Hydrogen produced from gasification and implemented in gasification

Workshop report

IEA Bioenergy: Task 33

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Introduction

The workshop, which took place in Edmonton, Canada on the 19. April 2023 gave an overview of gasification activities that focus on sustainable production of climate positive hydrogen.

Today, hydrogen is predominantly produced from fossil fuels. Anyway, its production from biomass via gasification can be an auspicious alternative for future decarbonized applications, which are based on renewable and carbon-dioxide-neutral produced hydrogen.

Production of renewable hydrogen, which can be considered as one of the most important energy carriers in the future, beside of renewable SNG or liquid biofuels is coupled with new challenges and drawbacks.

Overall, it can be stated, that governmental support and subsidies are necessary for successful implementation of hydrogen production based on biomass gasification technologies. Especially the first 15 years of the development towards market maturity and stable operation and production are critical and will need political support systems.

Workshop presentations

Gasification for hydrogen production in China: Company activity
/ G. Chen, Tianjin University

Nowadays, less than 10 gasification plants for hydrogen production are in operation in China, nevertheless, several plants are now in planning or under construction.

Three case studies were detailed presented during the workshop.

Table 1: Case studies on hydrogen production

No.	Location	Company	Demo-projects
Case 1	Ma ' Anshan, Anhui Province	China Datang Corporation Science and Technology General Research Institute Co. Ltd.	Biomass gasification-chemical looping hydrogen generation
Case 2	Wuhan, Hubei Province	WUHUAN Engineering Co., Ltd.	Biomass high-temperature gasification for hydrogen production technology
Case 3	Hefei, Anhui Province	Debo Energy Co., Ltd.	12MW Circulating Fluidized Bed for gasification coupled power generation

Case 1: Biomass gasification-chemical looping hydrogen generation

- Bio-CLHG system (Pilot scale/Demo scale)
- Feedstock: Biomass pellet Biomass treating: 15 kg/h
- Products: Hydrogen-Heat-Electricity
- Energy efficiency: >57%
- Syngas composition:
  CO: 15~30%, H2: 10~18%, CH4: 1~4%, CO2: 5~14, N2: 45~60%
- Gas yield: ~2 Nm3/kg
- Heating Value: 4.5~6 MJ/Nm3
- Gasification efficiency: 74~78%
- Bio-CLHG:
  - High purity of CO_2 was obtained in the reduction stage
  - H_2 purity via the Bio-CLHG reaches 90%-95%, others are uncondensed gas, and little residual syngas
  - Stable H2 production: 10 Nm^3/h

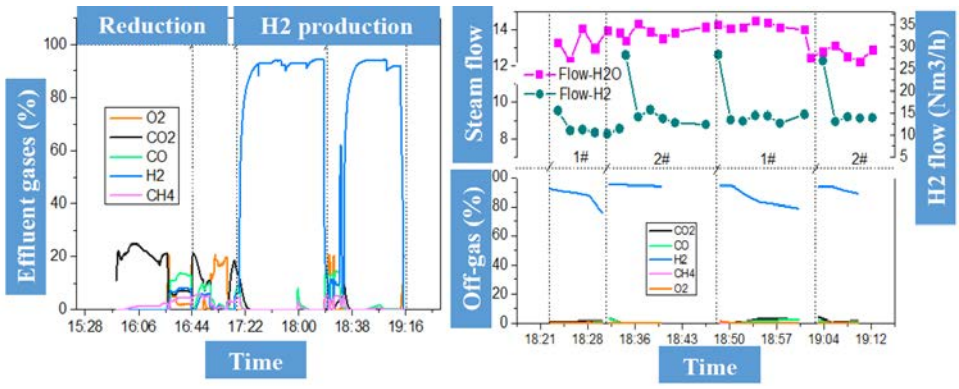


Figure 1: Bio-CLHG

Case 1 – Perspectives

- High efficiency Biomass gasification with Low tar yield.
- Large scale production of oxygen carrier with high reactivity and stability.
- Flexible, automatic and easy-control gasification & H2 production system.

Case 2: Biomass high-temperature gasification for hydrogen production technology

- Anaerobic pyrolysis of raw waste
- HT Gasification treatment of organic matter
- HT Melting treatment of inorganic matter

