DOE Bioenergy Technologies Office (BETO) 2021 Project Peer Review

Integration of IH^2 with the Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels

March 25, 2021

WBS: 3.5.1.101

Terry Marker

Gas Technology Institute

Integration of IH^2 with the Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels

Project Overview

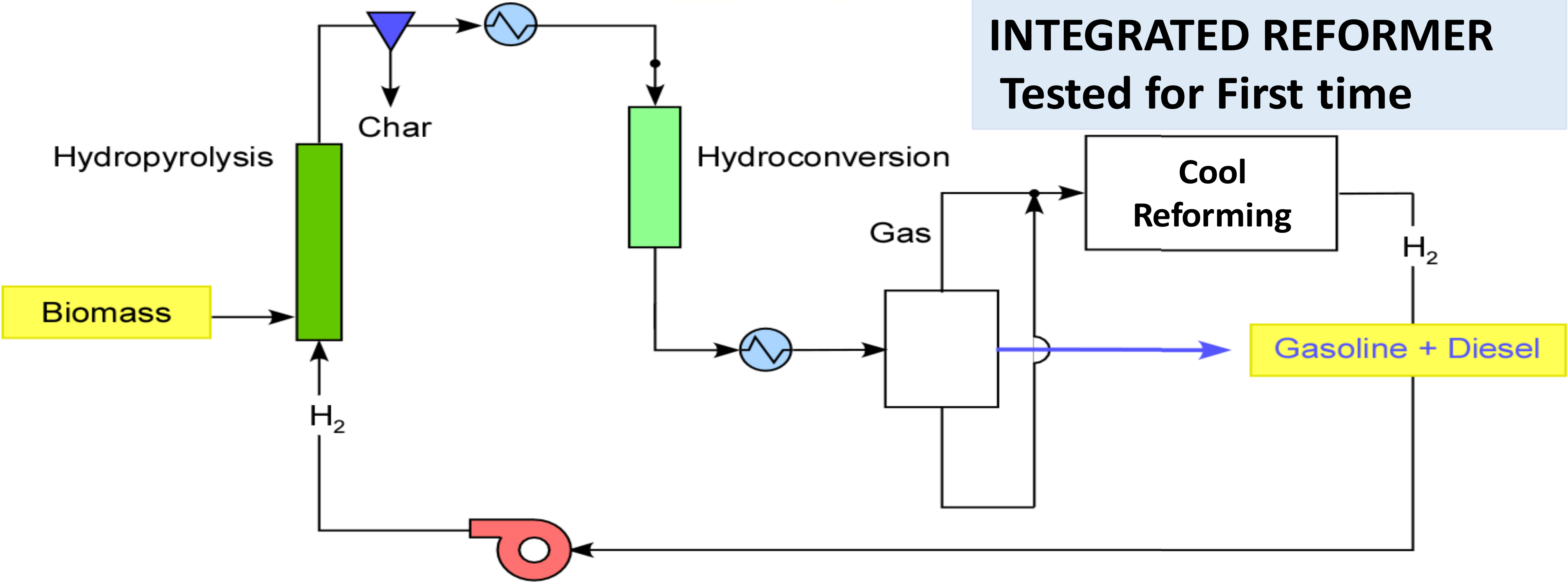
Project Overview

Integration of IH^2 with the Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels

- *Goal is to show IH^2 hydrogen self sufficiency and integrate IH^2 and Cool Reformer system to reduce IH^2 cost*
  - *GTI will demonstrate IH^2 hydrogen self sufficiency of the integrated IH^2 and Cool reformer system through pilot scale tests*
  - *Show integrated system is simple and low cost through testing and engineering work*
  - *Run the Integrated system for more than 500 hours and make more than 50 gallons of drop-in biofuel with <.4% oxygen*
  - *Reduce capital cost and operating cost by more than 25% with Cool Reformer and other improvements (Crumbles, Rapid Cycling Valves, RCPSA, Modular construction)*

Cool Reforming Integrated with IH² (Integrated Hydropyrolysis and Hydroconversion)

INTEGRATED REFORMER
Tested for First time



- Directly make desired products
- Run all steps at moderate hydrogen pressure (100-500 psi)
- Utilize C_1-C_3 gas to make all hydrogen required
- Avoid making “bad stuff” made in pyrolysis – PNA, free radicals

IH^{2}® 50 kg/d Continuous Pilot Plant

IH2® Product Yields from Wood

Table: Typical IH2 performance results for wood feedstock on a moisture and ash-free basis.

