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Cellulosic Biofuel Technology

Liquid Phase Catalytic (LPC):

- ❖ Low volumes with liquid phase
- ❖ Fast reactions and low residence times (hours)
- ❖ *Low temperature / pressure*
- ❖ *Converts raw biomass*
 - *Larger particle size*
 - *High moisture*

REACH

Other Types

Thermochemical Conversion:

- Vapor phase process
- Gasification and pyrolysis
- Large equipment needed to handle vapor volumes

Biochemical Conversion:

- Fermentation to alcohols
- Requires sugars as feedstock
- Very long residence time (days)

Liquid phase:
smaller equipment

+

Catalytic:
faster process,
smaller equipment

=

Lower Capital Costs





REACH Technology

RE

Renewable

*Low-temperature
Low-pressure
Enzyme-free*

A

Acid-hydrolysis

Biomass



Non-sugar
intermediates

CMF



other
bio-products

C

Condensation

*Molecule formation:
Can customize
carbon chain length
for desired product*



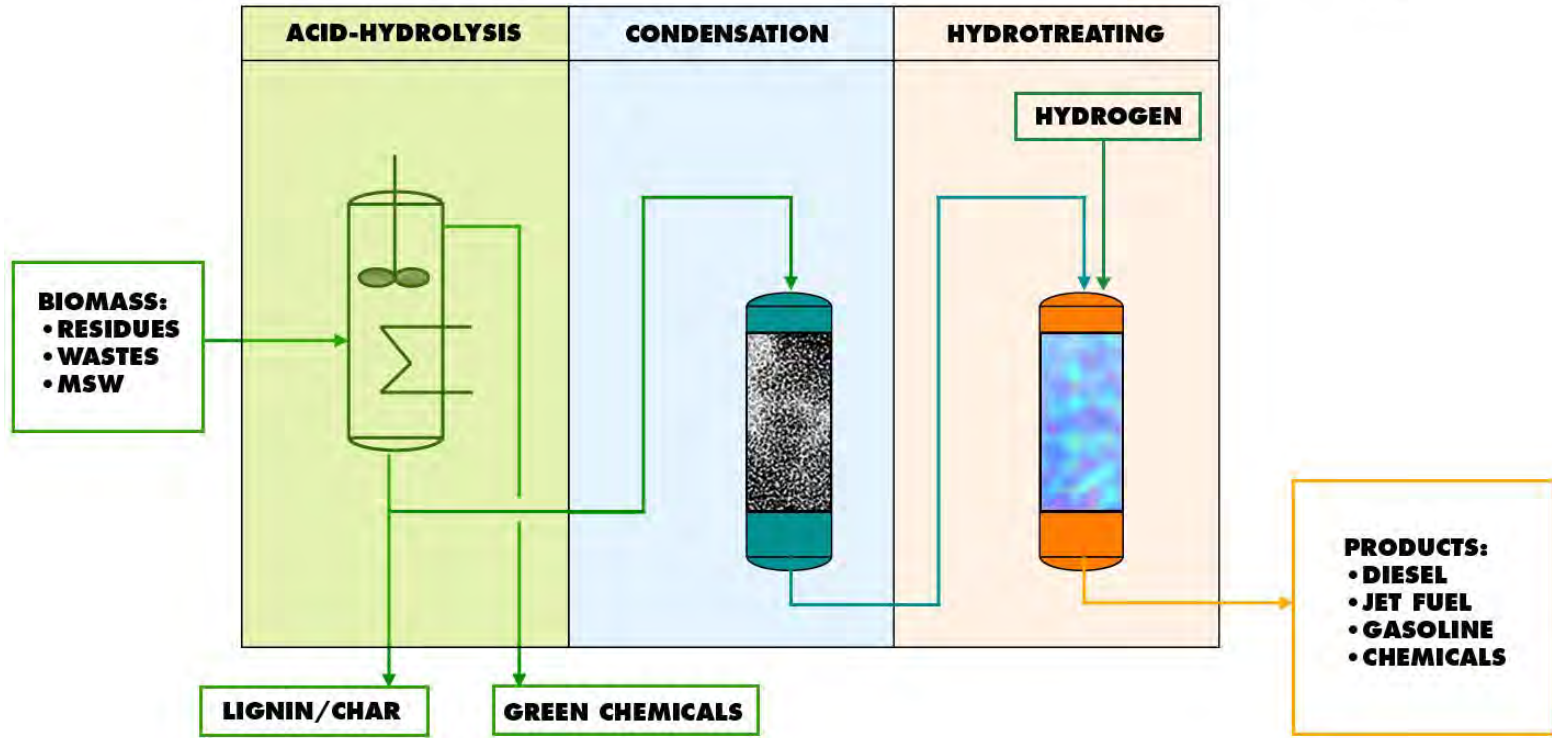
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Hydrotreating

