Forest Residues Problem

- Increasing volumes of slash in piles and landings
- Mechanized harvest, delimbing
  - Less chainsaw work in the brush to increase feller productivity and safety > more brush at landing
- Restrictions on open burning
- Risks of slash fire escapes
- Loss of forest productivity
  - under burned piles due to soil heating
  - Under unburned piles and clumps due to soil cover
Sorting tree tops

No sorting (current practice)

Sawlogs

Forest residues

Sawlogs

Processed tops

Slash piles
Why Bale? Operational Objective:
Enable cost-effective collection of branches & tops
Why Bale? Economic Objective:
Enable cost-effective transportation, storage, and processing
Deschutes NF field demo with Forest Resources Association, Friends of the Metolius, City of Bend, USFS R6 Staff
Yakama Forestry Burn Piles
Summary data from the trial includes:

- 37 total bales weighing 36.85 green tons
  - Truckload limit = 48 bales (cube) or 32 tons (weight)
- Average bale weight 1,992 pounds, average density 26.8 lb/ft$^3$
- Highest bale weight = 2,304 pounds, highest bale density = 32.6 lb/ft$^3$
- Average time to bale = 28 minutes, average time to tie = 13 minutes
- Fastest time to bale = 21 minutes, fastest time to hand tie = 7 minutes
- Moving and repositioning between bales took 2-4 minutes
# Moment-Method Modeling of Baling Time

## Biomass Baler Productivity Data

### Date:
January 29-30, 2014

### Location:
Springfield, Oregon NARA Logging slash baling experiments

### Conditions:
Operating at Weyerhaeuser TOPS yard from windrowed material

## Percentage of Total Time

<table>
<thead>
<tr>
<th>Operation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Avg</th>
<th>st dev</th>
<th>28</th>
<th>st dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>pulling pile apart</td>
<td>5%</td>
<td>9%</td>
<td>8%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
<td>4.2%</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>getting grapple load</td>
<td>23%</td>
<td>28%</td>
<td>14%</td>
<td>23%</td>
<td>29%</td>
<td>23%</td>
<td>5.9%</td>
<td>6.5</td>
<td>1.7</td>
</tr>
<tr>
<td>rebunching/drop&amp; rebunch</td>
<td>2%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>1.1%</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>waiting for ground crew</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0.0%</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>slashing grapple grip</td>
<td>14%</td>
<td>11%</td>
<td>17%</td>
<td>19%</td>
<td>13%</td>
<td>15%</td>
<td>3.4%</td>
<td>4.1</td>
<td>1.0</td>
</tr>
<tr>
<td>loading</td>
<td>14%</td>
<td>17%</td>
<td>11%</td>
<td>10%</td>
<td>16%</td>
<td>14%</td>
<td>3.1%</td>
<td>3.8</td>
<td>0.9</td>
</tr>
<tr>
<td>packing</td>
<td>6%</td>
<td>9%</td>
<td>8%</td>
<td>3%</td>
<td>3%</td>
<td>6%</td>
<td>2.6%</td>
<td>1.6</td>
<td>0.7</td>
</tr>
<tr>
<td>rejiggering material in baler</td>
<td>6%</td>
<td>0%</td>
<td>8%</td>
<td>6%</td>
<td>0%</td>
<td>4%</td>
<td>3.9%</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>waiting for baler cycle</td>
<td>31%</td>
<td>26%</td>
<td>33%</td>
<td>39%</td>
<td>39%</td>
<td>33%</td>
<td>5.6%</td>
<td>9.4</td>
<td>1.6</td>
</tr>
<tr>
<td>waiting - other</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0.0%</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>bale</td>
<td>bale</td>
<td>28</td>
<td>17.2</td>
</tr>
</tbody>
</table>

**Tie**

| 3.0 autotie |

| 440 8 hr day | 10.7 21.8 bales/day |
| 550 10 hr day | 13.4 27.2 bales/day |
Work Element Pie Chart

- 2015-08-19 Baling Field Trial
- Snoqualmie Pass, WA
Biomass Baling - Minimize costs for collection, handling, storage, and shipping

• Higher density is better:
  – reduces storage space,
  – increases transport payload,
  – enables more efficient grinding
  – Trade-off against heavier baler and more fuel consumption by baler

• Rectangular bales are better:
  – handling just like other baled recyclables and hay
  – use of conventional bale handling equipment
  – safer stacking on trucks and in bale-yards
Design of a Baler
Baling Research Equipment

Lab Baler (the Squid)  Pilot Scale Baler (Load King)

Mobile Engineering Prototype Baler (Bighorn Baler®)
The practice of engineering is as much negotiation and compromise as it is analytic

Louis Bucciarelli

Designing Engineers
## Who Cares?