Output	Wood
C_{4+} liquids, wt%	26
Oxygen in liquid, wt%	< 0.4
Gasoline, wt%	16
Diesel, wt%	10
Char, wt%	13
CO_x wt%	17
C_1-C_3, wt%	13
Water, wt%	36
H_2 uptake, wt%	4.6
H_2 make-up, wt%	0
Ammonia, wt%	0.18

- High liquid yields
- High process thermal efficiency
- A picture is worth…

Advantages of the Cool Reformer

- Can handle CO and CO2 in feed with no removal steps
- Improved extremely active catalyst – very robust
- Simple low-cost design

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Management

Project Management

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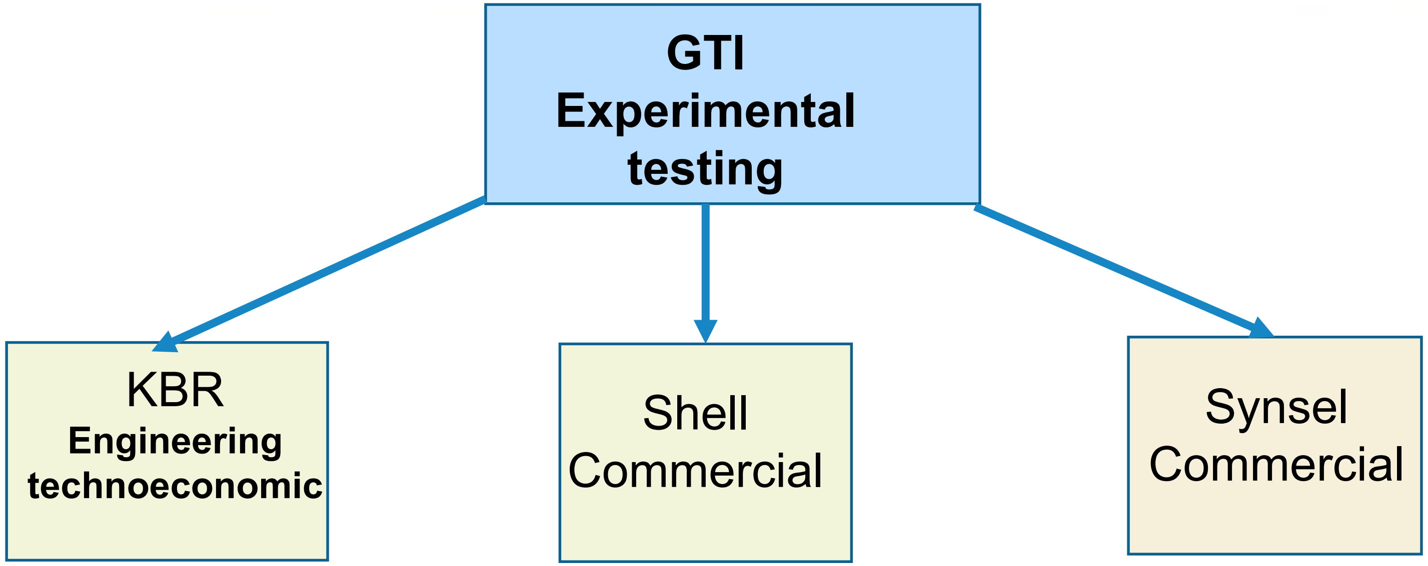

Additional Contractors

1 INL-Forest Concepts- IH2 Feed Preparation2

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Project Management –Risk Mitigation

Integration of IH^2 with the Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels

