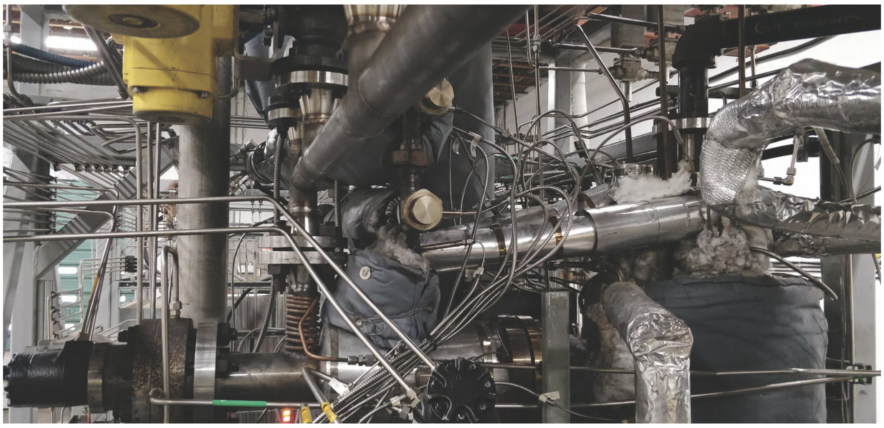
Feature

Unlocking bio-hydrogen from cellulosic waste



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Concerns around energy security, supply-chain resilience, and decarbonisation are accelerating interest in locally sourced energy systems. Across the energy sector, attention is turning to technologies that can convert low-value waste streams into fuels and chemicals while reducing carbon emissions.

One company seeking to address this challenge is Canadian technology developer G4 Insights, which has developed a bio-hydrogen production process based on woody and cellulosic biomass.

The company has developed a proprietary process known as PyroCatalytic Hydrogenation (PCH), which converts woody and cellulosic biomass into biomethane, bio-syngas, and bio-hydrogen, while also producing biochar and biogenic carbon dioxide (CO_2) as co-products.

"Resilience, localised supply chains and energy security are valued more than in the past", believes Edson Ng, CEO of G4 Insights. "And we must simultaneously focus on affordability and sustainability."

The technology is designed to unlock energy from cellulosic biomass resources that have historically been difficult to utilise, including residual forestry waste, straw, and waste wood.

While most biomethane production relies on anaerobic digestion, G4 says PCH has been developed to process underutilised cellulosic feedstocks and generate a range of energy products.

Alongside bio-hydrogen, the process can produce biomethane, bio-syngas, biochar and biogenic CO_2, allowing operators to optimise product output according to market demand while maintaining a carbon-negative overall process balance.

The cellulosic challenge

Local energy sourcing is a fundamental driver of supply chain resilience, and bio-based energy is generally produced and consumed locally. This is due to the low volumetric and gravimetric energy density of the biomass feedstocks, such as wood, grass, bagasse, and maize, compared to liquid fuels.

Bio-hydrogen can be produced by reforming biomethane, which primarily comes from anaerobic sludge digesters of purpose-grown crops such as grass or maize.

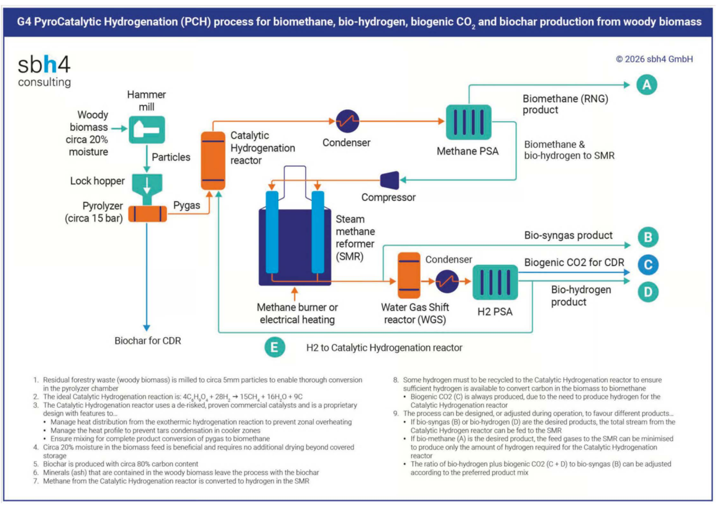
Despite many efforts to adapt the anaerobic sludge digestion, this process has not yet been successfully deployed at scale for highly cellulosic feedstocks such as straw and waste wood.

Ng described G4’s technology as a “technological breakthrough,” arguing that it could enable the use of cellulosic biomass resources that have historically been difficult to convert into energy products.

