EFFICIENCY IN THE PRODUCTION AND PREPARATION OF BIOMASS FOR ENERGETIC UTILISATION

by Werner Grosse

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Introduction

Estimated bio-energy potential in Germany in the year 2050

Source: FNR (2011)
Efficiency and effectiveness originally stem from the operations research branch of science. In the definition provided by AHN & DYCKHOFF (1997) both terms are allocated to a common system of goals:

**Effectiveness** - “do[ing] the right things”

Effectiveness for instance in terms of energy preparation by biomass could be defined as the difference between the energy output and the energy input.

**Efficiency** - “do[ing] the right things right.”

Efficiency for instance in terms of energy preparation by biomass could be defined as the quotient of the energy output (yield) and the energy input.

Output: Energy content of the product (caloric value)
Input: Sum of all forms of invested fossil energies
## Efficiency in the production and supply of biomass

<table>
<thead>
<tr>
<th>Product</th>
<th>„Energy efficiency&quot; OUTPUT : INPUT</th>
<th>„Energy effectiveness&quot; OUTPUT - INPUT GJ ha(^{-1})a(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rape</td>
<td>2 ... 5 : 1</td>
<td>23 ... 54</td>
</tr>
<tr>
<td>Silage maize</td>
<td>3 ... 15 : 1</td>
<td>62 ... 407</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>3 ... 15 : 1</td>
<td>62 ... 262</td>
</tr>
<tr>
<td>Wood from - Forestry (pine)</td>
<td>54 : 1</td>
<td>74</td>
</tr>
<tr>
<td>- SRC (poplar)</td>
<td>60 ... 64 : 1</td>
<td>177</td>
</tr>
</tbody>
</table>

Balance limit: Soil preparation to harvest, partial incl. transport to the storage / drying

Sources: BJÖRESSON (1996); EDER et al. (2009); KANZLER (2010); REINEKE et al. (2010); SCHOLZ / KAULFUß (1995); SCHWEINLE (2000); VENTURI (2003)

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**Energy efficiency and energy effectiveness for selected renewable raw materials**
### Wood chip drying processes

<table>
<thead>
<tr>
<th>Wood chip drying process</th>
<th>Output: input pre-drying $w = 50%$</th>
<th>Input: input MJ/t$_{atro}$</th>
<th>Output: input post-drying $w = 25%$</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cold air drying</td>
<td>$(7670; MJ/t_{atro}) : 208; MJ/t_{atro}$</td>
<td>$37 : 1$</td>
<td>$13260; MJ/t_{atro} : 285; MJ/t_{atro}$</td>
<td>Input: electric fan, including flow channels; Hartmann &amp; Strehler (1995), supplemented</td>
</tr>
<tr>
<td>2 Heated air drying</td>
<td>$(7670; MJ/t_{atro}) : 208; MJ/t_{atro}$</td>
<td>$37 : 1$</td>
<td>$13260; MJ/t_{atro} : 624; MJ/t_{atro}$</td>
<td>Input: heating unit and electric aeration fan, including flow channels; Hartmann &amp; Strehler (1995), supplemented</td>
</tr>
<tr>
<td>3 Dome aeration process</td>
<td>$(7670; MJ/t_{atro}) : 208; MJ/t_{atro}$</td>
<td>$37 : 1$</td>
<td>$13260; MJ/t_{atro} : 220; MJ/t_{atro}$</td>
<td>Input: 3 domes / 8 canals, 540 m$^2$ protective sheet, initial values according to Brummack (2006), supplemented$^1$</td>
</tr>
</tbody>
</table>

$w =$ water content  \hspace{1cm} SRC = short rotation coppice

$^1$ added to the direct energy expenditure (electricity and heating) cited by Hartmann & Strehler (1995) are expenditures for the materials (energy expended in products) used in fixtures and for protective sheets of identical size to those used in the dome aeration process.

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**Energy efficiency of various wood chip drying processes**

(material: wet wood chips derived from poplar SRC) (GROßE, 2006; KANZLER, 2010)
Energy expenditure in the pelleting process
(based on fresh wood with a water content of 55 %)

The energy expenditure required for the construction and maintenance of pelleting equipment was not quantified by the authors.

Based on WALLE et al. (2007), this accounts for 5 % of the direct energy expenditure required for pellet production, corresponding to 0.3 GJ t⁻¹. This results in an estimated energy expenditure for pellet production of 6 GJ t⁻¹.

Approximately one third of the calorific value of wood is, therefore, consumed solely in the production of the pellets.

### Energy expenditure, MJ t⁻¹

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Electricity</th>
<th>Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying</td>
<td>85.7</td>
<td>4 320.0</td>
</tr>
<tr>
<td>Reduction</td>
<td>67.3</td>
<td>0</td>
</tr>
<tr>
<td>Pelleting</td>
<td>183.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Cooling</td>
<td>7.2</td>
<td>0</td>
</tr>
<tr>
<td>Machinery</td>
<td>66.2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>410.0</strong></td>
<td><strong>4 322.9</strong></td>
</tr>
</tbody>
</table>

Source: Obernberger / Thek 2009
Energy balance per hectare in a comparison of central electricity and heat generation with maize (whole plant) and poplar wood chips (basic data derived from slide 2)

1) wood chips (w = 25 %)
2) biomass combined heat and power (CHP) plant, degree of efficiency= 0.85
3) biomethane production with centralised conversion to electricity in a CHP plant (efficiency values according to Dressler et al., 2011)
Conclusion

- The different plant types and the processes applied can be compared under the aspects energy efficiency and effectiveness.

- In production, preparation and conversion of biomass to heat and power the decision-making process between for the right technology should to allow for the aspect of energy efficiency absolute.

- The results, in the form of energy balances from production to the generation of electricity and heat, indicate the benefits of the use of fast growing tree species and of wood for additional energy generation.

- In comparison to maize, an agricultural crop with the highest biomass yields, heat and electricity can be obtained from short rotation coppice plantations with species such as poplar comparatively effectively and efficiently.

- With just one third of the energy input required in the production process of poplar wood chips in comparison to silage maize, it is possible to generate the same amounts of heat and electricity using 2.5 more area of land required to produce biomethane from silage maize with subsequent heat and electricity generation.
Example of a well accepted Short Rotation Plantation at the Middle Saxon Uplands

Plantation structure and landscaping aesthetics

Thank you for attention!