Pure Energy Ratio of logging residue processing

Radomír Klvač
Idea

How to define (assess) which of the technologies used for logging residues processing is the most suitable with regards to environment.

Is the use of logging residues effective, can we earn more than we invested with respect to renewable and fossile energy?
Terms "energy balance" or "energy ratio" are used to characterize relations between the energy input and output.

Energy balance is a difference between the energy output and input.

Energy ratio is a ratio between the energy output and energy input.

Pure = renewable
Processing chains identification

- **Chain saw**
  - Slash rake *
  - Harvester (possible productivity decrease)
  - Chain saw (main felling)
    - Slash rake *
    - Chain saw (thinning)
      - horse *
      - Tractor *

- **Bundler**
  - Bundle transport by forwarder
  - Bundle haulage by TTUs

- **Locality stump**

- **Locality road side**
  - Bundle haulage by TTUs
  - Chipper
    - Chips haulage by TTUs
  - Tractor *

- **Locality costumer**
  - Shredder
  - 1 t DM
  - E. cont. 19.2 GJ
Processing chains

Slash rakes

Productivity: 65/8 steres per shift/hour
Fuel consumption: 3.9 l.h⁻¹; 0.5 l.stere⁻¹

* 1 t DM = 5.22 m³, 10.5 stere
Processing chains

**Bundler**

- Average production rate: 13844 bundles (FU) per year
- Number of working hours: 3474 hours per year
- Fuel consumption: 7.3 l.h⁻¹; 1.83 l.FU⁻¹
- Consumption of oils: 0.62 l.h⁻¹; 0.16 l.FU⁻¹

<table>
<thead>
<tr>
<th>period</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMH</td>
<td>3389</td>
<td>3558</td>
</tr>
<tr>
<td>bundles (pcs)</td>
<td>10041</td>
<td>17647</td>
</tr>
<tr>
<td>Tons (1bundle = 340.85 kg)</td>
<td>3360.6</td>
<td>6015</td>
</tr>
<tr>
<td>Utilization</td>
<td>79.6 %</td>
<td>83.6 %</td>
</tr>
<tr>
<td>Productivity pcs.SMH⁻¹</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

* 1 t DM = 5.22 m³, 10.5 steres
Processing chains

Frowarder after bundling

capacity of forwarders ranges between 10 – 20 bundles (FU)
1 bundle = 179 kg DM

Fuel consumption: 13.72 l.h⁻¹; 1.25 l.FU⁻¹
Consumption of oils: 0.64 l.h⁻¹; 0.06 l.FU⁻¹

* 1 t DM = 5.22 m³, 10.5 steres
Processing chains

**Hauling of bundles**

Distances were 206 and 114 km and this is why we considered mean hauling distances for the transportation of bundles to be 75 and 150 km.

- Average productivity: 53 bundles (FU) per haulage
- Fuel consumption: 50 l/100 km; 1.42 and 2.83 l/FU
- Consumption of oils: 0.45 l/100 km; 0.013 l/FU

*1 t DM = 5.22 m³, 10.5 steres*
Processing chains

Chain saw

Slash rake * 212 MJ

Harvester (possible productivity decrease)

Chain saw (main felling)

Chain saw (thinning)

Slash rake *

212 MJ

horse *

Tractor *

Shredding

Average consumption of diesel oil per hour was 23.5 litres
The productivity of the crusher may reach up to 22 tons per hour
actual production rate ranged about 15 tons per hour.

Fuel consumption: 1.6 litres per ton

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Processing chains

**Horse and/or Tractor**

Energy consumption of horses amounts to 13.7 MJ.hour\(^{-1}\) (Magagnotti and Spinelli, 2011)

- **Farm tractor**
  - Fuel consumption: \(1 - 1.2 \text{ l.m}^{-3}\)
  - Transmission oil consumption: \(6.7 \text{ l.1000 m}^{-3}\)
  - Motor oil consumption: \(6.7 \text{ l.1000 m}^{-3}\)
  - Consumption of lubricants: \(1.7 \text{ kg.1000 m}^{-3}\)
  - Lubrication spray: \(1 \text{ l.1000 m}^{-3}\)

\*1 t DM = 5.22 m\(^3\), 10.5 steres
Processing chains

Logging residue forwarding

According to the loading area size, the capacity of forwarders ranges from 4 – 7 stacked cubic metres (steres) of logging residues (FU). Output per hour fluctuates in dependence on the logging system (preparedness of the site) and average skidding distance.

