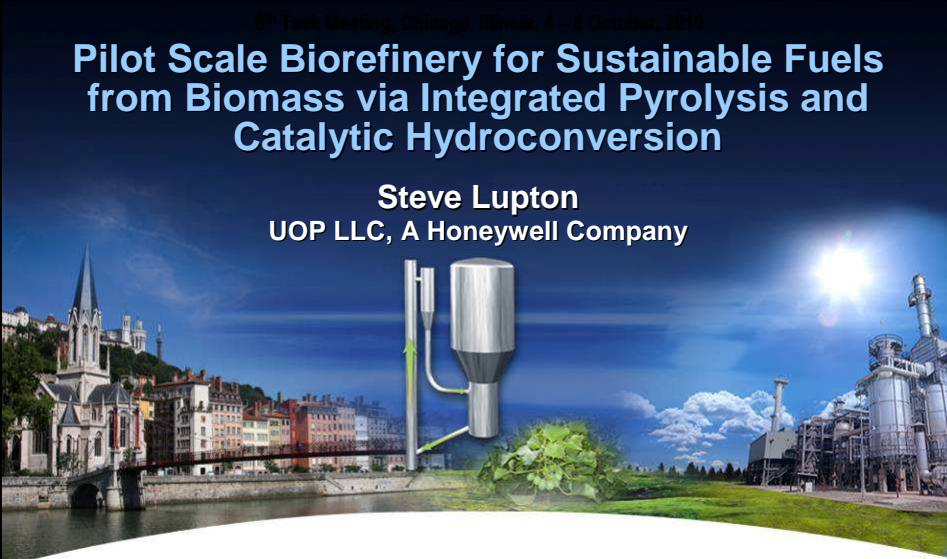


**Pilot Scale Biorefinery for Sustainable Fuels from Biomass and Algal Residues via Integrated Pyrolysis and Catalytic Hydroconversion**


8<sup>th</sup> Task Meeting, Chicago, Illinois, 4<sup>th</sup> October, 2010

# Pilot Scale Biorefinery for Sustainable Fuels from Biomass via Integrated Pyrolysis and Catalytic Hydroconversion

**Steve Lupton**  
UOP LLC, A Honeywell Company




IEA Bioenergy Task 42 - Biorefining  
8<sup>th</sup> Task Meeting, Chicago, Illinois,  
4<sup>th</sup> October, 2010



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## Discussion Topics



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- Introduction to UOP Renewable Energy & Chemicals
- The UOP Integrated Biorefinery Project
  - Scope & Timeline
  - Pyrolysis via RTP™ Rapid Thermal Processing
  - Hydroconversion Upgrading to Transport Fuels
- Initial Life Cycle Analysis (LCA)
- Summary



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**Pilot Scale Biorefinery for Sustainable Fuels from Biomass and Algal Residues via Integrated Pyrolysis and Catalytic Hydroconversion**

## UOP Overview



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- Leading supplier and licensor of processing technology, catalysts, adsorbents, process plants, and technical services to the petroleum refining, petrochemical, and gas processing industries for over 90 years
- UOP Technology Furnishes: 60% of the world's gasoline; 70% of the world's modern detergents; 60% of the world's para-xylene
- ~3000 employees worldwide
- '08 Financials: ~\$2 billion sales;
- Strong relationships with leading refining and petrochemical customers worldwide
- 70+ processes in 6,000+ units in hydrocarbon processing industry; 300+ catalysts, adsorbents; 31 of 36 refining technologies in use today created by UOP




2003 National Medal of Technology Recipient



Track Record Of Technology Innovation

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## UOP RE&C Technologies & Capabilities



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Feed	Process	Product
Natural Oil/Fats Hydrogen	UOP/Eni Ecofining™ Process	Honeywell Green Diesel™ .....▶ Honeywell Green Jet Fuel™ (if req) <span style="border: 1px solid red; padding: 2px; color: red; font-weight: bold; font-size: small;">HVO: '000's barrels/day</span>
Natural Oil/Fats Hydrogen	Renewable Jet Process	Green Jet Fuel .....▶ Green Diesel

Envergent Technologies – UOP/Ensyn JV

Biomass	Rapid Thermal Processing (Pyrolysis)	Green Power / Fuel Oil (today)
'00's tonnes/day		Upgrading Process
		↓ Green Fuels (2013/4)

