How to establish a market for carbon capture and storage with biochar in Denmark?

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Nordic Biochar Network Webinar
24th of May, 2024

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Agenda

1. The CIP Foundation and biochar
2. Status on biochar and market drivers
3. Elements in establishing a market for biochar
   - Technology
   - Feedstock
   - Payment for carbon storage
   - Regulations
   - Demand for biochar
   - Socio-economic value
   - Knowledge and research
   - Perception and acceptance
4. Recent developments and the next steps?
5. Questions?

The CIP Foundation's publications on carbon storage with biochar

Link to the video

Part I: the CIP Foundation and its work on biochar

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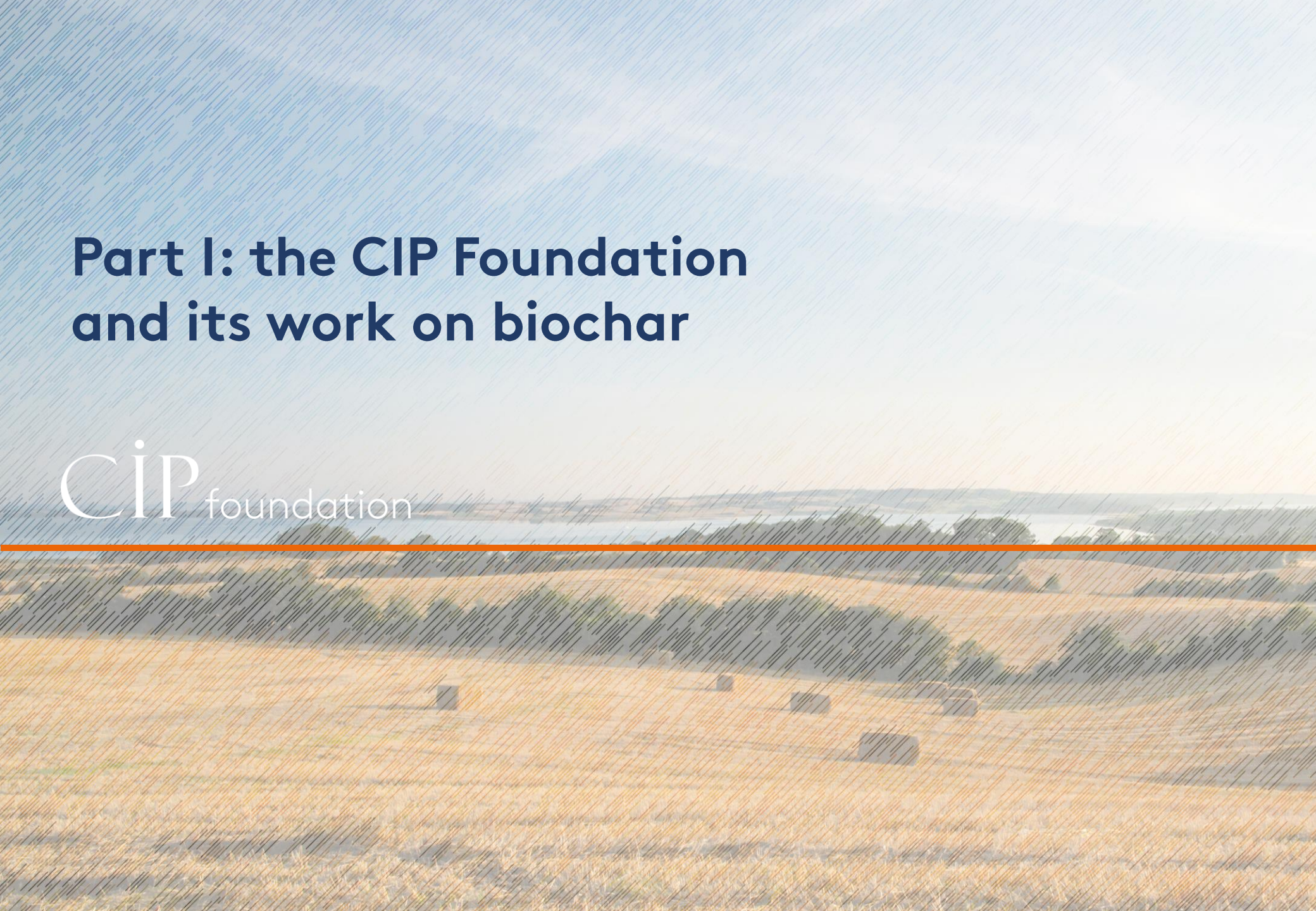


What is the CIP Foundation?

The CIP Foundation is a non-for-profit foundation working with **climate and sustainability projects**, that provide long-term and action-oriented solutions to structural challenges for the Danish society.

The board of the CIP Foundation

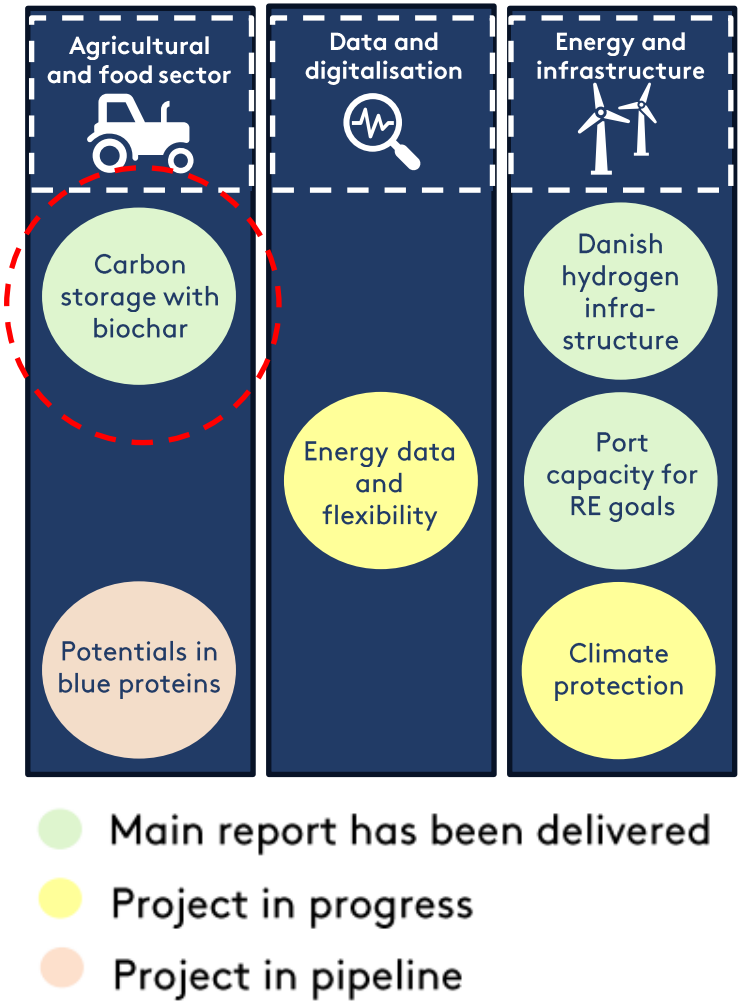
The CIP Foundation's purpose is to identify areas for necessary societal changes and through knowledge-based and investigative projects come up with concrete proposals on how to solve the challenges and demonstrate how how they can be realized and financed.

The CIP Foundation's projects must supply solutions that:

- Support the transition to a CO_2-neutral society
- Form long-term, sustainable solutions for future generations
- Bring societal value
- Create export potential for Danish companies

The CIP Foundation is **financed** by Copenhagen Infrastructure Partners (CIP) and about 20 member companies.

The CIP Foundation works within three pillars



Why work with biochar and how did we go about it?

Motivation

§ The Danish Climate Act requires Denmark to bring down emissions by 70% in 2030 compared to 1990.

Specific target for agriculture in 2030: 55-65% reduction or 6.1-8 Mt of CO_2e.

The Agricultural Agreement (2021) delivered 2.4 Mt reduced emissions costing > 3 bill. DKK

Ambition of 2 Mt from biochar in 2030 (technological potential)

What did the CIP Foundation do?

- An **in-depth investigation** into biochar production from pyrolysis as a method of carbon storage and climate mitigation.
- Test the foundation for **market-driven negative emissions** from agriculture utilizing biomass waste products like straw residues and digestate.
- Demonstrate **co-benefits** and the **competitiveness** of biochar as a Carbon Dioxide Removal (CDR) technology.
- Involve experts from academia, companies and authorities.

What did we examine?

Relevant **feedstocks**

Climate effects of biochar

Business case and income flows in the value chain

Climate credits – how to document and trade carbon storage in the form of biochar?

Relevant **value chains,** co-locations, owner ship structures and potential business models

Regulatory barriers and opportunities

Side effects of using biochar on agricultural land

International trends and other countries' approaches

Societal abatement costs

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Part II: Status on biochar and the main drivers

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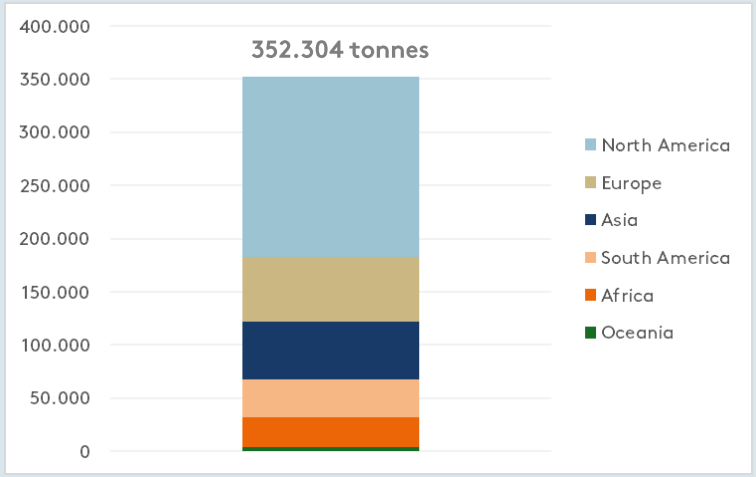
Global biochar production

