# Activities Around Advanced Hydrocarbon Fuels from Biomass

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# 2009 Solicitation
## *Advanced Fuels "Beyond Ethanol"*

- Create a U.S. Advanced Biofuels Research Consortium to develop technologies and facilitate subsequent demonstration of infrastructure-compatible biofuels ($35 million)

FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

U.S. Department of Energy
Golden Field Office

**Recovery Act: Development of Algal / Advanced Biofuels Consortia**

**Funding Opportunity Announcement Number: DE-FOA-0000123**

**Announcement Type: Initial**

**CFDA Number: 81.087**

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**Application Due Date:** September 14, 2009, 11:59 PM Eastern Time

- Create a U.S. Algal Biofuels Research Consortium to accelerate demonstration of algal biofuels ($50 million)

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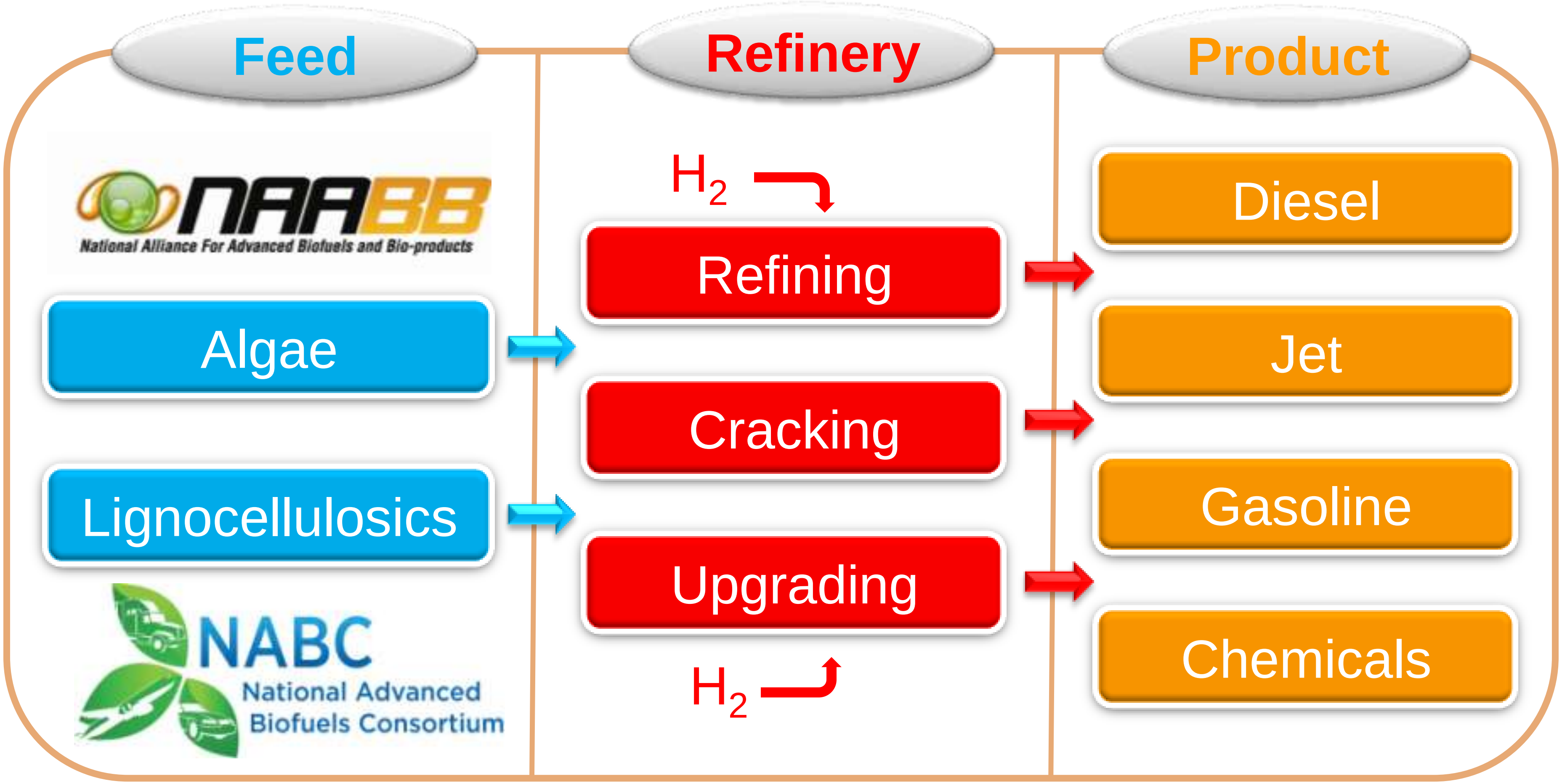
# Refinery Processing of biomass

