the Energy to Lead

Partnering with Industry to Develop Advanced Biofuels

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Biomass 2014
July 29, 2014

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Advanced Biofuels Tenets

- Converting indigenous resources is good for the economy
- Abundant non-food biomass is available
- Drop-in, infrastructure-compatible fuels have vast markets
- Seek commercial competitiveness without subsidy
- Scale of supply requires innovation for process efficiency
- Policy needs to ensure access to markets
- Funds are needed for development and initial deployment

GTI Biofuels Program

Biomass is renewable, precious carbon. We strive to find the highest, best use in the economy for biomass. Our focus is on thermal processes to convert whole biomass into products.

- Biomass pretreatment – upgraded, homogenized feed product
- IH^{2}® process – innovative thermal, catalytic conversion for drop-in gasoline, jet, and diesel hydrocarbon fuels
- Pilot gasification platform – testing to build technology confidence (e.g., wood2gasoline project)

Partners in Process Development

Process Design Package for Commercial Plant

Pilot-Scale Tests

Laboratory Gasification Tests

Feedstock Properties Tests

Modeling / Simulation

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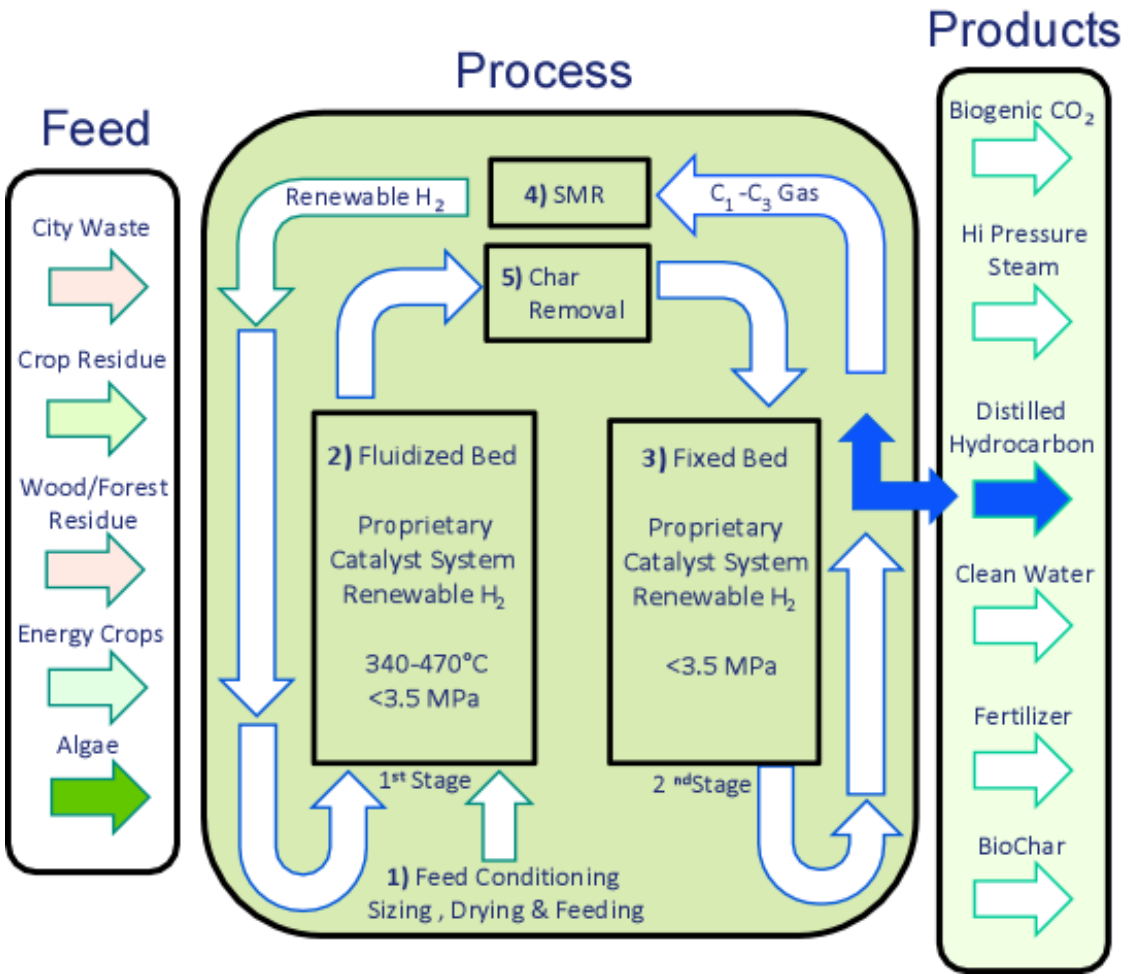
The IH^{2}® Process…

- Utilizes a fluid-bed reactor, employs moderate pressures and temperatures, a hydrogen environment, and active catalysts.
- Quickly liberates oxygen and adds hydrogen to saturate vapors volatized from rapidly heated particles of biomass.
- Depends on exothermic hydrogenation reactions to provide process heat and product yield.
- Uses liberated oxygen to provide water for steam reforming.
- Produces a drop-in refinery blendstock – with the same set of molecules found in gasoline and diesel fuels.
- Also produces light C_1 – C_3 hydrocarbon gases that can supply all of the hydrogen required by the process.
- Has a very low carbon footprint.