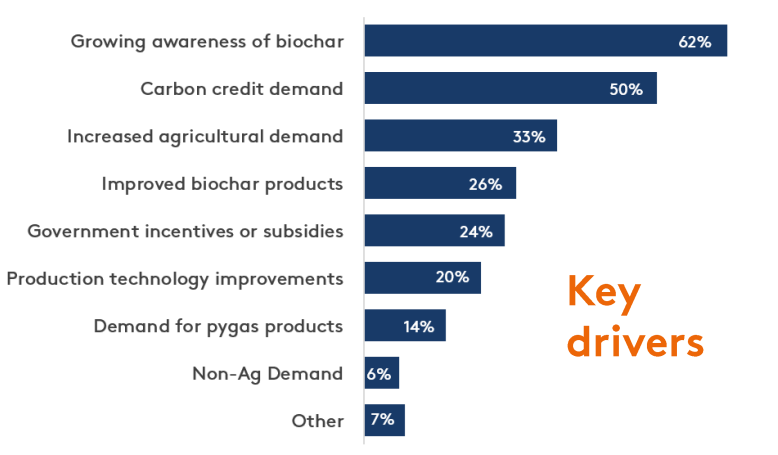
Total biochar production in the world (2023)

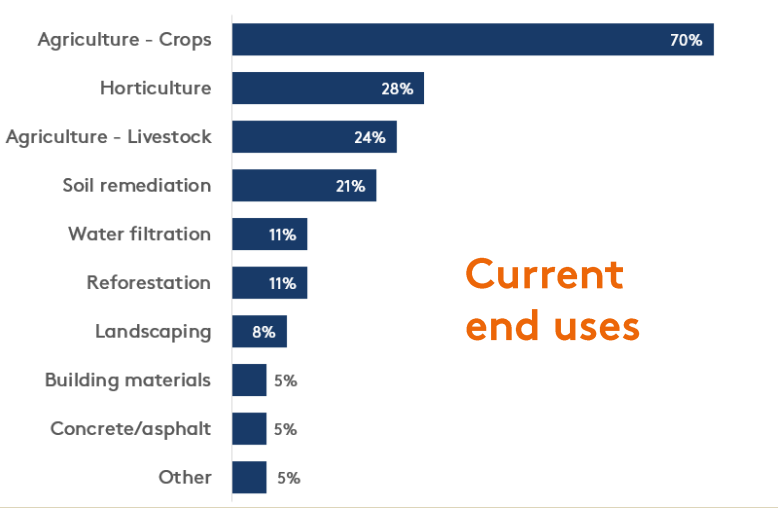


Source: IBI (2024), "Global Biochar Market Report 2023"

- North America is the world's largest producer of biochar followed by Europe and Asia.
- The numbers for Europe seem a bit underestimated compared to EBI data.
- Uncertainty about the size of production in China.

Survey on biochar 2023





Source: IBI (2024), "Global Biochar Market Report 2023"

What is happening in the EU in relation to biochar?

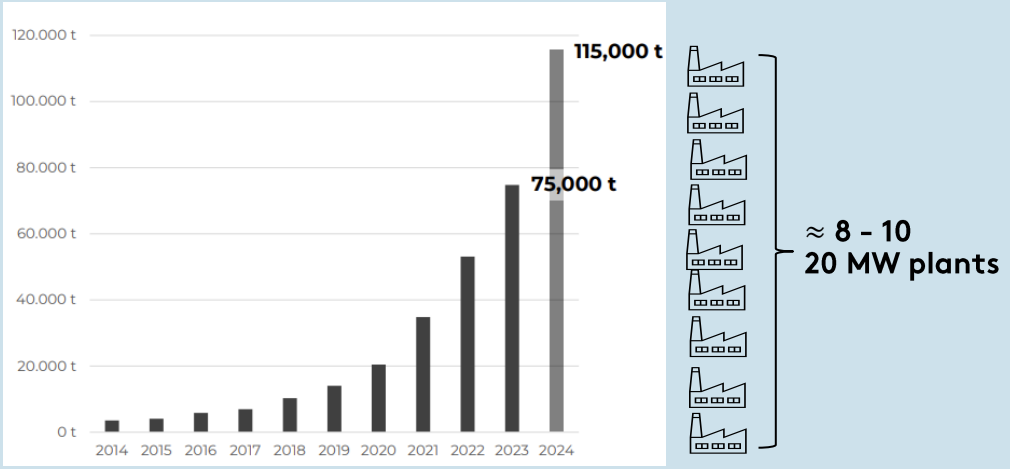
EU Carbon Dioxid Removal Framework (CDRF)

- Carbon removals must contribute to EU goal of climate neutrality.
- Need for common framework for different carbon removal and storage methods.
- Develop common criteria for carbon storage certification and a common registry to promote market opportunities through greater transparency and credibility and the prevention of greenwashing.
- Various carbon removal methods are categorized after permanence of the carbon storage.
- The work in the expert group continues until 2028.

Revised EU Fertilizer Act 2022

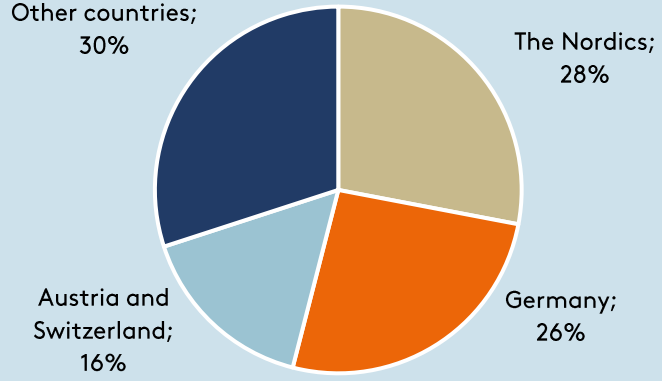
- Allows biochar as a fertilizer product in the EU when it is plant-based or made from animal manure.
- CE marking of biochar allows it to be marketed and traded
  - Certainty for producers - businesses know the products can be traded in the EEA without restrictions.
  - Credibility for customers - consumers enjoy the same level of health, safety, and environmental protection throughout the EEA.
  - Biochar is tested against threshold values for problematic content of e.g. PAH, heavy metals etc.
- Starting point for the regulation of several other countries.

European biochar production 2013-2023 and expected capacity end of 2024



Source: EBI (2024), "European Biochar Market Report 2023-2024" and own calculations

Production capacity of biochar in Europe, at the end of 2023

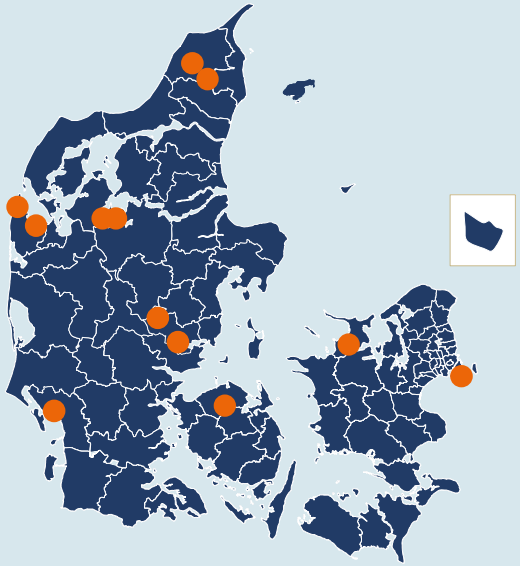


Source: EBI (2024), "European Biochar Market Report 2023-2024"

Status of the biochar production in Denmark

Facilities for biochar production in Denmark

- 12 production sites in Denmark, geographically distributed across the country.
- Different plant sizes and different types of feedstock.
- New facilities currently under construction or testing will increase capacity significantly, equivalent to roughly 45,000 tonnes CO_2e storage annually.

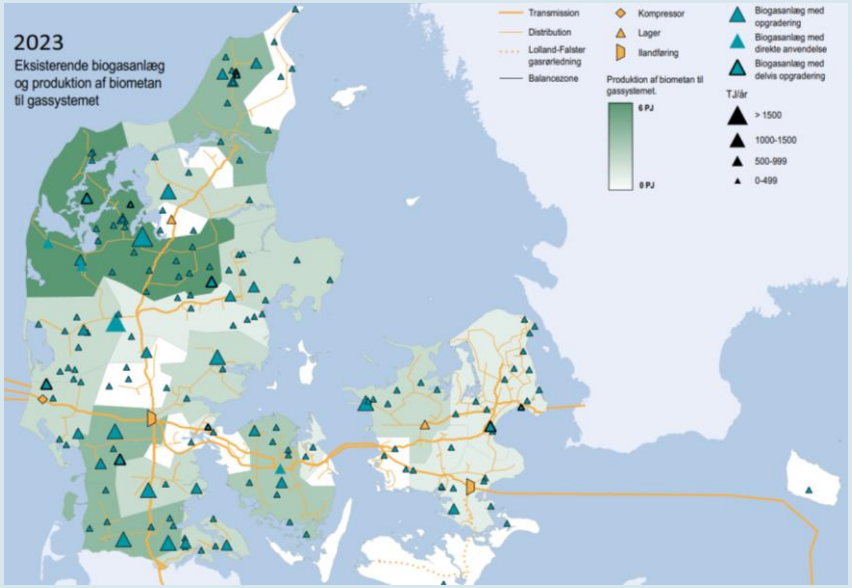


Source: The CIP Foundation (2024)

Denmark as a biochar nation?

- Danmark is not among the first nor the largest producers of biochar in Europe.
- In the process of building up an industry and a production capacity that may be in the European top.
- Process facilities of 20 MW will be among the largest in Europe.

Pyrolysis co-located with Danish biogas plants?