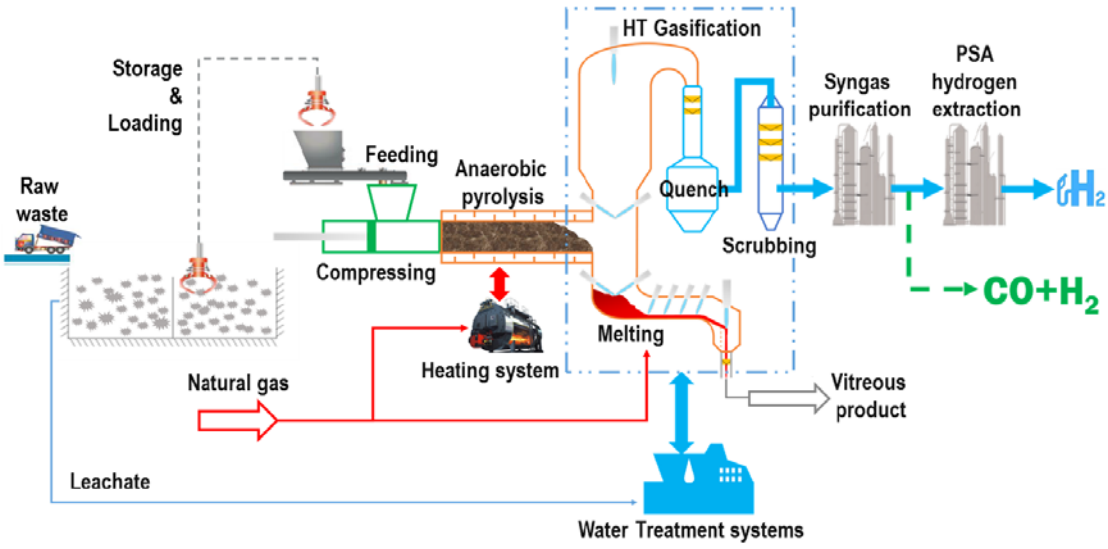


Figure 2: Process flow diagram

- Capacity 2ktons/day
- Feedstock: biomass, MSW, RDF, sludge

Case 2 – Perspectives

- A stable source of raw biomass
- Stable hydrogen applications scenarios
- Industrial coupling with existing ne energy to produce hydrogen

Case 3: Gasification cogeneration system-Downdraft fixed bed /Updraft fixed bed/ Fluidized bed

At the moment more than 100 operational cases in China and abroad.
Examples:

- The project of state grid Hubei Wuhan's 10.8MW circulating fluidized bed gasification coupled power generation
- The project of Huadian's 12MW Circulating Fluidized Bed for gasification coupled power generation in Xiangyang, Hubei
- The project of biomass gasification for electricity generation in Greece
- The project of biomass gasification for electricity generation in Slovenia

Case 3 – Perspectives

Development direction of biomass gasification:

Methanol production, aviation fuel production, hydrogen production.

Torrgas modular syngas platform for the production of green hydrogen, circular synthetic chemicals and biofuels
/ R. Post van der Burg

Torrgas solution: Two-stage gasification of torrefied biomass

Table 2: Two-stage gasification of torrefied biomass

Item	Feature
Step 1: low temperature gasification (< 750°C)	+ Removal of ash from pyrolysis gas => no ash in temperature gasifier => reduction in problems (no slagging)
	+ High quality byproduct: char
	- Lower efficiency to syngas
Step 2: high temperature gasification (~ 1200°C)	+ Cracking of tars => robust technology, high quality for application in catalytic processes 0.1 mg/Nm^3 dry basis)*
Step 2: oxygen based gasification	+ nitrogen free syngas => high quality syngas for application in the process industry

* typical for biomass gasifiers: FB 6,000-14,000 mg/Nm^3, downdraft 400-800 mg/Nm^3

Hydrogen project under development:

- 50 MWth torrefied biomass input
- External torrefaction
- H_2 production capacity 6.5 kton/a @ 40 bar
- H_2 quality acccording to local grid specifications
- Byproducts: biochar, Foodgrade CO2 (local offtake)