Process Overview



- Process a wide variety of biomass feedstocks
- Directly make hydrocarbon distillate products (gasoline, jet and diesel)
  - **R100 Gasoline (Wood)**
  - **R60+ Diesel (Wood)**
- Self-generate all hydrogen and water required
- Run all steps at moderate pressure and temperature
- LCA shows 95% GHG reduction for woody feeds
- Technology licensed to CRI Catalyst

Thermal, Catalytic Biofuels Production

RENEW. REFINE. REFUEL.

> Over 3,000 hours of testing to date in pilot plant

Gasoline-Range Hydrocarbons

Diesel/Jet-Range Hydrocarbons

GRI
DELIVERING INNOVATION

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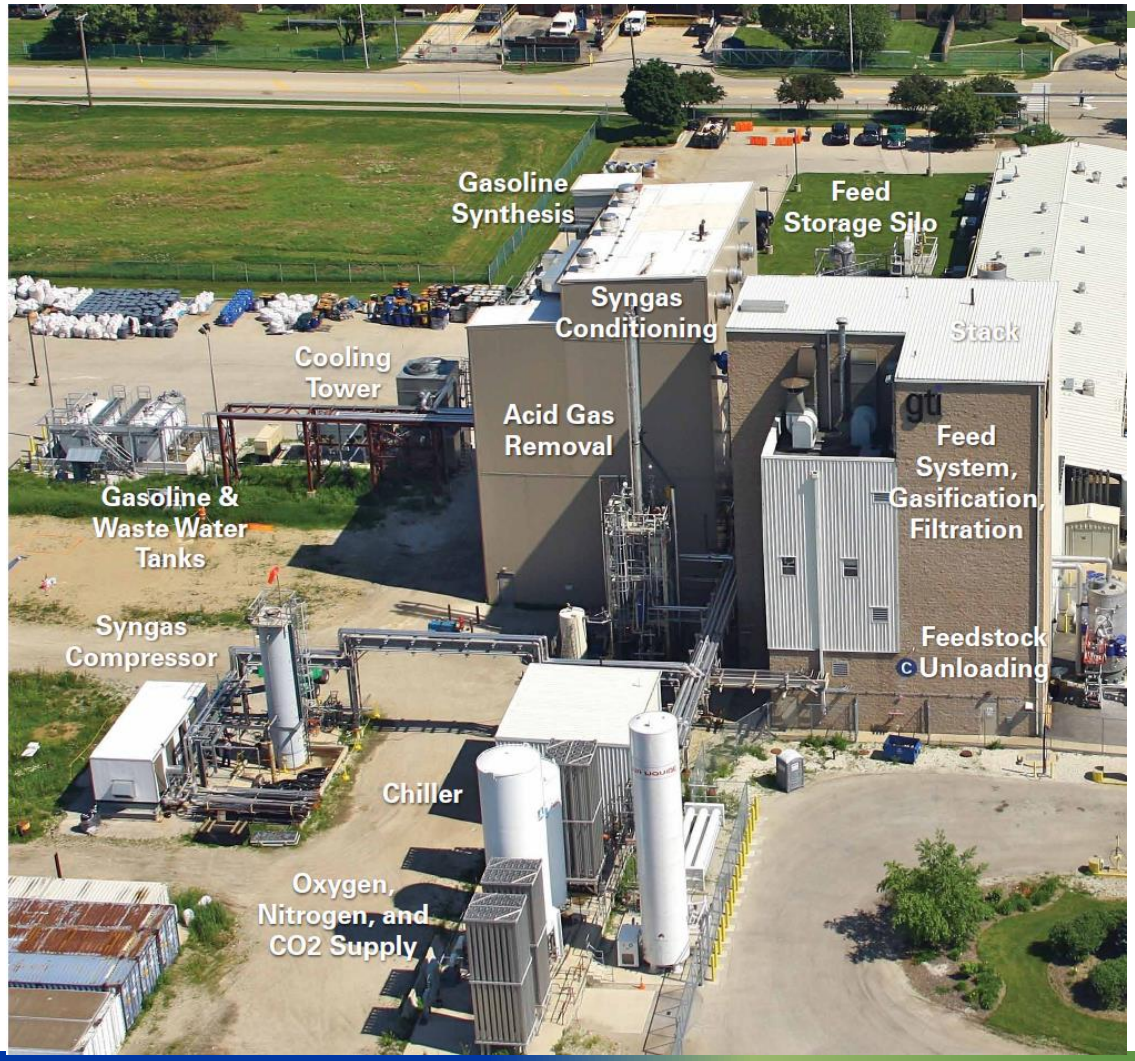
Integrated Biorefinery Pilot Plant



