The role of feedstock for biochar and energy in reducing the carbon footprint of bioenergy projects — A case study in North Europe

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BIOCHAR & BIOENERGY FOR CARBON SEQUESTRATION

L.E. Fryda & R. Visser
INTRODUCTION

Horticulture consumes (fossil) energy: heating, CO$_2$, substrates (peat), fertilizer (NPK), water…

- Need to reduce fossil energy use
- Need to preserve peat bogs (reduce carbon loss)

Biochar & bioenergy as sustainable alternatives? Which biochar?
An ideal situation: high yield premium quality biochar, valorisation of co-products

~50% yield
~25% heat surplus

Source: Schafer et al., Biomass and Bioenergy 120 (2019) 281–290
EXAMPLES & REALITY

High % @ low T

Surplus energy @ high T, low %
“Edinburgh Tool” (UK Biochar Research Center): accelerated ageing method, simulates the oxidative degradation (ageing) of biochar in soil

Biochars from variable conditions have variable stability: affects CCS

<table>
<thead>
<tr>
<th>Biochars &amp; control</th>
<th>% Carbon in oxidized biochar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood (park residue) biochar, gasification 670°C</td>
<td>90.0</td>
</tr>
<tr>
<td>Beech wood / pine wood, gasification 670°C</td>
<td>97.5</td>
</tr>
<tr>
<td>Oak biochar, pyrolysis 400°C</td>
<td>21.5</td>
</tr>
<tr>
<td>Oak biochar, pyrolysis 600°C</td>
<td>86.1</td>
</tr>
<tr>
<td>Commercial biochar *</td>
<td>98.0</td>
</tr>
<tr>
<td>Pine wood biochar, gasification 670°C</td>
<td>89.5</td>
</tr>
<tr>
<td>Cocoa biochar, pyrolysis at 650°C, steam activated</td>
<td>98.1</td>
</tr>
<tr>
<td>Graphite *</td>
<td>99.0</td>
</tr>
<tr>
<td>Active Carbon 1*</td>
<td>99.0</td>
</tr>
<tr>
<td>Active Carbon 2*</td>
<td>99.0</td>
</tr>
<tr>
<td>Fresh cocoa shell</td>
<td>25.3</td>
</tr>
</tbody>
</table>
GASIFICATION FOR BIOCHAR PRODUCTION

- High quality biochar
- Broad range of feedstock
- High energy quality

Important to co-produce Energy for the system economics
SYSTEM DESCRIPTION AND GHG STUDY

Goal of the study
• To evaluate the environmental impact of production & application of (bio)heat and biochar
• To compare with the current (reference) situation: natural gas & peat use (peat & NG substitute)

Disposal of spent substrate in soil
DATA INVENTORY & ASSUMPTIONS

- Pilot & lab scale experiments (mass and energy flows, feedstock and products composition of biochar & product gas)
- Ecoinvent database, papers, reports, literature
- IPCC’s Global Warming Potentials (IPCC 2007).
- No distinction is made between fossil and biogenic carbon: Timing of emissions and uptake (biomass growth) is taken into account
- Use of Simapro 8.5
CO₂ BALANCE (BIOMASS, BIOCHAR, PEAT)

CO₂ balance = \( f(\text{growth & decay of biomass, combustion, carbon storage in biochar, decay peat & biochar}) \)  NO Soil Organic Carbon changes assumed

Balance over 100 year  \( TH = \text{CO}_2\text{,uptake/sequestration} - \text{CO}_2\text{, decay} - \text{CO}_2\text{,harvest/bioenergy} \)

*Harvest = immediate use (combustion, release of CO₂)

⇒ CO₂ value to include in the calculation (input in the fossil CO₂ emissions table of the input file) => A “worst” case in bioenergy when carbon neutrality cannot be sure

⇒ References: de Rosa, Schmidt etc
Ener & Char:
main product = heat delivered

biochar is dependent

FU = 1MJ
## WHAT IF WE PRODUCE MAINLY BIOCHAR

<table>
<thead>
<tr>
<th></th>
<th>Enerchar</th>
<th>PyroChar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed (kg)</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Total $n_{eff}$ to energy (syngas)</td>
<td>0.85</td>
<td>0.35</td>
</tr>
<tr>
<td>Thermal output MWh</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Biochar ($m^3$)</td>
<td>2.75</td>
<td>6</td>
</tr>
<tr>
<td>Biochar (kg)</td>
<td>275</td>
<td>600</td>
</tr>
<tr>
<td>$CO_2$ sequestration (kg$CO_2$ / kg char)</td>
<td>-2.78</td>
<td>-1.38</td>
</tr>
<tr>
<td>Peat replacing capacity</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td>Stability biochar (%)</td>
<td>&gt;90</td>
<td>&lt;40</td>
</tr>
<tr>
<td>Stability peat</td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td>$CO_2$ release peat (kg$CO_2$ / kg peat) (decay)</td>
<td>1.47</td>
<td></td>
</tr>
</tbody>
</table>
CO2 EMISSIONS ENER&CHAR VS PYRO-CHAR

**Ener&Char:** although biochar little, gets credit from heat

**PyroChar:** mainly biochar, little credit from heat

This graph reflects quality of biochar.
KEY MESSAGES & OUTLOOK

- Stability of biochar crucial for CCS estimation:
The CCS potential of biochar is linked with its carbon recalcitrance which can vary considerably among Low T pyrolysis and high T gasification

- Energy plus biochar: fast growing biomass provides quick CO$_2$ return (minimizes carbon debt)

- Biochar plus energy: also forest products become relevant, C is stored in soil for very long (CCS potential)

- Case by case study necessary, parameters to consider: stability, biochar and energy yield, feedstock origin and growth cycle, reference system

- Plans to include iLUC emissions: how will the system behave
THANK YOU

Lydia Fryda

Research funded by the Dutch Ministry of Economic Affairs, EU, K and P projects, TKI projects, funding for personal development (training), personal communication, studying

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