System analysis of large-scale biochar production and use in Stockholm

The biochar-energy trade-off

Energy

Carbon sequestration

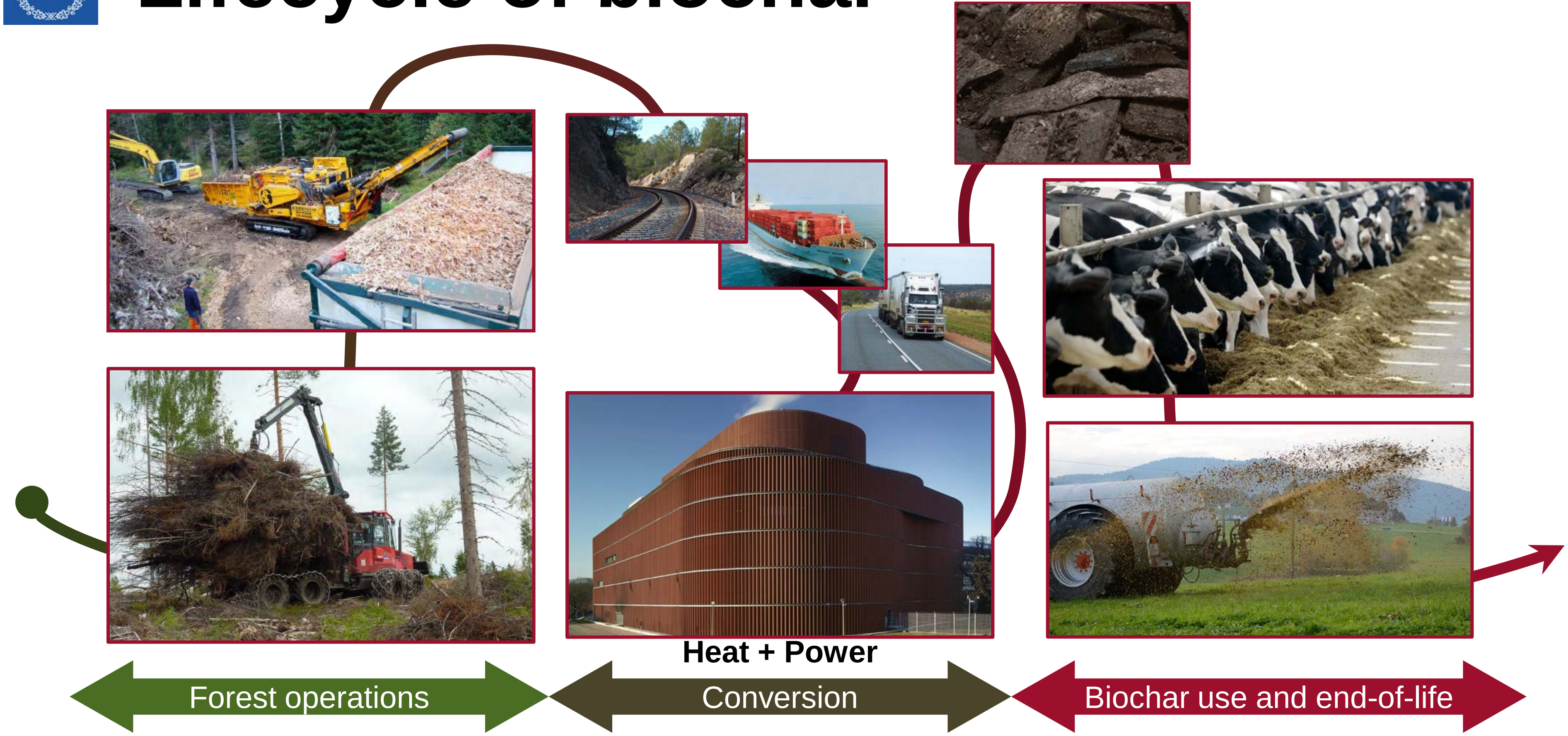
Food

Materials

Ecosystem services

1. Life-cycle approach
2. Specific study

Lifecycle of biochar

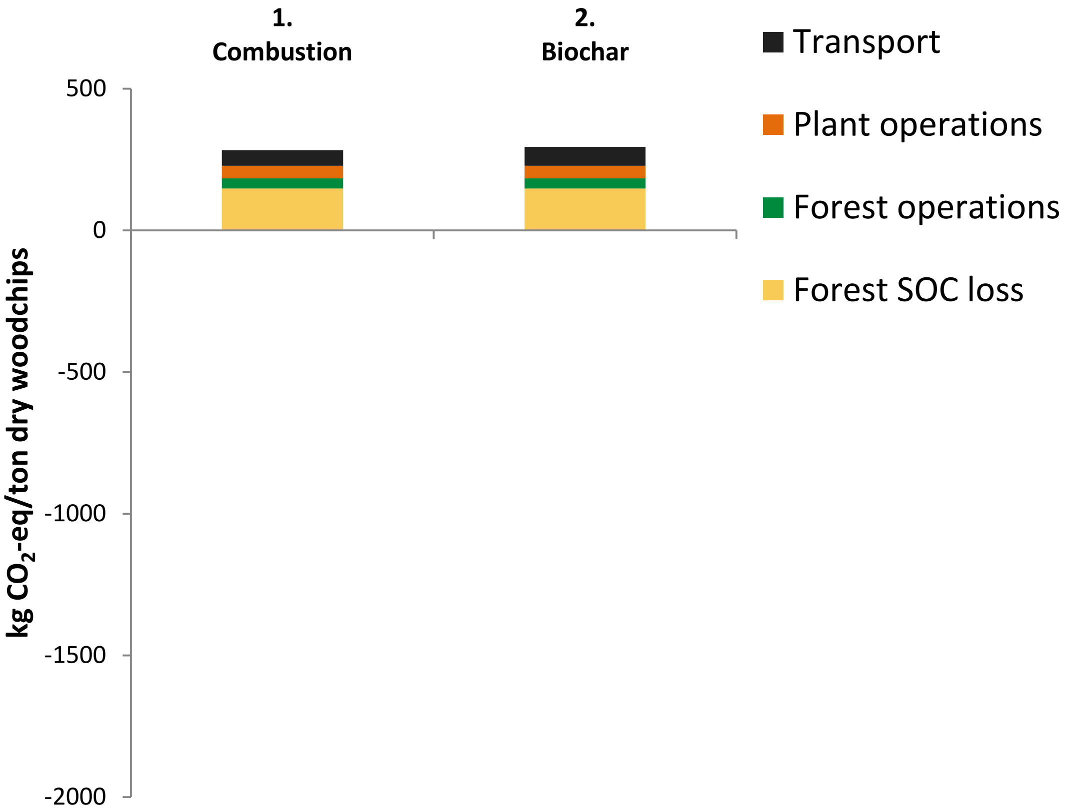


