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Ecosystem recovery promoting biocovers for mining sites

Mobile manufactured biochar in mine closure, costly yet carbon negative

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Mobile-manufactured biochar in mine closure, costly yet carbon-negative – A techno-economic and life cycle assessment of growing media value chains

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ABSTRACT

This concept case explored a circular bioeconomy-based value chain to produce new high-quality growing media to be used in mine closures. Our specific interest was in the production of biochar from waste wood using the mobile pyrolysis unit and use of biochar as a supplement in mine closure growing media. A life cycle costing (LCC) and environmental impact assessment (LCA) was conducted for the production and value chain of four different growing media solutions based on mixtures of composted sewage sludge (COM), fly ash (ASH), peat, till, and waste-wood-based biochar (BC).

The application of wood waste biochar to compost-till growing media (10 % by volume) increased the costs by 51–71 % (BC-COM-TILL, €28.60 m^{-3}). The most affordable scenario was based on compost, ash and till (€16.76 m^{-3}). Environmental impacts were acknowledged in the costs according to their carbon dioxide equivalent (CO_2eq) emissions assessed in LCA (€52.56 CO_2eq t^{-1}). Accounting for the long-term carbon storage capabilities of the materials, the emissions were highest in peat and till based solution (74.7 kg CO_2eq m^{-3}), and lowest in the most expensive solution with biochar (-49.7 kg CO_2eq m^{-3}). The biochar-based solution turned into a carbon sink with negative CO_2eq emissions.

The study 1) highlighted the lower emissions of growing medias based on circular bioeconomy-based solutions compared to peat used in the traditional growing media solution; 2) showed that the climate emissions of biochar-based growing media were negative; 3) indicated that the price of biochar-based growing media was high, while suggestions were made to moderate the cost. The positive effects of biochar on the plant growth in mine areas have been documented elsewhere, but not acknowledged in this study's environmental or economic results.

1. Introduction

The green transition to an economy independent of fossil fuels triggers ore resource mining. In 2023, the European Commission released its proposal for a new EU raw materials initiative, known as the Critical Raw Materials Act (CRMA) (European Commission, 2024). Strategic raw materials are essential for example for the green transition, digitalization and defense industry needs. The target includes opening new mines across Europe and extracting minerals from the waste of decommissioned mines. Due to the geological features of Nordic regions, there is a high prospectivity potential for critical raw materials. For example, Finland's mineral deposits make it the world's 13th most attractive country (1st in Europe) for mining investments (Yunis and Aliakbari, 2021). Currently, 44 mines operate in Finland, producing over 100 million tons of waste rocks and tailings that need enclosure annually (Kaivosteollisuus, 2022). Similar increasing mining activity trends have been reported in other northern latitude countries like Sweden and Canada, as well as globally (Yunis and Aliakbari, 2021).

Coinciding with increasing metal demand, the EU is committed to energy saving and a reduction of greenhouse gas (GHG) emissions by at least 55 % by 2030 from 1990 levels (European Commission, 2019). EU policy therefore encourages member states to adopt a circular economy,

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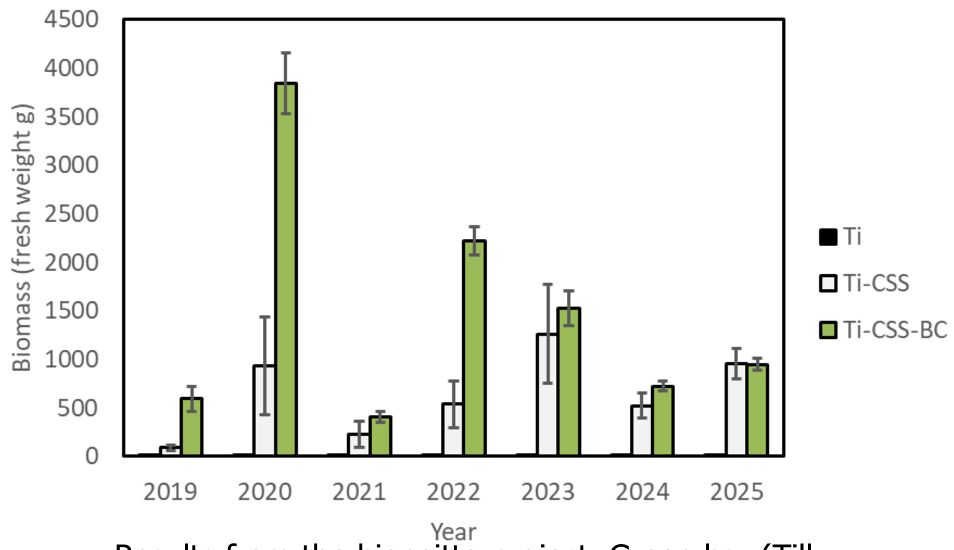
Background

Biochar has shown to increase plant growth substantially in central Lapland mining area.