Figure 3: Hydrogen project under development

Decentral production of PEMFC suitable hydrogen from air gasification of wood

/ V. Gubin, F. Thelen

Project FCTRAC – production of green hydrogen from biomass and residues

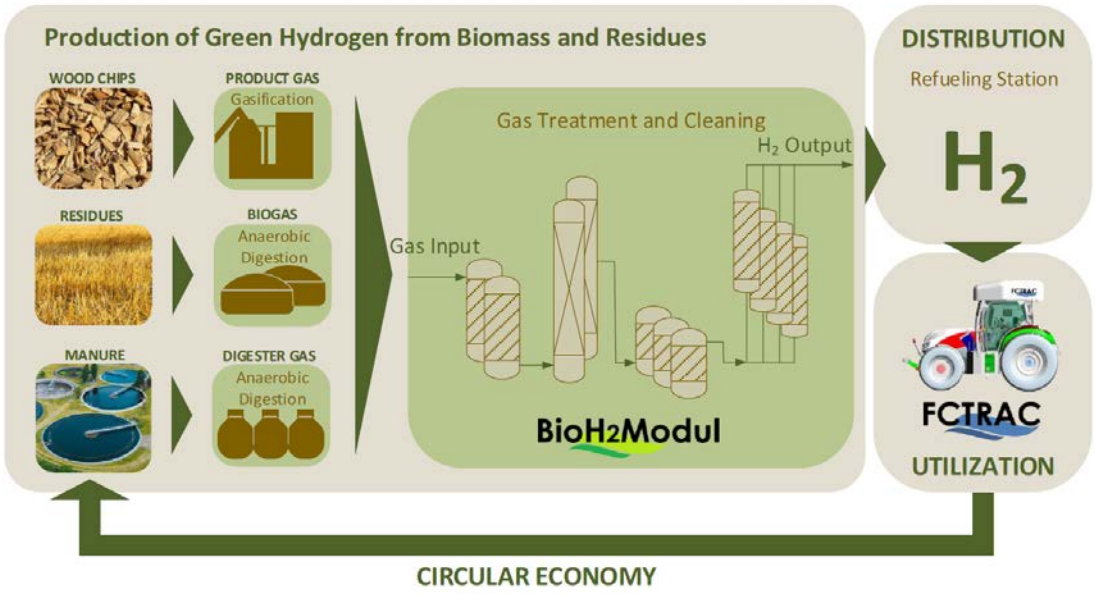


Figure 4: Project FCTRAC

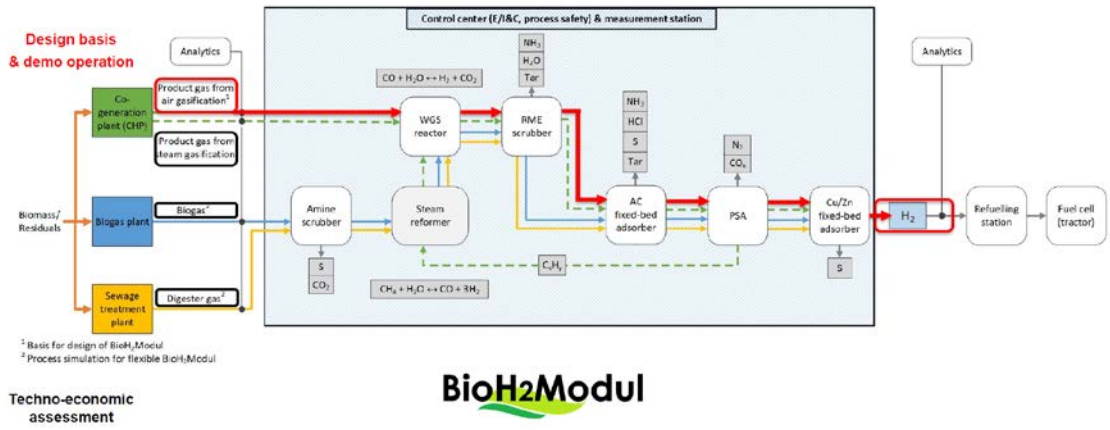


Figure 5: Process chain for hydrogen production from biomass-derived gases

The hydrogen produced will be in ISO 14687 quality.

Next steps:

- Detailed engineering completed
- Ongoing plant approval procedure
- Commissioning of $BioH_2$-modul in September 2023

Mini $BioH_2$ modul – experiments with a lab-scale PSA plant for hydrogen production from synthetic gas mixtures:

- Adsorbent screening with manual operation of the PSA
- Selection of adsorbents and determination of adsorbent quantities
- Automated operation of the PSA

So far achieved:

Table 3: Mini $BioH_2$ Modul

	Key performance indicators: H_2-…			
Process efficiency	Purity	φ_{H2} =	> 99,9	[Vol.%]
	Recovery	Y_{H2} =	79,0	[%]
	Productivity	P_{H2} =	1,33	[Nl/(kg·min)]

Circular economy pilot plants and projects at the RWE Innovation Centre / T. Ginsberg

RWE is conducting research into the possible uses of hydrogen in the GET H2 project and through the installation of a 105-MW power-to-gas electrolysis facility in Lingen, Germany. RWE is also a partner in hydrogen research in the region of Groningen, Netherlands, and South Wales, UK.

RWE develops innovative Waste-to-Products processes.

As a feedstock sewage sludge is used for production of hydrogen/SNG/chemicals/fuels and waxes.

Frow sewage sludge will be phosphorus and phosphoric acid recovered and produced.

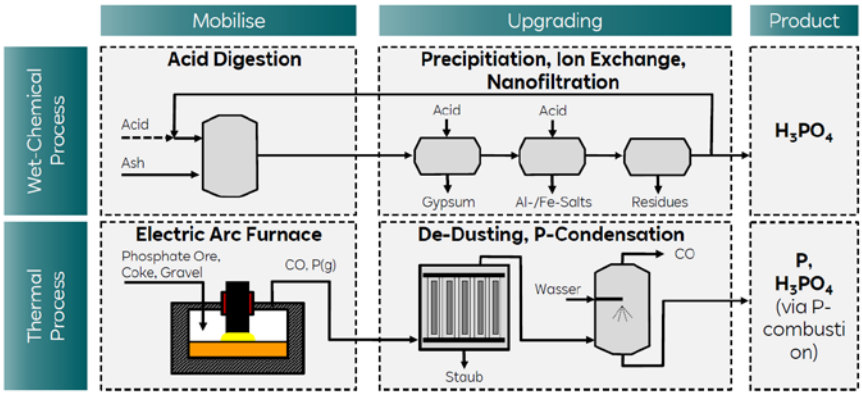


Figure 6: Wet-chemical and thermal processes comparison

In the project ITZ-CC an erection of Multi Fuel Conversion Pilot Plant (MFC) was planned. RWE cooperates with Frauenhofer UMSICHT and Ruhr Universität Bachum as project partners.