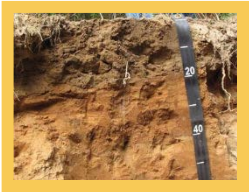
Four words about the model

A ***future*** and ***large*** plant

A ***generic*** and ***explorative*** farm

Climate impact *at production*





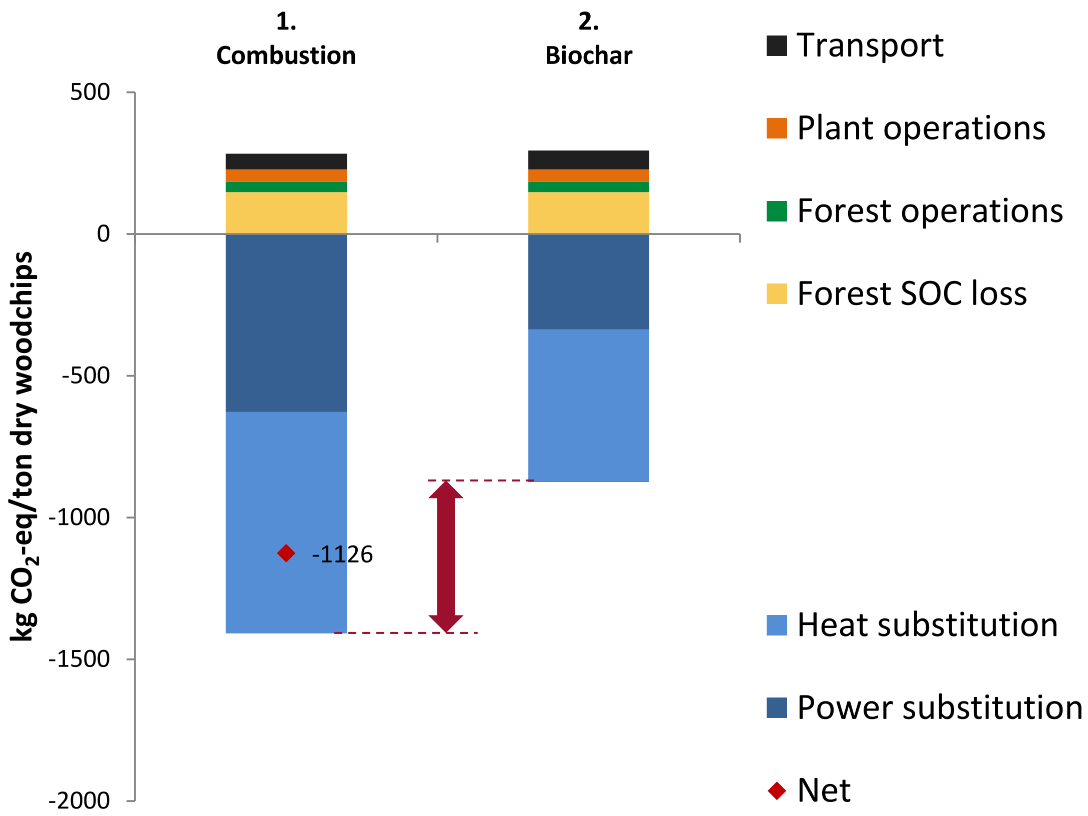
kg $CO_{2\text{-eq}}$/ton dry woodchips

1. Combustion: 283 kg $CO_{2\text{-eq}}$/ton
2. Pyrolysis: 294 kg $CO_{2\text{-eq}}$/ton

g $CO_{2\text{-eq}}/MJ_{fuel}$ (LHV)

1. Combustion: 14.9 g $CO_{2\text{-eq}}/MJ_{fuel}$
2. Pyrolysis: 15.5 g $CO_{2\text{-eq}}/MJ_{fuel}$

Climate impact *after energy use*



$$S_i = U_0 \times \eta_i \times EF_i$$

$$S_i = U_0 \times \eta_i \times \left[\,(1-\alpha_i) \times EF_{i,h} + \alpha_i \times EF_{i,p}\right]$$

