



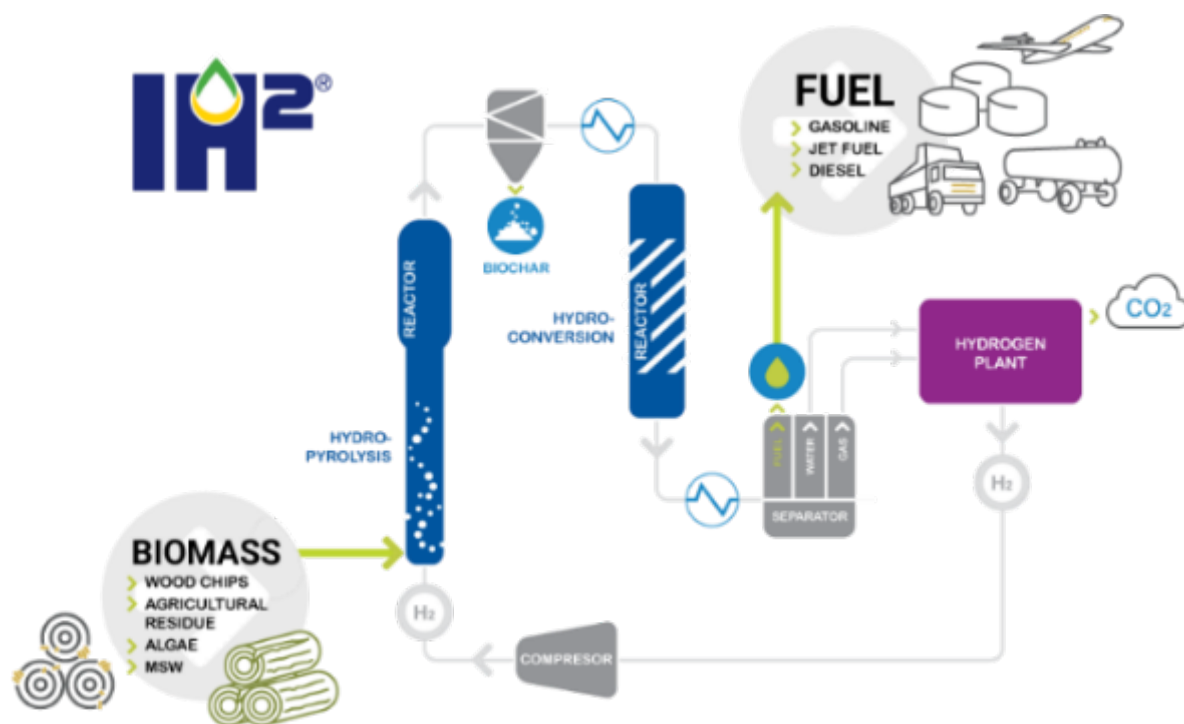
GTI's IH² and E-Reformer Two Innovative Conversion Technologies