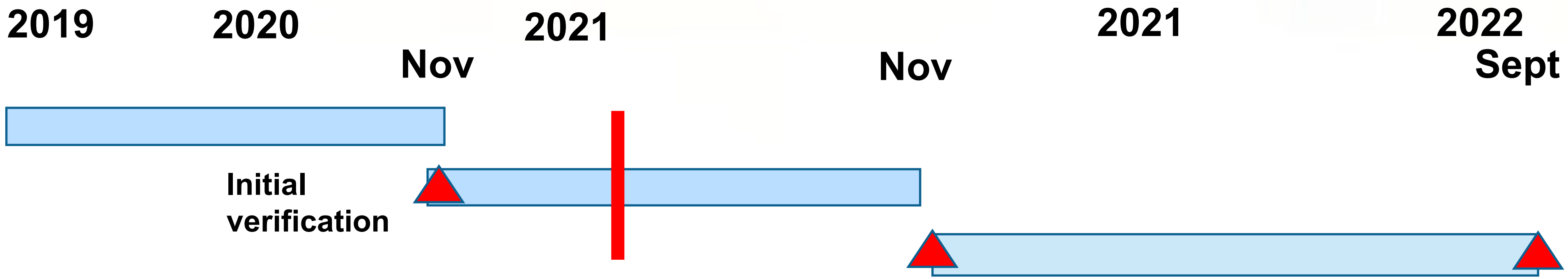
- Monthly Team Meetings
- 3 phase approach with important milestones and intermediate reports

Integration of IH2 with the Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels

Approach

Approach

Integration of IH^2 with the Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels



- Produce wood feed
- Tie-in/Shakedown
- Short term integrated testing with H2 self sufficiency

- Long term integrated testing with hydrogen self sufficiency
- Final Engineering
- Final Technoeconomic
- Final report
- Reduce capital and Operating Cost 25%

We are currently in Budget Period 2

Second Budget Period Key Tasks/Milestones

In Progress

- Receive 3 tons of crumbles
- Shakedown Cool Reformer – IH^2 integrated system
- Short term testing of integrated system and show H2 self sufficiency for > 50 hours and make 4 gallons of IH2 product <0.4% oxygens
- Intermediate Verification

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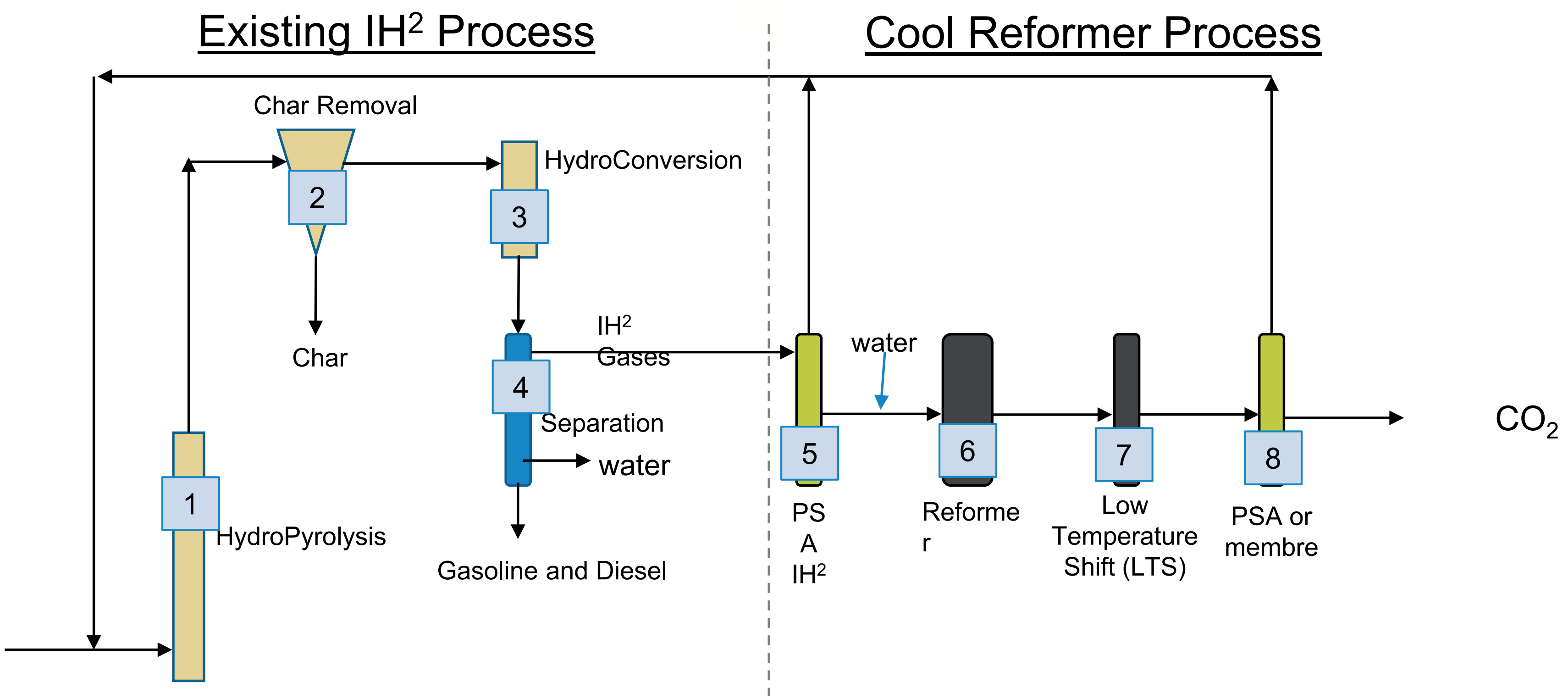
Integrated Cool Reformer and IH² Pilot Plant



