Sustainable Transport Fuels from Biomass and Algal Residues via Integrated Pyrolysis and Catalytic Hydroconversion

May 21st, 2013

Steve Lupton
Principal Investigator
IBR Scope Block Flow Diagram

Integrated Bio-Refinery (IBR) Complex

Utilities

Biomass

H₂

Gas to H₂ Reformer

Rapid Thermal Processing Unit

1 ton per day

RTP™ Unit

Metals Finishing Unit (MFU)

4 Barrels per day

UG1

Pyrolysis Oil Conversion Unit

UG2

Spent Air

Wastewater

Steam

Gasoline Blend Stock

Jet Fuel Blend Stock

Diesel Blend Stock

Located at Tesoro Kapolei Refinery and Operated by UOP
Integrated BioRefinery Pilot Plant - Biomass to Transport Fuels

- **$25M Pilot Scale (1 ton/day)** Project under the DOE Energy Efficiency and Renewable Energy program and partially funded under the American Recovery and Reinvestment Act.

- **Plant located at Tesoro/Hawaii refinery, operated by UOP**

- **Commercially relevant biomass feedstocks**

- **Phase I: RTP pyrolysis & RTP Green Fuel stabilization units commissioned in 2012**

- **Phase II: Hydroprocessing Unit, Product Fractionation Unit, & PNNL Catalytic Hydrothermal Gasification Unit commissioning targeted for 2015**

Commercialization Strategy:
Create Bridges Across the Biomass Supply Chain
Project Quad Chart

Timeline

• Project start date
  – BP 1: Q2, 2010
  – BP 2: Q1, 2011
• Project end date
  – RTP Commissioned 2012
  – Start-up Planned 2015
• Percent complete
  – 50%

Budget

Total Project Funding

<table>
<thead>
<tr>
<th></th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal</td>
<td>$25,000,000</td>
</tr>
<tr>
<td>UOP</td>
<td>$13,000,000</td>
</tr>
<tr>
<td>Total</td>
<td>$38,000,000</td>
</tr>
</tbody>
</table>

Planned UOP Cost Share 34%

Project Development

Project Status

• Project schedule has slipped 12 months
• Project scope remains unchanged
• Project will be complete by September, 2015

Project Participants

• UOP will Operate Units
• Fabrication of RTP & Upgrader Units by Zeton
• Installation by Ambitech
### IBR Project Schedule with Baseline

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tr>
<td>5</td>
<td>Preliminary RTP engineering and costing</td>
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<td></td>
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</tr>
<tr>
<td>6</td>
<td>Preliminary site engineering and costing</td>
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<td>7</td>
<td>RTP module design and construction</td>
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<td>8</td>
<td>Budget period 2</td>
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<td>Site design and construction</td>
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<td>10</td>
<td>RTP and UGI commissioning and operation</td>
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<tr>
<td>11</td>
<td>Preliminary UGI engineering and costing</td>
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<td>12</td>
<td>UGI module design and construction</td>
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<tr>
<td>13</td>
<td>UGI site construction</td>
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<td>IBR operation</td>
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<td>15</td>
<td>End of DOE funding</td>
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</tr>
</tbody>
</table>
Cost Performance – Federal Funds

IBR Cumulative Federal Invoicing

- Approved DOE Amount or BAC and EAC here
- Planned DOE Amount or PV
- Actual DOE Amount invoiced or AC and EV here

USD

Jan-10  Mar-10  May-10  Jul-10  Sep-10  Nov-10  Jan-11  Mar-11  May-11  Jul-11  Sep-11  Nov-11  Jan-12  Mar-12  May-12  Jul-12  Sep-12  Nov-12  Jan-13  Mar-13  May-13  Jul-13  Sep-13

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Cost Performance – UOP Cost Share

UOP Current Cost Share: $11.3M
40% of Total Spending

Cumulative cost share

- approved cost share or BAC and EAC in our case
- planned cost share (PV)
- actual cost share (AC and also EV here)