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GTI Energy

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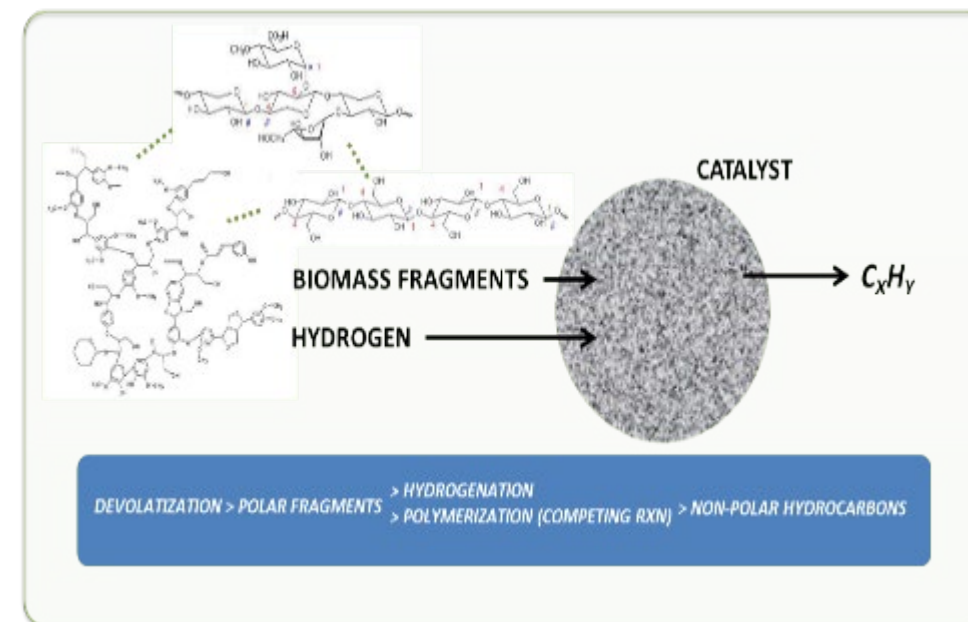
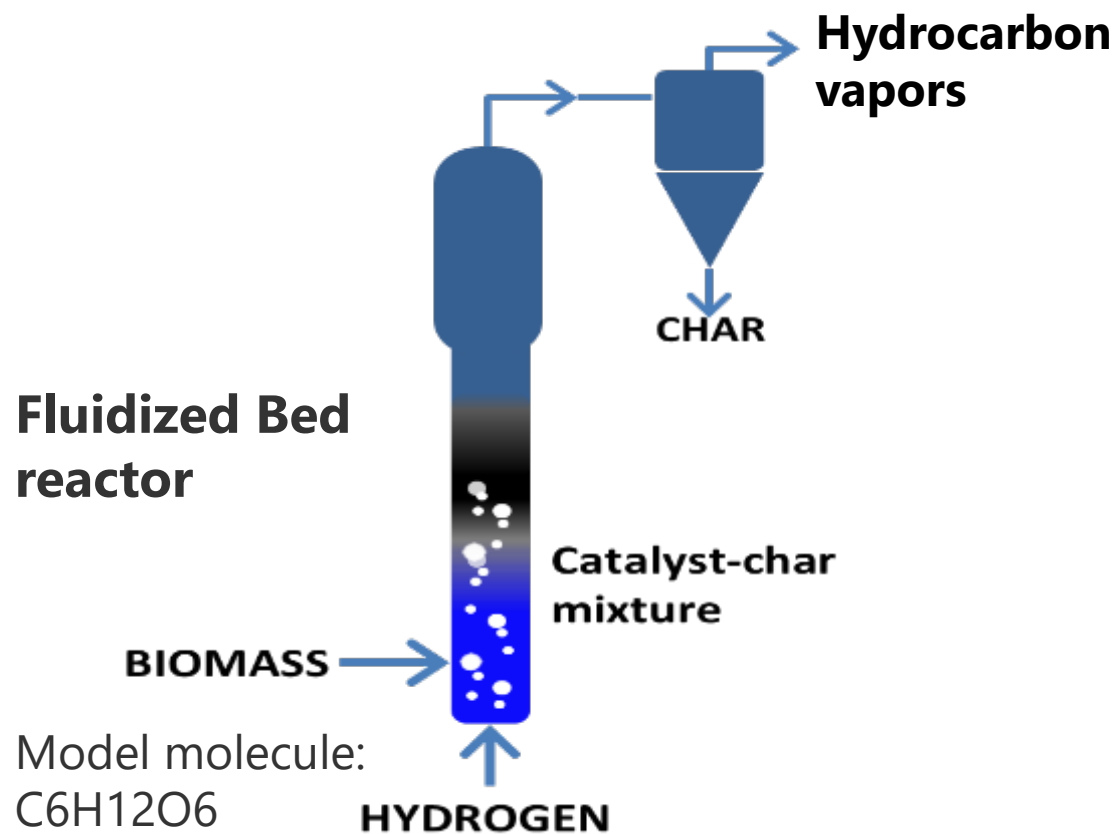
What is IH² technology?



An Innovative Process

- Directly converts solid biomass into liquid hydrocarbon fuels
- Removes all oxygen from the feed and generates high-quality gasoline, jet, and diesel boiling-range fuels
- Economic at scales relevant to biomass availability (> 100 tpd)
- Gives the highest GPT yield of oxygen-free transportation fuels of any biomass conversion process
- Sequesters carbon as durable biochar
- Demonstrated at 50 kg/d and 5 t/d scale