Thus, it is an attractive component for future mine closure solutions.

The results presented are part of the Biopeitto projects. The projects are focused on establishing a value chain to implement a biocover solution for a mining site in Lapland, with a specific interest in using biochar derived from waste wood as a growing medium supplement.

In addition to growth benefits, biochar can have environmental advantages in carbon sequestration, of which economic benefits are also evaluated in this study.



Results from the biopeitto-project. Green bar (Till, Compost, Biochar) includes biochar application.

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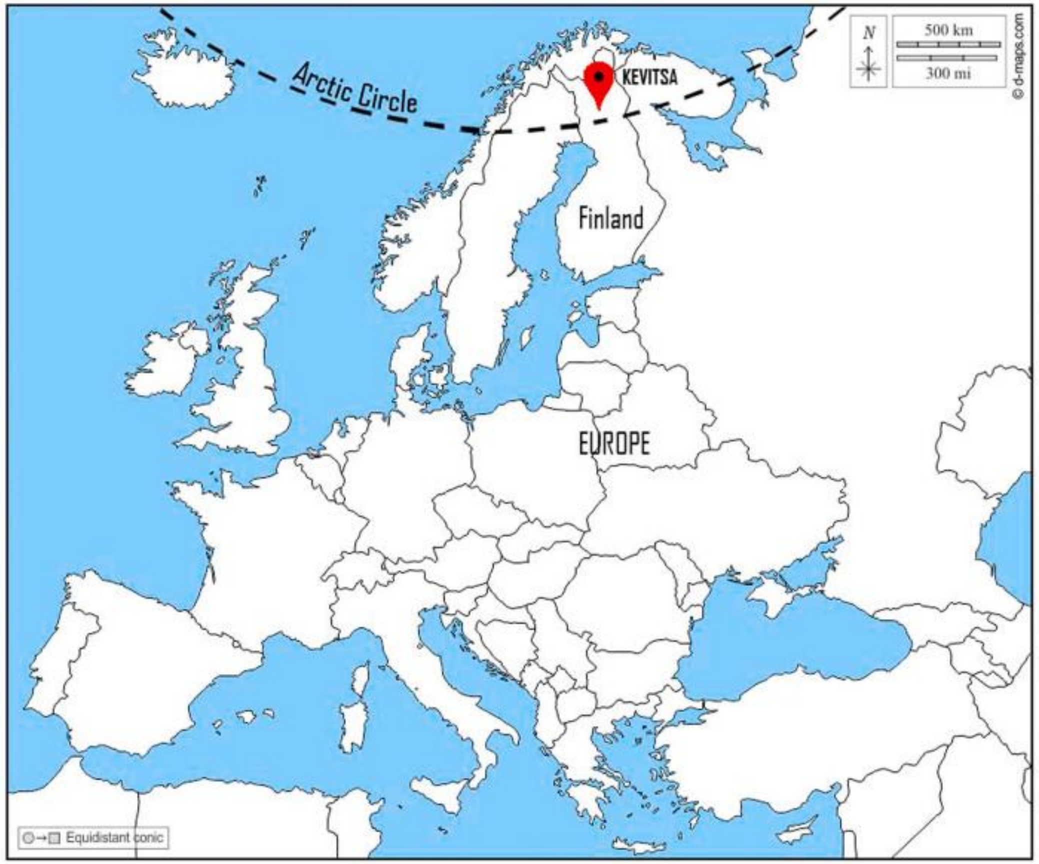
Study is based on the case conceptualized for rehabilitation of Kevitsa mining site in Biopeitto-project

A life cycle costing (LCC) and life cycle assessment (LCA) were undertaken to evaluate the production processes and value chains of four growing media scenarios:

(i) COM-TILL: 50 % till and 50 % composted sewage sludge
(ii) COM-ASH-TILL: 50 % till, and 50 % composted sewage sludge and fly ash (3 ‰)
(iii) COM-BC-TILL: 50 % till, 40 % composted sewage sludge, and 10 % waste wood-based biochar
(iv) PEAT-TILL: 50 % peat, and 50 % till.



