Creating a Sustainable Biomass Infrastructure

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UOP Vision

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Fuel Additives / Blends

Ethanol | Biodiesel

Fuels

Diesel | Gasoline

UOP's Bio-Fuels Technology Goals

Identify and utilize processing, composition, and infrastructure synergies to lower capital investment, minimize value chain disruptions, and reduce investment risk.

Ready Now

- Vegetable oils to diesel, petrol and jet fuel

Ready in 2010

- Lignocellulosic biomass to fuels
- Algal oils to fuels

Green Diesel vs. Biodiesel (FAME)

Veg Oil/ Grease

Methanol → **Biodiesel (FAME)** + Glycerol

Hydrogen → **Green Diesel** + Propane

	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
Cetane	40	50-65	70-90
Lubricity	Baseline	Good	Baseline
Stability	Baseline	Poor	Baseline

Ecofining™ Process to Produce Green Diesel
ENI Unit Start-up: 2009

Green Diesel Blending Benefits

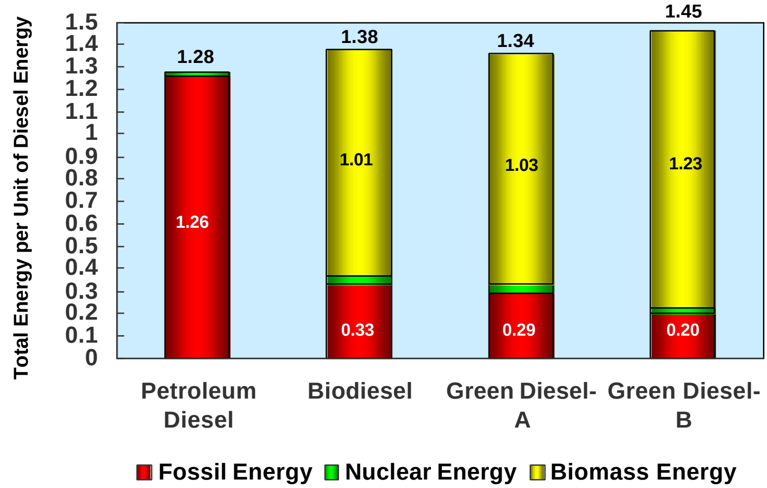
Diesel Pool Components	*Barrels in Pool*	*Cetane Index*
Kerosene	500	41
Straight Run Diesel	7500	52
Hydrotreated LCO	2000	20
Green Diesel	2346	74
Average Cetane		50

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 high cetane, low density, excellent cloud point.
- Green Diesel is similar to GTL but with better economics.
- Permits blending low value fuels into ULSD or a reduction in cetane enhancing additives.

Towards an Economically Attractive Biofuel

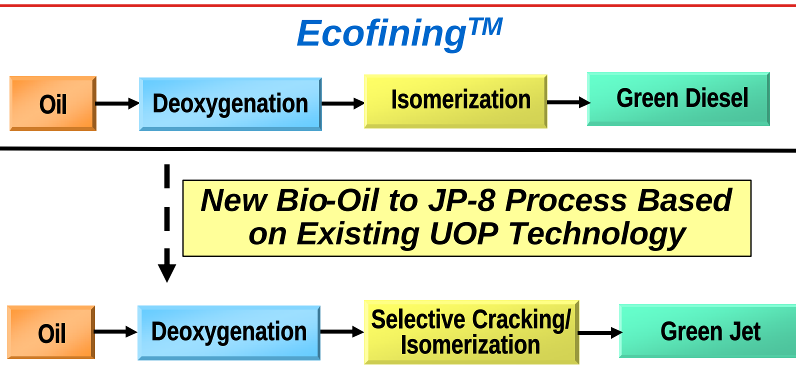
Life Cycle Analysis: Total Energy Comparison



