Torrefaction

A Pathway Towards Fungible Biomass Feedstocks?

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Bioeconomy Hurdles

• Producing and accessing sustainable and affordable feedstocks
• Cost-competitive conversion technologies
• Optimizing distribution infrastructure
• Educating the consumer

Forest Resources

SOURCE: Forest Resources of the United States—2007, USDA.
Forest Resources

• **Annual forest growth:**
  > 4X what it was in 1920

• **U.S. forest biomass:**
  > 50% per acre than it was in 1953

• **Net annual forest growth:**
  > 70% removals

**SOURCE:** *Forest Resources of the United States—2007,* USDA.
How Much?

• Annual harvest: 320 million dry tons
• Roundwood: 227 million dry tons
• Residues: 68 million dry tons

“Most of this residue is left onsite because its small piece size makes it unsuitable and uneconomic for the manufacturing of forest products.”

Cost?

Source: Spatial distribution of simulated forest residue thinnings at $60 per dry ton U.S. Billion-Ton Update, US DOE, 2011.
Cost of Forest Biomass

• Biomass volume from fuel treatments (potential): 60 million dry tons
• Cost to combat wildfires: $2.3 billion

Current Situation

Low-cost forest biomass is available!

How do we expand its use as a bioenergy carrier and a feedstock for biorefineries?
Challenges

Cost
(at Biorefinery Gate)
• Handling
• Transportation
• Storage

Heterogeneity

But …

• Energy (wood) pellet industry is growing*:
  – 4.6 million ton export market (2015)
  – 9.7 million (2020)

• Sets an effective price floor for woody biomass

• RINs cannot compete!

*Source: RISI, 2016.
Torrefaction

- Mild pyrolysis: *Reaction in an absence of oxygen*
- Atmospheric
- Typical process temperatures: 200-300°C
Kinetics

Sources: Bergman et al. 2005.
FOREST BIOMASS

TORREFACTION

PHASE
- SOLID
- LIQUID
- GAS

END-USE
- ENERGY CARRIER
- SOIL AMENDMENT
- FILLER
- REAGENT
- VINYL ACETATE
- PRESERVATIVE
- FUEL

Source: ANL Consultants LLC, adapted from M. Hoeft 2013.
Overall Efficiency 90.6%

Drying
Torrefaction
Pelletizing

T = 270°C

Flue Gas

### Energy Density

<table>
<thead>
<tr>
<th>Material</th>
<th>Bulk Density (kg/m³)</th>
<th>Energy Density (GJ/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>400</td>
<td>6.5</td>
</tr>
<tr>
<td>Pelletized Wood</td>
<td>700</td>
<td>10.7</td>
</tr>
<tr>
<td>Torrefied Wood</td>
<td>300</td>
<td>7.5</td>
</tr>
<tr>
<td>Pelletized</td>
<td>700</td>
<td>16.0</td>
</tr>
<tr>
<td>PRB Coal</td>
<td>850</td>
<td>18.0</td>
</tr>
</tbody>
</table>

**Sources:** Handbook of Clean Energy Systems, 2015; IEA Task 40, 2016
Comparison to Coal

Advanced Bioenergy Carrier

- High energy density
- Low sulfur
- Low ash
- Friable
- Homogeneous
  and …
Water Resistant!

Source: IEA 2016.
Torrefaction: **Global Capacity & Outlook**

**Status**
- in operation
- under construction
- planned
- unknown
- closed

**(Proposed) Production capacity**
- below 100,000 t/a and more
- below 50,000 t/a
- below 20,000 t/a
- below 3,500 t/a

Drivers

• Dispatchable, base load power generation
• GHG reduction and compliance
Greenhouse Gas Emissions

Drivers

• Dispatchable, base load power generation
• GHG reduction and compliance
• Capital avoidance
Thermal power

In April of 2014, Ontario Power Generation burned its last piece of coal to generate electricity in Ontario. This move off coal was North America’s single largest climate change initiative and the equivalent of taking seven million cars off the road. This made Ontario the first jurisdiction in North America to fully eliminate coal as a source of electricity generation.
Case Study

Case No. 1: Atikokan Generating Station

- 205 MW
- Converted to 100% white wood pellets
- Cost: $170 million
Source: Ontario Power Generation (OPG), 2016.
Case Study

Case No. 1: Atikokan Generating Station

- 205 MW
- Converted to 100% white wood pellets
- Cost: $170 million

Case No. 2: Thunder Bay Generating Station

- 150 MW
- Coal conversion to “advanced biomass”
- Cost: $5 million
PGE

- Exit coal by 2020
- Reposition as a 240 MWe “super peaker” using 100% torrefied biomass as fuel
- Test burn
  - 8,000 tons
- Largest conversion in the U.S.
- ~1,000,000 tons/yr of torrefied wood!

Co-Firing

- Blended with coal and co-fired
- “Drop-in”
- “All the above” strategy to complete phase-out of coal?

Conclusions

- Torrefaction is almost ready
  - Viable energy carrier
- Base load power generation
- Opportunity for liquid fuels?
Thank You!

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