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# National Advanced Biofuels Consortium

**Project Objective** – Develop cost-effective technologies that supplement petroleum-derived fuels with advanced "drop-in" biofuels that are compatible with today's transportation infrastructure and are produced in a sustainable manner.

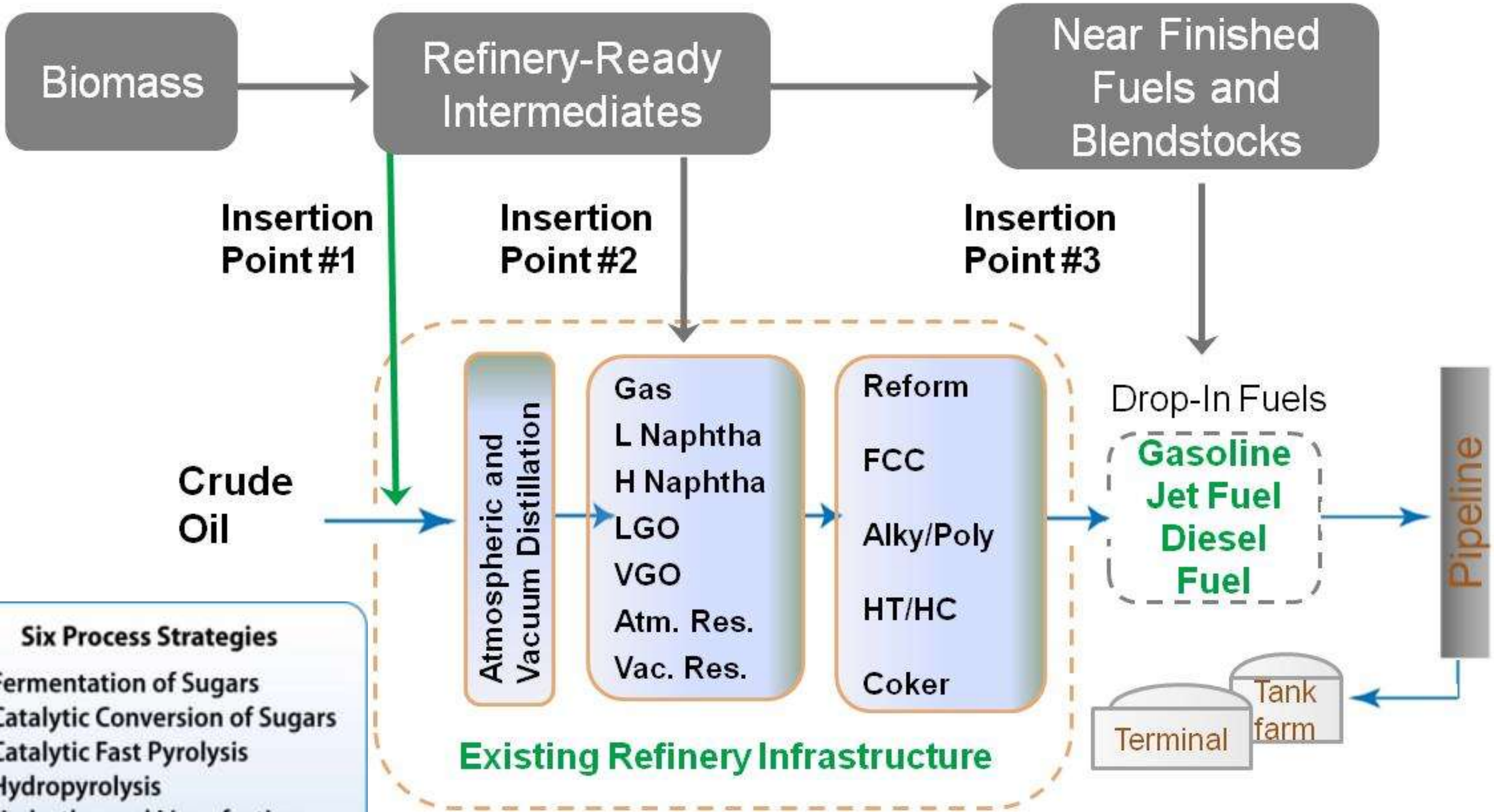
**ARRA Funded**: - 3 year effort
- DOE Funding $35.0M
- Cost Share $12.5M