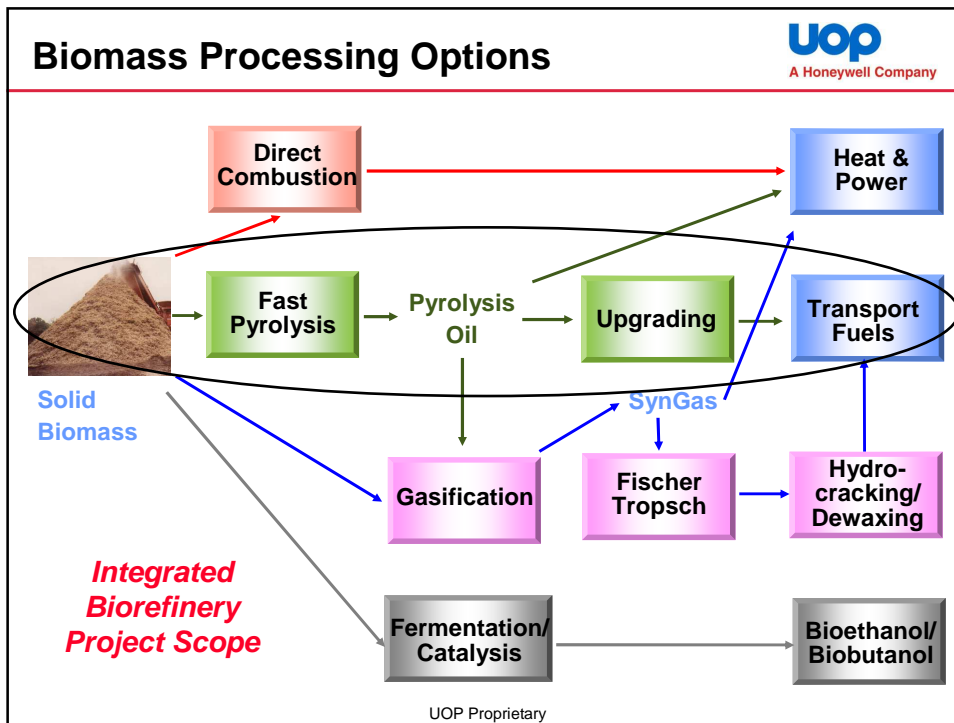
**UOP RE&C Capabilities**

- Studies
  - ✓ Scoping
  - ✓ Revamp
  - ✓ Blending / LP
- Engineering Design
- Catalyst Supply
- Key Eqpt Supply
- Start-Up Services
- Training Services
- Technical Support

Sustainable technologies – feedstock flexible & 2nd Gen ready

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**Integrated Biorefinery Demonstration**  
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The demonstration flow is:

