



**Envergent**  
TECHNOLOGIES

A Honeywell Company

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

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# Agenda

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

# Envergent Technologies LLC – UOP / Ensyn Joint Venture



- **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**



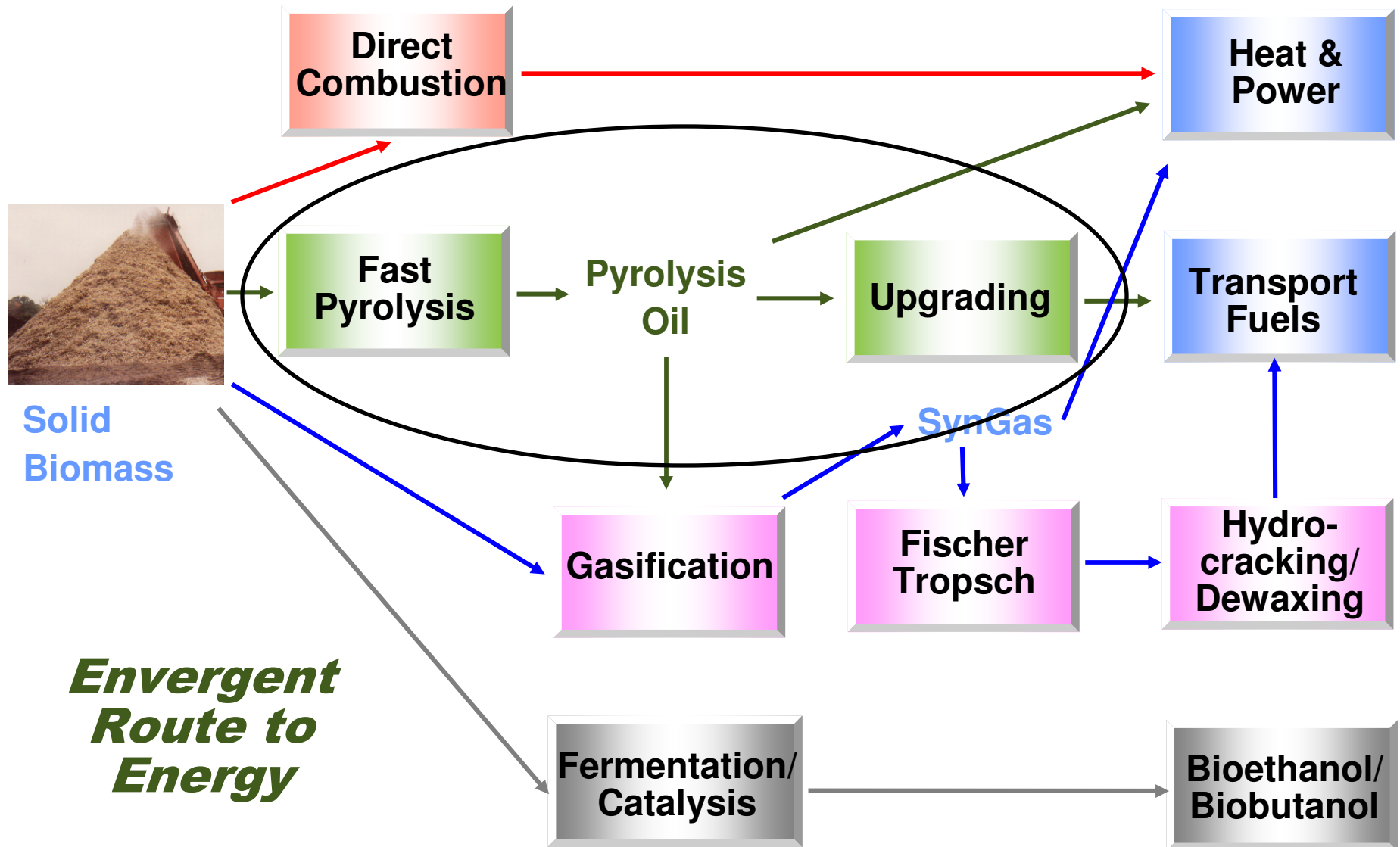
- **Leading process technology licensor~\$2 billion in sales, 3000 employees**
- **Co-inventor of FCC technology**
- **Modular process unit supplier**
- **Global reach via Honeywell & UOP sales channels**