Key Technical Challenges
Budget Period 2

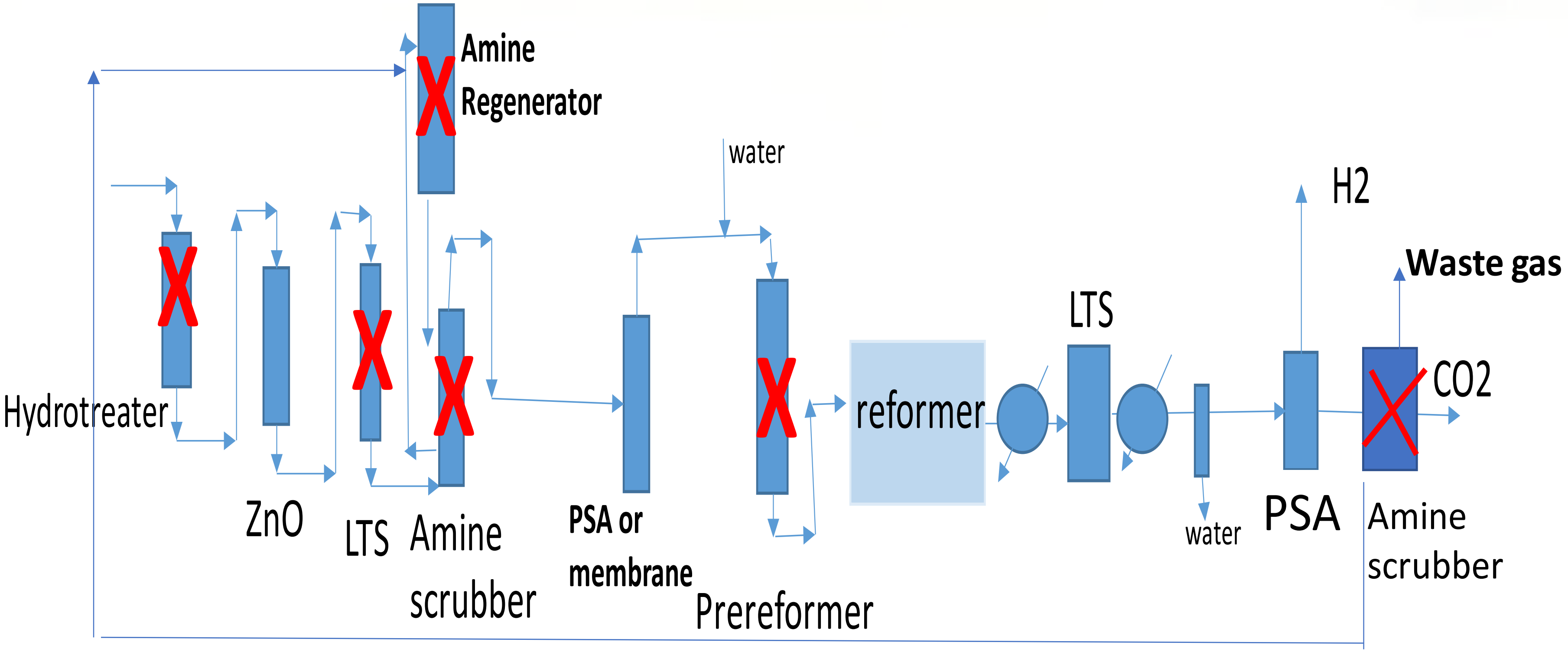
- Integrated system working stably
- Showing Hydrogen self sufficiency over short period

