IEA Bioenergy
Technology Collaboration Programme

Green hydrogen and Green CO2 production – a pathway to the future

June 2023

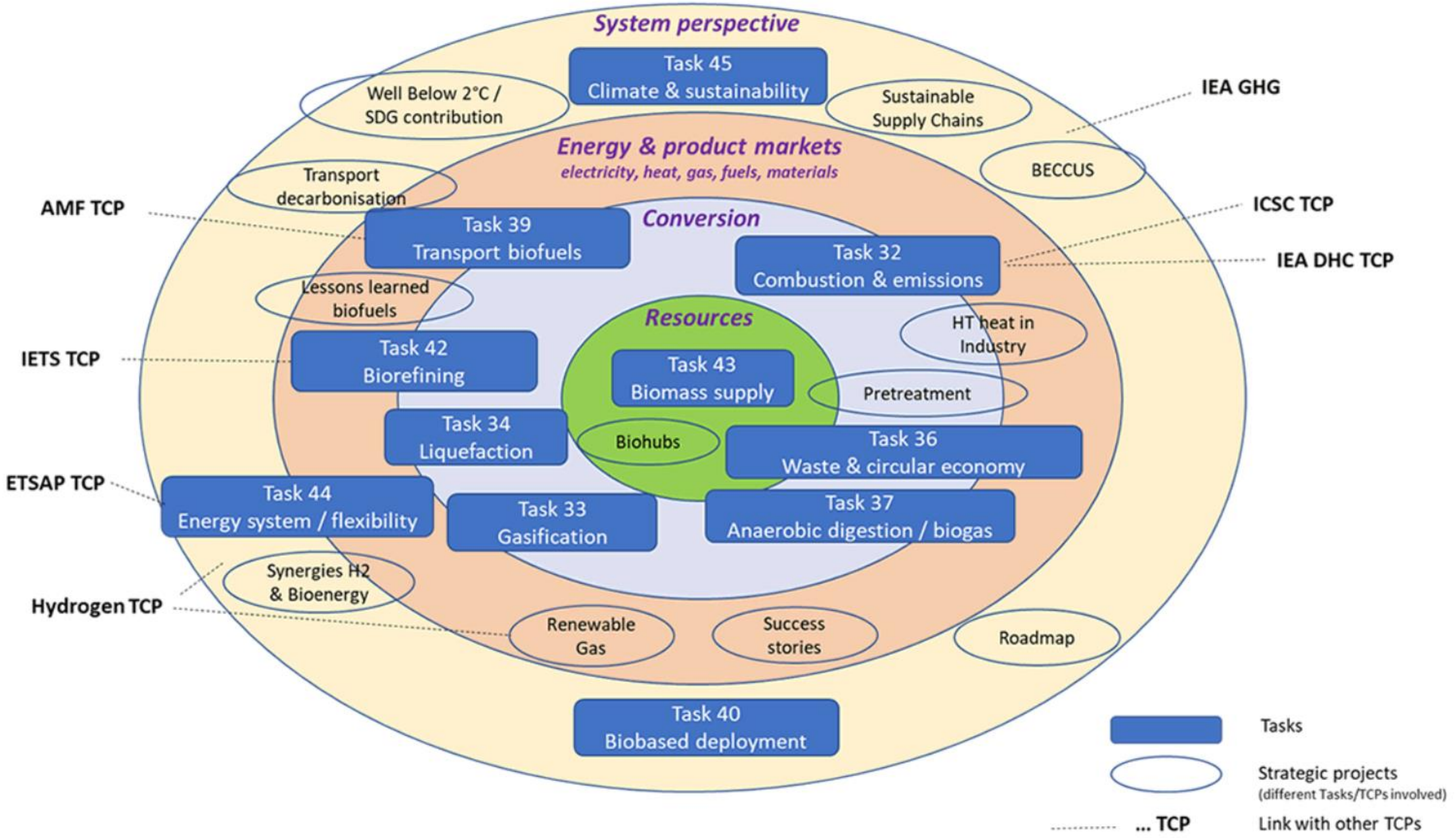
Berend Vreugdenhil (TNO)
Prepared in collaboration with Joakim Lundgren (LTU)

Berlin

Outline

- What is IEA Bioenergy / Task 33
- Background to biobased hydrogen
- Feedstock Potential
- Production Costs
- Developments
- Conclusions

IEA Bioenergy at a glance



IEA Bioenergy Task 33 topics

Task 2.6 CO_2 (UK)

- Task 2.1 CHP (Austria)
- Task 2.2 SNG (Netherlands)
- Task 2.3 Biofuels (Germany)
- Task 2.4 Chemicals (USA)
- Task 2.5 Hydrogen (Sweden)