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• RTP unit was commissioned and operated in 2012
• During commissioning a number of mechanical and process issues were identified and rectified prior to successful operation of the RTP unit.
• Pre-commissioning work on UG1 (metals removal) was also completed during 2012. Operation of the UG1 is scheduled for later in 2013. Minor modifications were made to the UG1 to correct minor piping issues.
• QA/QC Lab was operational during the RTP commissioning and operation and was able to analyze basic pyrolysis oil samples.
• Both Lab and Pilot testing of the UG2 process have identified issues that have prevented us from issuing a final process design to Zeton so they can provide a firm price for the design and construction of UGII.
• Closure of Tesoro Refining Operations requires new source of hydrogen.
Project Overview

Rapid Thermal Processing (RTP™)
Project Overview

RTP Green Fuel Stabilization

- Solids Removal Unit
- Metals Removal Unit
- Biochar
- Metals Solution

RTP Green Fuel Upgrading

- Hydrodeoxygenation unit
- Fractionation

Hydrogen

Stabilized RTP Green Fuel

RTP Green Fuel

Whole Oil

After Solids Removal

After Metals Removal

 wt/wt

0.00%
0.50%
1.00%
1.50%
2.00%
2.50%

Ash (%) Solids (%)

Naphtha
Light Ends
Lt distillate
Hvy distillate

Aqueous byproduct to be treated by PNNL’s CHG Technology

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Project Overview

Catalytic Hydrothermal Gasification (CHG)

Technology Developed by PNNL

Aqueous stream from Pyrolysis oil Upgrading contains soluble organics

Aqueous Wastes

Heat Recovery

Catalytic Reactor, 350°C 200 atm

Gas/Liquid Separation

Electricity

Gas Product

Process Heat

Reform to H₂

Clean Water

Recovered methane from CHG treatment of aqueous stream is a source of renewable H₂

Pressure Letdown

Electricity?
1 – Project Management

UOP Integrated BioRefinery Project
Project Organization Chart

UOP Integrated BioRefinery Project

Project Sponsors:
- UOP RE&C: Jim Rekoske
- Envergent: Dave Cepla

Legal: John Bowles
Accounting: Andy Stolarz

Principal Investigator: Steve Lupton

Client
US Department of Energy: Liz Moore
Independent Engineering Service:
SAIC: Mike McCurdy

Project Director: Mike Lunda

Project Partners:
- Host: Tesoro
- Feed Pre-Treat: Mesa
- Feed supply: Ceres, Cargill, Imperium, Hawaii BioEnergy
- Refiners: Tesoro, Chevron
- End-users: GM, Boeing, Honeywell

Upgrader Development:
- Lance Baird

R&D
- Stan Frey

Upgrader Research:
- Tim Brandvold

UOP Specialists:
- Engineering, QA/QC
- Logistics, E&I

Modular Design & Fabrication
UOP Co-coordinator: Jim Hagen

Operations
Site Manger:
- Bob Jensen

UOP Operations Staff

Operations Site Manger:
- Bob Jensen

Site Logistics, Utilities & Installation:
AMBITECH
- Const. Manger: Lou Van Gelder

Site Permits & Environmental:
- Group 70, Arcadis

Subcontractors:
- Modular RTP: Zeton
- Modular MFU: REMCO
- RTP Process Design: Ensyn
- Modular Upgrader: Zeton
- IBR Control System: Honeywell

Project Partners:
- Host: Tesoro
- Feed Pre-Treat: Mesa
- Feed supply: Ceres, Cargill, Imperium, Hawaii BioEnergy
- Refiners: Tesoro, Chevron
- End-users: GM, Boeing, Honeywell

Subcontractors:
- LCA: Michigan Tech.
- Feedstock Testing: Ensyn
- Catalytic Hydrothermal Gasification: PNNL

Site Contractor:
- American Pipe & Boiler

Modular Design & Fabrication
UOP Co-coordinator: Jim Hagen
2 - Technical Accomplishments/ Progress/ Results

UOP IBR Site, Kapolei, Oahu, Hawaii
IBR Site - Looking South to Tesoro Refinery
Motor Control, Transformer, Compressor and Chiller
2 - Technical Accomplishments/ Progress/ Results

UG-I System (MFU & Tanks)
2 - Technical Accomplishments/ Progress/ Results

RTP Module and Control Room/Offices

RTP™ Unit

Offices & Control Room

Feed Stock Unloading Area
2 - Technical Accomplishments/ Progress/ Results

Quality Control Lab

IBR Site Lab
2 - Technical Accomplishments/ Progress/ Results

**Operations Crew**

RTP™ Unit shakedown occurred under the supervision of UOP Field Service Engineers and local operators trained by UOP.

