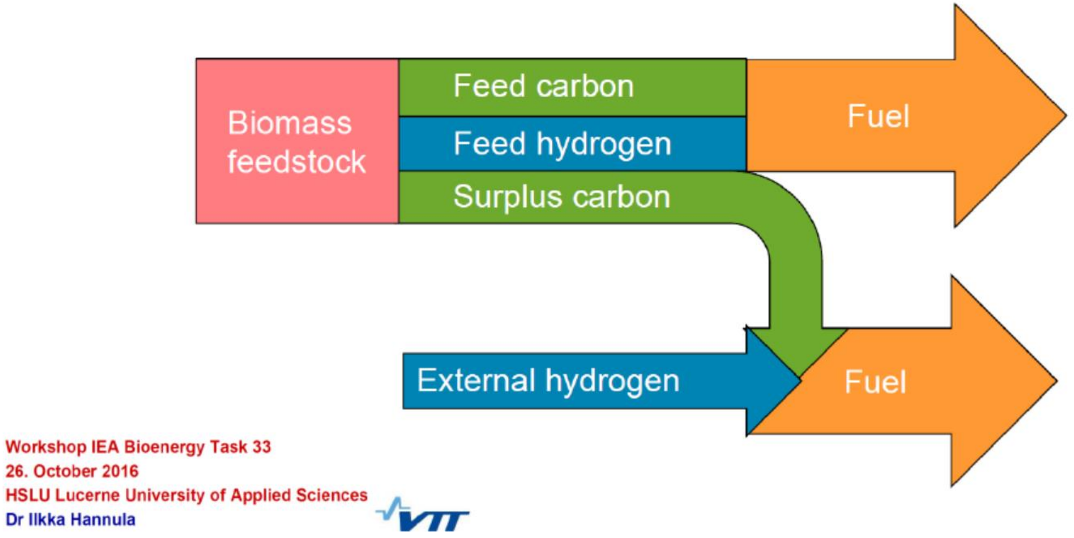


Boosting the production with external hydrogen - Fischer Tropsch products



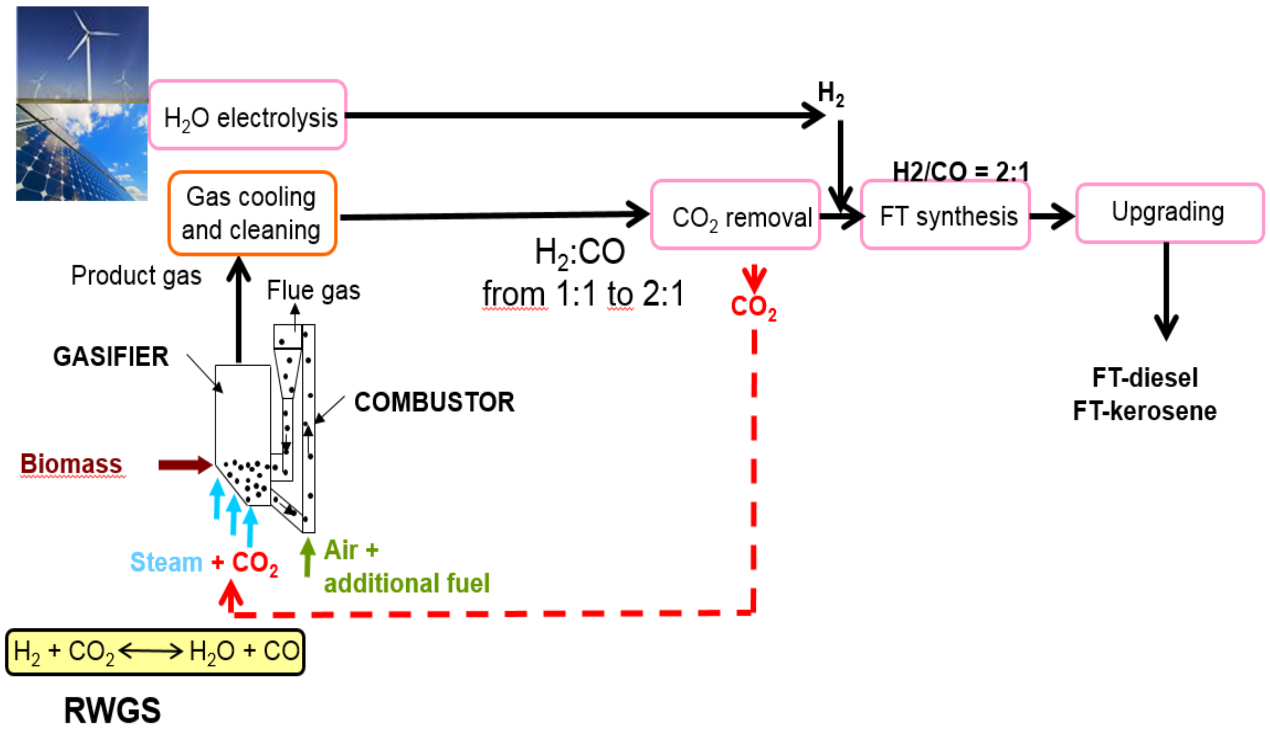
Using of additonal (external) hydrogen the FT products amount could be doubled

