ETIP Bioenergy
European Technology and Innovation Platform

Gasification as key enabling technology for advanced biofuels

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ETIP-B WG 2

Clara public workshop
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TU Darmstadt

The European integrated SET plan

- The integrated European Strategic Energy Technology Plan (SET plan) identifies 10 actions for R&I, biomass related ones:
  - Integrating renewable technologies
  - Reducing costs of technologies
  - Resilience and security of energy systems
  - Energy efficiency in industry
  - Renewable fuels and bioenergy
  - Carbon capture and storage

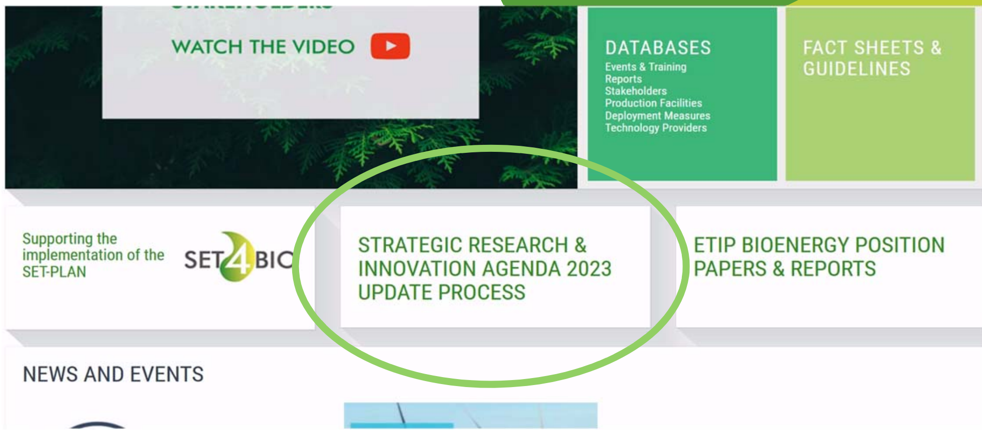
- European technology and innovation platforms (ETIP) support the implementation of the SET plan bringing together industry and researchers in key area in EU countries.
- In addition, the SET plan consists of the European Energy Research Alliance (EERA) and the SET plan Information System (SETIS)

ETIP Bioenergy

- Stakeholder forum for renewable fuels and bioenergy
- Focusing on research, development and deployment (RD&D)
- Recognised by the European Commission as key actor
  Important tool: the strategic research agenda (SRIA)

- Structure
  - Steering Committee
  - WG1 Biomass availability
  - WG2 Conversion
  - WG3 End-Use
  - WG4 Policy and Sustainabilty
  - Biomethane Task Force

SRIA update



- Goal: Provide the basis for EU´s RD&D on renewable fuels and bioenergy
- Content:
  - Latest technological developments,
  - Weaks and strengths of different technologies, recommendations for their development and deployment, outlook to beyond 2030
  - Biomass availability
  - Deployment of renewable fuels and bioenergy so far
  - Specific markets: e-fuels, aviation, shipping, biomethane
- Elaborated by a series of online expert work meetings 01-03.2023

ETIP: an open forum to each interested and committed partner

Outlook from SRIA draft revision

- Gasification-based technologies need to contribute if we are to meet targets in the transport sector
- Advanced biofuel target for 2030 already require a few hundred new advanced biofuel production plants at average size of 50.000 - 100.000 t/y (beyond HVO)
- Specific comments to gasification based process routes
  - Gasification technology has to adapt to different feedstocks, e.g. waste
  - Downstream technology should be chosen with respect to the $CO:H_2$ ratio
  - Consider implementation of renewable hydrogen
  - Syngas fermentation to new products
  - Hydrogen production
  - Solutions for logistics of feedstocks are needed

Examples from our own work

Renewable hydrogen integration

Expectations at the example of biomass gasification based fuels
to compensate for hydrogen deficit and by-produced CO_2

