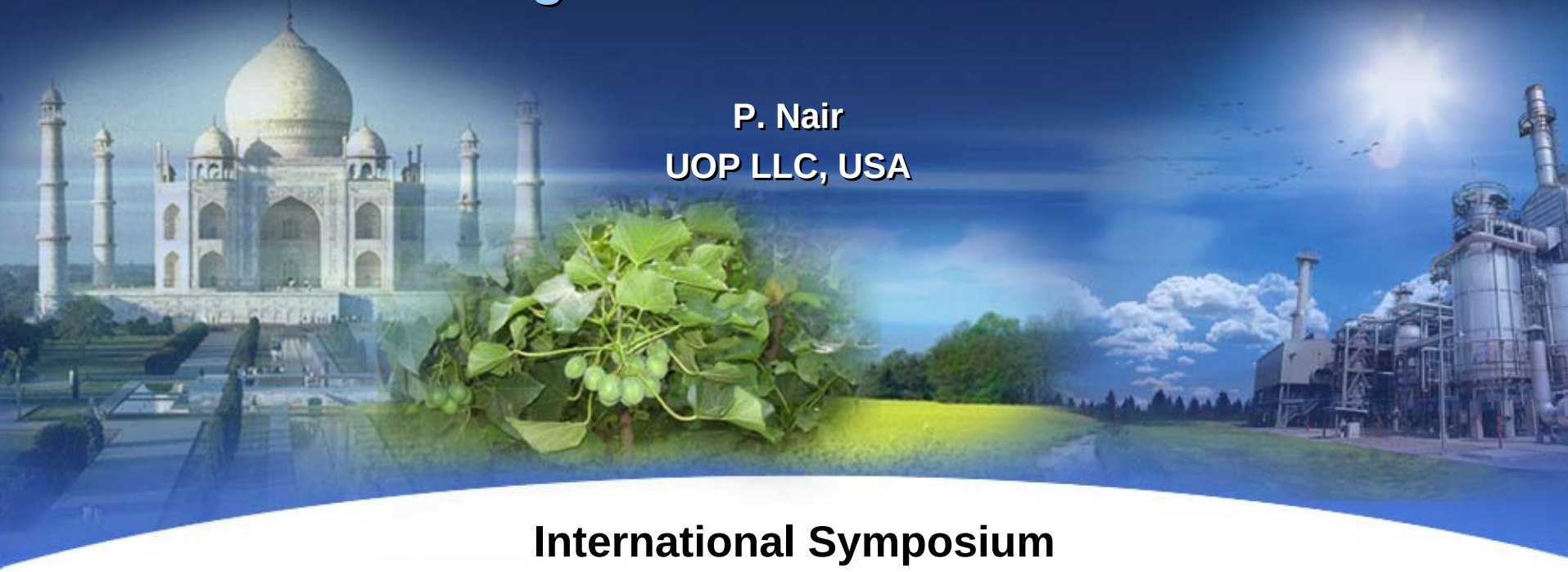
# UOP/Eni Ecofining™ Process

# Refining Renewable Feed stocks



**P. Nair**
**UOP LLC, USA**

**International Symposium on Biofuels**
**September 25-26, 2007**
**New Delhi, India**

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# Biorenewables in Oil Refineries

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***Need***

- **Profitable Processing Options**

***Approaches***

- **Stand alone options**
- **Co-processing options**
- **Hydrogen generation**
- **Higher value products**

# Why Consider Renewable Fuels in Refineries?

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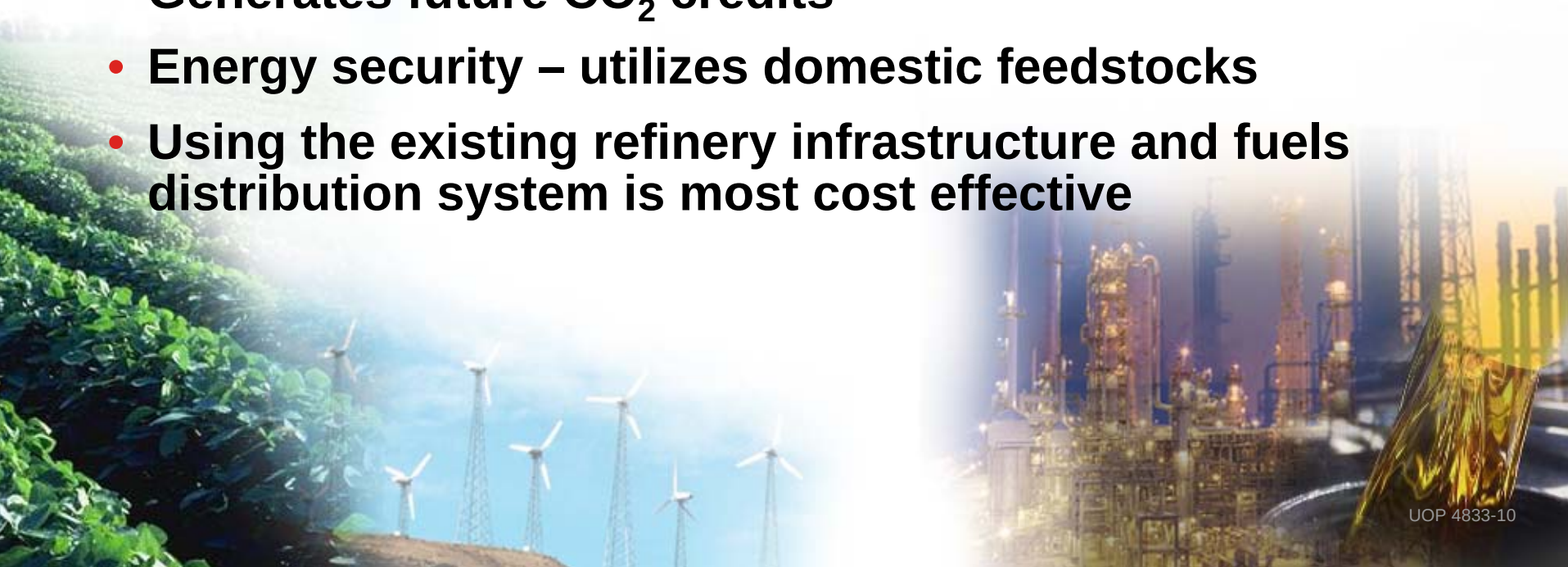
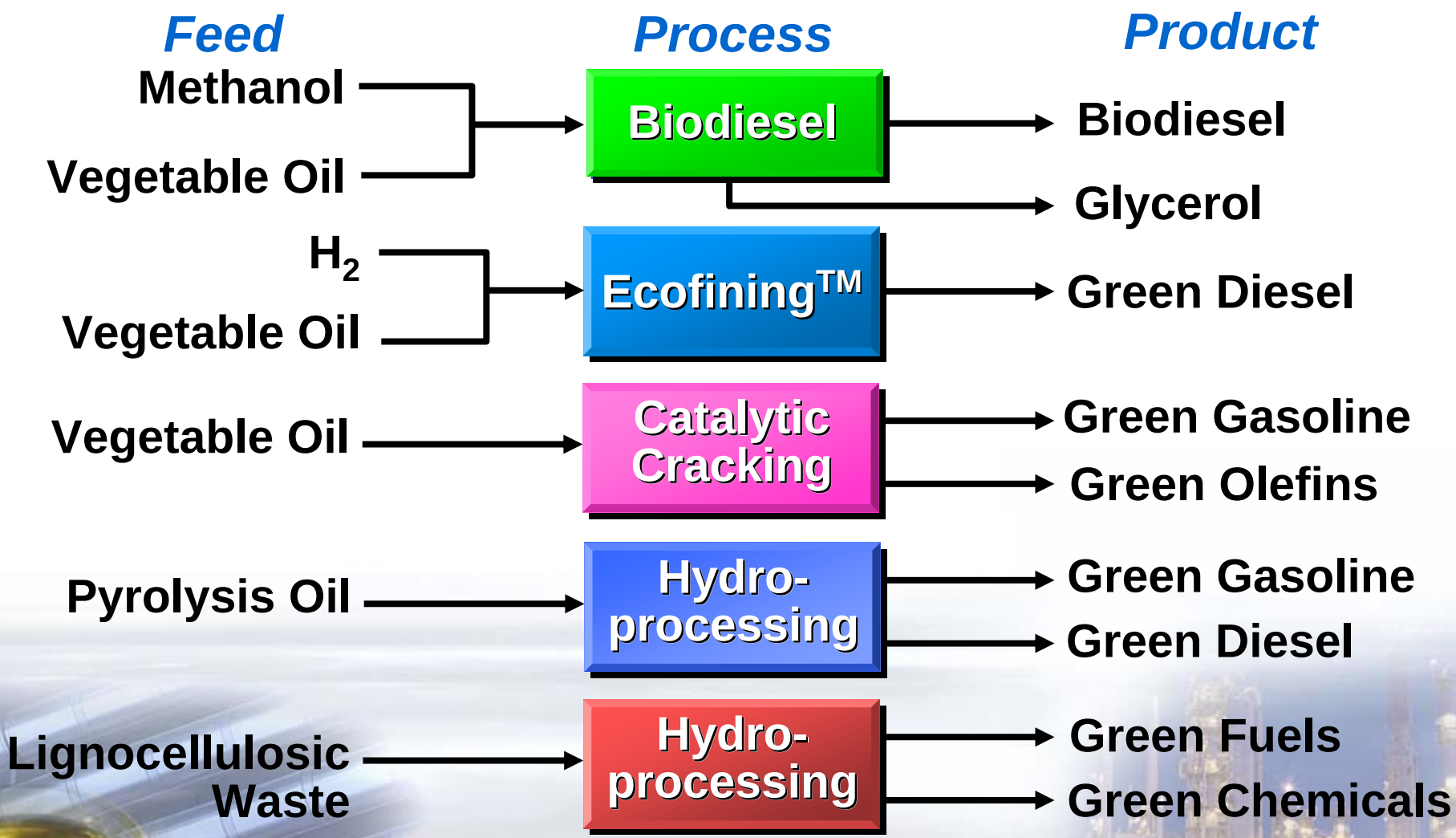
- Renewables are going to make up an increasing share of the future fuels pool
- Allows the refiner to control the quality of the renewable blending components required to meet mandates
- Provides a source of high quality diesel blendstock
- Generates future $CO_2$ credits
- Energy security – utilizes domestic feedstocks
- Using the existing refinery infrastructure and fuels distribution system is most cost effective