Generic Energy Substitution

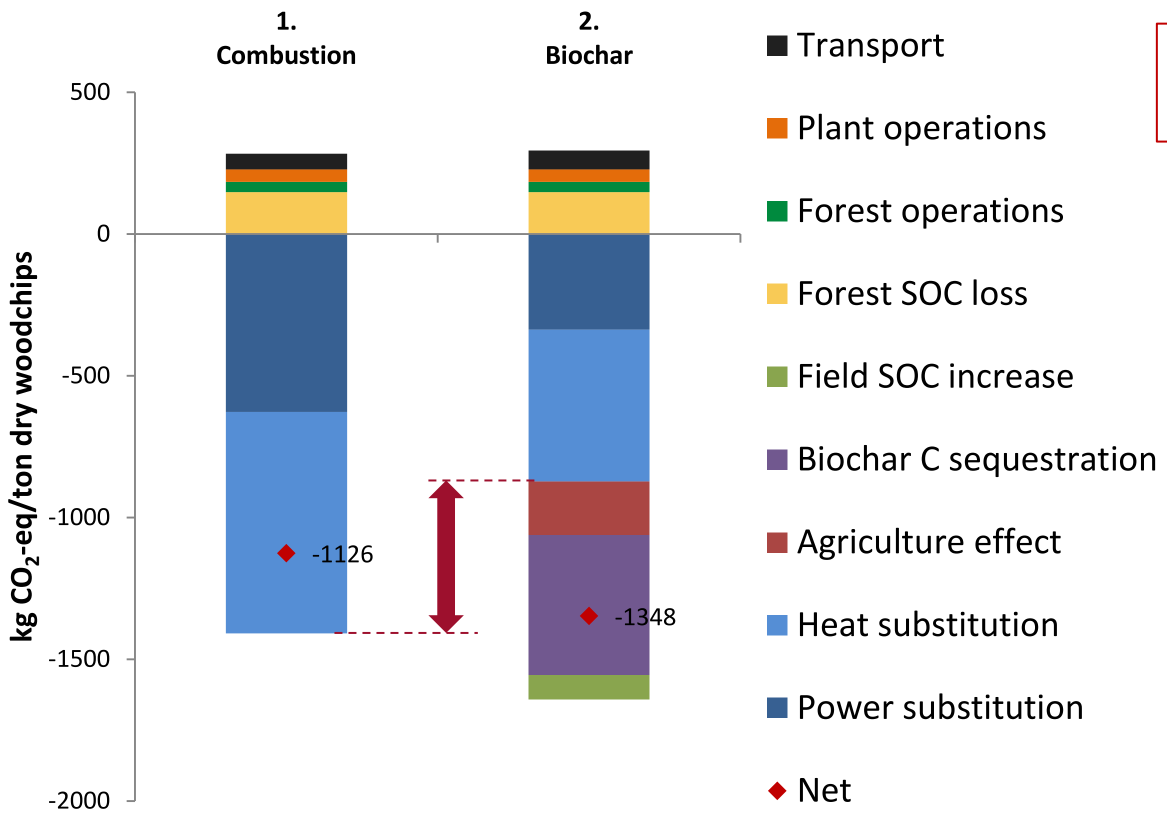
CHP from Natural Gas

Energy Penalty

~ 540 kg $CO_{2\text{-eq}}$/ton woodchips

Is the biochar use compensating the energy penalty?