Integration of IH² with the Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels

Impacts

- Speed Commercialization of IH²
- Make IH² lower cost and more commercially attractive

Process Steps Removed from Current Hydrogen Plant design by use of Cool Reformer System



Cool reformer system requires less equipment

Simpler = better for small skid mounted designs

Other IH^2 Process Improvements to be Included In Engineering design

- Replacement of Hammermilled feeds with Crumbles feeds – More energy efficient and lower capital cost
- Use of Rapid Cycling Valves for Lockhoppers – Reducing Lockhopper cycles from 15 minutes to 5 minutes resulting in 75% smaller lockhoppers
- Use of RCPSA for H2 purification instead of PSA
- Move to skid mounted modular design
- Overall Goal is to significantly reduce overall IH^2 cost

Integration of IH^2 with the Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels

Progress and Outcomes

Cool GTL Reformer– Connected to IH2

Cool Reformer Pilot Plant – Control Room

- Integration In Progress
- Shakedown and testing in Summer

Integration of IH^2 with Cool Reformer for the Conversion of Cellulosic Biomass to Drop In Fuels

Summary

- Unique new Reformer
- Engineering evaluation of other IH^2 process improvements including Crumbles, Rapid cycling valves for smaller Lockhoppers, RCPSA, Modular construction
- Project in Budget Period 2
- Key Step in the Successful Commercialization of IH^2

Quad Chart Overview - Integration of IH^2 with Cool Reformer for the Conversion of Cellulosic Biomass to Drop-In Fuels

Timeline

- Project start date Oct 2019
- Project end date Sept 2022

	FY20 Costed	Total Award
DOE Funding	*$149,111*	$1,320,000
Project Cost Share	$28,000	$341,000

Project Partners*

- KBR
- Shell, Synsel

Project Goal

Show Integrated Cool Reformer and IH^2 , Hydrogen Self Sufficiency and reduce IH^2 capital and operating cost

End of Project Milestone

- Long term Integrated testing of Cool reformer and IH2 to show H2 self sufficiency over 300 hours. Operate integrated system for more than 500 hours and make 50+gallons of IH2 hydrocarbon liquid with<0.4% oxygen
- Engineering improvements show 25% reduction in capital and 25% reduction in operating costs for IH2 with all improvements.
- 3 Technoeconomics show IH2 drop in fuel for < $2.5/GGE

Funding Mechanism

DOE DE-EE-0002029 – Topic area AOI-4 ,

FOA issued in 2019

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Additional Slides

IH2® Long-Term Operation

- Over 6000 hours of IH2 pilot plant operation on various softwood and hardwood feedstocks, as well as corn stover and sugarcane bagasse
- Long-term tests validated catalyst life, provided process economic model inputs, and produced liquid product for fuel certification tests

IH2® Pilot Reactor Liquid Yield
(weight percent)