# Biomass Processing Routes



# UOP/Eni Ecofining Process Development Objectives

- Joint development of UOP and Eni
- Develop a processing route to convert vegetable oil to high quality diesel
  - Economic
  - Sustainable
  - Leverages refinery assets and infrastructure

# Vegetable Oil Processing Alternatives

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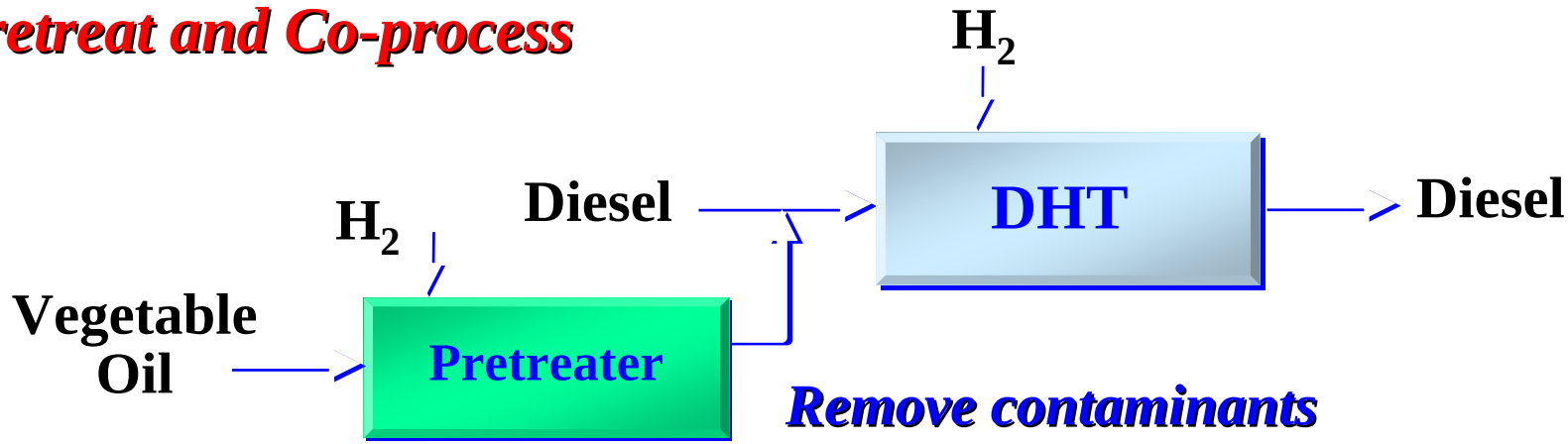
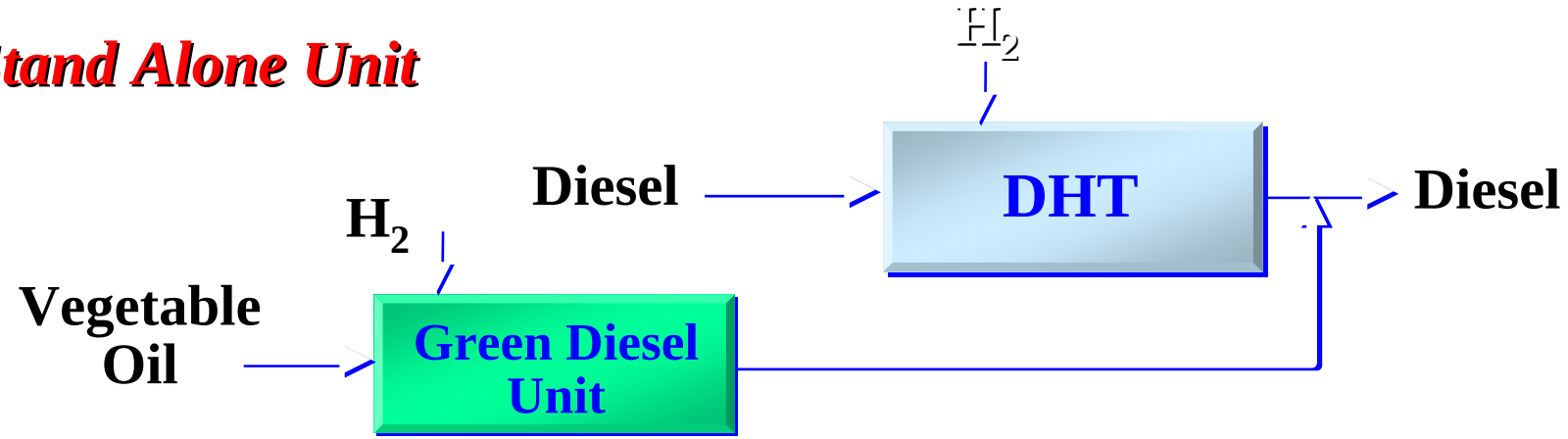
## *Pretreat and Co-process*