*Deoxygenation:
Final drop-in
hydrocarbon fuel*



Renewable Acid-hydrolysis Condensation Hydrotreating (REACH) Technology



Technology Development Advantages



Hydrolysis
similar to pulp &
paper
technologies



Condensation
Hydrotreating
similar to petroleum
refining



Scalable,
proven
methodologies



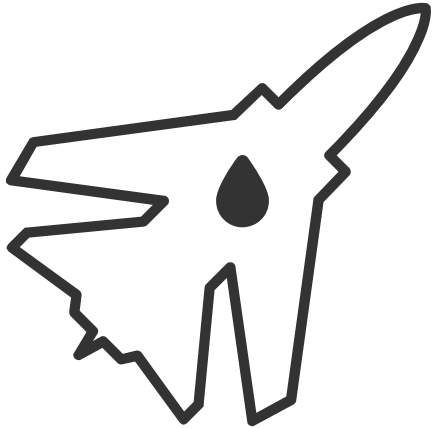
Quicker
ramp-up to
full capacity



Independent of
genetic
research

Primary Fuel Products

**Drop-in
Hydrocarbon
Jet Fuel**



**Drop-in
Hydrocarbon
Diesel Fuel**



Valuable Chemicals & By-products

Levulinic Acid (LA)

- Plasticizers
- Solvents
- Polymers

Formic Acid

- Food safe fumigant/ animal feed supplement
- Environmentally friendly de-icer
- Fuel cell feed

Furfural

- Solvent for extraction processes
- Resin manufacturing

Lignin

- Solid Fuel
- Fertilizer / Soil Enhancer
- Hydrogen Production
- High Value Products

FDCA

- Monomer for PEF



Cost Structure (Corn Stover)

CapEx:

\$ **3–5**

/annual gal
capacity

For example, a 15 mil
gal plant at \$4/annual
gal capacity would
cost \$60 million

OpEx:

\$ **1.06**

/gal **excluding**
capital charges

\$ **1.62**

/gal **including**
capital charges

Cost Breakdown

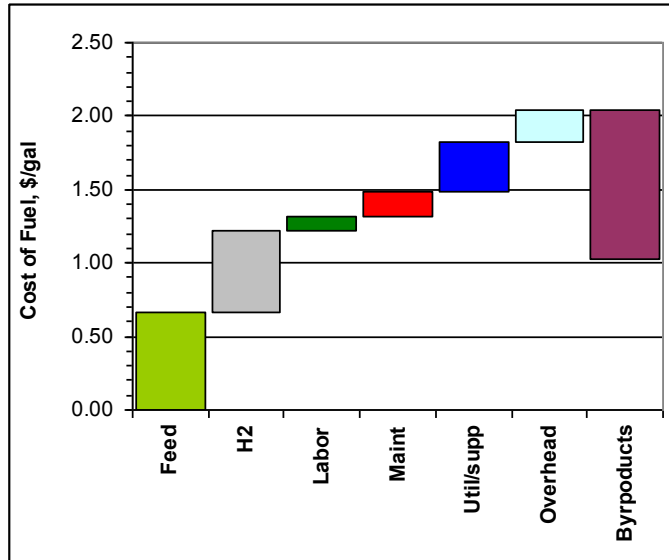
Base Case

\$ **50**

/dry ton feed

1.06

\$/gal



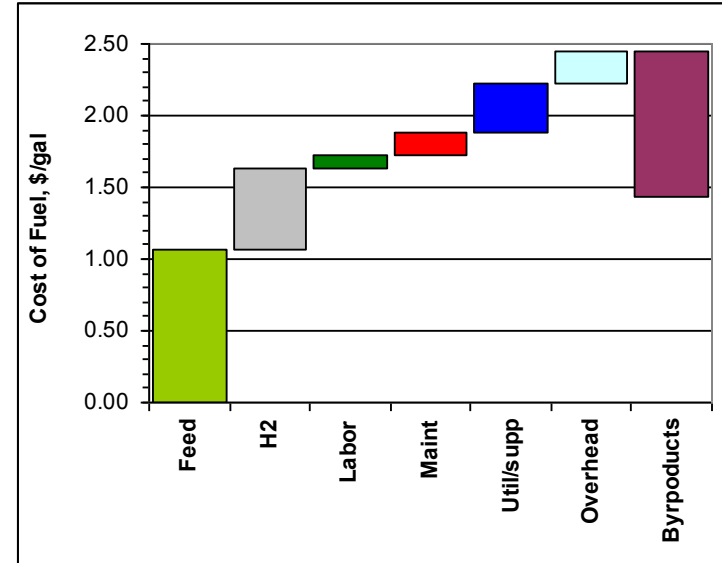
Sensitivity

\$ **80**

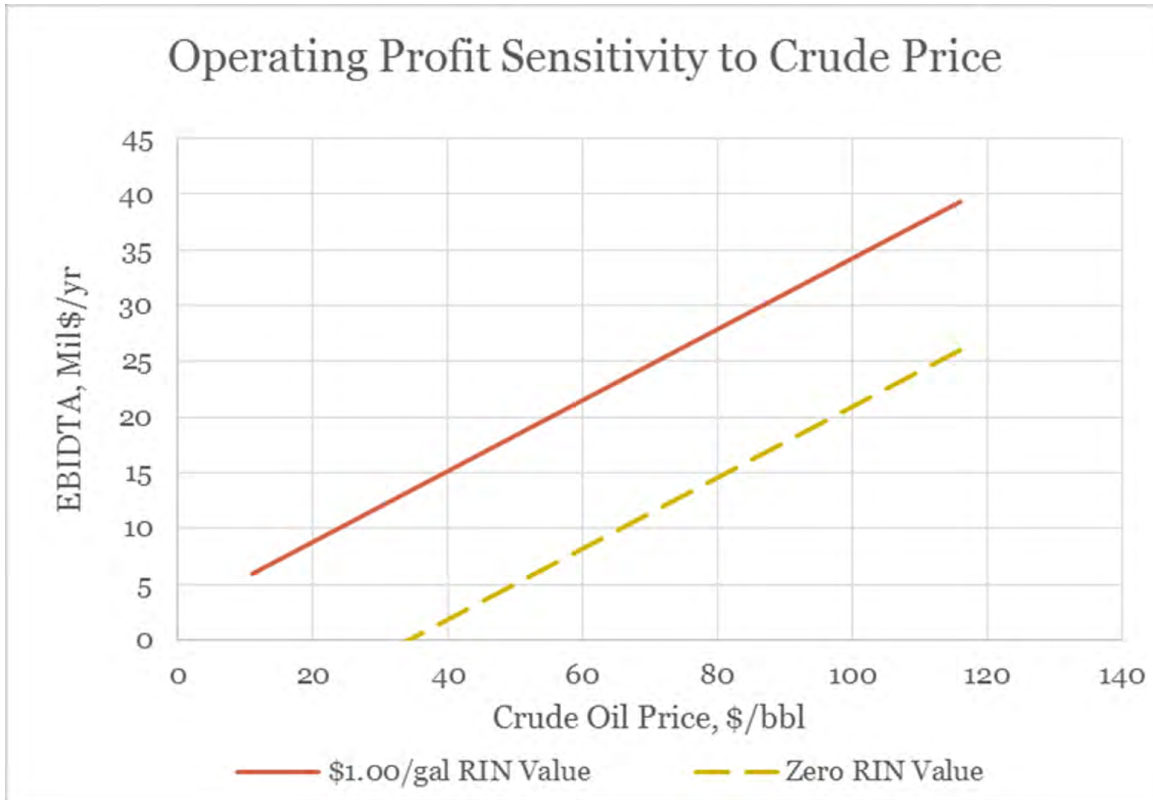
/dry ton feed

1.46

\$/gal



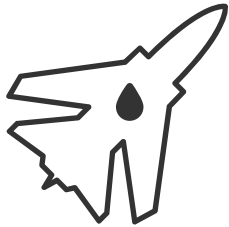
Economics Good at Lower Crude Prices



Market

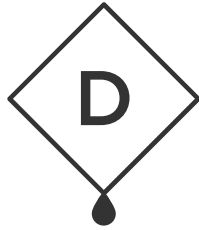
U.S. liquid fuels sales
in 2011 was estimated
at

**200+ Billion
gallons**



>22B

Jet Fuel



>45B

Diesel Fuel

*Source: US Energy
Information Association*

RFS2 mandates
advanced biofuels
ramp up to a minimum
of

**21 Billion gallons
annually by 2022**

or

**\$84 Billion
market for 2nd
generation
biofuels
assuming \$4/gal**

A

2%

Market Share



nearly

\$2Billion

for Mercurius



Customers

The US Navy
is committed to supply 50%
of its fuel needs with
non-petroleum fuels by 2020

Many airlines, including
Alaska, Delta, and United have
committed to **using increasing**
amounts of biofuels

Diesel vehicle fleets
are potential **high**
volume customers

Customers for optional
chemicals and by-products
include **agricultural and**
specialty chemical
companies



Pilot Project

- ✧ Awarded \$4.6 grant from the Dept. of Energy in 2013
 - 50% matching
 - Focused on military fuels
- ✧ Current project partners:
 - Purdue University
 - University of Maine