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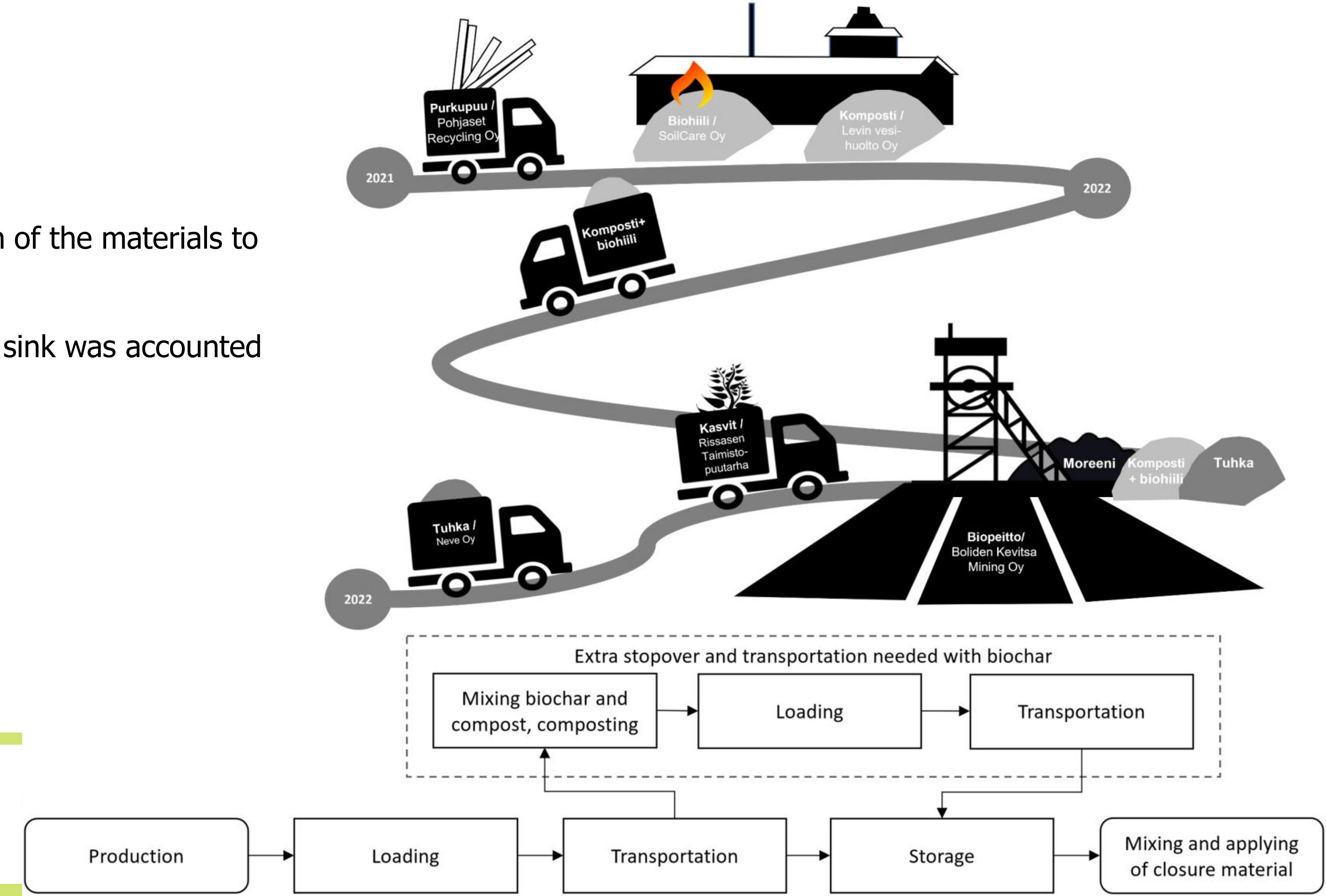
Study is based on the case conceptualized for rehabilitation of Kevitsa mining site in Biopeitto-project

Value chain covered the stages from production of the materials to applying the growing media on the mining site.

The CO2e emissions or compensation from the sink was accounted in the economic analysis (52.56 €/CO2eq t).



