CIP foundation

How to market CCS with biochar in Denmark

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CIP foundation

Preface

Biochar could potentially play a major role in the transition of Danish agriculture. It is a mature technology that can store CO2 effectively for many centuries. The socio-economic costs of carbon sequestration with biochar are competitive compared with other climate measures.

The technology behind biochar can be rolled out on market terms, thereby releasing resources for investment in further green transition. Market-driven CO2 reductions in agriculture require that biochar sequestration be paid for through climate credits, for example. A subsidy scheme in the start-up phase can relieve some of the current uncertainty in the business case. The absence of direct regulation of biochar is a source of uncertainty and is an obstacle to market development

Fødevareproduktion er i dag en af de største kilder til de globale, menneskeskabte klimaforandringer. Landbruget i Danmark står for knap 1/4 af de danske udledninger, der primært skyldes biologiske processer*. Dansk landbrug og fødevareproduktion er i et krydsfelt med krav om lavere klimaaftryk og nødvendige investeringer i grøn omstilling, men også et fortsat behov for fødevareproduktion og eksport.

Klimamæssigt har verden brug for, at flere fødevarer produceres klimaeffektivt og på et mindre areal. Udvikling og brug af nye løsninger kan gøre dansk landbrug og fødevareproduktion til klimaeksemplet, hvor lavere udledninger er forenelige med fortsat vækst og eksport.

Landbrugsaftalen fra 2021 forudsætter, at hovedparten af landbrugets CO_2-reduktioner realiseres gennem nye teknologier og ikke gennem afvikling eller neddrosling af landbrugets samlede produktion. Folketinget har med Landbrugsaftalen besluttet, at pyrolyse og produktion af biokul skal være et centralt virkemiddel til reduktion af landbrugets udledninger af klimagasser med et potentiale på op til 2 mio. ton CO_2-lagring årligt.

Pyrolysen er en fleksibel teknologisk platform, som kan tilpasses ændringer i landbruget og skabe merværdi for en lang række afgrøde- og landbrugsrester. Knytter man en betaling for CO_2-lagringen har teknologien potentiale til at blive udrullet på markedsvilkår og frigøre ressourcer, der kan investeres i yderligere grøn omstilling. Biokul kan med klare rammevilkår spille en afgørende rolle og har potentialet til at blive for landbruget, hvad vind har været for energisektoren.

Biokul er et klimavirkemiddel og et stabilt kulstoflager ligesom DACCS og BECCS. Der er ikke tale om konkurrerende virkemidler, men om virkemidler der supplerer hinanden. Landbruget har fordel af et virkemiddel, der langtidslagrer den CO_2, planterne optager. Industrien og energisektoren har brug for virkemidler, der kan indfange CO_2 fra produktionen og lagre den.

CO_2-lagring møder nogle gange den kritik, at det var bedre, hvis der blev investeret i reelle CO_2-reduktioner fremfor i lagringsteknologier. Der skal ske massive reduktioner de kommende år, men det ene udelukker ikke det andet. Hvis vi skal leve op til Parisaftalens målsætning, er vi ifølge FN´s klimapanel, IPCC, nødt til at anvende negative emissionsteknologier.

Vi skal ikke alene reducere udledningen af CO_2e, vi skal også trække eksisterende drivhusgasser ud af luften.

CIP Fondens handlingsplan for en markedsdreven produktion af biokul skal ses i sammenhæng med vores vision om et bæredygtigt landbrug, der baserer sig på innovation og brug af nye teknologier. Med det sigte, at Danmark kan vedblive med at være et foregangsland, og vi kan fastholde den stærke position på de globale markeder.

Rapporten kan både læses i sin helhed, men også bruges som opslagsværk alt efter, hvad man interesserer sig for. Nogle pointer fremgår flere gange – det er fordi, de er vigtige!

CIP Fonden følger i 2024 op med et fokus på de eksportmuligheder, som lagring af CO_2 i biokul rummer.

God læselyst!

Anne Arhnung
Medlem af CIP Fondens bestyrelse

Charlotte Jepsen
Ledende partner i CIP Fonden

Anne Arhnung
Uafhængigt bestyrelsesmedlem

Charlotte Jepsen
Managing Partner in the CIP Foundation

* Hvad er CO2? (lf.dk)

Summary

Biochar could potentially play a major role in the transition of Danish agriculture. It is a mature technology that can store CO_2 effectively for many centuries. The socio-economic costs of carbon sequestration with biochar are competitive compared with other climate measures.

