

Novel biobased H₂ production routes

Saija Rasi, johtava tutkija Markku Vainio, tutkija

Luonnonvarakeskus
JustH2Transit -hanke
1.10.2026 HYGCEL seminaari















Background

- This work is part of the WP1 "Review of transition and bottlenecks"
 - Overall goal is to get a holistic view on energy production needs and supply capacity, H₂ production now and in future as well as finding possibilities for matching different production routes
- In this task "Geographical distribution of resources" review is made about the geographical distribution of H₂ production resources in Finland
 - In collaboration with LUT-university
- In order to combine wind and solar with biobased H₂ production, some simplifications must be made





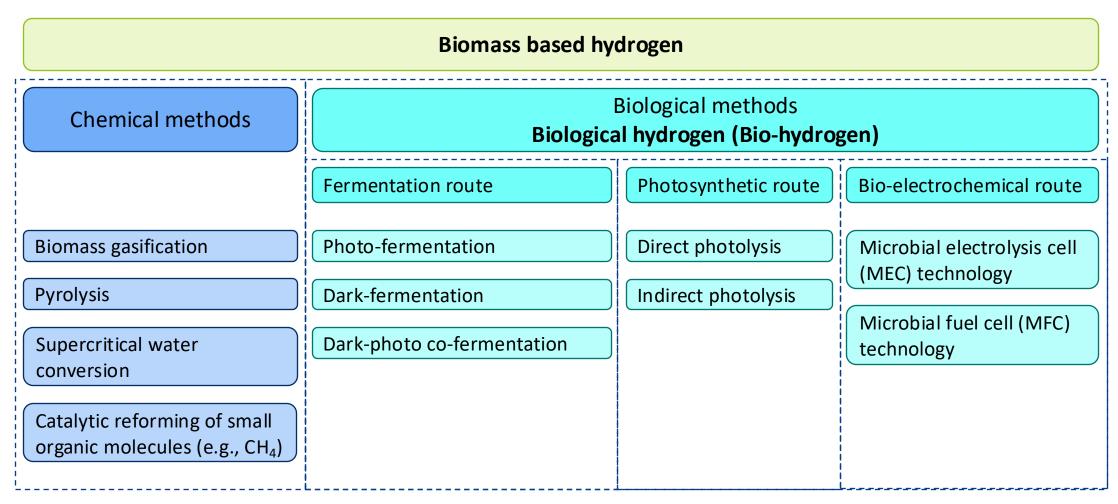
Biomass based hydrogen

- Must be noted the difference between biomass-based hydrogen and biohydrogen.
 Biomass based hydrogen refers only to raw materials but can be produced by "non-biological" methods, such as gasification.
- Biohydrogen, on the other hand, also refers to processing technology.
- Many biological methods are still at a low TRL level, while thermochemical conversion routes are more advanced, both are still widely studied.





Definition and classification of processing routes to produce biomass-based hydrogen







Principles of biological methods

Biological methods Biological hydrogen (Bio-hydrogen)

Fermentation route

Photo-fermentation

Fermentative conversion of organic materials mainly in purple non-sulfur (PNS) bacteria

Dark-fermentation (DF)

Anaerobic microbial community, use of organic feedstock materials

Dark-photo co-fermentation

DF effluent, incl. organic acids, used as a substrate for photofermentation -> better overall performance (e.g., higher H₂ yield)

Photosynthetic route

Direct photolysis

Decomposing of water through photosynthesis, cyanobacteria and green algae

Indirect photolysis

Bioconversion of CO₂ to starch and glycogen, which are used as substrates by microalgae or cyanobacteria

Bio-electrochemical route

Microbial electrolysis cell (MEC) technology

Electro-chemically active bacteria oxidizes the organic substrates at the anode

-> protons (H⁺) and electrons (e⁻)
Are transported to the cathode
-> 2H⁺ + 2e⁻ -> H₂
External current used