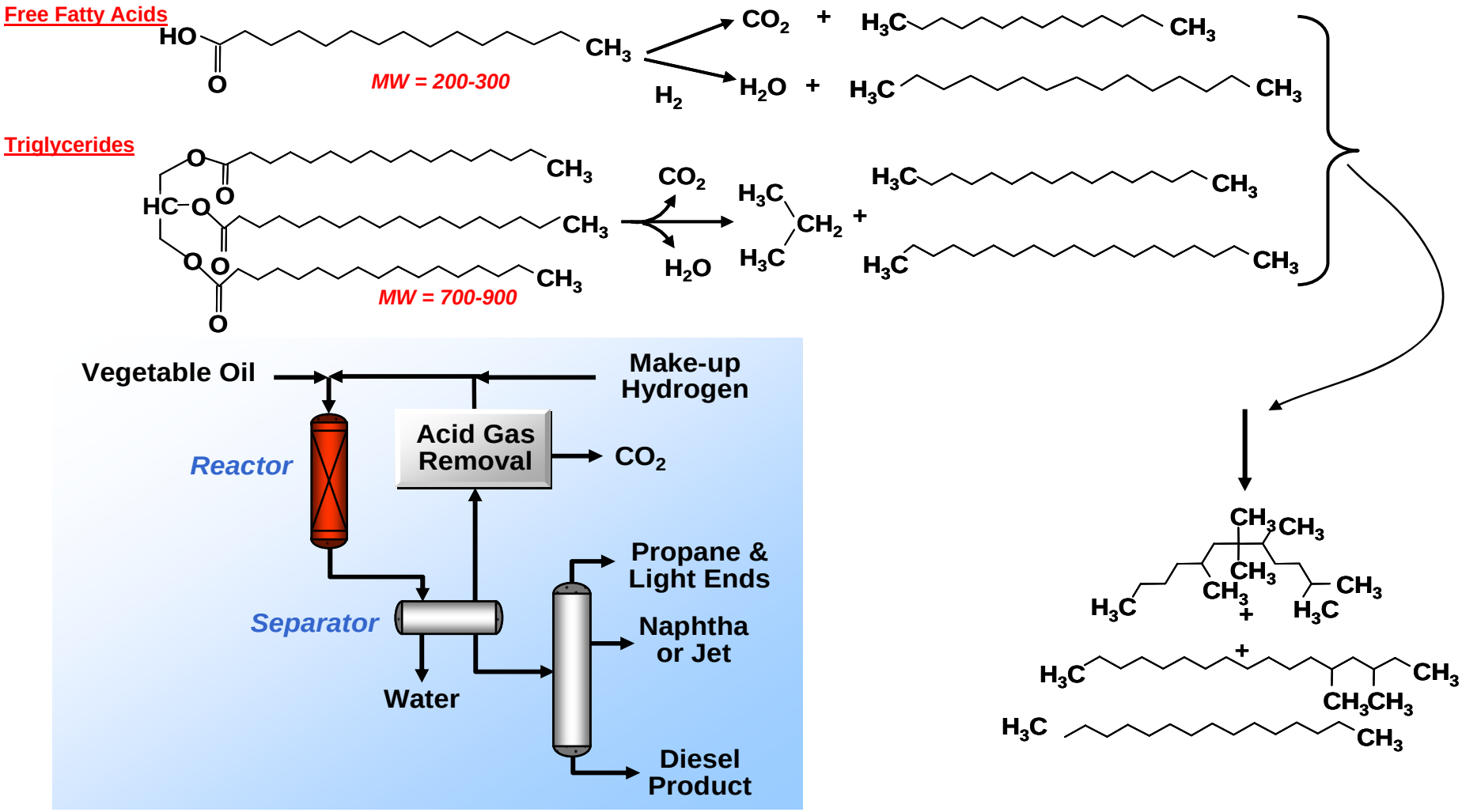

*Remove contaminants*

## *Stand Alone Unit*



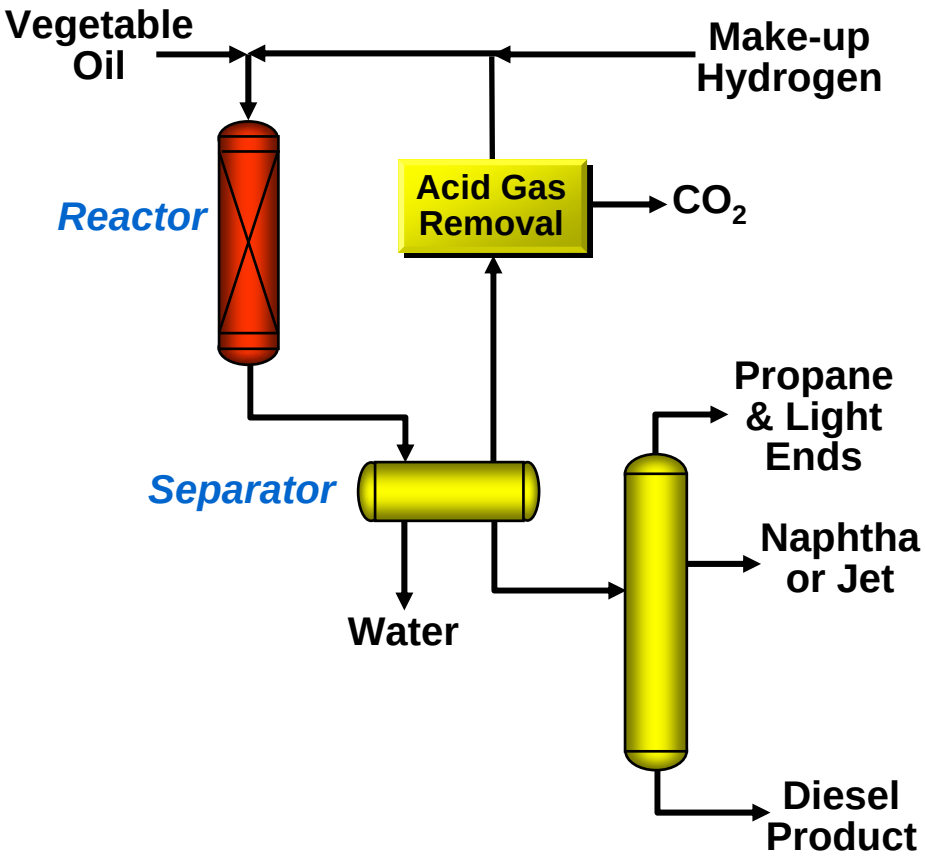

***Separate unit avoids DHT catalyst life issues and increased flexibility***

# Ecofining Process Chemistry



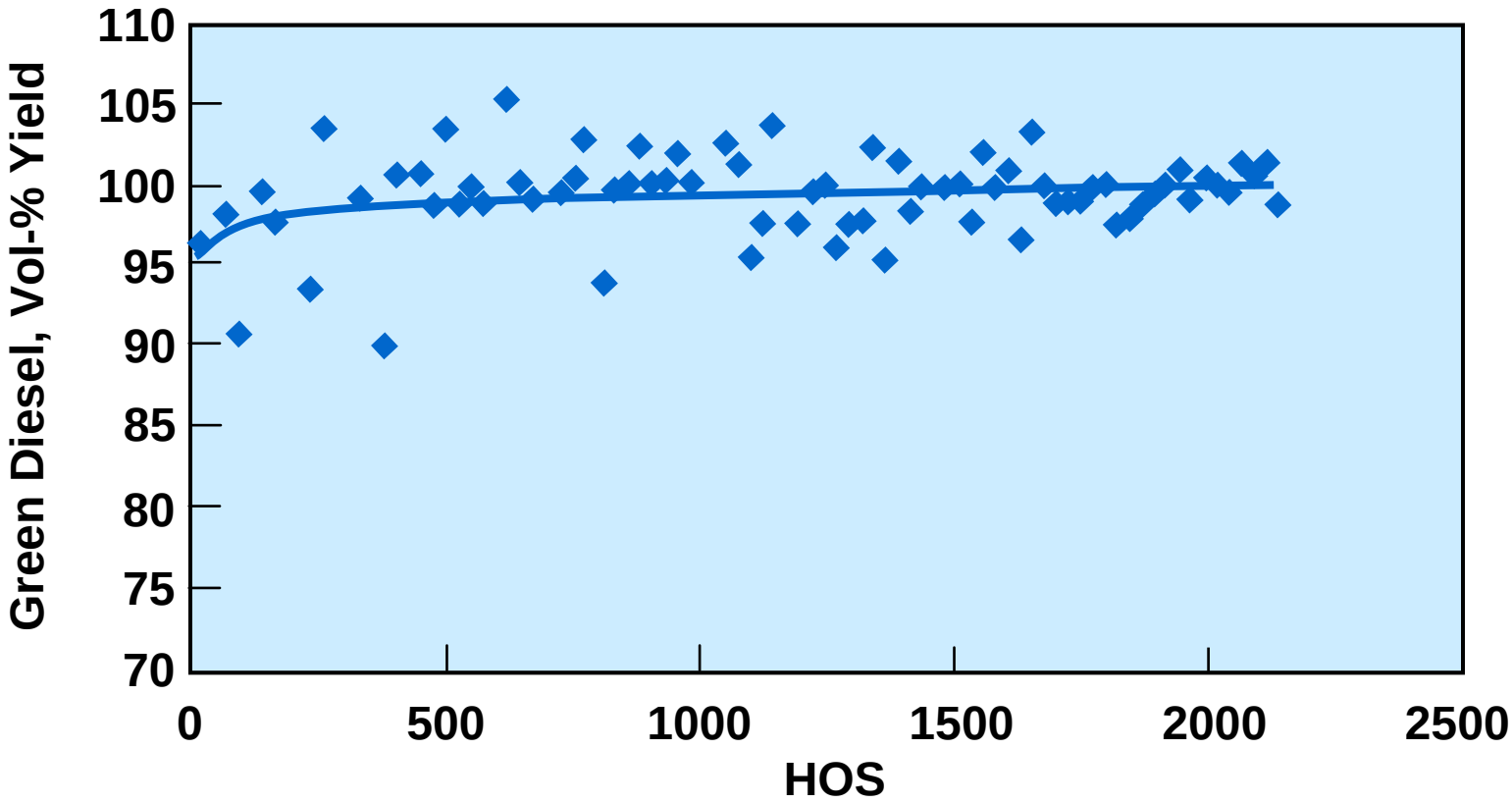

*Ecofining Feed Testing Program – Soy, Rapeseed, Palm, Jatropha, Algal, Tallow*

# Processing Bio Oil with the Ecofining Process




- Upgrade bio oil using hydroprocessing and isomerization
- Product is an high cetane diesel blending component
- Hydrocarbon product, not an oxygenated compound
- Co-production of propane, naphtha, and high quality jet fuel possible
- Standalone system enables control of cloud point and cetane as well as seasonal variance

# Extensive Pilot Plant Testing to Establish Process Viability




*Catalyst Stability Demonstrated*

# Ecofining Process Performance

| | |
|---|---|
| ***Feed*** | |
| **Vegetable Oil, wt-%** | **100** |
| **Hydrogen, wt-%** | **1.5-3.8** |
| ***Liquid Products*** | |
| **Naphtha, vol-%** | **1-10** |
| **Diesel, vol-%** | **88-99** |
| **Cetane Number** | **> 80** |