Petroleum Fuels Production is Most Energy Efficient

Green Diesel has the Smallest "CO_2" Footprint

Production of Jet Fuel



✓ *Properties Met*

Integrated Biofuels Production

Emerging Issues

Food supply: small impact on the fuel market, yet large impact on food supply

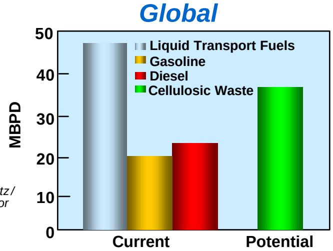
Land and water: competition for land and water resources that are already in high demand

Environmental: loss of biodiversity, soil erosion, nutrient leaching, soil and water pollution and deforestation

Second generation development can ease these issues

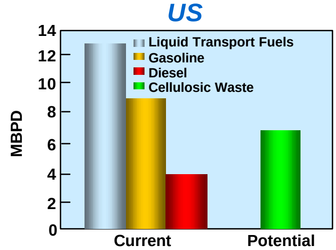
Enablers for a Sustainable Biomass Infrastructure

Global

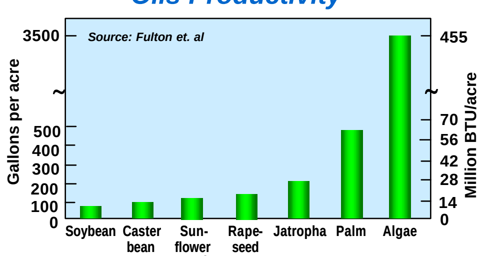


Source: Purvin & Gertz / Eric Larsen: Energy for Sustainable Development, 2000

US



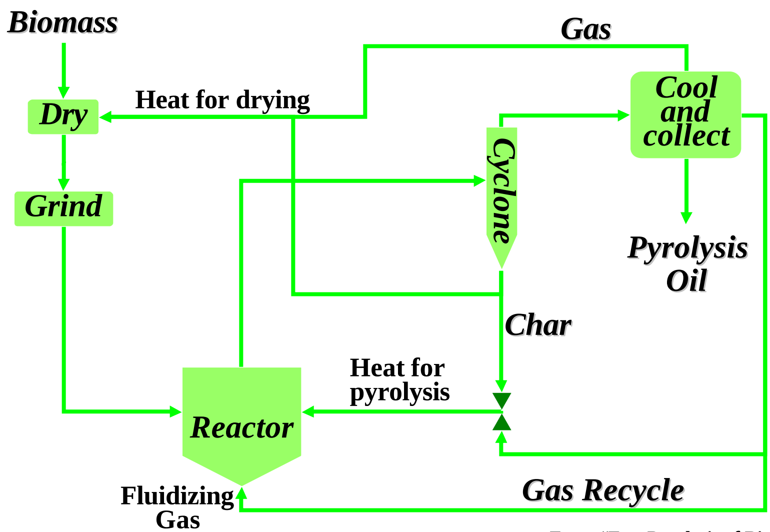
Oils Productivity



- **Cellulosic waste could make a significant contribution to liquid transportation pool.**
- **Algal Oils could enable oils route to biodiesel, Green Diesel and JP-8 (military jet fuel).**

Increases Availability, Reduces Feedstock Cost
Technology Breakthroughs Required

Typical Fast Pyrolysis Process

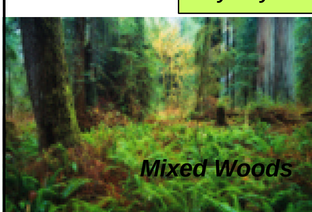


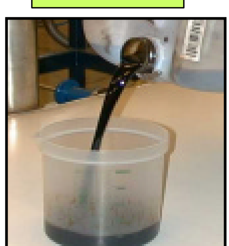
From "Fast Pyrolysis of Biomass: A Handbook." A.V. Bridgwater et al.