Climate impact *after biochar use*



Biochar use phase

~ 770 kg $CO_{2\text{-eq}}$/ton woodchips

25%

CH_4 , N_2O

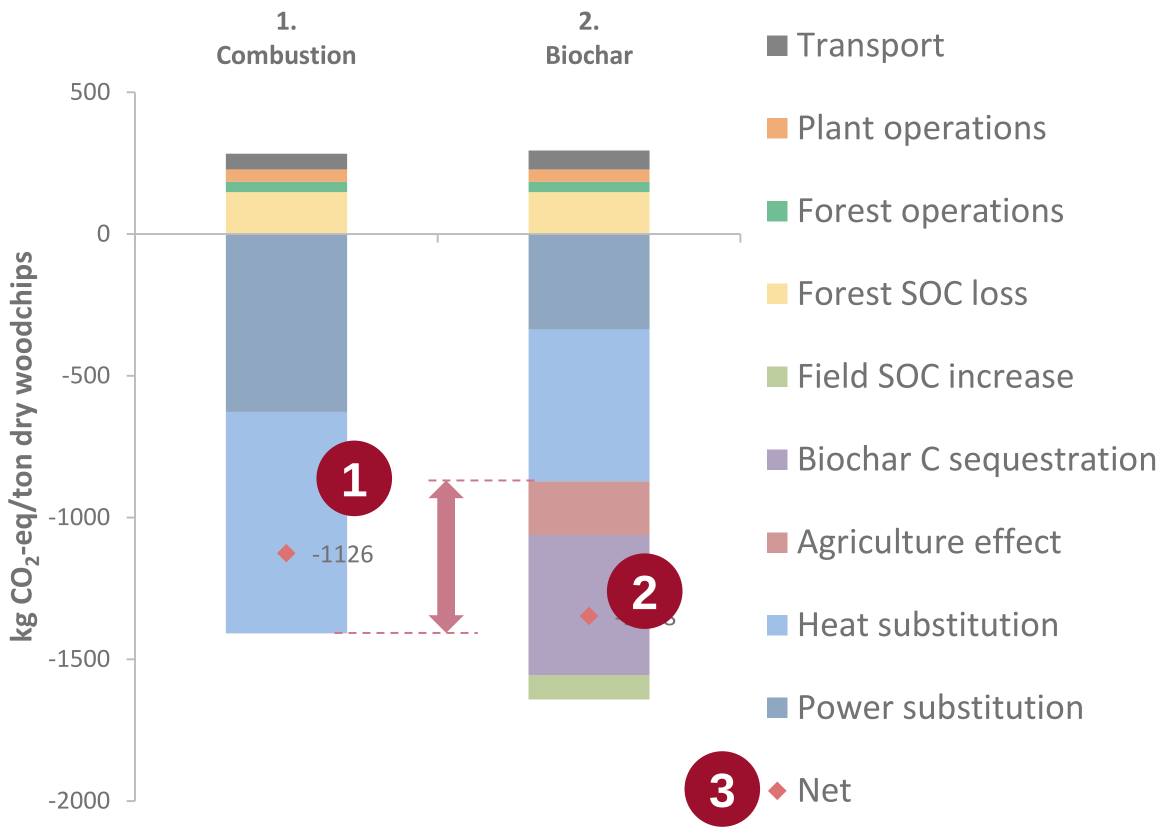
64%

CO_2

11%

CO_2

So what? Life-cycle interpretation

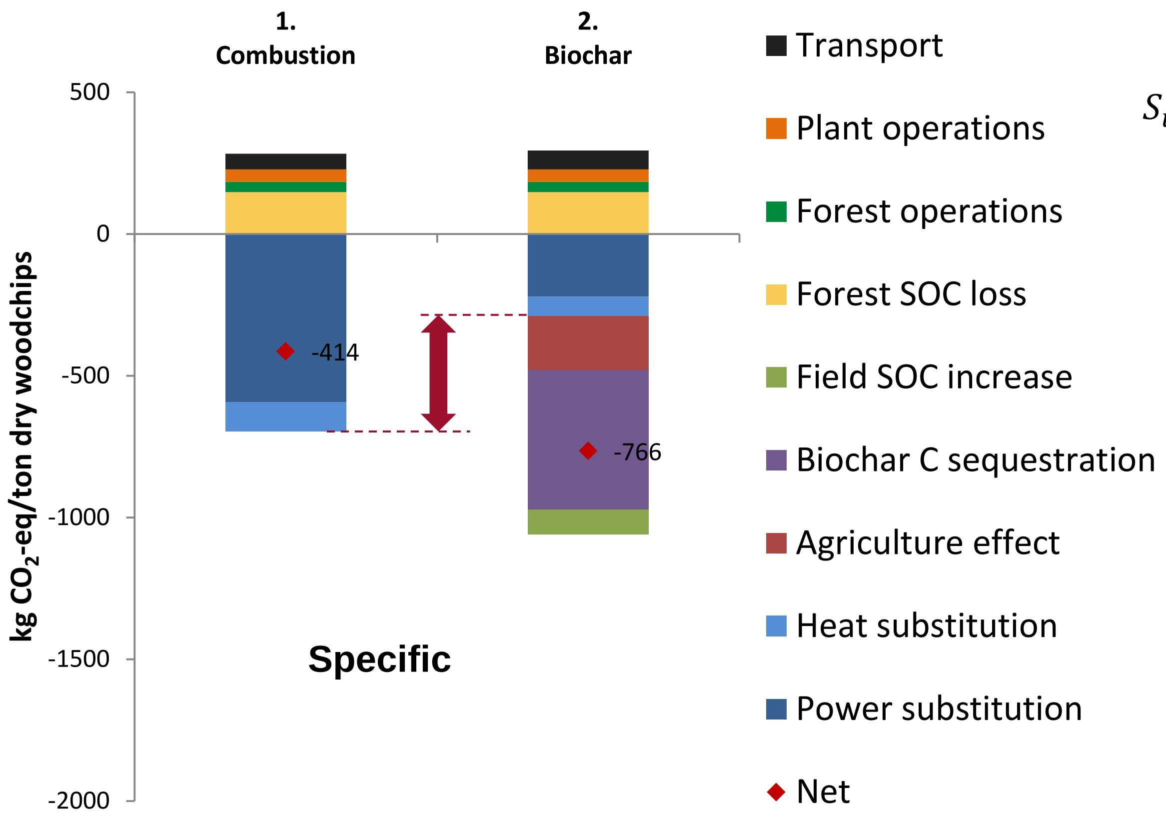


1 **Methodological choices**
How is the penalty affected by choices?

2 **Uncertainty**
How certain are the biochar effects?

3 **Sensitivity**
What if key parameters are changed?

(1) Specific energy substitution



$$S_i = U_0 \times \eta_i \times EF_i$$

$$S_i = U_0 \times \eta_i \times \left[(1 - \alpha_i) \times EF_{i,h} + \alpha_i \times EF_{i,p} \right]$$

How is Stockholm's energy system responding to a change in production? Which fuels are replaced?

$$S_i = \sum (\Delta C_{fuel} \times EF_{fuel}) + \Delta C_p \times EF_p$$

Energy Penalty

~410 kg CO_2/ton woodchips

