Challenge # 1. Feedstock & Production

1. Target Market
2. Temporal Supply of Biomass
3. Feedstock Conditioning
4. Utilities & Resources

Northeast Heating Oil Demand

- Northeast is largest regional consumer of heating oil in the U.S.
- Northeast is the location of >80% of the 7.2 million U.S. homes that used heating oil in 2009
- Average household consumes 850 gallons of heating oil per season (October – March)
- New York, Maine, Massachusetts, New Jersey, and Vermont have announced state mandates to transition to ultra-low sulfur fuels

Northeast Heating Oil Supply-Demand Balance and Projections: Annual Average 2007-2013

(Thousand bbl/d)
(Rounded to closest 10,000 bbl/d)

	2007	2008	2009	2010	2011*	2012 Outlook	2013 Outlook
Consumption	**470**	**370**	**360**	**310**	**290**	**310**	**280**
Supply	470	370	360	310	290	340	310
In-Region Production (+)	210	190	160	140	140	120	100
Net Receipts from Other Regions (+)	180	170	170	140	160	160	160
Imports (+)	80	70	100	80	60	60	50
Exports (-)	40	60	50	50	80	–	–
Stock Decrease (+) / Increase (-)	40	–	-20	–	10	–	–
Surplus (+) / Gap (-)	–	–	–	–	–	30	30

*Data through November 2011.

Notes: Projected consumption is based on data from EIA's *Short-Term Energy Outlook*. It includes a switch in consumption from heating oil to ULSD of an additional 70,000 bbl/d beginning in July 2012, based on New York's requirement that heating oil move to ULSD specifications. Projected production is based on assumed yields and the capacity of remaining refineries. Sunoco Philadelphia is assumed to close in July 2012. Projected imports are 3-year historical averages adjusted down by U.S. Virgin Islands contributions. Historical net receipts are estimated. Projected net receipts are 3-year historical averages. The Surplus/Gap indicates the under- or over-supply needed to meet consumption.

Source: U.S. Energy Information Administration.

Markets for Pyrolysis Oils

Commercial
Heating Oil No. 4

Winter: Residential
Heating Oil No. 2

Industrial Boilers
Heating Oil No. 6

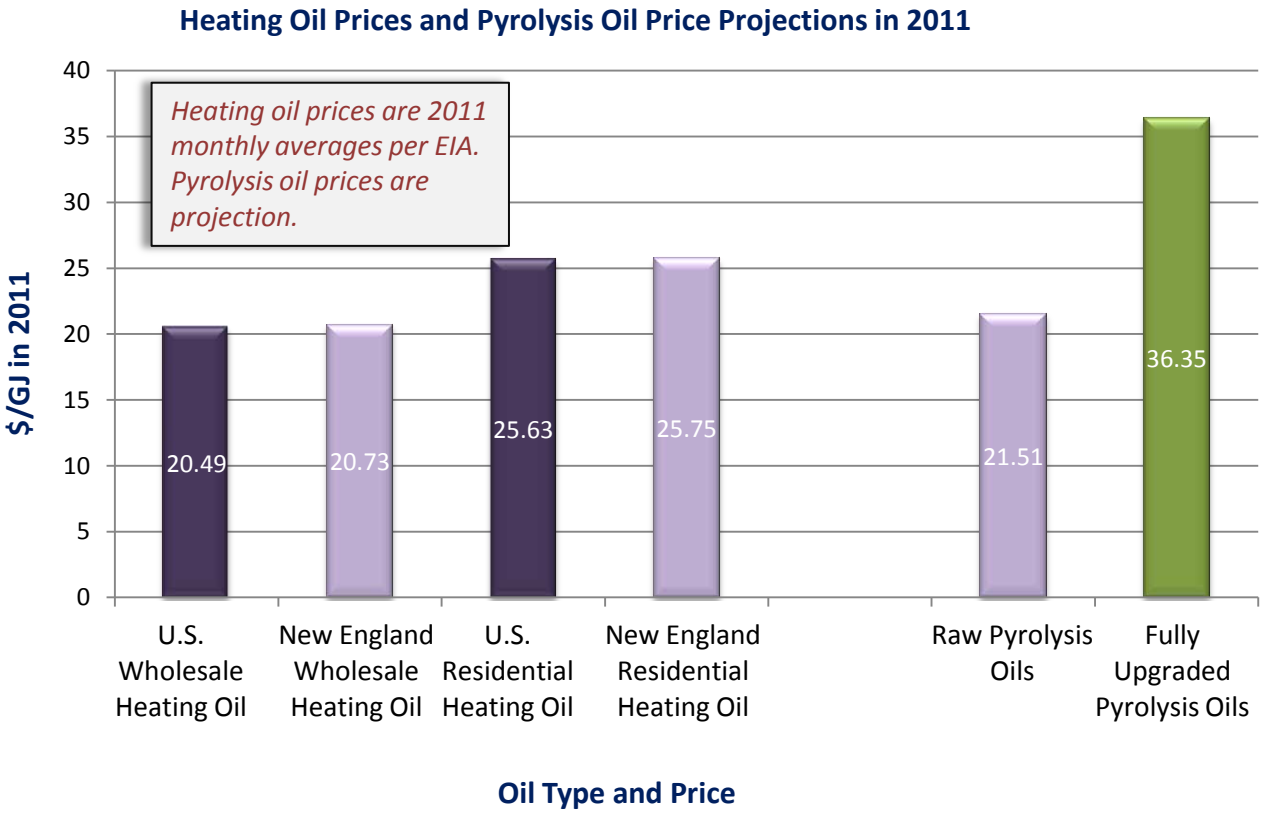
Summer: Transportation
Diesel / Gasoline