Microbial fuel cell (MFC) technology

Similar anodic process with MEC, but produces electric current and voltage by itself (in contrary to MEC which requires an external voltage supply)





Biological route

- Most advanced technology in biological routes is dark fermentation
- It is based on conventional anaerobic digestion but altering the process conditions the end product is switching from CH₄/CO₂ gas to H₂/CO₂
- Depend on the raw material different kind of pre-treatment is needed to improve the H₂ yield
- Based on the literature the H₂ yield is varying great amount with different kind of pre-treatments
- In example when comparing with the 29 different pre-treatment with food waste, the H₂ yield is varying from 6 to 162 Nml/g VS with average of 93 Nml/g VS





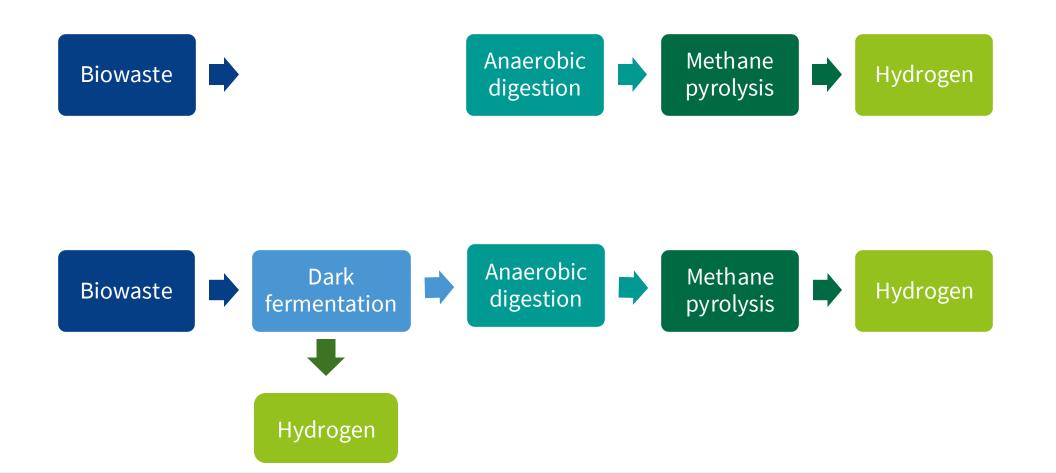
Extended process

- In addition of direct routes, biomass based hydrogen can be produced from (biobased) CH₄
 - Different kind of methane pyrolysis or steam reforming can be done for CH₄ streams which increase the hydrogen yield
- Dark fermentation can also be connected with conventional anaerobic digestion
- With fermentation or digestion there are always CO₂ present in the gas stream which need to remove in order to have pure H₂ or CH₄





Examples from biowaste to hydrogen via anaerobic processes







Comparison of selected routes with houshold biowaste

- In Finland aprox. 483 655 t/a ww of household biowaste is produced
- The calculation here includes many estimates and averages, which are highly dependent on the parameters or pre-treatments of the different processes, e.g.
 - Biogas from biological processes is purified before methane pyrolysis
 - Methane pyrolysis conversion rate 100 %
 - Energy values calculated from the CH₄ and H₂
 - Process energy consumption is not taken account





Case: Biowaste

Anaerobic digestion

2 Anaerobic digestion Methane pyrolysis

3 Dark fermantation Anaerobic digestion

4 Dark fermantation Anaerobic digestion

	H ₂ t/a	CH ₄ t/a	GWh _{LHV}
1	0	39 793	553
2	9 948	0	331
3	1801	19 897	337
4	6 775	0	226

Methane pyrolysis





Conclusion

- H₂ production from biomasses can be done with various technologies
- The appropriate technology depends on the materials used and the desired end product
- TRL levels of biological processes are still low
- More research needed to get optimized process routes and depend on the materials used and the need of the end product
- In JustH₂Transit project, calculations are done to most common organic waste and side-streams
 - Geographcal distribution
 - Techno-economic calculations and LCA



Thank you!











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