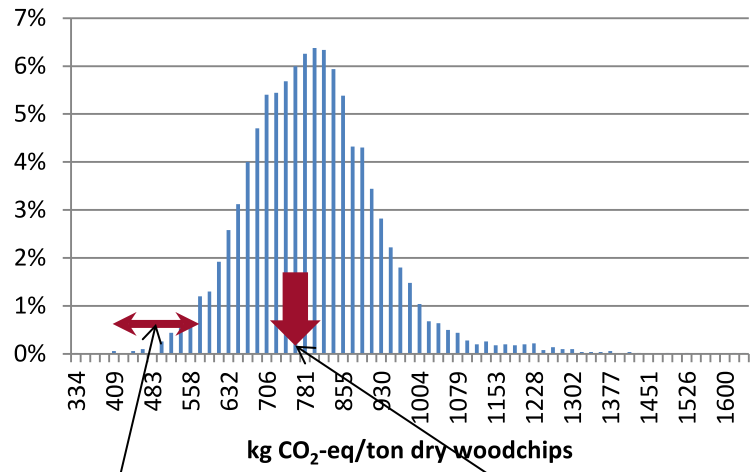
Power-dominated penalty

(2) Biochar effects are uncertain

List of Random Variables

	Variable	Value	a/mean	b/stdev	Distribution	Mean
1	r.ent.CH4	3%	0,00	0,05	uniform	2,5%
2	r.sto.CH4	11%	0,00	0,25	uniform	12,5%
3	r.sto.vol.NH4	16%	0,00	0,25		12,5%
4	r.sto.N2O.d	6%	0,00	0,25		12,5%
5	r.sld.vol.NH4	5%	0,00	0,60	uniform	30,0%
6	r.sld.lea.NO3	58%	0,00	0,60	uniform	30,0%
7	r.sld.N2O.d	77%	0,15	0,30	*normal*	
8	r.mld.vol.NH4	42%	0,00	0,60	uniform	30,0%
9	r.mld.lea.NO3	53%	0,00	0,60	uniform	30,0%
10	r.mld.N2O.d	-7%	0,15	0,30	*normal*	
11	r.soil.CH4	*-48%*	*-0,50*	*0,00*	uniform	-25,0%
12	ar.feed	*0,17*	0,00	0,24	uniform	0,12
13	ar.mixing	*0,02*	0,00	0,06	uniform	0,030
14	SOC.decay	*3,9%*	0,00	0,10	uniform	5,0%
15	SOC.input	*4,5%*	0,00	0,10	uniform	5,0%
16	BC.stability	*82%*	0,7	0,9	uniform	80,0%