Lignocellulose gasification	$C_6H_8O_4 + 2\ O_2 \rightarrow 5.2\ CO + 2.8\ H_2 + 0.8\ CO_2 + 1.2\ H_2O$
Water-gas-shift	$2.5\ CO + 2.5\ H_2O \leftrightarrows 2.5\ CO_2 + 2.5\ H_2$
Sum after shift	$C_6H_2O_4 + 2\ O_2 \rightarrow 2.7\ CO + 5.3\ H_2 + 3.3\ CO_2$
BtL synthesis	$2.7\ CO + 5.3\ H_2 \rightarrow 2.7$ "CH_2" $+ 2.7\ H_2O$
RWGS	$3.3\ CO_2 + 3.3\ H_{2,ext} \leftrightarrows 3.3\ CO + 3.3\ H_2O$
PtL synthesis	$3.3\ CO + 6.6\ H_{2,ext} \rightarrow 3.3$ "CH_2" $+ 3.3\ H_2O$
PBtL	$C_6H_8O_4 + 2\ O_2 + 10\ H_{2,ext} \rightarrow 6$ "CH_2" $+ 8\ H_2O$
Water electrolysis	$10\ H_2O \leftrightarrows 10\ H_2 + 5.5\ O_2$


bioliq plant, KIT
Energy Lab 2.0, KIT

1. H_2 boosted bioliq process with FT synthesis

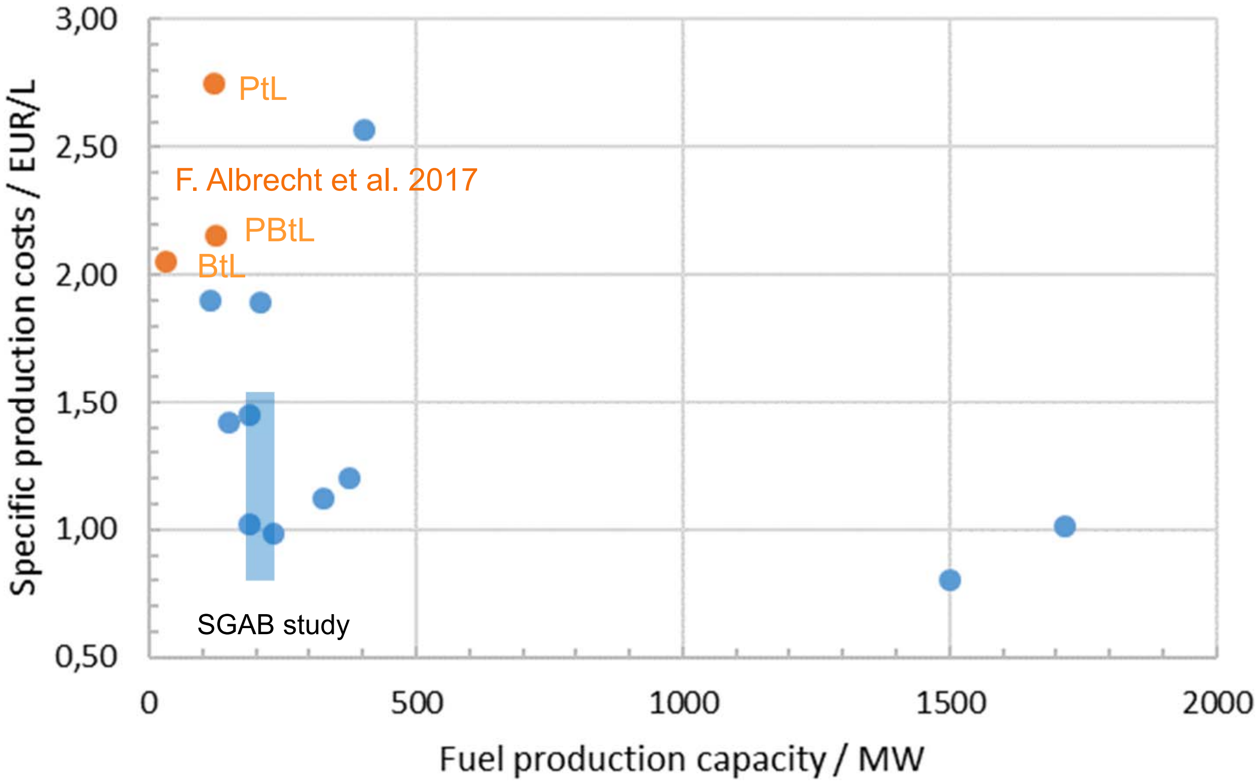
- Thermal fuel capacity: 110 MW_{th}
- Share of electricity costs: 50.7 %
- Full heat integration and export