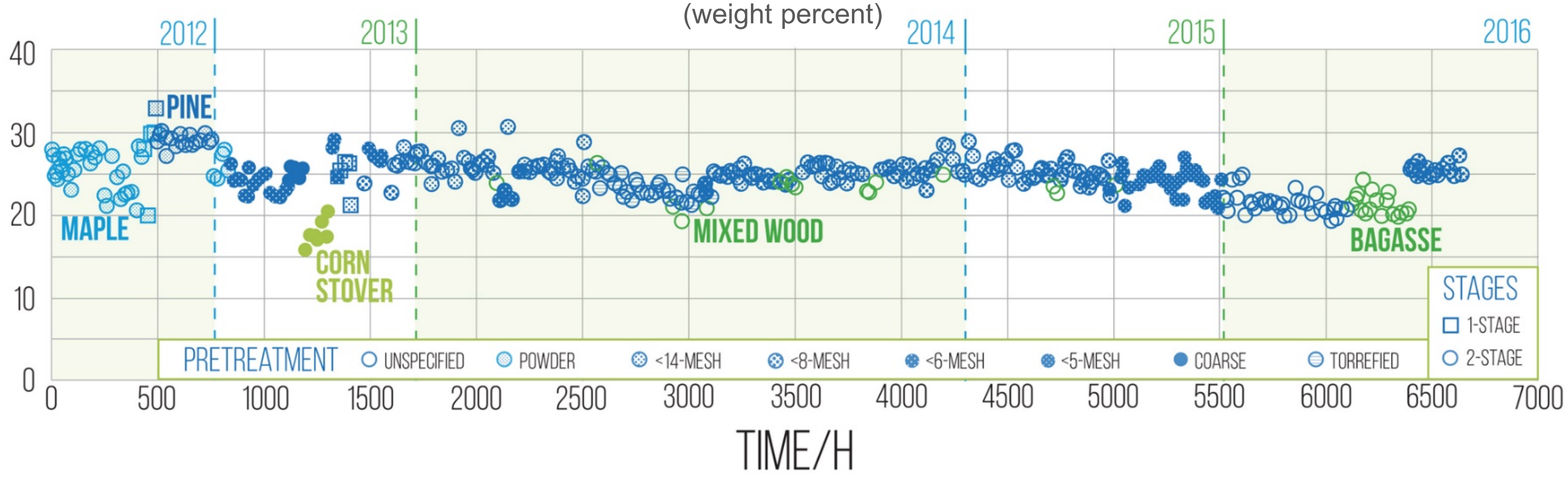

Figure: Liquid yield versus time on stream from IH2 pilot scale reactor during feedstock testing 2012-2016.