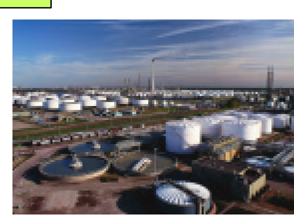
Pyrolysis Oil to Fuels

Stabilization — *Full Deoxygenation (HDO)*

Biomass → Pyrolysis → Hydro-treatment → Hydro-cracking → Deoxygenated Fuel







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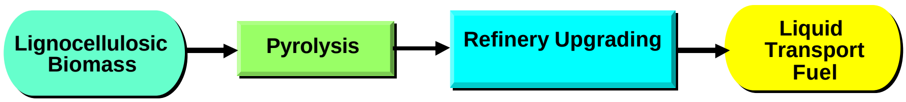
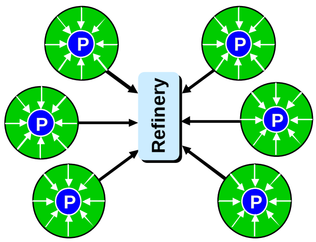
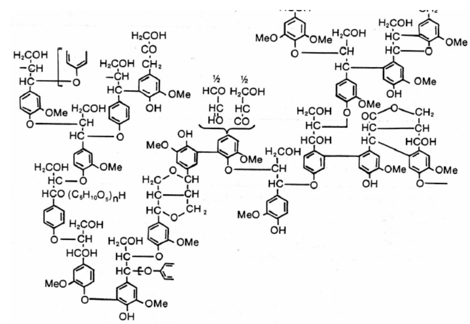
Waste Biomass to Liquid Transportation Fuels







DOE CRADA Goals and Objectives

- ***Background and Rationale*** **Pyrolysis-derived bio-oils are relatively inexpensive to produce, but there is little market for the resulting crude bio-oil product. Selective hydrotreating will be used to generate higher value biocrude. The national labs with UOP to examine the feasibility of bio-oil upgrading in a petroleum refinery.**
- ***Partners*** **NREL, PNNL**
- ***Goals and Objectives*** **The objective of this project is to upgrade biomass pyrolysis oils to petroleum refinery feedstock in a cost-effective manner.**
  - **Prepare & characterize various sources of pyrolysis oil**
  - **Characterize Py Oils from different biomass feedstocks**
  - **Optimize conversion using hydroprocessing**
  - **Create database; correlate py oil properties with processability, product properties; define standards**
  - **Conceptual designs and process model for economic studies**
  - **LCA of optimized process configuration**

Biomass Program's Biorefinery Pathways alignment

Pathway Milestones	*Project Alignment*
4.9/5.9 Demo/ validate direct fuel production from lignin intermediates	**Demonstrate fungible fuel production (gasoline/diesel) from several lignocellulosic feedstocks**
6.9/7.4 Demo/ validate bio-oil production to stable intermediate	**Hydroprocess Py Oil to stable oil for refinery processing**

UOP 4814A-03

Task 1, 2: Oil Production & Characterization

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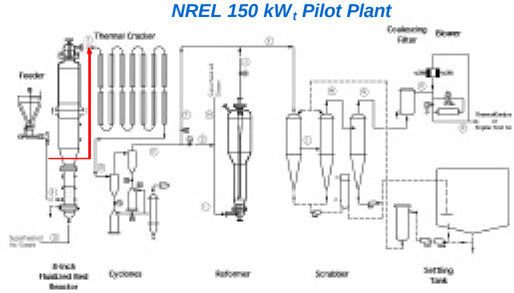
Task 1. Oil Production

- 3 Pyrolysis Oil Production Tests Completed
  - 2 with corn stover
  - 1 with mixed wood
- Chemical Analyses Completed
- Material Balances Completed

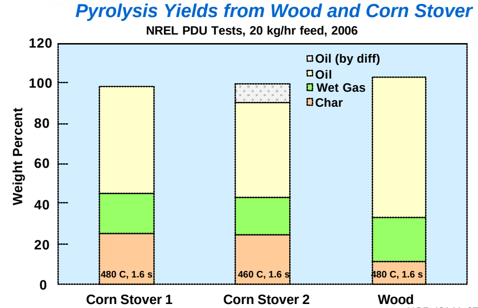
Task 2. Oil Characterization

- Proximate analysis
  - E.g. moisture, ash, volatiles
- Ultimate Analysis
  - E.g. elemental
- Ash Analysis
  - E.g. metals