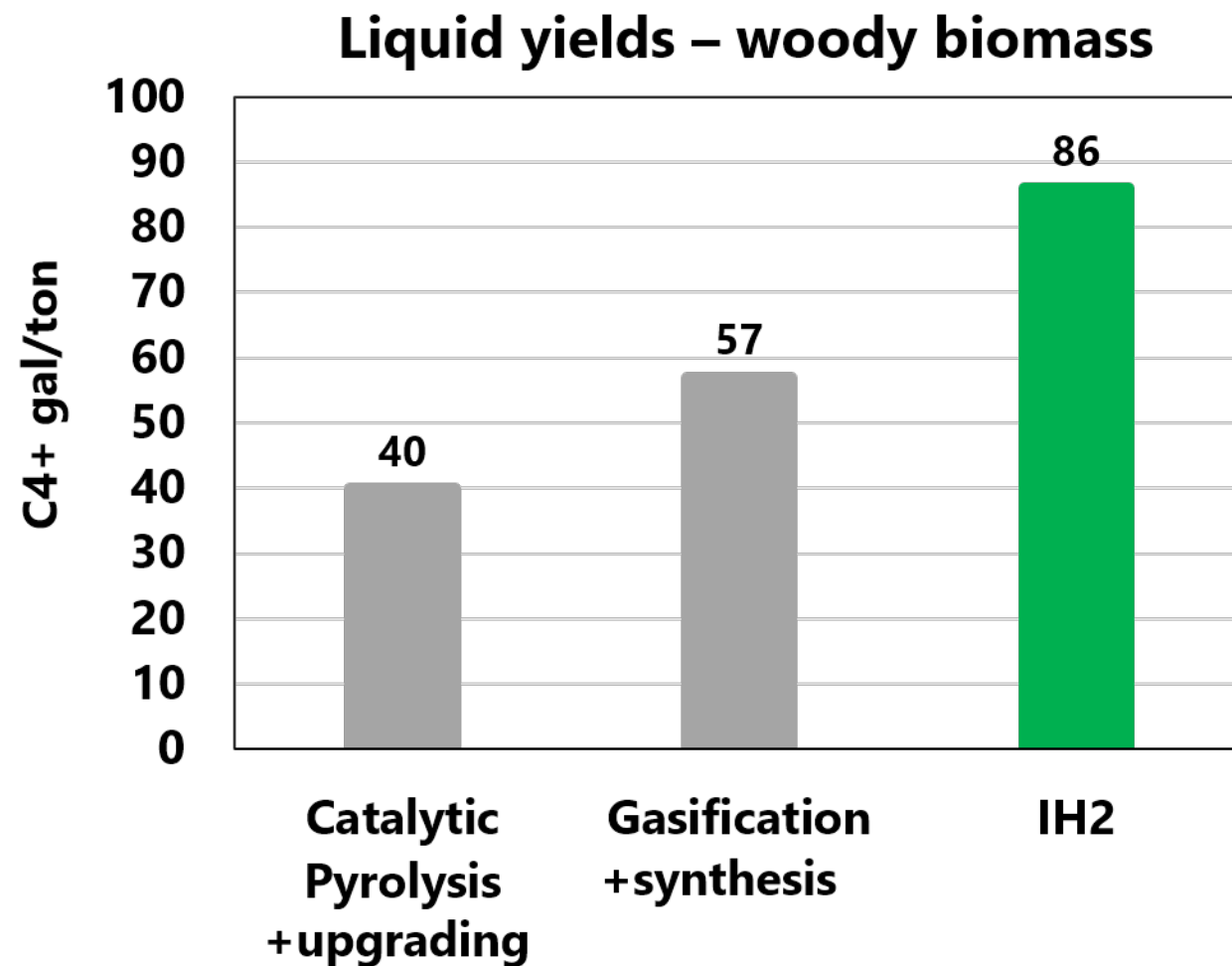
Hydropyrolysis reactor and chemistry



Biomass flows through a catalyst bed, converting continuously to char and hydrocarbons