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Biochar production and value chain in COM-BC-TILL scenario

* there is a minor inconsistency in E-LCA: emissions were estimated based on an electric shredder, while costs were calculated using a fuel-powered shredder.

1. Raw material, Waste wood 2. Pre-shredding* 3. Storage

4. Loading the pyrolysis retort

5. Biochar pyrolysis
AMACEE 1700,
Soil Care Oy

Cycle time 12 h
(550–600 ◦c).

Capacity 5 m3 of biochar per cycle with 6.5 m3 of wood as input.

By-products are tar and wood vinegar

6. Biochar after pyrolysis 7. Post-shredding* 8. Transportation to composting sit
to be mixed with waste water sludge compost. And then some storing,
Loading and transportation, and mixing of growing media material components.

Biochar production and value chain in COM-BC-TILL scenario

Finally, the chain lead to an applied growing media in mining site, which was the end of our LCA and LCC boundaries in each scenarios.

And what's the catch. Well, 80 % of biochar is considered permanent (or long term) carbon storage. Using biochar in growing media acts as a carbon sink. Our goal was to incorporate also this emission/sink effect on the economic analysis.

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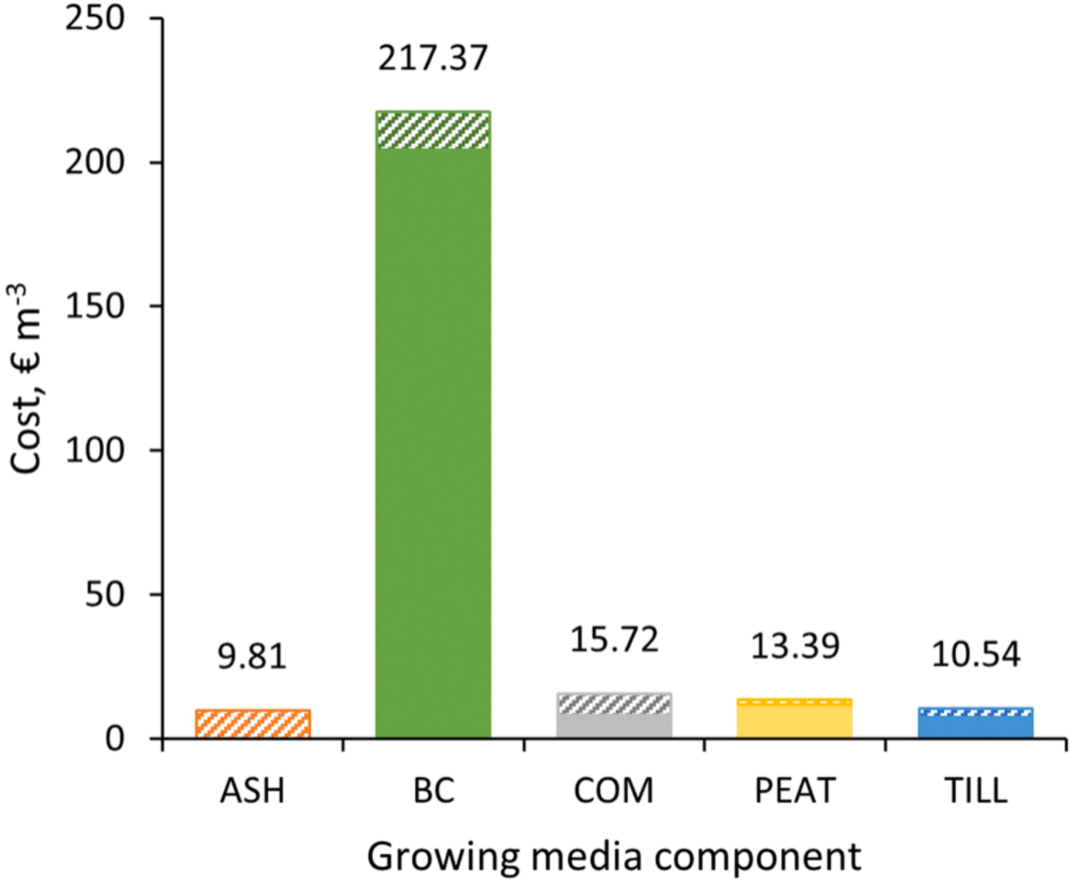
Production and transportation costs of the different growing media components delivered to the mining site



Biochar (by volume) is multiple times more expensive material than any of the alternatives analyzed.