Current focus of our working group

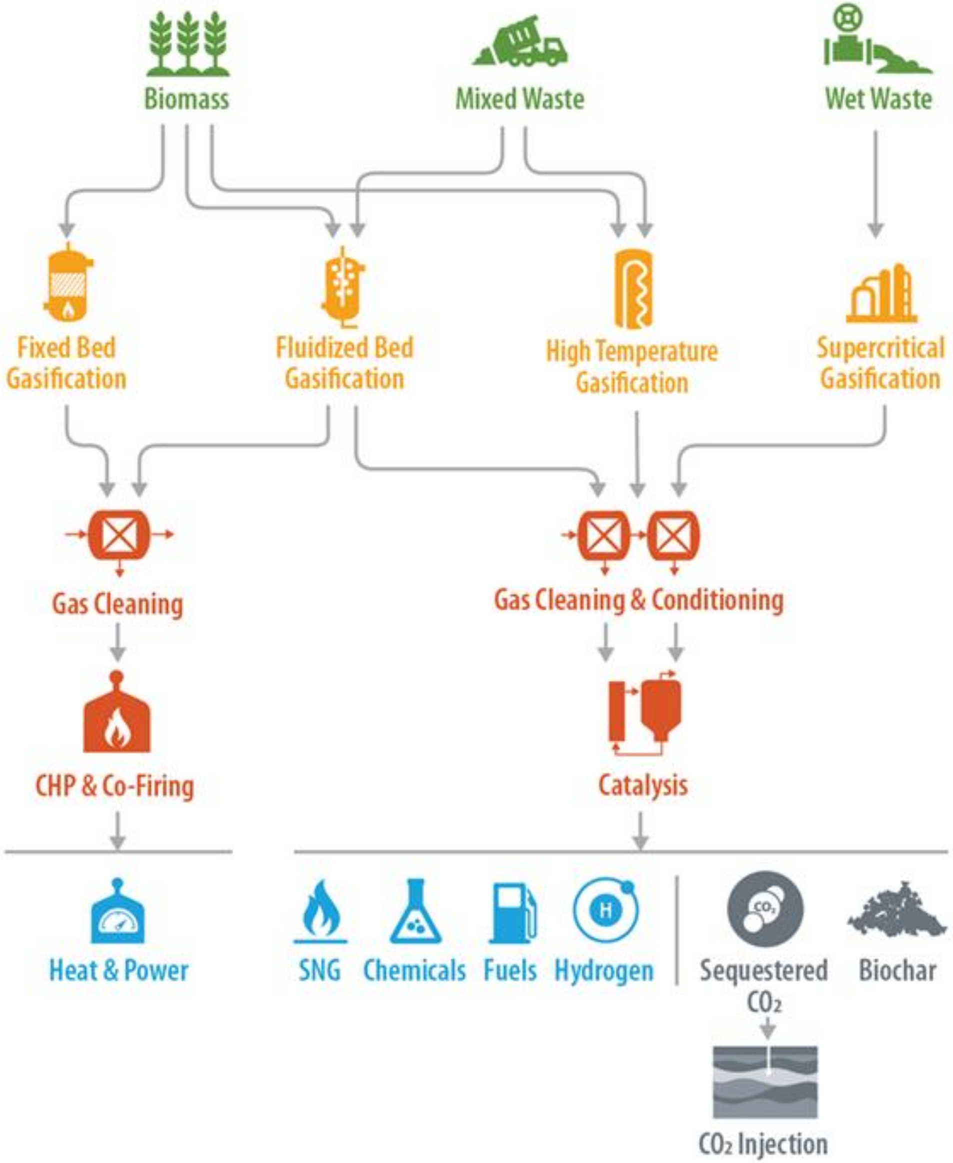
- Platform for technology suppliers. Explaining and highlighting the benefits for the different applications in which gasification is key
- Identification of threats and opportunities for the various applications.
- Suggestion for R&D topics to further boost the application pathway
- Working towards an implementation strategy (first SNG and fuels) which will be used in communication with policy makers.

Who to contact

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

	Austria (Jitka Hrbek) jitka.hrbek@boku.ac.at		Belgium (Benjamin Berger) brg@ecam.be
	USA (Robert Baldwin) Robert.Baldwin@nrel.gov		France (Chourouk Nait Saidi) c.naitsaidi@atee.fr
	India (Mohana Rao) mohanrd@indianoil.in		Italy (Donatella Barisano) donatella.barisano@enea.it
	Sweden (Joakim Lundgren) Joakim.Lundgren@ltu.se		Germany (Thomas Kolb) thomas.kolb@kit.edu
	The Netherlands (Berend Vreugdenhil) berend.vreugdenhil@tno.nl		UK (Patricia Thornley) p.thornley@aston.ac.uk
	Canada (Travis Robinson) travis.robinson@NRCan-RNCan.gc.ca		China (Guanyi Chen) chen@tju.edu.cn

Gasification pathways



Background

- Why biomass-based H_2?
- Brings important benefits
  - Non-weather dependent, fossil-free, large-scale hydrogen production
  - Negative CO_2-emissions
  - Process integration opportunities

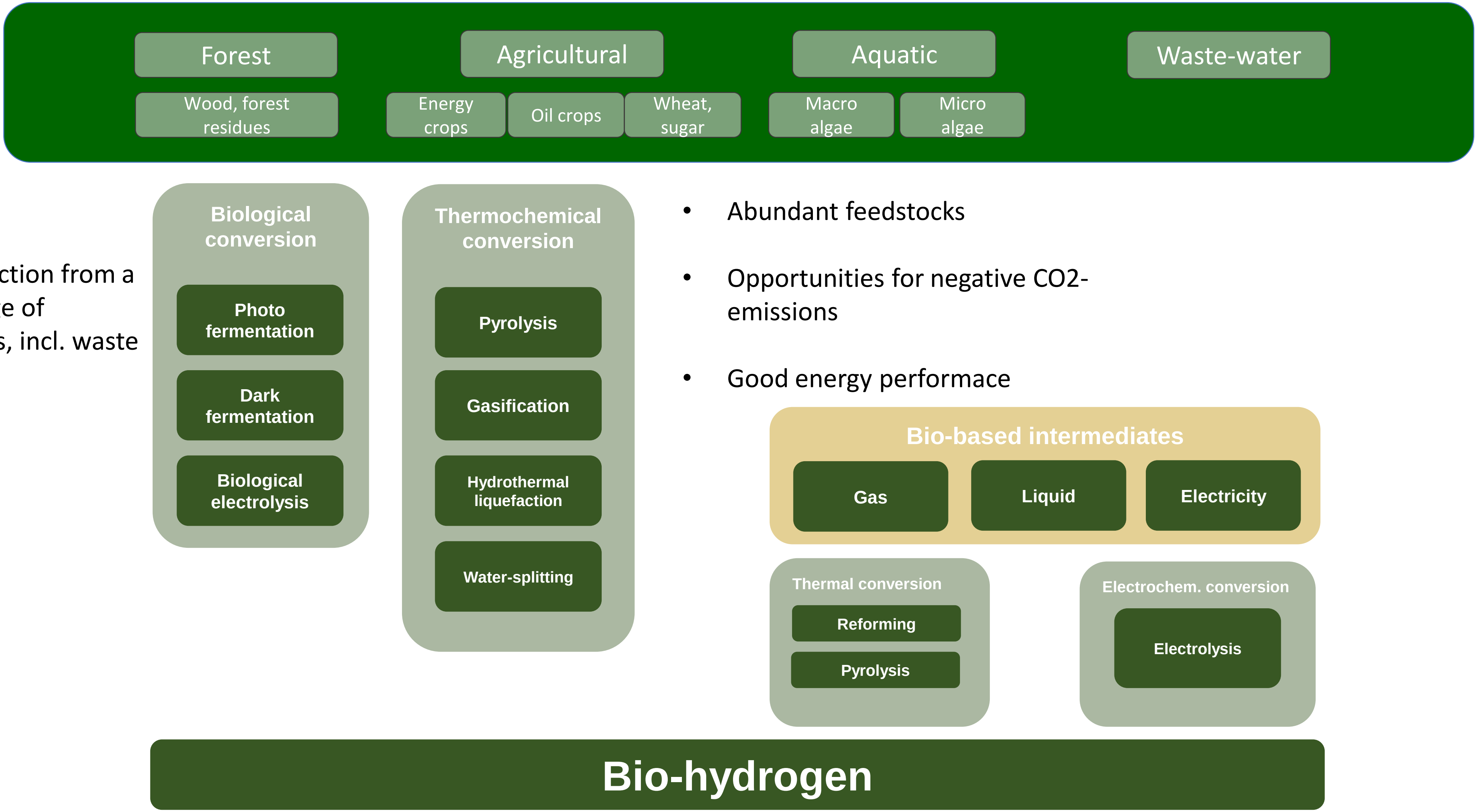
Figure 4. An Illustrative Hydrogen Colour Spectrum