**Total $47.5M**

**Consortium Leads**
National Renewable Energy Laboratory
Pacific Northwest National Laboratory

**Consortium Partners**
Albemarle Corporation
Amyris Biotechnologies
Argonne National Laboratory
BP Products North America Inc.
Catchlight Energy, LLC
Colorado School of Mines
Iowa State University
Los Alamos National Laboratory
Pall Corporation
RTI International
Tesoro Companies Inc.
University of California, Davis
UOP, LLC
Virent Energy Systems
Washington State University

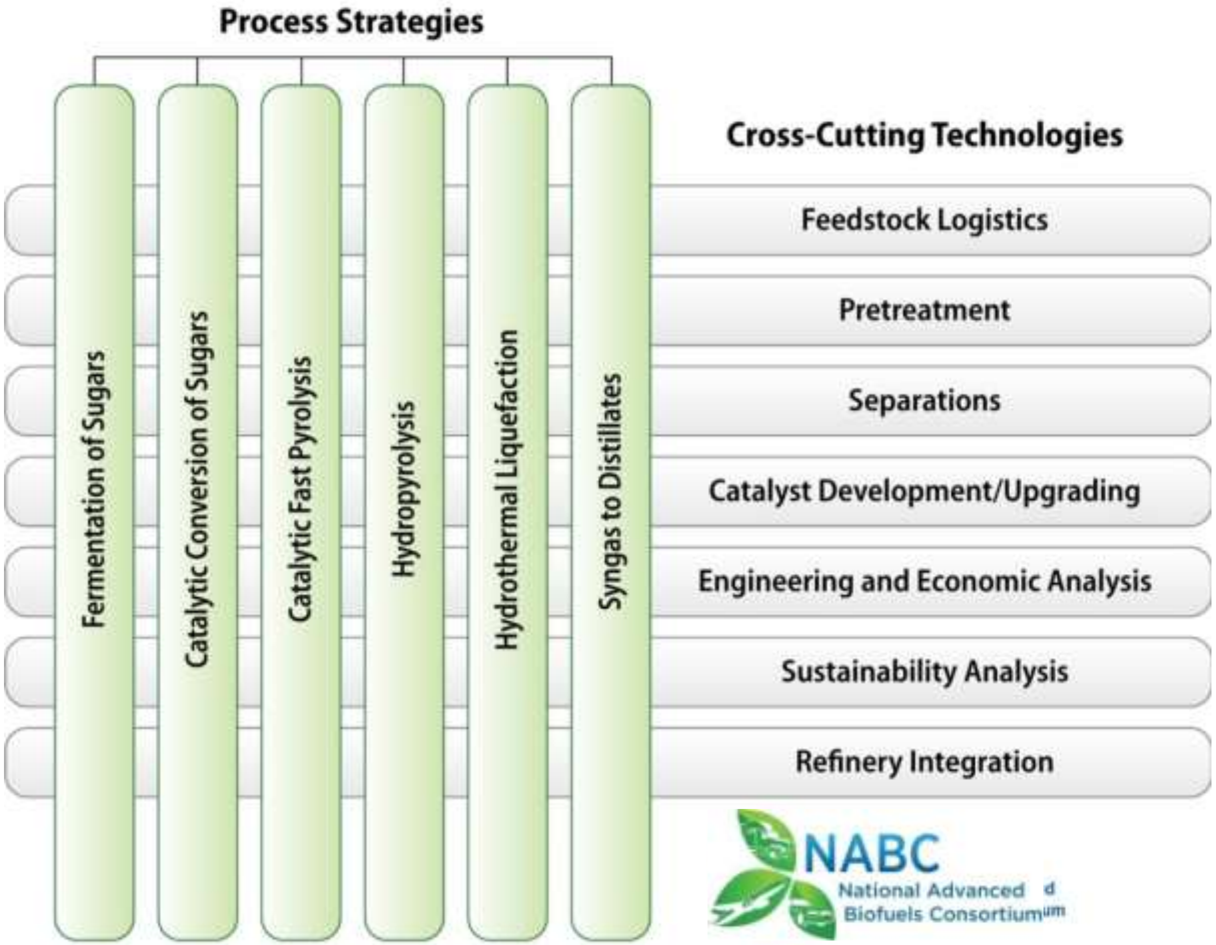
# Refinery Integration Strategy




**Six Process Strategies**

1) Fermentation of Sugars
2) Catalytic Conversion of Sugars
3) Catalytic Fast Pyrolysis
4) Hydropyrolysis
5) Hydrothermal Liquefaction
6) Syngas to Distillates

