



**Envergent**  
TECHNOLOGIES

A Honeywell Company

## **Rapid Thermal Processing (RTP™): A Proven Pathway to Renewable Liquid Fuel**

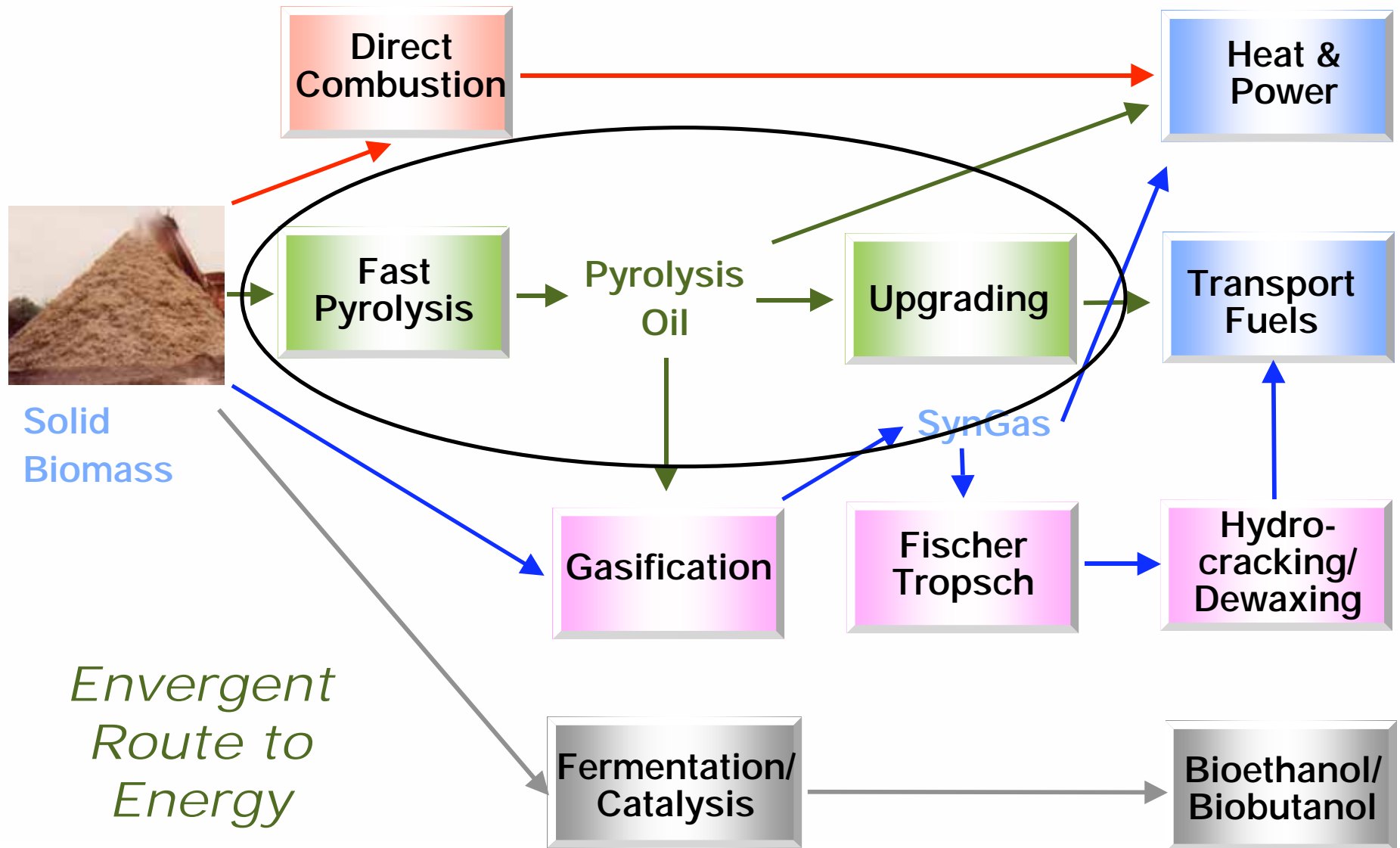
**Mark Reno**  
**Managing Director**  
**November 3, 2009**