	Terminology	Technology	Feedstock/ Electricity source
PRODUCTION VIA ELECTRICITY	Green Hydrogen	Electrolysis	Wind, Solar, Hydro, Geothermal, Tidal
	Purple/Pink Hydrogen		Nuclear
	Yellow Hydrogen		Mixed-origin grid ener
PRODUCTION VIA FOSSIL FUELS	Blue Hydrogen	Natural gas reforming + CCUS gasification + CCUS	Natural gas, coal
	Turquoise Hydrogen	Pyrolysis	Natural gas
	Grey Hydrogen	Natural gas reforming	
	Brown Hydrogen	Gasification	Brown coal (lignite)
	Black Hydrogen		Black coal

**GCG footprint given as a general guide but it is accepted that each category can be higher in son*

Source: Global Energy Infrastructure (GEI), 2021

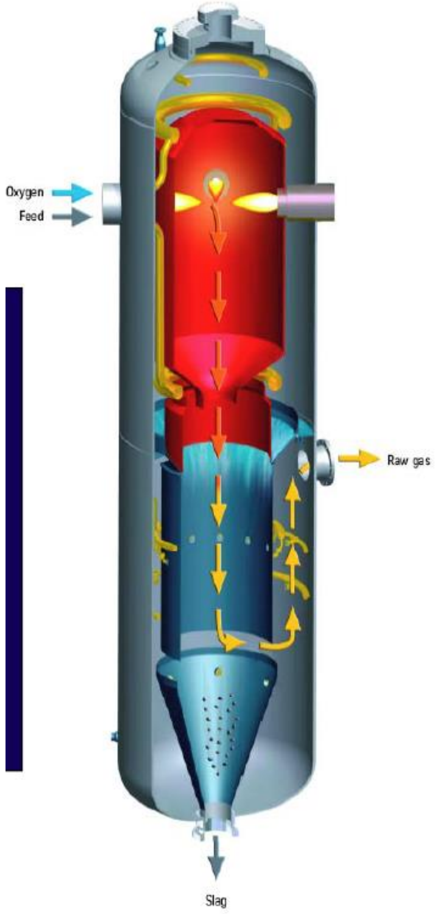
Many pathways to produce bio-hydrogen



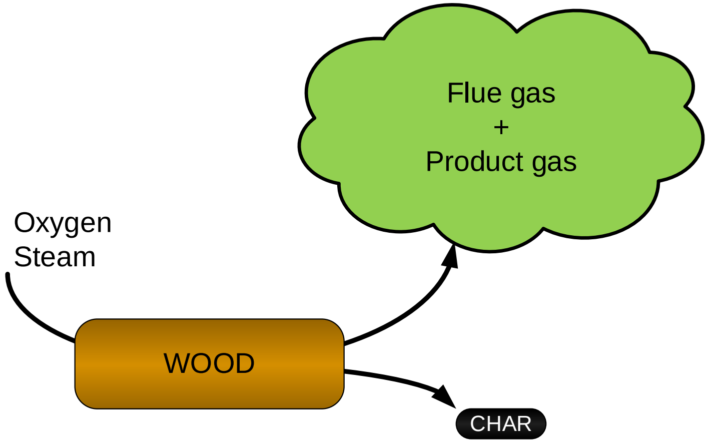
- H2-production from a wide range of substrates, incl. waste streams

- Abundant feedstocks
- Opportunities for negative CO2-emissions
- Good energy performace

What is gasification?