Ash was the most affordable of the materials (Production of ash was considered free because it is waste or side stream material, thus the costs are formed only by loading and transportation)

Solid color in a bar represents production costs; hatched pattern, transportation or loading costs. Ash had no production costs, so the column has only hatched pattern (BC = biochar, COM = compost)

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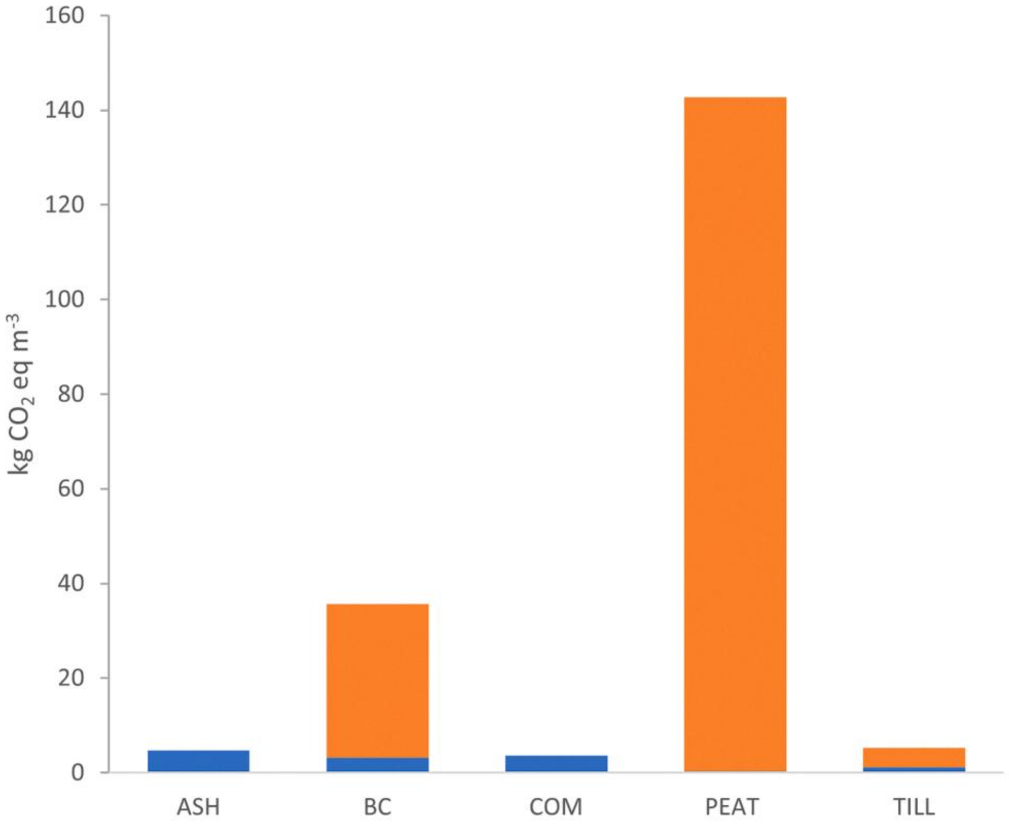
Emissions from production and transportation of different growing media components
(decomposition or sequestration in the field not included)



Production (or extraction) of peat caused the highest emissions of the different material components.

Production of biochar had the second highest emissions. However, these figures do not include the carbon sequestration potential of biochar, only production and delivery emissions.

Orange bars represent production emissions; blue represents emissions of transportation to the mine. (BC = biochar, COM = compost)