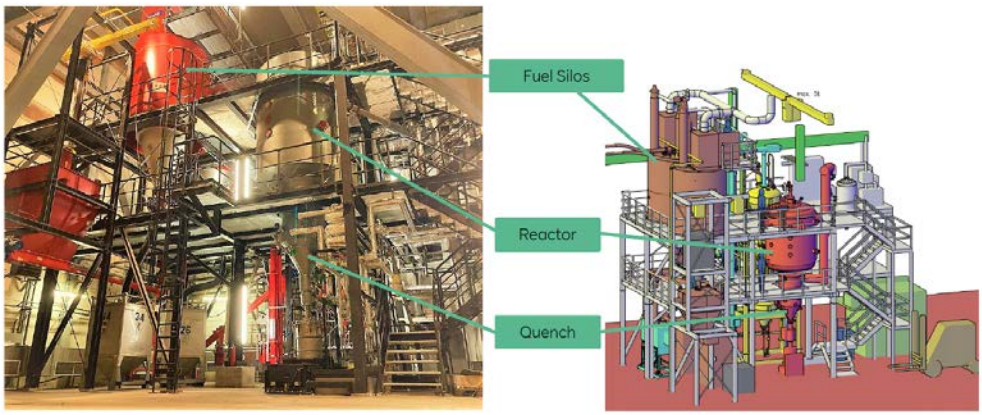


Figure 7: Multi Fuel Conversion Pilot Plant

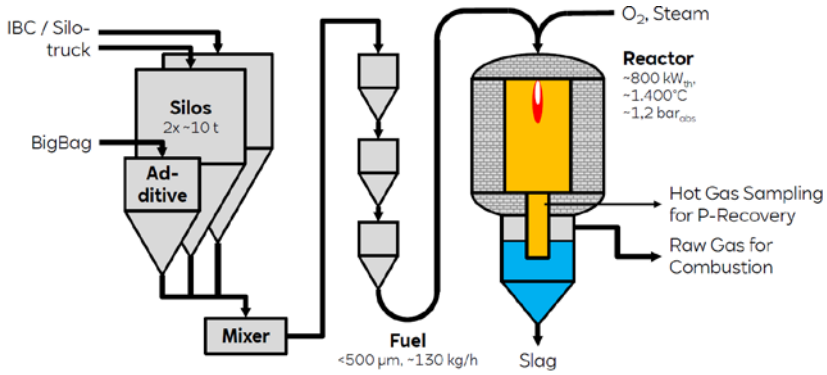


Figure 8: EF reactor

RWE focuses on hydrogen production from MSW as well. FUREC converts non-recyclable waste into feedstock via waste pre-treatment at Buggenum site and converts it into synthesis gas.

Green hydrogen from waste - Plagazi
/ R. Bock

Green hydrogen production from non-recyclable waste is a Swedish patented technology.

The Plagazi patented process can be seen in the following figure. From waste is using a plasma reactor syngas produced, which could be converted into green hydrogen. The by-product is CO_2, which is captured directly.

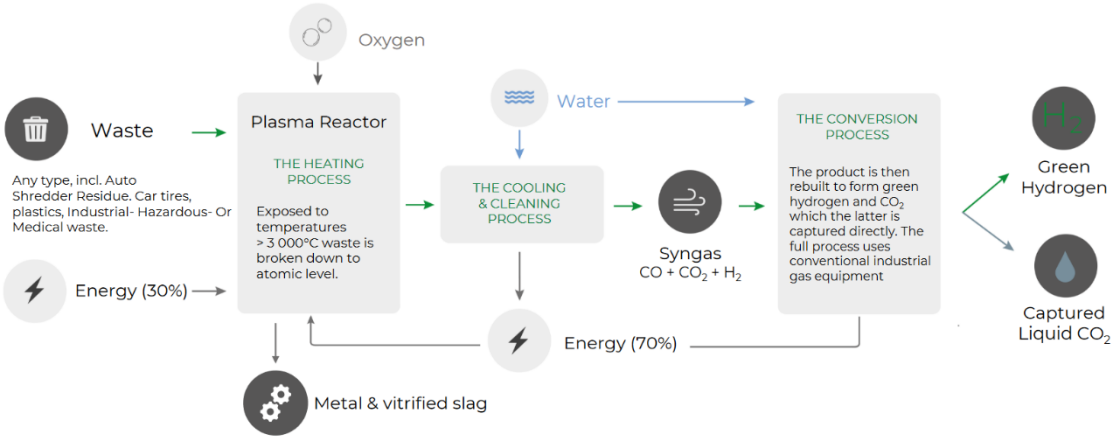


Figure 9: Plagazi process

Plagazi has several actual projects, some of them are visible in the figure below.

Figure 10: Plagazi – actual projects

One of the projects is in Köping, which starts in 2025.

Köping hydrogen park

- Project start 2025
- 51 MW green hydrogen
- 10 MW electricity consumption
- <10 kWh / KG H2
- 66 000 tons waste recycled
- 10 MW district heating
- 150 000 tons CO2 caught via CCS
- Investment 1500 Mill. SEK

- Partners

Northern Lights, SANDVIK, Petrofac, Carbfix, Atlas Copco, ABB, Alfa Laval, Nordkalk, Köpings Kommun, PowerCell, Inlandsbanan