# Agenda

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- Introduction
- Rapid Thermal Processing (RTP™) Technology
- Applications
- Project Development
- Summary

# Lignocellulosic Biomass Processing Options



# Rapid Thermal Processing (RTP™) Technology

## Pyrolysis Oil



## Solid Biomass



- 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



*Commercially Proven Patented Technology*

# RTP™ Operating History & Commercial Experience



- Commercialized in the 1980's
- 7 units designed and operated in the US & Canada
- Continuous process with >90% availability

<i>Plant</i>	<i>Year Built</i>	<i>Operating Capacity (Metric Tonnes Per Day)</i>	<i>Location</i>
Manitowoc RTP™ – 1	1993	30	Manitowoc, WI, USA
Rhinelanders RTP™ – 1	1995	35	Rhinelanders, WI, USA
Rhinelanders Chemical #2	1995	2	Rhinelanders, WI, USA
Rhinelanders RTP™ – 2	2001	45	Rhinelanders, WI, USA
Rhinelanders Chemical #3	2003	1	Rhinelanders, WI, USA
Petroleum Demo # 1	2005	300 barrels per day	Bakersfield, CA, USA
<b>Renfrew RTP™ – 1 (Owned and operated by Ensyn)</b>	<b>2007</b>	<b>100</b>	<b>Renfrew, Ontario, Canada</b>

Note: design basis for wood based plants assumes feedstocks with 6 wt% moisture content.

*Significant Commercial Experience*

# Feedstock Sources

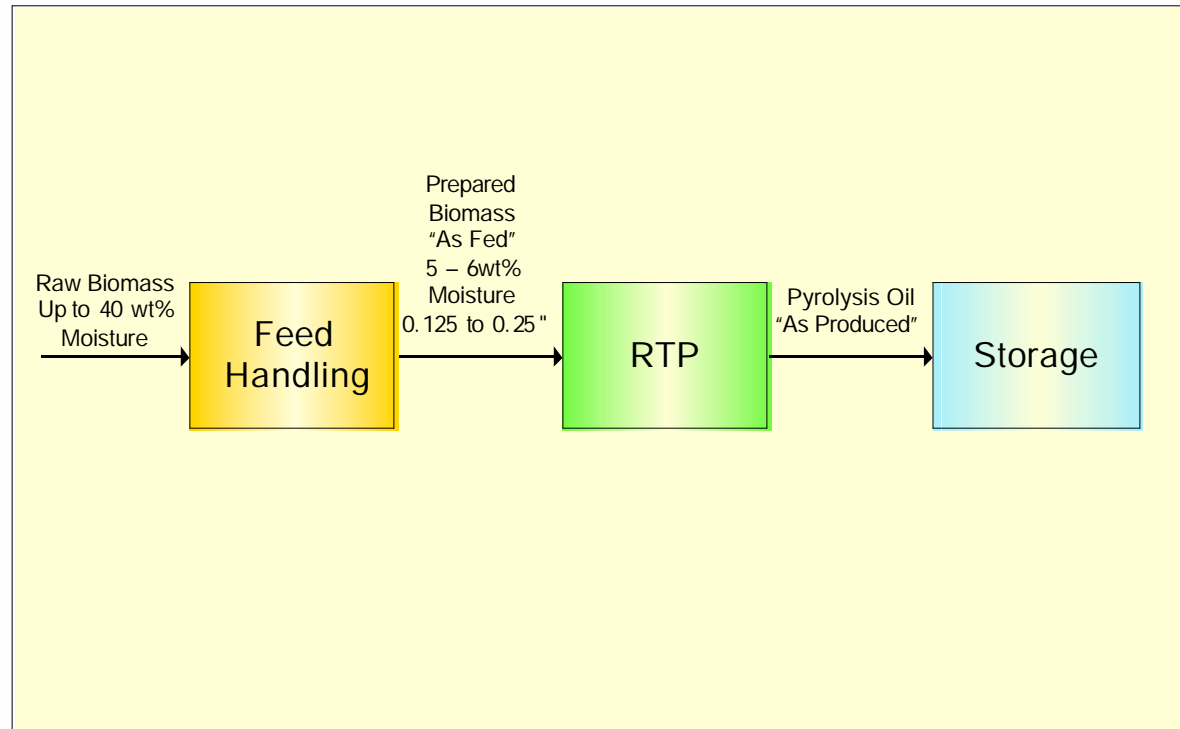
- **Forestry and Pulp and Paper**
  - Wood chips, sawdust, bark
  - Forestry residues
- **Agricultural**
  - Residues – corn stover, expended fruit bunches from palm (EFB), bagasse
  - Purpose-grown energy crops – miscanthus, elephant grass
- **Post-consumer**
  - Construction and Demolition Waste, Categories 1&2
  - Municipal solid waste (future)
- **DoE study 2005 - > 1 billion ton per year available in United States alone**