# Research Strategies

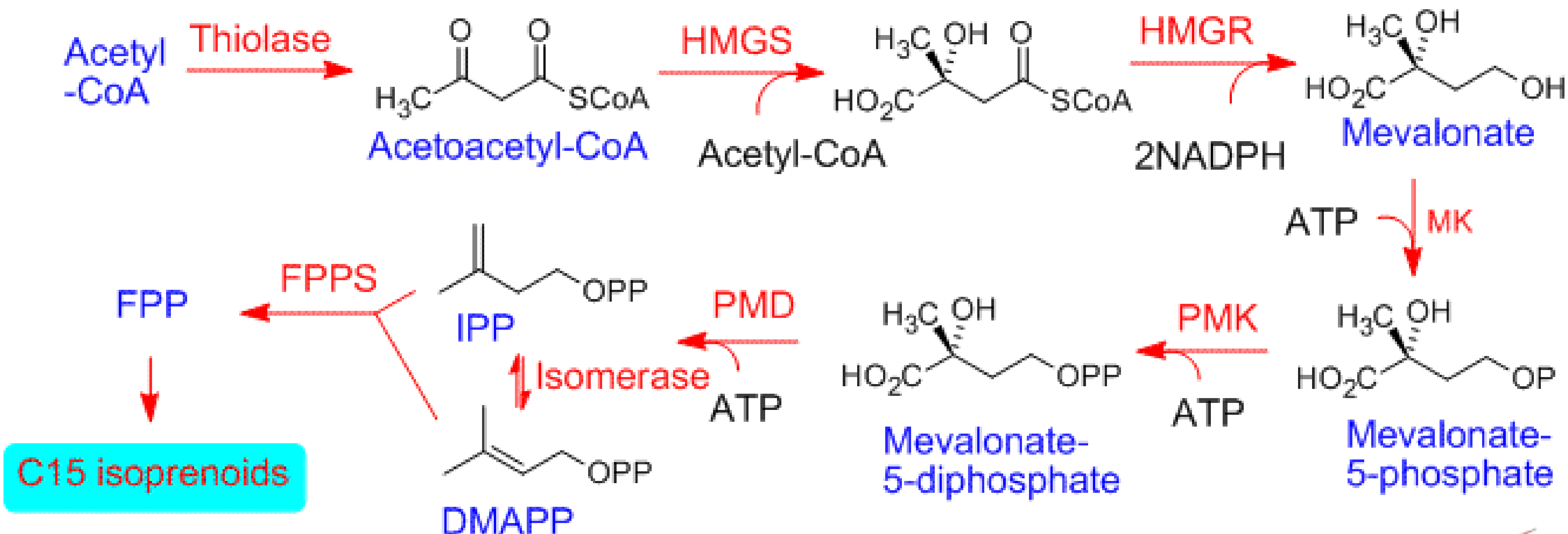



Courtesy UOP

**NABC matrix of technology and strategy teams will ensure development of complete integrated processes.**

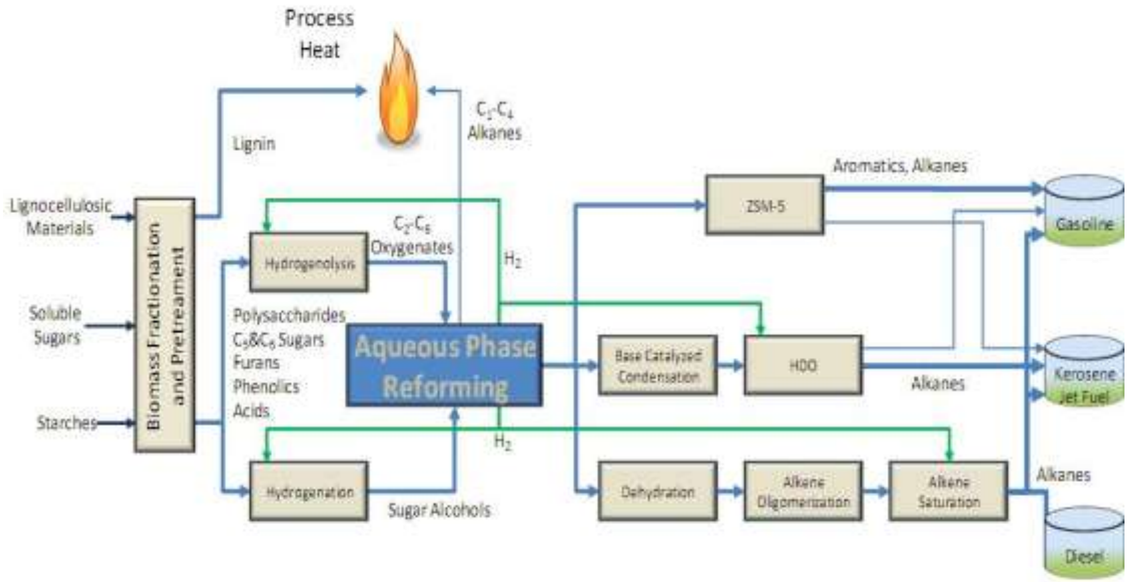
# Fermentation of Sugars

- The fermentation technology builds on isoprenoids. The primary (5-carbon) building block is isopentenyl pyrophosphate (IPP).
- Will be looking at organism development for C5 sugar utilization and biomass hydrolysate compatibility.




