Dear Reader,

On October 7, 2024, the Danish government launched its Strategy and Work Programme for Pyrolysis in conjunction with the opening ceremony of the Stiesdal SkyClean's 20MW plant in Vrå. This facility is capable of annually processing 40,000 tons of dried biogas digestate, converting it into 57,000 MWh of energy and producing Biochar Carbon Removal (BCR) equal to 25,000 tonnes of CO_2e permanent carbon removal. SkyClean's biochar is free of toxins and will be used for sequestration in agricultural soils. You can find more information here.

The opening ceremony of the Stiesdal SkyClean 20MW plant and the launch of the Danish government's Pyrolysis Strategy and Work Programme took place at SkyClean's facility in Vrå. The strategy was presented by three ministers: Lars Aagaard, Minister for Climate, Energy and Utilities; Jacob Jensen, Minister for Food, Agriculture and Fisheries; and Jeppe Bruus, Minister for Green Tripartite.

From left: Henrik Stiesdal founder of Stiesdal SkyClean, Lars Aagaard Minister for Climate, Energy and Utilities, Jeppe Bruus Minister for Green Tripartite, Jacob Jensen, Minister for Food, Agriculture and Fisheries, and Søren Smalbro Mayor of Hjørring.

Pyrolysis Denmark welcomes the government's Pyrolysis Strategy and Work Programme and expresses gratitude for the trust and high level of ambition. This initiative positions Denmark as a first-mover country and promotes pyrolysis technologies and Biochar Carbon Removal (BCR) in Denmark.

The following memo is an English summary and deep dive of the Danish "Pyrolysis Strategy and Work Programme" published by the Danish government on October 7, 2024. The official version in Danish can be found here**.** This memo is published by Pyrolysis Denmark and serves as an unofficial document. It's intended as a resource for the international BCR community as inspiration for similar policy development in other countries.

Best regards,
Morten Heick

Vice Chairman of Pyrolysis Denmark
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About Pyrolysis Denmark: Pyrolysis Denmark is the trade association for suppliers and operators of pyrolysis technology in Denmark. Its members share the mission of removing carbon from the atmosphere. The association was founded in 2024 by six leading Danish BCR companies. The purpose of Pyrolysis Denmark is to promote and maintain the Danish pyrolysis industry's first-mover advantage, facilitate Danish exports and job creation, support the green transition, and contribute to Denmark's climate goals. You can find more information here

Sign up for Pyrolysis Denmark's newsletter and stay informed about BCR and pyrolysis in Denmark. **Sign up here**

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PYROLYSE DANMARK

Memo on the Danish Strategy and Work Programme for Pyrolysis

Summary
Denmark aims for climate neutrality by 2045 and a 110% reduction in greenhouse gas emissions by 2050 (compared to 1990). The government supports pyrolysis, a technology that converts biomass into carbon-rich biochar, which can store CO_2 in agricultural soils for centuries, helping reduce emissions in the agricultural sector.

The Danish government is working to accelerate pyrolysis technology to meet the 70% emissions reduction target by 2030 and the long-term goals for 2045 and 2050. Danish companies are already developing pyrolysis, and the government's Pyrolysis Strategy and Work Programme aims to scale up the technology, overcoming barriers and driving its role in Denmark's green transition.

The strategy and work programme can be summarized in 3 focus areas:

Focus Area 1: Clear and Simple Regulation

- Establish clear and simple regulations within EU law for the application of biochar from mid-2026.
- Greater clarity on siting options for pyrolysis plants through amendments to the Planning Act from January 1, 2025.
- Study the formation, content, and breakdown of environmentally harmful substances in relation to the pyrolysis process and the production of biochar by 2026.
- Explore potential environmental and agronomic effects through multi-year field trials.
- Strengthen municipal guidance through advisory statements on permits by the end of 2024, along with guidance on environmental approvals.
- Establish a pyrolysis task force to coordinate the implementation of government initiatives and involve a working group of relevant stakeholders.
- To establish the foundation for clear and simple regulation the government has allocated a total of EUR 13.5 million from the Research Reserve for 2023 and 2024 to this effort.