| **Sulfur, ppm** | **< 1** |

*Water and $CO_2$ also produced as deoxygenation products*

# Green Diesel Fuel Properties

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| | *Petroleum ULSD* | *Biodiesel (FAME)* | *Green Diesel* |
|---|---|---|---|
| Oxygen Content, % | 0 | 11 | 0 |
| Specific Gravity | 0.84 | 0.88 | 0.78 |
| Sulfur content, ppm | <10 | <1 | <1 |
| Heating Value MJ/kg | 43 | 38 | 44 |
| Cloud Point, °C | -5 | -5 to +15 | -30 to -10 |
| Distillation, °C | 200 to 350 | 340 to 355 | 265 to 320 |
| Cetane | 40 | 50-65 | 70-90 |
| Lubricity | Baseline | Good | Baseline |
| Stability | Good | Marginal | Good |

- Superior fuel properties
- Compatible with petroleum diesel
- Compatible with conventional diesel engines
- Meets ASTM D-975 and EN-590 specs

# Green Diesel Blending Benefits

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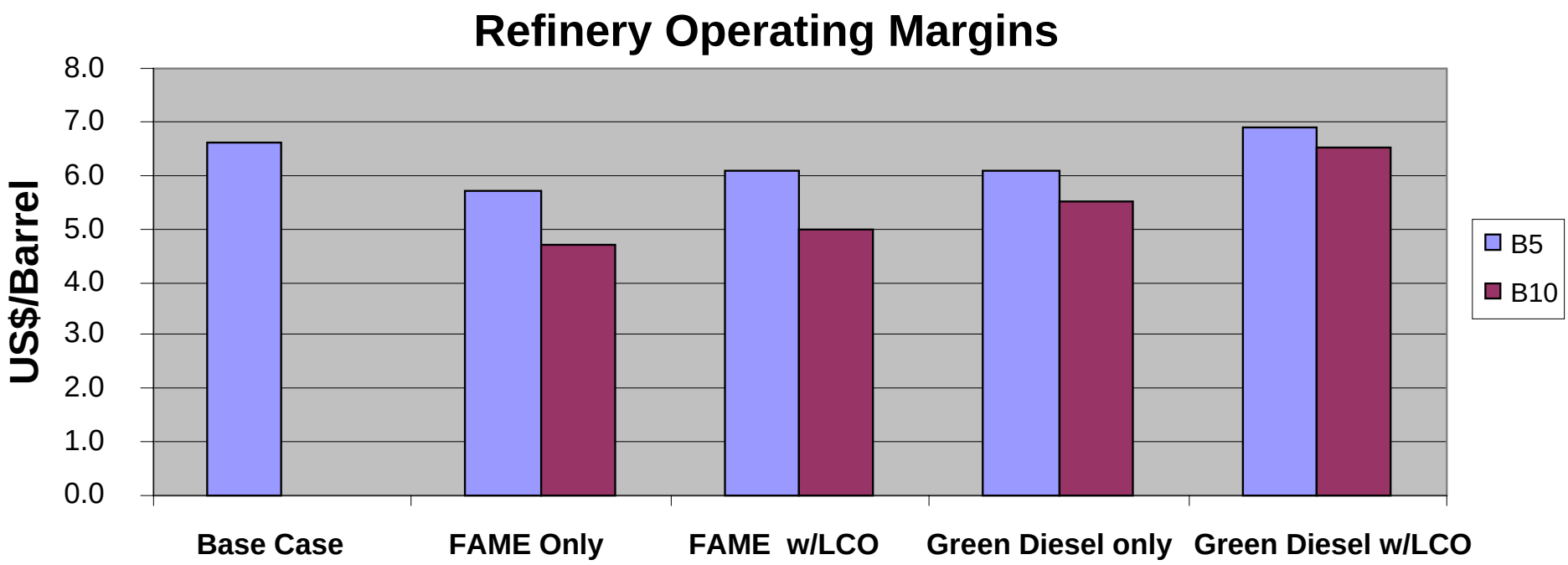
| *Diesel Pool Components* | *Barrels in Pool* | *Cetane Index* |
|---|---|---|
| Kerosene | 500 | 41 |
| Straight Run Diesel | 7500 | 52 |
| Hydrotreated LCO | 2000 | 20 |
| Green Diesel | 2346 | 74 |
| Average Cetane | | 50 |