**Mevalonate pathway for diesel fermentation intermediate production (Amyris)**

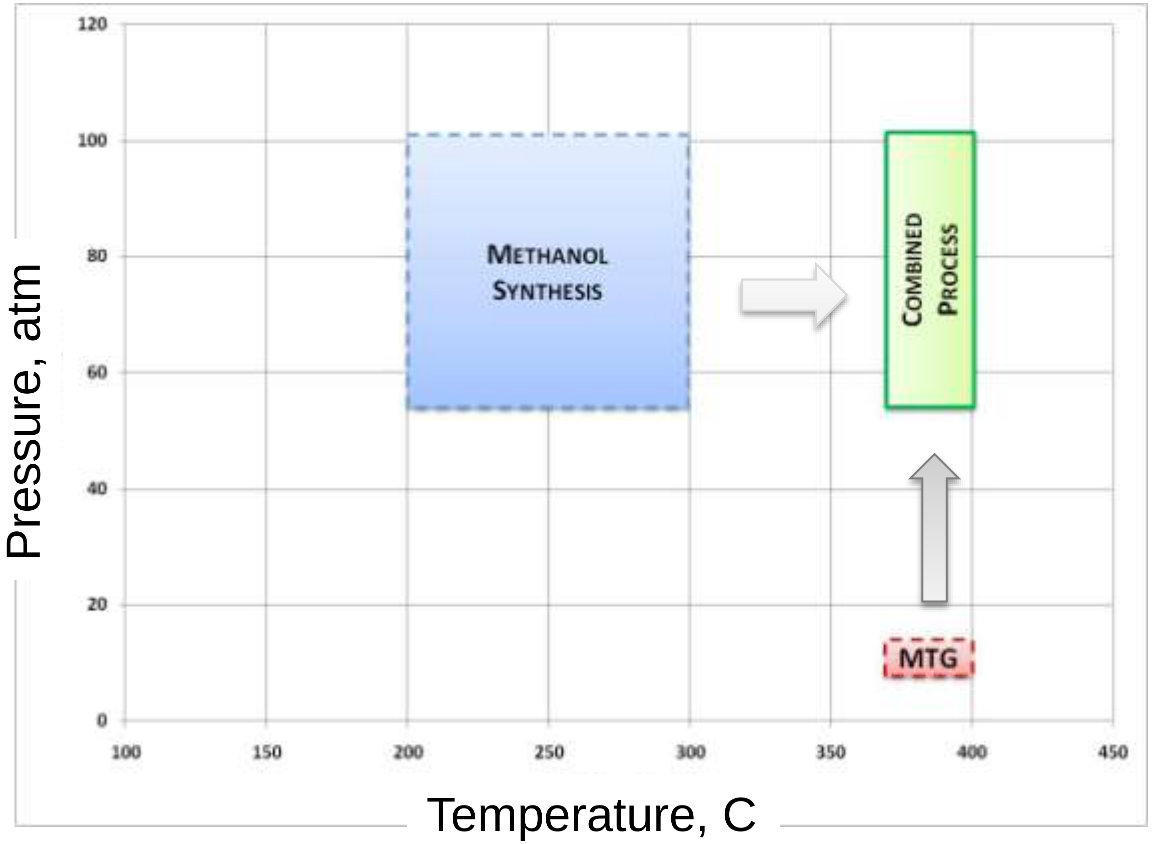
# Catalysis of Lignocellulosic Sugars




- Develop a catalytic process to convert lignocellulosic biomass into gasoline and jet fuels.
- Process steps consists of novel integration of catalytic steps that are known in the petroleum refining industry.
- Key steps include: (1) pretreatment/fractionation, (2) hydrogenation, (3) aqueous phase reforming (APR) and (4) acid catalyzed dehydrations/ condensations.
- APR is done under moderate temperatures and pressures (ca. 175 - 300 C and 150 - 1300 psi).

# Syngas to Distillates

- Integrate and combine unit operations with catalyst improvements to produce gasoline and diesel.
- Combine the MTG/MOGD conversions efficiently into a single reactor along with effective catalyst regeneration.