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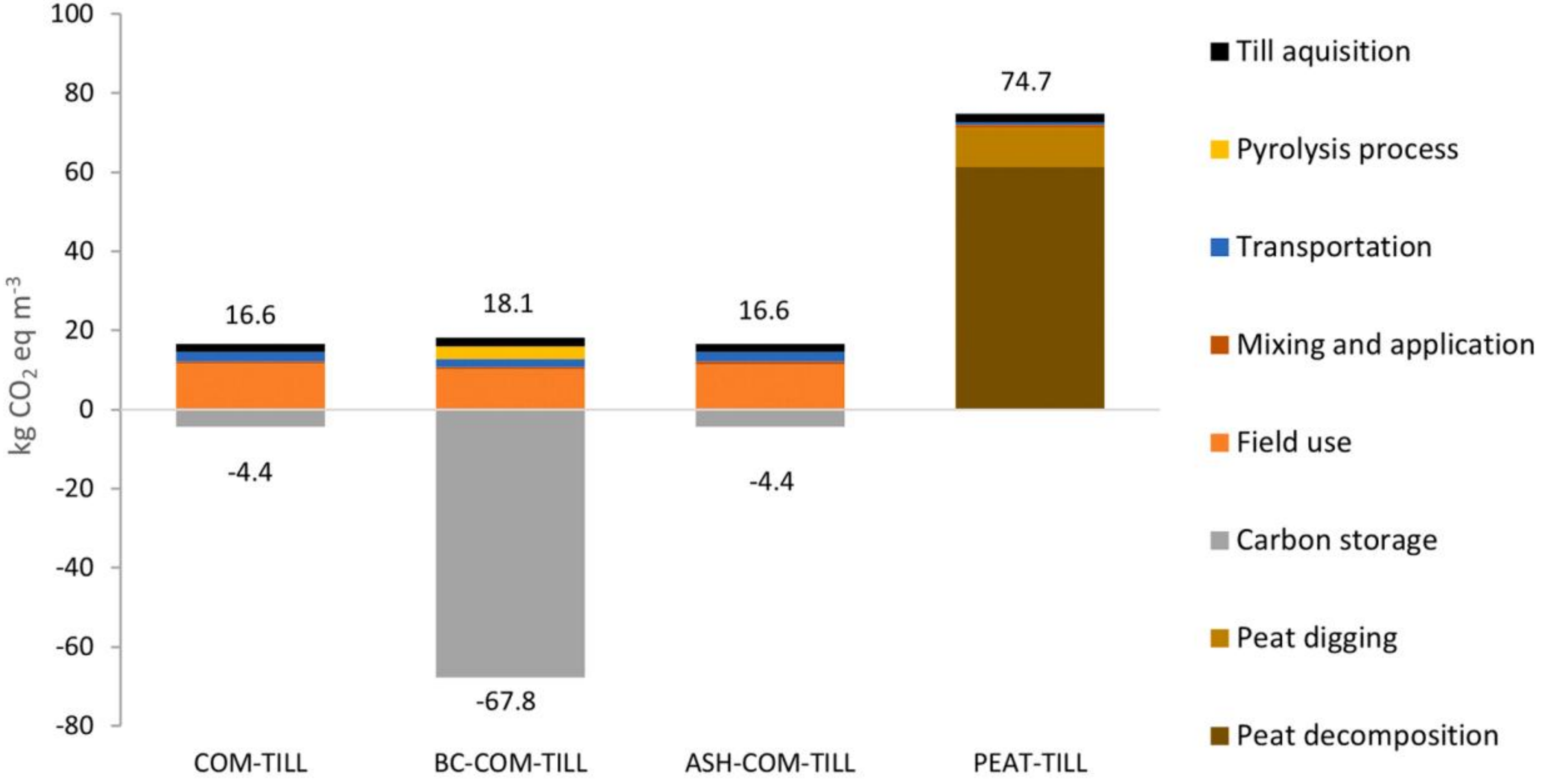
Total emissions and sequestration from mining closure scenarios



80 % of carbon in biochar was considered permanent
5 % of carbon in compost was considered permanent