	BtL	PBtL	PtL, max
Product capacity / MW	32.6	123.3	123.5
Carbon conversion	24.9 %	97.7 %	99 %
Fuel efficiency	29.8 %	45 %	46.2 %
Overall efficiency	63.0 %	56.6 %	62.4 %
Net production cost / EUR/L_{ge}	2.05	2.15	2.75

F. Albrecht et al., Fuel 194 (2017)

Production cost estimate

- Meta-study on production costs of FT-fuels from wood biomass via the bioliq process

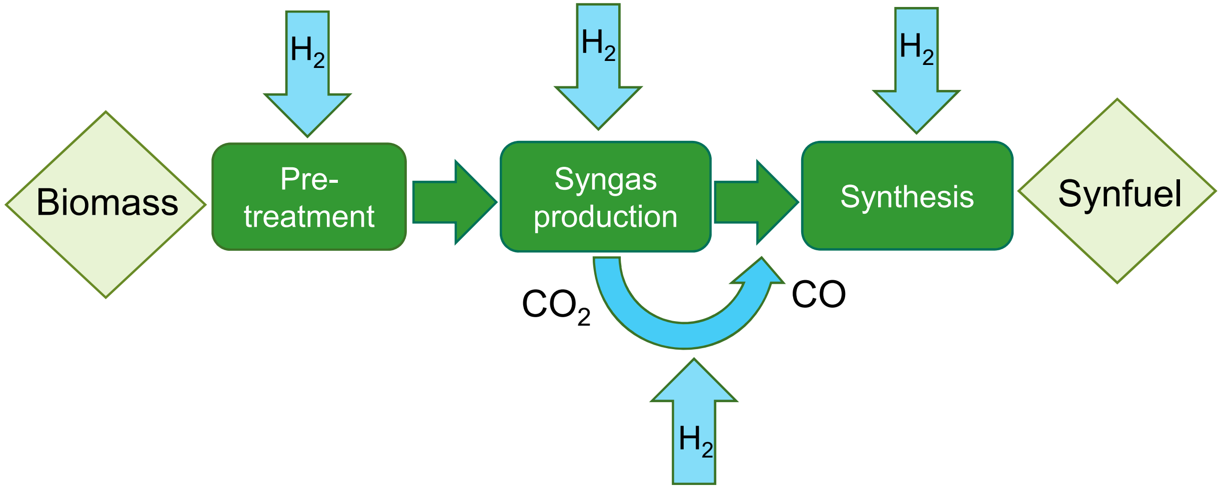


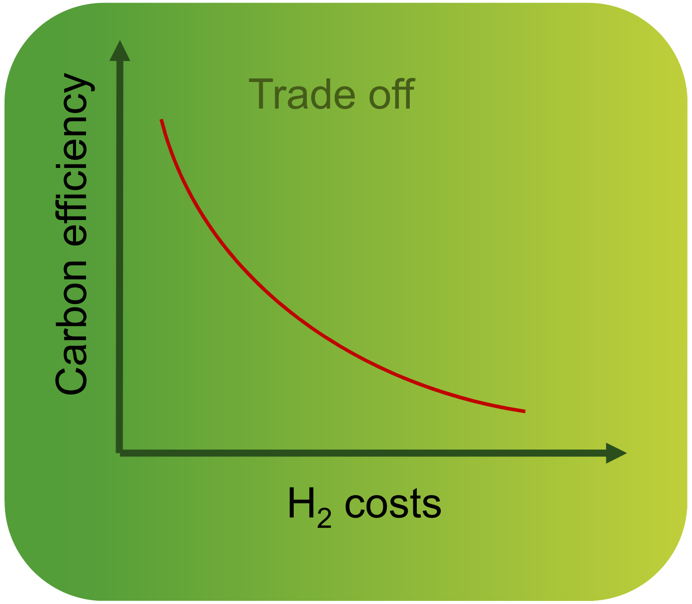
N. Dahmen, J. Sauer, Processes (2021)