Focus Area 2: Enhanced Incentives for Expansion

- Establish a subsidy scheme of EUR 1.4bn (DKK 10bn) for biochar stored in agricultural soils from 2027.
- Prioritize funding for research, development, and demonstration of pyrolysis technology in connection with an upcoming green research and innovation initiative.
- Provide guidance on displacement factors when reporting pyrolysis-based fuels to meet the national CO_2 displacement requirement.
- Support the European Commission's efforts to implement a sound and credible pan-European certification system for carbon removal in the EU (EU CRCF).
- Analyze opportunities to target CAP (Common Agricultural Policy) support for the use of biochar in agriculture during the next CAP reform period.

Focus Area 3: Climate Impact and Emissions Accounting

- Develop an emissions factor for biochar to be included in the Danish greenhouse gas inventory from 2027.
- Measure methane emissions in 2024 and set an emissions factor for pyrolysis plants by 2025.
- Prepare a knowledge synthesis on alternative storage options for biochar by 2025.

Deep Dive

Environmental Regulation
Biochar can be produced from various types of biomass and can have different properties depending on the biomass and production conditions, such as pyrolysis temperature and residence time in the facility. The physical properties of the soil and its biology are affected when biochar is applied. Some studies have shown that biochar can improve soil properties, for example, enhancing the soil's ability to retain water and nutrients. However, there is still a lack of knowledge and documentation on the long-term environmental and agronomic effects of biochar under practical farming conditions in Denmark. New knowledge on these aspects could also contribute to a better understanding of biochar's climate impact and influence farmers' incentives to use biochar on their fields.

The potential fertilization value of biochar could also impact the incentive to use it in agriculture. Particularly, the phosphorus content in biochar is significant, as phosphorus is a limited resource and one of the essential nutrients for plant growth. Therefore, applying biochar to fields may positively affect plant growth. At the same time, regulations on the application of phosphorus to agricultural land can be a limiting factor in certain areas. There is also uncertainty about how available the phosphorus in biochar is for plant uptake and whether it might risk being leached into the water environment.

Although it is currently possible to apply biochar to agricultural land if its production, marketing, and use comply with existing regulations, navigating the applicable rules can be a challenge for both producers and users. The need for clear and simple regulations is emphasized by Danish pyrolysis companies, who call for quick resolution of regulatory barriers to prevent unnecessary delays in the market development of pyrolysis and biochar.

The government therefore aims to establish the foundation for clear and simple regulation and has allocated a total of EUR 13.5 million from the Research Reserve for 2023 and 2024 to this effort.

In the short term, environmental trials will be conducted to investigate the formation, content, and breakdown of environmentally harmful substances in connection with biochar production. These trials will provide knowledge by mid-2025, which will form the basis for establishing clear and simple legal frameworks for the use of biochar from mid-2026, to the extent possible in accordance with EU law. Research funds will also be allocated to study the potential long-term agronomic and environmental side effects of biochar storage in agricultural soils under Danish conditions. It is important to the government that the regulatory framework is developed in collaboration with the industry and other relevant stakeholders, as effective cooperation will support the commercialization of the pyrolysis sector.

Therefore, the government is establishing an inter-ministerial pyrolysis task force to coordinate and ensure progress in the implementation of the government's roadmap for pyrolysis and to include a NEKST implementation forum for pyrolysis, consisting of relevant stakeholders.

Local Planning
The government proposes to provide greater clarity on where pyrolysis plants can be established by amending the Planning Act. In the future, when municipal plans are developed, guidelines for the location of pyrolysis plants must be included. The government aims for the proposed amendment to the Planning Act to take effect on January 1, 2025.

Enhanced Incentives for Expansion
Currently, there is insufficient financial incentive to produce and store biochar in agricultural soil, and thereby reduce greenhouse gas emissions in the agricultural sector. As part of the "Agreement on a Green Denmark" of June 24, 2024, the government and parties in the green tripartite partnership propose establishing a subsidy scheme of approximately EUR 1.34 billion (DKK 10 billion) for the storage of biochar produced via pyrolysis, running until 2045.

In addition to this, the government will prioritize funding for research, development, and demonstration of pyrolysis technology as part of an upcoming green research and innovation initiative aimed at accelerating the adoption of pyrolysis technology by 2030.

