ECONOMIC ASSESSMENT OF BIOCHAR PRODUCTION AND USE

Katarina Elofsson[a] and Addisu Anteneh Dilnessa[a]
Department of Environmental Science, Aarhus university

TASK AND METHOD

Task	Method
Costs for production and use of biochar for the three scenarios.	Literature review.
Economically optimal process conditions.	Literature review.
Revenues from sale of biochar and energy side streams.	Chapters 2 and 7, official statistics.
Net costs for the production of biochar.	The three above steps.
Operative business model for biochar.	Litterature review, economic theory.
Location and size of facility.	Economic theory.
Biochar and CO2 credits.	Literature review and governmental reports.

THE LITERATURE REVIEW

- Relatively few studies.
- Vary with respect to technologies applied, feedstock used, system boundaries, and data:
  - Fast and slow pyrolysis.
  - Varying plant size.
  - Different feedstock: maize, straw, sludge, forest biomass, others. But not biogas digestate residues.
  - Some include on-farm effects, others do not.
  - Differences in the consideration of transports.
  - Economic and environmental data from different countries and years.
- We have converted **results** to 2021 year value, using the same discount rate (i.e., interest rate) and life time across studies. This gives comparable results across studies.

INVESTMENT COSTS

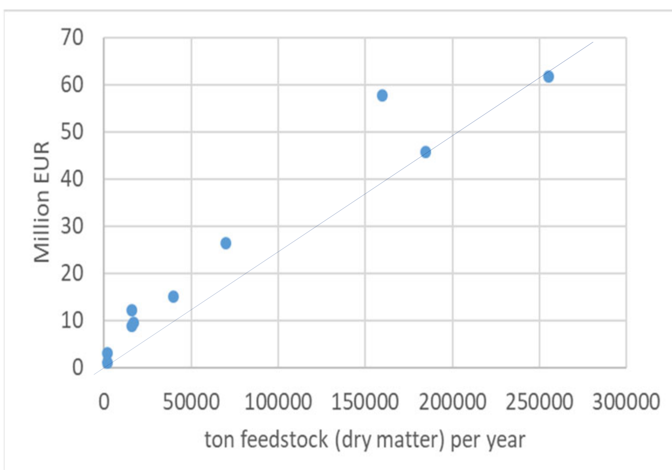


Fig. 1. Plant investment costs in Million EUR in 2021 year value in relation to annual feedstock input (dry matter) for the plant in question.

OPERATION COSTS

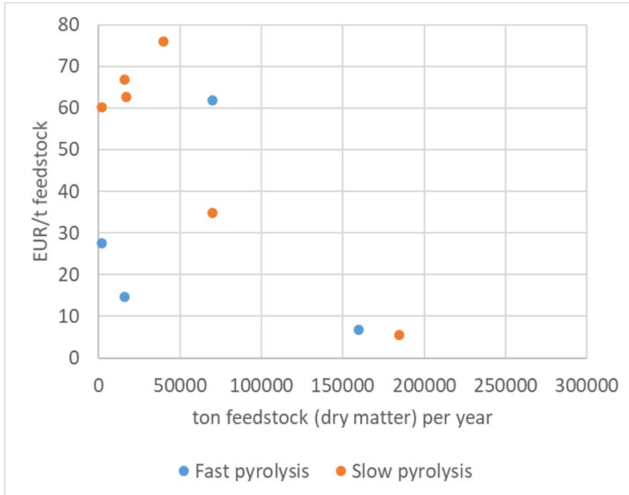


Figure 2. Operating costs in EUR per ton feedstock (dry matter), in 2021 year value. Blue dots refer to fast pyrolysis, red dots to slow pyrolysis.