Note: There are approx. 190 biogas plants in Denmark, of which 101 are based on feedstock from agriculture (especially livestock manure).
Source: Danish Energy Agency

EXAMPLE:

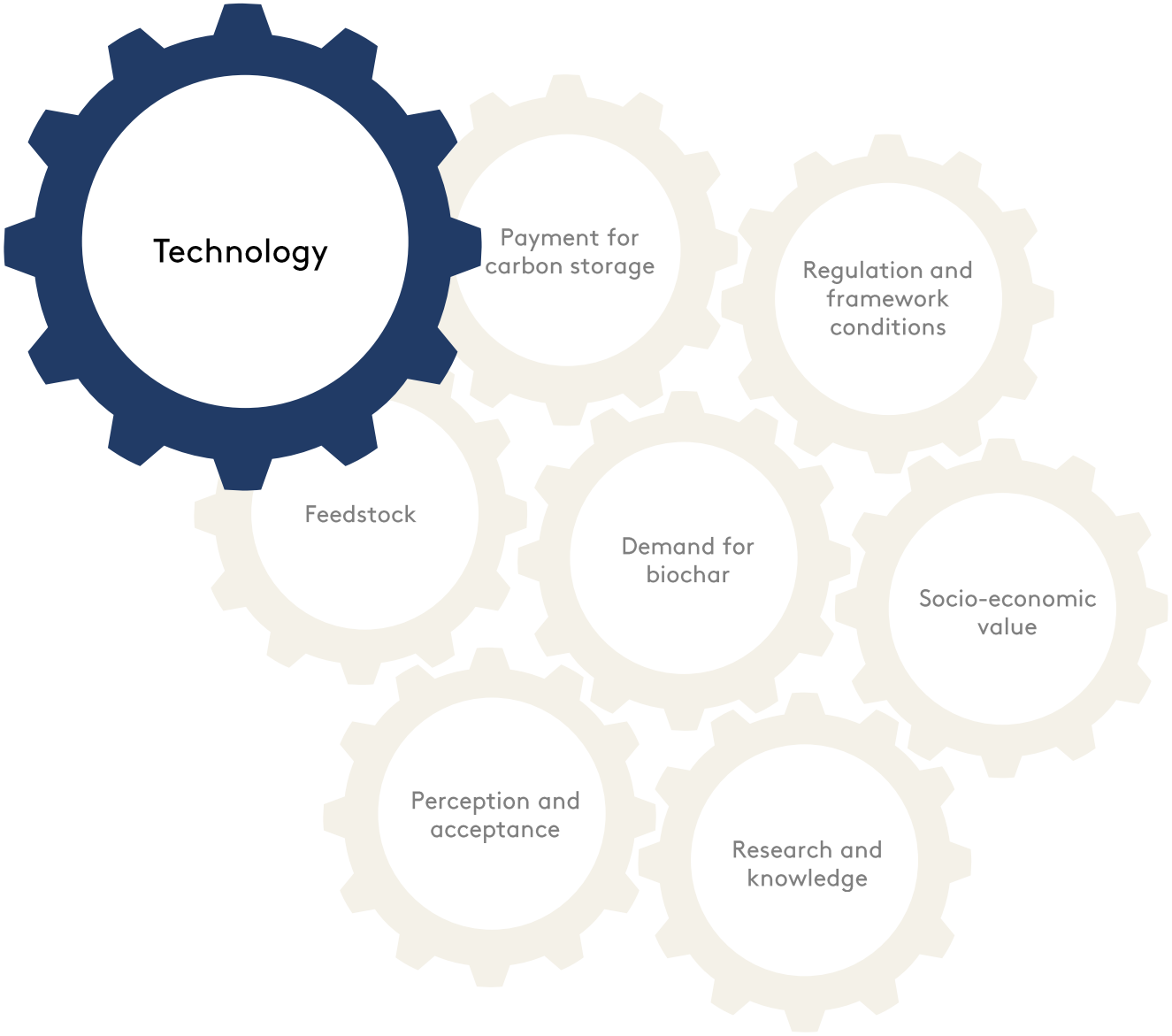
- Feedstock: residual fibres from biogas production
- Plant size: 20 MW, 28.500 tonnes of dry matter
- Depending on the method for calculating the carbon storage effect the political goal will require about **70-90** pyrolysis plants or almost one plant by every biogas plant based on feed-stock from livestock manure.
- Over time the technology and its efficiency will improve reducing the need for a built-out.

Part III: Which wheels must turn to drive the market for biochar?

Different elements are needed and must cooperate to build a market for biochar

Source: CIP Foundation

Is the technology ready, scaleable and mature enough for commercial use?

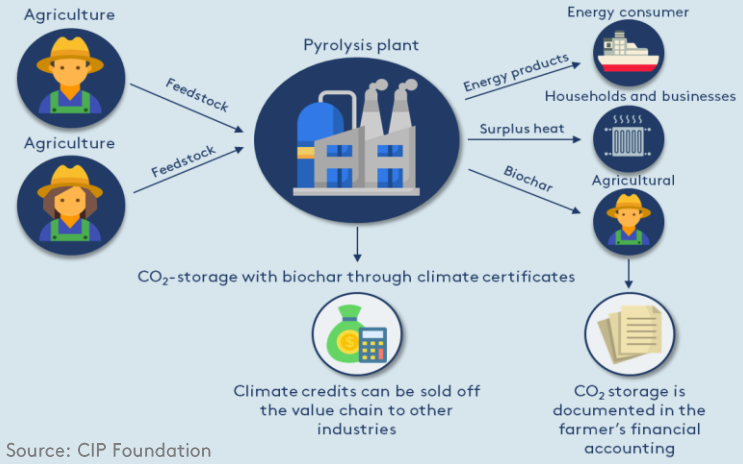


The technology is ready for commercial use and scaling

Industrialising biochar production

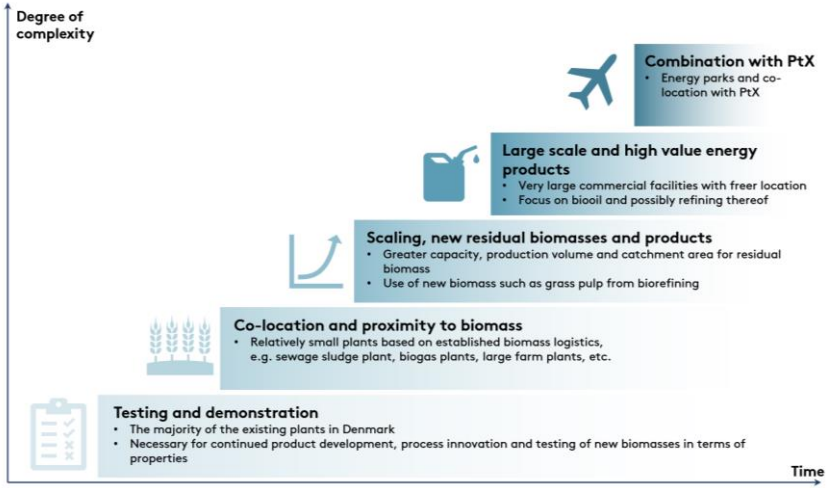
- The technology (pyrolysis) is mature for commercial use (TRL8) and scaleable. Now, it must prove its potential in reality with stable production patterns and standardization.
- Need for bringing down costs (CAPEX and OPEX) and de-risking.
- Build-out of entire value chain with sound business cases.
- Funding for plants, for carbon removal and for energy products.
- Long-term off-take agreements on both sides of the value chain

Value chain with climate credits



Source: CIP Foundation

Development of technology for pyrolysis and biochar



Source: CIP Foundation

Notice

- Collaboration across sectors – from agriculture to industry and the energy sector.
- Carbon price, e.g. through a climate credit, may affect ownership structures, financing models etc.
- Co-location benefits if situated near established logistics for feed-stock (e.g. biogas plants, bio-refinement of grass, breweries, dated heating plants, sewage sludge plants, sawmills etc.)
- Co-location is also relevant for off-take of green energy, e.g. energy-intensive production, district heating networks, refineries, energy parks, PtX production and further processing of the green energy.

What inputs are needed for biochar, and is it available in the necessary quantities?

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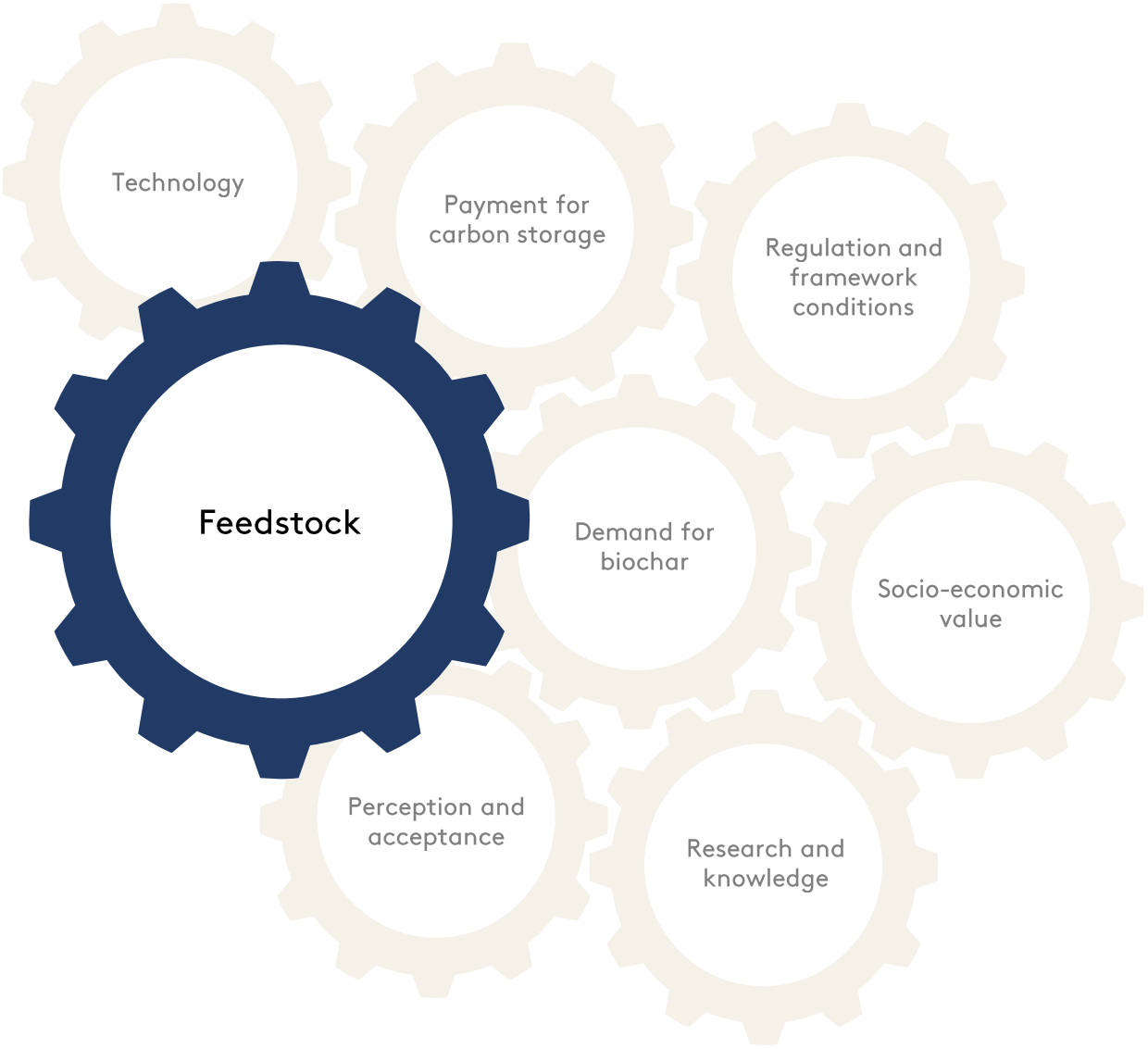
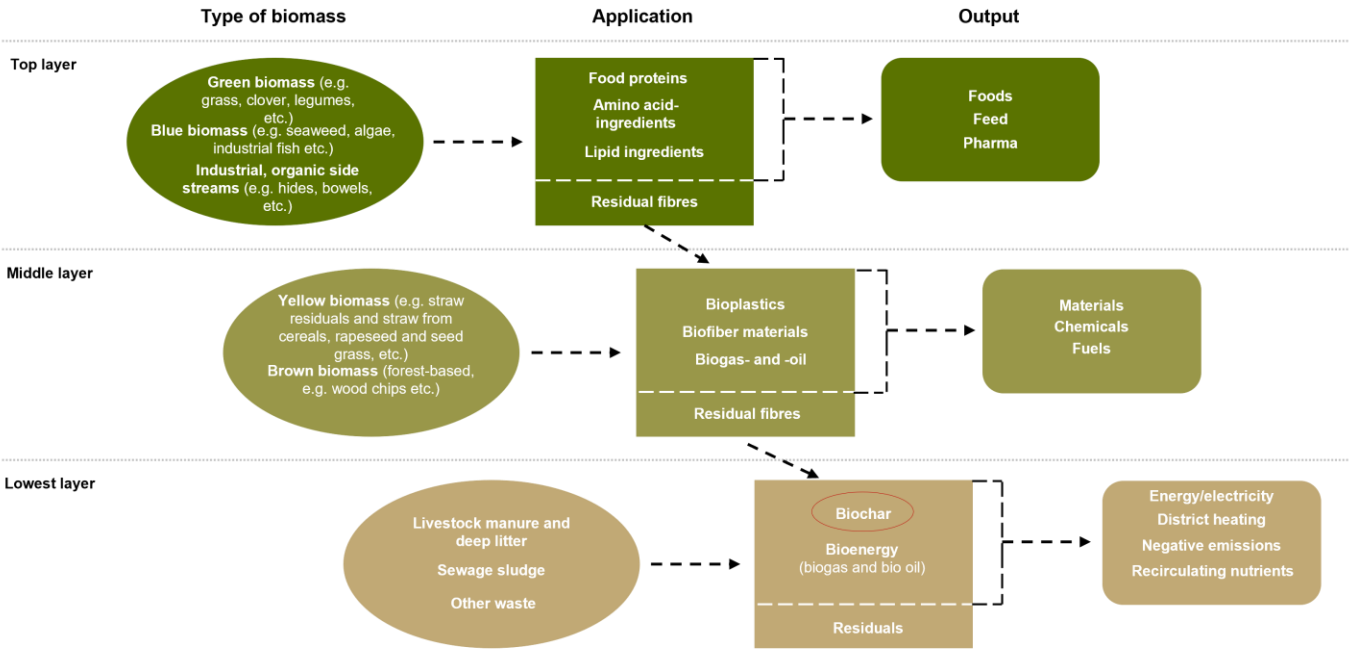