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

Project WindDiesel

Power to Liquids and Chemicals



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:

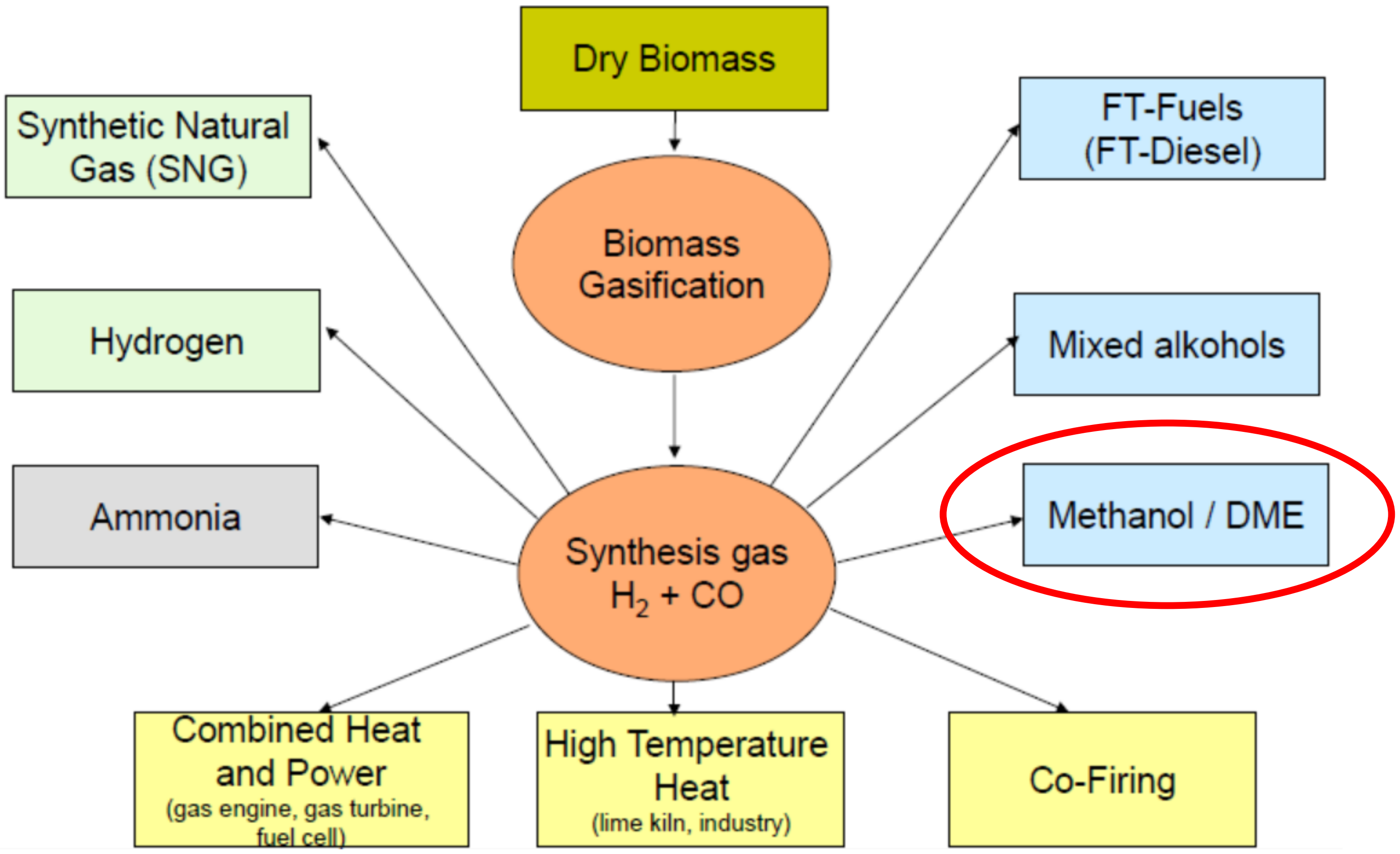
- 100 MW Biomasse
- 0 MW Wind
- 49 MW FT-Product
- Carbon Conversion: 0.31

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.