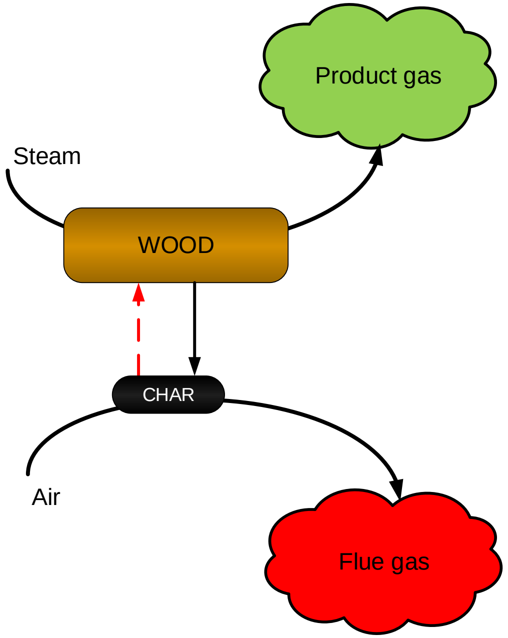


Direct gasification

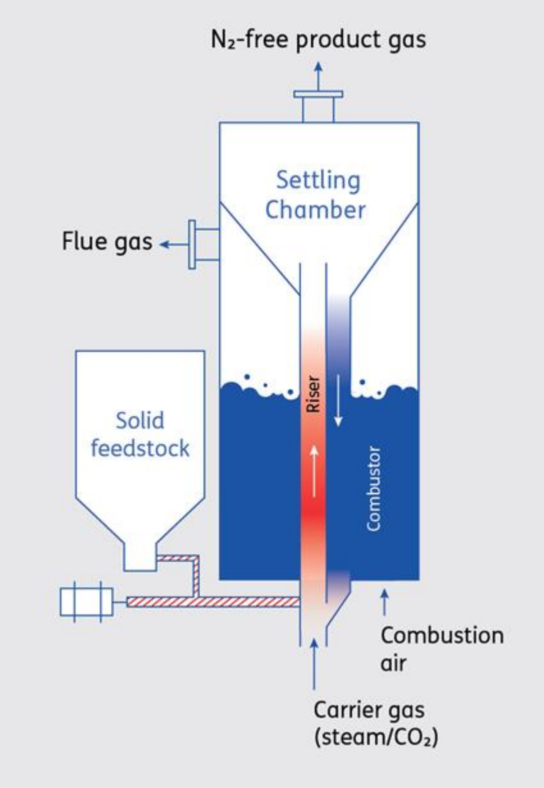


Heat + Feedstock (s) → Syngas (g) + Char (s)

Indirect gasification



Heat + Feedstock (s) → Product (g) + CO_2 (g)

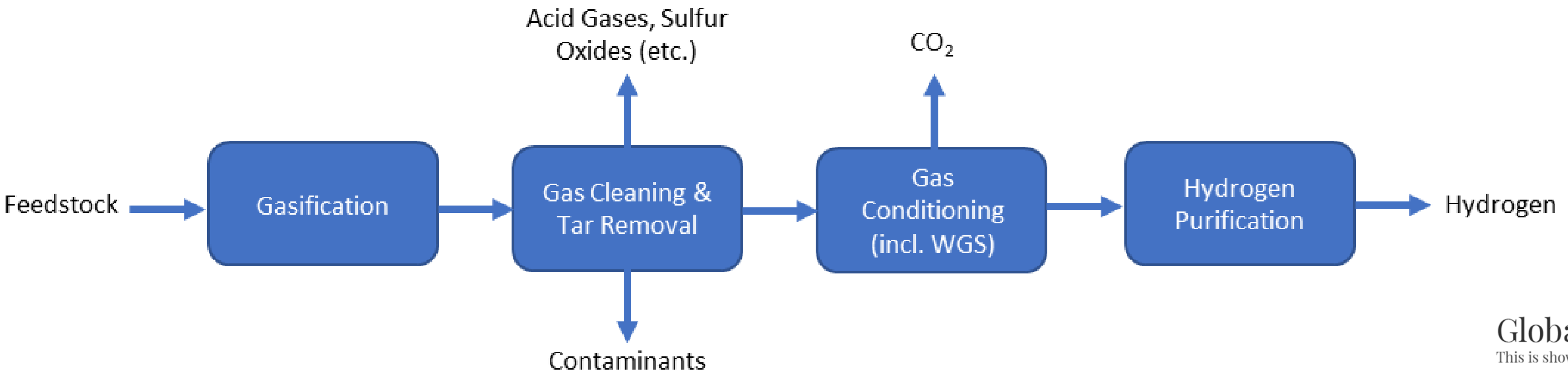


Which technology is suitable for what?

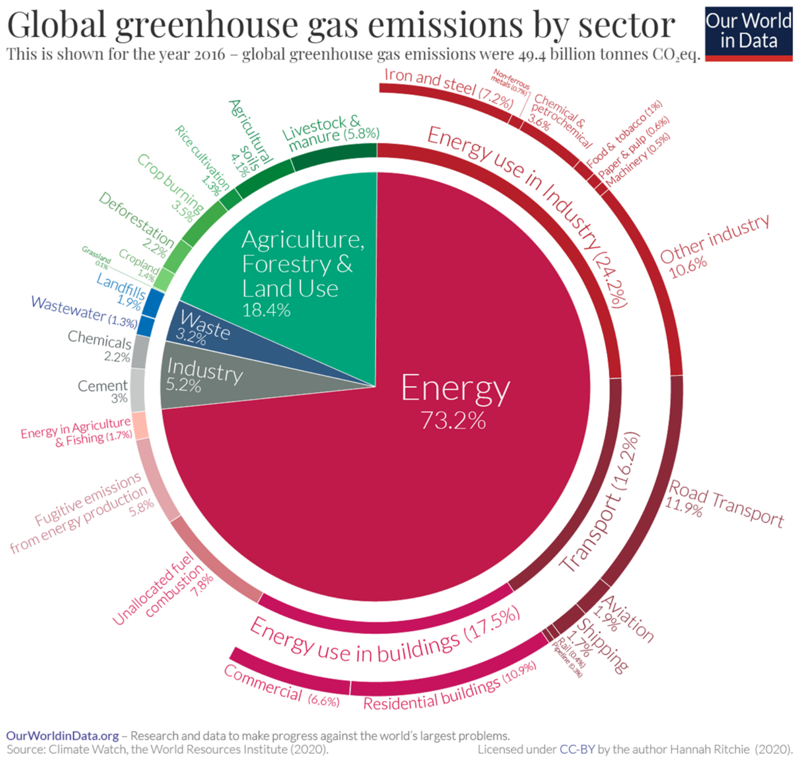
Technology/Product	Methane	Hydrogen	DME/MeOH	FT-prod. (diesel/jet/LPG etc)	Fuel gas(kilns, CHP etc)	Comments
Air-blown gasification						Suitable in smaller scales
Oxygen blown entrained flow gasification						Suitable in larger scales
Steam/oxygen blown fluidized bed gasification						Suitable in larger scales
Steam/oxygen blown indirect						Suitable in medium scales
2-stage gasification						Suitable in smaller scales (in modules)

Doubtful technical and economic performance
Doubtful economic performance
Feasible