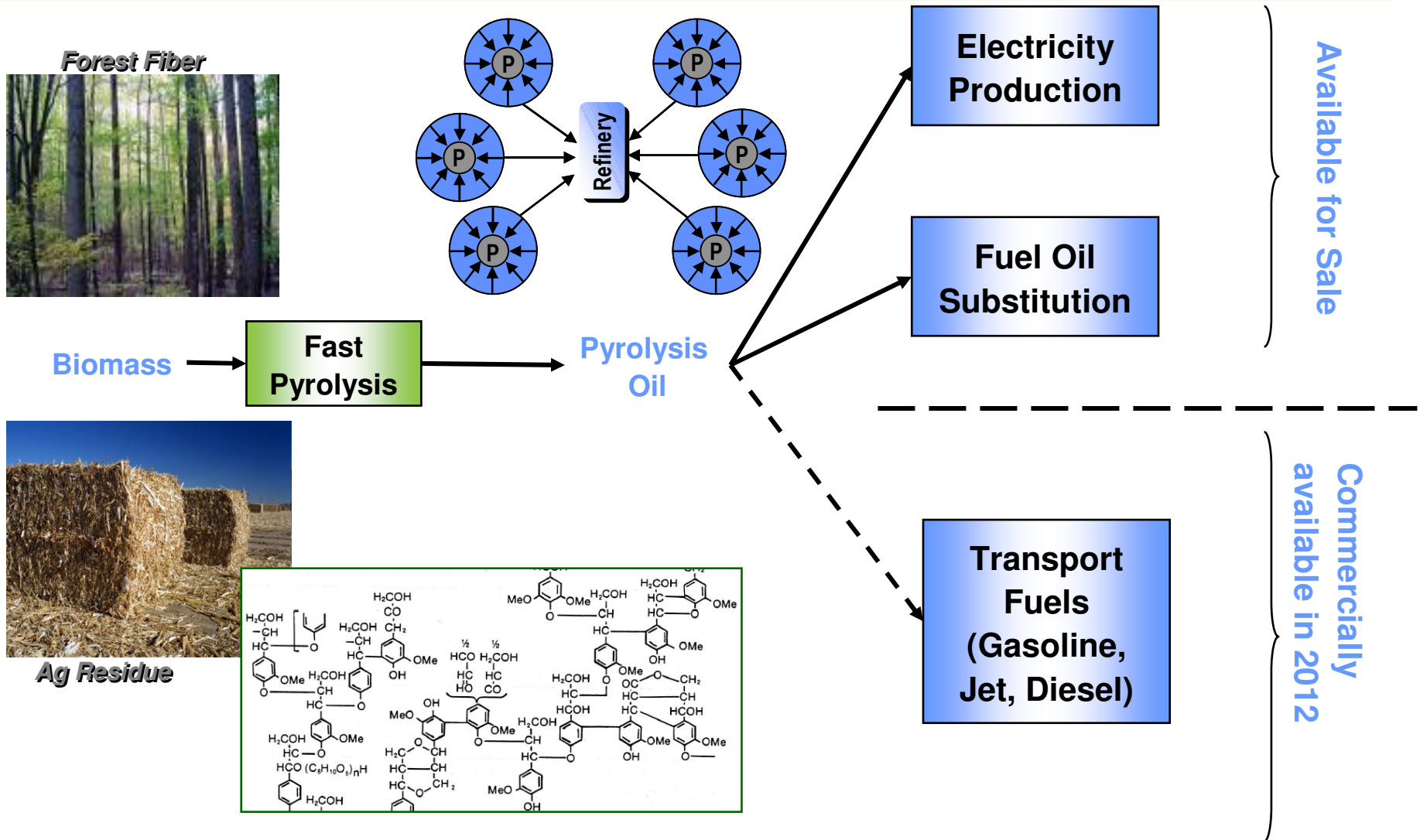
- **Over twenty years of commercial fast pyrolysis operating experience**
- **Developers of innovative RTP™ fast pyrolysis process**
- **Eight commercial RTP units designed and operated**