Options for hydrogen feed-in

Biomass gasification processes

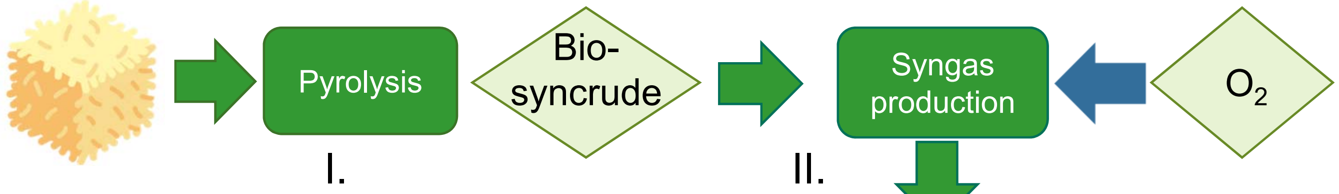
- Carbon dioxide capture and reverse-water-gas-shift reaction
- Addition of hydrogen to gasification of biomass
- Addition of hydrogen to fuel synthesis

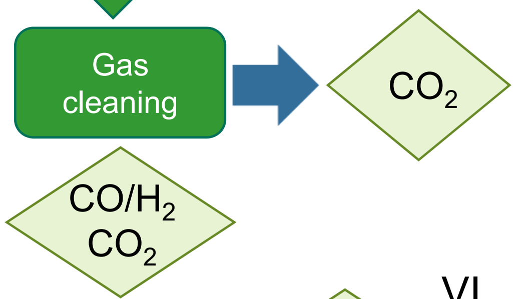




2. H_2 boosted bioliq process with MtG

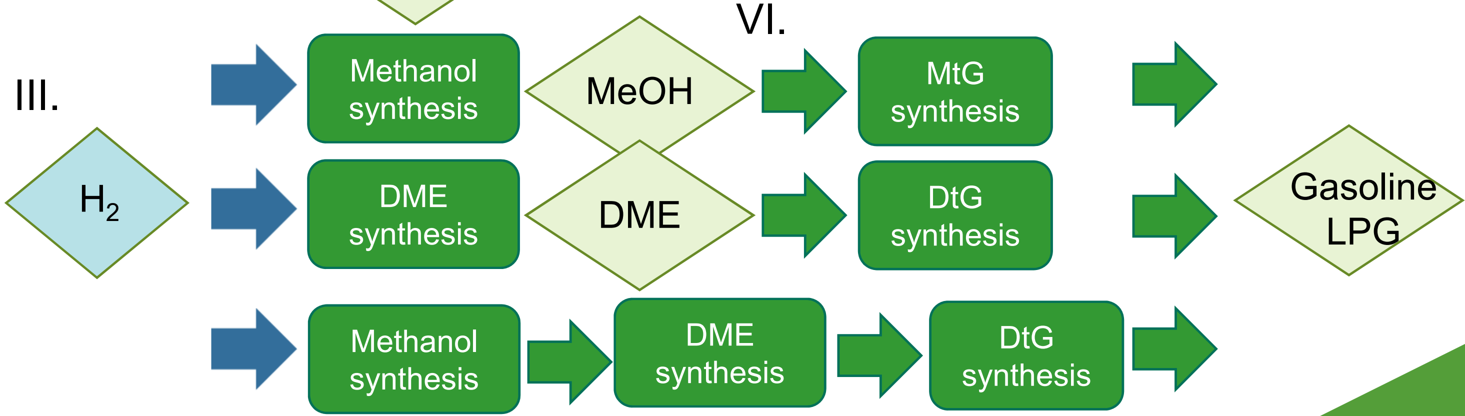
Addition of H_2 to synthesis





I. Fast pyrolysis for bio-oil production
II. HP entrained flow gasification
III. Renewable hydrogen supply
IV. Methanol/DME to gasoline processes

