Learning from Biomass Supply Chains

Forest Biomass Feedstock for Biomass Powerplants

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BIOMASS POWERPLANTS

• Existing Biomass Powerplant Industry

• Relative Abundance and Distribution of Forest Biomass Feedstock

• Methods, Costs, and Constraints of Obtaining Forest Biomass Feedstock

• Regulatory Constraints and Incentives to Acquisition and Use

• Innovative Solutions

Burney Forest Power – 30 Megawatts (MW) Consumes 240,000 Bone Dry Tons (BDT) of Feedstock Annually
14 Stand-Alone + 8 Co-Gen – Total 22 Operating Powerplants with 562 MW of Operating Capacity (consumes total of 4.5 million Bone Dry Tons (BDT) of Feedstock/Year)

12 Idle Powerplants with 257 MW of Operating Capacity (Potential to Consume 2 million BDT of Feedstock/Year)
Distribution of Forest Biomass Feedstock (Light Green – National Forest, Light Orange – Private Forest)

Bakersfield to Oregon Border
Relative Abundance of “GREEN” FOREST BIOMASS Feedstock

Forest Biomass generated from Mechanical Thinning on National Forests annually
= 1.1 million Bone Dry Tons (BDT) (138 Megawatts (MW))

Private Land Forest Biomass generated from Timber Harvesting annually
= 1-2 million BDT (125-250 MW)

Saw/Veneer Mill Residues = 1.1 million BDT (138 MW)
Forest – No Fuels Reduction

National Forest Mechanically Thinned
GREEN FOREST BIOMASS Pile

1 Bone Dry Ton (BDT) = about 2 green Tons

8,000 BDT = 1 Megawatt (MW) of Electric Power
75% of Tree Mortality is from Interstate 80 south to Bakersfield

The Sierra National Forest east of Fresno has 760,000 acres (75% of the entire Forest) impacted

Standing Beetle-Killed Trees are beginning to rot off sufficiently at the base to fall over

In the high severity beetle-kill zone (Sonora-Bakersfield), there is up to 50 Bone Dry Tons of dead trees/acre
Abundance of Insect and Disease Killed Trees

Central and Southern Sierras alone have over 3.9 million acres impacted containing 96 million dead trees with about 50 million bone dry tons of beetle-killed trees.
2 Primary Forest Biomass Disposal Options

Open Field Pile Burning

Controlled Combustion in a Biomass Powerplant Boiler
## Comparison of Emissions Between Biomass Boilers and Open Field Burning

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Field Burning (lb./Ton)</th>
<th>Biomass Boiler (lb./Ton)</th>
<th>% Reduction for Biomass Boiler (Percent)</th>
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</thead>
<tbody>
<tr>
<td>Sulfur Oxides</td>
<td>1.7</td>
<td>0.04</td>
<td>97.6%</td>
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<tr>
<td>Nitrogen Oxides</td>
<td>4.6</td>
<td>0.70</td>
<td>84.8%</td>
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<tr>
<td>Carbon Monoxide</td>
<td>70.3</td>
<td>0.40</td>
<td>99.4%</td>
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<tr>
<td>Particulates</td>
<td>4.4</td>
<td>0.26</td>
<td>94.1%</td>
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<tr>
<td>Hydrocarbons</td>
<td>6.3</td>
<td>0.00</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>87.3</td>
<td>1.40</td>
<td>98.4%</td>
</tr>
</tbody>
</table>
Methods/Costs of Forest Biomass Removal

Cut, Skid, Delimb, Pile

Load and Haul Commercial Size Trees

$30/BDT (Generally paid for from green tree thinning lumber value)
Costs of Forest Biomass Removal (Cont’d)

- Chip, Load
  $26/BDT

- Haul ($110/hour Chip Van)
  (about $40/BDT)
Total Cost of Forest Biomass Delivered to a Powerplant

Cut, Skid, Pile (Limbs, Tops, Small Trees & Brush) $30/BDT
Chip and Load $26/BDT
Haul $40/BDT

Total Forest Biomass Delivered Cost = $66-96/BDT (lower amount of green tree thinning has sufficient commercial size trees to pay for getting biomass into a pile)

6.6 to 9.6 cents/kW-hr Forest Biomass Feedstock delivered +
6 cents/kW-hr to own, operate, maintain, repair, and routinely retrofit a Biomass Powerplant

Total = $12.6-15.6 cents/kW-hr compared to Wind/Solar at 5 cents/kW-hr
Regulatory Constraints and Incentives to Acquisition and Use

Incentive?

How to get Forest Biomass (12-15 cents/kW-hr) competitive with 5 cent/kW-hr Wind/Solar?

98% reduction in Emissions by consuming wood waste in a Biomass Boiler compared to Open Field Pile Burning

The published monetized value of the emissions reduction is 11 cents/kW-hr (Environmental Benefit)

About $5/month on a residential Electric Bill in the form of a Public Goods Charge
Most Promising Innovation
• Wood-Based Nanotechnology

• The Microfibrils from cellulose have exceptional strength and flexibility

• Products that Microfibrils can be used for:
1) Reinforced Concrete (up to +26% strength)
2) Flexible Electronics; single crystal silicon nanomembranes for thin film Transistors, . . .
3) Advanced electrodes for solar cells and generating hydrogen fuel
4) . . .
- Pulped Cellulose
### BioRam Biomass Powerplants and Feedstock Requirements from Tier 1/Tier 2 High Hazard Zones

<table>
<thead>
<tr>
<th>Powerplant</th>
<th>Utility</th>
<th>Term</th>
<th>Start Date</th>
<th>MW</th>
<th>2017</th>
<th>2018</th>
<th>2019+</th>
<th>% from Tier 1/ Tier 2 HHZ</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Ultrapower (Chinese Station)</td>
<td>SCE</td>
<td>5 Yr</td>
<td>3/1/2017</td>
<td>18</td>
<td>50</td>
<td>60</td>
<td>80</td>
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<td></td>
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<tr>
<td>RioBravo-Fresno*</td>
<td>SCE</td>
<td>5 Yr</td>
<td>1/2/2017</td>
<td>24.3</td>
<td>50</td>
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<td>80</td>
<td>Reverted</td>
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<tr>
<td>RioBravo-Rocklin</td>
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<td>5 Yr</td>
<td>1/2/2017</td>
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<td>60</td>
<td>80</td>
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<tr>
<td>Burney Forest Power</td>
<td>PGE</td>
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<td>12/15/2017</td>
<td>29</td>
<td>50</td>
<td>60</td>
<td>80</td>
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<tr>
<td>Wheelabrator (Anderson)</td>
<td>PGE</td>
<td>5 Yr</td>
<td>12/1/2017</td>
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<td>80</td>
<td>80</td>
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<td>Loyalton</td>
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<td>Idle</td>
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<tr>
<td>Honey Lake Power (Wendel)</td>
<td>SDG&amp;E</td>
<td>5 Yr</td>
<td>1/1/2017</td>
<td>24</td>
<td>50</td>
<td>60</td>
<td>80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* - reverted to 8.9 cents/kW-hr to relieve eliminate their Tier 1/Tier 2 feedstock requirement
Tier 1/Tier 2 High Hazard Zones (21 million acres)

80% of forest biomass feedstock requirement for BioRam Powerplants

Tier 1 High Hazard Zones:
These are areas where tree mortality directly coincides with critical infrastructure. They represent direct threats.

Tier 2 High Hazard Zones:
These are areas defined by watersheds (HUC 12, average 24,000 acres) that have significant tree mortality as well as significant community and natural resource assets.