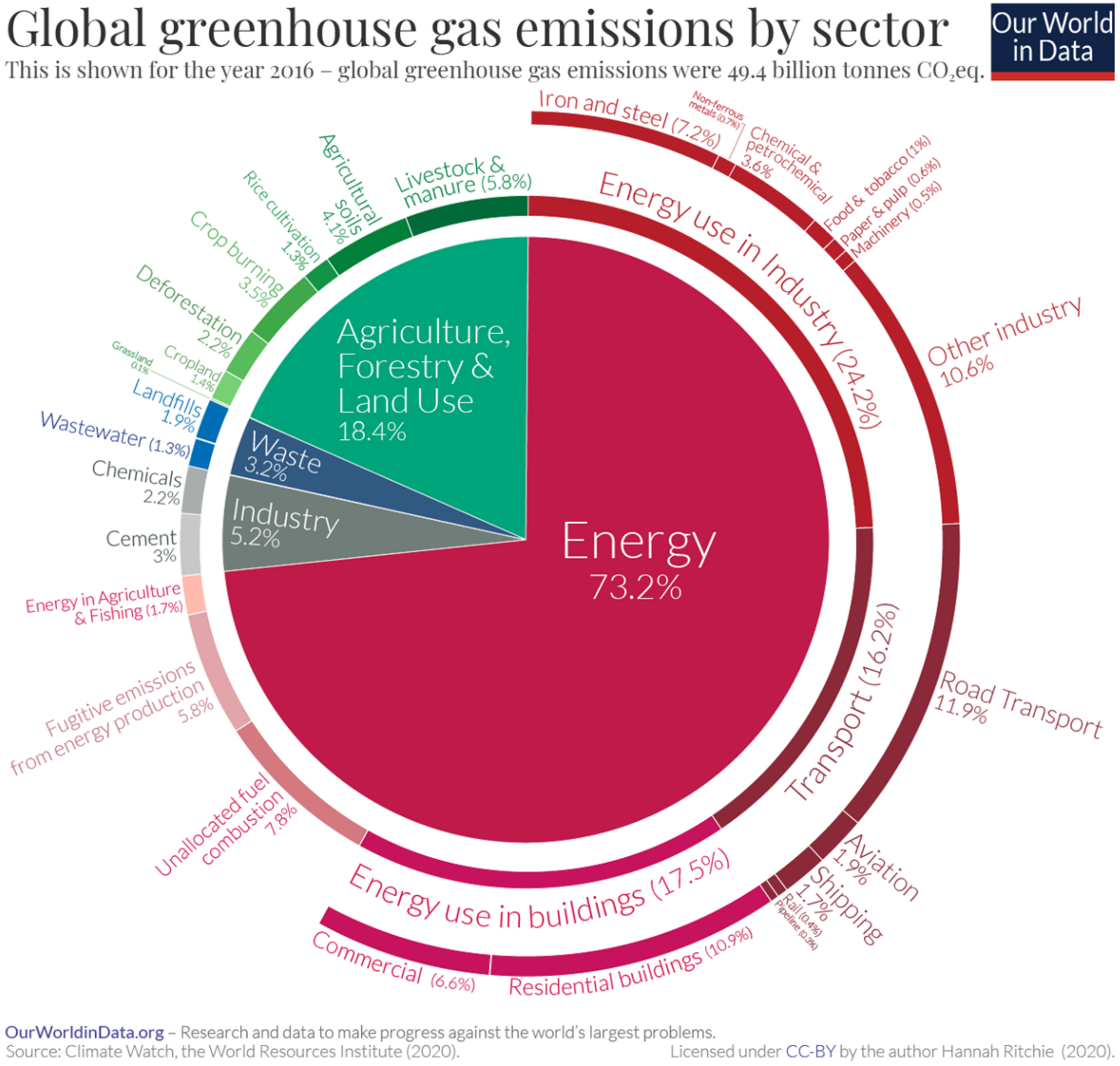
Production potential



- **For every tonne of dry biomass gasified, about 0.1 tonne of hydrogen can be produced together with 1.5-2 tonnes of CO_2, i.e., 15-20 kg CO_2 per kg hydrogen.**



Production potential

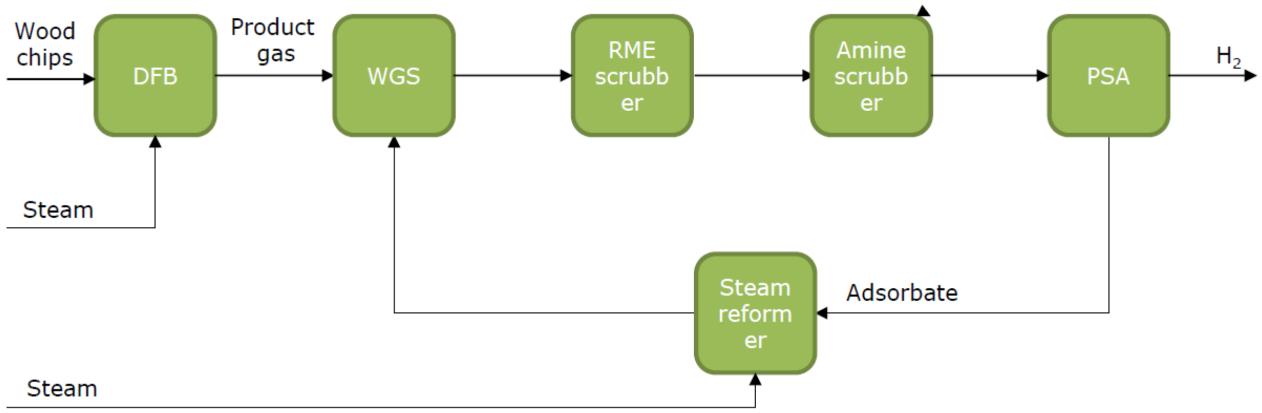


- Crop burning results in 1.5 billion tonnes of CO_2-eq. Lets assume we valorize this waste material we could produce about 120 million tonnes of H_2