**Required Diesel Cetane:** 50 min
**LCO Quantity Blended:** 2000 bbl/day
**LCO Uplift ($4.60/bbl):** $9200/day
**Green Diesel Benefit:** $3.90/bbl

- Green Diesel has a high cetane, low density and excellent cold flow properties
- Cold flow properties are controlled by paraffin isomerization
- These properties make Green Diesel a premium blending component
- Enables blending low value LCO into ULSD or a reduction in cetane enhancing additives

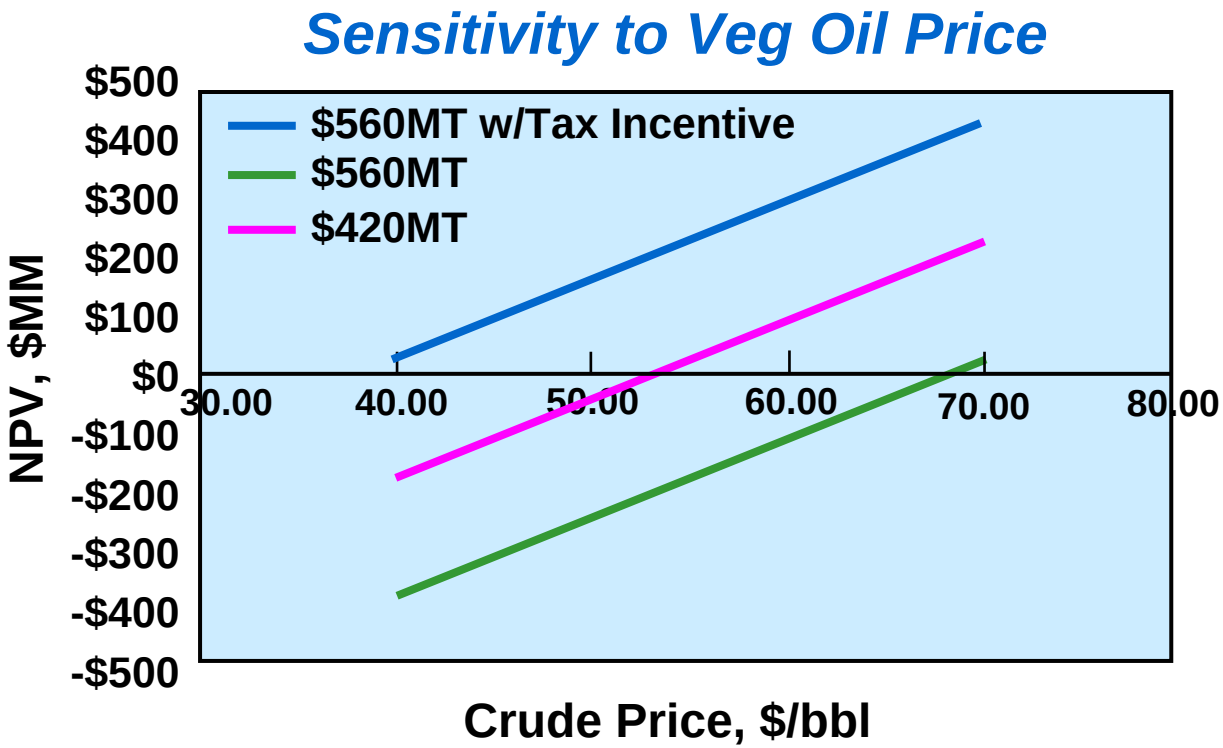
*Towards and Economically Attractive Biofuel*

# Example LP Blending Study: Green Diesel + LCO




- **Assumptions**
  - **150K BPD European Refinery configuration with FCC & HCU**
  - **Refinery processes a mix of Mid-East crudes**
  - **Product slate per EU norms; EN 590 for diesel**
- **Purchase FAME, LCO, Green Diesel as need to meet B5 or B10 blend**
- **In this example, margin premium of *Green Diesel over FAME w/LCO addition* is:**
  - **~$40 million annually for B5**
  - **~$80 million annually for B10**

# Ecofining Process Economics




- **Palm oil ($420/MT, $1.47/gal): Profitable at crude > $52/bbl**
- **Soy oil ($560/M , $1.96/gal): Profitable at crude > $67/bbl**
- **Soy oil w/ $1/gallon subsidy: Profitable at crude > $38/bbl**

*Driven by Feedstock Cost*

# Economics: Current and Future Targets

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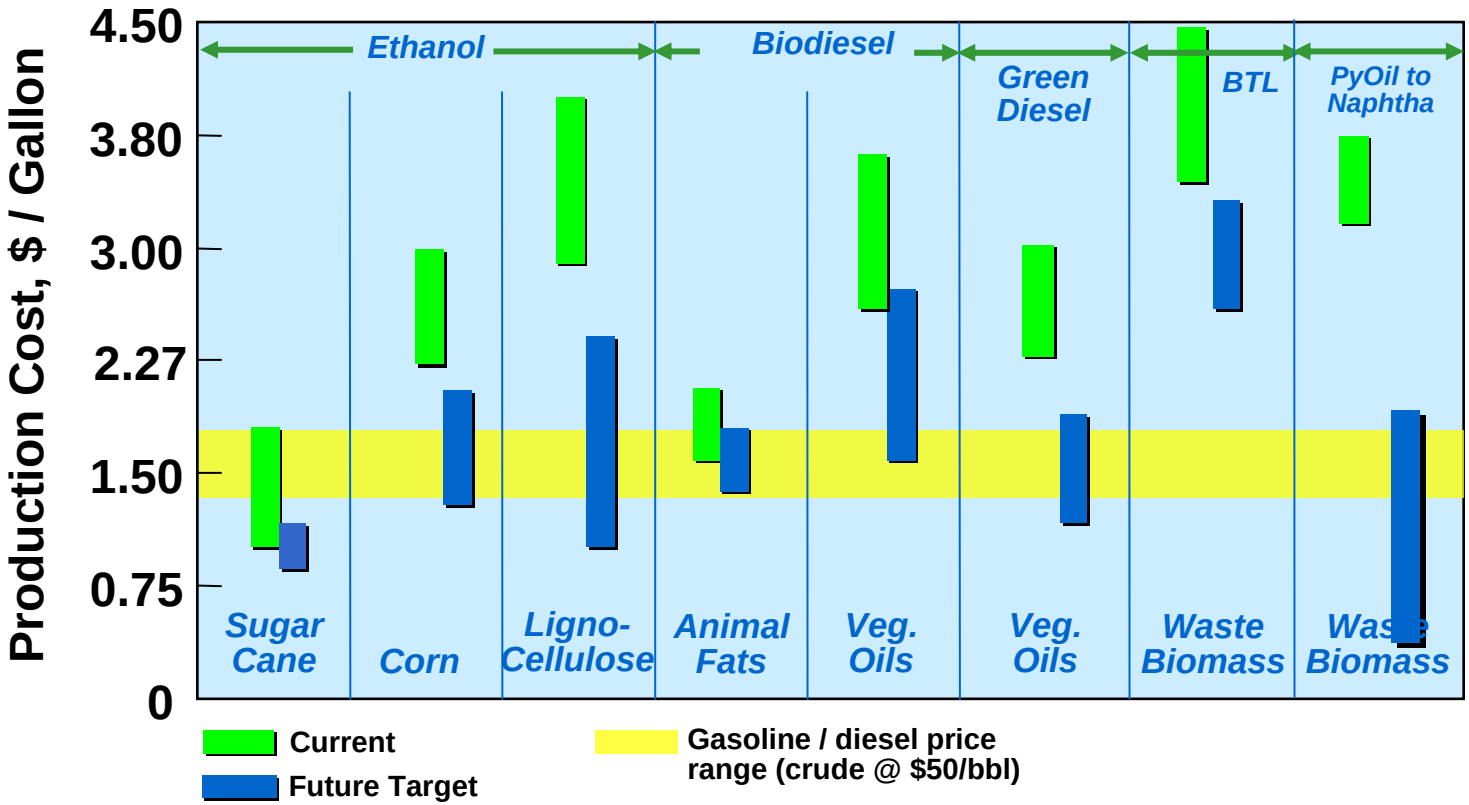
## Current & Target Biofuel Costs




