

Biodiesel

- On average, U.S. produced ~4.3 bil gallons (annual average from 2005-07)
 - ~60% from soybean oil
 - ~28% from animal fat and grease
- USDA expects soybean acreage to level off at 71 million, but soybean oil production to trend up
 - higher soybean yields and oil extraction rates
 - <50% of biodiesel production increases from domestic first-use vegetable oils



Biodiesel

(cont.)

- EIA forecast: 1.6 bil gal biodiesel in 2015
 - USDA: 440 million (~28%) soybean-based
 - ~28% from animal fat and grease
- EPA: By 2022, corn oil (dry mill extraction) will be largest source of biodiesel (~40% of production)



Oilseed Alternatives

	lb/acre seed	% oil	gal/acre oil	Acres for 15 MM gal/yr	Double crop?
soy	2,500	20	70	215,000	no
canola	2,000	40	105	145,000	in Southeast
camelina	1,750	30	70	215,000	in Southwest
pennycress	1,500	35	70	215,000	yes
coriander	3,000	25	100	150,000	yes

Rhode Island – 669,000 acres



Fast Pyrolysis Oil + Fractionation

- **Biofuel Oil™** can be blended as 5% with petroleum fuel oil.
- **Wood *** 70% total bio-oil; 46% Biofuel Oil™; biochar 18%
- **Cornstover*** 65% total bio-oil; 31% Biofuel Oil™; biochar 20%

500 TPD wood → 15 MMGPY* Biofuel Oil™

Requires 12,500 to 23,300 acres of forest

	Heating Value	Moisture Content
Typical Bio-oil	6,900-8,200 BTU/lb	15-30%
Avello Biofuel-Oil™	10,000-11,000 BTU/lb	6-11%
No. 2 Fuel Oil	~19,000 BTU/lb	0.1%

* yields based on 7% moisture



Torrefaction: A Technology to Densify & Enhance Biomass

- **Untreated biomass may be 50% water, it's bulky and it's not the most efficient or useable fuel or bio-feedstock. Torrefaction:**
 - Drives off most of the water
 - Reduces the bulk
 - Makes a better co-fire feedstock to burn with coal
 - Makes superior briquettes and pellets
- **Mobile torrefaction, applied at the point of harvest:**
 - Reduces transportation costs of biomass, per BTU
 - Produces a more valuable biomass shipment



Torrefaction: Adding Value and Reducing Transportation Cost/BTU

- Untreated Biomass:
 - Bulky
 - Moist
 - Fibrous
 - Perishable
 - Waste
 - Expensive to transport
- Torrefied Biomass:
 - Dense, If Pelletized, Etc.
 - Dry & Water Resistant
 - Easily Crushed
 - Does Not Rot
 - Valuable Fuel
 - Energy Dense



The Process of Torrefaction

- Heating (300-400° C) wood, in a low-oxygen environment, liberates water, volatile organic compounds (VOC's), and hemicellulose (HC) from the cellulose and lignin.
- The VOC's and HC are combusted to generate 80% of the torrefaction process heat.
- The remaining, warm lignin acts as a binder when the torrefied wood is pelletized.
- Torrefied wood can easily replace coal in combustion or be a feedstock for further pyrolysis or gasification for combined heat and power or Fischer-Tropsch liquids.



Making Electricity With Torrefied Wood

- Torrefied wood is a much better fuel for co-firing with coal than untreated wood.
- Torrefied wood can be ground to a particle size, similar to that of pulverized coal, with the same or less energy use.
- Untreated wood requires many times the energy use, in grinding (by a factor of 7.5 to 15), to achieve a similar particle size.