IH^2 adds hydrogen directly to biomass fragments

High liquid yields – Excellent product quality



IH² Fuels

<1% Oxygen

<0.1 TAN

No water

Excellent stability

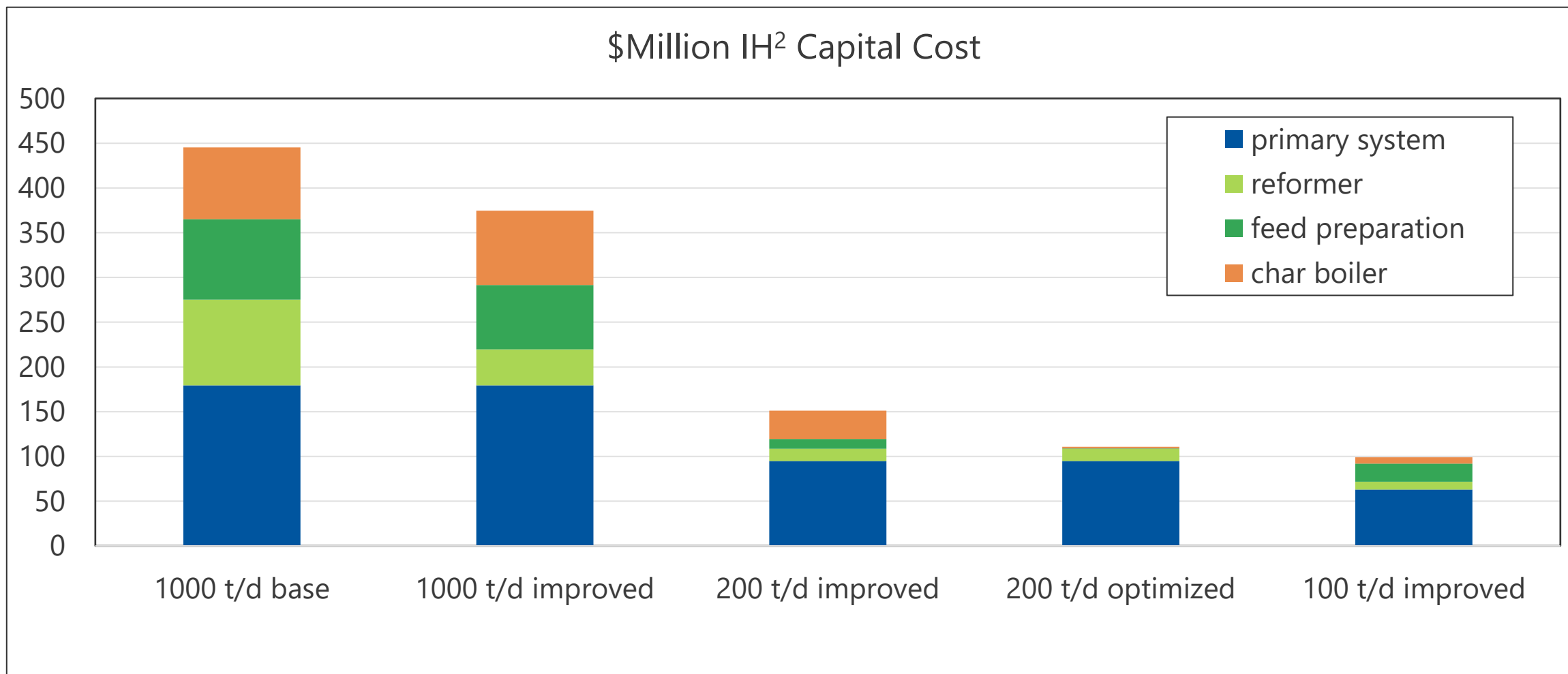
Heating value = 18,000 BTU/lb

No upgrading needed

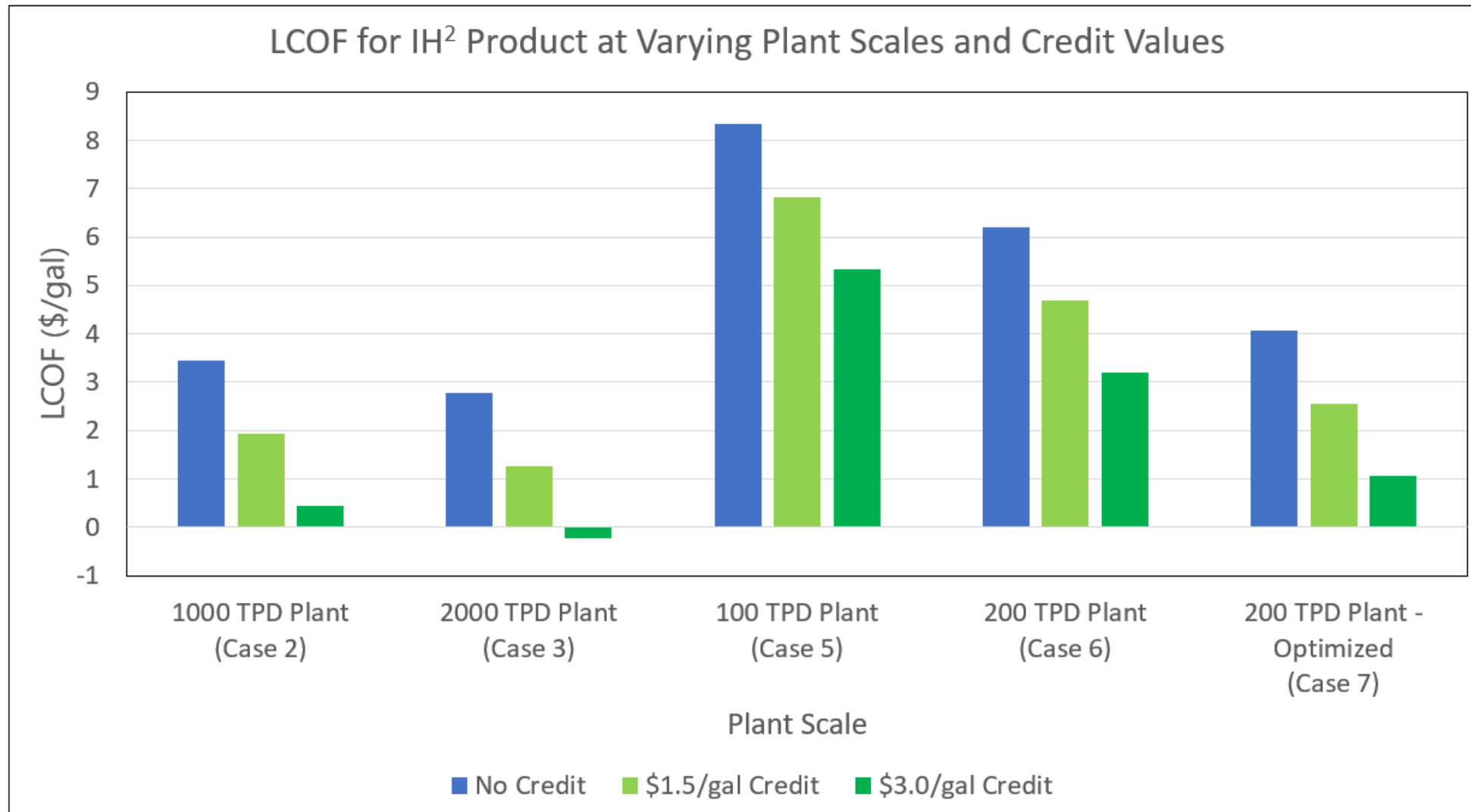
The fundamentals of IH^2 are strong

- Rapidly adds hydrogen to the devolatilized vapors before they can form difficult-to-hydrotreat secondary products (high-molecular weight multi-ring aromatics)
- All condensable volatiles are converted to HC, no losses from oxygen addition or incomplete upgrading
- Directly makes high yields of high-quality fuel products