NREL 150 kW$_t$ Pilot Plant



Pyrolysis Yields from Wood and Corn Stover



Tasks 3-5: Hydroprocessing and Data Base Development

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Tasks 3 & 4. Hydroprocessing

- Continuous-flow bench-scale reactor tests have been performed to test catalysts and processing conditions.
- Recovered products are analyzed at PNNL and UOP to determine composition and value

Task 5. Database Development

- An ACCESS database has been developed to manage the data from the pyrolysis and hydroprocessing tests.
- The database provides a tool to analyze the field of data to determine important processing trends and potential process improvements.

Task 6: Modeling and Economic Analysis

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Bio-oil Compositions			
Bio-oil (from mixed wood)			Gasoline
	Min	Max	Typical
Paraffin, wt%	5.2	9.5	44.2
Iso-Paraffin, wt%	16.7	24.9	
Olefin, wt%	0.6	0.9	4.1
Naphthene, wt%	39.6	55.0	6.9
Aromatic, wt%	9.9	34.6	37.7
Oxygenate, wt%	0.1	0.8	

Carbon Recovery ~ 50%

Task 7: Life Cycle Analysis

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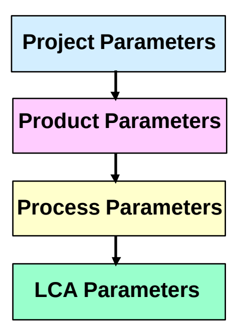
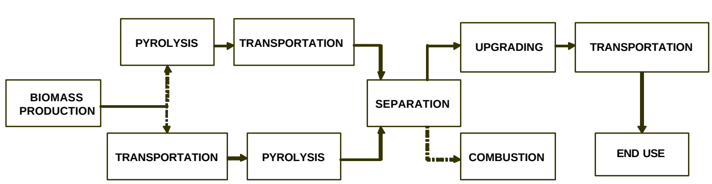
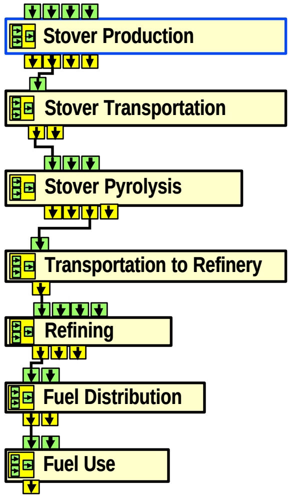
- Methodology Developed
  - Limited to Inventory Analysis
  - Based on NREL Corn Stover to Ethanol LCA
  - Primarily 1st order Analysis
- TEAM chosen as software
- Preliminary Model under Construction
- Final Model and Report Dependent on Completion of Tasks 1, 2, 3, 4

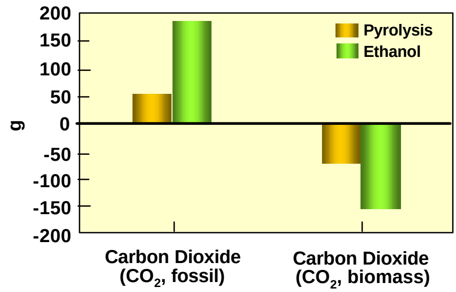
The Scoping Phase





Pyrolysis Oil Life Cycle Analysis





LCA analysis shows the pyrolysis oil fuel has a lower CO_2 footprint than E85 Ethanol

NREL, DOE Methodology, TEAM

UOP 4865-15R

Achieving Sustainability

- Green Diesel is a first step in creating a sustainable biomass infrastructure.
  - Excellent fuel
  - Investment is similar to biodiesel
  - Economics are better than for biodiesel
- Cellulosic waste and algal oils have the potential to make significant contributions.
- Technology breakthroughs are required
  - Biomass collection and densification
  - Conversion of lignocellulosic waste
    - Biochemical platform
    - Thermochemical platform
  - Algal oil growth, harvesting and oils extraction
- Technology neutral and performance based standards will prevent standardization of old technology.

Acknowledgements

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