**Control Room**

RTP™ Unit Shakedown, 2012
2 - Technical Accomplishments/ Progress/ Results

Bulk Properties of Hydrogenated Product From Lab Scale Upgrading

<table>
<thead>
<tr>
<th>Elemental and Physical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen, mass%</td>
</tr>
<tr>
<td>Carbon %</td>
</tr>
<tr>
<td>Hydrogen %</td>
</tr>
<tr>
<td>Nitrogen %</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Degree API</td>
</tr>
<tr>
<td>Water, wppm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GCxGC, wt%</th>
<th>Gasoline</th>
<th>Kerosene/Jet</th>
<th>Diesel + Fuel Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffin</td>
<td>2.7</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Isoparaffin</td>
<td>1.6</td>
<td>2.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Naphthene</td>
<td>75.4</td>
<td>50.9</td>
<td>21.6</td>
</tr>
<tr>
<td>Aromatic</td>
<td>20.2</td>
<td>46.2</td>
<td>78.0</td>
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</table>

Estimated Fractions by SimDist D2887, wt%

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Fractions</td>
<td>~55</td>
<td>~23 - 31</td>
<td>~23 - 46</td>
</tr>
<tr>
<td>by SimDist D2887,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wt%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3 - Relevance

ASTM D7566 Certification

D7566: Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Annex for each class of synthetic blending component (up to 50%)

- Annex 1: Fischer-Tropsch hydroprocessed SPK (FT-SPK, 2009)
- Future annex: Pyrolysis Oil to Jet – Hydroprocessed Depolymerized Cellulosic Jet (HDCJ) – sample sent to AFRL for evaluation and testing

Product From the UOP IBR Will Support Certification of HDCJ Fuel
Upgraded Jet Fuel Cut Properties to HDCJ Committee

<table>
<thead>
<tr>
<th>Test</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density Relative D4052</td>
<td>0.8622</td>
<td>g/mL</td>
</tr>
<tr>
<td>Freeze Point D7153</td>
<td>&lt; -80</td>
<td>°C</td>
</tr>
<tr>
<td>Flash Point D7094</td>
<td>56.6</td>
<td>°C</td>
</tr>
<tr>
<td>Trace metals U389</td>
<td>&lt; 0.6</td>
<td>wppm</td>
</tr>
<tr>
<td>Chloride D7539</td>
<td>0.3</td>
<td>wppm</td>
</tr>
<tr>
<td>Nitrogen D4629</td>
<td>&lt; 0.2</td>
<td>wppm</td>
</tr>
<tr>
<td>Oxygen U730</td>
<td>&lt; 0.03</td>
<td>wppm</td>
</tr>
<tr>
<td>Sulfur D2622</td>
<td>1</td>
<td>wppm</td>
</tr>
<tr>
<td>n-paraffins</td>
<td>0.8</td>
<td>wt%</td>
</tr>
<tr>
<td>isoparaffins</td>
<td>2.8</td>
<td>wt%</td>
</tr>
<tr>
<td>Monocycloparaffins</td>
<td>22.7</td>
<td>wt%</td>
</tr>
<tr>
<td>Dicycloparaffins</td>
<td>13.2</td>
<td>wt%</td>
</tr>
<tr>
<td>Single ring aromatics</td>
<td>40.1</td>
<td>wt%</td>
</tr>
<tr>
<td>Indans/ tetralins</td>
<td>20.1</td>
<td>wt%</td>
</tr>
<tr>
<td>Naphthalenes</td>
<td>0.3</td>
<td>wt%</td>
</tr>
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</table>

Boiling Point, °C vs. Wt% Distilled

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### Upgraded Pyrolysis Oil Products

<table>
<thead>
<tr>
<th>Pyrolysis Oil Feed to Fuels Feed/Product Analysis</th>
<th>Pyrolysis Oil</th>
<th>Upgraded Fuel</th>
<th>Gasoline Requirements</th>
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</thead>
<tbody>
<tr>
<td>Water, %</td>
<td>~25</td>
<td>0.03</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>O, %</td>
<td>51</td>
<td>&lt;0.1</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td>TAN, meq/g</td>
<td>91</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