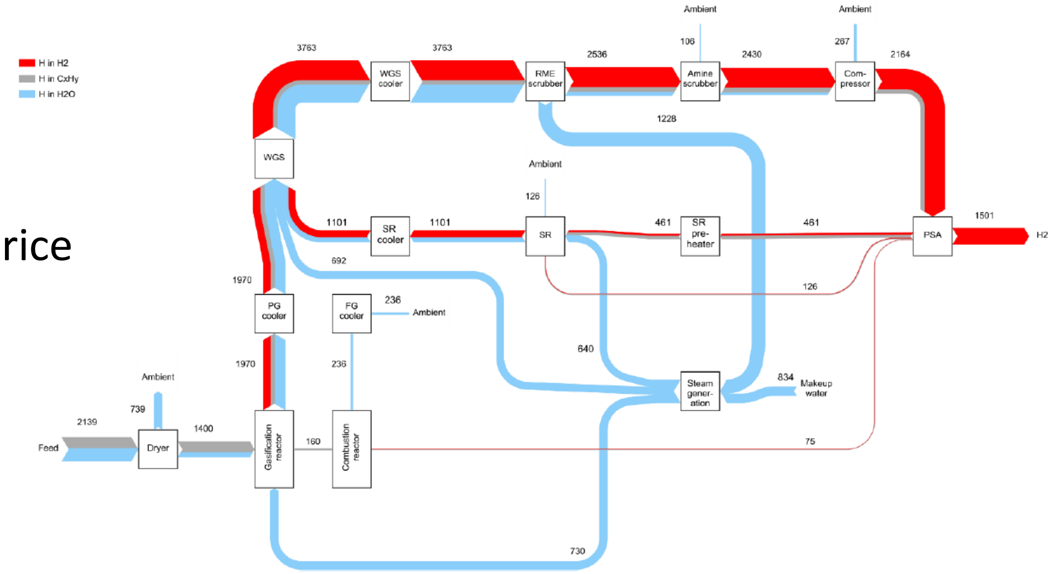
- Production potential is huge, we lack the proper supply chains (as they exist for coal, oil and gas)

~ 14000 PJ

Costs of hydrogen production

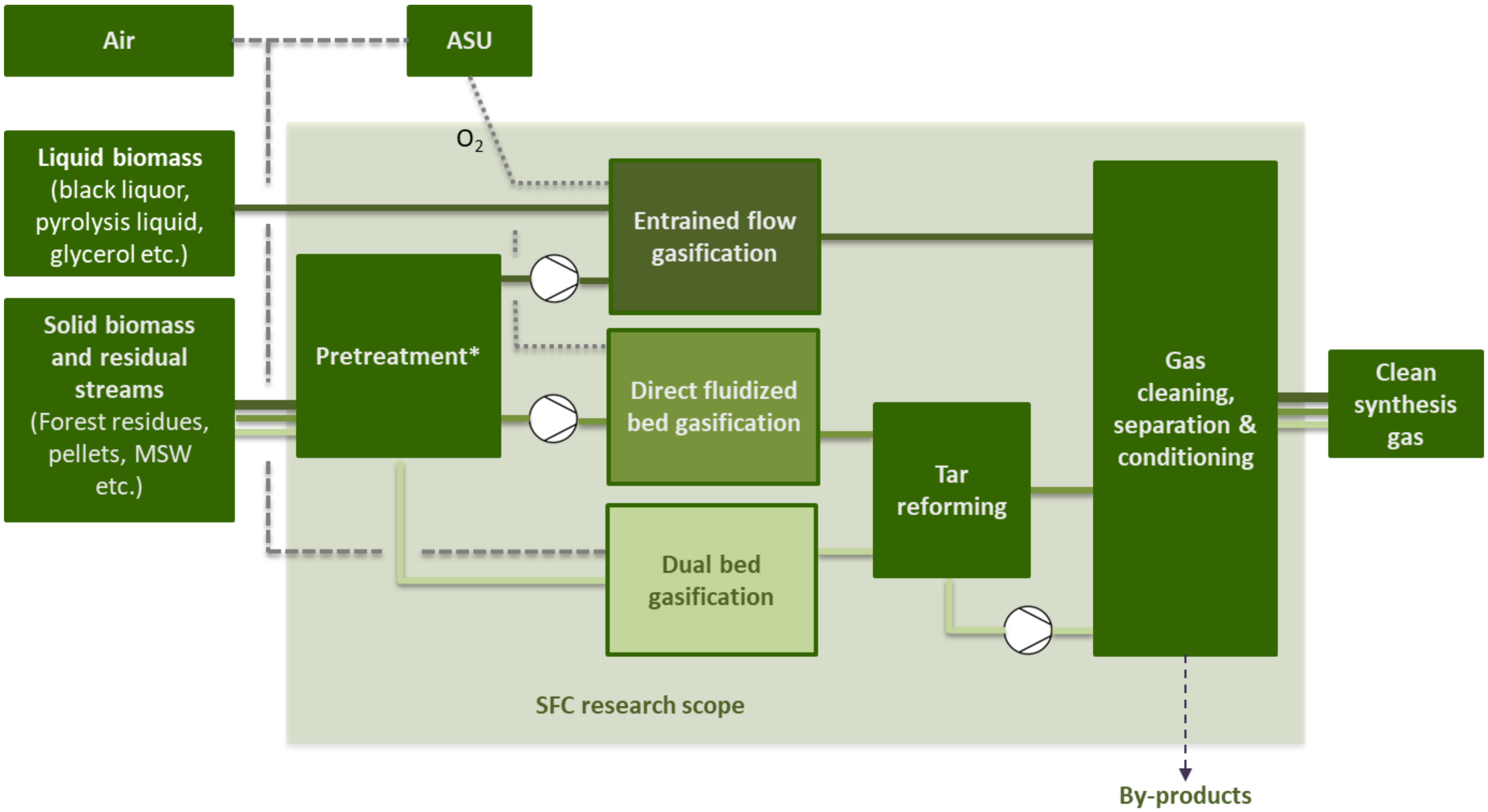


2,7 Euro/kg Selling price



http://www.ieatask33.org/app/webroot/files/file/publications/Hydrogen/Wasserstoffstudie_IEA%20final.pdf