<table>
<thead>
<tr>
<th>Influencers &amp; Constraint Owners</th>
<th>Direct Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landowner / Land Manager</td>
<td>Baler Owner</td>
</tr>
<tr>
<td>Forester/Logging Supervisor</td>
<td>Baler Operator</td>
</tr>
<tr>
<td>Forest Operations Contractor</td>
<td>Baler Mechanic</td>
</tr>
<tr>
<td>Biomass Hauling Contractor</td>
<td>Baler Manufacturer</td>
</tr>
<tr>
<td>Biomass Bale-Yard Manager</td>
<td>Baler Hauler (mobilization and moving)</td>
</tr>
<tr>
<td>Forest Operations Safety Regulator</td>
<td>Equipment Dealer/Parts-Service Provider</td>
</tr>
<tr>
<td>Fire Protection Regulator</td>
<td>Bale Hauling Truck Driver</td>
</tr>
<tr>
<td>Invasive Species &amp; Diseases Regulators</td>
<td>Bale Handling Equipment Operator</td>
</tr>
<tr>
<td>Insurance Carrier</td>
<td>Biomass Grinder Operator</td>
</tr>
<tr>
<td>Financial Institution/Credit Provider</td>
<td></td>
</tr>
<tr>
<td>Environmental Sustainability Interests</td>
<td></td>
</tr>
<tr>
<td>Bioenergy Advocacy Interests</td>
<td></td>
</tr>
<tr>
<td>Forest Products Certification Bodies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What’s Important to Them?

• Safety – everyone defines safety in their own context
• Cost of ownership and operation
• Bale size, shape, weight, durability, ...
• Productivity of baler and “system” in the context of operational requirements
• Bale processing implications with horizontal or tub grinders
• Bale logistics system complexity from logging unit to end user
• Maintenance intensity and complexity
• Noise, dust, ...
• Necessary minutia – fuel type, spark arresters, controls, ...
Customer Requirements are Bimodal
Need Two Basic Baler Models

• Highly mobile & agile system to recover small spatially dispersed piles – 80% of the machines, 40% of the biomass
  – 0.3 - 3 tons per pile or roadside windrow
  – Piles 10 – 1,000 meters apart
  – Objective: Biomass removal at a reasonable cost

• High production system for large piles at landings with good truck access – 20% of the machines, 60% of the biomass
  – 20 - 200 tons per pile or continuous large windrow
  – Biomass forwarders may bring piles from 1-km radius to the baling operation
  – Objectives:
    • Highest production rates with low operating cost per ton baled
    • Provide alternative to in-woods grinding and bulk hauling
Other Stakeholder-Driven Top-Level Design Specifications

- Minimize operators
  - Wireless remote-operate from tracked grapple-loader
  - Eliminate ground crew and human chainsaw operators
- Minimize cost and time for moving to and within forest
  - Physical size does not require oversize load permits
  - Gross weight does not require overweight load permits
  - Enable transport under a range of contractor operating paradigms
- Modular baler unit
  - Baler independent of carrier to enable mounting on “anything”
  - Forwarder, 6x6 truck chassis, tracked undercarriage, hook-lift frame
Forest Biomass Utility Baler

• Modular baler unit that can be mounted to:
  – On-road or off-road trailer
  – Log forwarder
  – Tracked undercarriage
  – Truck chassis or flatbed truck
  – Hook-lift skid
• Bale size and weight optimized for:
  – Skid-steer loader handling
  – Smaller Peterson* horizontal grinders
• Primary uses:
  – Baling roadside windrows and supporting thinning crews
  – Baling slash from keyhole and stranded landings
  – Recovering dispersed slash
Forest Biomass Large Baler (conceptual)

- Modular baler unit that can be mounted to:
  - Tracked undercarriage
    - remote-operated by loader
  - Off-road/mining truck chassis
  - Log forwarder
  - On-road or off-road trailer
- Bale size and weight optimized for:
  - Track-hoe and off-road forklift handling
  - Largest Peterson* horizontal grinders
- Primary uses:
  - Baling piled slash at cable and ground logging sites
  - Baling dispersed slash piles within units and secondary roads
  - As an alternative to in-woods grinding
# Conceptual Forest Residuals Balers

(Updated October 1, 2015)

<table>
<thead>
<tr>
<th>FCLLC Engineering Prototype (FCEP)</th>
<th>Urban Chipper Replacement</th>
<th>Forest Biomass Utility Baler</th>
<th>Forest Biomass Large Baler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bale Size (inches)</td>
<td>32x48x56</td>
<td>32x48x56</td>
<td>34x48x96</td>
</tr>
<tr>
<td>Bale Density (lb/cu.ft – @ 50% MC wb)</td>
<td>15-25</td>
<td>15-20</td>
<td>20-30</td>
</tr>
<tr>
<td>Bale Weight (lb)</td>
<td>800 – 1,400</td>
<td>1,000 – 1,400</td>
<td>1,000 – 1,500</td>
</tr>
<tr>
<td>Loader</td>
<td>Self-loading grapple</td>
<td>Self-loading grapple</td>
<td>Self-loading grapple</td>
</tr>
<tr>
<td>Theoretical/Operational Capacity (bales/hr)</td>
<td>3/2</td>
<td>5/3</td>
<td>10/4</td>
</tr>
<tr>
<td>Horsepower</td>
<td>28</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>Crew</td>
<td>2 (manual tie)</td>
<td>2 (manual tie)</td>
<td>1 (auto-tie)</td>
</tr>
<tr>
<td>Running Gear</td>
<td>5&lt;sup&gt;th&lt;/sup&gt; Wheel Trailer</td>
<td>Category 3 trailer</td>
<td>Modular</td>
</tr>
<tr>
<td>Capital Cost ($) Est.</td>
<td>$110,000</td>
<td>$130,000</td>
<td>$350,000</td>
</tr>
</tbody>
</table>
Thank You

www.forestconcepts.com

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* Peterson is a brand of Peterson Pacific Corporation
Mention of corporations or brand names does not constitute an endorsement or recommendation.

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