What can biochar be made from?

- ❑ Biochar is preferably made from biomass residues – from agriculture, the industry, households etc.
- ❑ Biochar is at the lowest level of a circular utilization of feedstocks based on residues with no significant market value at the bottom of a cascade use of feedstock.
- ❑ The feedstock residues gain additional value when converted to biochar as the pyrolysis process converts it into green energy and biochar with carbon storage associated with income streams.
- ❑ This encourages increased collection of the feedstock residues than otherwise (and thereby more biogenic carbon than otherwise)

Cascade use of feedstock prioritized by purpose and circular utilization



Source: CIP Foundation based on recommendations from Det Nationale Bioøkonomiske Panel, August 2022

Relevant feedstocks in Denmark (examples)

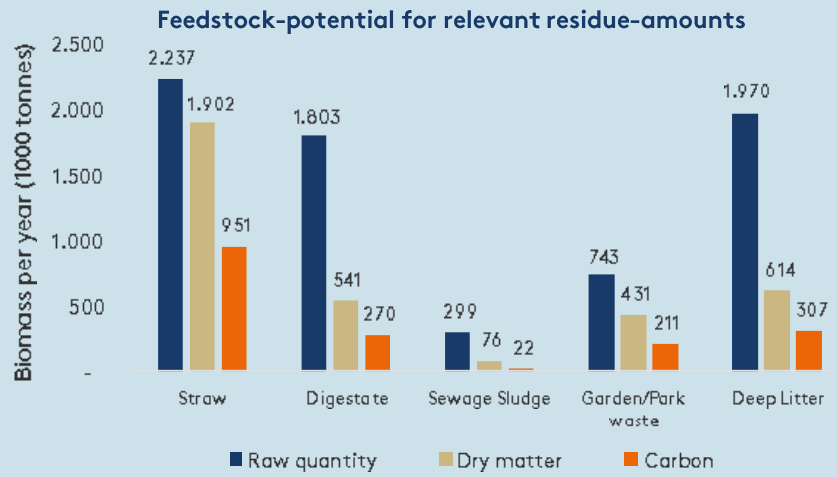
- Straw residues
- Grass (incl. roadside grass, residues from bio refinement etc.)
- Other crop residues
- Crop shears
- Livestock manure (e.g. from cattle, pigs, and chickens)
- Deep litter
- Digestate (residual fibres from biogas)
- Garden and park waste
- Wood waste
- Seaweed
- Waste from slaughterhouses
- Residual grains from breweries
- Food waste
- Sediments from street litter
- Sewage sludge

Relevant feedstocks in other countries

- Rice straw and rice hulls
- Nut shells e.g. from coconut plants
- Fibers from corn plants
- Palm leaves
- Bamboo
- Livestock manure (from sheep, chicken, cattle, pigs)
- Wood fibres, wood chips, and wood residues (e.g. pulp from paper production)

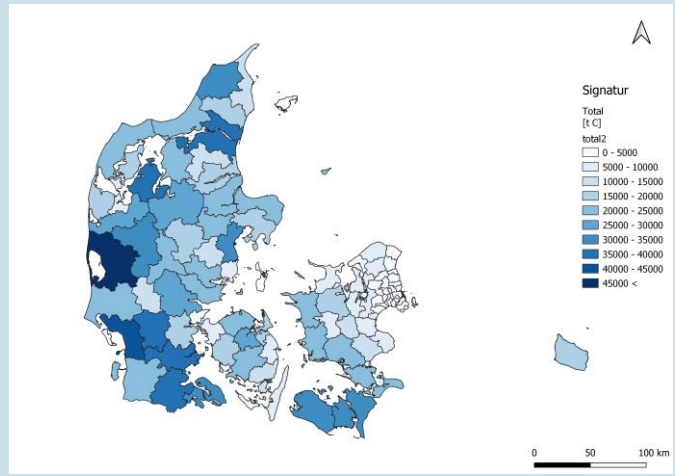
Feedstocks – relevant types, amounts, and locations in Denmark?

Quantities and carbon content of five different feedstocks



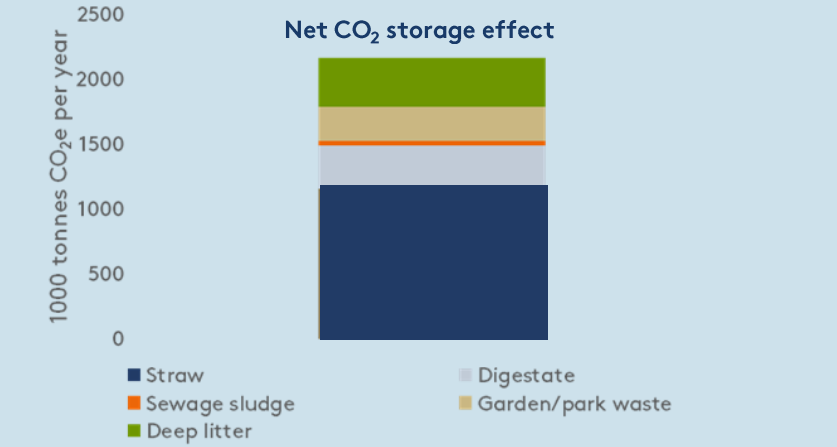
Source: NIRAS (2023) for the CIP Foundation