 - Michigan State University Bioeconomy Institute (MSUBI)



Looking Ahead > >

Fatty Acids

- Nutraceuticals
- Specialty chemicals

Cyclic Ethers

- High cetane diesel additive
- Specialty chemicals

Lignin Products

- Unique-properties based products
- Jet fuel and diesel

Polymers

- 2,5-Furandicarboxylic acid (FDCA) for PEF
- Succinic acid (SA) for BDO to PBT and PBS
- From biomass not sugar



FDCA for PEF

PEF Advantages over PET = Better Beer Bottle!

- Superior Barrier Performance
 - ✓ O₂ 10x better
 - ✓ H₂O 2x better
 - ✓ CO₂ 4x better
- Thermal Stability
 - ✓ 12C higher than PET
- Mechanical Properties
 - ✓ 1.6x better (tensile modulus)
- Renewable
- Reduced product degradation
- Lighter for lower transport costs



Key Partners in REACH Development

CSIRO (Australia)
process optimization research

Purdue University
scientific/engineering/aviation
expertise

UMaine
continuous flow optimization,
engineering

MSUBI
pilot plant operations



UC Davis
Hydrolysis technology & IP

**Pacific Northwest
National Laboratory**
past hydrotreating &
catalyst development

Haldor Topsoe
catalyst / hydrotreating
technology



Value Proposition



Low cost –
Capex and
Opex



Feedstock flexibility:
- Larger-sized, high-
moisture feedstock ok
- No inhibitor issues



Distributed
model-
capable



Fuel products
with increasing
demand



~90% reduction
in GHG



High value
co-products



Co-processing
options



Patented
process





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