Synergies of green hydrogen and bio-based value chains deployment / J. Lundgren

There are many pathways to produce green-hydrogen…

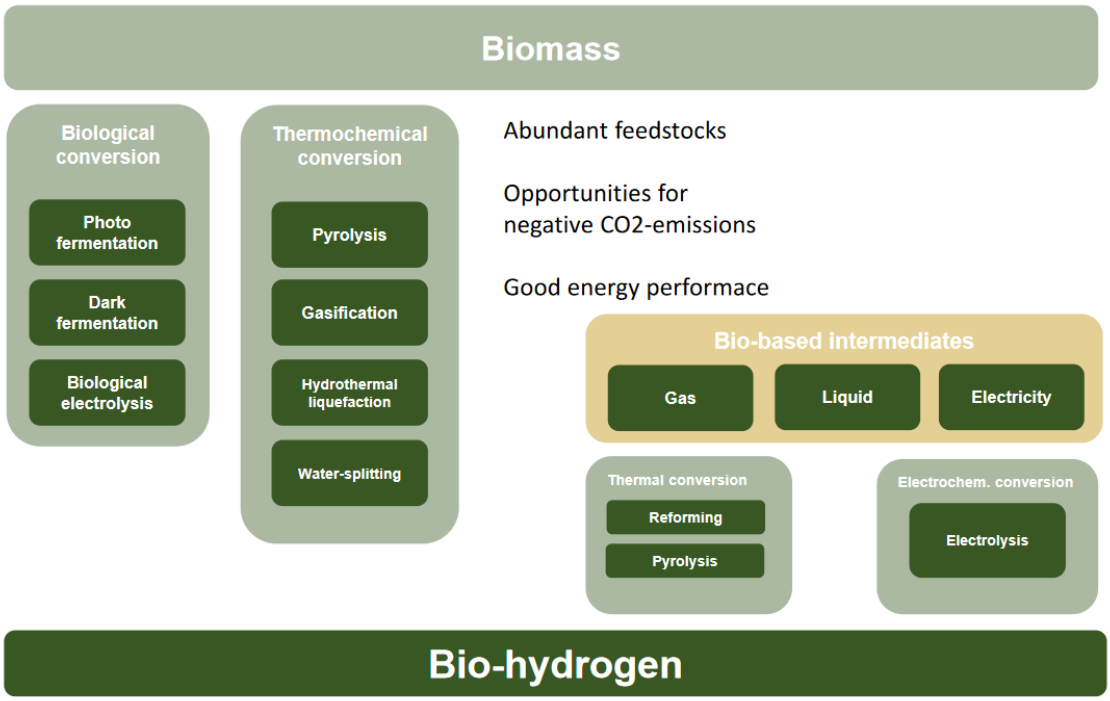


Figure 11: Hydrogen production pathways

…as well as many options for integrating hydrogen in bio-conversions:

- Gasification based processes
- Pyrolysis/HTL based processes
- Microbial processes

Biomass conversion technologies have limited carbon efficiencies, but addition of hydrogen improves this.

• Gasification-based biofuel production has great potential for integration - Doubled (or even tripled) yield from the same amount of biomass.

• The carbon efficiency can increase to over 90 percent if the energy and hydrogen for the process are taken from electricity instead of from the biomass raw material.

• The GHG-performance of bio-electro-fuels is good if the GHG footprint of the electricity used in the process is low.

Intertask project on green hydrogen – aims:

- Illustrate how green hydrogen and bio-based value chains can support each other
- Identify and assess the synergies in between green hydrogen and bio-based value chains in different sectors and at different timeframes
- Technology maturities, economics, sustainability performances, and infrastructural topics are addressed through Case Studies.
- What is needed to realize the potential of these synergies?
- The project will provide science-based views on several value chains, the drivers and barriers for the deployment, and measures to overcome barriers.

Production of bio-electrofuels at LTU Green Fuels
/ F. Granberg

LTU Green Fuels is a R&D centre with globally recognized truck record. The detailed information regarding gasification and synthesis process can be seen in the table below.

Table 4: LTU Green Fuels – technical data of the process

Gasification, *(Pressurized, oxygen-blown Chemrec technology)*	**Gasification + Synthesis**
3 MW, 20 t DS/day of black liquor (biomass)	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 Bio-methanol produced
Co-gasification with pyrolysis oil (150 ton) tested >1000 h	> 1 000 ton Bio- DME produced

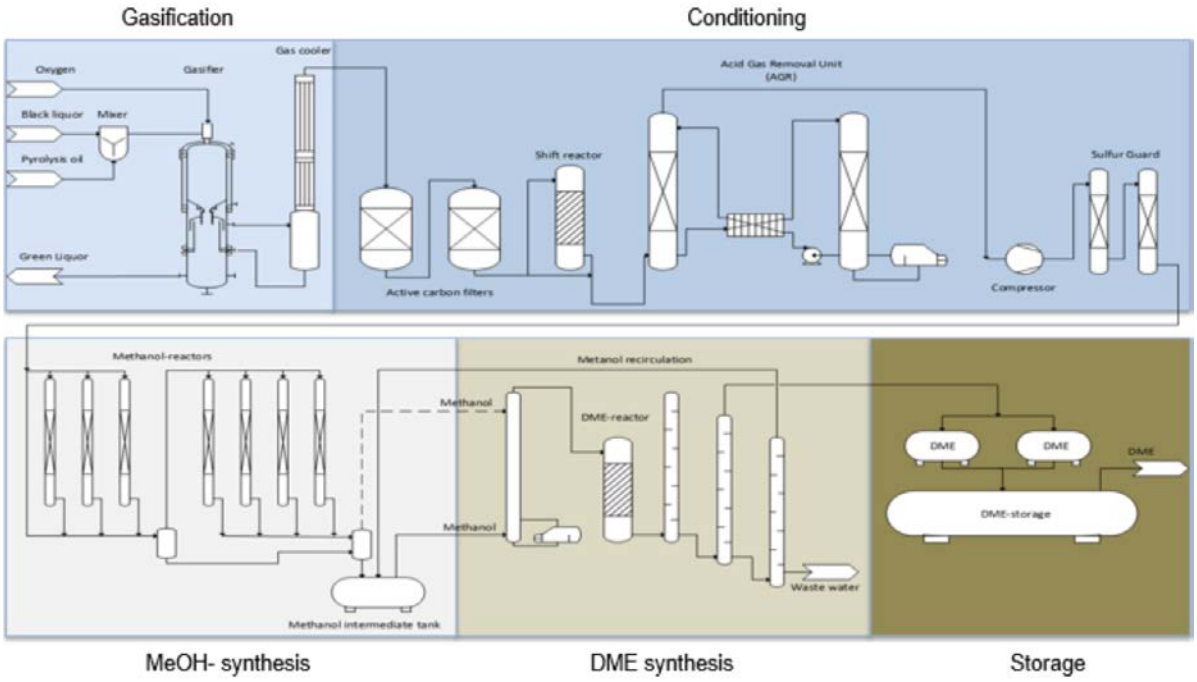


Figure 12: Green fuels flow sheet

In 2018-2020 a pre-study on SAF pilot plant (1t/day) was conducted.