Geographic distribution of the five types of feedstocks



Source: NIRAS and the CIP Foundation

Sufficient biomass for the political targets of 2 Mt carbon storage

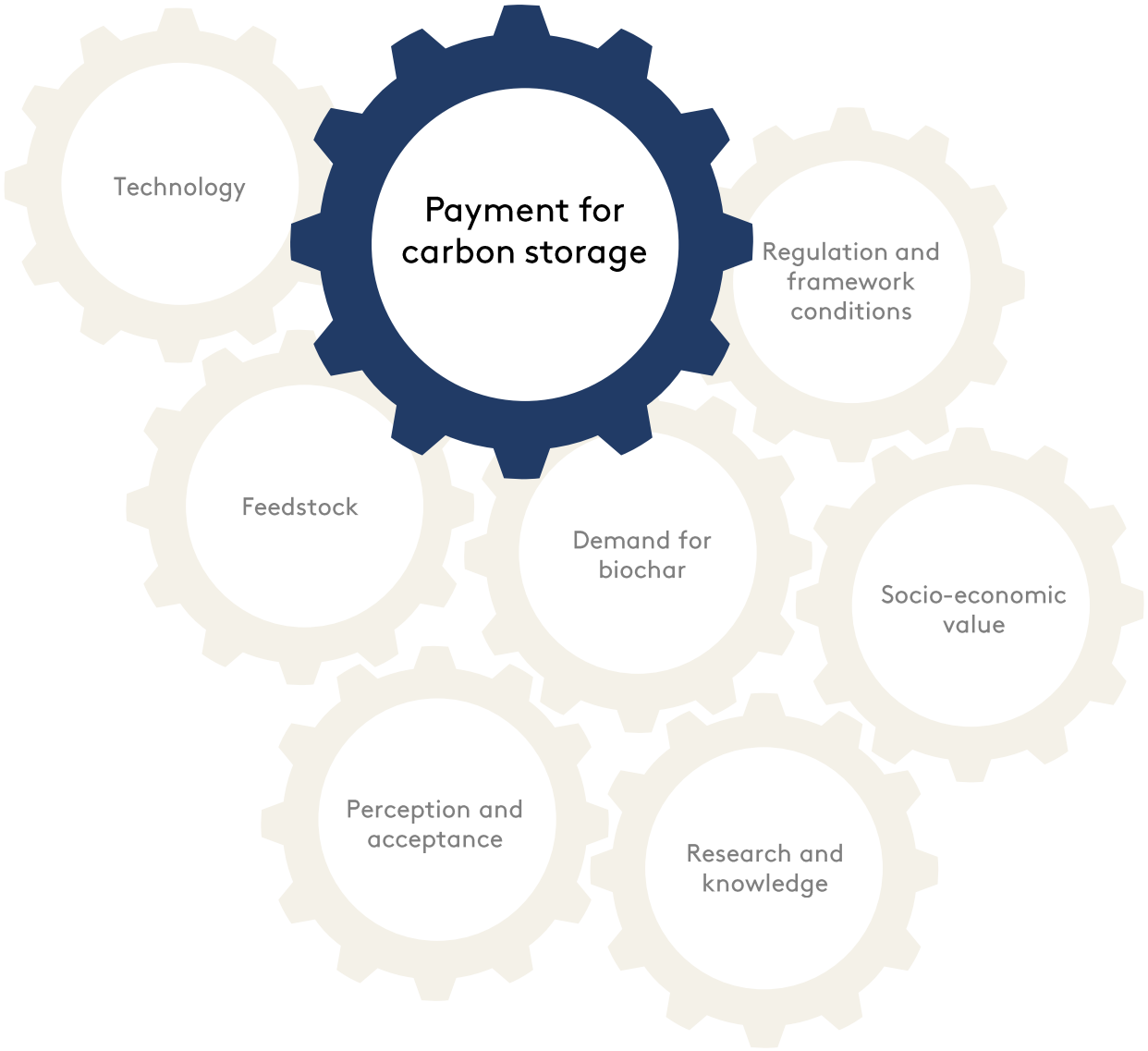


Source: NIRAS (2023) for the CIP Foundation

Conclusions regarding feedstocks and biochar

- Biomass is a limited resource to be used where it provides most value.
- Many relevant waste materials, residues etc. for biochar - almost all feedstocks can be pyrolyzed, but the properties of the biochar depend on the specific type of feedstock.
- Moving towards 2030, Bioøkonomisk Panel estimates a potential increase in plant-based feedstock of up to 10 Mt annually.
- CO_2 storage is especially relevant with biochar based on carbon rich feedstocks.
- Pyrolysis of sewage sludge is more about purification of the feedstock (environmental effects) than carbon storage.

Who pays for the carbon storage in biochar?



What about the business case? Is it profitable to produce biochar?

What affects the price of producing biochar?

- Feedstock (price, energy- and carbon content)
- CAPEX and energy balance
- Energy prices (sale of energy products)
- Location – proximity to feedstock and to the off-take of energy-products and process heat
- Sale of climate credits (and potentially also biochar)

The CIP Foundation has analysed the use of biochar, the sale of energy products and the costs of production and storage for 1 tonne of CO_2e with pyrolysis of feedstocks.

What can be expected from the business case?

✓ The business case will reward a high carbon content in the feedstock, if an efficient conversion to biochar can be created. Here, the carbon content can be allocated via a climate credit per 1 tonne of CO_2e.

✓ The business case will reward use of feedstock that does not have significant economic use otherwise, and that does not require significant pre-treatment e.g. in the form of separation and drying.

✘ The business case will not reward climate effects beyond the carbon storage in the biochar because there are no market payments for these in the process.

✘ The business case will not reward other gains such as the biochars' proporties as a fertiliser or ability to sustain relocation of phosphorus, when no pricing of the biochar itself is included.

! The business case is dependent on payments for the carbon storage through a climate credit (or gate-fee for the feedstock).

Relation between type of feedstock and contents

Feedstock	Carbon (C)	Nitrogen (N)	Phosphorus (P)
Straw/grass	High	Low	Low
Sewage Sludge	Low	Medium	Medium
Digestate	Medium	Medium/ high	High

Source: Knowledge synthesis on biochar from Aarhus University, Elsgaard et al (Sept. 2022)

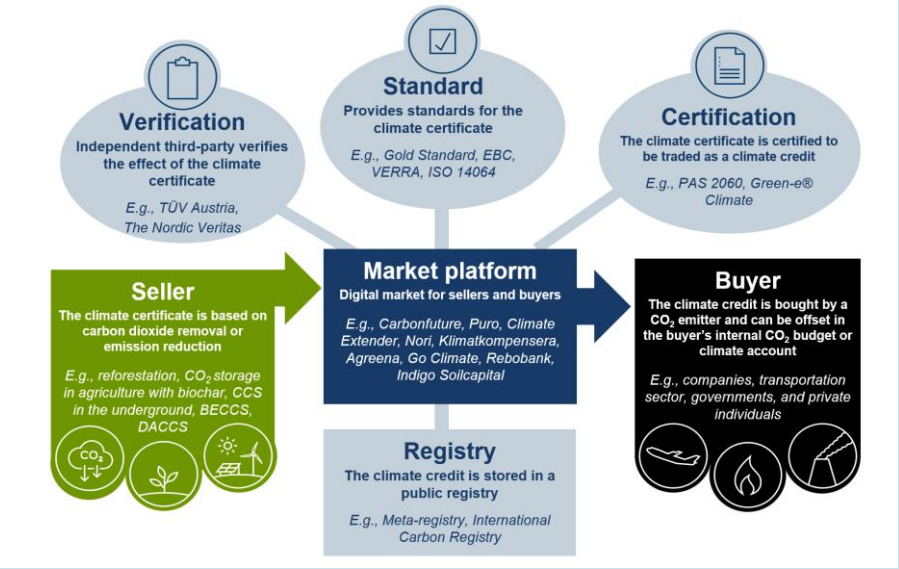
Sound business case applications?

Approx. per tonne CO_2e stored < 750 DKK (100 euro)	Digestate	Straw residues	Sewage sludge
Simple set-up	✓	✓/✘	(✓)
Extended set-up with bio-oil	✓/✘	✓	✓/✘
Price of feedstock	Free	Cost	Revenue
Pre-processing	Requires separation and drying	Ready for use	Requires drying

Source: The CIP Foundation based on firm-data from Stiesdal SkyClean and AquaGreen

How can the costs of carbon storage be covered? The role of climate credits?

The process of creating a climate credit



Source: CIP Foundation and SEGES (2023)

The voluntary market for climate credits

In 2022, climate credits delivering 615,000 tonnes of carbon storage were sold globally. 40 per cent or 240,000 tonnes of those were from biochar – the single largest contributor.

Largest customers: Airbus, Shopify, Swiss RE, UBS Financial, Microsoft, Klarna, JP Morgan Chase, and H&M Group.

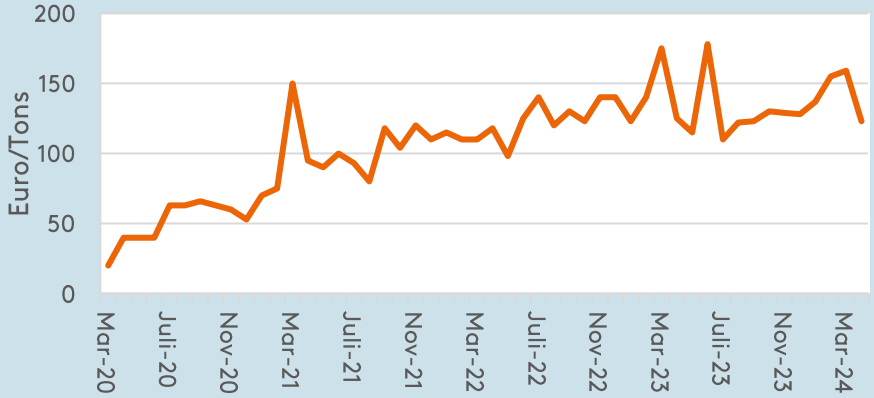
Major shifts in the market in 2023
Purchases grew rapidly to 4.3 Mt of carbon storage, but deliveries happened at a slower pace. Especially BECCS, but also DACCS have "overtaken" biochar regarding the number of credits sold.

Largest customers were Microsoft and Amazon.

Approx. 300,000 tonnes of carbon storage sold from biochar climate credits (1/4 more than in 2022).

