

### Distributed Production of Bio-oils and Bio-chars for Agricultural and Energy Applications

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#### Fast Pyrolysis

Rapid thermal decomposition of organic compounds in the absence of oxygen to produce liquids, char, and gas

- Dry feedstock: <10%
- Small particles: <3 mm
- Short residence times: 0.5 - 2 s
- Moderate temperatures (400-500 °C)
- Rapid quenching at the end of the process
- Typical yields
  - Oil: 60 - 70%
  - Char: 12 -15%
  - Gas: 13 - 25%
- Advantages
  - Operates at atmospheric pressure and modest temperatures (450 C)
  - Yields of bio-oil can exceed 70 wt-%
- Disadvantages
  - High oxygen and water content of pyrolysis liquids makes them inferior to conventional hydrocarbon fuels
  - Phase-separation and polymerization of the liquids and corrosion of containers make storage of these liquids difficult

#### Storage & Transportation

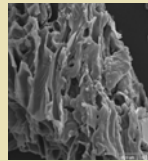
Distributed preprocessing allows transport and storage as liquid  
High acidity requires storage in stainless steel or plastic  
Stability problems need to be solved

#### Post Processing to Motor Fuels

Hydrocracking of bio-oil  
Gasification of bio-oil  
Fermentation of bio-oil

#### Technical Barriers

Preparing dry, finely divided biomass particles  
Maintaining high bio-oil yields  
Improving bio-oil stability  
Determining optimal scale of facility



#### Co-Products

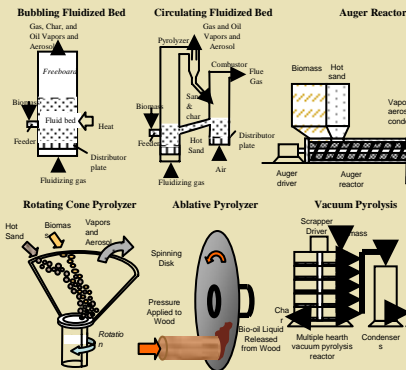
Gas (CO, H<sub>2</sub>, light hydrocarbons)  
Char: Several potential applications  
Process heat  
Activated carbon  
Soil amendment

#### Bio-Oil

Source: Piskorz, J., et al. In Pyrolysis Oils from Biomass, Soltes, E. J., Milne, T. A., Eds., ACS Symposium Series 376, 1988.	White Spruce	Poplar
Moisture content, wt%	7.0	3.3
Particle size, μm (max)	1000	590
Temperature	500	497
Apparent residence time	0.65	0.48
<b>Bio-oil composition, wt %, m.f.</b>		
Saccharides	3.3	2.4
Anhydrosugars	6.5	6.8
Aldehydes	10.1	14.0
Furans	0.35	--
Ketones	1.24	1.4
Alcohols	2.0	1.2
Carboxylic acids	11.0	8.5
Water-Soluble – Total Above	34.5	34.3
Pyrolytic Lignin	20.6	16.2
Unaccounted fraction	11.4	15.2



#### Fast Pyrolysis Reactors

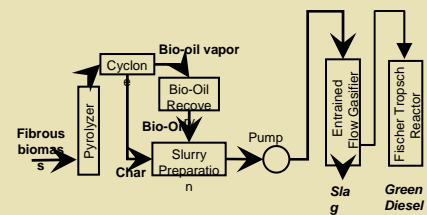


#### Relative Merits of Various Reactors

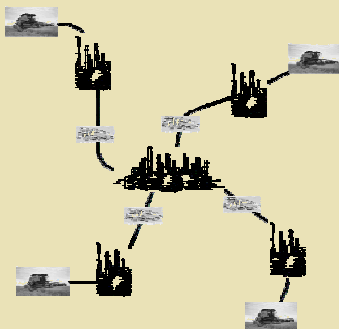
Reactor Type	Status	Bio-oil wt%	Complexity	Feed size	Inert gas need	Specific size	Scale up
Fluid bed	Demo	75	Medium	Small	High	Medium	Easy
CFB	Pilot	75	High	Medium	High	Large	Easy
Entrained	None	65	High	Small	High	Large	Easy
Rotating cone	Pilot	65	High	Small	Low	Small	Hard
Ablative	Lab	75	High	Large	Low	Small	Hard
Auger	Lab	65	Low	Small	Low	Medium	Easy
Vacuum	Demo	60	High	Large	Low	Large	Hard

The darker the cell color, the less desirable the process.  
Adapted from PNEC Energy Lab, 1 - 20 kg h<sup>-1</sup>  
Pilot: 20 - 200 kg h<sup>-1</sup>  
Demo: 200 - 2000 kg h<sup>-1</sup>

#### Bio-Oil Gasification



#### Distributed Pyrolysis Model



#### Transportation Cost Model

Biomass Transportation Cost:  
267.8 + 25.5 x distance [\$/TJ]

Bio-oil Transportation Cost:  
70 + 1.5 x distance [\$/TJ]

Cost Analysis for 500 MMGPY Diesel Production (0.7 Scale Factor, 100 Distributed Plants)

Case	Central Gasification	Distributed Gasification	Distributed Pyrolysis
Transportation	\$0.45	\$0.19	\$0.37
Capital	\$0.57	\$2.29	\$0.82
Biomass	\$0.77	\$0.77	\$1.18
O&M	\$0.26	\$0.68	\$0.42
<b>Total [\$/gal]</b>	<b>\$2.05</b>	<b>\$3.92</b>	<b>\$2.78</b>

#### Production Cost Comparison