*Breakthroughs Required to Create Economically Viable Biofuels Infrastructure*

# UOP/Eni Ecofining Process
## *Commercialization Status*

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- **Intensive co-development program with Eni since 2005**
- **Basic engineering design completed 2Q07**
- **First commercial unit start-up in 2009**

Eni

# Vegetable Oil Co-Processing Issues

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- **Significant cost associated with co-processing at >5%**
  - **Reactor design changes may be needed to accommodate additional heat release**
  - **Revamp of the recycle $H_2$ system to account for CO, $CO_2$ and $H_2O$ production**
  - **Need a pretreat reactor to remove Na, Ca, P and other metals in the vegetable oil feedstock**
  - **Cold flow property issues may limit the volume of vegetable oil that can be processed**
  - **Opportunity cost of reducing diesel feed to hydrotreater to accommodate vegetable oils**
  - **Shorter cycle lengths due to higher temperature operation**
- **A more cost effective and profitable solution is a unit optimally designed to process biologically derived feedstocks**

# Life Cycle Analysis for Renewables Processing

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- **Scope: from extraction through combustion (in transportation use)**
- **Functional Unit: 1 kg of each fuel**
  - **Assumption: Each fuel performs the same in transportation use**
- **Primary Focus: fossil energy consumption and emission of GHG, though other impact categories are included**

# Total Energy Comparison

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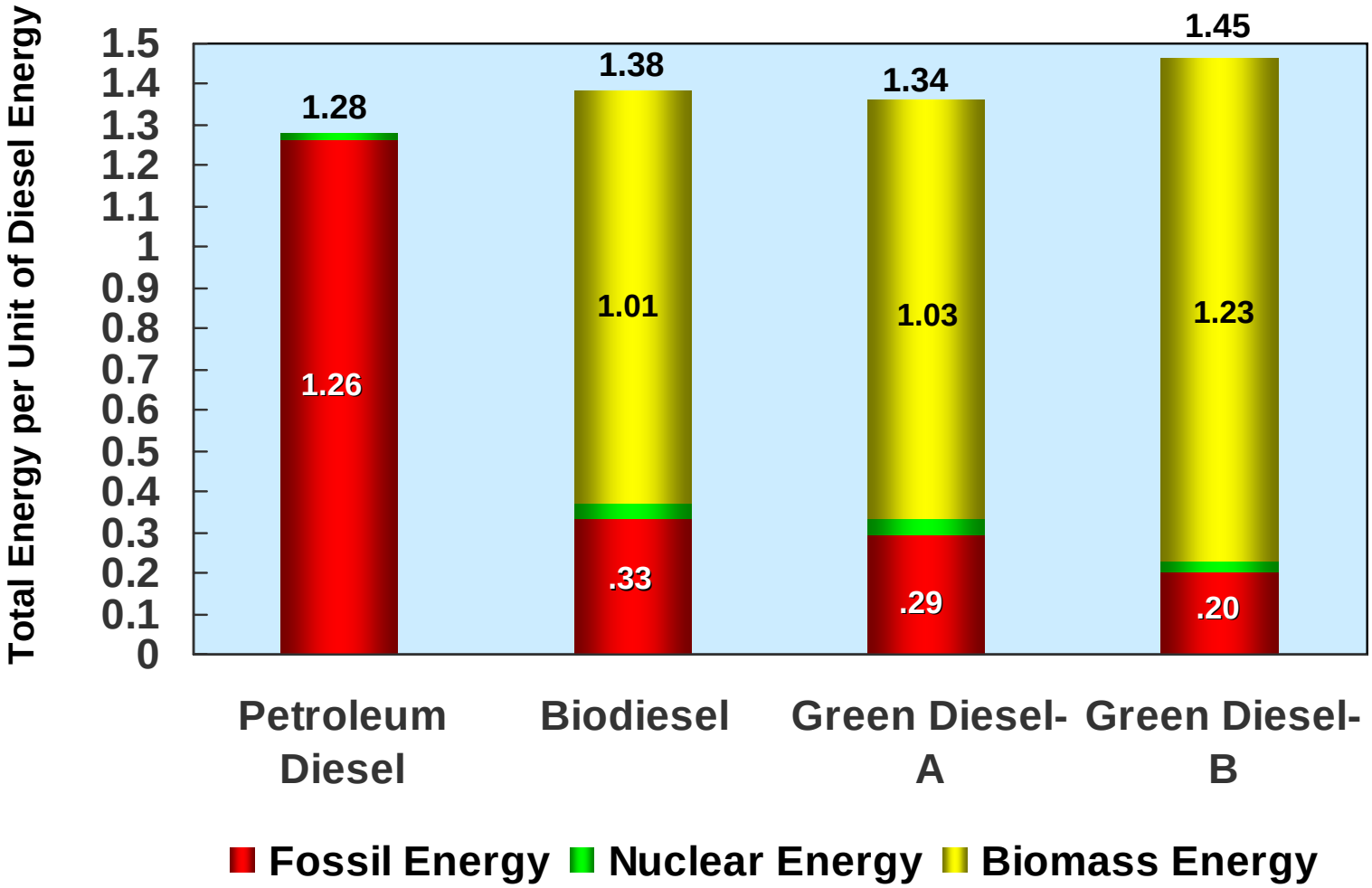
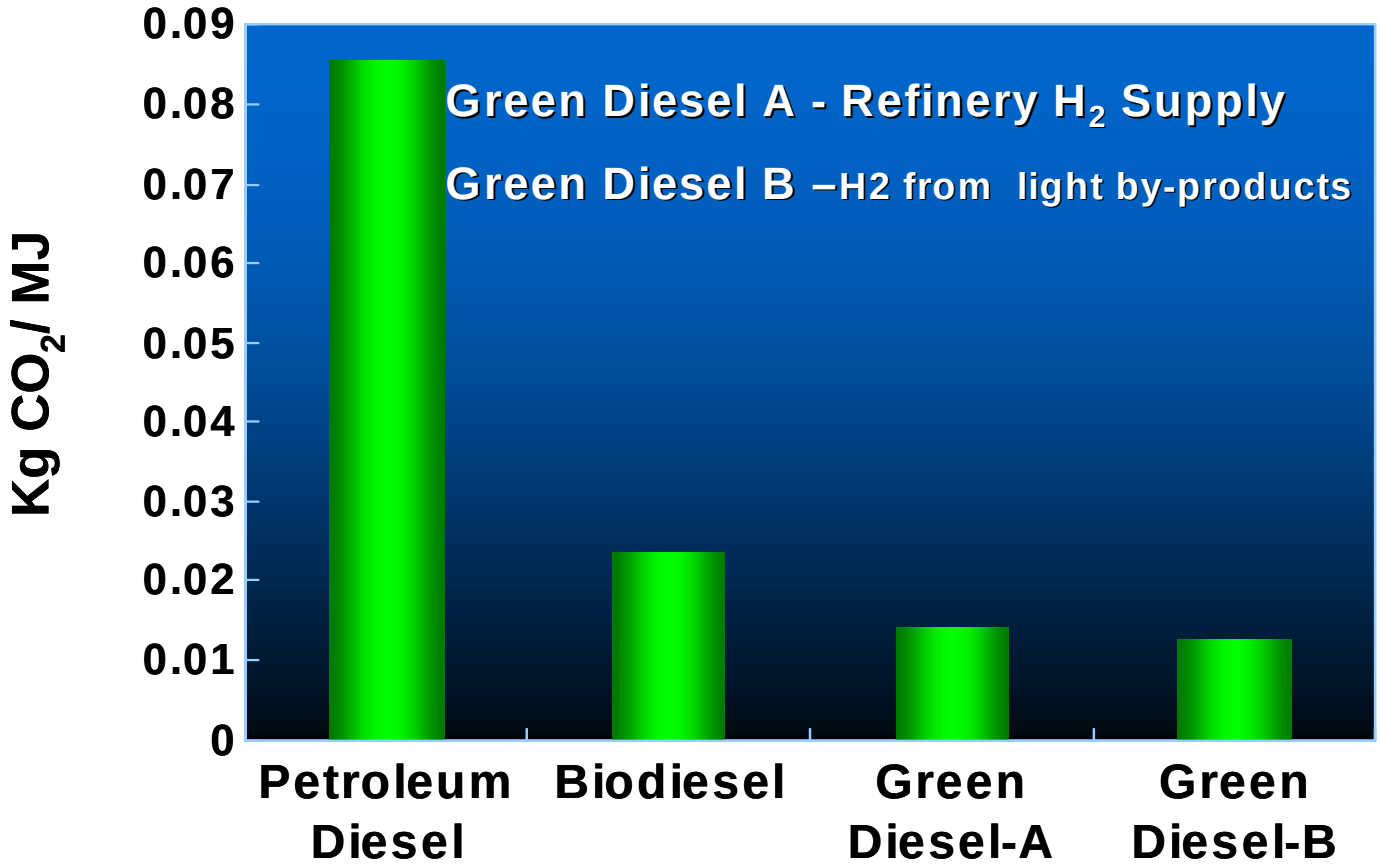