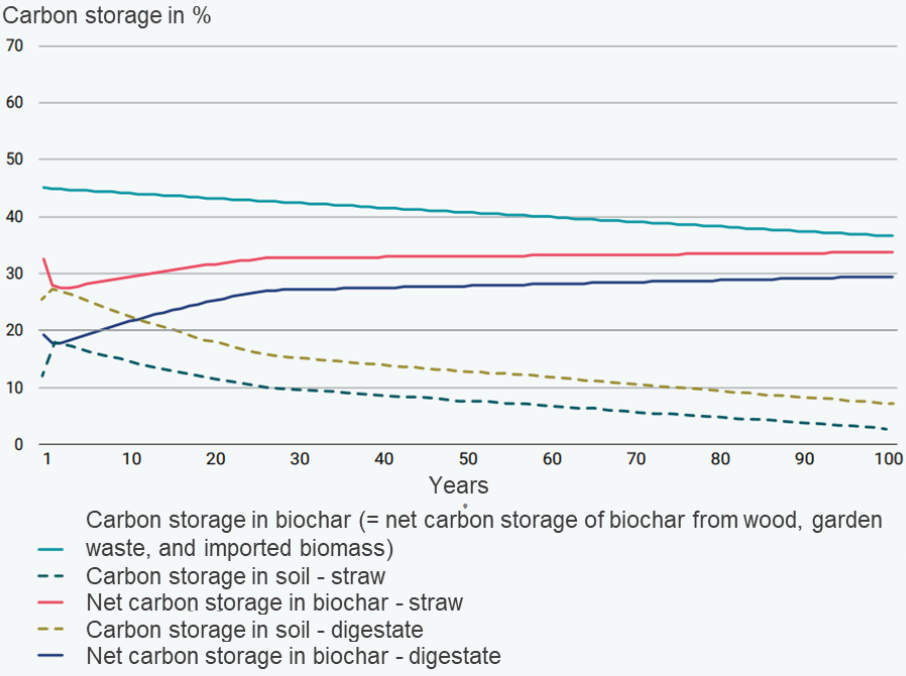
Pyrolysis technology could become more competitive when the green energy products generated during biochar production can be sold. Pyrolysis gas and oil are byproducts that can be processed into high-value alternatives to other fuels. Green fuels based on pyrolysis gas and oil could help meet CO_2e displacement targets, particularly in road transport. New pyrolysis-based fuels will need to be certified under one of the European Commission's approved voluntary schemes. The Danish Energy Agency can provide guidance on the current application possibilities.

Climate Impact and Emissions Accounting

Currently, the Danish Government does not find any clear guidelines for the certification of biochar or its potential for CO_2 storage. The government will therefore support the European Commission's efforts to establish a sound and credible pan-European certification system for carbon removal in the EU, as well as the subsequent development of methodologies.

The overall climate effects of pyrolysis depend on various factors, and there is currently no clear understanding of the climate impact of storing biochar in agricultural soil. Specifically, Denmark lacks a method to quantify the climate effects associated with the use of biochar stored in agricultural soil. As a result, the climate benefits from biochar storage cannot yet be included in Denmark's greenhouse gas inventory. The government has initiated the development of a method to calculate the climate impact of biochar stored in agricultural soils. This method is expected to be ready by 2026 and included in the national climate reporting and projections from 2027.

There is also a risk that pyrolysis plants may release methane during the production process. In response, the government launched a measurement program in 2024 to examine and document potential methane emissions from pyrolysis facilities. The results will help determine whether methane emission limits are necessary.



