IH²* TECHNOLOGY: RENEW. REFINE. REFUEL.

RENEWABLE FUEL PRODUCTION USING IH² TECHNOLOGY

SHELL CATALYSTS & TECHNOLOGIES
TRANSFORMING ENERGY TOGETHER

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Integrated hydropyrolysis and hydroconversion (IH²) technology is a continuous catalytic thermochemical process can provide a very cost-effective route for producing fungible, liquid hydrocarbon transportation fuels from renewable resources.

The IH² process converts a broad range of residues, including forestry, agricultural, aquacultural and sorted municipal waste (up to 20% plastic content) to gasoline, jet fuel and diesel-range hydrocarbon fuels and/or blend stocks. IH² technology was invented by the Gas Technology Institute in Des Plaines, USA, and has been further refined through joint development with Shell Catalysts & Technologies (formerly CRI Catalyst Company), which owns the exclusive rights for worldwide licensing and deployment.

TECHNOLOGY OVERVIEW

The IH² process has four primary elements (Figure 1). The first is biomass conditioning: sizing to ~3 mm and drying to 10–30 wt% moisture to optimise fluidisation and devolatilisation.

The second element involves a variety of reactions including hydrodeoxygenation of the devolatilised biomass over proprietary Shell Catalysts & Technologies' catalysts in the presence of low-pressure hydrogen. This is mainly to remove oxygen and terminate other undesirable reaction pathways to provide a stable raw hydrocarbon product.

The third element is fixed-bed hydroconversion, which uses other proprietary Shell Catalysts & Technologies' catalysts to further refine the product from the earlier step and transform it into a finished hydrocarbon fuel or blend stock.

The fourth element is the separation, purification and conversion of the light gases generated in the hydropyrolysis reactor in a hydrogen manufacturing unit to produce renewable hydrogen in sufficient quantity to supply all the process needs. The individual elements of the process are all available at commercial scale, which minimises design and operational risks, and enable rapid implementation of the IH² technology.