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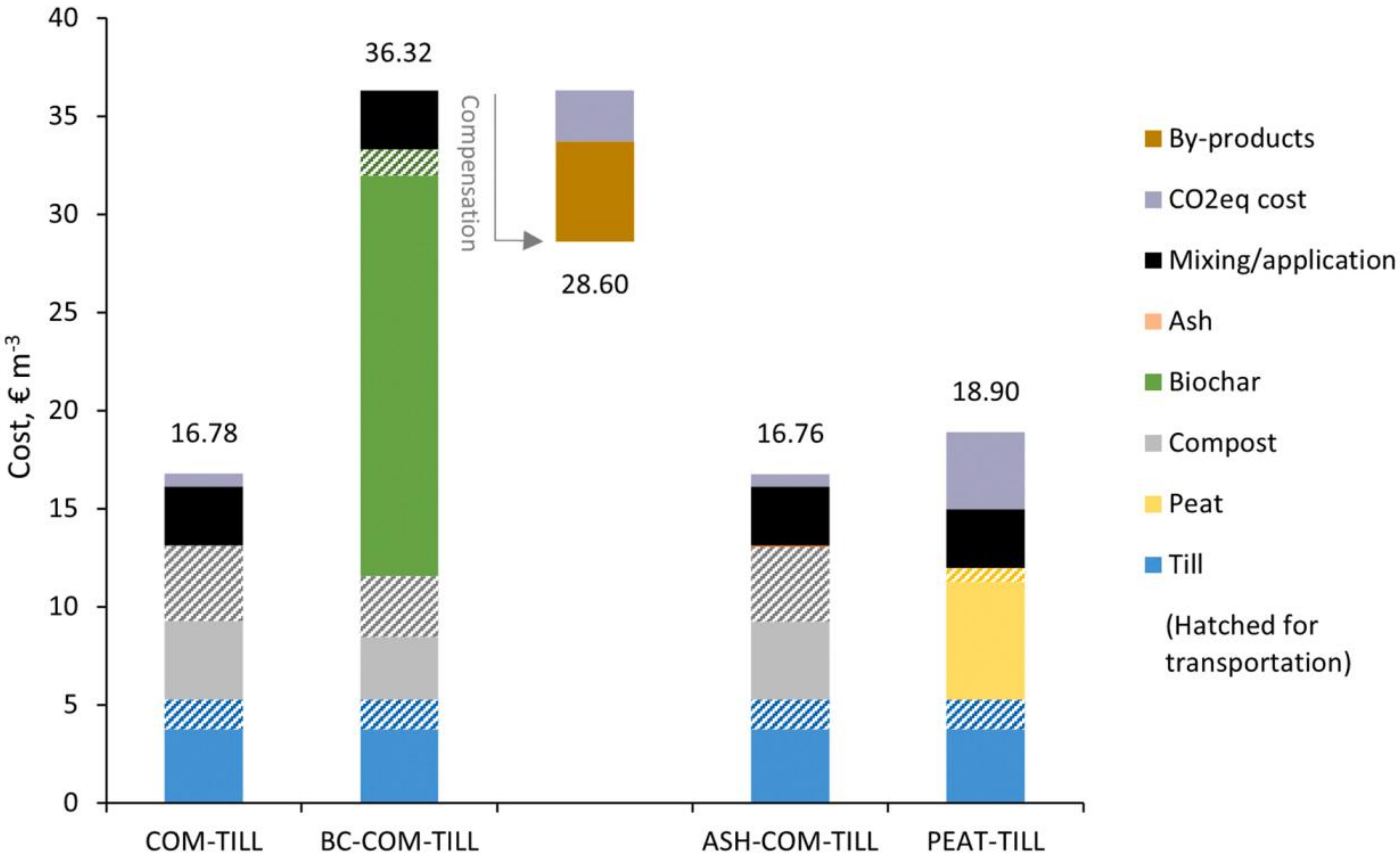
Costs of mining closure scenarios