The technology behind biochar can be rolled out on market terms, thereby releasing resources for investment in further green transition. Market-driven CO_2 reductions in agriculture require that biochar sequestration be paid for through climate credits, for example. A subsidy scheme in the start-up phase can relieve some of the current uncertainty in the business case. The absence of direct regulation of biochar is a source of uncertainty and is an obstacle to market development

NEW CLIMATE MEASURE BASED ON WELL ESTABLISHED TECHNOLOGY

Biochar as a recognised and effective climate measure is relatively new in both Denmark and abroad. On the other hand, biochar production exploits nature's own CCS, and we have been making biochar for many years.

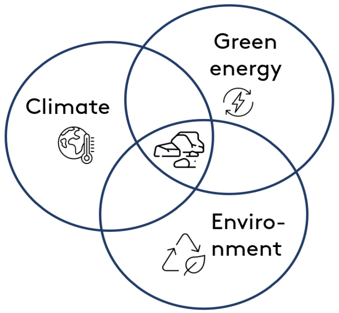
We all know that plants absorb CO_2 from the atmosphere through nature's own photosynthesis process. When you heat plant residues, for example grass, straw or wood, in a pyrolytic oven to around 500-600 OC in an anoxic environment, the carbon from the biomass is distributed fairly evenly between gases (green energy) and a stable residual product (biochar), which can store the carbon stably for a very long time.

Making biochar from biomass residuals, and in this way capturing and removing CO_2 from the atmosphere, and then storing it, is a negative emissions technology.

TECHNOLOGY WITH THREE CLEAR OBJECTIVES

Pyrolysis of biomass residuals can benefit in three important areas simultaneously:

Figure A: *Biochar is beneficial on several fronts*



Source: CIP Foundation's own graphic

The pyrolysis process generates green energy in the form of pyrolysis gas and bio-oils that can be used as green fuels, and the process also generates surplus heat that can be used in district heating or to heat installations or buildings. This type of green energy does not depend on the wind blowing or the sun shining, and it is therefore a good supplement in future energy systems.

The climate benefits when biomass residuals are used in a pyrolysis plant instead of being spread on a field to decay, for example. Processing prevents emissions of powerful greenhouse gases from the biomass residuals, and the green energy from the process can be used to displace other climate-impacting alternatives. Finally, it has been documented that biochar in itself can serve as a CCS technology. This is new.

"Biochar has a number of positive side-effects when it used on agricultural land. The soil becomes better at retaining water and this benefits crops, and it is possible to recirculate important nutrients such as phosphorus and potassium to nutrient-poor areas."

On the other hand, there is nothing new about the possible environmental benefits of using biochar in the soil. In fact, this is why biochar has been made for many years. In other countries, biochar has been used as a natural means of enriching the soil for many years. People in the Amazon region started using biochar to enrich the soil more than 2,500 years ago. The soil in the rain forest is often sandy and infertile below the first, thin soil layer. Adding biochar made it possible to transform the soil and make it richer and more fertile soil to cultivate food.

In Europe and a number of other countries, biochar is today used especially to improve the soil on farms and as a fertilizer for gardens and parks.

Biochar makes the soil more resistant to drought, it reduces emissions of potent climate gasses from the soil, and nitrogen leaching from the soil to water bodies can be also be reduced.

Biochar can also be used in other places, for example as a feed supplement, in building materials and insulation, in soil remediation and filtration, and even in health products.

EFFECTIVE CO_2 STORAGE AND OTHER CLIMATE IMPACTS

Even though the biochar is used as fertilizer, for example, it still stores the carbon stably and for a long time.

"There is scientific consensus that biochar is a reliable climate measure with long-term sequestration effects."

80 % of the carbon in biochar will still be there after 100 years and…

75 % will be there after 1,000

After only a few years, biochar stores more carbon net compared with the alternative of spreading residue straw or biogas fibres on fields.

"Besides the direct carbon storage, which removes CO_2 from the atmosphere, there are further positive climate impacts in the form of emissions avoided and fuel displacement."

The climate impacts of Danish-produced biochar are encouraging, and as a rule, one tonne dry matter of biomass residuals can be "converted to" a minimum of one tonne of climate benefits. Straw and residual fibres from biogas have the largest total climate impacts in the long term, while processing sewage sludge into biochar, for example, has short-term positive climate impacts in the form of emissions prevented.