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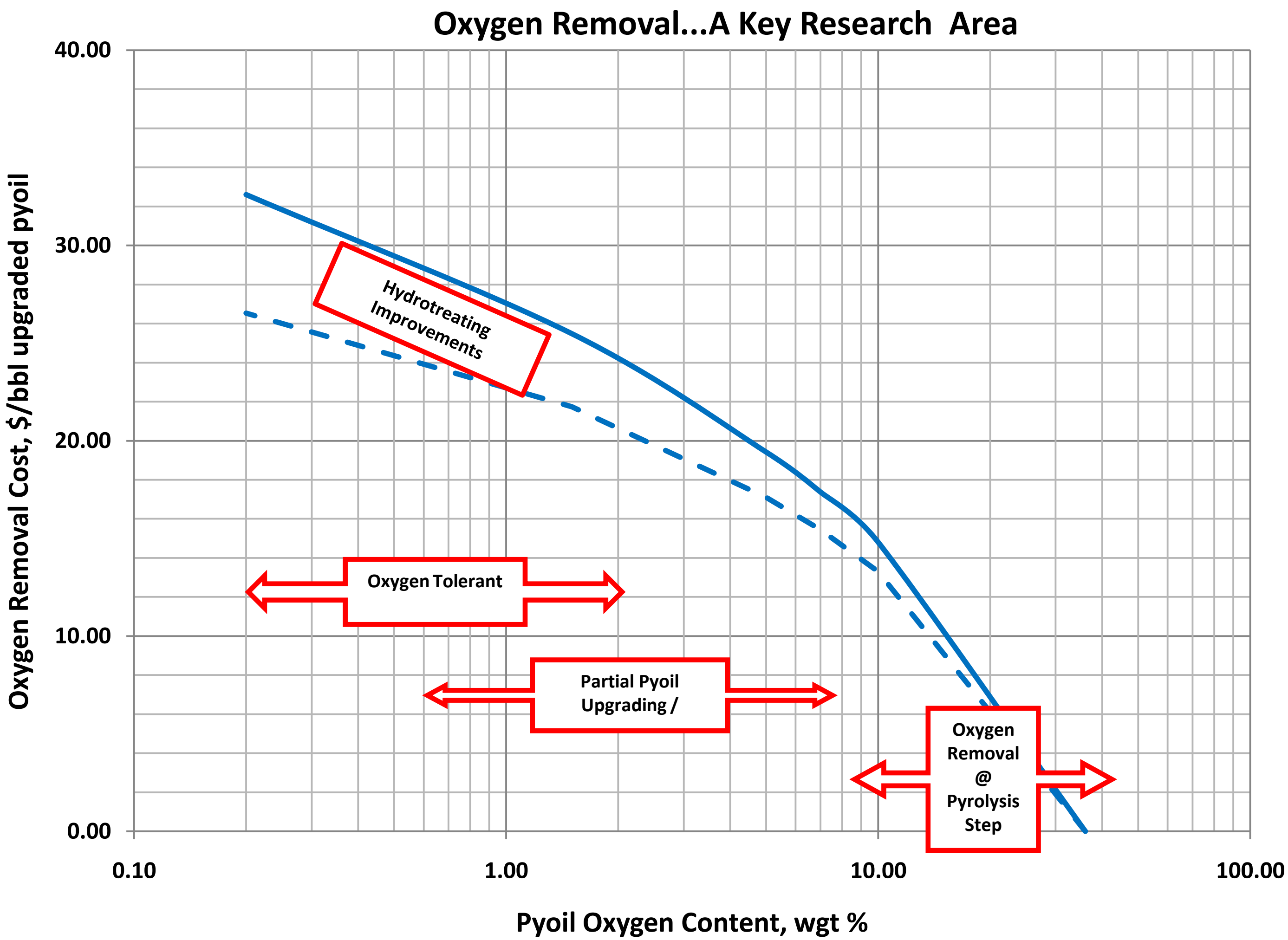
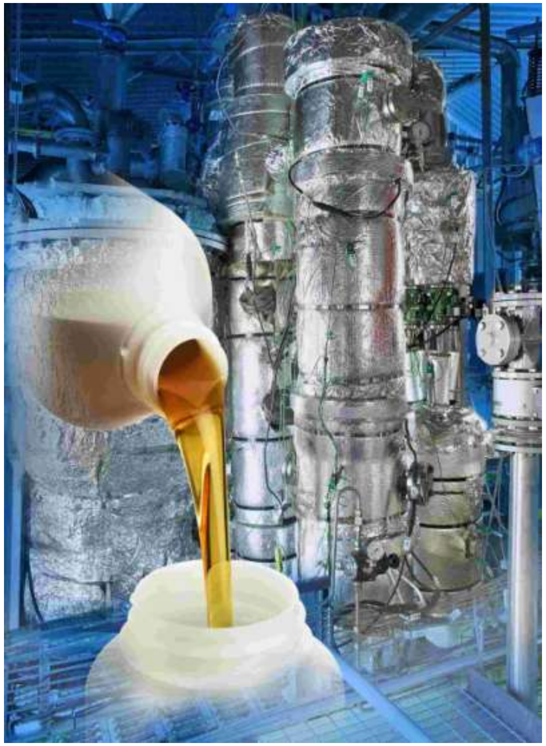
# Insertion Point 1&2 Strategies