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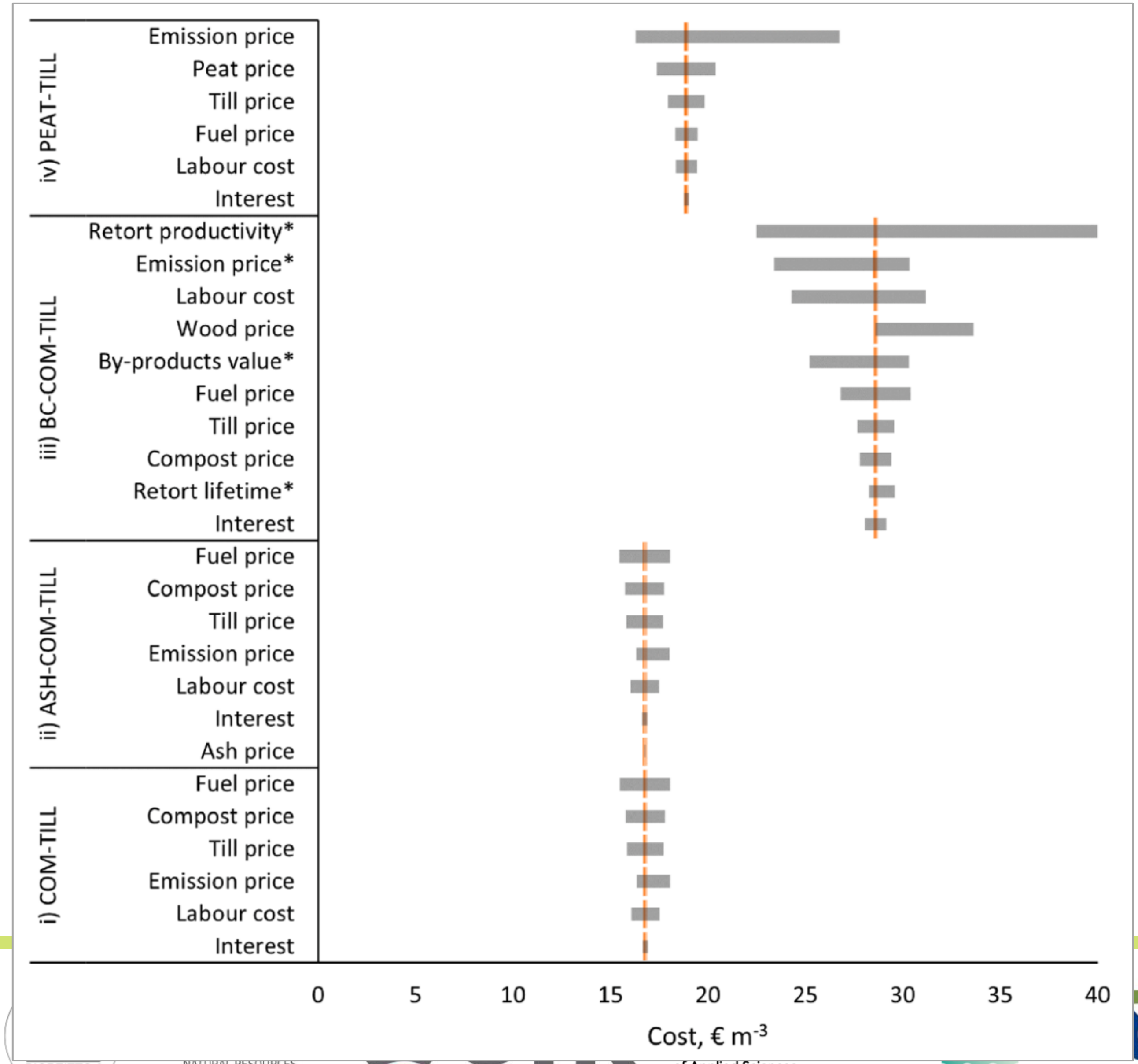
Sensitivity analysis of costs

Parameter	Low	Base	High
Ash, € m^{-3}		**0**	10
Compost price, € m^{-3}	6	**8**	10
Crude Oil, € l^{-1}	0.47	**0.94**	1.41
Diesel, € l^{-1}	0.73	**1.46**	2.19
Electricity, € kWh^{-1}		**0.0877**	
Emissions, € CO2e t^{-1}	17.52	**52.56**	157.68
Employee cost, € h^{-1}	20.49	**27.32**	34.15
Interest, %	3	**5**	7
Wood vinegar, € l^{-1}	0.15	**0.30**	0.45
Peat, € m^{-3}	9	**12**	15
Propane, € kg^{-1}		**2.50**	
Retort lifetime, years	6	**8**	10
Retort productivity, m^3 $year^{-1}$	425	**850**	1275
Tar, € l^{-1}	1.50	**3.00**	4.50
Till price, € m^{-3}	5.63	**7.50**	9.38
Water, € m^{-3}		**5.12**	
Wood, € m^{-3}		**0**	30



High price for emissions, especially combined with higher productivity of the retort and lower labor costs can lead to BC-COM-TILL scenario being more affordable than PEAT-TILL.

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Conclusions & implications

Circular-bioeconomy-based mine closure solutions generate lower emissions compared to peat, traditionally used as a growing media material. By replacing peat use with composted sewage sludge CO2eq emissions lowered by 84 %.

From the climate emissions perspective, the growing media containing biochar and compost became a carbon sink. However, biochar induced climate benefit was realized with c.a. 10 € additional price per m^3 compared to the other growing medias.

Mobile biochar manufacturing was costly, and production can be less expensive in large-scale fixed facilities (Shabangu et al. 2014 and Hakala et al. 2020), especially when surplus energy will be utilized.

- Biochar is relatively affordable to transport, for that reason economies of scale of the facility may be more important than savings in transportation.
- Large facility with abundant feedstock might be better than localized production.

However, also the mobile manufacturing process can be still streamlined and made more efficient. For example, A modified version of the studied retort has been later developed to utilize surplus energy (even though benefits might not be as high as in large scale facility).

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Thank you

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