Synthesis gas utilization

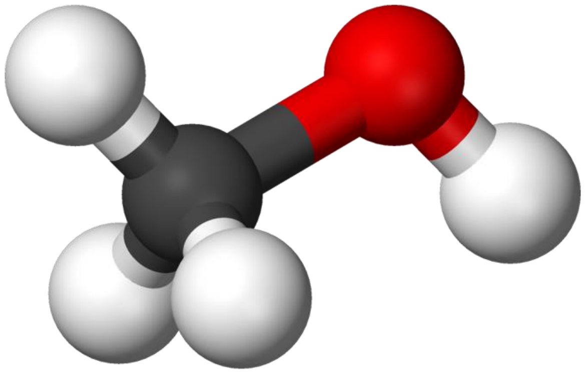


Methanol production

Methanol could be produced according to

$CO_2 + 3 H_2 \rightarrow CH_3OH + H_2O$

$CO + 2 H_2 \rightarrow CH_3OH$



Disatvantages:

- No existing infrastructure for direct usage in transportation sector
- For the production process of renewable methanol, it is necessary to consider:

• storage of hydrogen

• production, storage and distribution of methanol

• methanol utilization

Methanol production

Advantages:

- Relatively simple and efficient production
- It is possible to convert methanol to gasoline

$$nCH_3OH \rightarrow (CH_2)_n + nH_2O$$

Gasoline can be used immediately in existing infrastructure

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Boosting the production with external hydrogen - Gasoline

Configurations

- Allothermal gasif./steam
- Autothermal gasif./steam+oxygen

Input

- 100 MW (LHV) of wet (50%) biomass (5,92 kg/s of dry biomass)

Output gasoline

Steam gasification

- 51,0 MW / 98,0 MW

Oxygen gasification

- 51,8 MW / 134,0 MW

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ELSEVIER

Hydrogen enhancement potential of synthetic biofuels manufacture in the European context: A techno-economic assessment

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ABSTRACT

Potential to increase biofuels output from a gasification-based biorefinery using external hydrogen supply (enhancement) was investigated. Up to 2.6 or 3.1-fold increase in biofuel output could be attained for gasoline or methane production over reference plant configurations, respectively. Such enhanced process designs become economically attractive over non-enhanced designs when the average cost of low-carbon hydrogen falls below 2.2–2.8 €/kg, depending on the process configuration. If all sustainably available wastes and residues in the European Union (197 Mt/a) were collected and converted only to biofuels, using maximal hydrogen enhancement, the daily production would amount to 1.8–2.8 million oil equivalent barrels. This total supply of hydrogen enhanced biofuels could displace up to 41–63 per cent of the EU (European Union)'s road transport fuel demand in 2030, again depending on the choice of process design.

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HSLU Lucerne University of Applied Sciences
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Table 2
Summary of examined plant configurations.

Configurations	Gasifier type	Stoichiometry adjusted by	CO_2 removal	Electrolyser	ASU[a]	End product
OG	O_2	Sour shift	Yes		Yes	Gasoline
OG+	O_2	H_2 addition		Yes		Gasoline
OM	O_2	Sour shift	Yes		Yes	Methane
OM+	O_2	H_2 addition		Yes		Methane
SG	Steam	Gasifier	Yes		Yes	Gasoline
SG+	Steam	H_2 addition		Yes		Gasoline
SM	Steam	Gasifier	Yes		Yes	Methane
SM+	Steam	H_2 addition		Yes		Methane

[a] ASU = cryogenic Air Separation Unit.

Boosting the production with external hydrogen - Gasoline

By an external hydrogen source following maximal fuel output could be achieved:

- **1,9 – fold for steam gasification**
- **2,6 – fold for oxygen gasification**

Overall carbon conversion for enhanced configurations:

- **58,4 % for steam gasification**
- **79,4 % for oxygen gasification**

Economically feasible over base case when hydrogen cost is lower than:

- **2,7 €/kg for steam gasification**
- **2,8 €/kg for oxygen gasification**

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Economics

Important parameters influencing the electrofuel price:

- Costs of renewable hydrogen
- Costs of biomass
- Size of gasification unit
- Number of operating hours
- Heat utilization
- Usage or selling of oxygen from electrolysis
- Subsidy

Conclusions

- Thermal gasification as a source of carbon for electrofuels production offers a great possibility of technologies and products synergies
- Renewable hydrogen access is not essential for the gasification process but boosts the amount of final product (fuel) significantly

Price of electrofuels is still higher as of fossil ones,

but what price do we really pay for fossils?





Thank you very much for your attention

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