1 tonne biochar ~ 2 tonnes stored CO_2e

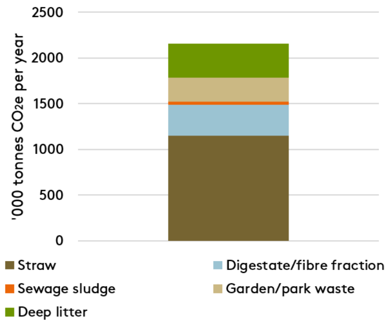
ENOUGH BIOMASS RESIDUALS TO MEET POLITICAL GOAL

Biochar is the last phase in circular use of biomass, and it is based on residues with no appreciable alternative use. These residues include straw and other crop residues, residual biogas fibres and sewage sludge, and it can have added commercial value if it is used in the pyrolysis process and converted to green energy and biochar that can store CO_2.

".....and there are enough biomass residuals to achieve the goal in the Agriculture Agreement to store 2 million tonnes of CO_2e annually."

Straw residues, residual fibres from biogas production and deep litter are particularly important in production of biochar because they contain relatively high amounts of carbon. The good news is that there is enough residual biomass to achieve the goal in the Agriculture Agreement to store 2 million tonnes of CO_2e annually. And there is great potential for more biomass residuals from Danish agriculture, with up to 10 million tonnes of bioresources in 2030, see Nationale Bioøkonomiske Panel (2022). Primarily more residual straw and hay, which is very suitable for making biochar.

***Figure B:** Residual straw, biogas fibres, deep litter, sewage sludge, and garden/park waste can support storage of 2 million tonnes CO_2e*



Source: NIRAS (2023)

Biochar is also a good opportunity to reuse phosphorus from the biomass and redistribute it, thereby avoiding having to import phosphorus, which is otherwise a scarce resource. In practice, phosphorus caps for agricultural land put a limit on the amount of biochar that can be spread on fields.

PYROLYSIS TECHNOLOGY CAN BE ROLLED OUT ON MARKET TERMS IF THE CARBON STORAGE IS PAID FOR

Building pyrolysis plants requires major initial investments, and this means that the regulatory framework and future long-term revenue flows must be clear. There must be clear agreements between parties for biomass residuals as input and biochar as output and there must be payment for the costs of CO_2 storage.

"The costs of CCS using biochar can be covered through climate credits, CCS subsidies for a period, or through a higher willingness to pay from consumers for the products made within the value chain."

Analyses of the value chain and the potential revenue flows show that the technology behind biochar could be rolled out on market terms, thereby releasing resources for investment in further green transition.

".. pyrolysis and biochar is at a technological stage with potential for deployment on market terms and with contributions to CCS in the agricultural sector, where there are no other alternatives at this scale"

Commercialisation of carbon storage with biochar requires collaboration across sectors and stakeholders that do not necessarily normally work together, and it requires that everyone involved profits from participating in the value chain. In simple terms, the value chain will consist of 1) a supplier of biomass (e.g. agriculture or biogas plants), 2) a pyrolysis plant, 3) receivers of biochar (e.g. agriculture) 4) receivers of energy products (e.g. shipping companies) and 5) receivers of surplus heat from the pyrolysis plant (e.g. a heating plant).

WHAT AFFECTS PROFITABILITY?

The business case depends on the biomass used, the need for pre-processing, the energy and carbon content in the biomass, and the sales prices of energy in the form of heat and green petroleum products. Some biomass residuals are almost free, for example residual fibres from biogas, while other biomass costs money, such as straw residues. Moreover, there is payment for receiving some residues, for example sewage sludge. The different types of biomass also differ according to the amount of prior dehydration and separation required.

Profitability is strengthened by symbioses and combining locations, i.e. if the pyrolysis plant is located close to an input supplier, for example a biogas plant or a wastewater treatment plant, or close to an output receiver, for example an energy utility, or close to infrastructure such as the district heating grid.

"If the value chain is to be financially sustainable, agriculture has to benefit from supplying biomass and subsequently using the biochar on fields."

If biochar production and storage in agriculture is to be profitable, there must be revenues for carbon storage in biochar which, together with the revenues from energy, can reward the farm supplying biomass, the pyrolysis plant producing biochar, and the farm receiving biochar and storing it.