THE IH² PROCESS – HOW IT WORKS

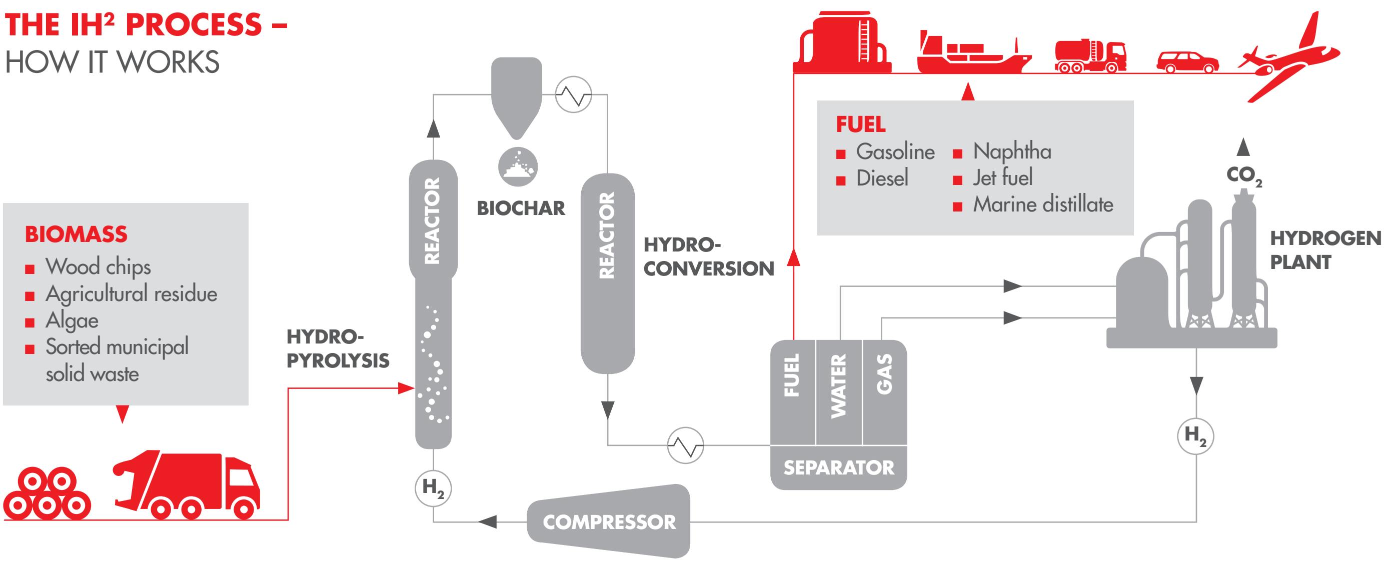

Figure 1: The IH² process.

*IH² is a registered trademark of the Gas Technology Institute.

IH² demonstration facility products and feedstock.

Research staff in Bangalore discussing the technology in front of a lab unit.

IH² TECHNOLOGY DEVELOPMENT

Several capital investments have been made during the development of IH² technology. The Shell Technology Centre Bangalore, India, has bench-scale operating units and high-throughput testing facilities that focus on advancing the technology. As of the end of 2018, more than 30 process and catalyst inventions have resulted from the efforts at Shell Technology Centre Bangalore and the collaboration with the Gas Technology Institute.

In 2012, the Gas Technology Institute commissioned a pilot-scale 50 kg/d IH² plant. This plant has operated for more than 10,000 h and has validated all the basic design principles. Key aspects of IH² technology, including the feedstock handling and supply system, the hydropyrolysis and hydroconversion reactors, and the separation and discharge systems for the residual char have been successfully demonstrated. Thousands of litres of liquid hydrocarbon have also been produced during these experiments. Woody biomass and agricultural residues have been successfully fed through the IH² pilot plant and converted to gasoline, kerosene and diesel products with undetectably low oxygen content and undetectable corrosivity, as measured by total acid number. These hydrocarbon liquids have been comparable with or superior to those produced during the initial laboratory-scale experiments.

MORE THAN 30 PROCESS AND CATALYST INVENTIONS HAVE RESULTED FROM THE EFFORTS AT SHELL TECHNOLOGY CENTRE BANGALORE.

IH²-5000 DEMONSTRATION FACILITY

The IH²-5000 demonstration facility, which processes 5 t/d of feedstock on a dry, ash-free basis, at the Shell Technology Centre Bangalore was completed in Q3 2017 after more than 350,000 work-hours on-site without a safety incident. Zeton, Inc., of Canada, constructed a modular skid-mounted main processing unit; Hydro-Chem, a Linde affiliate in Atlanta, USA, supplied the hydrogen manufacturing unit; and Dresser Rand of Gujarat, India, supplied the hydrogen compressor.

Successful operation of the demonstration facility has been a key milestone in the scaling up and commercialisation of the IH² process. The first hydrocarbon product was produced in October 2017. The demonstration plant has completed several runs and the technology performance outcomes have been in line with what was expected. Following these initial runs, operations have been temporarily paused to make necessary modifications and build the capacity for the plant to process higher amounts of feedstocks and run for longer periods of time. Shell Catalysts & Technologies is seeking to prove that woody biomass and forestry residue, suitable agricultural residue and, eventually, sorted municipal solid waste derived feedstocks can be converted into lower carbon (typically designed to achieve above a 72% greenhouse gas reduction) transportation fuels, including petrol, diesel and jet-fuel on a commercial scale.

The demonstration facility aims to showcase the integration of the IH² process with a steam reformer using the off-gases from the main process to achieve hydrogen self-sufficiency. It will also validate the product quality and yield structure of the process using multiple commercial feedstocks and catalyst particle sizes under commercially relevant hydrodynamic conditions. For initial licensees, the unit also provides a training platform for operators.

The IH² demonstration facility at Shell Technology Centre Bangalore.

The final gasoline and diesel fractions are water-white products.