#### Pyrolysis Oil Feed to Fuel Transportation Fuel Yield\(^1\)

<table>
<thead>
<tr>
<th>Overall Yield, % of Pyrolysis Oil</th>
<th>Mass</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>~50% of material in gasoline boiling range 40-200°C</td>
<td>41</td>
<td>60(^2)</td>
</tr>
</tbody>
</table>

1. Demonstrated yield from at multiple equipment scales.
2. Equals > 90 gallons per dry MT for woody biomass.

\(^1\) Upgraded Product D2887 SimDist

\(^2\) RON of gasoline ~80-89

~40% of material in distillate boiling range

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3 - Relevance

Renewable Gasoline GHG Emissions

PRELIMINARY MODEL RESULTS (WOODY FEEDSTOCK)

Fuel Combustion
Fuel Transportation
Fuel Production
Transportation of Feedstocks
Feedstock Production, RMA
Feedstock Chemicals

Petroleum Diesel
PyGasoline: Logging Residue
PyGasoline: Poplar
PyGasoline: Willow
Petroleum Gasoline

Lifecycle GHG Thresholds in EISA (% reduction from 2005 baseline)

- Renewable fuel: 20%
- Advanced biofuel: 50%
- Biomass-based diesel: 50%
- Cellulosic biofuel: 60%

Upgrading RTP Green Fuel Makes Cellulosic Biofuels
4 - Critical Success Factors

Py Oil Stabilization

Pyrolysis close to biomass source for densification

Upgrader integrated with Refinery

Hydrogen from Refinery Header

Commercial Scale Production of Transportation Fuels from Biomass

Biofuels to Refinery Pool

Commercial Application is Distributed Model

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There is sufficient forestry residue alone co-located with refining assets to support commercialization. Additional feedstocks are available on a regional basis.
5. Future Work

• Resolve hydrogen supply issues resulting from closure of Tesoro refining operations

• Shakedown of UG I in June, 2013

• Finalize design for UG II, August, 2013

• Construct and Install UG II at Kapolei site, Q4, 2014

• Conduct Independent Engineer Evaluation, Q1 – Q2, 2015
Summary

- Pyrolysis oil has been upgraded at bench scale into transportation fuel blend stocks

- A process is to be installed to convert biomass to cellulosic biofuel suitable for transportation fuel at high yield at the 1 ton/day scale.

- Some scale-up issues still need to be resolved prior to fabrication and installation of Upgrader at site
Acknowledgements

• The authors wish to acknowledge the support of:
  - The Honeywell - UOP Renewable Energy and Chemicals R&D groups
  - The broad Honeywell-UOP technical community
  - the Honeywell-UOP Renewable Energy and Chemicals business group, Envergent Technologies, and Ensyn Corporation
  - The group of Dr. Doug Elliott at Pacific Northwest National Laboratories for past and ongoing collaborations on biomass pyrolysis oil upgrading and Catalytic Hydrothermal Gasification
  - The group of Prof. David Shonnard, Michigan Technological Univ., for ongoing LCA collaborations

• The material presented is based in-part upon work supported by the Department of Energy, Energy Efficiency & Renewable Energy, Biomass Program, under Award Number DE-EE0002879, Recovery Act - Pilot Scale BioRefinery: Sustainable Transport Fuels From Biomass And Algal Residue Via Integrated Pyrolysis And Catalytic Upgrading.

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Additional Slides
### Response to Past PEER Review Comments