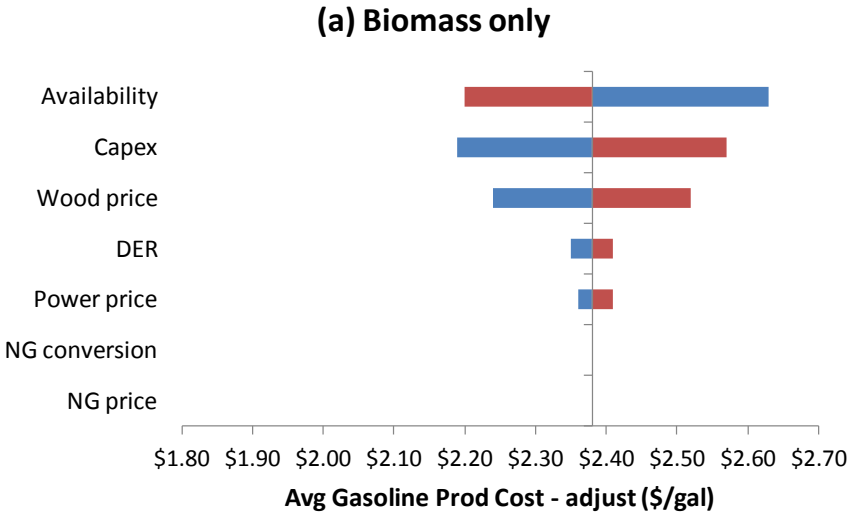
> Demonstrated a gasification-based process for conversion of woody biomass to gasoline

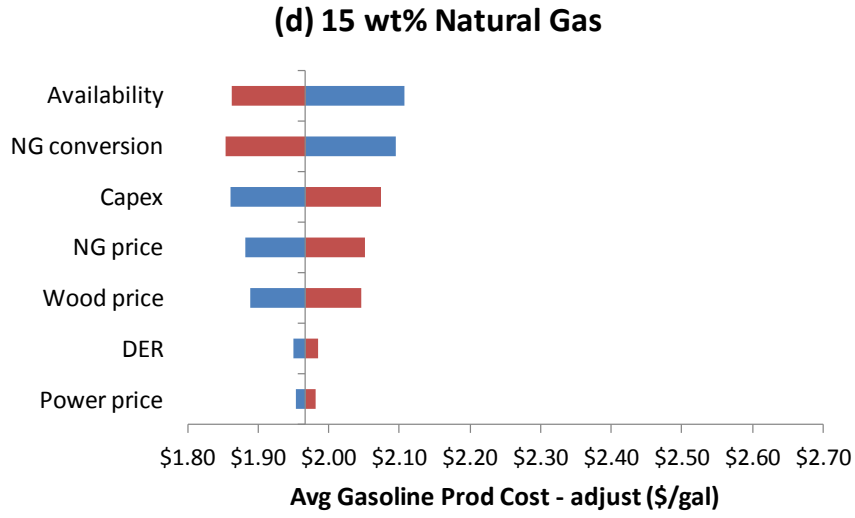
Pilot Plant Key Results

- 1,000 hours of pilot-scale testing including demonstration of fully integrated operation – on time and on budget
- Produced more than 10,000 gallons of 89-92 octane gasoline
- 61-65% syngas to motor fuel conversion (LHV energy basis)
- Engine emissions from 80% biogasoline blend were ‘substantially similar’ to standard gasoline
- Fleet test with 50% biogasoline blend logging 75,000 miles on each of 4 vehicle pairs
- Pilot results reduce technical risk sufficiently for licensors to offer commercial package

NEXT STEP:

Natural Gas Plus Biomass for Gasoline Production



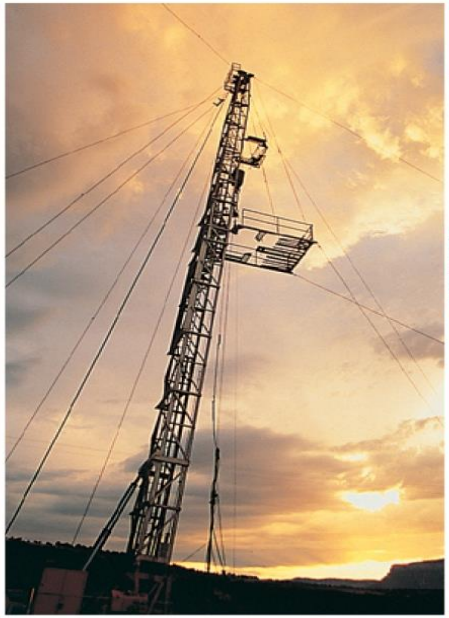


Enhanced commercial prospects:

- Increased capital efficiency
- Reduced production costs
- Lower sensitivities to key risk factors

DER is debt/equity ratio

Turning Raw Technology into Practical Solutions



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