Biothermal Offers Competitive Economics Particularly in Northeast

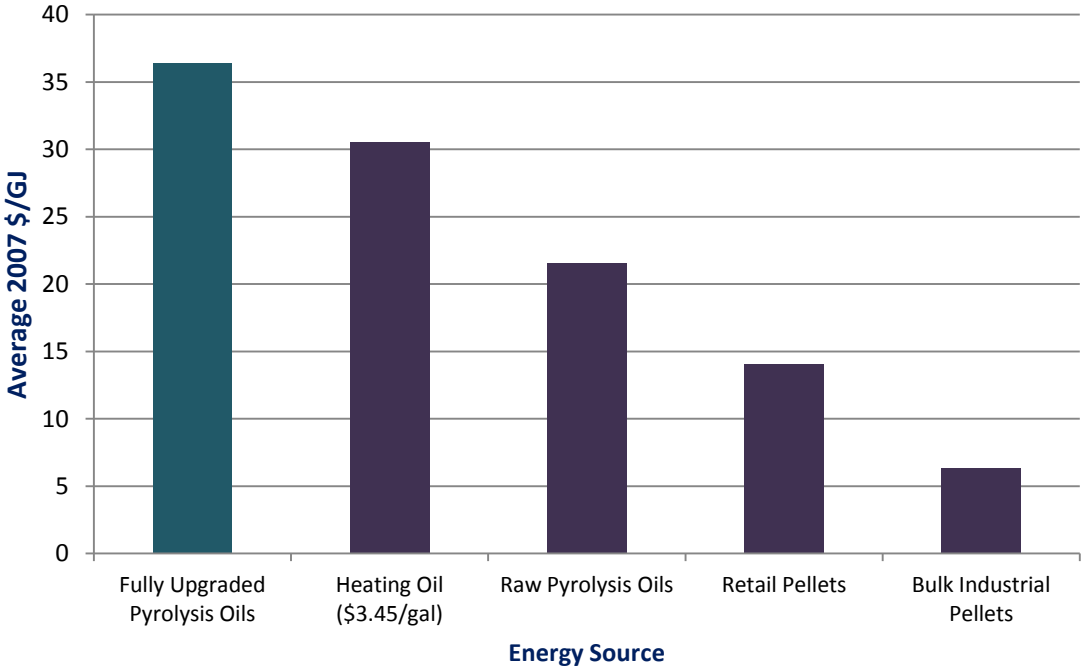
Bio-oils as a heating oil substitute may present a significant opportunity to solve a relevant problem, save consumers money… particularly in the Northeast