Syngas	Vol.%
CO	36.0
H_2	35.0
CO_2	18.0
CH_4	2.0
H_2O	6.0



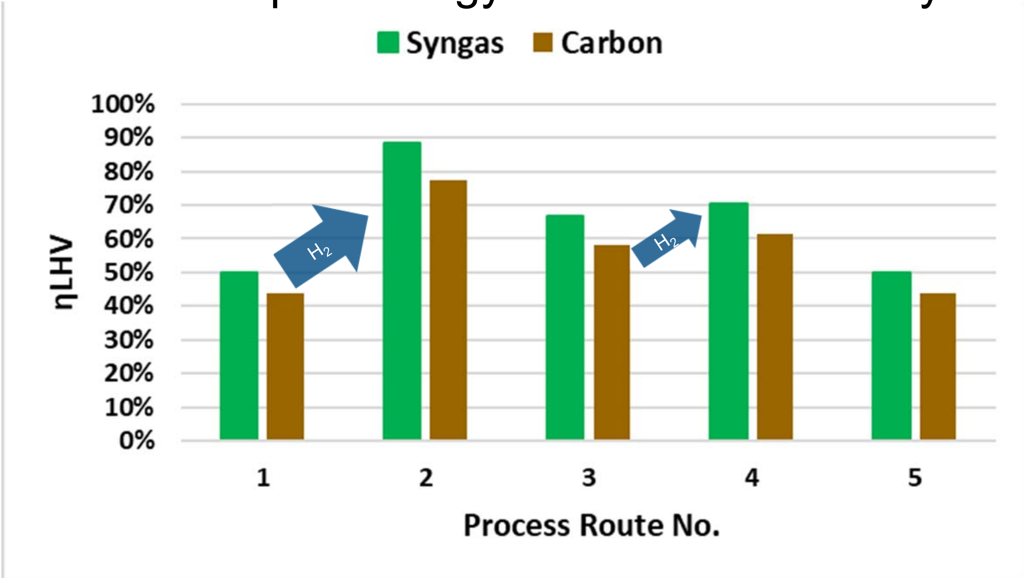
H_2 boosted bioliq process with MtG

Addition of H_2 to synthesis

reFuels

- Gasoline production from biomass based syngas ($CO/H_2 \cong 1$)
- Simulations with kinetic models validated by data from industrial plants
- In total, synthesis via MeOH can most benefit from H_2 addition, while fuel via DME performs better without H_2 supply.

Nahpha energy and carbon recovery



1: via one step MeOH synthesis
2: via one step MeOH + external H_2
3: via one step DME synthesis
4: via one step DME + external H_2
5: two step MeOH/DME synthesis

