Renewable Fuels from Biomass Sources and compatibility with existing infrastructure and processes

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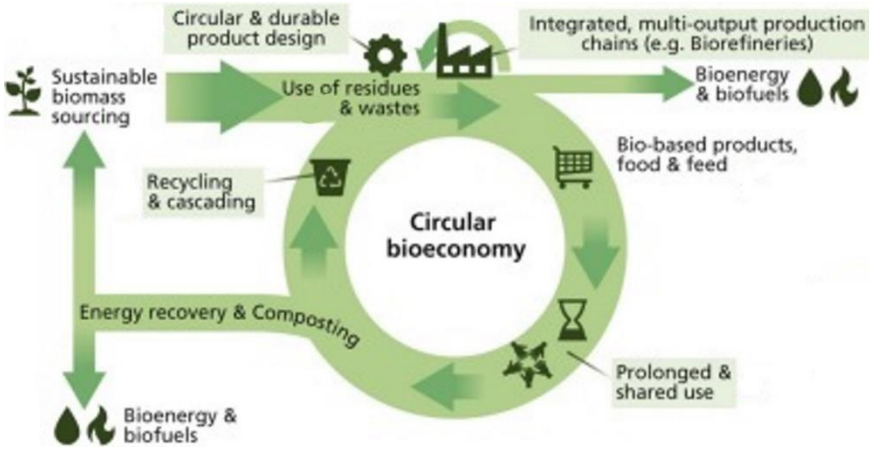
Biomass

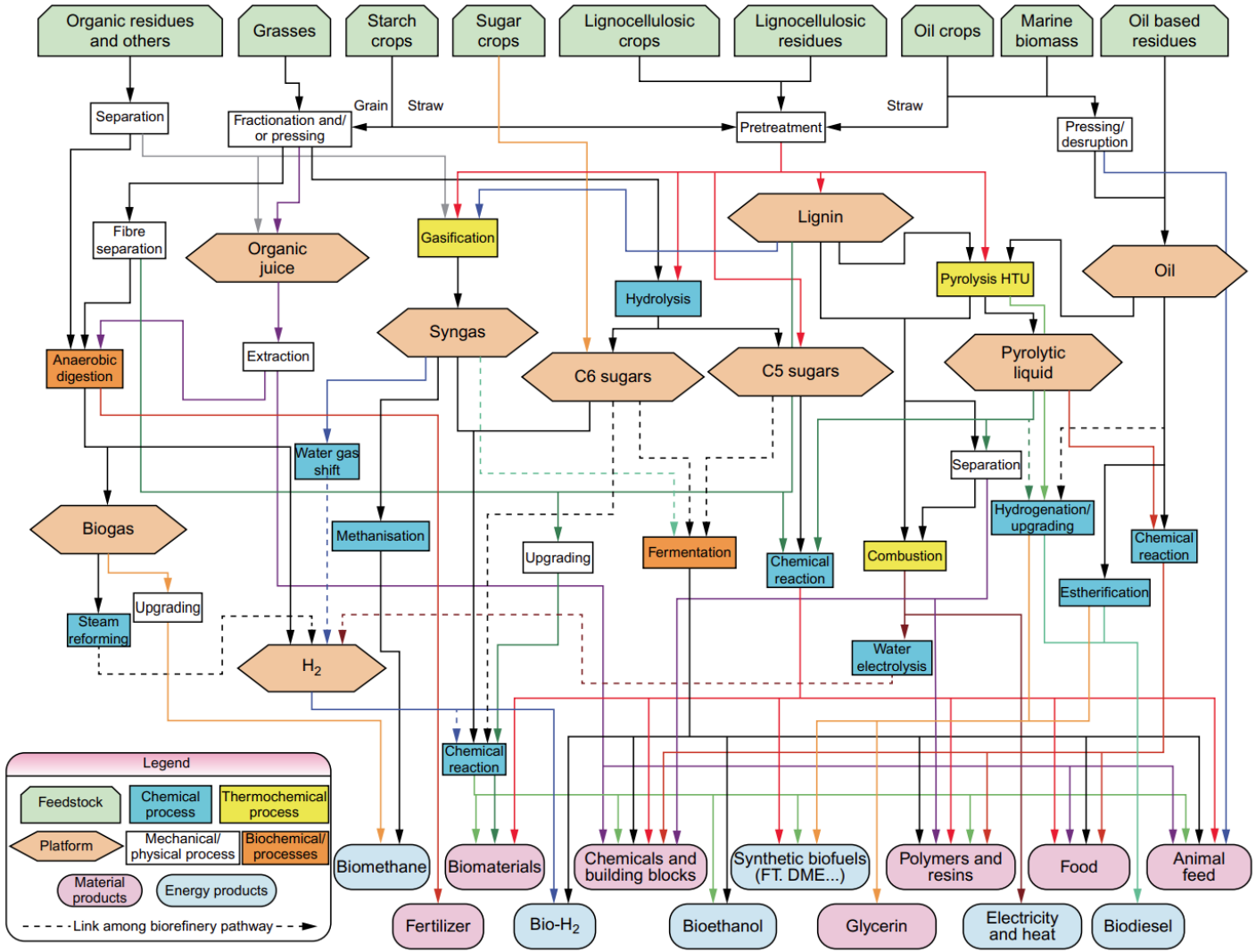
- Biomass is the most versatile renewable energy source. It can be used to produce:
  - renewable electricity
  - renewable thermal energy
  - liquid or gaseous fuels for transport and stationary applications
  - valuable chemicals