- Can directly make drop-in gasoline, jet, and diesel with a third stage, avoiding any need for refinery post-processing

Small commercial plants mitigate investment risk



Economic case still holds at the smaller scales with incentives



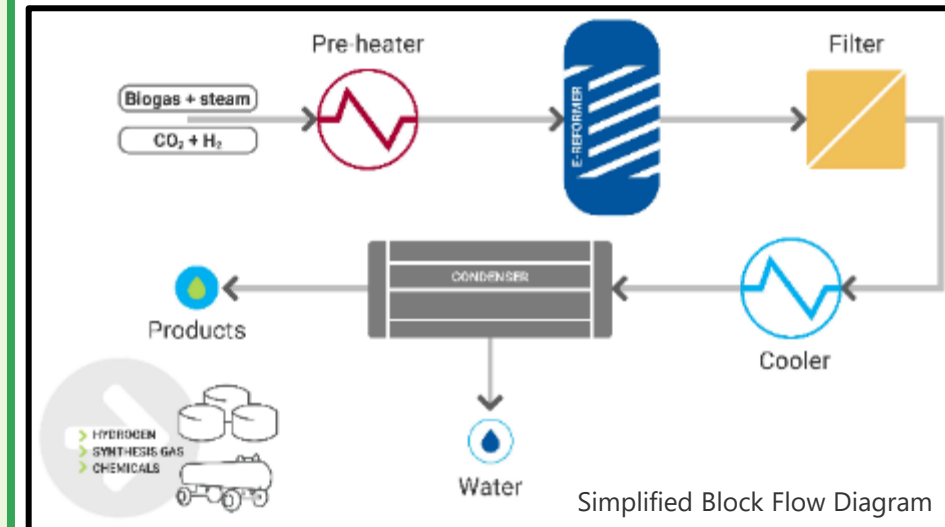
IH² conclusions/path forward

- IH² continues to be one of highest potential biomass to drop in fuel technologies.
- IH² technology has been successfully demonstrated for over **13,000 hours** at GTI at **50 kg/day** and for months at **5 t/day** scale
- **100-200 t/day** IH² size is an ideal first-of-a-kind size to lower risk and minimize investment — modular and quick to build