M. Ebrahimi, KIT-IKFT

H_2 boosted bioliq process with MtG

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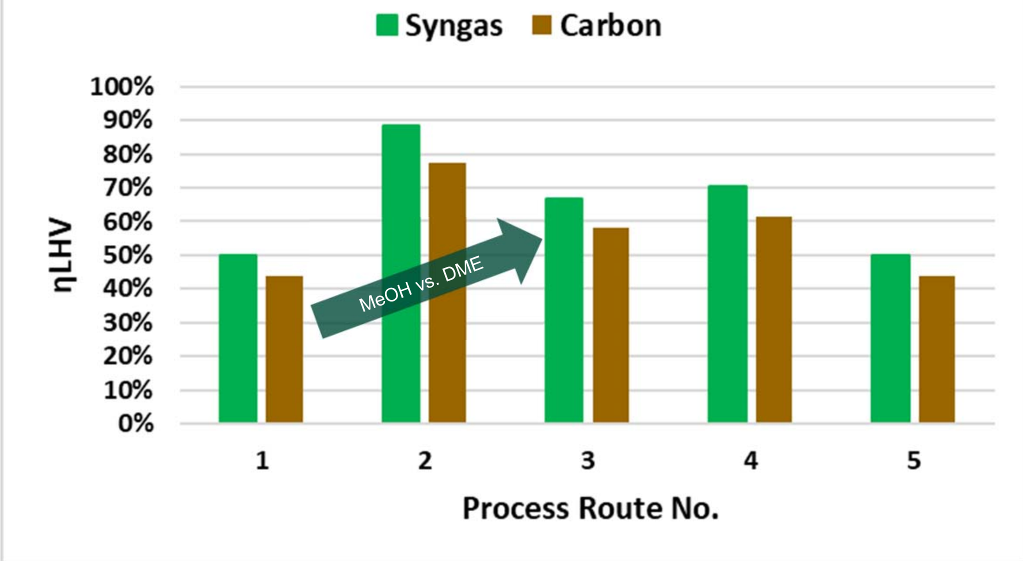

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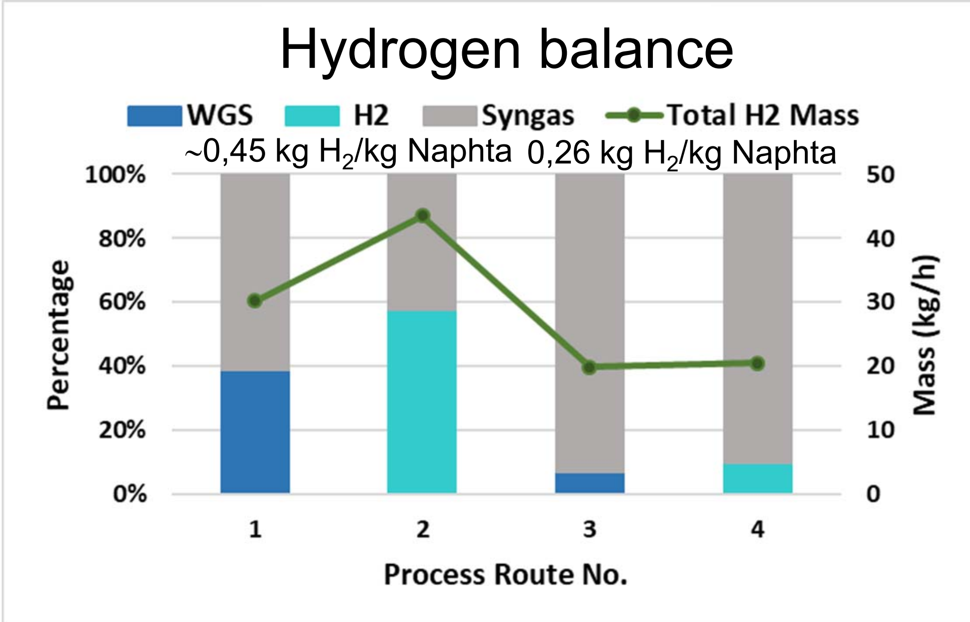
H_2 boosted bioliq process mit MtG

Addition of H_2 to synthesis

- Gasoline production from biomass based syngas ($CO/H_2 \cong 1$)
- Simulations with kinetic models validated by data from industrial plants
- In total, synthesis via MeOH can most benefit from H_2 addition, while fuel via DME performs better without H_2 supply
- DME route promises to be a good compromise in terms of costs!