Biothermal leverages ongoing work in the OBP bio-oil production and upgrading CTGs, and other work in thermochemical including:

- Corrosion/material compatibility
- Feedstock logistics and pre-processing
- Densification
- Fast pyrolysis



Biomass Derivatives Competitive with Heating Oil Costs



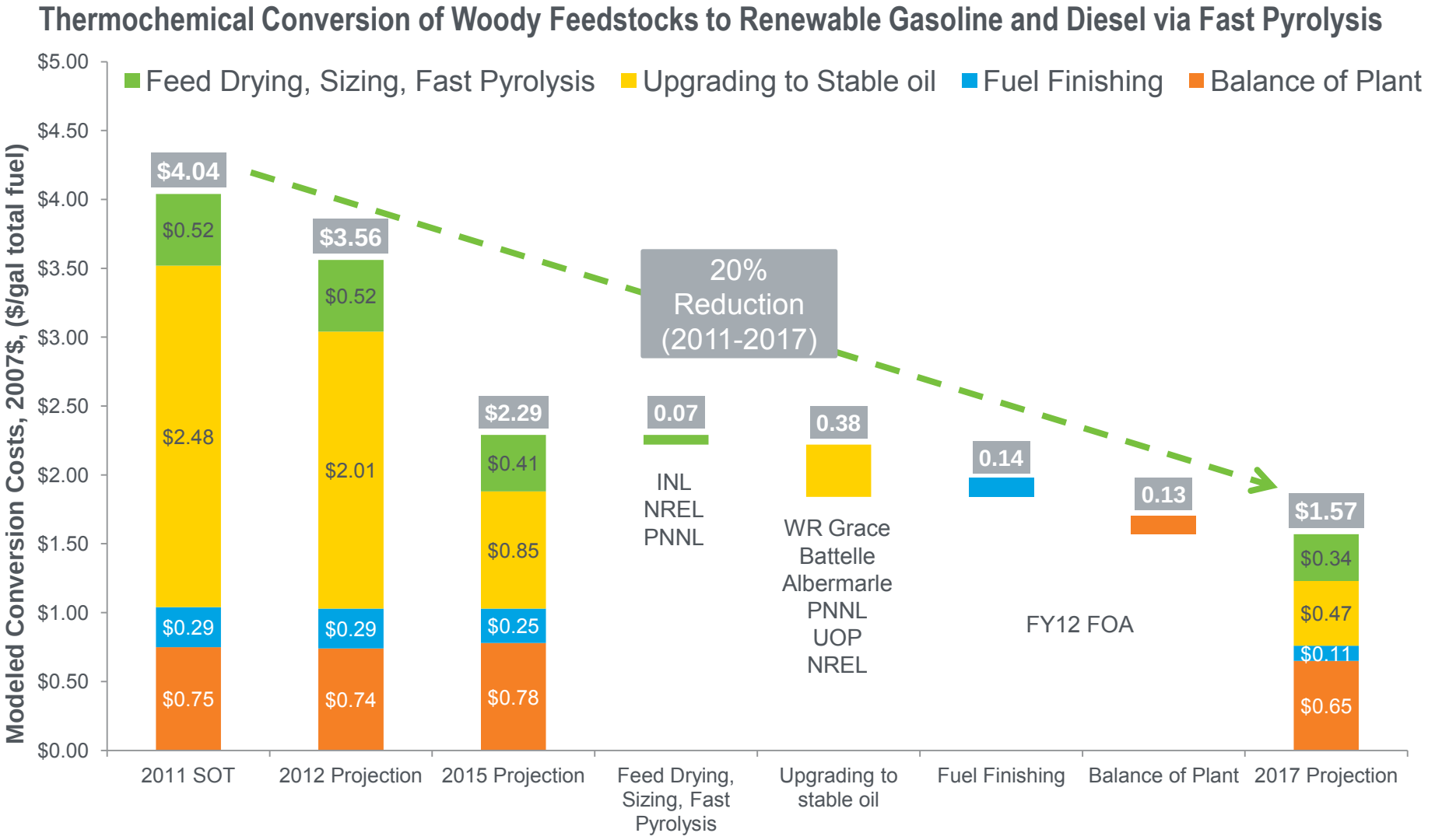
Transportation fuel

Heat or electricity

- Data are from literature, except heating oil is adjusted from 2011 winter average
- Fuel costs vary widely based on feedstock, location, and technology option
- Conditioned pyrolysis can be substituted for heating oil in NE
- Retail pellet costs are based on current prices in NE (~$243/ton)