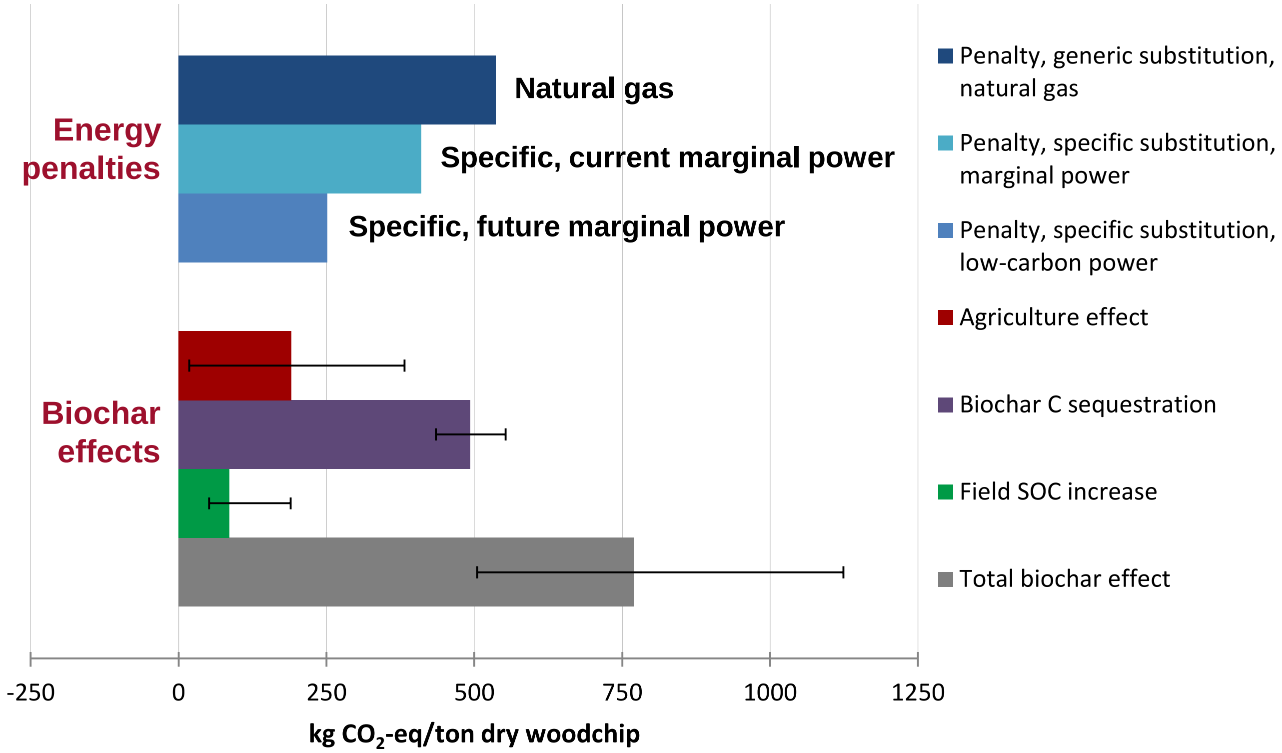
Monte-Carlo simulation provides a range of likely values around the ”best guess”.



Energy penalty range

Average use phase under many assumptions

Two kinds of biochar systems



1 Biochar system in a fossil reference

Penalty and Carbon sequestration are of same order of magnitude.

Agricultural effects are necessary to overcome penalty, but uncertainties are large.

2 "Ideal" biochar system

With a low-carbon power, agricultural effects alone could overcome the energy penalty.

Carbon sequestration then becomes an actual benefit

Conclusions

The ***climate suitability*** *of "using woodchips for biochar" is function of*

(i) Background energy system

(ii) Performance of biochar in the field

In this study, this energy context, this biochar use and our assumptions:

(i) Energy penalty: 400-500 kg CO_2-eq/ton woodchips, dominated by the fate of power production

(ii) Biochar in the field: 770 kg CO_2-eq/ton woodchips, but very uncertain, exploratory rather than predictive, require manure-related experiments and long-term carbon monitoring

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Summer Nights, Eugene Jansson, 1898