FUEL QUALITY

Hydrocarbons produced from various biomass types have been distilled into their respective fractions. The final gasoline, jet fuel and diesel fractions were water-white products. Using recently developed proprietary catalyst systems created at the Shell Technology Centre Bangalore, the various fractions met or exceeded the relevant regional standards for drop-in fuels or high-quality blend stocks. The gasoline and diesel is currently undergoing ASTM, EN and BS qualification.

Gasoline meets the ASTM D4814-16d specification for regular grade US gasoline in an E10 formulation. It is also EN 228: Petrol – Jan 2009 compliant in an E10 formulation; otherwise it can be used as high-quality blending stock. Gasoline is also BS VI compliant for India in an E6 blend for regular grades.

Improved catalyst systems have also been developed for the diesel fraction that have resulted in water-white distillate that meets the ASTM D975-15c specification for regular grade US diesel, is EN 590:2009+A1:2010 compliant with cetane boosters, and BS VI compliant for India.

The jet fuels are currently in the ASTM D4054 approvals process. Jet fuel matches the Table 1 Performance Criteria for World-wide Civil Jet Fuel Grade Jet A/A-1 (e.g., ASTM D1655).

MUNICIPAL SOLID WASTE AS FEEDSTOCK

According to the World Bank, the current global municipal solid waste generation level is approximately 1.3 billion tonnes a year and is expected to increase to about 2.2 billion tonnes a year by 2025. Waste composition is influenced by factors such as climate, culture, economic development and energy sources, but all municipal waste contains a portion of organic material. This organic portion ranges from 28 to 64%; paper represents a separate category.

The IH^2 pilot plant with a 50-kg/d feedstock rate at the Gas Technology Institute.

As IH^2 technology produces liquid hydrocarbons from residual organic biomass, the sorted separated organic fraction of municipal solid waste is a viable feedstock. The laboratory-scale IH^2 facilities at the Shell Technology Centre Bangalore have successfully converted municipal solid waste to liquid hydrocarbons. Shell Catalysts & Technologies is seeking to prove the technology using municipal solid waste derived biomass feedstocks in the demonstration facility as well. The benefits of converting municipal solid waste to fuel include reducing surface and landfill waste accumulation, improving environmental quality and supplementing fossil fuel demand with a renewable hydrocarbon. In addition, municipal solid waste represents a potentially cost-advantaged feedstock.

ECONOMIC EVALUATIONS

In 2013, the economics associated with a generic 2,000-t/d woody biomass feed, 230-million-l/y facility were examined by the National Renewable Energy Laboratory and validated by a global engineering and construction company. Since 2013, nearly a dozen site-specific capital and operating cost estimate on commercial facilities have been completed to the FEL-2 standard (±30%) as paid client studies.

INTEGRATION

The IH^2 technology platform can provide synergies with existing operations. The fully profited manufacturing cost can be improved through asset integration or co-location with existing facilities such as paper mills, ethanol plants, agricultural processing facilities, recycling operations or fossil hydrocarbon refineries. In the refinery example, an existing reformer and/or other units or utilities could be used, which would significantly reduce the fully profited manufacturing cost. When integrated with an existing ethanol plant, the inclusion of an IH^2 facility can create a higher value from biomass than would be afforded by heat and electrical power sales.

SUCCESSFUL OPERATION OF THE DEMONSTRATION FACILITY HAS BEEN A KEY MILESTONE IN THE SCALING UP AND COMMERCIALISATION OF THE IH^2 PROCESS.

USING RECENTLY DEVELOPED PROPRIETARY CATALYST SYSTEMS CREATED AT THE SHELL TECHNOLOGY CENTRE BANGALORE, THE VARIOUS HYDROCARBON FRACTIONS MET OR EXCEEDED THE RELEVANT REGIONAL STANDARDS FOR DROP-IN FUELS OR HIGH-QUALITY BLEND STOCKS.

CONTACT US

For more information, please visit **www.shell.com/ih2**

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