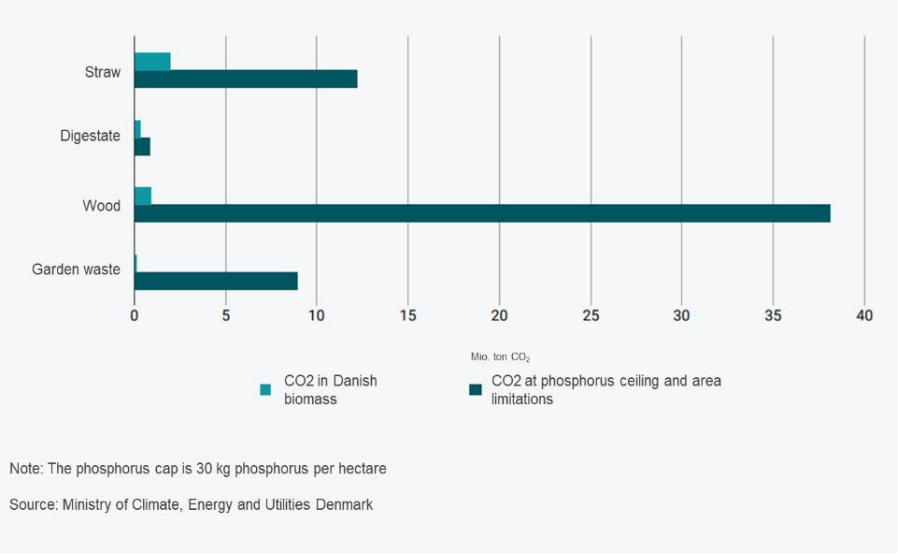
Note: It is assumed that 45% of the carbon in the biomass is sequestered in the biochar in year 1.for the current use of biomass, where biomass applied to agricultural land contributes to carbon storage today, while biomass used for combustion does not contribute to storage today. Variations in the first years are due to transitions between carbon pools in the C-TOOL model, which is the model used for the soil carbon pools for Denmark's emission inventory, cf. Note on the inclusion of the effect of biomass in C-TOOL/the national greenhouse gas inventory, Steen Gyldenkærne, 2023.

Source: Ministry of Climate, Energy and Utilities Denmark

The government expects that, based on the results from the ongoing research initiatives, national regulations for the use of biochar in agricultural soil can be implemented from mid-2026. Biochar is therefore expected to be applied on a larger scale from 2027 once regulatory frameworks are in place.

Technical Potential for Biochar Application

The technical potential for biochar application is substantial, assuming that phosphorus regulation is the limiting factor and no distinction is made between Danish and imported biomass. If the potential is limited to biochar produced from Danish biomass resources that are currently either applied to agricultural soils or used for combustion, this would lead to a significantly lower amount of biochar and reduced CO_2 effects, ranging from 0.1 million tons of CO_2 for garden waste to up to 2 million tons of CO_2 for straw. If the potential is further narrowed to only reflect biomass applied to Danish agricultural soil, the potential is reduced to approximately 1 million tons of biochar per year, with a CO_2 effect of 1.6 million tons per year.

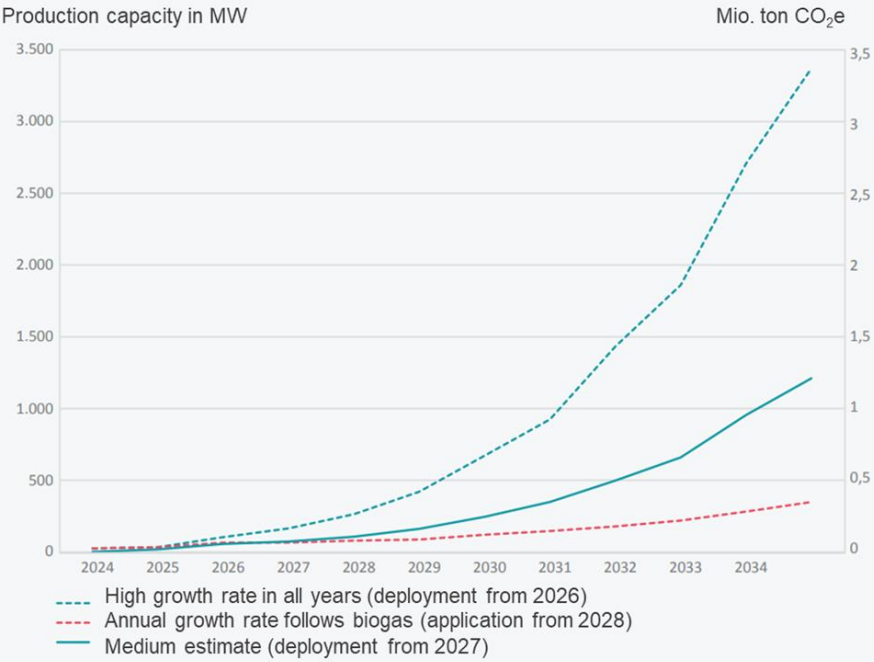


Note: The phosphorus cap is 30 kg phosphorus per hectare

Source: Ministry of Climate, Energy and Utilities Denmark

Rollout of Pyrolysis

It is estimated, with considerable uncertainty, that the expansion of pyrolysis plants could grow from nearly 30 MW of production capacity in 2024 to between 120 MW and 680 MW by 2030, and to between 320 MW and 3,400 MW by 2035. The projected expansion corresponds to CO_2 reductions of 0.1–0.7 million tons in 2030 and 0.3–3.4 million tons in 2035. This reflects an average estimate for CO_2 reductions through biochar storage of 0.3 million tons of CO_2 in 2030 and 1.2 million tons of CO_2 in 2035.