*Cellulosic Feedstocks Widely Available*

# Feed Handling / Preparation

- **Water is a heat sink**
  - Dried to 5-6 wt% moisture content for efficient RTP™ reactor operation
- **Size impacts heat transfer**
  - Biomass sized to 0.125-0.25 inch (3-6 mm)
- **Capacity of unit expressed on bone dry feed basis**
  - BDMTPD
  - Zero water content



*RTP is Self-Sustaining – Excess Heat Dries Raw Biomass*

# RTP™ Product Yields

*400 BDMTPD of Hardwood Whitewood*

<i>Feed, wt%</i>	
Hardwood Whitewood	100
<i>Typical Product Yields, wt% Dry Feed</i>	
Pyrolysis Oil	70
By-Product Vapor	15
Char	15

*Yields For Various Feeds*

<i>Biomass Feedstock Type</i>	<i>Typical Pyrolysis Oil Yield, wt% of Dry Feedstock</i>
Hardwood	70 – 75
Softwood	70 – 80
Hardwood Bark	60 – 65
Softwood Bark	55 – 65
Corn Fiber	65 – 75
Bagasse	70 – 75
Waste Paper	60 – 80

*Cellulosic Feedstock Flexible With High Yields of Pyrolysis Oil*

# RTP™ Pyrolysis Oil Properties

- Pourable, storable and transportable liquid fuel
- Energy densification relative to biomass
- Contains approximately 50-55% energy content of fossil fuel
- Stainless steel piping, tankage and equipment required due to acidity
- Requires separate storage from fossil fuels