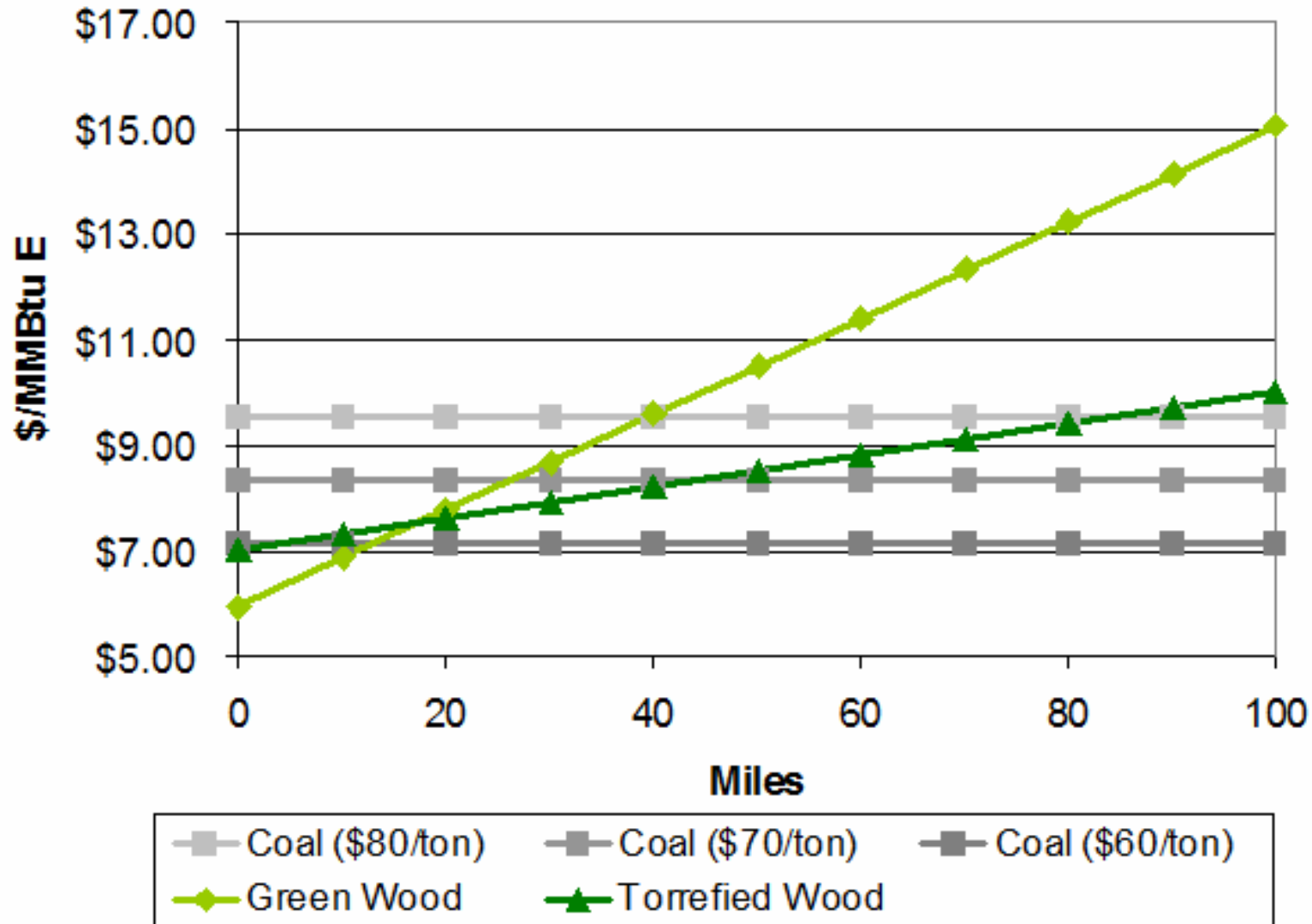


Pelletizing & Briquetting Torrefied Wood

- At torrefaction temperatures, the lignin in wood becomes plastic and can actually become a binder of individual wood particles.
- Pellets made from torrefied wood may withstand 1.5 to 2 times the crushing force of normal wood pellets.
- Torrefied pellets show little water uptake on immersion (7-20% of mass), unlike normal pellets.
- University research in the 1930's and 1940's details benefits of torrefied wood pellets.



Fuel Cost per MMBtu Electricity by Distance to Plant



Torrefied Wood's Advantages As A Co-Fire Fuel With Coal

Assumptions used in previous chart:

- Coal is valued at \$60-\$80 per ton delivered price
- Torrefied wood (11,000 BTU/lb.) has a heating value nearly that of coal (12,000 BTU/lb.)
- Torrefied wood generates electricity with a similar efficiency to coal (35% fuel to electricity)
- Untreated wood has a lower efficiency of conversion (23% fuel to electricity)
- Wood can be processed into chips at a cost of about \$15/green ton
- Transportation costs for chips and/or torrefied wood are about \$0.23 per ton, per mile