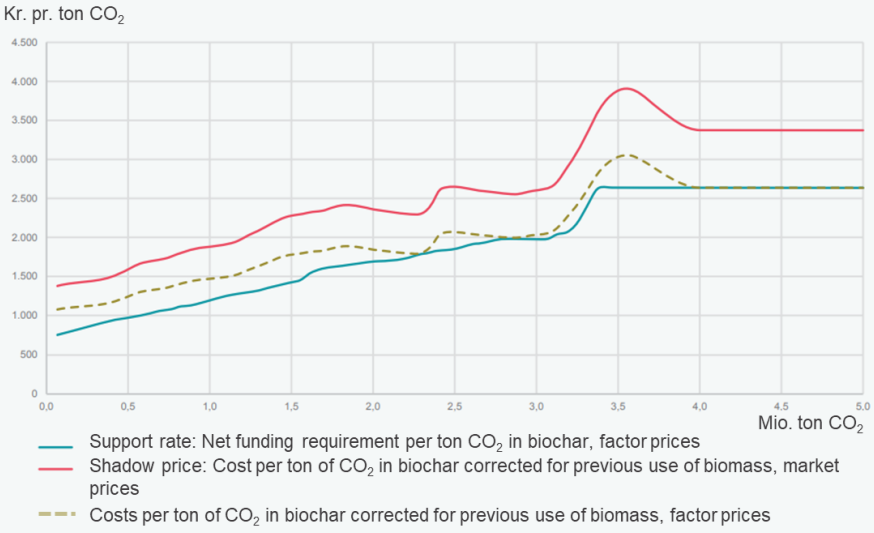
Note: Estimating production capacity development for immature technologies is associated with considerable uncertainty

Source: Ministry of Climate, Energy and Utilities

CO_2 Shadow Pricing and Revenue Assumptions

The production and application of biochar are estimated, with significant uncertainty, based on the prices used for biomass, the investment and operational costs of the pyrolysis plant, the costs associated with the application of biochar, and the revenues from the sale of energy products. Currently, the marginal shadow price is estimated to be between approximately EUR 188 and EUR 536 per ton of CO_2 (2025 prices), as shown in the figure. The shadow price represents the socio-economic cost per ton of CO_2 within Denmark's borders, taking into account the alternative CO_2 storage effect from the current use of the biomass.

The shadow price varies along the curve, depending on which biomass is assumed to be utilized, which is determined by the estimated prices of the biomass. The average shadow price along the curve is estimated to be around EUR 335 per ton of CO_2 (2025 prices).



Note: The figure shows the marginal shadow price and net cost per ton CO_2. Costs increase depending on the amount of biochar, as biomass costs are estimated to increase as more biomass of potentially better quality and from greater distances needs to be allocated. Different types of biomass come into use for pyrolysis along the curve, resulting in jumps in cost per ton of CO_2. The curve is smoothed to reduce these fluctuations.
When correcting for the biomass's previous use, the average for the biomass's current use has been used.