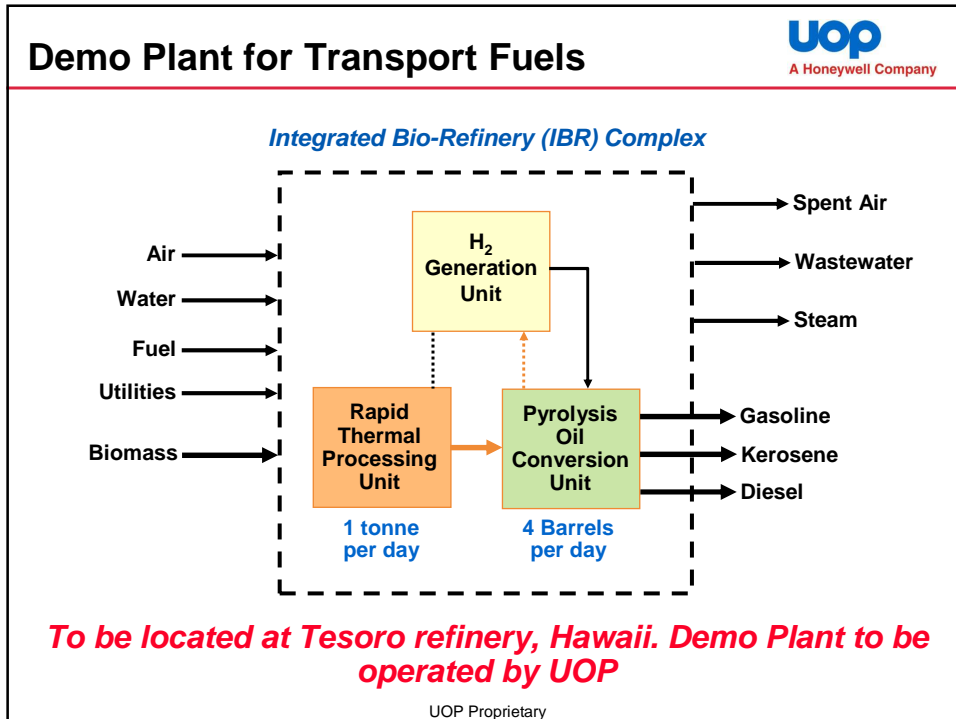
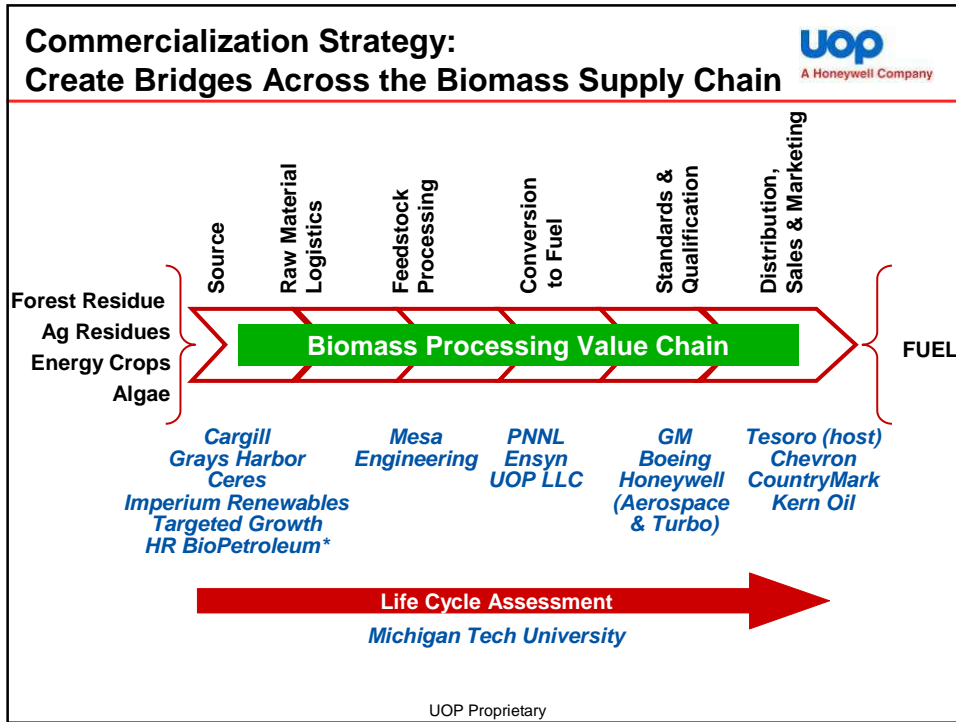
**Solid Biomass** → **Fast Pyrolysis** → **Pyrolysis Oil** → **Upgrading** → **Transport Fuels**

- UOP has received a \$25M grant (in negotiation phase) from the US DOE (Project # DE-EE0002879) to demonstrate technology for the conversion of second generation renewable feedstocks to transport fuels
- Demonstration will be done via a Pilot Plant at the Tesoro refinery in Hawaii, USA, with cross industry commercial partners
- Objectives:
  - Demonstrate scalability of feedstock-flexible technology to produce drop-in transport fuels from lignocellulosic feedstocks
  - Demonstrate supply chain from feedstock to pyrolysis oil conversion & fuel usage
  - Pilot plant will validate that pyrolysis oils from a range of feedstocks can be processed in a common upgrading unit
  - Pilot data will enable development of value proposition for each step in the supply chain, establishing techno-economic feasibility at commercial scale

**Technology that complements traditional refinery technology.  
 Demonstration Complete within Three Years**

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## Feedstocks Sources

- Corn Stover (Cargill)
- Cane Bagasse (Cargill)
- Switch Grass (Ceres)
- Guinea Grass (Imperium)
- Algae Biomass (Hawaii BioEnergy)
- Forest Residue (Grays Harbor)








*Wide range of Second Generation Feedstocks to be utilized*

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## Project Phases & Timeline