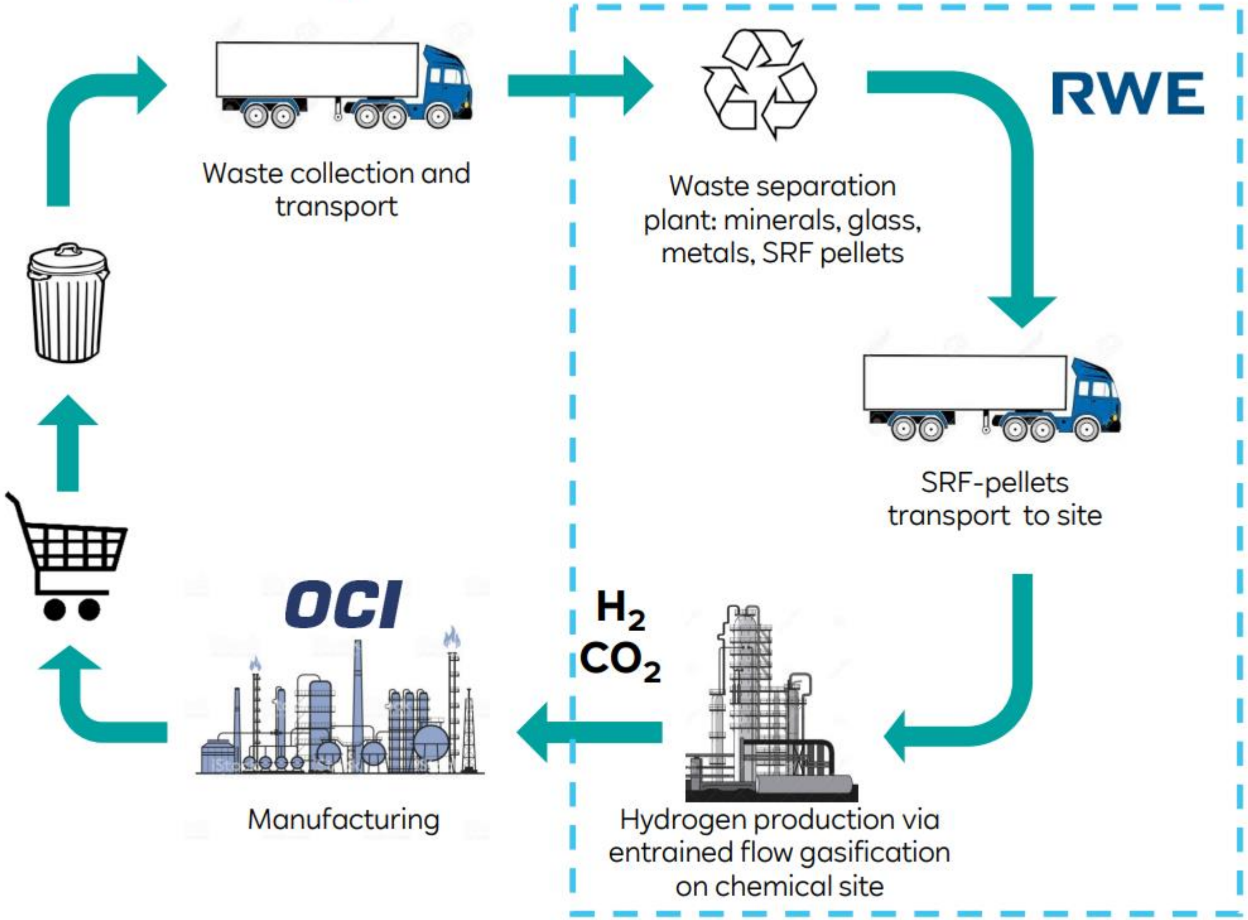
Hydrogen Production outline based on gasification



Example 1: Furec - RWE

Waste-to-hydrogen produces green and circular hydrogen

Contributing to Project FUREC („Fuse Reuse Recycle”)