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

# Lignocellulosic Biomass Processing Options



# Pyrolysis Oil to Energy & Fuels Vision



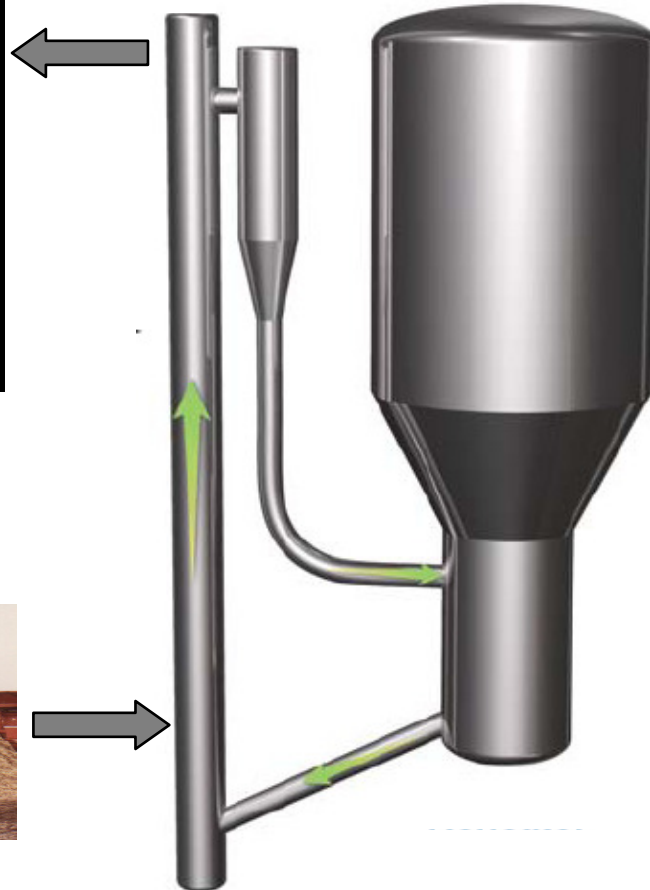
## *Phased Commercialization*

# Rapid Thermal Processing (RTP™) Technology

## Pyrolysis Oil



## Solid Biomass



***Commercially Proven Patented Technology***

# RTP™ Operating History & Commercial Experience



- Commercialized in the 1980's
- 8 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 Chemical #1	1989	1	Manitowoc, WI, USA
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>

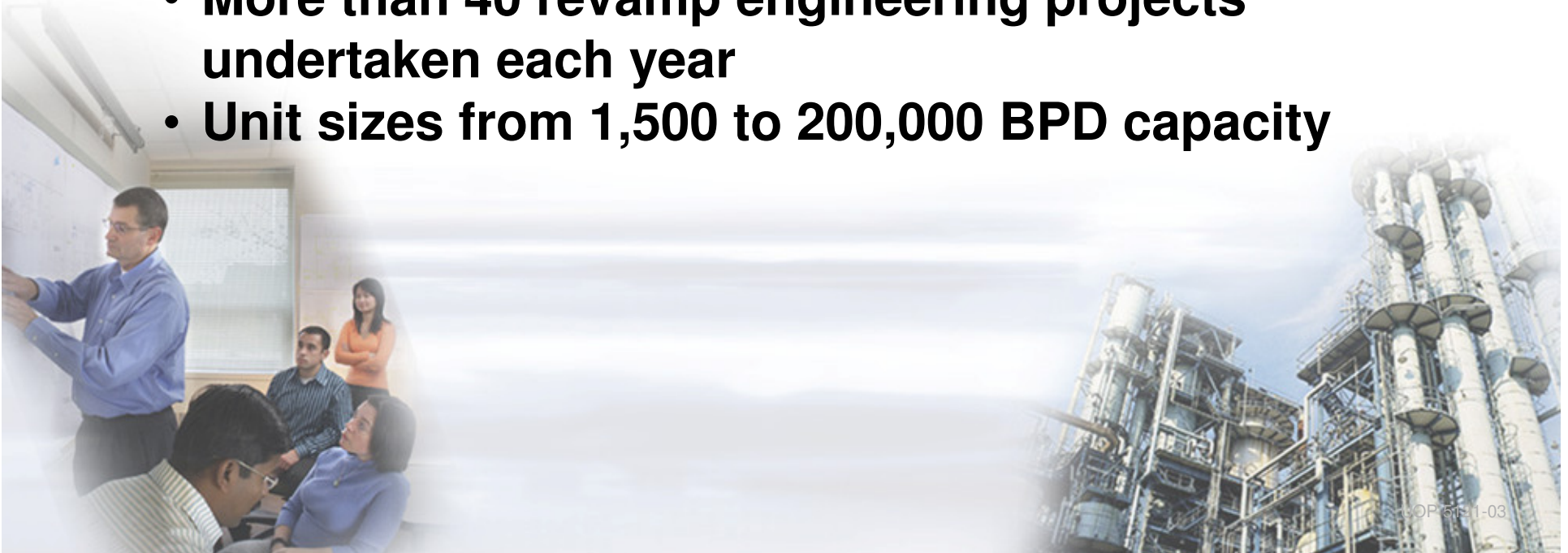
Note: design basis for wood based plants assumes feedstocks with 6wt% moisture content.