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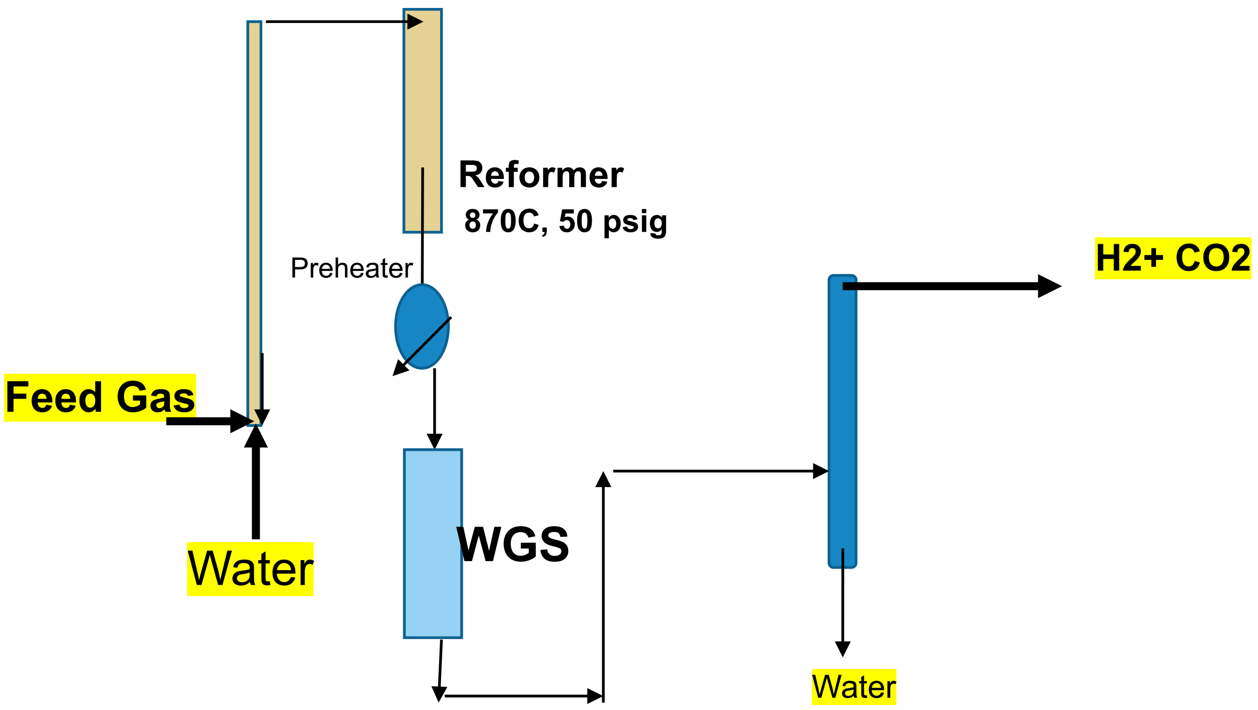
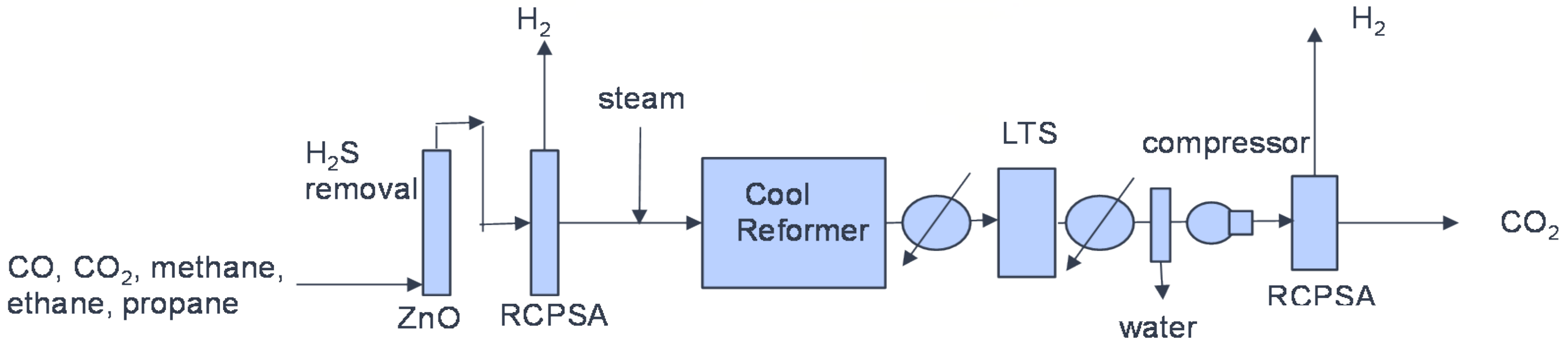
Initial verification – Passed – Nov 2020

- Cool Reformer in Small Pilot Plant in 554

Cool Reformer Process



Simplified Gas Feed and Post Treatment for Cool Reforming



- CO and CO_2 go to reformer
- No need for gas pretreatments
  - No gas hydrotreating to remove organic sulfur
  - No low-temperature shift (LTS)
  - No amine scrubbing to remove CO_2
- Simple reformer with new catalyst
  - No prereformer
  - Lower temperature operation
- Estimated cost* for 500t/d wood feed is <$23 million
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* Estimated from component literature database

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