Source: CDR.fyi

Prices for biochar-based climate credits at NASDAQ

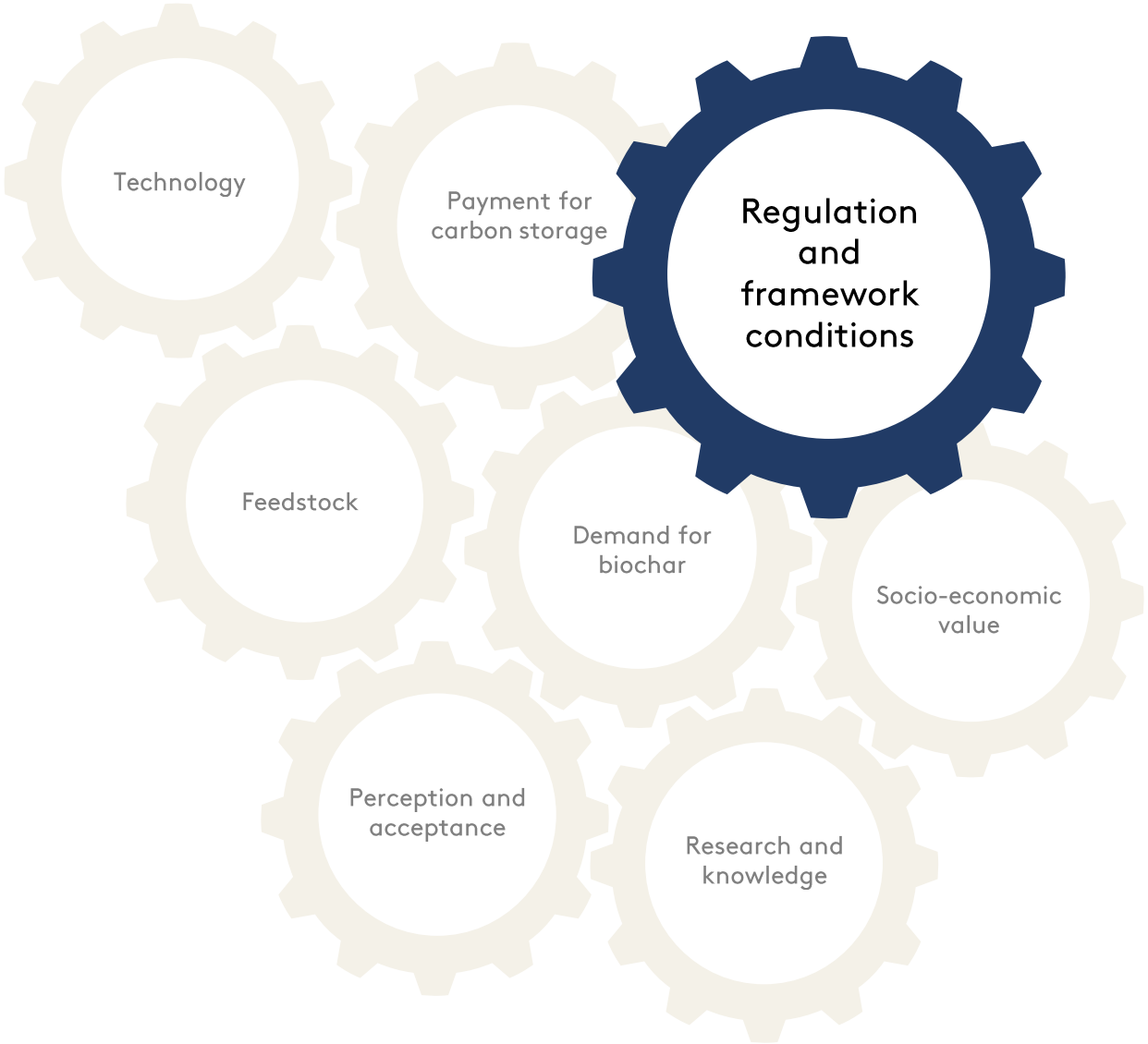


Source: Carbon Removal Marketplace, part of the CORCCHAR index, Nasdaq

Conclusions

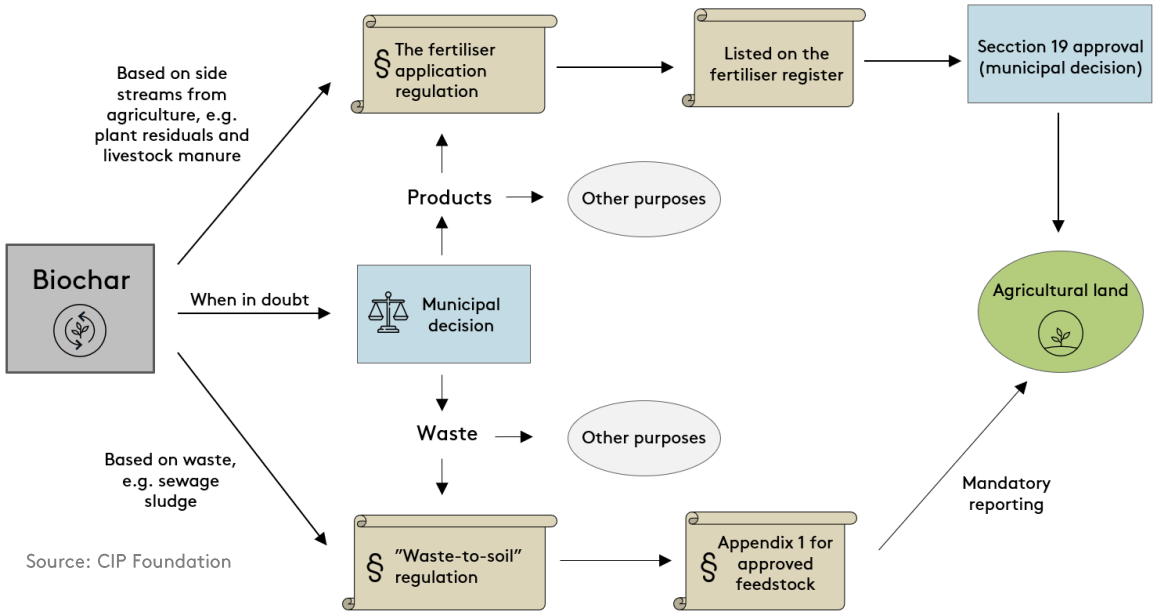
- A market-based carbon price is available in a small, but growing market.
- The climate effect is accounted for in the buyer's climate-accounts and helps the company's climate-targets, e.g. of net-zero emissions.
- The willingness to pay depends on the credibility and reliability and storage time of the project behind the credit.
- Climate credits based on biochar-projects are currently sold at approximately 125 euros per tonne of stored carbon.

Are regulations and framework conditions in place for the biochar market?



Regulation – what is permitted with biochar in Denmark?

Regulatory paths for dispersal of biochar on agricultural soil in Denmark



Source: CIP Foundation

Danish regulation of biochar

Indirect regulation of biochar through regulation of feed-stock.

Lack of general permission to biochar on agricultural land

- Biochar from agricultural biomasses (e.g. plant-residues and livestock manure) have no general authorization and need a specific environmental approval (section 19 approval).
- Application of biochar on Danish soils based on sewage sludge is permitted because dispersal of sludge is permitted, and the biochar is a product thereof.

Revised Fertiliser Use Notice and Fertiliser Regulation (August 2023)
("Gødningsanvendelsesbekendtgørelse" and "Gødskningsbekendtgørelse")

- Recognises biochar for the first time directly in Danish legislation.
- Regulates *how* to handle the biochar and *how* to document the use.

Section 19 approval ("risk of contaminated soil")

When a new product come into contact with soil or groundwater, that is not authorized in a specific legislation, a section 19-approval is required in accordance with the Environmental Protection Act.

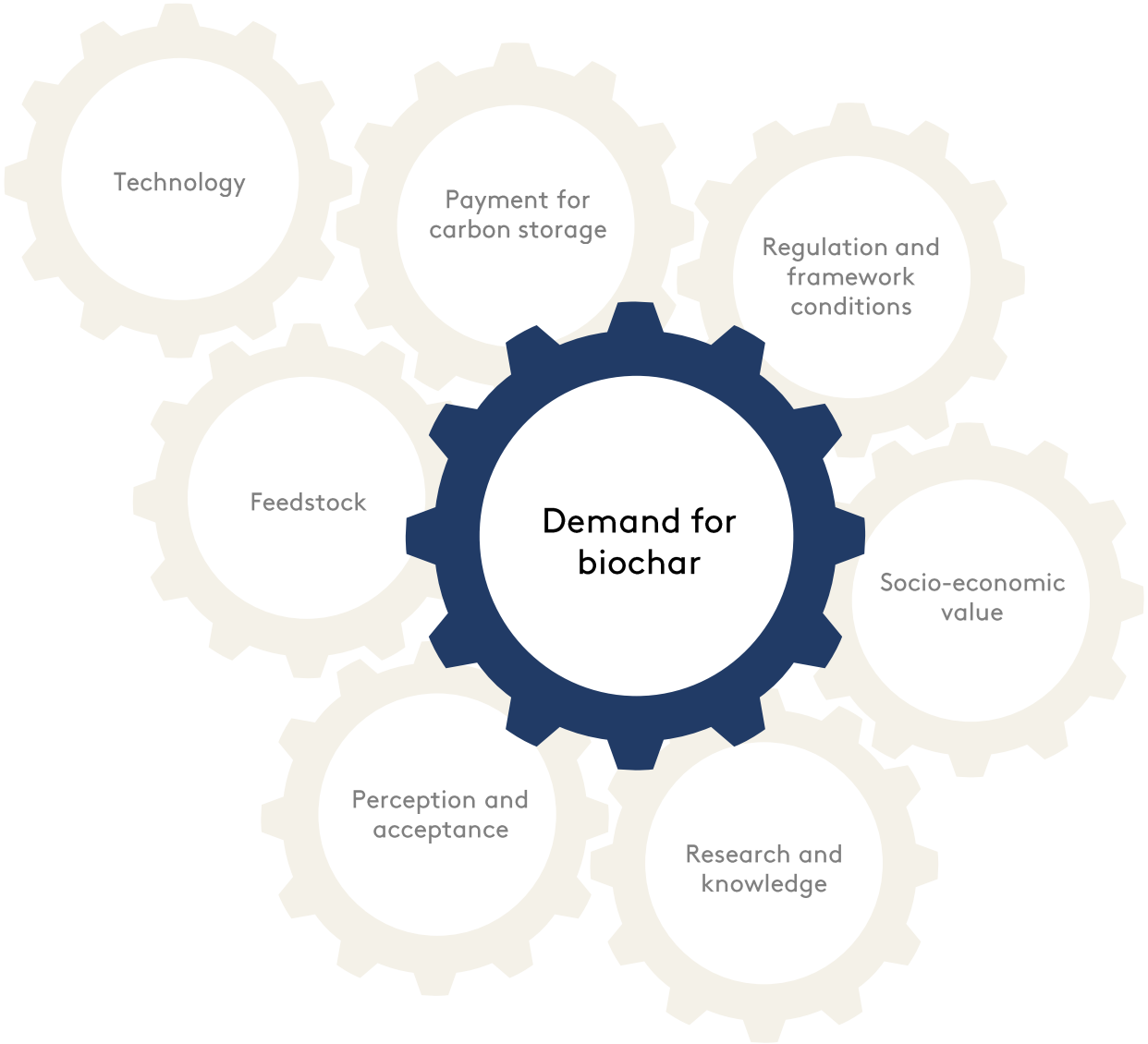
The section 19 approval is issued by the municipality, but is challenging for a new market because the permit is:

- Temporary
- Limited to a specific lot of land
- Can be withdrawn
- Time-consuming administration
- Risk of local variation in the permitting process
- Signals a risk of contaminated soil to business partners, financial institutions, as well as food- and commodity producers.

Conclusions

- Biochar is new to legislation. Like technology must be developed, so must legislation to deal with "new products".
- Biochar needs its own legislation.
- In the meantime – a need for standardized processes of approval.

Demand for biochar – end uses



How can biochar be used?