ANNUAL PRODUCTION COSTS PER TON FEEDSTOCK

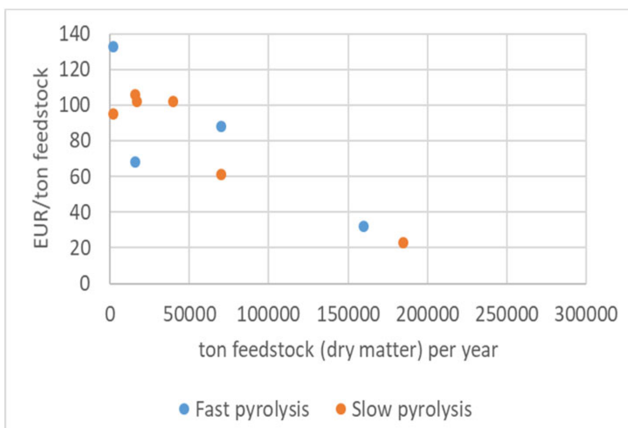
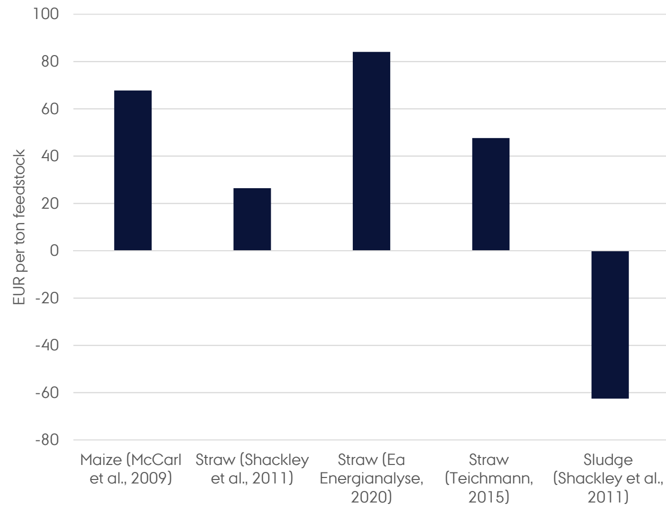


Fig. 3. Annual costs in EUR per ton feedstock (dry matter), in 2021 year value. Blue dots refer to fast pyrolysis, red dots to slow pyrolysis. Life time of plant is assumed to be 20 years, and the discount rate is set to 3.5%.

FEEDSTOCK COSTS



- Fig. 4. Feedstock cost in EUR per ton feedstock (dry matter), in 2021 year value for biochar produced with slow pyrolysis.

COSTS PER TON OF BIOCHAR

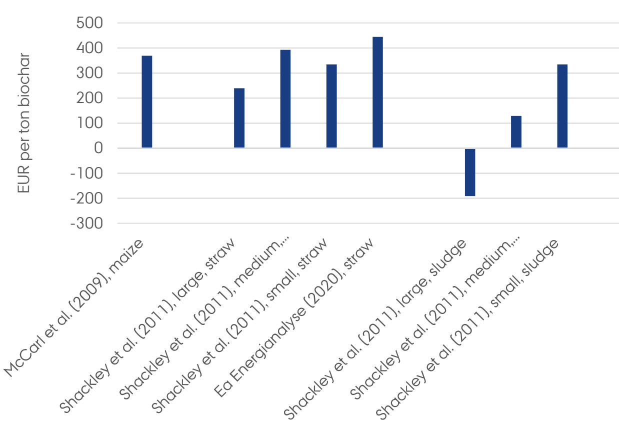


Figure 8.5. Costs per ton of biochar, including feedstock costs, but excluding the value of nutrients and energy side streams. Estimates are grouped by feedstock.

POTENTIAL REVENUES FOR BIOCHAR NUTRIENTS AND ENERGY SIDE STREAMS

	N, kg/ton biochar	P, kg/ton biochar	K, kg/ton biochar	Nutrient value, EUR/ton biochar
Straw	0 – 13.7	4.2	37.5	12.03 – 25.73
Biogas digestate	0 – 11.5	58.1	35.7	57.69 – 69.19
Sewage sludge	0 – 21.7	39.0	27.3	47.38 –69.08

Table 8.1. Average nutrient content per ton of biochar, price of fertilizer nutrients in EUR/kg, and nutrient value of biochar in EUR/ton.