Source: Ministry of Climate, Energy and Utilities

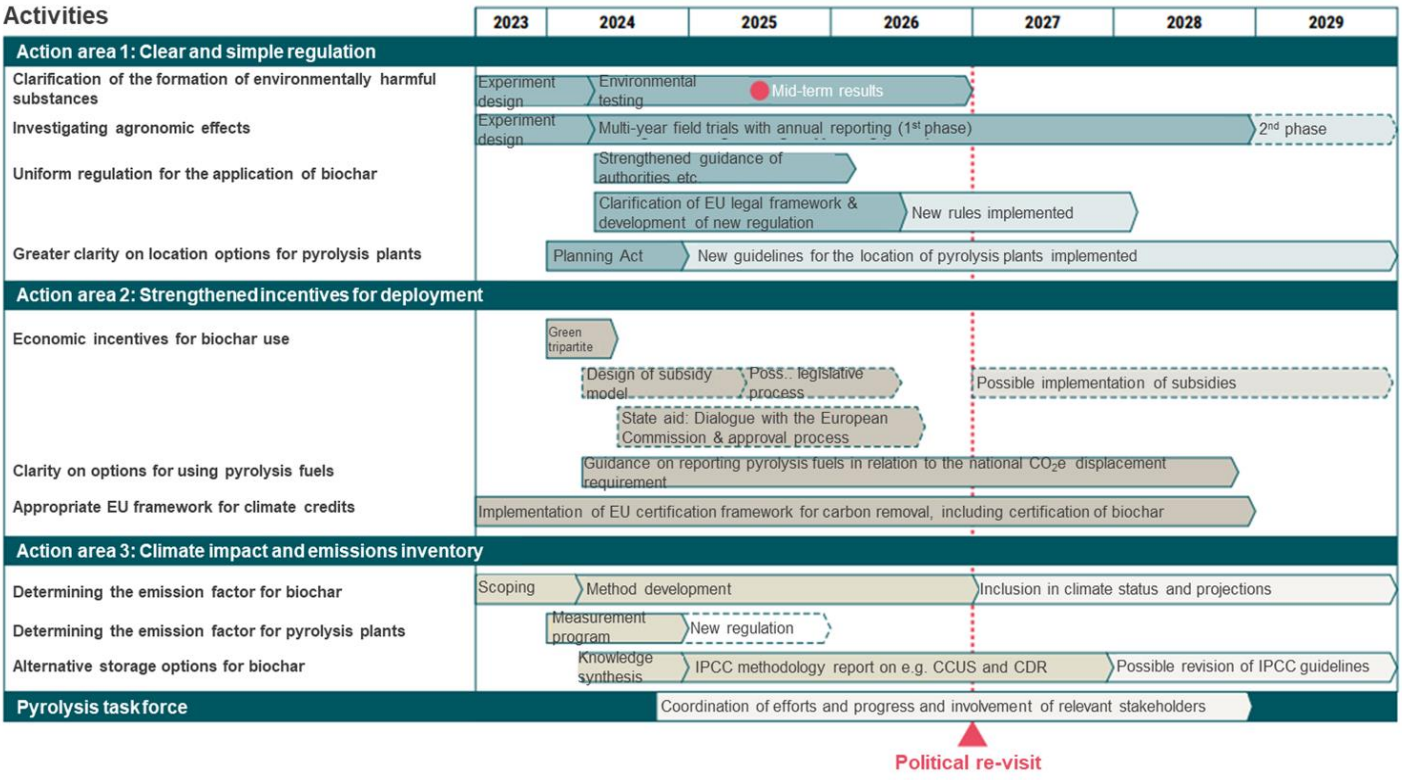
The above CO_2 shadow price is based on the following revenue assumptions:

- Pyrolysis Oil: Priced like fuel oil plus CO_2 quota, minus 10% for conversion, transport, and storage costs. Estimated at EUR 56 (DKK 420) per MWh in 2030, rising to EUR 82 (DKK 620) per MWh by 2050.
- Pyrolysis Gas: Expected to replace pipeline gas, valued at EUR 25 (DKK 190) per MWh, following the price of pipeline gas minus 10% for infrastructure costs.
- Excess Heat: Priced based on renewable heat with a 10% deduction for conversion, estimated at EUR 24 (DKK 180) per MWh.
- Electricity Consumption: Projected at EUR 71 (DKK 530) per MWh in 2027, dropping to EUR 58 (DKK 430) by 2035.
- Biomass Pricing:
  - Straw: EUR 74–227 (DKK 550–1,690) per ton.
  - Digestate: EUR 0–44 (DKK 0–330) per ton.
  - Wood: EUR 125–170 (DKK 950–1,300) per ton.
  - Garden Waste: EUR 75–134 (DKK 560–1,000) per ton.

These prices vary based on transport costs and previous biomass use.