## *Significant Commercial Experience*



## UOP FCC Background

- **UOP has been designing FCC units since the early 1940's – one of the co-inventors**
- **Licensed over 250 units – more than 50% of world-wide capacity**
- **Achieved 60% share of competitive new unit licenses awarded since 1970**
- **More than 40 revamp engineering projects undertaken each year**
- **Unit sizes from 1,500 to 200,000 BPD capacity**





# Feedstock Sources

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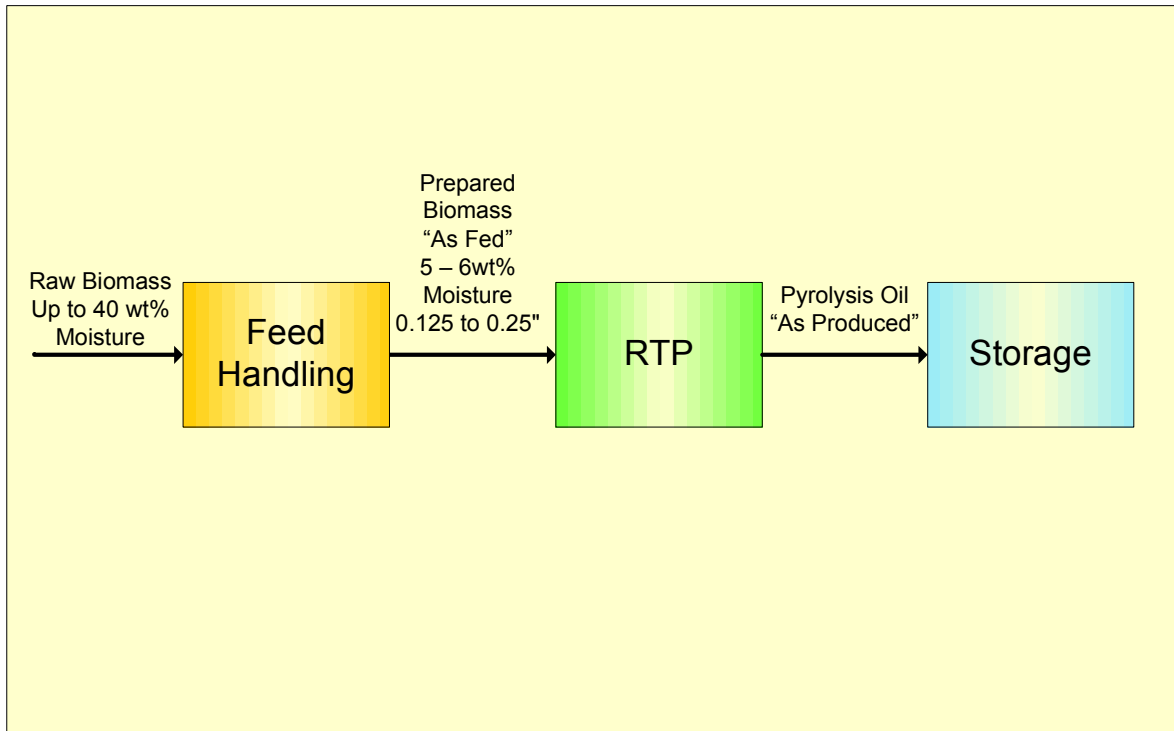
- **Forestry and Pulp and Paper**
  - Wood chips, sawdust, bark
  - Lignin
- **Agricultural**
  - Residues – corn stover, expended fruit bunches from palm (EFB), bagasse
  - Purpose-grown energy crops – miscanthus, elephant grass
- **Post-consumer**
  - Construction and Demolition Waste, Categories 1&2
  - 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 5-6wt% moisture content for efficient RTP™ reactor operation
- **Size impacts heat transfer**
  - Biomass sized to 0.125 to 0.25"
- **Capacity of unit expressed on bone dry feed basis**
  - Zero water content



- **Many suppliers of similar equipment in existing industry:**
  - Pulp & Paper
  - Agricultural
  - Forest