	Energy output, GJ/ton	Value of energy output, EUR/ton biochar
Straw	34.22	58.86
Biogas digestate	20.04	51.01
Sewage sludge	17.20	56.24

Table 8.2. Energy output in GJ per ton of biochar, and value of of energy output, for different feedstock in EUR/ton biochar. Biochar is produced with slow pyrolysis.

NET COSTS FOR BIOCHAR AFTER CONSIDERATION OF REVENUES FOR NUTRIENTS AND ENERGY SIDE STREAMS

Feedstock	EUR/ton biochar
Straw	268 to 281
Biogas digestate residues	(-30) to (-18)
Sewage sludge	(-35) to (-13)

This should be interpreted with care. In particular, statistics on prices for sewage sludge and biogas digestate residues are not available in the Danish context.

LOCALIZATION AND SIZE OF FACILITIES

- **Feedstock is bulky** and transports therefore costly.
- Biochar is less bulky and transports are cheaper.
- Strong **economies of scale** in biochar production.
- **Feedstock costs** (and therefore net production costs) can be very low for sewage sludge and biogas digestate residues.

➢ These facts favor **large plants located close to large amounts of available sewage sludge and biogas digestate residues**.

COSTS OF BIOCHAR USE AT FARM LEVEL

Source	EUR per ton biochar	Calculation
Teichmann (2015)	21/12	Transport, unloading and storing with biochar storage on the farm/at the biochar plant
Shackley et al. (2011)	7	Hauling and spreading
EA Energianalyse (2020)	2.30	Spreading

Literature review shows mostly rather simple estimates of costs are farm level. Methods are highly variable.

➢ Results points to the importance of considering transport and storage costs also for the biochar end product.

COST-EFFECTIVENESS AND CARBON OFFSETTING

	CO_2-eq removal per ton biochar	Cost (EUR per ton biochar)	Cost (EUR per ton of CO_2-eq removal)
McCarl et al. (2009), fast pyrolysis, maize residues	24.39	3465	142
McCarl et al. (2009), slow pyrolysis, maize residues	4.24	369	87
Teichmann (2015), slow pyrolysis, straw	3.09 – 4.77	132 – 252	28 – 81
Shackley at al. (2011), slow pyrolysis, straw	1.49	238 – 392	159 – 263
Shackley at al. (2011), slow pyrolysis, sludge	0.92	(-192) – 334	(-208) – 363
EA Energi analyse (2020), slow pyrolysis, incl. pyrolysis oil CO_2 impacts			117
EA Energianalyse (2020), slow pyrolysis, excl. pyrolysis oil CO_2 impacts, including green premium			65
Energistyrelsen (2022), 2022 CO_2 price			83
Det Økonomiske råd (2020), CO_2 price to meet 2030 targets			161
Average carbon offset price EU ETS 2021 (CAP, 2022)			40

POLICY INSTRUMENTS AND BUSINESS MODEL

The literature suggests:

- Biochar use could potentially be supported under the Rural Develop Programmes.
- In the shorter term, support to production can be motivated for technology development, learning, and development of sufficient scale economies.
- In the medium and long term, support where the level is based on the **externality benefit** of biochar should be the rule. Thus: based on **the value of the carbon removal effect**, while considering an appropriate time frame of the carbon effect.

KNOWLEDGE GAPS

Comparisons between biochar as a carbon mitigation tool, and other measures for biological or technical carbon sequestration.

The economically optimal localization of biochar plants (empirical issue).

Pricing of sewage sludge and biogas digestate residues.

Farmers' willingness-to-accept application of biochar.

AARHUS UNIVERSITY