Electric reforming – Another innovative process

Description

- Electric reformer utilizes electric heat to complete reactions (currently evaluating resistive and inductive heating)
- Three reactions occur simultaneously: steam methane reforming, dry reforming, and reverse water gas shift (RWGS)
- Feed gas: Biogas (can be CO₂ rich) + steam, methane + steam, or CO₂ + H₂
- Proprietary catalyst can handle heavier hydrocarbons, CO₂, and CO
- No pre-reformer used as with conventional fired SMR
- E-Reformer technology has many applications:
 - Standalone H₂ generator
 - First stage for liquid fuels production
 - Chemical production (methanol, ethylene, propylene, etc)



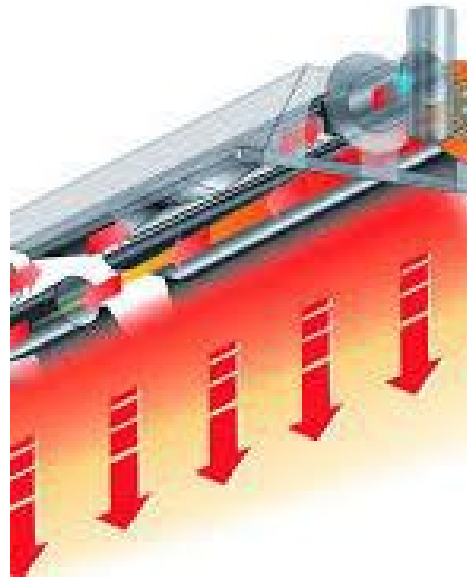
Value Proposition

- **Modular** design
- **Smaller footprint, cheaper,** and more **efficient** than current fired reactors
- **40% CAPEX savings** as compared to fired SMR by carrying out conversion of bio-based, CO₂ containing gases, and recycle streams in one step
- **Higher product yields** from the elimination of feed gas combustion
- **Lower CO₂ emissions** due to elimination of furnace for heat

Replace fired heaters in reformers with electric heaters – for more compact, low-cost design