Green Diesel A - Refinery $H_2$ Supply

Green Diesel B - $H_2$ from light by-products

# Climate Active CO2 Production




***Ecofining has the smallest CO2 footprint***

# Production of Jet Fuel

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## *Ecofining™*


***New Bio-Oil to JP-8 Process Based on Existing UOP Technology***


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Honeywell

Cargill

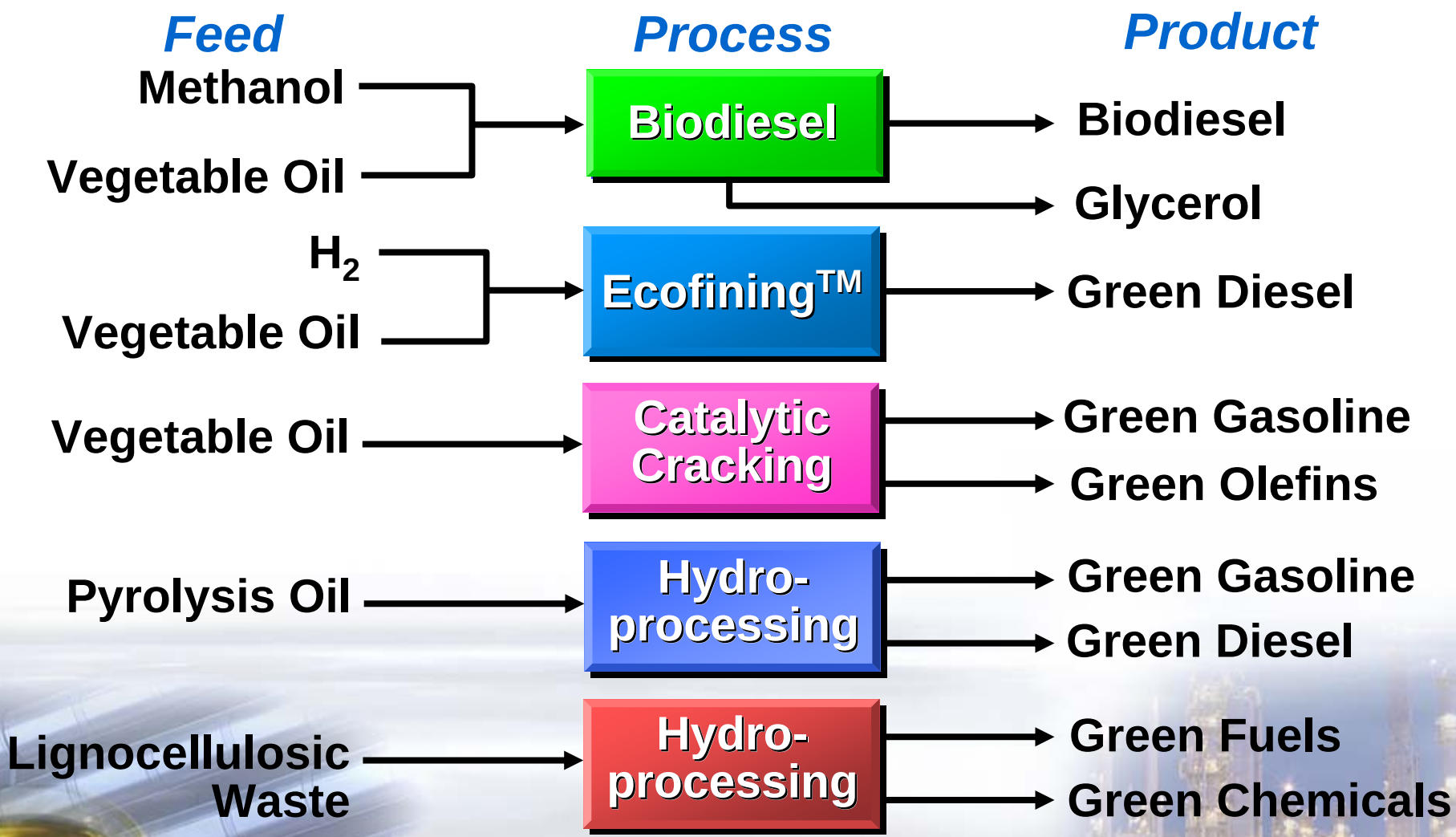
ASU
Arizona State University

Southwest Research Institute

Sandia National Laboratories

*Integrated Biofuels Production*

# Biomass Processing Routes



# FCC Co-Processing of Bio-oils

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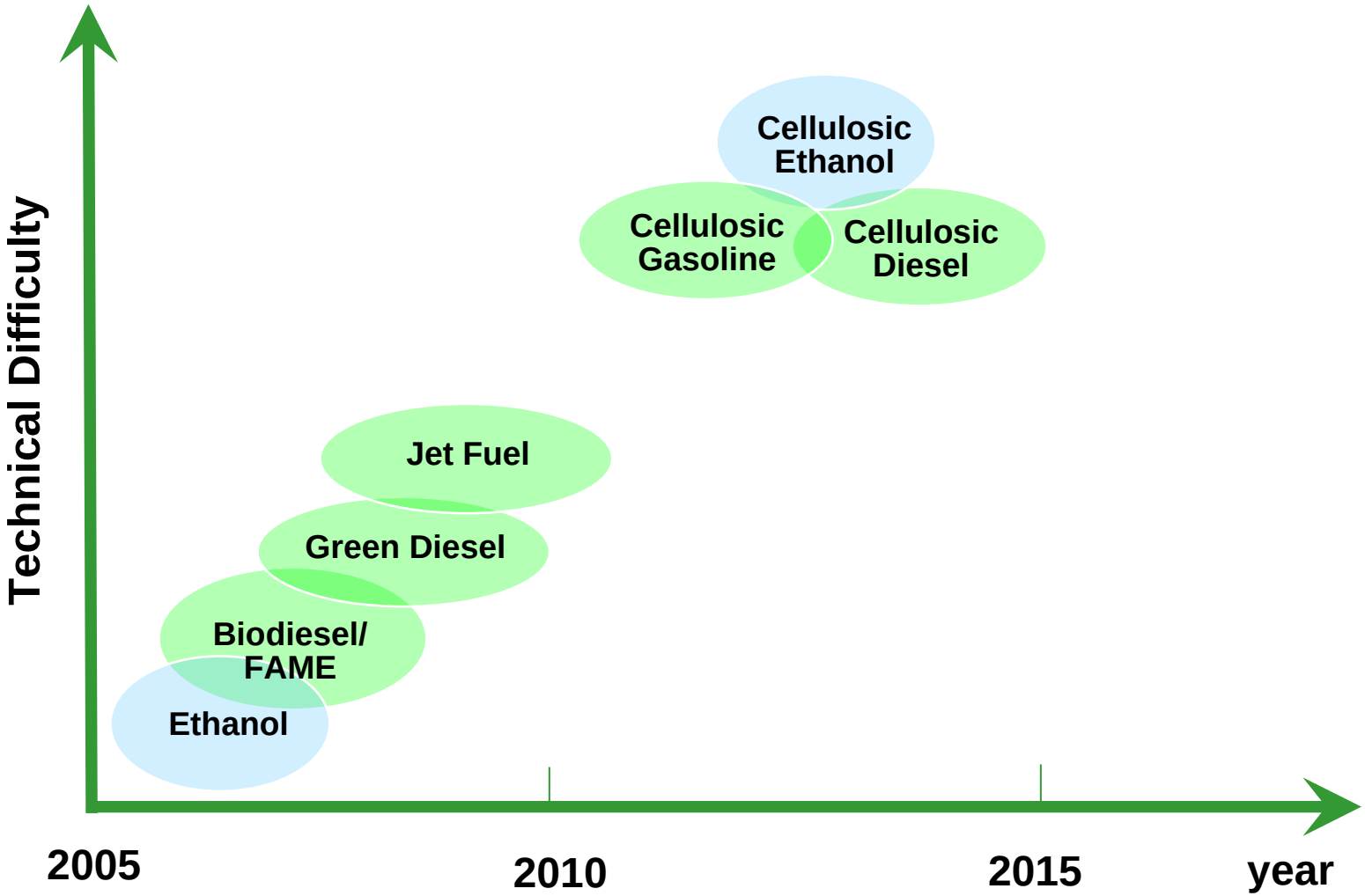
- Tested palm, soybean and jatropha oil feedstocks blended with VGO
  - 5, 10, 15 and 100% blends tested
- Demonstrated benefits:
  - Higher propylene yield demonstrated with palm
  - No change in gasoline yield
  - Reduced dry gas yield
  - Reduced LCO and CSO yield
- Demonstrated oxygen is converted to gases