<table>
<thead>
<tr>
<th>Project Approach</th>
<th>UOP Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound plan to build and implement plant using successful UOP practices and suppliers.</td>
<td>Technical data from lab and pilot testing on feedstocks is proprietary and business sensitive information so it is not possible to present this data in a public forum such as the Peer Review. This data was presented to DoE staff as part of the comprehensive project review which is held with DoE and the Independent Engineering Group.</td>
</tr>
<tr>
<td>Project is being performed in two stages. DOE requested acceleration. Phase 1 is RTP and UG1. Same UOP approach as commercial plants. Modules fabricated offsite and transported to project site. Large number of project participants. Could be difficult to coordinate.</td>
<td>The selection of the Hawaiian site was largely driven by UOP’s refinery partner for this project, Tesoro. Tesoro was willing to provide a site for the pilot only at this location. Tesoro has since ceased operations at the site but the expense of removing the installed equipment to a new location is prohibitory expensive.</td>
</tr>
<tr>
<td>High appreciation of the need for feedstock flexibility, does add complexity to pilot operations. Process robustness will be proven with further successful operations. Location at refinery in HI adds unnecessary logistics and shipping issues so one to four 55 gallon drums of product/day is available on-site for refining. Care will need to be taken to ship and store feedstocks.</td>
<td>There are certain unique logistics issues situated with strategic supply of transportation fuels in the State of Hawaii which support the location of the IBR project at that location.</td>
</tr>
<tr>
<td>Biomass into pyrolysis oil to a fungible hydrocarbon fuel scale - 1T/day or 4 barrels per day of hydrocarbon product unit operation at an existing plant integrate into other refinery infrastructure - and what is the best way to do that finally slide 8 - seems like the approach is all about operations; no early in the talk specifics about research, demo, deployment and the like. - the first dig into feedstocks and LCA came on the 11th slide under accomplishments/progress/results</td>
<td></td>
</tr>
<tr>
<td>As expected, this project's strategic, technical, and management teams possess the right skills and have the right experience to implement a solid PMP. The implementation of the PMP met the milestones. Overall, given the project team, this reviewer has solid confidence the PMP will continue to effective. A weakness was the absence of a summary of pilot results which could be used by reviewers to gauge roughly the soundness of the technical approach. This especially applies to the performance or piloting of the Ensyn’s pyrolysis unit and data related to upgrading the py-oil, so this reviewer reduced scoring on this criteria by one mark.</td>
<td>There are certain unique logistics issues situated with strategic supply of transportation fuels in the State of Hawaii which support the location of the IBR project at that location.</td>
</tr>
<tr>
<td>UOP has a technically sound approach to project execution, but the timeline presented does not include planned versus actual progress, so it isn’t possible to measure how they’re doing versus what they planned.</td>
<td></td>
</tr>
</tbody>
</table>

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## Response to Past PEER Review Comments

<table>
<thead>
<tr>
<th>Benefits and Expected Outcomes</th>
<th>UOP Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very expensive $36MM for 1 tpd and 4 barrels/day demonstration plant. Commercial plant would be 1600 tpd and 6,400 barrels/day at an unknown cost. No additional data provided.</td>
<td>The economics associated with the UOP technology is business sensitive information and cannot be disclosed in a public forum. This is reviewed in depth each year during the comprehensive project review with DoE and the Independent Engineers</td>
</tr>
<tr>
<td>Specific performance parameters not provided. General benefits targeted toward refinery applications. Project will have to be scaled about 400 times for commercial application.</td>
<td></td>
</tr>
<tr>
<td>No disclosure according to the mandated format. Even a hint would have been nice.</td>
<td></td>
</tr>
<tr>
<td>DOE, Fuels Consumers, Refinery Host, UOP LLC Ensyn, Auto manuf, Farming, Pulp and Paper</td>
<td></td>
</tr>
<tr>
<td>Developers of new energy crops incl algae, none of the following was addressed: a, b, c, d, e, f, from above</td>
<td></td>
</tr>
<tr>
<td>Data from operations will benefit from refinery location and partner experience in motor fuel production. Program will demonstrate process and provide economic data for scale-up. If all six feedstocks are tested significant data will be developed.</td>
<td></td>
</tr>
<tr>
<td>No economics presented</td>
<td></td>
</tr>
</tbody>
</table>
## Response to Past PEER Review Comments