*Phase I - Feedstock Characterization (2010/11)*

```

                    graph LR
                    A[500 Kg of each feedstock] --> B[Bench Scale Pyrolysis  
Establish optimal process conditions for each feedstock type]
                    B --> C[Py-Oil  
Analytical characterization]
                    C --> D[UOP Pilot Upgrading  
Establish optimal process conditions for each feedstock Py-oil]
                    D --> E[Product  
Analytical Characterization  
Handling studies by Refining Panel]
                    
```

*Phase II – Performance Testing of Integrated BioRefinery (2012/13)*

```

                    graph LR
                    A[30 metric tonnes of each feedstock] --> B[Integrated Pyrolysis-Upgrading Pilot BioRefinery]
                    B --> C[Product  
Quality and integration studies by refining Panel  
Qualification Testing  
• Gasoline for automotive (GM) and aromatics for Jet (Honeywell, Boeing)]
                    
```

*Phase III – Operational Phase of Integrated BioRefinery (2013/14)*

```

                    graph LR
                    A[150 metric tonnes of Biomass  
Local Hawaiian Supplies  
Via Tesoro – Hawaii Bio-Energy] --> B[Integrated Pyrolysis-Upgrading Pilot BioRefinery]
                    B --> C[Product  
Integration Into Refinery Infrastructure  
(Tesoro, Chevron, Countrymark, Kern Oil)]
                    
```

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### RTP Rapid Thermal Process Technology

**Pyrolysis Oil**

**Solid Biomass**

*Proven Technology, full scale designs available*

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- 510°C, <2 seconds
- Biomass converted to liquid pyrolysis oil
- Fast fluidized bed, sand as heat carrier
- High yields; >70 wt% liquid on woody biomass
- Light gas and char by-product provide heat to dry feed and operate unit

### RTP Pyrolysis Oil Properties

- Pourable, storable and transportable liquid fuel
- Energy densification relative to biomass
- Contains approximately 50-60% energy content of fossil fuel
- Stainless steel piping, tankage and equipment required due to acidity
- Requires separate storage from fossil fuels

*Comparison of Heating Value of Pyrolysis Oil and Typical Fuels*

Fuel	MJ / Litre	BTU / US Gallon
<b>Methanol</b>	<b>17.5</b>	<b>62,500</b>
Pyrolysis Oil	19.9	71,500
<b>Ethanol</b>	<b>23.5</b>	<b>84,000</b>
<b>Light Fuel Oil (#2)</b>	<b>38.9</b>	<b>139,400</b>

*Suitable for Energy Applications & Upgrading to Fuels*

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## Pyrolysis Oil Upgrading

**Objectives**


- ✓ Remove oxygen molecules
- ✓ Reduce acidity and viscosity
- ✓ Break up molecules to make high octane gasoline or diesel/jet precursors
- ✓ Commercialization expected in 2014

**Solution**

- ✓ Thermochemical upgrading; leverage existing hydroprocessing technologies
- ✓ Continuous, reliable guaranteed process, per current refinery standards

**Preliminary Results**


- 30 Wt% hydrocarbon yield from dry biomass



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**Preliminary Yields from Hydrocarbon**

Fuel & Property	Preliminary Value
Gasoline	Approximate Yield, %
	Boiling Range, °C
	Octane Number
Diesel	Approximate Yield, %
	Boiling Range, °C
	Cetane Number
Heavies	Approximate Yield, %
	Boiling Range, °C



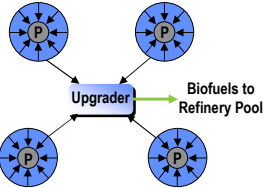
Achieved in Lab, Working on Stability and Scale-up


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## Integration into Commercial Refinery

**Options for integration of Py oil into a refinery:**

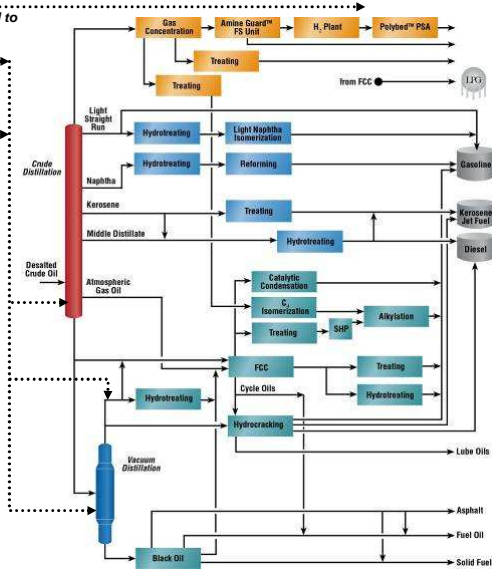
- As stabilized Py oil
- As partially or fully deoxygenated (upgraded) Py oil
- For by-products (light acids, oxygenates) as H<sub>2</sub> generation