  - Quantifying impact on commercial operations (GasCon and downstream units)
  - Quantifying impact on waste water

# FCC Co-Processing: Gasoline and Olefin Yields

| *Yields, wt%* | *VGO* | *15% Palm Oil* |
|---|---|---|
| Dry Gas | 5.9 | 5.5 |
| Propylene | 10.2 | 11.2 |
| Propane | 1.9 | 1.9 |
| $C_4$'s | 13.7 | 15.1 |
| Gasoline | 36.7 | 36.2 |
| LCO | 9.6 | 8.7 |
| HCO | 17.7 | 15.6 |
| Coke | 4.3 | 3.9 |
| $H_2O$, CO, $CO_2$ | 0 | 1.9 |
| Total | 100.0 | 100.0 |

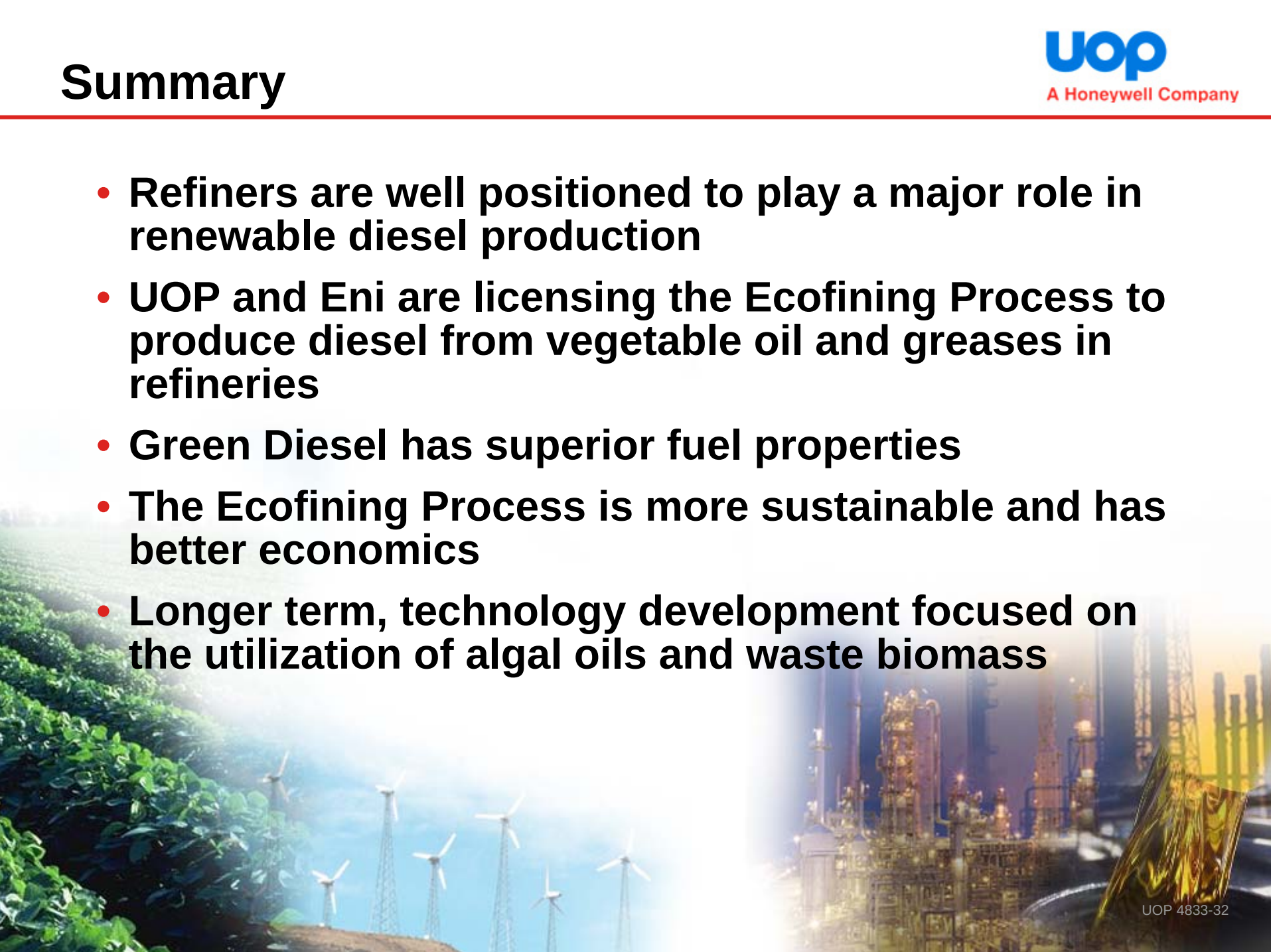
# Timeline of Commercialization of Biofuels




*Significant technology breakthroughs are required to make cellulosic biofuels economic.*

# Summary

- Refiners are well positioned to play a major role in renewable diesel production
- UOP and Eni are licensing the Ecofining Process to produce diesel from vegetable oil and greases in refineries
- Green Diesel has superior fuel properties
- The Ecofining Process is more sustainable and has better economics
- Longer term, technology development focused on the utilization of algal oils and waste biomass




Q&A