- Biomass is the only renewable energy source that can be carbon negative an advantage that can improve the financing outlook of biomass investments:
  - CO_2 can be captured at the production facility and be used to produce carbon neutral synthetic fuels and chemicals.
  - Air CO_2 can be removed from air and sequestered in the soil if appropriate agricultural and forestry practises are followed.
- Biomass processes are inherently appropriate for circular economy applications.

(Figure source: P. Stegmann, M. Londo, M. Junginger, The circular bioeconomy: Its elements and role in European bioeconomy clusters, Resources, Conservation & Recycling: X, Volume 6, 2020, 100029)

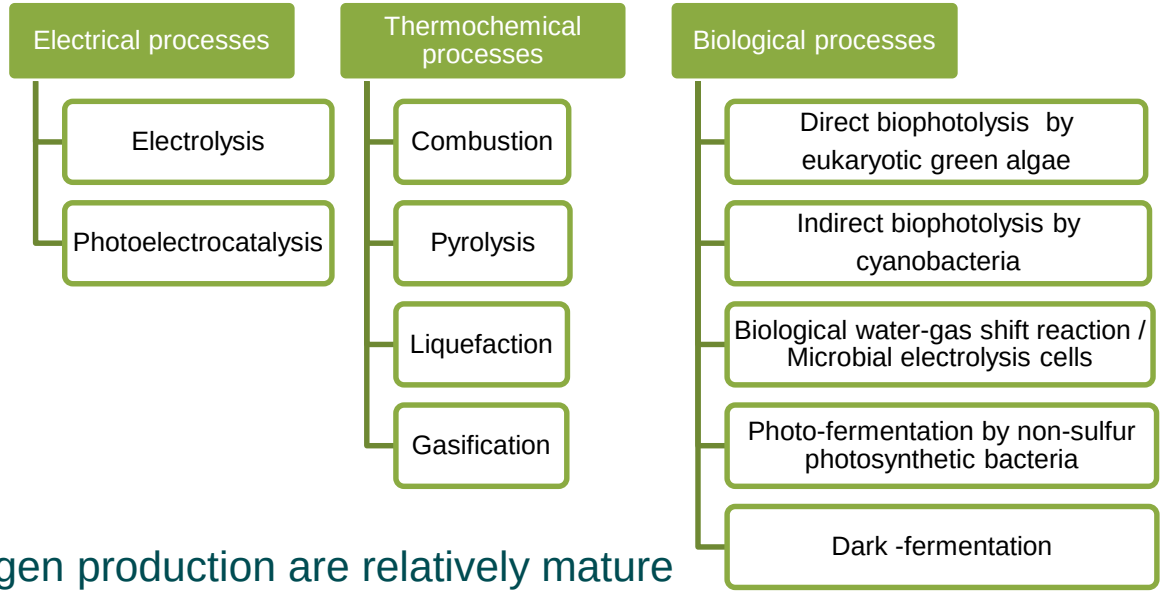
Bio-refineries



Source: Kamm, Birgit, Patrick R. Gruber, and Michael Kamm, eds. Biorefineries-industrial processes and products. Vol. 2. Weinheim: Wiley-VCH, 2006

Renewable Hydrogen from biomass

- Cogeneration from biomass using various feedstock is a commercial and cost-competitive technology. It can be coupled with any electrolyzer. Biomass electricity is more flexible than intermittent renewables like solar and wind, which become less cost-competitive to biomass when they are coupled with batteries.



- Gasification technologies for hydrogen production are relatively mature and demonstration projects can be designed and deployed since they can be cost-effective.
- Some of the rest of the technologies for hydrogen production are promising (e.g., biophotolysis and photoelectrocatalysis), but still at low TRL.