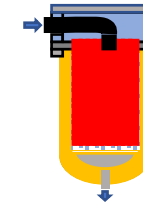


Standard Fired heater



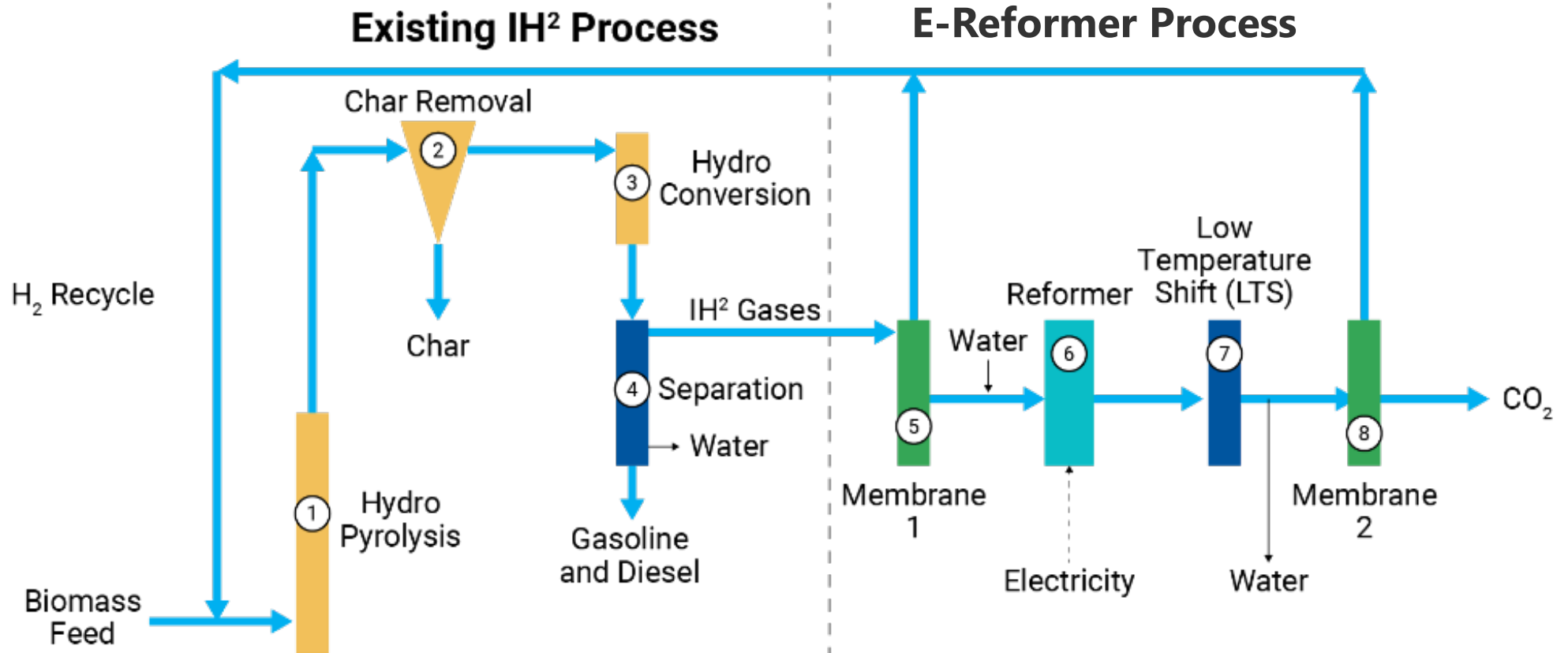
Radiant multitube heater is bulky, requiring lots of surface area

**1/10 the size of a fired heater
98%+ heating efficiency**



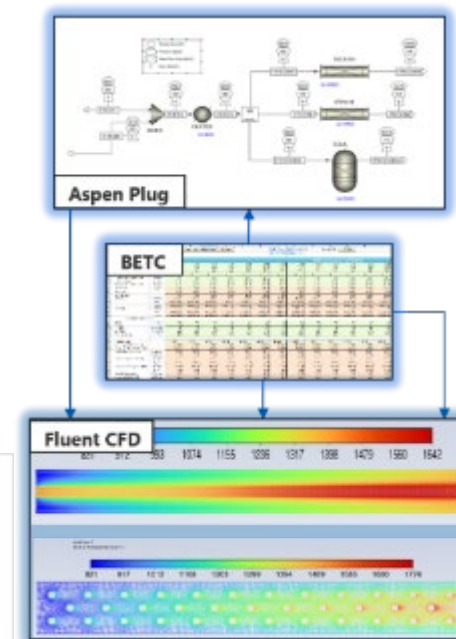
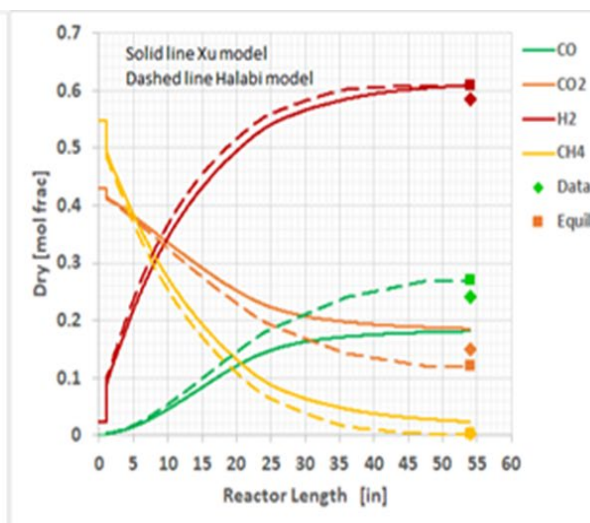
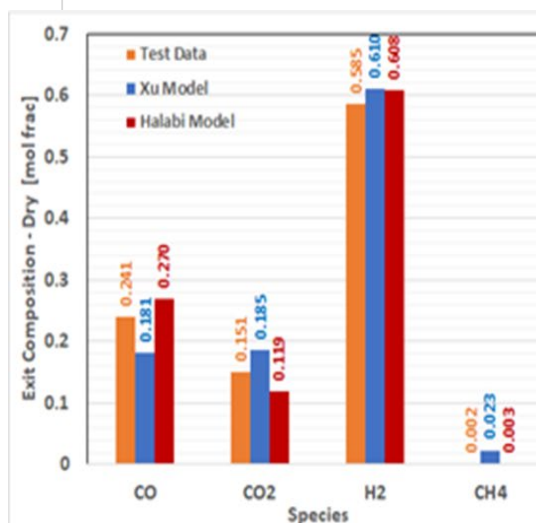
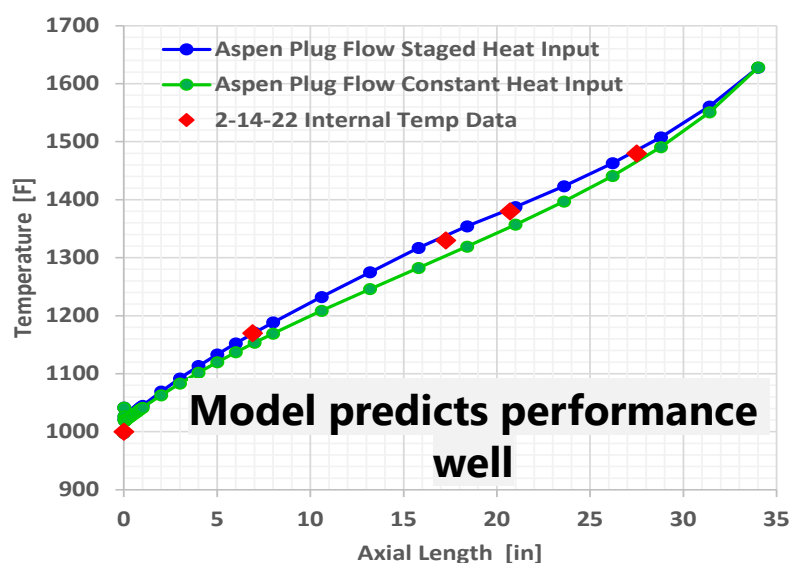
Packed bed with SiC and immersion heaters = most compact approach