***Feed Preparation Is Critical For RTP Performance***

# RTP™ Product Yields

## 400 BDMTPD of Hardwood Whitewood

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

## Yields For Various Feeds

<b>Biomass Feedstock Type</b>	<b>Typical Pyrolysis Oil Yield, wt% of Dry Feedstock</b>
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

- **Contains ~60% the energy content of crude-based fuel oils**
- **High viscosity and acidity**
- **~40-50% oxygen content**
- **Pourable and transportable liquid fuel**

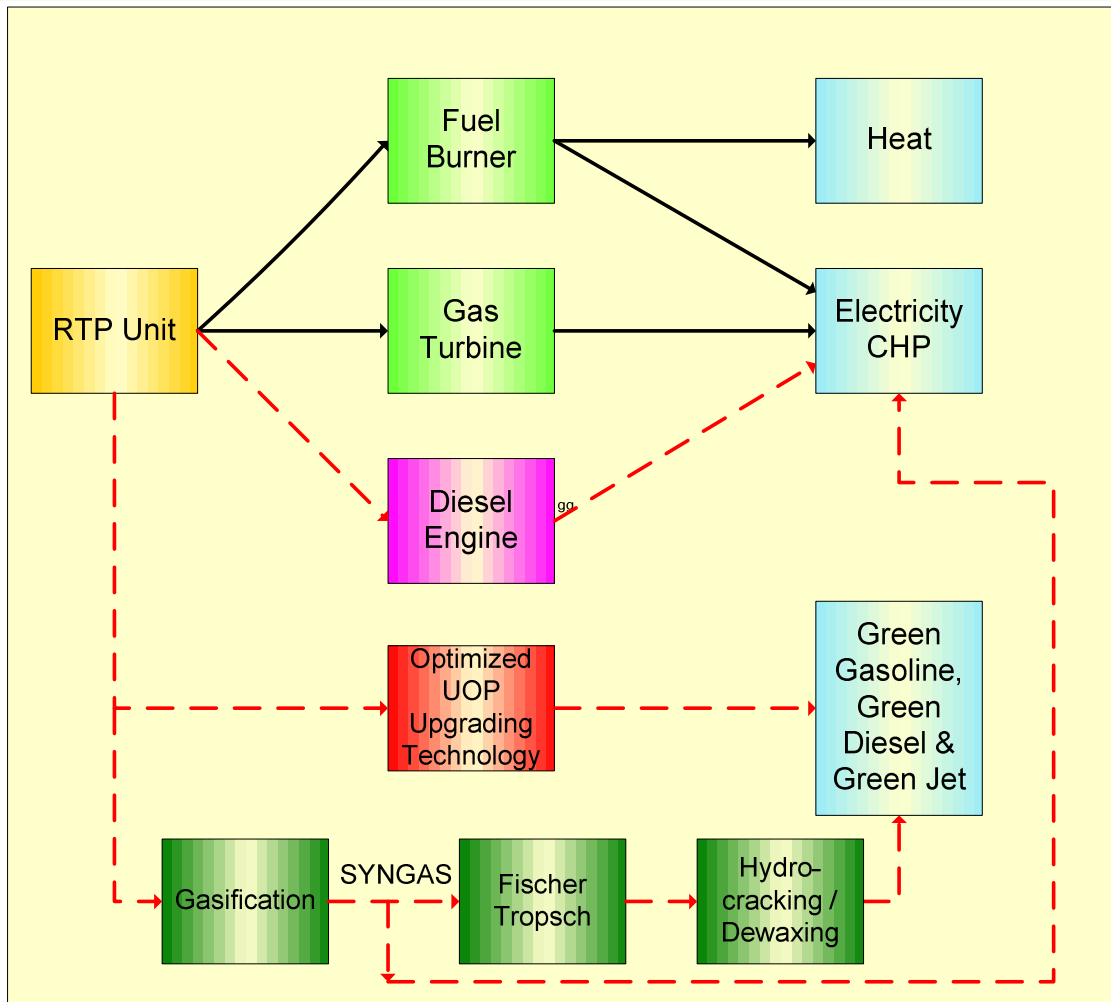


*Comparison of Heating Value of Pyrolysis Oil and Typical Fuels*

Fuel	MJ / Litre	BTU / US Gallon
Methanol	17.5	62,500
<b>Pyrolysis Oil (Wood)</b>	<b>21.0</b>	<b>75,500</b>
<b>Pyrolysis Oil (Bark)</b>	<b>22.7</b>	<b>81,500</b>
Ethanol	23.5	84,000
Light Fuel Oil / Diesel	38.9	138,500