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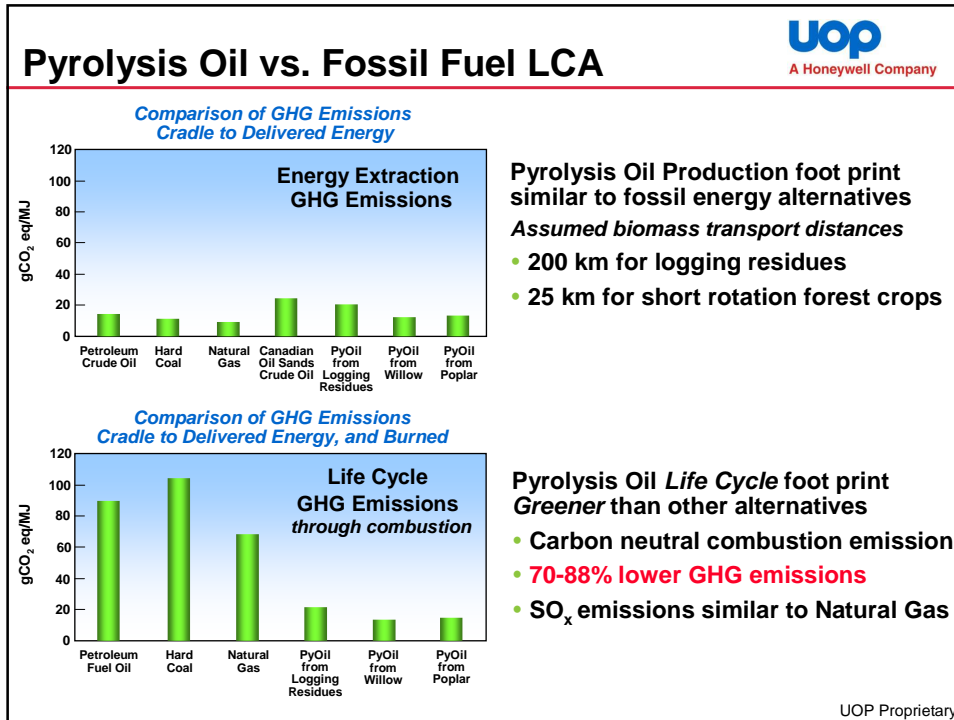
Light acids/ oxygenates may be used to supplement H<sub>2</sub> generation




IBR Project will explore options

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## Summary

- A cross industry consortium will demonstrate sustainable transport fuels via an Integrated Biorefinery Pilot Plant in Hawaii
- The IBR will utilize commercial RTP Pyrolysis technology combined with Catalytic Hydroconversion to upgrade pyrolysis oil into 'drop-in' transport fuels
- A variety of 2<sup>nd</sup> Gen renewable biomass feedstocks will be tested
- Initial LCA work on this biofuel route indicates that GHG emission reductions of 70-90% are possible compared to fossil equivalents




*More information at [www.uop.com](http://www.uop.com)*

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**Q & A**



**THANK YOU!**



**Envergent Technologies LLC – UOP / Ensyn Joint Venture**

  
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- Formed in October 2008
- Provides pyrolysis oil technology for fuel oil substitution and electricity generation
- Channel for UOP R&D program to upgrade pyrolysis oil to transportation fuels

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<ul style="list-style-type: none"><li>• Leading process technology licensor ~\$2 billion in sales, 3000 employees</li><li>• Co-inventor of FCC technology</li><li>• Modular process unit supplier</li><li>• Global reach via Honeywell &amp; UOP sales channels</li></ul>	<ul style="list-style-type: none"><li>• Over 20 years of commercial fast pyrolysis operating experience</li><li>• Developers of innovative RTP™ fast pyrolysis process</li><li>• Eight commercial RTP units designed and operated</li></ul>

**Second Generation Renewable Energy Company – Global Reach**