E-Reformer integration with IH² tested at 50 kg/day



Anchored modeling mitigates scale-up risk

- Particle bed model, AspenPlus plug flow model, and CFD models developed
- Reforming catalytic kinetics included
- Use CFD results to determine spacing of heating elements and size of reactor
- Anchored to experimental data



Models anchored for resistive heating and leveraged for future projects

E-Reformer large pilot validation

TRL 6 (after completion of DOE award EE0009754)

- Biomethane, and $H_2 + CO_2 \rightarrow$ syngas
- Lower cost compared to state-of-the-art methane reformers (~10% footprint)
- Higher yields and reduced emissions due to elimination of NG furnace
- More uniform heat transfer & faster ramp rates

E-Reformer large pilot at GTI Energy



E-Reformer Validated from Bench to 160 kW Pilot - Path to Commercial Scale



COMPLETE

Bench-Scale Development & Catalyst Validation

Catalyst formulation, reaction kinetics, and proof-of-concept for resistive heating approach established. Key process parameters including conversion efficiency, temperature profiles, and product selectivity quantified at bench scale.

COMPLETE

3 kW Resistive Pilot - First Integrated System

First full-system pilot with integrated feed, reactor, and product handling. Validated conversion performance and thermal management. Process control strategy developed. CFD and Aspen plug-flow models anchored to experimental data and confirmed to predict performance well.

COMPLETE

160 kW Resistive Pilot - Commercial-Scale Parameters Validated

Significant scale-up from bench to 160 kW pilot successfully demonstrated. Commercial-scale design parameters confirmed. Reactor spacing and heating element sizing determined by CFD. Models leveraged for projecting inductive heating performance at larger scale.

IN PROGRESS

Inductive Heating Demonstration - DOE-Funded Project

First application of inductive heaters in a catalytic environment. DOE-funded project (\$3.75M total: \$3M federal + \$750K cost-share). Seeking additional industry cost-share partners.

E-Reformer conclusions/path forward

- The E-Reformer Technology has been proven experimentally, and the models have been validated
- It has been demonstrated successfully for over **4500 hours** at **3kW** and **1800 hours** at the **160kW** scale
- The pairing of these two innovative technologies results in a low-cost biomass conversion approach
- E-Reformer demonstration shows that replacing combustion heat with immersed electrical heat is viable and can provide better bulk and local temperature control for endothermic processes



Questions?

Support from US DOE Awards EE0008919 and EE0009754