M. Ebrahimi, KIT-IKFT



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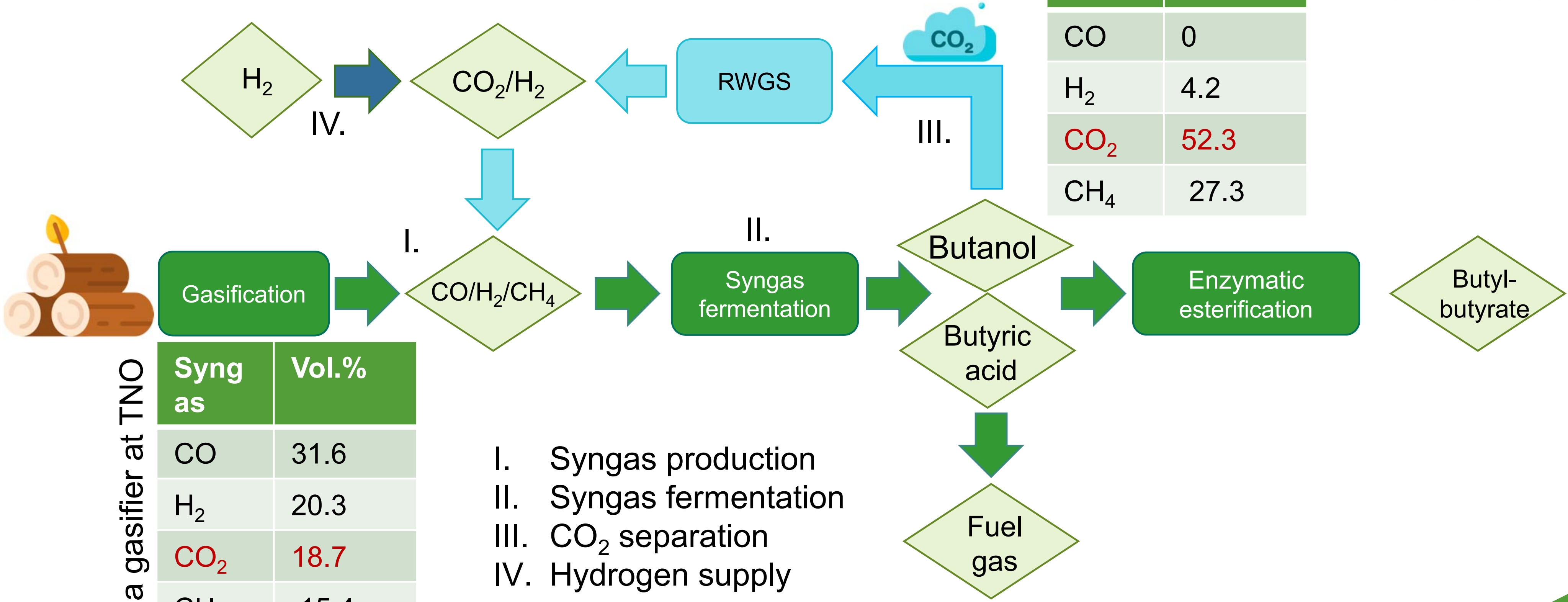
3. Syngas fermentation to C_4/C_8 hydrocarbons



Gas	Vol.%
CO	0
H_2	4.2
CO_2	52.3
CH_4	27.3

Milena gasifier at TNO

Syngas	Vol.%
CO	31.6
H_2	20.3
CO_2	18.7
CH_4	15.4
H_2O	4.8

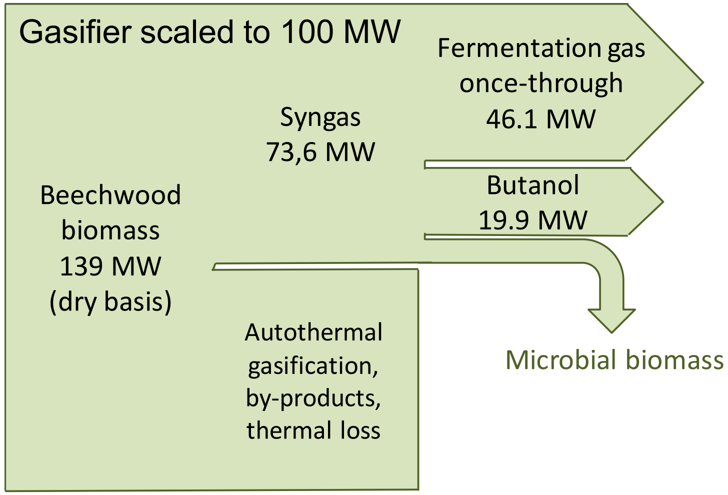
I. Syngas production
II. Syngas fermentation
III. CO_2 separation
IV. Hydrogen supply