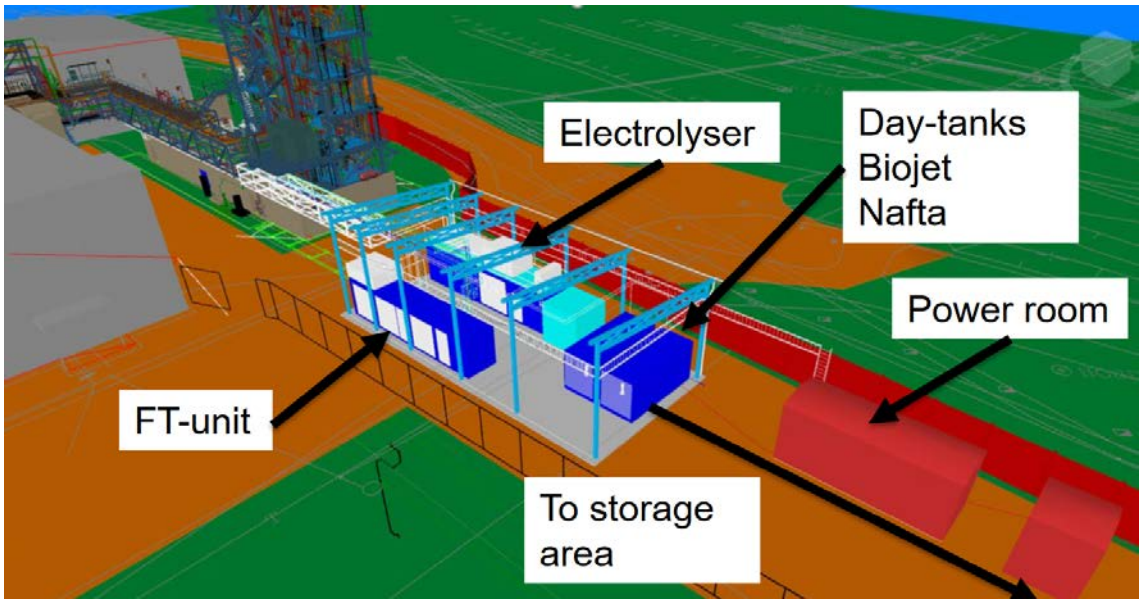


Figure 13: SAF pilot plant

The study included also hydrogen boosted FT production. In that case the production of a jet fuel could be boosted of 33% and naphtha production of 28%.

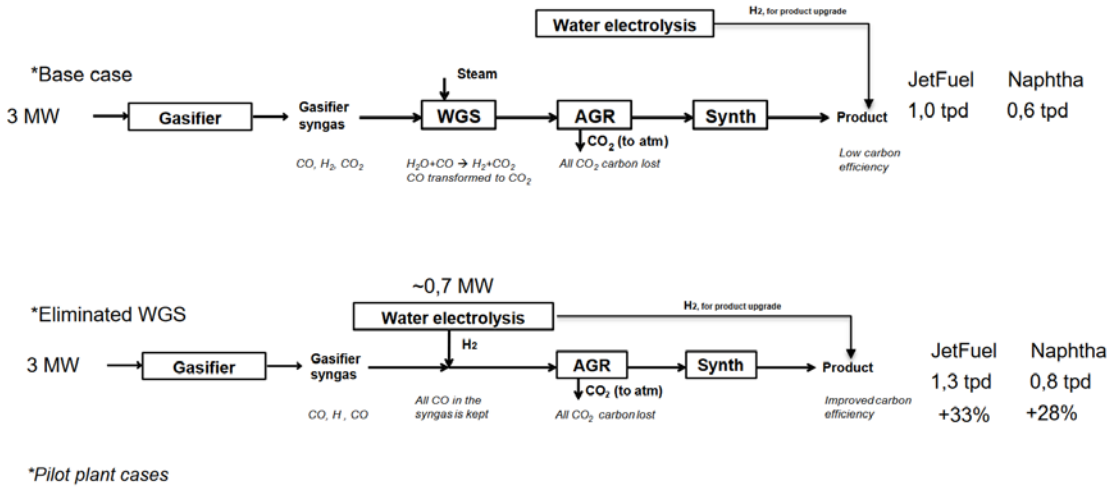


Figure 14: Graphics of base case in comparison with hydrogen-boosted production

In 2020-2023 project TREEPOWER – sustainable aviation fuel is conducted. The concept is based on a pre-feasibility study for SAF in Northern Sweden. The study shows that it could be possible to produce 35 000-70 000 ton/year FT-crude. An example of this new concept can be seen in the following figure.