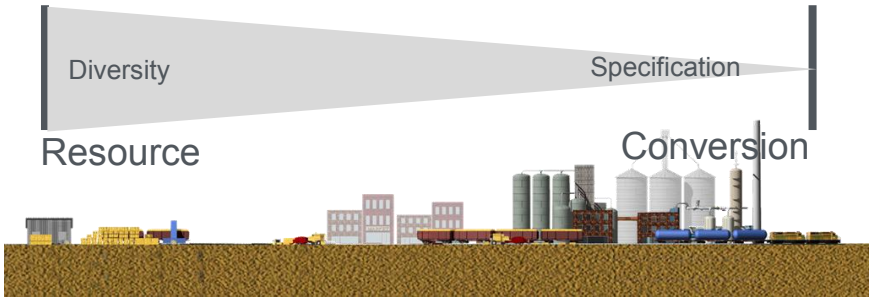
- **Densifying biomass for heating (e.g. pyrolysis oil or pellets) can be a cost-competitive feedstock for residential heating system**
- **These are not "drop-in" fuels for current liquid handling/infrastructure/applications**
- **Logistics and supply chain considerations begin to predominate for residential biothermal**
- **What does a simple payback period look like for retrofit?**

Fast Pyrolysis Waterfall – 2017



Supply chains costs associated with various grades of oil

	Product Fired in Boiler				
$/gal	**Fuel Oil**	**Heating Oil**	**Medium Grade**	**Low Grade**	**Pyrolysis Oil**
Feedstock	0.36	0.31	0.27	0.24	0.22
Feedstock Logistics	0.7	0.67	0.58	0.52	0.47
Total Pyro, Stab. & Upgr.	1.5	1.42	1.26	1.03	0.4
Fuel Transportation	0.23	0.23	0.25	0.25	0.27
Storage	0	0	0.22	0.7	2.58
Modifications to Boiler	0	0	0.5	1.1	2.43
Total Cost	2.95	2.63	3.08	3.83	6.37



Logistics

System Component	Options	Variables	
Biomass Production	Forestry residues Energy crops Felling Chipping Baling	Harvesting window (wood versus agric.) Production costs (location dependent)	
Pretreatment	Storage Chipping / Milling Drying Pelletizing	Equipment capacity Capital and O&M Energy consumption (power, fuel, heat)	Load factor Dry matter loss Moisture loss Particle Size
Transport	Truck Train Ship	Transport distance Speed Capacity Product weight Product volume	Capital and O&M Fuel consumption Load factor Transfer time & costs
Storage & Use	Bales versus Chips Covered or Tarpped	Capital and O&M	Decomposition

Feedstock Availability in NE

Quantity of biomass available in the NE states at various prices.

Cost ($/ton)	Woody Biomass (tons)	Ag Residues (tons)	Urban Wood Waste (tons)	MSW (tons)
10	0	0	0	0
20	784,800	0	752,600	1,301,200
30	3,350,200	0	1,886,300	1,471,600
40	4,072,900	248,200	2,446,900	1,558,700
50	4,583,600	530,600	3,762,400	1,730,200
60	4,961,400	737,700	3,762,400	1,730,200
70	5,430,000	838,000	3,762,400	1,730,200
80	6,205,300	909,000	3,762,400	1,730,200
90	7,030,400	961,900	3,762,400	1,730,200
100	7,894,600	1,031,400	3,762,400	1,730,200

Challenge #1

Target Market

Biomass Supply

Feedstock Conditioning

Utilities & Resources