Renewable Natural Gas / Biomethane / Renewable Methanol

- Biogas can be treated to:
  - Renewable natural gas (pipeline-quality gas fully interchangeable with conventional natural gas)
  - Renewable Methane (biomethane)
  - Renewable Methanol
- It is produced mainly through:
  - Anaerobic digestion with anaerobic organisms, which digest material inside a closed system.
  - Fermentation of biodegradable organic matter including manure, sewage sludge, municipal solid waste, biodegradable waste, or any other biodegradable feedstock, under anaerobic conditions.
  - Pyrolysis or gasification
- Most anaerobic digestion facilities currently in operation produce electricity and heat. If markets are available, these facilities can be upgraded to produce renewable natural gas/ biomethane/ methanol.

Renewable Ammonia

- Most ammonia is produced using the Haber-Bosch process with high emissions (>2.16 kg CO_2-eq/kg NH3) & energy use (>30 GJ/tonne NH_3)[1]. With current pricing natural gas derived ammonia is very expensive at ~800-1200 €/t [2].
- Multiple pathways are available for biomass produced ammonia with direct gasification presenting the most cost-effective approach with a projected cost below 400 €/t assuming biomass cost of 58.75 €/dry tonne.
- The TRL for all the renewable ammonia gasification process steps is 9, but as an integrated process the overall TRL is lower.
- There are economies of scale to be harvested. Smaller systems are not cost-effective.
- Neutral CO_2 is a byproduct to be captured and utilized.

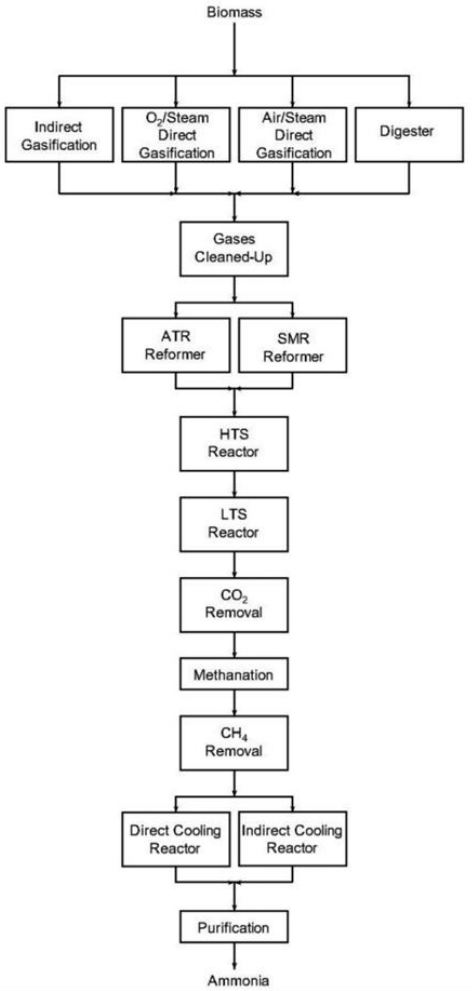


Figure source: Sánchez, A., Martín, M., & Vega, P. (2019). Biomass based sustainable Ammonia production: Digestion vs Gasification. ACS Sustainable Chemistry & Engineering

[1] Ghavam Seyedehhoma, Vahdati Maria, Wilson I. A. Grant, Styring Peter, Sustainable Ammonia Production Processes, Frontiers in Energy Research, Vol. 9, 2021/

[2] https://fertilizerpricing.com

Biomass resources

- Usually, two main approaches are used to classify biomass:
  - Based on types of biomass existing in nature (e.g., according to ecology or type of vegetation)
  - Based on use and application of biomass as feedstock.
- Many different categories have been proposed in literature which include:
  - Wood and woody biomass
  - Herbaceous biomass
  - Fruit biomass
  - Aquatic biomass
  - Animal and human waste biomass
  - Biomass mixtures
- **Competition with food must be avoided at all times**. Circular economy models under the water – energy – food nexus need to be employed to ensure optimal balance between food, feed for animals and fuels.
- **BSEC countries have considerable biomass resources.**

Transitioning to renewable fuels

- ✓ Renewable natural gas by definition *can technically and safely be injected into, and transported through, the natural gas system.*
- ✓ Renewable hydrogen can be blended into the natural gas grid:
  - In some projects mixtures of 20% hydrogen have been realized without any problems[1].
  - Technology is commercially available to upgrade the existing infrastructure for blends up to 90% in hydrogen with ability to extract 99.9999% pure hydrogen while natural gas is still being delivered[2].
- ✓ Renewable ammonia, renewable biomethane and renewable methanol can be directly used in current applications.
- ✓ Capture of neutral CO_2 from biomass processes as well as soil carbon sequestration in agriculture and forestry can provide extra income streams facilitating the investments.

Sources:
[1] https://www.greentechmedia.com/articles/read/green-hydrogen-in-natural-gas-pipelines-decarbonization-solution-or-pipe-dream
[2] https://www.lindehydrogen.com/technology/natural-gas-grid-conversion

Thank you for your attention!

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