Any other words, someone has to pay for the biochar's positive impact on the climate!

The CIP Foundation has examined the micro-economic profitability of CCS with biochar for the total value chain. The conclusion is that, today, producing biochar from residual fibres from biogas does pay in a simple set-up in which pyrolysis gas is also produced. It is also profitable if the biochar is made from residual straw, provided bio-oil is also produced. This is provided co-financing of around DKK 400-700 per tonne for carbon storage can be obtained.

Biochar from sewage sludge will also be profitable if there is a slightly higher willingness to pay for processing than is currently paid to farmers to apply the sludge directly on their fields.

CLIMATE CREDITS CAN CO-FINANCE CARBON STORAGE IN BIOCHAR

A climate certificate is proof that one tonne of CO_2 has been removed from the atmosphere. When a certificate is traded, it is called a climate credit.

There are good prospects for co-financing carbon storage in biochar through the growing global market for climate credits, because the technology supplies reliable and long-term storage which cannot be reversed, and it is a readily communicated solution with several co-benefits.

The market for climate credits is in rapid development, driven by increasing demand for products with a lower climate footprint, and by companies with ambitious climate targets (for example net-zero emissions), but which cannot necessarily reduce all their emissions themselves or among their closest cooperation partners. Climate credits can be used as set-off in companies' climate accounts.

"Willingness to pay for climate credits primarily depends on the duration of the climate impact and the documentation and certainty of the project."

A climate credit based on CCS with biochar costs around EUR 130 per tonne CO_2e. In summer 2023, the first climate credits based on Danish biochar were sold by SkyClean for EUR 160 per tonne CO_2e.

NEED FOR STANDARDISED FRAMEWORK

The market for climate credits, including biochar credits, can be strengthened by establishing a uniform, standardised certification framework with clear guidelines for how climate impacts are calculated, used and communicated, and with clear verification from an independent third party. A fixed system for Monitoring, Reporting and Verification (MRV) is also required.

There are currently several standards globally on the voluntary market for climate credits. Even though they also have MRV systems, it can be difficult to navigate between the various standards. The EU is working on a standardised certification framework for carbon removal, and this is expected to be in place around 2028. This framework may become the norm for future climate certification.

"A European standard for certification of carbon removal is on the way, and it could strengthen the market for purchases and sales of climate certificates."

If, in the current negotiations, the EU can classify biochar as a climate measure with long-term and stable storage effects on an equal footing with other CO_2 storage technologies such as DACCS and BECCS, this will give an important signal to the market.

CLEAR SIGNALS FROM INTERNATIONAL REGULATION

In 2018, the UN Intergovernmental Panel on Climate Change (IPCC) decided to recognise biochar as a Net Zero Emissions technology, and the panel has subsequently estimated a global reduction potential of 2.6 bn. tonnes CO_2e annually. In other words, there is a need for a broad range of CCS technologies, if we are to keep down global temperature increases. Both to capture emissions from hard-to-abate industries, but also to capture past CO_2 emissions from the atmosphere.

In 2022, the EU allowed biochar based on plant residues to be used as a fertilizer in the EU for the first time, and later also biochar based on livestock manure via the revised Fertilizing Products Regulation. Now biochar fertilizers may be sold within the EU if they are CE-labelled and meet certain limit values for the contents of the biochar.

BIOCHAR IS ALMOST NON-EXISTENT IN DANISH REGULATION

In summer 2023, biochar made from agricultural residues was incorporated as a fertilizer product in regulations in Denmark for the first time. But only in regulations for how to use biochar. This does not mean that it is permitted to use biochar on fields.

In Denmark, it is generally not permitted to use biochar based on agricultural residues. A special environmental permit is required. More specifically, a section 19 permit from the municipality. The permit is temporary and only applies for specific fields and specific amounts of biochar. This type of permit is used when there is no other regulation. It is

impossible to base market deployment on this.

Regulations on biochar in Denmark have to be derived indirectly through other regulations. Paradoxically therefore, Danish regulation does allow biochar based on waste such as sewage sludge to be spread on fields. And this is one of the residual biomass types that may contain the most substances of concern. Therefore, some biochar can be used in Denmark.

Paradox: biochar based on waste is allowed in Denmark, while biochar based on cleaner biomass such as straw residues or grass requires a special environmental permit.