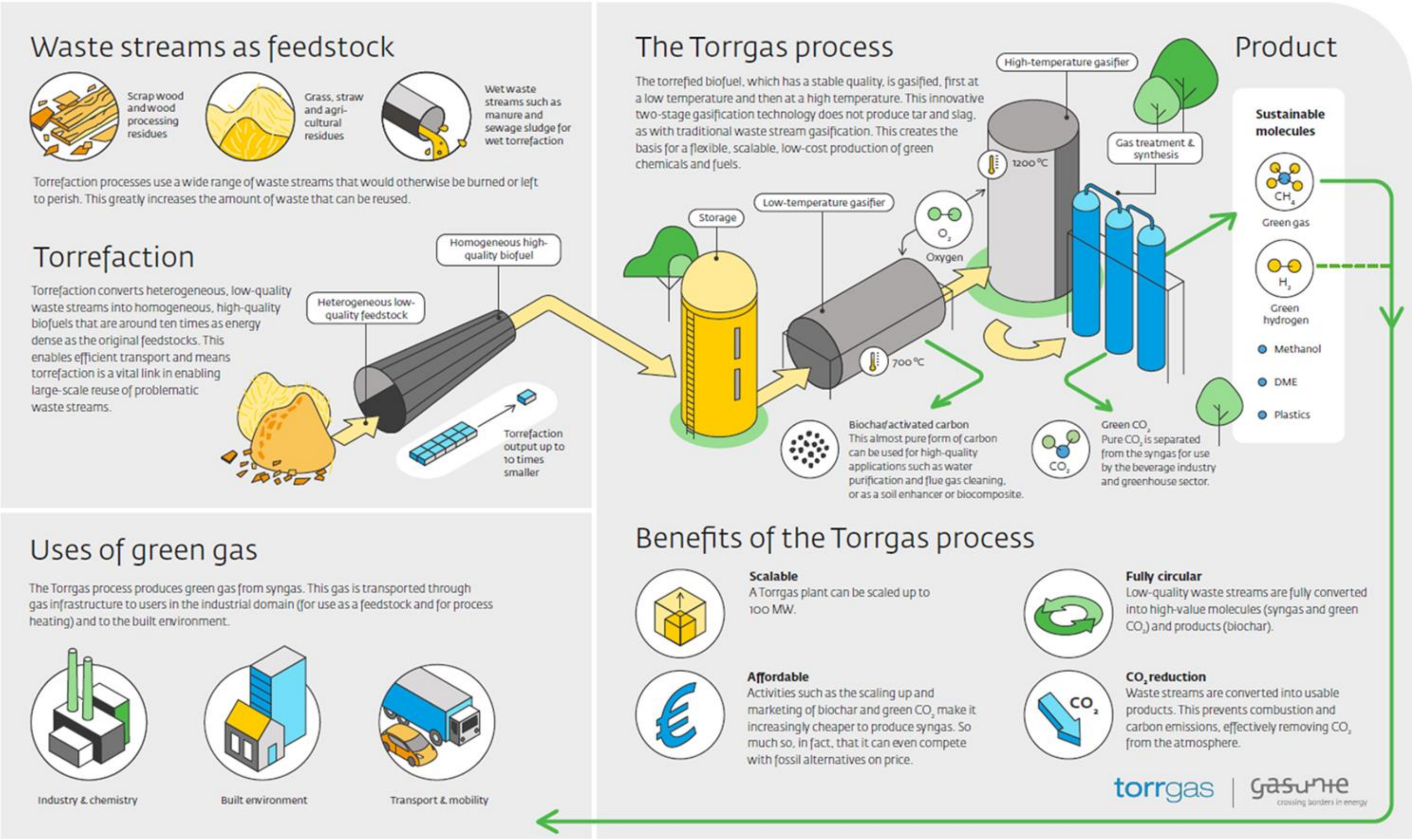


PROJECT furec

Project typicals

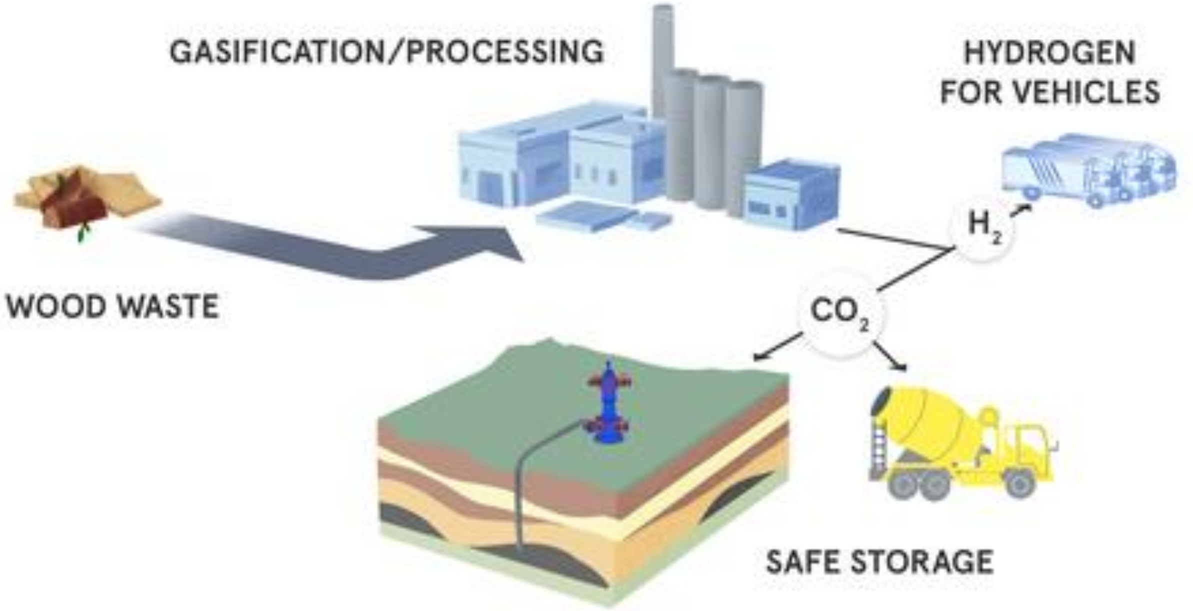
- Processing of Municipal Solid Waste and dried sewage sludge (700.000 t/a)
- Production of hydrogen (≈50.000 t/a)
- CO_2 reduction:
  - 475.000 t/a @ 0 kg/MWh Power
  - 330.000 t/a @ 180 kg/MWh Power
- 800.000 t/a of CO_2 pure, ready for CCS/CCU
- Estimated investment: >500 M€
- Other positive value products: minerals / glass / metals / slag / sulfur / salt
- Commissioning: 2026

Example 2: Torrgas



- Torrgas develops a 50 MW demonstration unit to produce hydrogen by gasifying torrefied biomass
- Additionally, biochar will be produced, which may be used as a soil improver.
- The technology is scalable to 100 MW (1,4 PJ green gas) per gasifier unit.

Example 3 and 4: North America



- US company Mote plans a facility to convert wood waste into hydrogen while capturing, utilizing, and sequestering the CO_2
- Canadian company H2Naturally has three plant locations for gasification- based bio-hydrogen with CCS planned for British Columbia.

Other developments

- Plagazi (S) using waste plastic to produce hydrogen
- NettEnergy (NL) using roadside grass to produce hydrogen and biochar
- China Datang Co. Ltd (China) using biomass pellets
- Jin Tong Ling Technology Group (China) using straw to produce hydrogen
- Indian oil company (In) using biomass to produce hydrogen
- Dok-Ing (Croatia) developing a gasification process on waste to hydrogen

Conclusions

- Gasification pathways exist and are very versatile (a solution for most waste materials)
- Benefits are not only with stability, security of supply, feedstock diversification, but also on the carbon credits (net-negative with CCS)
- Synergies with e-fuels, by providing a clean renewable source of carbon
- Typical hydrogen production ranges between 60 – 105 gram/kg of feedstock
- Typical CO_2 abatement potential is 15-20 kg/kg of hydrogen

Berend Vreugdenhil
berend.vreugdenhil@tno.nl

Joakim Lundgren
Joakim.Lundgren@ltu.se

IEA Bioenergy
Technology Collaboration Programme

www.ieabioenergy.com