Liakakou et al. (2021), Fuel 290, 120054.

Energy balance from syngas fermentation

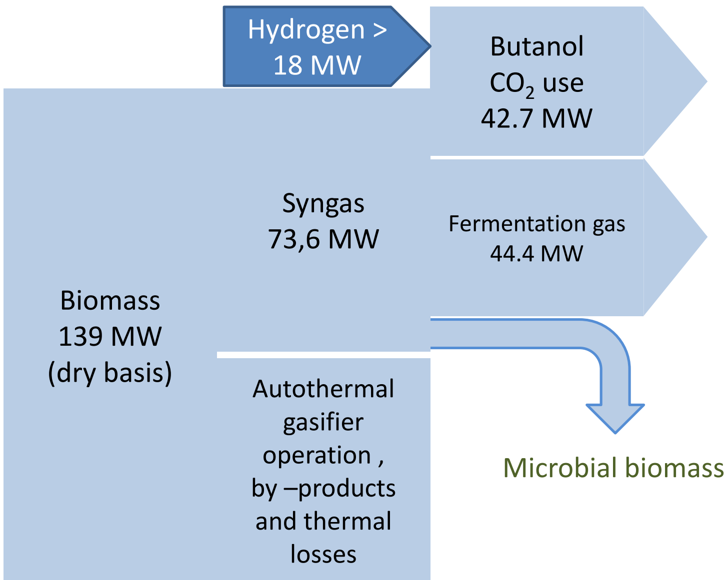
Addition of H_2 to fermentation gas

Case 1: Once through



C-recovery:
21.2 % beechwood
17.0 % lignin

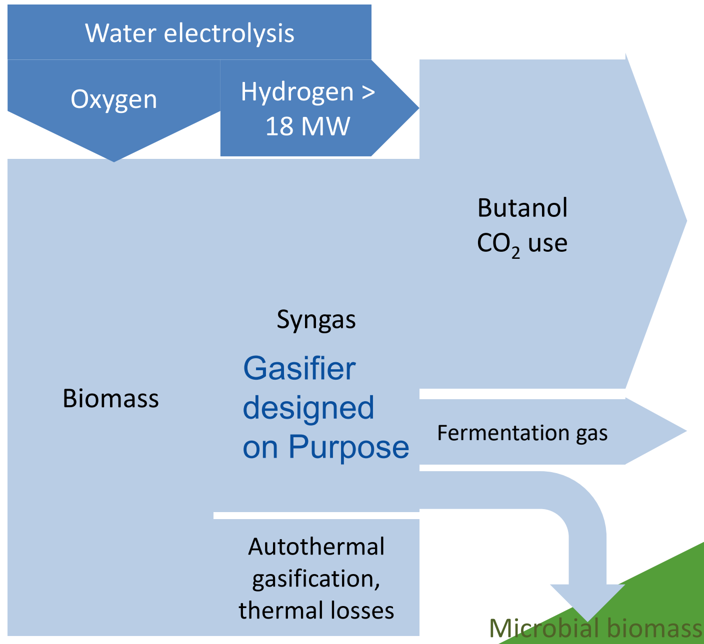
Case 2: CCU



74.1 % beechwood
79.3 % lignin

Specific production cost reduce by 50% when increasing the yields by a factor of ~ 4!

Further improvment?!



AMBITION final report; ambition-research.eu

European Technology and Innovation Platform

www.etipbioenergy.eu

Project Partners

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