<table>
<thead>
<tr>
<th>Critical Success Factors</th>
<th>UOP Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, they listed –many critical success factors and have highlighted sub-topics in each area that will be examined and evaluated when the project is operational. Ascertaining the impact of each critical factor in the project implementation was difficult but they have moved to the purchase stage so clearly have overcome most/all known hurdles. It was unclear, for example, if catalyst stability was an issue that they had overcome, or was one that they intended to overcome once the project is operational. For commercialization of this system, feedstock supply and associated deployment of distributed pyrolysis units remains a significant issue and this has been evident in other Platform projects involving ag-waste feedstock. The project cost ($36 MM total money) seems extraordinarily high for a pioneer demo-scale plant, even in Hawaii. This reviewer assumes the DOE has examined this closely.</td>
<td>The demonstration of multiple feedstocks in the UOP process shows the versatility of the process and shows that the technology is not dependent on any one source or type of feedstock such as agricultural wastes or energy crops.</td>
</tr>
<tr>
<td>The presentation identified critical success factors for commercialization and described actions being taken in the pilot plant to address these factors.</td>
<td>The RTP™ Unit was fabricated, delivered and installed on schedule and on budget. Shakedown occurred in 2012 and minor equipment changes were made. Pyrolysis oil was successfully produced.</td>
</tr>
<tr>
<td>Project has a local partner for permits and applications are submitted, slated for May 2011 issuance.- NEPA is completed.- Site layout and equipment selection has occurred.- Construction start planned for July 2011.- Modules for pilot unit are being constructed by Zeton in Burlington, Ontario, Canada.- While an renowned pilot plant constructor, long shipping route.</td>
<td>UOP learned from permitting process and expects upgrader permitting to be less onerous. The project costs have been closely monitored by DoE and the project has been subjected to yearly detailed audits by independent auditors.</td>
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<tr>
<td>Plan is to use plant data to determine the parameters for process success.</td>
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<tr>
<td>LCA feedstock supply contracts establish refinery partnerships commercial size units establish customer off-take agreements fair detail in summary, but only outlined the contribution from the pilot project; no discussion of any problems or expected critical path</td>
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<tr>
<td>Success factors clearly identified, but not a very good explanation of how the pilot plant will achieve them other than to say that it will.</td>
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## Response to Past PEER Review Comments

<table>
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<tr>
<th>Technical Progress and Accomplishments</th>
<th>UOP Response</th>
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<tr>
<td>Wide range of feedstocks used in process development. Good progress overall toward the project.</td>
<td>Project schedule is shown in this presentation. Budget Period 1 was on schedule and on budget. There has been some slip in schedule for BP2 due to closing of the Tesoro Refining operations and with scale up issues for the uprader but overall project progress is in alignment with the project schedule.</td>
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<tr>
<td>Site partners and location is well defined. Scope of work is largely not defined as bench scale work appears yet to be performed for many of the feedstocks other than wood which shows promise for gasoline. Location adds logistics complexity which seems to be affecting the schedule progress and cost of the project.</td>
<td>Again, the details cannot be shared in a public presentation. However, project execution and schedule reviews by DoE’s independent engineer and the DOE Project Officer are being conducted on a bi-weekly basis.</td>
</tr>
<tr>
<td>Issuance of purchase orders is a major step towards project implementation and demonstrates the maturity of the engineering work. Project was correct in emphasizing the complexity of implementing a project within a refinery footprint and this acknowledge should help put a stop to the casual assumption that placing pyrolysis/reformer plant at a refinery is an easy thing to do. Specifically they mentioned the impact of refinery standards and performance inside the refinery fence line. Testing of various feedstocks is beneficial at this stage but eventually, the pioneer commercial project will focus on only one or two feedstocks.</td>
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<tr>
<td>BP1 to be completed 7/11. BP2 to start 7/11. Fuel products will be released into the refinery process Basic engineering, preliminary detail design and equipment sourcing complete for RTP and UG1. NEPA determination (CX) and environmental permits are underway.</td>
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<td>Progress is apparently being made on both permitting and technical fronts. The claim is made that equipment design and procurement is on schedule, but that schedule is not shown. Also, the explanation of technical accomplishments is quite sketchy. It would be very useful to have some more technical detail regarding experimental results to date rather than just the broad brushstroke verbal overviews.</td>
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## Project Relevance