***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***

# Pyrolysis Oil as Burner Fuel

- **Energy densification/improved logistics and flexibility**
- **Relatively low emissions (NO<sub>x</sub>, SO<sub>x</sub>, ash)**
- **Consistent quality/improved operations**
  - ASTM standard established last month
- **Stainless steel piping, tankage and equipment required due to acidity**
- **Requires separate storage from fossil fuels**

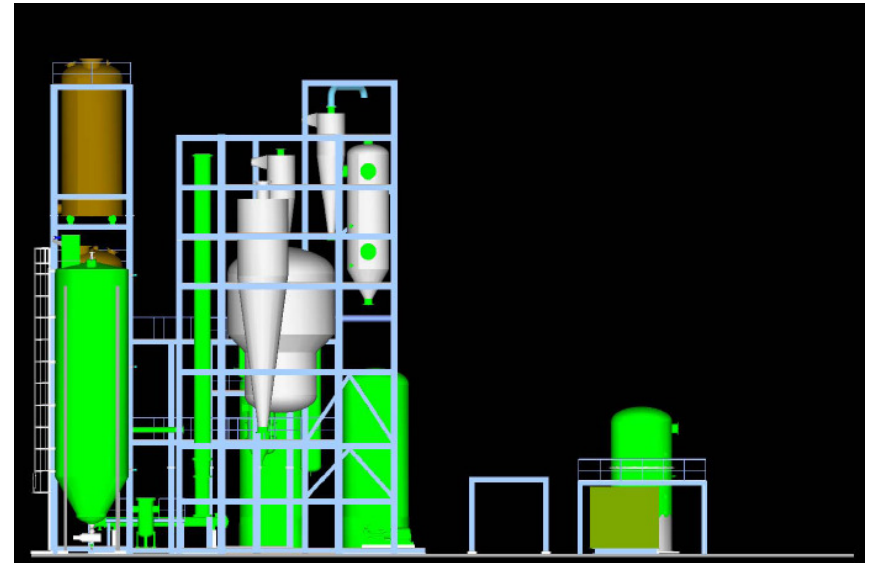
***25-30% Lower Cost than #2 Fuel Oil on an Energy Basis***

## ***ASTM D7544, Standard Specification for Pyrolysis Liquid Biofuel***

PROPERTY	VALUE	TEST METHOD
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
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