Multiple purposes of biochar

Production of **green energy** (pyrolysis/syngas, process heat and bio-oils)

Stable and long-term **carbon storage**

Different **applications** of biochar in different sectors and with different properties:

- Some allow for recirculation of nutrients from original feedstock
- Carbon storage depends on end-use
- Some take advantage of other properties of biochar

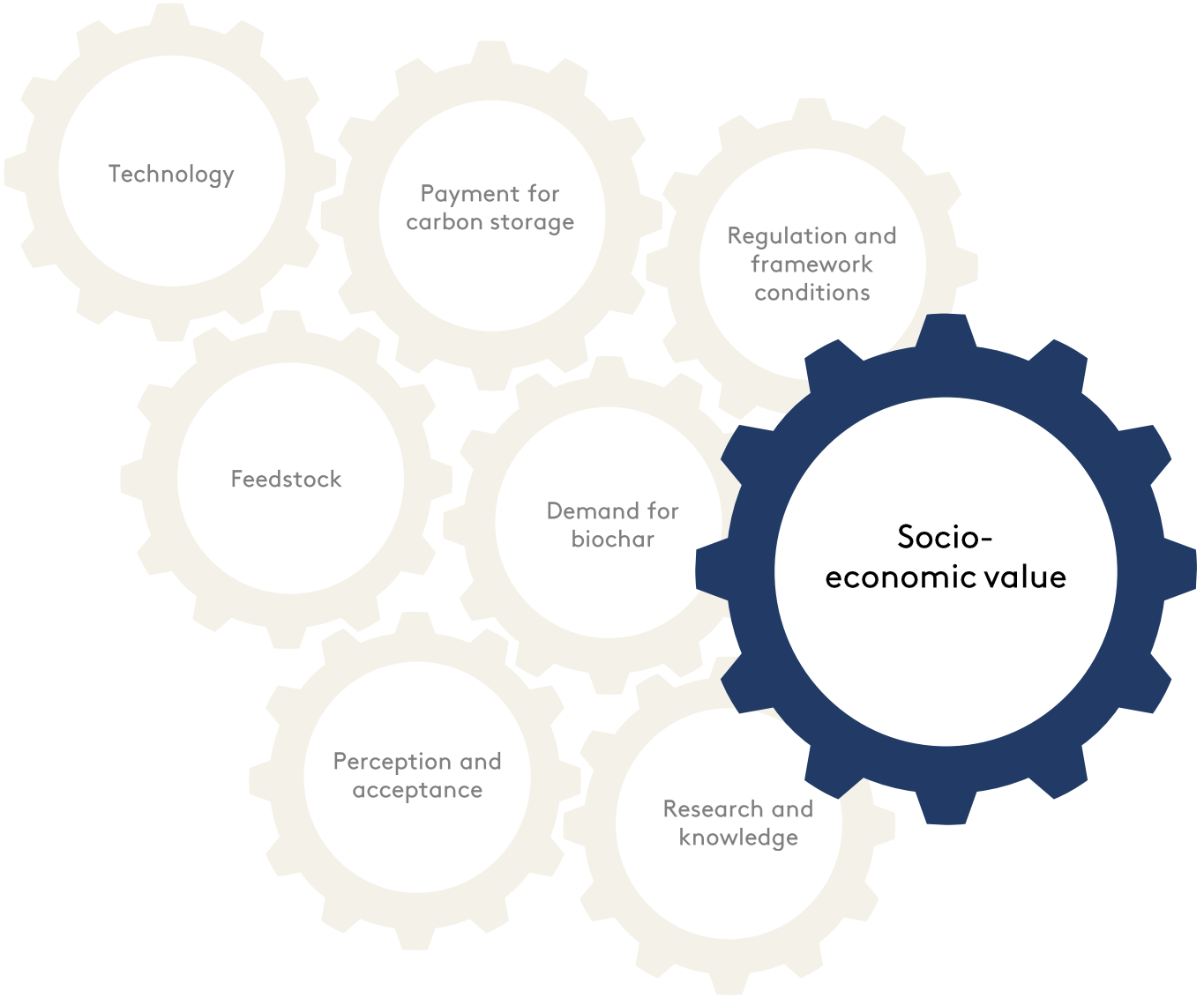
Multiple applications may be a **mixed blessing**

- Flexibility for producers of biochar.
- But also more markets and applications to understand for developers, investors and regulators

Examples of applications in different sectors

Source: CIP Foundation

What is the societal value of biochar?



What are the societal gains from biochar?

What is a socio-economic abatement cost?

The price of reducing or substituting a fossil-based emission with a carbon neutral alternative or removing one tonne carbon from the atmosphere. Include side-effects, but disregard profits.

Comparable across technologies to find the most cost efficient way to achieve climate improvements.

Structural and lasting gains from biochar

- Green energy (substitution of fossil energy and complementing more volatile RE sources)
- Efficient use of residual feedstocks
- Avoided emissions from increased feedstock handling
- Cost-effective, stable and long-term carbon storage
- Positive side-effects when used on agricultural soils

Socio-economic gains (partial effects)

- Contribute to political emission reduction targets
- Local job creation and economic activity in less populated areas

Commercial dynamics

- Ties agriculture, energy production, and carbon storage closer together
- Synergies in co-location
- New income streams
- Potential export case

Socio-economic costs are not aligned

What does it cost to <u>emit</u> CO_2e? (EU-ETS)

approx. 80-95 euro per tonne of CO_2e increasing to 150 euro in 2035

Source: Danish Energy Agency, Climate Status and Outlook (2023)

What does it cost to <u>bring down</u> emissions?

approx. 200 euro per tonne of CO_2e

Source: The Danish Council on Climate Change (2023), IEA (2022), IPCC (2022), and EEA (2021)

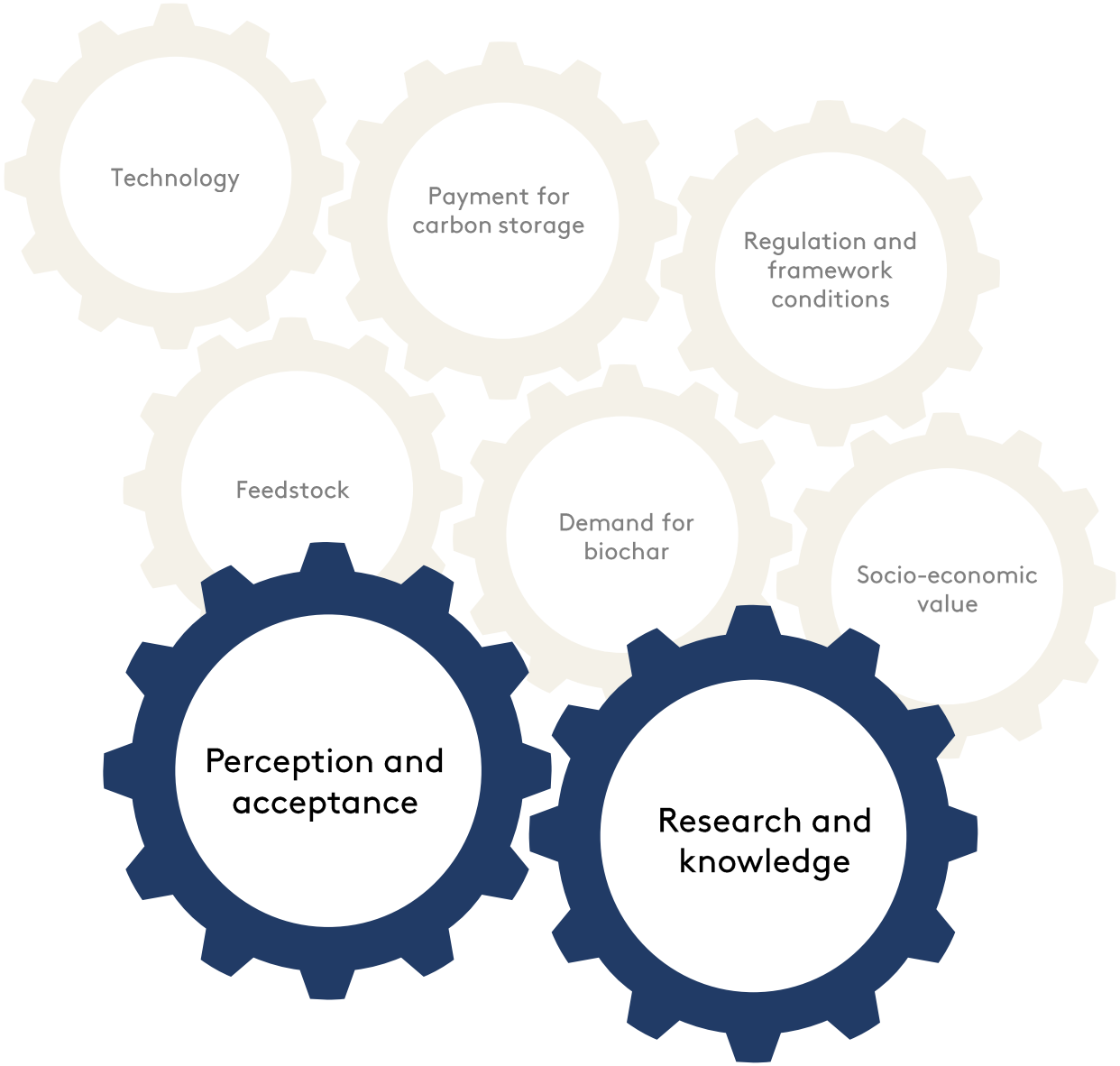
Socio-economic abatement costs for different CDR technologies

per t/CO_2e in EUR

	Digestate	Straw	BECCS	DACCS
Abatement cost	- 90	- 35	- 195	>> - 200
Abatement cost + side-effects	- 60	- 35	- 210	
Abatement cost + side-effects + climate credits	+ 5	+ 30	- 120	

Source: EA Energy Analyses (2024)

How to spread scientific results and practical guidelines and sustain public perception and acceptance of biochar?



Much research on biochar, but the knowledge must be "translated" into guidelines

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Fuel 217 (2018) 240–261

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Review article

Properties of biochar

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ARTICLE INFO

Keywords:
Biomass
Biochar
Biocarbon
Biocoal
Charcoal
Pyrolysis
Torrefaction

ABSTRACT

Biochar can be used in a large number of applications amendment. The properties of carbonized biomass depend of suitable conditions to produce a char with the desi pendencies and influencing factors, both quantitatively a the results from a large number of experiments on biochar properties that can be achieved by feedstock selection ar torrefaction as well as slow pyrolysis at high temperatu process conditions, the treatment temperature has by Especially the rather narrow temperature range between 2 is therefore very sensible to influences and possibly diffic

1. Introduction

Biochar, the solid product of biomass pyrolysis, has been produced and utilized for several thousand years and is best known as charcoal (when produced from woody biomass). The applications of biochar are very diverse, ranging from heat and power production, flue gas cleaning, metallurgical appli husbandry, building material, greenhouse gas emissions, it h years as a replacement for f applications.

Carbonization decomposes part of its carbon content. Th comes more carbonaceous ar technical processes. Feedstock depending on the desired pro olysis in the temperature rang number of problematic charac mechanical properties such a factor in co-firing and co-gasi designed for coal is to be used as a very high carbon conte temperatures. In addition to t generation, gas and water p

been used as a soil ame carbon. It is clear that demands and requirem This paper gives a l how they can be achi tions. It includes an

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Effects of biochar on soil microbial commun

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Obviously, only a fraction of these c

https://doi.org/10.1016/j.fuel.2017.
Received 19 September 2017; Receiv
Available online 02 January 2018
0016-2361/ © 2017 Elsevier Ltd. All

HIGHLIGHTS

- A first meta-analysis was performed focusing on the effects of biochar on both soil microbial biomass and diversity.
- The relative contribution of biochar and soil properties, farming practices and experimental conditions were evaluated.
- Microbial biomass and prokaryotic diversity are highly dependent on biochar properties and its application rate.
- Fungal communities' indices are mainly dependent on the soil properties (soil texture, pH and SOC).