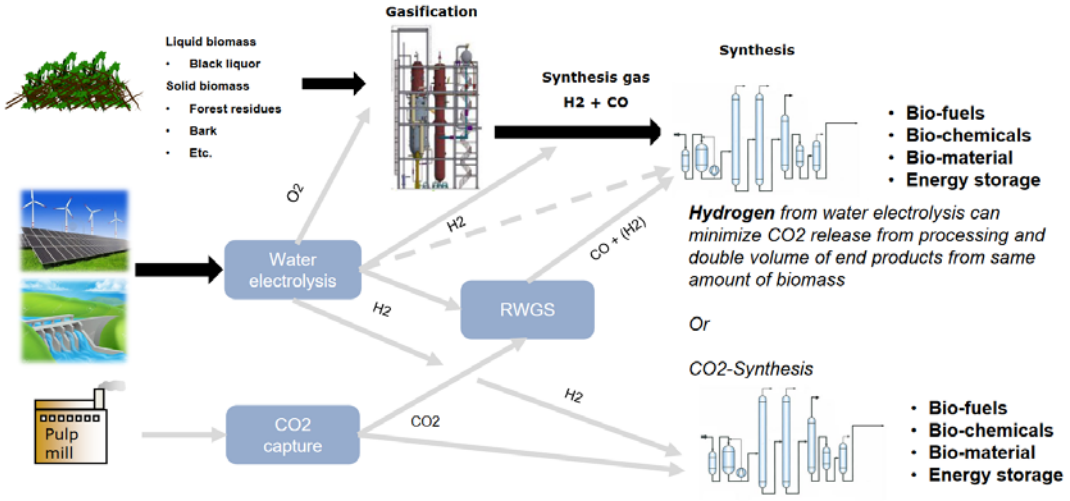


Figure 15: TREEPOWER concept

Other present and future projects:

- Value chain demonstration of hydrogen boosted production
- Planning for solid biomass gasification
- Pending application for hydrogen production project
- 2x hydrogen pipeline project

Mote: Carbon-negative hydrogen from waste biomass
/ J. Stolaroff

The concept is to turn woody waste through gasification process into hydrogen and CO_2. In this case, hydrogen should be used for vehicles and CO_2 should be safe stored underground.

After the first investigations, Mote is entering front – end engineering design for their first facility. It should by 60 ton/day hydrogen produced and 400 000 ton/year CO_2 removed.

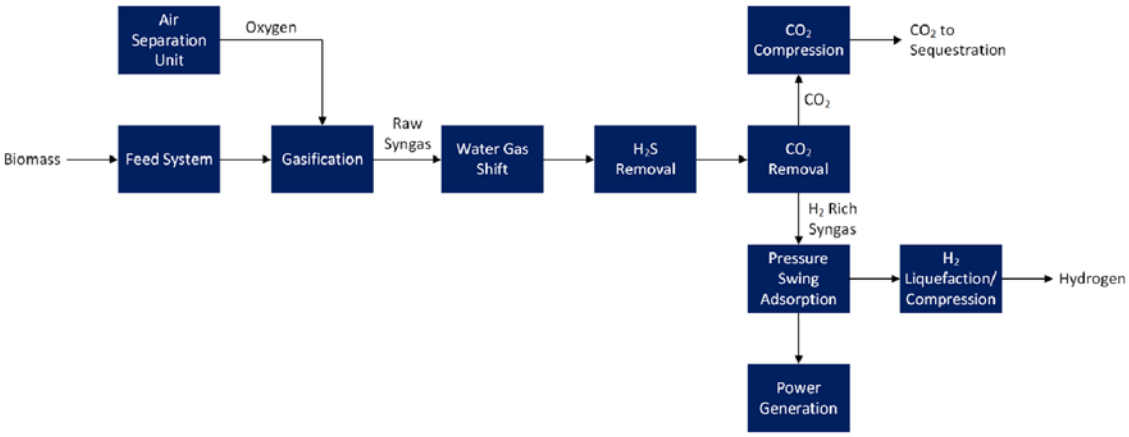


Figure 16: Mote – process overview

In the workshop presentation a nice comparison between gasification and hydrogen production through PEM electrolysis is given. There are several advantages, why the gasification process should be better than electrolysis:

- Electrolysis CapEx is high when considering electricity
- Hydrogen through gasification is less capital intensive than electrolysis and saves huge swaths of land
- Carbon removal through gasification and waste management are clear benefits of the process