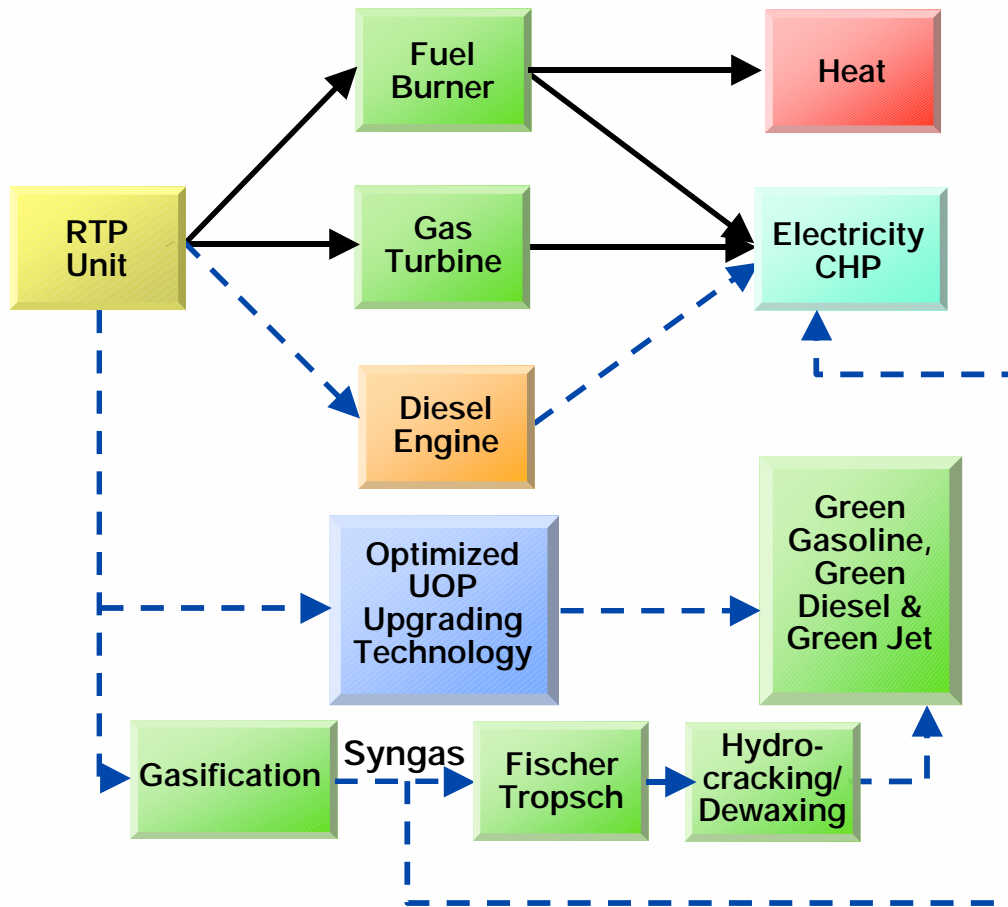


*Comparison of Heating Value of Pyrolysis Oil and Typical Fuels*

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

*Suitable for Energy Applications*

# Pyrolysis Oil Energy Applications



- Compatible with specialized turbines
- Specialized burner tips improve flame/burning
- Convert to steam to use existing infrastructure
- Use as a blend in diesel engines
- Upgradable to hydrocarbon fuels