GRAPHICAL ABSTR

ARTICLE INFO

Editor: Abasiofiok Mark Ibekwe

Keywords:

ABSTRACT

Changes in soil microbial communities may impact soil fertility and stability because microbial communities are key to soil functioning by supporting soil ecological quality and agricultural production. The effects of soil

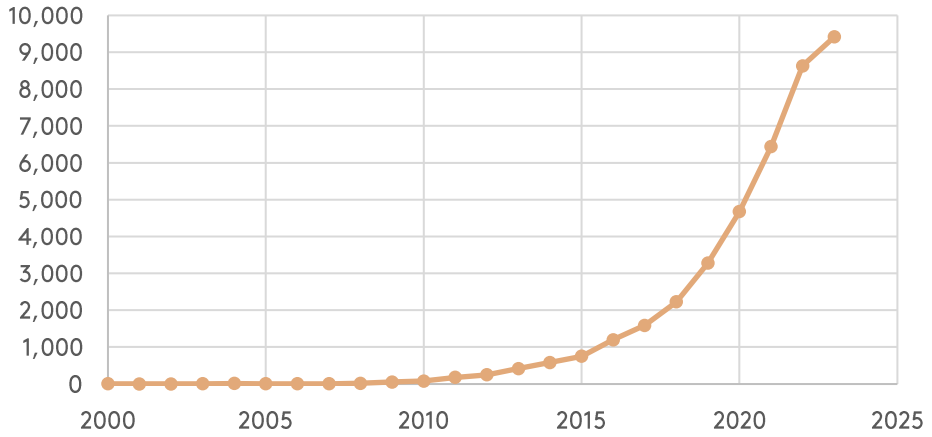
JRC Scientific and Technical Reports

Biochar Application to Soils

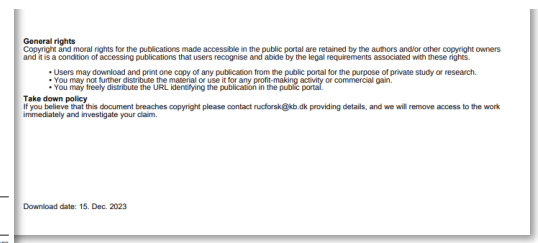
A Critical Scientific Review

f. van der Velde, I. Diafas

Increasing number of scientific publications on biochar



08/01-2024, https://www.sciencedirect.com/search?qs=biochar



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WLEDGE SYNTHESIS ON
CHAR IN DANISH AGRICULTURE

ARD (ED.), ANDERS PETER S. ADAMSEN, HENRIK B. MØLLER, ANNE WINDING, UFFE
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T NO. 208 · SEPTEMBER 2022 · ADVISORY REPORT

AARHUS
UNIVERSITY
DCA - DANISH CENTRE FOR FOOD AND AGRICULTURE

Myths and questions often heard about biochar …

"Biochar cannot store carbon for very long …"

"Carbon capture and storage is just an excuse for a continued CO_2e emittance …"

"Biochar production will cause more fossil energy import! "

"Biochar requires an energy consuming process – it consumes more energy than it produces … "

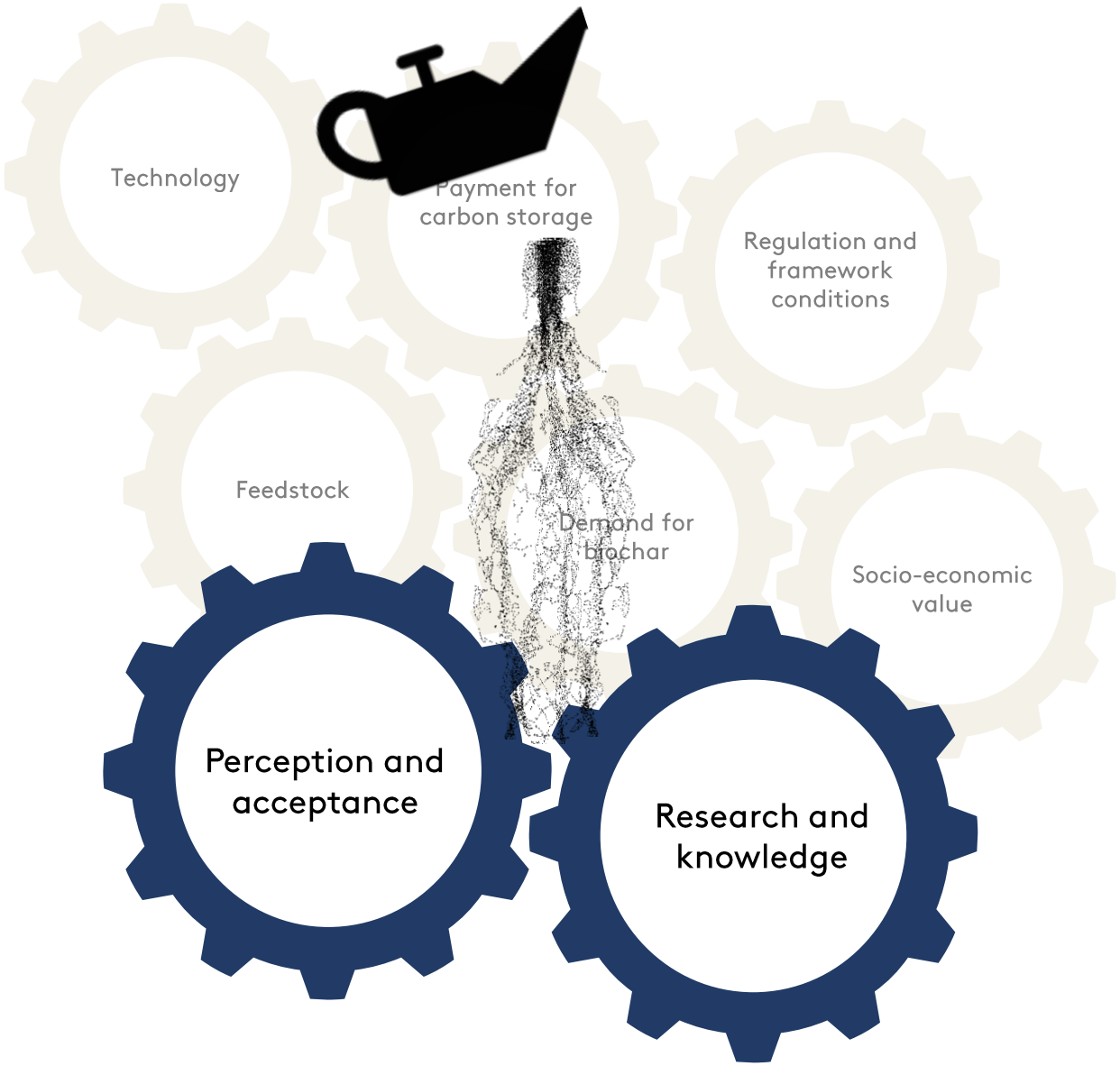
"We need the feedstock for other important processes – there are not enough biomass residues …

"Why store biogenic carbon? Won't we need it in future for PtX production?"

"Biochar is toxic and pollutes the soil in a way that can not be reversed once started … "

How to spread scientific results and practical guidelines and sustain public perception and acceptance of biochar?

CIP foundation



Part IV: Conclusions and the next steps

Main conclusions regarding biochar as a method for CCS in the agricultural sector

Benefits

#1: Biochar is a relevant and effective climate change mitigation tool for the agricultural sector and for society, where the socio-economic costs are relatively low compared to alternatives.

#2: Biochar is based on a circular use of feedstock, where the conversion to CCS and green energy is the last stop for the residuals before important nutrients are recirculated to the agricultural soil with the biochar.

#3: There are enough residual feedstocks in Denmark to generate carbon storage to meet the political objectives.

#4: Biochar can store carbon in a stable and very long-term manner. More than 80% remains after 100 years, and more than 75% remains after 1000 years.

#5: The business case behind biochar looks promising, but requires co-financing of the CO_2-storage e.g., through the sale of carbon removal certificates and/or support for the carbon storage.

#6: Use of biochar in soil has multiple positive side-effects through strengthening the soil's quality and making it more robust against climate change.

Challenges

#7: Myths about biochar and lack of knowledge on the opportunities for carbon storage may delay a more widespread use.

#8: Biochar is not yet regulated as a fertiliser in Denmark lacking a general authorization to use for biochar from agricultural residues.

#9: The 2 Mt political objective for 2030 requires a massive built-out of facilities in a short period of time. But the target remains relevant for the years to come.

#10: Diverging effects of biochar. Research results on the effects of biochar must be collected, reviewed and cathegorized depending on feedstock, process, application etc. and translated into evidence based practical guidelines. Research programs must be developed and more knowledge on long-term effects of biochar usage must be collected along the upscaling of biochar production.

The CIP Foundation's main recommendations

- **Establish a legal framework for the use of biochar made of agricultural residues**
- **Allow access to CCS subsidies on a competitive basis with other CDR technologies during the initial phase**
- **Develop guidelines for the use of biochar in agriculture**

The next steps for biochar?

Political processes as drivers

Carbon tax on agriculture
- Recommendations from an economic expert committee (february 2024)
- Biochar is integral part of 2 out of 3 recommended models and promoted by carbon storage subsidies

Tri-party negotiations on agriculture
- Covering different topics from carbon tax, to targets for reforestation and cancellation of carbon-rich farm-land, biodiversity, water quality, and perhaps also nitrogen leakage
- Deadline June 2024 followed by political negotiations on carbon tax

Pyrolysis strategy from government

New climate targets for 2035 and 2040

EU development of CRFD
- Standardised documentation for carbon removals and signal to climate credit markets

EU Agri-ETS?
- Better alignment between prices of emitting GHG and of removing or decreasing emissions.
- Expansion of EU ETS system to include removals
- Expansion of EU ETS system to include agriculture

Action points for market players, researchers and knowledge persons

- ❑ Robust results on the effects of different types of biochar
- ❑ Long-term effects of using biochar? Other side effects?
- ❑ Disperse and "translate" knowledge on biochar to build awareness
- ❑ Develop local models for long-term off-take of feedstock, biochar and energy products
- ❑ Share learning processes in order to accelerate and scale the technology and industry and build skills
- ❑ Develop guidelines and field management application methods and other usages
- ❑ Risk management
  - Standardised production processes
  - Conservative thresholds for biochar content
  - Start with a simple set-up
- ❑ Etc.

Still a lot to do to reach the Danish moonshot for biochar which remains relevant also after 2030

Thank you for your attention!

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Questions?

See more on cipfonden.dk