Carbon-negative Bright Green TM Hydrogen
/ B. Jackson

Aim: Natural Air Capture (NAC) with CCS – large scale CO_2 removal from the air

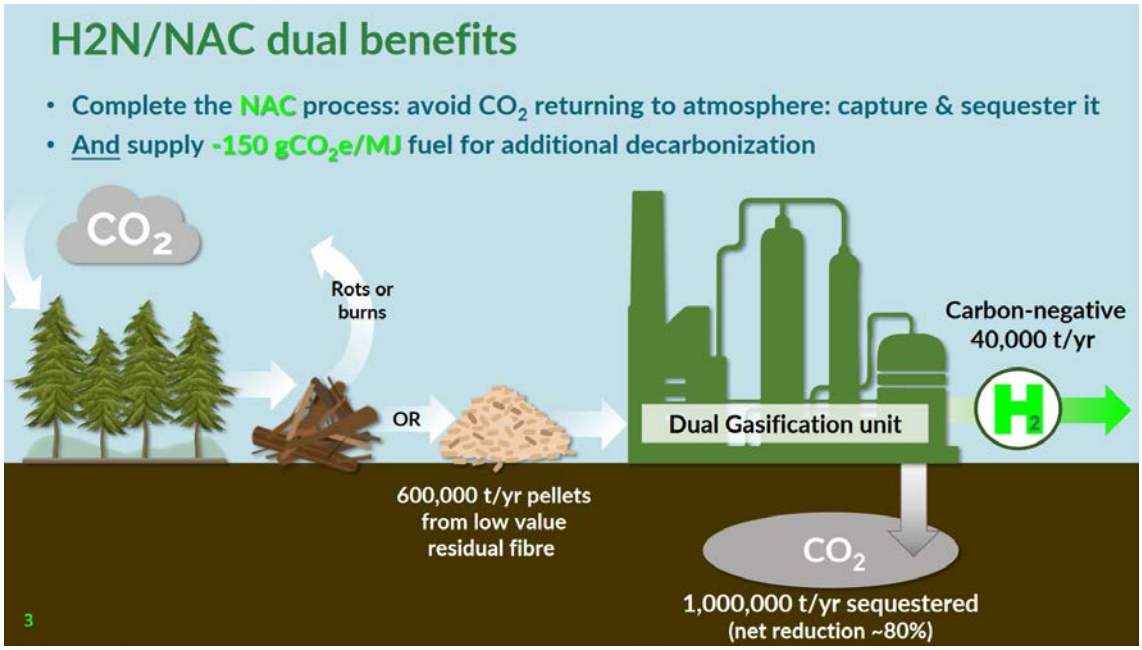


Figure 17: Hydrogen production and CO_2 sequestration

Partners:

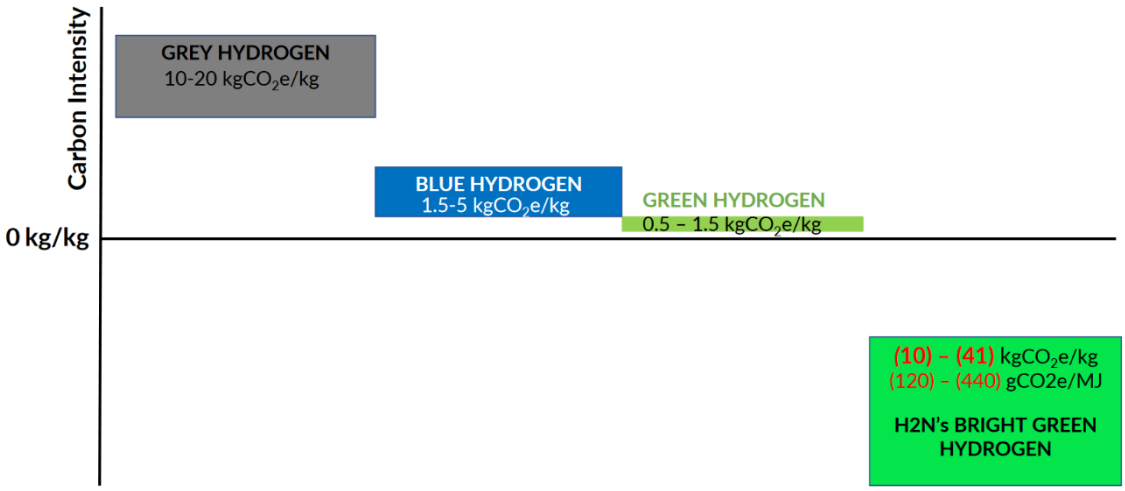
- **Weyburn – early CCS**
- **Sturgeon Refinery –pioneering blue H2 in heavy oil**
- **Alberta Carbon Trunk Line – first to move CO_2 at scale**
- **Qube – first to scale AI based emission detection**

H2N in Alberta´s industrial heartland – world´s first:

- Natural Air Capture 4-unit Hub with 4,000,000 tonnes of CO 2 stored/year
- 160,000 tonnes/year of carbon-negative Bright Green TM hydrogen
- Site selection underway Q2 2023

The strategy of the project:

- Complete detailed engineering before manufacturing
- Manufacturing and installation - not modularization and construction
- 2 x 1 configuration for economies of scale & reliability
- Reduce costs through replication
- Time expansion to match fibre supplies



Source: The Potential Role of Biohydrogen in Creating a Net-Zero World: The Production and Applications of Carbon-Negative Hydrogen and H2N 's own LCA analysis

Figure 18: Negative emissions bright green™ hydrogen

It is not easy to be first, thus H2N scale up should be focusing on those areas:

- Feed Delivery Systems:
  - Evaluating optimum delivery systems into the gasifier
- Tar Destruction & Conversion
- Bed material & additive selection
- Shift Catalyst selection & protection
  - Focus on testing syngas for impurities and breakthrough for different feedstocks
- Heat Integration & Recovery
- Wastewater treatment and Recycling
  - Testing of wastewater and design for maximum recycle and re-use

Conclusions

The technology of hydrogen production through gasification is not new. Anyway, there are still no commercial operational facilities for hydrogen production through gasification in large scale. The reason could be a relatively high price of hydrogen through gasification compared to fossil-based hydrogen and investment risks. Even if it was shown in the workshop that production of hydrogen and CCS through gasification process offers great benefits in comparison with e.g., PEM electrolysis, the massive support from governments is still necessary to increase this way of hydrogen production. Unfortunately, the most of policy makers do not realize that it is finally necessary to handle and not just to talk about the environmental problems, which are already present.

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Technology Collaboration Programme