Fuel consumption: \(13.72 \text{ l.h}^{-1}; 2.29 \text{ l.FU}^{-1}\)
Consumption of oils: \(0.64 \text{ l.h}^{-1}; 0.11 \text{ l.FU}^{-1}\)

*1 t DM = 5.22 m\(^3\), 10.5 steres*
Processing chains

Cipping

The calculation was made for a machine assembly containing the chipper JENZ HEM 420 Z (JH 420 Z) and the tractor FENDT 716 VARIO.

Average production rate: 6608 tons (FU) per year
Number of working hours: 2702 PMH per year
Fuel consumption: 7.18 \( l.h^{-1} \); 2.96 \( l.FU^{-1} \)
Consumption of oils: 0.06 \( l.h^{-1} \); 0.026 \( l.FU^{-1} \)

* 1 t DM = 5.22 \( m^3 \), 10.5 steres
Processing chains

Haulage of chips

Average productivity: 35 and 70 steres per journey
Fuel consumption: 60 l/100 km\(^{-1}\) and 65 l/100 km\(^{-1}\)
Fuel consumption: 1.71 l/FU\(^{-1}\) and 0.93 l/FU\(^{-1}\)
Consumption of oils: 0.45 l/100 km\(^{-1}\); 0.013 l/FU\(^{-1}\)

<table>
<thead>
<tr>
<th>Average hauling distance</th>
<th>TTU type*</th>
<th>Energy balance (MJ. stere(^{-1})) from the operational phase</th>
<th>Energy balance (MJ.t(^{-1}) DM) from the operational phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>small</td>
<td>80.9</td>
<td>270</td>
</tr>
<tr>
<td></td>
<td>large</td>
<td>49.2</td>
<td>164</td>
</tr>
<tr>
<td>100</td>
<td>small</td>
<td>133</td>
<td>443</td>
</tr>
<tr>
<td></td>
<td>large</td>
<td>72.8</td>
<td>243</td>
</tr>
<tr>
<td>150</td>
<td>small</td>
<td>185.3</td>
<td>618</td>
</tr>
<tr>
<td></td>
<td>large</td>
<td>98.4</td>
<td>328</td>
</tr>
</tbody>
</table>

* 1 t DM = 5.22 m\(^3\), 10.5 steres
**Processing chains**

**Locality stump**
- **Chain saw**
- **Slash rake** *\(212\) MJ*

**Bundler**
- 1 bundle = 179 kg DM
- **Bundler**
- **Bundle transport by forwarder**
  - 1 bundle = 179 kg DM
  - **Bundle transport by forwarder**
- **Harvester** (possible productivity decrease)
- **Locality road side**
- **Chips haulage by TTUs**
  - 1 stere = 300 kg
  - **Chips haulage by TTUs**

**Locality customer**
- **Shredder**
  - 1 t DM = 1,72 t chips by 58%
- **112 MJ**

**Slash rake** *\(212\) MJ*
- **Chain saw** (main felling)
- **Slash transport by forwarder**
  - 1 t DM = =10.5 steres
- **1068 MJ**

**Chain saw** (thinning)
- **Tractor** *\(261\) MJ*
- **horse** *\(72\) MJ*

**Chipper**
- **(air dried - 35% of humidity)**
- **196 MJ**

**Locality stump**
- **1 t DM = 5.22 m³, 10.5 steres**

**Chips haulage by TTUs**
- **196-618 MJ**

**Bundle haulage by TTUs**
- **385-705 MJ**
  - (differ by hauling distance)

**Bundle transport by forwarder**
- **310 MJ**

**1 t DM**
- **1812-2196 MJ**
  - **1558-1941 MJ**

**1 t DM**
- **1714-2258 MJ**

**1 t DM**
- **1968-2513 MJ**

**1 t DM**
- **2099-2644 MJ**

**multiplied by 1.2 (whole life cycle)**
PER for logging residue processing

Depending on the chosen technological chain, the pure energy ratio ranged from 8 – 12. With this multiple gain of energy, the used method of manufacturing and processing raw material for fuel (chips) can be considered highly effective and contributing to sustainable management.
<table>
<thead>
<tr>
<th>Technology</th>
<th>En. content 1 t DM</th>
<th>En. use of processing*</th>
<th>En. balance supplied to costumer**</th>
<th>Boiler efficiency</th>
<th>En. balance 1t DM</th>
<th>pure energy ratio</th>
</tr>
</thead>
</table>

Col. = Column

* Hauling distances are considerably shorter in district heat plants and energy use for haulage is therefore markedly lower. Large power plants require the collection of sources from longer distances and energy intensiveness ranges at the upper limit.

** The longer the storage time, the greater the material degradation is (ca. 5% per month). This is why a higher degradation risk exists in large power plants due to the necessary advance storage of supplies.
Thank you for your attention