# 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



***Modular Delivery Provides Faster Execution and Higher Reliability***

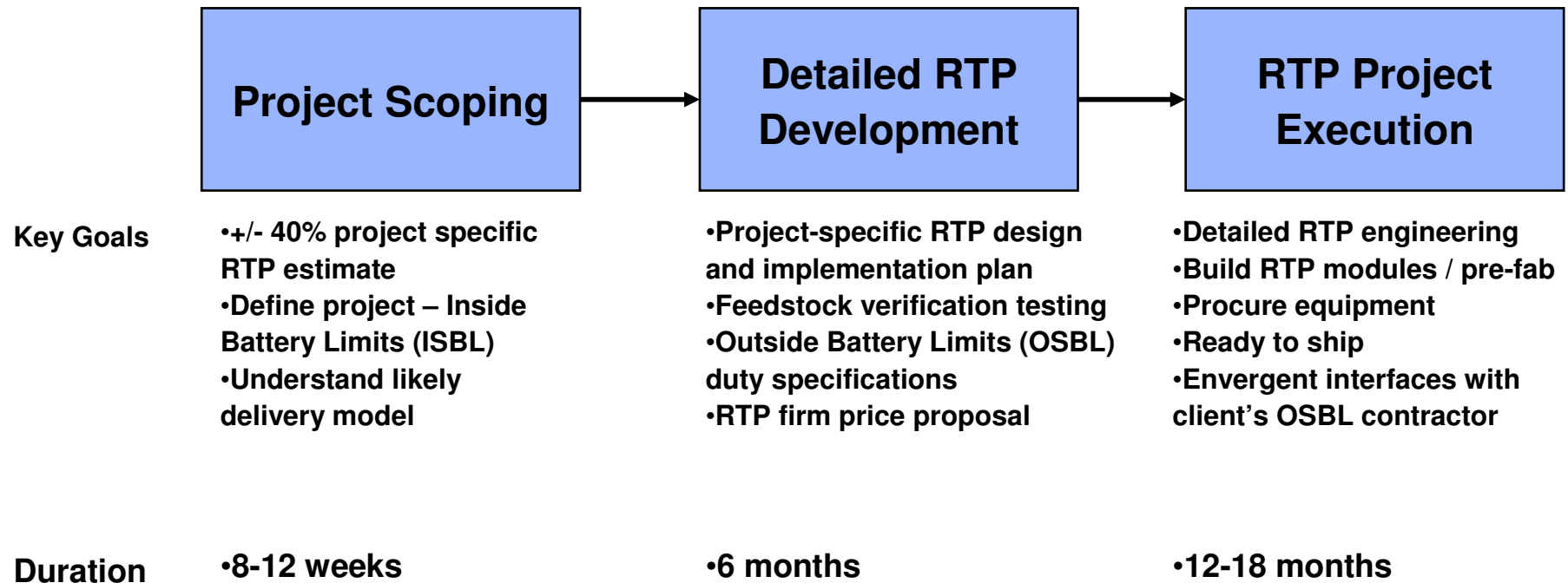


# RTP™ Project Execution – Envergent Scope



## • Three-phase work process

- Develops project specific scope
- Enhances capital figures to reduce uncertainty



***Equipment Delivery – Guaranteed Performance***

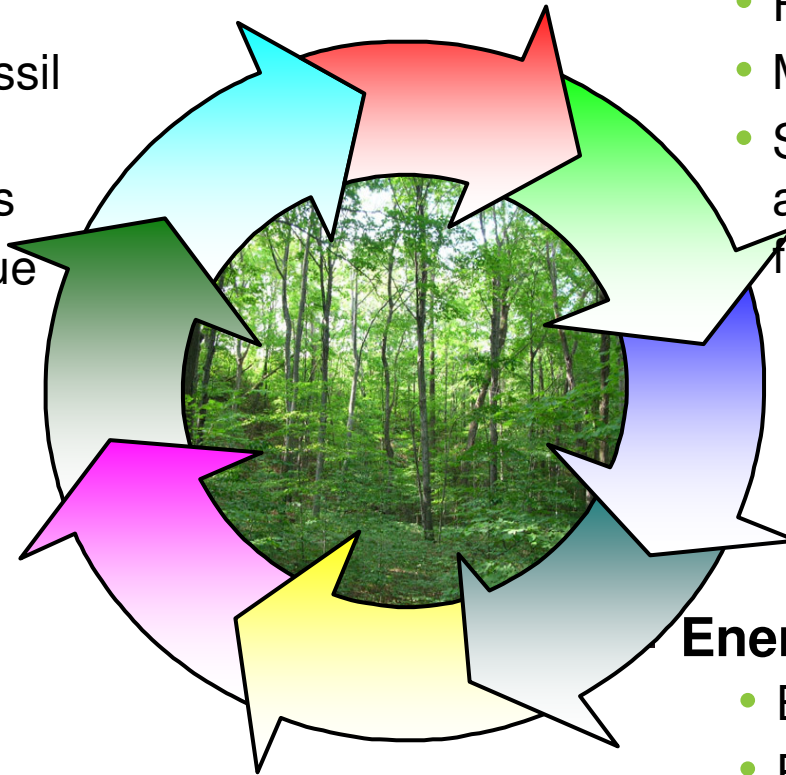
# RTP™ Project Benefits

## Economics

- Economic solution for renewable energy
- Competitive relative to fossil fuels
- Leverages existing assets
- Provides alternate revenue stream

## Environment & Social

- Reduction of greenhouse gases and emissions
- Waste disposal
- Minimum environmental impact
- Agriculture development
- Employment



## Technical

- Proven application
- Feedstock flexibility
- Minimal net utilities
- Storable product allows decoupling from end user

## Energy Security

- Energy diversification
- Reduction of fossil energy requirements

***Pyrolysis to Energy Now – Transport Fuels in 2012***

# RTP™ Summary

- **Commercially proven technology: 8 units designed and operated**
- **Reliable operation with 90% on-line availability**
- **Designed to maximize pyrolysis oil yield, 70 wt% based on hardwood whitewood feed**
- **Cost competitive with fossil fuel oil**
- **Engineering and modular delivery by world-renowned industry leader**
- **Technology for upgrading to transportation fuels expected to be available in 2012**