Research into converting residual forestry waste and other cellulosic post-harvest wastes has been ongoing for decades. Current technologies centre around various thermal techniques such as torrefaction, pyrolysis, and gasification.

G4 PyroCatalytic Hydrogenation in 10 steps

1. Woody biomass feedstock preparation to create particles with dimensions in the order of 5mm;
2. Pyrolysis of the biomass to create pyrolysis gas (pygas) and biochar;
3. Recovery of the biochar as a valuable co-product;
4. Conversion of the pygas and residual tars to biomethane in a proprietary catalytic hydrogenation reactor;
5. Stream-splitting to recover a portion of the biomethane as product and feed the balance to a steam methane reformer (SMR);
6. Conversion of the bio-methane to bio-syngas reformate in the SMR;
7. Water gas shift (WGS) to convert carbon monoxide (CO) from the bio-syngas to green bio-hydrogen and CO_2;
8. Separation of CO_2 from green bio-hydrogen using pressure swing adsorption (PSA);
9. Recovery of the biogenic CO_2 as a valuable co-product;
10. Recycling green bio-hydrogen from the SMR to the hydrogenation reactor.



Overcoming catalyst fouling

Research into the catalytic conversion of uncleaned pygas has taken place over many years. Until now, this direct conversion of uncleaned pygas has been held back by the propensity of tars in the pygas to coke onto the catalyst, which generally uses a nickel-based compound as the active material.

In the PCH process, conversion of pygas to biomethane is achieved in the catalytic hydrogenation reactor. According to G4, two features distinguish the process from previous approaches. Firstly, bio-hydrogen is introduced into the reactor. Secondly, the reactor design itself is proprietary to G4 Insights.

“The hidden secret of G4’s technology is the internal design of the hydrogenation reactor,” Ng said. “It carefully controls the strong exotherm to avoid catalyst damage. Simultaneously, it achieves an exceptionally high conversion of tars and other chemicals in the pygas to methane through tight control of the temperature profile in this reactor.”

Carbon negative, flexible output

In G4’s PCH process, both the pyrolysis and the steam methane reforming (SMR) stages require heat input to drive the chemical reactions.

The SMR requires heat input, and it also emits heat because the reformate gases are cooled between the water gas shift (WGS) stage and the pressure swing adsorption (PSA) unit. This heat can be recovered and used to drive the pyrolysis reaction.

In the case of PCH, bio-methane produced in the catalytic hydrogenation reactor, or natural gas, can be used. Ng added, “The SMR can be electrically heated. Electrical heating of the SMR with renewable power, such as that from hydro, wind and solar resources, simultaneously reduces the carbon intensity of the bio-methane and maximises the bio-methane yield.”

Electrified reforming and electrically heated SMRs are being developed by Topsøe with its eREACT system and Sypox. In a classical flame-heated SMR, approximately one-third of the methane feed is to the burner. Therefore, if this energy input is replaced by renewable electricity, the CO2 intensity of the products from the SMR can be reduced by 30%.

Throughout the PCH process, biomethane, biosyngas and green bio-hydrogen are generated at various stages. Biochar and biogenic CO_2 are also important co-products. The process can be configured to favour different combinations of biomethane, bio-syngas, and bio-hydrogen depending on project requirements.

“Production of more than one bio-energy gas enables revenue diversification from the investment to reduce the commercial risk,” claimed Ng. “During operation, some deviation from the design point can also swing the product mix towards market needs. This enables arbitrage to maximise production of the most profitable product(s) at any moment in time.”

The biogenic CO_2 can either be sequestered or liquefied and sold into the merchant CO_2 market. The biochar can be monetised as a soil improver, and will also be eligible for CO_2 removal certificates since it permanently binds atmospheric carbon.

According to G4, when the overall carbon balance of the PCH process is considered, the resulting bio-hydrogen can be produced with a negative carbon intensity

G4 argues that revenues from co-products such as biochar and biogenic CO_2 could help offset production costs and improve the economics of bio-hydrogen projects.

While the technology can produce multiple energy vectors, its ability to utilise low-value forestry residues and other cellulosic waste streams is central to the company’s commercial proposition.

Validation

The company says it has accumulated over 2,000 hours of testing in Canada, generating data on reactor performance and catalyst behaviour.

G4 sees potential for the technology in applications where forestry residues and other cellulosic waste streams are available and where demand exists for low-carbon fuels, carbon removals and biogenic CO_2.

The company is now planning to build commercial pilot plant at 40 dry tonnes per day biomass input to produce four tonnes of bio-hydrogen nine tonnes of biochar per day.

Future commercial plants processing 250, 500, and 750 tonnes of biomass per day are also planned.