Pyrolysis Rollout and Timeline/Workstreams

The government's initiatives will be implemented over the coming years. A political review will take place in 2026/2027 to follow up on the progress of the implementation. The workstreams and timelines are shown below:



The government will initiate the following workstreams:

Focus Area 1: Clear and Simple Regulation workstreams

- **Amend the Planning Act:** From January 1, 2025, municipalities will be required to develop guidelines for the location of pyrolysis plants as part of municipal planning revisions.

- **Clarify Environmental Impacts:** Investigate the formation, content, and breakdown of harmful substances during biochar production to establish environmentally justified regulations. This research began in December 2023 and is expected to conclude by mid-2026, with EUR 2.01 million (DKK 15 million) allocated from the 2023 Research Reserve and EUR 938,000 (DKK 7 million) from the 2024 Research Reserve.

- **Field Trials on Biochar in Agriculture:** Multi-year field trials will assess the large-scale use of biochar in agriculture without unacceptable risks to the environment, nature, and agronomy (e.g., soil biology, nutrient availability, crop yields). These trials, starting in 2024, will also explore biochar's fertilizing value, with annual reports on findings. EUR 8.43 million (DKK 63 million) and EUR 1.87 million (DKK 14 million) have been allocated for 2023 and 2024, respectively.
- **Establish Regulatory Framework:** Based on research findings, clear regulations for biochar use will be implemented by mid-2026, compliant with EU law. Adjustments may be made depending on future research results.

- **Strengthen Municipal Guidance:** Provide municipalities with guidance on §19 permits through the Danish Environmental Protection Agency to streamline case handling and hold information meetings or workshops for stakeholders, environmental authorities, and others.

- **Create a Pyrolysis Task Force:** Establish a cross-ministerial pyrolysis task force to coordinate the implementation of government initiatives and develop a future carbon storage market via biochar. The task force will create a NEKST implementation forum with relevant external stakeholders.

- **Support Environmental Approvals:** Develop guidance for environmental authorities to support approval processes for pyrolysis plants, including emissions data collection from existing facilities and adjustments to the revised air guidance.

- **Evaluate Biochar Stack Covering Requirements:** By late 2026, assess whether current requirements for covering biochar stacks made from livestock manure can be relaxed based on ongoing environmental trials.

Focus Area 2: Enhanced Incentives for Expansion workstreams

- **Establish a subsidy scheme from 2027** for the storage of biochar produced via pyrolysis. The subsidy will be granted per ton of CO_2 stored in agricultural soil.

- **Allocate funds** as follows:
  - EUR 27 million (DKK 0.2 billion) in 2027,
  - EUR 40 million (DKK 0.3 billion) in 2028,
  - EUR 54 million (DKK 0.4 billion) in 2029,
  - EUR 81 million (DKK 0.6 billion) annually from 2030 onward,
  - In total EUR 1.34 billion (DKK 10 billion) by 2045.

- **Prioritize funding** for the demonstration and development of pyrolysis technology by 2030 as part of future green innovation and research initiatives.

- **Explore opportunities** to use Common Agricultural Policy (CAP) funds in the next reform period to support biochar application for carbon storage in agricultural soils, promoting the technology transition using EU agricultural subsidies.

- **Provide guidance** on displacement factors for reporting pyrolysis gas or oil to meet national CO_2 displacement requirements.

- **Support the European Commission** in implementing a credible pan-European certification system for carbon removal.

- **Proactively establish clear guidelines** for biochar certification.

Focus Area 3: Climate Impact and Emissions Accounting workstreams

- **Develop a method** to include the climate impact of biochar stored in agricultural soils in Denmark's greenhouse gas inventory from 2027. This method will be approved by the Danish Centre for Environment and Energy (DCE), responsible for reporting to the UN. Once approved by the UN's review panel, biochar's climate effect can be incorporated into emissions reporting.

- **Conduct greenhouse gas emission measurements** during biochar production, including methane emissions. A project funded with EUR 134,000 (DKK 1 million) from the Research Reserve started in 2023, with a contracted company performing the measurements. The initiative is expected to be completed by 2025, at which point the need for methane regulation at pyrolysis plants will be assessed.

- **Work actively with the IPCC** to develop a method for accounting for alternative biochar storage options. The first step, a method report on negative emissions, is expected by 2027. Denmark will then advocate for pyrolysis and biochar storage to be included in the report.

- **Produce a knowledge synthesis in 2024** to evaluate the pros and cons of alternative biochar uses beyond agricultural soil application.