# Catalytic Fast Pyrolysis

- Pyrolysis occurs at ambient pressure and temperatures between 400 and 600 C at reaction times approaching 0.5s.
- Gives relatively high oil yields approaching 70% by weight.
- Fast pyrolysis oil however has many undesirable properties:
  - High water content: 15-30%
  - High O content: 35-40%
  - High acidity; pH = 2.5, TAN > 100 mg KOH/g oil
  - Unstable (phase separation, reactions)
  - Low HHV: 16-19 MJ/kg
- Will be looking at catalytic methods to produce improved bio-oils for insertion into the refinery.



Courtesy VTT, Finland

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# Hydropyrolysis

- Hydropyrolysis, (pyrolysis in the presence of hydrogen and added catalyst) is carried out at pressures that are substantially higher than those employed for fast pyrolysis (c.a. 250–500 psi).
- Produces an oil-like product that has much of the oxygen removed and is more suitable for co-processing in a petroleum refinery or for upgrading to finished fuels.
- In this project we will investigate methods to reduce hydrogen demand.

Courtesy Veba Oel

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NABC National Advanced Biofuels Consortium

# Hydrothermal Liquefaction

- Hydrothermal liquefaction occurs in liquid-phase media at temperatures between 300-400  C and at the vapor pressure of the media.
- Temperature is 374  C with pressure between 2500-3000 psi.
- Catalysts are employed to speed the hydrogen transfer reactions.
- Product oils have low water content and are lower in oxygen (c.a. <10%). but have other undesirable physico-chemical properties such as a relatively high viscosity.
- The focus will be on new reaction media and catalysts that reduce process severity while maintaining high reaction rates and low oxygen content of the oil.


Courtesy Veba Oel

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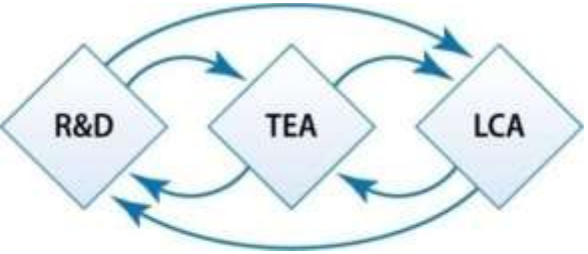
# Sustainability and GHG Analysis

**GHG Reduction Potential of Advanced Biofuels based on preliminary data**

| Feedstock | Process Technology | Fuel Products | GHG Reduction vs. Conventional Fuels | Source |
|---|---|---|---|---|
| Corn stover | Fast Pyrolysis with refinery hydroprocessing | Gasoline and Diesel | 62% vs. conventional (gasoline + diesel) | NREL/UOP analysis |
| Corn Stover | Hydrolysis plus aqueous reforming of sugars | Gasoline | 94% vs. conventional gasoline | Virent analysis using GREET |
| Energy Cane | Hydrolysis plus fermentation to hydrocarbons | Diesel | >90% vs. US diesel | Amyris analysis |

- Sustainability includes elements of economic and environment as well as societal benefits.
- Metrics, include GHG emissions, air toxics, water quality, and water use.
- LCA tools for quantifying land use change:
  - Global Trade Analysis Project (GTAP) model, being incorporated into GREET by ANL.
  - Systems dynamic land use change model developed by John Sheehan (University of Minnesota) and Nathaniel Greene (NRDC).



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# Process Efficiencies

## Early comparison of Liquid Fuel Yields

| Fuel Production Technology | Process Energy Efficiency |
|---|---|
| Conventional Petroleum Refining to Gasoline | 85% |
| Conventional Petroleum Refining to Low-S Diesel | 87% |
| Biomass Gasification / Fischer-Tropsch | 41% |
| Fast pyrolysis (with HDO) | 77% |
| Hydropyrolysis | 82% |

# Questions?

***Biofuels for Advancing America***

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