*Multiple Applications for Pyrolysis Oil,  
a Renewable Fuel Available Today*

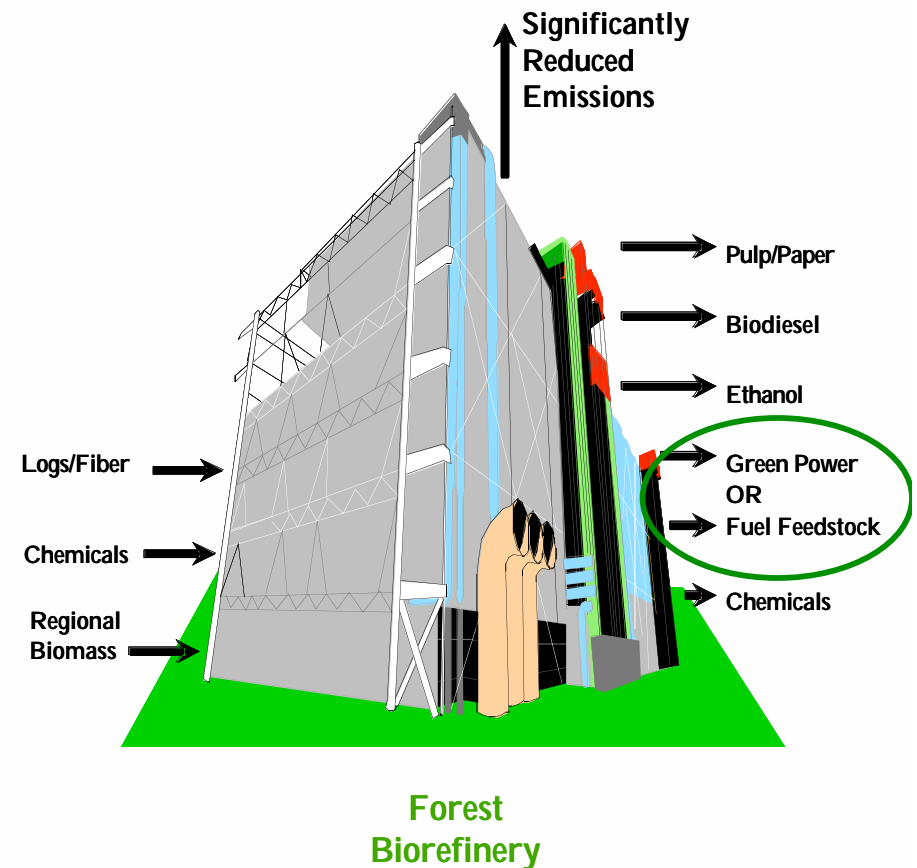
# Benefits and Uses of Pyrolysis Oil

## • Benefits

- Energy densification relative to biomass (i.e. forest residue)
- Fuel consistency – ASTM D7544
- Flexibility to process biomass in one location and economically ship/store pyrolysis oil for use at other place/time
- GHG emission reduction of 70-90% relative to fossil fuels

## • Uses

- Internal replacement of fossil fuel for heat/steam generation
- Production of electricity for internal use
- Alternate revenue stream from external sale
- Future upgrading to green transportation fuels



*RTP™ Plays a Key Role in the Biorefinery*

# Pyrolysis Oil: Replacement of Fossil Fuels to Generate Heat



- **Consistent quality/improved operations**
  - ASTM D7544, Standard Specification for Pyrolysis Liquid Biofuel, established last month
- **Low cost liquid biofuel**
  - ~40% cheaper to make and use pyrolysis oil than to purchase #2 fuel oil on an equivalent energy basis
    - 400 BDMTPD unit
    - Assumes 60 \$US/bbl crude
    - Includes RTP operating cost and 15-yr straight line depreciation of CAPEX
    - 330 Days per Year

<i>Property</i>	<i>Value</i>	<i>Test Method</i>
Gross Heat of Combustion, MJ/kg Point, °C	15 min	ASTM D240
Pyrolysis Solids Content, wt%	2.5 max	ASTM D7544, Annex I
Water Content, wt%	30 max	ASTM E203
pH	report	ASTM E70
Kinematic Viscosity, cSt @ 40 °C	125 max	ASTM D445
Density, kg/dm <sup>3</sup> @ 20 °C	1.1 – 1.3	ASTM D4052
Sulfur Content, wt%	0.05 max	ASTM 4294
Ash Content, wt%	0.25 max	ASTM 482
Flash Point, °C	45 min	ASTM D93, Procedure B
Pour Point, °C	-9 max	ASTM D97

# Pyrolysis Oil: Production of Green Electricity

- **Compatible with specialized turbines**
- **Green electricity production cost is 0.10 \$US/kW-h**
  - Includes RTP operating cost and 15-yr straight line depreciation of CAPEX (including gas turbine)
- **Experience in stationary diesel engine as blend with fossil fuel**
  - Operation with 100% pyrolysis oil under development



# Pyrolysis Oil: Upgrading to Green Transportation Fuels



## • Objectives

- Remove oxygen molecules
- Reduce acidity and viscosity
- Break up molecules to make gasoline and diesel/jet precursors
- Commercialization expected in 2012



## • Solution

- Thermochemical upgrading; leverage UOP's extensive hydroprocessing experience
- Continuous, reliable guaranteed process, per current refinery standards



*Achieved in Lab, Working on Scale-up*

# Pulp and Paper Integration Strategies



## *RTP Product Applications*

- Satisfy energy demand within the pulp and paper operation
- Generate electricity from plant residues that could be sold back to the grid
- Yield char product that can be used as a soil supplement to enhance ag performance
- Produce a fuel oil substitute for heat and power generation
- Produce green transportation fuels