NEED FOR CLEAR FRAMEWORK CONDITIONS

The absence of direct regulation of biochar is a source of uncertainty and is an obstacle to market development. The same applies for rules for locating pyrolysis plants, as these often require time-consuming changes to local development plans, etc. In this context, there is something to learn from the biogas market, by allowing pyrolysis plants to be sited in rural zones.

Major investment decisions for market deployment are unlikely to be made, given the significant uncertainty about the time horizon and permits, with risks of local variations.

"There is a need for clear framework conditions and particularly for a clear legal basis for use of biochar on Danish farms, provided they comply with the limit values for the biochar's content."

As biochar can be produced on the basis of a number of different types of biomass residuals, legal authority to use biochar on Danish fields should be independent of the type of biomass used. Instead, there should be regulation on the content of the biochar. This will ensure that regulation is simple and unambiguous.

Socio-economic costs of storing one tonne CO_2e:

Biochar from straw	DKK 250
Biochar from biogas fibres	DKK 700
BECCS	DKK 1,450
DACCS	DKK 1,500

If possible environmental impacts and income from climate credits are also taken into account, biochar has a socio-economic gain, while BECCS remains a cost.

Source: EA Energianalyse (2024)

RISK OF NEGATIVE IMPACTS CAN BE PREVENTED

As biochar is nothing new for agriculture, there should be extra efforts to prevent potential adverse environmental and sustainability impacts. For example, this could be when setting limit values for the content of different substances in the biochar. It is important to apply a prudence principle based on the most restrictive existing limit values across fertilizer products, EU regulation and requirements for different climate certificates.

Not because negative impacts have been demonstrated from using biochar in agriculture, but so that there is confidence in its use. Regulation should not be less restrictive for biochar than ir currently is for other fertilizers. On the other hand, there is nothing to indicate that biochar regulation should be more restrictive than other fertilizer products.

Continued research and knowledge-building from practice is required. The knowledge should systematised and form the basis for guidelines on the use of biochar.

Then a market can be established and followed by research experiments and measurements that can guide future development of regulations.

COMPETITIVE COSTS TO SOCIETY FOR CO_2 STORAGE WITH BIOCHAR

From a macro-economic perspective, the cost of storing one tonne of CO_2 from the atmosphere using biochar is competitive compared to other CCS technologies such as DACCS and BECCS. Biochar is therefore an effective and relatively cheap way for society to achieve climate improvements compared with other climate measures.

"From a socio-economic perspective, a relatively low displacement cost is associated with using biochar as a climate measure."

Taking into account some of the adverse environmental side-effects of the different methods, the net result is improved for biochar based on residual fibres from biogas production (digestate), whereas it is worse for BECCS and largely neutral for biochar based on straw residues.

Also taking into account the possibility of payment for the service derived from CO2 storage, for example through climate credits, changes the picture, and the use of biochar ends up as a small gain for society, while BECCS remains a net socio-economic cost, although this method can also obtain financing through climate credits.

Including potential revenues from climate credits in the socio-economic calculation gives an impression of the extent of support required from government funding for this type of CCS. This may be required in a start-up period for the market, and while the international market for climate credits is under development, standardisation and consolidation. However, in the longer term, there are prospects that carbon storage with biochar will also be financially sustainable for society.

Biochar as a climate measure is a socio-economically good investment. And one of the few climate measures with potential at this level, particularly in agriculture. Therefore, promoting the market should be considered through clear regulation, effective approval processes, and through CCS subsidies during market start-up to cover some of the costs of CO2 storage, that would otherwise have to be met by an, as yet, uncertain market for climate credits.

RECOMMENDATIONS AND A ROLL-OUT PLAN FOR LARGE-SCALE PRODUCTION OF BIOCHAR

Biochar could potentially play a major role in the green transition of Danish agriculture. It is based on a mature technology, and biochar can store large amounts of carbon effectively for up to 1,000 years. Furthermore, the socio-economic shadow prices of carbon sequestration with biochar are very competitive compared with other climate measures.

In contrast to the large carbon-capture installations at CHP plants and large industrial enterprises, for example, this type of CCS can be decentral and close to where biomass residues exist.

For agriculture as a whole, all the biochar stored in agricultural land will reduce the total reduction requirement for agriculture. Even though climate credits are sold, the net storage will still count in national and sector-based emission inventories.

"All reductions from using biochar in agriculture will reduce the collective requirements for agriculture as a whole – even if climate credits are sold, for example."