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<td>see slide 12 - appears to relevant to the DOE mission regarding at least feedstocks, crop processing and the algal pathway</td>
<td>UOP feels that the integration of the biomass pyrolysis/upgrading technology piloted in the IBR project has certain synergies when co-located with traditional petroleum refining operations for the following reasons:</td>
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<tr>
<td>Relevance somewhat limited by the UOP plan to target refinery customers.</td>
<td>1. Refineries have the appropriate outside battery limit (OSBL) infrastructure, such as supply of hydrogen gas that support the UOP IBR process units (upgrader).</td>
</tr>
<tr>
<td>Project provides pathway to renewable gasoline that potentially will integrate well with existing refining infrastructure. Relevant specifically to HI to help develop a state-specific renewable component. Replication at mainland locations may be significantly different.</td>
<td>2. The hydrocarbon fuel products that will be produced by the IBR make blending components that are quite fungible with existing petroleum fuel products and may enhance the properties of these existing fuels.</td>
</tr>
<tr>
<td>Presentation identified relevance to DOE Biomass Pathway Milestones. Looking at feedstock that is relevant to rest of US</td>
<td>3. Refineries have incentives, under the RFS regulations, to produce a portion of their fuels that are both fungible with existing petroleum fuel products but which have the required GHG savings mandated under the RFS.</td>
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<tr>
<td>Fits well with MYPP. Addresses the underlying area of pyrolysis oil utilization at a refinery.</td>
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<tr>
<td>This project is directly relevant to the MYPP goals. Integration of BioRefinery concepts into petroleum refineries is a key to the long term advancement of the biofuels industry.</td>
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### Technology Transfer and Collaborations

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<tr>
<th>Project partners and refinery host for project are benefits for increased tech transfer.</th>
<th>UOP experience in IP for refining industry will help successes to be developed.</th>
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<tbody>
<tr>
<td>UOP experience in IP for refining industry will help successes to be developed. Project partners and refinery host for project are benefits for increased tech transfer.</td>
<td>It was also explained that UOP is an open licensor of technology and that the existing worldwide refining base represents major potential customers for the upgrading component of the technology whereas forest products companies, pulp &amp; paper companies, farming co-operatives, etc, may be an existing customer base for the pyrolysis component of the technology.</td>
</tr>
<tr>
<td>Technology transfer and collaboration beyond the immediate project team was not discussed.</td>
<td>It may be quite possible that a refinery may licensing the py-oil upgrading component of the technology but the forest products and/or biomass producing companies may license the pyrolysis component with off-take agreements with the refineries.</td>
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<tr>
<td>Not addressed in presentation.</td>
<td>Many collaborators identified – very good. Technology transfer to the refinery sector will be crucial in the long term, so that’s a very favorable approach.</td>
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<td>Overall Impressions</td>
<td>UOP Response</td>
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<td>Very expensive project with solid program plan and partners.</td>
<td>The $36M project costs were flagged by some reviewers as high compared to other projects. A detailed breakdown of the project costs could not be presented in this public format. However, a detailed breakdown of the project costs show that the equipment costs are very similar to many of the other projects. The overall project has a considerable amount of process development costs borne by UOP at its own expense that are not directly related to equipment fabrication and installation at the Hawaii site.</td>
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<td>Potential for significant fuel volume contributions is very far into the future.</td>
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<td>Overall, this is a good project with a solid team. If it goes well they will go a long way to proving the basics of their chosen technology platform, but more importantly, they will provide the basis to assess the practicality behind distributed pyrolysis units and refinery based py-oil upgrading.</td>
<td>Also, many of the costs, such as environmental and construction permitting are independent of the size of equipment being fabricated and installed and are the same for this project as for a 1000 ton/day BioRefinery project. Likewise operations are even more complex and expensive to run this 1 t/day pilot than for a full-scale commercial plant due to the fact that at the pilot scale there are more manual tasks required than for full-scale plants which are more integrated.</td>
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<tr>
<td>Approach and progress appear to be good. Information on commercial plant was missing.</td>
<td>Likewise, HS&amp;E considerations are just as complex and requires just as much attention at pilot scale as for full-scale.</td>
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<tr>
<td>Well formulated project making good progress but with limited application to refineries.</td>
<td>It is true that the logistics associated with the demonstration in Hawaii do added significantly greater transportation costs for both equipment and feedstocks.</td>
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<td>20M dollars with a small pilot plant - pretty expensive for a pilot 36M with UOP Honeywell scale of commercial plant is 6400bbl/day unit with feedstock at -1600 tpd with few cost pieces feedstock integrity means they are dried.</td>
<td></td>
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<tr>
<td>This appears to be a good project. My concern is the project cost. It appears that the total cost will be about $36 million for a one ton per day pilot plant. I’d sure like to see what the pro-forma economics look like for a commercial plant. The capital cost per ton of feedstock will have to be several orders of magnitude lower.</td>
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Ten (10) US patent applications and four (4) Foreign applications have been submitted covering py-oil upgrading to hydrocarbon fuels covering both process designs and catalyst composition.