*Mill Energy in Balance*  
*RTP Provides Alternate Revenue Generation Strategy*

# Potential Revenue Streams

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- **Fuel oil substitution**
  - 400 T/D pyrolysis unit produces 1600 bbls no. 6 fuel substitute
  - Number 6 residual fuel price approximately \$0.7/gallon (Energy equivalent basis)
  - Revenue \$47,000 per day
- **Electricity Generation**
  - 400 T/D pyrolysis unit produces 280 T/D py oil feed to generation step
  - 1 ton py oil produces 1000 Kwh in CHP turbine
  - Assume electricity price of \$0.1/Kwh
  - Revenue possibility \$28,000 per day
- **Char production as fertilizer supplement**
  - 400 T/D pyrolysis unit produces 60 T/D char
  - Char as soil supplement worth \$75/T, revenue \$4,500

# Pyrolysis Oil for Transport Fuels

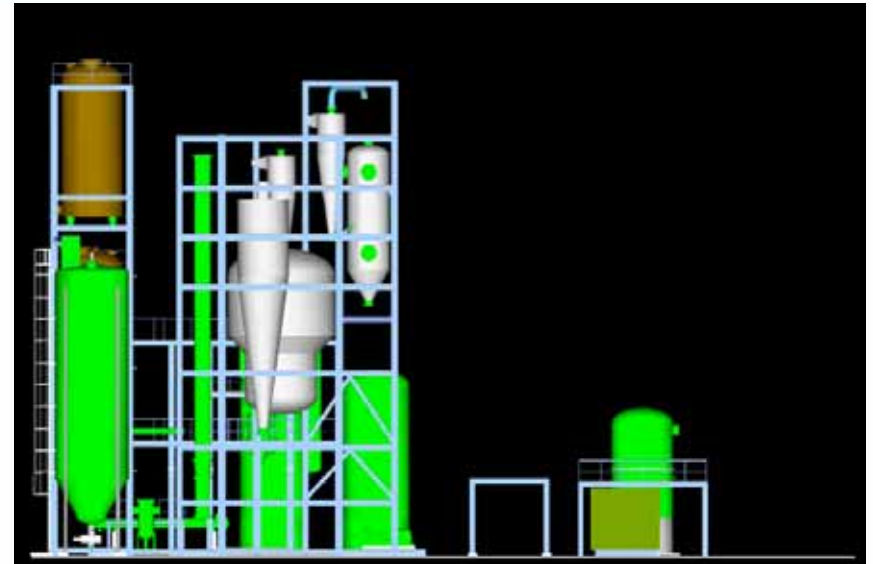
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- **Assume pyrolysis oil is converted to road gasoline and diesel**
  - 400 T/D pyrolysis unit will produce 800 bbls transportation fuel product
  - Assume \$1.75 per gallon rack price of gasoline and diesel products
  - Production of 33,600 gallons of transport fuels, value \$58,800 per day

***\$20,000,000 per year Product Value***

# Delivery & Scope of Supply

- **Standard sized modular units offered**
  - 100, 200, 400 and 1000 Bone Dry Metric Tons per Day (BDMTPD)
  - Design adjusted to meet site specific requirements
- **Design based on hardwood whitewood**
  - If alternate feedstock being processed, unit performance to be re-rated
  - Unit performance is *guaranteed*
- **Broad modular experience in refining, petrochemical and oil & gas industries**



*Modular Delivery Provides Faster Execution and Higher Reliability*

# RTP™ Summary

- Commercially proven technology: 7 units designed and operated
- Reliable operation with 90% on-line availability
- Designed to maximize pyrolysis oil yield, 70 wt% based on hardwood whitewood feed
- Performance guaranteed
- Cost-competitive with fossil fuels
- GHG emission reduction of 70-90%
- Engineering and modular delivery by world-renowned industry leader
- Products can supplement P&P plant revenue stream
- Technology for upgrading to transportation fuels expected to be available in 2012