The collective gains in the form of reduced net emissions from agriculture therefore entail a corresponding reduction in the need for a carbon tax or other instruments aimed at agriculture.

Biochar has potential to contribute to Denmark's 2030 target, and the goals of climate neutrality in 2045 and net negative emissions in 2050. Not by 2 million tonnes of carbon storage by 2030, which is the objective of the Agriculture Agreement, as it is not possible to build capacity for this, but it is likely within relatively few years after 2030, depending on the framework conditions.

Even though other countries have been making biochar for some time, they have not had climate impacts as their primary focus. Denmark has potential to develop a biochar industry in light of existing logistical opportunities for a number of types of biomass residuals, possibilities to sell green energy and surplus heat through well-developed infrastructure, and possibilities for joint localisations.

Technologically, Denmark is also up to speed, and at the beginning of 2024, Denmark will have one of the largest biochar-production facilities in Europe. Other Danish producers are also underway with large, commercial installations.

So there is a basis for biochar, the supporting technology, and effective documentation of the climate impacts to be a new Danish export stronghold. Export opportunities, competence building and learning effects are the themes for the next initiatives by the CIP Foundation within the area.

The most important challenges to using this promising technology in Denmark are linked to absence of direct regulation of biochar in Danish legislation, new value-chain collaborations to obtain revenues to cover the costs of carbon storage, and more knowledge about how biochar can be used in practice. With this backdrop, the CIP Foundation recommends:

The CIP Foundation's main recommendations

- **Establish a legal basis for biochar made of agricultural residues.**
- **Support the start-up with CCS subsidies; to be replaced by the market for climate credits.**
- **Develop guidelines for the use of biochar in agriculture.**

***Tabel A**: Recommendations from the CIP Foundation to promote biochar as a means of carbon storage in agriculture*

	Regulator	Market players	Researchers and experts
Central recommendations	Establish a legal basis for biochar made of agricultural residues.	Support the start-up with CCS subsidies; to be replaced by the market for climate credits.	Develop guidelines for the use of biochar in agriculture.
General recommendations	• Start with **framework regulation** and **limit values** for the biochar contents, based on the strictest current limits across different regulation and by applying a prudence principle, which can be tightened or relaxed in line with new knowledge. • **Inter-ministerial task force** with focus on authorisation and process simplification for quicker establishment of biochar production. • Develop **method to calculate net CO_2 storage** with biochar in the national emission inventories, so that storage can also be recognised and included in political objectives. • **Identify relevant areas for pyrolysis plants** in combination with current municipal projects to identify suitable areas for biogas production and energy parks for quicker establishment.	• Spread **awareness among potential investors** to accelerate interest in the technology. • Establish logistics chains with the possibility of **long-term agreements** (PPPs) for biomass and biochar. • Accelerate **scaling and learning processes** to develop the pyrolysis technology to large-scale. • Start **development of energy products for high-value use** and prepare possible upgrading, methanation and future coordination with PtX.	• **Categorisation of research results** according to evidence, biomass, pyrolysis process and area of application to make insights more practicable. • Initiate **long-term field studies** and gain an overview of the long-term environmental and agronomic impacts of use on agricultural land. • Develop **practical knowledge** for optimal use of biochar and exchange experience. • Extend **competence development**, training activities and learning tools for the people who are to develop, operate and administrate/supervise etc. biochar processes.
Specific recommendations	• **Equate pyrolysis plants with biogas plants** in the Planning Act to support possible location close to residual biomass. • Support quicker **environmental classification** of pyrolysis plants and thus the process for environmental assessments with outset in standard examples. • Adjust **phosphorus caps** with regard to biochar-release over time. • Work to get carbon storage with biochar **in other sectors**, for example the construction sector, recognised in national emission inventories (via the IPCC). • Develop **standard processes** for municipal assessments and section 19 permits, until central regulation is in place. • Establish a "**compliance assessment body**" to approve biochar with CE labelling as a fertilizer product.	• Develop **field management methods** for biochar (agriculture and materials suppliers). • Develop **combination of biochar and other fertilizer products** to achieve the best effects.	• Investigate the impact of biochar on **nitrogen leaching** from soil to the aquatic environment. • Examine the **interplay** between biochar, soil type, and the effect of different types of living organisms in the soil under Danish conditions.

Source: The CIP Foundation