THE POTENTIAL AND RISKS OF CARBON DIOXIDE REMOVAL BASED ON CARBON CAPTURE AND STORAGE IN THE EU

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Executive summary and recommendations

Rapid and deep emission reductions must be the priority and cornerstone in the EU's climate policy. Carbon dioxide removal based on carbon capture and storage (CCS-based CDR), such as bioenergy with carbon capture and storage (BECCS) or direct air carbon capture and storage (DACCS), will at the same time be necessary to complying with the Paris Agreement and reaching climate neutrality in the EU. The EU needs to accelerate efforts to permanently remove CO_2 from the atmosphere, and at the same time mitigate barriers and risks on the way to ensure a sustainable deployment.

The development and deployment of these methods in the EU is still at an early stage. Today, there are **only limited examples of BECCS projects and no DACCS projects in the EU**. The European Commission has an aspirational objective to remove 5 million tonnes of CO_2 from the atmosphere annually and permanently store it through technological solutions by 2030 as well as reporting and accounting the origin of any tonne of CO_2 captured, transported, used, and stored by 2028.

Until now, there has been **limited regulatory focus directed towards the deployment of CCS-based CDR in the EU**, consisting mostly of public funding from EU funds and state aid from Member States as well as the legal conditions for carbon capture and storage (CCS). In parallel with public funding, **the voluntary carbon markets are expected to play a greater role** in the business case for BECCS and DACCS projects in the future, but more clarity is needed on the relationship between these markets and EU targets and policies.

The role and regulation of carbon dioxide removal (CDR) in the EU is gaining increasing political traction with the proposal for a voluntary regulatory framework for the certification of carbon removals (CRCF), the upcoming industrial carbon management strategy, and the policy debate around the EU climate targets and policies post-2030. At this critical juncture, it is important to assess the potential for CCS-based CDR in the EU and the policy interventions needed to foster the deployment in a manner that ensures environmental integrity and avoid mitigation deterrence.

Potential for BECCS and DACCS in the EU

CONCITO estimates based on the best available data that the current amount of **emitted biogenic CO_2 is around 209 million tonnes per year from large scale energy and industry facilities as well as biogas production in the EU**. The largest sources of biogenic CO_2 emissions are the power and heating sector followed by the pulp and paper sector. Member States in Northern and Western Europe currently account for most of the biogenic emissions from industrial point sources. **The estimate on current biogenic CO_2 emissions should not be conflated with the economic or sustainable BECCS potential, which is restricted by several factors** including costs, infrastructure, limited availability of sustainable biomass, political feasibility, and social acceptance.

Due to the lack of robust official data, the current amount of emitted biogenic CO_2 is underestimated to some extent. Therefore, **CONCITO recommends the European Commission to propose obligations for all industrial facilities to report and account all biogenic CO_2 emissions (including the type of biomass feedstock used)** as an important step for informed decision-making.

Looking forward, **the potential of BECCS and DACCS towards reaching climate neutrality and net-negative emissions hereafter remains unclear** and depends on residual emissions, technology costs, infrastructure development, availability of sustainable biomass as well as political and social acceptance. The European Commission currently estimate broad ranges for the CCS-based CDR potentials, reflecting these uncertainties, where BECCS could provide 5 to 276 million tonnes of carbon removals in 2050, while DACCS could provide 83 to 264 million tonnes of carbon removals in 2050.

At the same time, the use of biomass could more than double towards 2050, if regulation in the EU remains unchanged, putting pressure on carbon stocks, biodiversity, and food security both inside and outside the EU. The biomass consumption for energy purposes in the EU is already at a level that could be considered at odds with a sustainable level of bioenergy use in a global context.

Prioritization and stronger regulation of biomass use is needed prior to further incentivizing the deployment of BECCS to avoid lock-in of high biomass use for purposes that could be served by other means e.g., electrification.

Policy interventions to sustainably deploy BECCS and DACCS in the EU

CONCITO recommends considering a **broad range of policy interventions to include BECCS and DACCS in EU climate policy**. To ensure a fast and sensible development and deployment of CCS-based CDR in the EU, certain barriers and risks need to be mitigated.

The table below summarizes **important barriers and risks as well as policy interventions** to be considered in the EU's climate and energy policy moving forward:

Barriers and risks	Content	Possible policy interventions
Rapid emission reductions	Carbon removals must not distract from the necessity of rapid and deep emission reductions.	• Consider separate reduction and removal targets and instruments in EU climate policy.
Economic incentives and infrastructure	To ensure a quick realization of the potentials for BECCS and DACCS, there is a need for better economic incentives to deploy the technologies as well as improved infrastructure for transport and storage of CO_2.	• Careful integration of BECCS and DACCS in the EU Emissions Trading System (EU ETS). • Additional EU funding (especially for DACCS). • Ensuring adequate and coordinated development of EU-wide infrastructure for transport and storage of CO_2.
Climate effect and availability of biomass	BECCS deployment should be approached in full consideration of the risk of increasing use of biomass as well as the net-emissions from burning biomass and the limited availability of sustainable biomass. Biomass must be prioritized for high-value purposes (e.g., hard-to-abate industry, materials in buildings and food production). More accurate incentives/restrictions on the use of biomass (e.g., in the power and heating sector) must be considered to avoid lock-in of high biomass use due to BECCS.	• Include net-emissions from biomass in the EU ETS. • Limit role of biomass and remove crop-based biofuels in the Renewable Energy Directive. • Phase-out subsidies for biomass use in the power and heating sector. • Phase-out of biomass boilers in residential heating (e.g., through ecodesign requirements).
Voluntary carbon markets and robust certification	Development and use of carbon removal certificates needs to accurately reflect the differences between different methods in terms of permanence, scalability, and sustainability. The actual carbon removal for BECCS and DACCS across its lifecycle depends on several factors (including the net-emissions from burning biomass).	• Clarify the role of voluntary carbon markets in EU climate policies. • Ensure robust definitions and clear rules on use of different types of carbon removal certificates. • Develop robust methodologies for BECCS and DACCS (including accounting of net-emissions from burning biomass) under the CRCF.

Report

The potential and risks of carbon dioxide removal based on carbon capture and storage in the EU

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Introduction

Carbon dioxide removal based on carbon capture and storage (CCS-based CDR), such as bioenergy with carbon capture and storage (BECCS) or direct air carbon capture and storage (DACCS), will play a role to limit the global average temperature to 1.5 °C. CCS-based CDR is important for balancing a limited amount of hard-to-abate emissions, such as long-haul aviation and agriculture, and for reducing atmospheric concentration of CO_2 through net-negative global emissions in the second half of the century.

There are several ways to deliver carbon dioxide removal (CDR), which the European Commission divides into three overall categories, namely 1) permanent carbon storage , 2) carbon farming (e.g. CDR through soils and forests) and 3) carbon storage in long-lasting products and materials (e.g. CDR through wood-based materials in buildings). There is a big difference between the various methods, their technological maturity, permanence, scalability, costs, and sustainability, which must be considered in the regulation of CDR.

This report will focus on CCS-based CDR, which are methods ensuring CDR for millennia. The focus of the report is therefore on two methods: BECCS and DACCS. Biochar[1] will not be considered, since there still is a lack of clarity around the degree of permanence of this type of storage. The report also excludes other CDR methods from its scope such as enhanced rock weathering and ocean alkalinization[2] due to the lack of access to the potential and effects in the EU and need of further research (e.g. impacts on human health).

While both BECCS and DACCS are ultimately based on geological carbon storage, there are significant differences between them. According to the IPCC, the cost of BECCS and DACCS is highly uncertain. However, their assessment suggests that the cost of carbon removals from BECCS falls within the range of 100-200 EUR per tonne in 2050, while DACCS ranges between 100-300 EUR per tonne in 2050. Moreover, the climate mitigation potential of DACCS is primarily constrained by its technological maturity, the amount of renewable energy and infrastructure for transport and storage, whereas BECCS also faces limitations related to the climate effects due to limited availability of sustainable biomass.

In the next chapters, the report will assess the 1) current deployment and policies in the EU, 2) potential for BECCS and DACCS and 3) possible policy interventions required to foster a sensible and sustainable deployment in the EU.

1 The approach relies on the process of pyrolysis, where biomass carbon is transferred into the more stable biochar that e.g. can be used as soil amendment enhancing the soil properties and storing carbon in the soil.
2 Enhanced rock weathering refers to the spread of fine grained silicate rocks containing calcium or magnesium on land (e.g. cropland) which react with CO_2 by forming carbonate minerals and hence remove CO_2 from the atmosphere. Ocean alkalinization refers to methods of increasing seawater pH to enhance the absorption of CO_2 from the atmosphere.

Current deployment and policies in the EU

In this chapter, the report will focus on the current deployment and polices regarding BECCS and DACCS in the EU.

1. Current deployment of CCS-based CDR

Today, BECCS and DACCS are not widely deployed in the EU. A limited number of BECCS projects are on-going, notably a waste-to-energy facility in the Netherlands and small-scale CO_2 capture from bioethanol plants. However, there is a growing number of BECCS projects under development – e.g. the Stockholm Exergi BECCS facility in Sweden and the Ørsted BECCS facilities in Denmark. There are currently no operational DACCS facilities in the EU, and no upcoming projects are under development. Outside of the EU some countries, such as the US and Iceland, host small scale and operational DAC facilities, although the majority focuses on utilization of the CO_2 captured rather than storage. There are some upcoming projects of DACCS on the way globally.

2. Current policies in the EU

Today, the European Commission has as an aspirational objective to remove 5 million tonnes of CO_2 from the atmosphere annually and permanently store it through technological solutions by 2030. This was put forward in the Communication on 'Sustainable Carbon Cycles' in December 2021. As part of the Communication, the European Commission also established an objective to report and account any tonne of CO_2 captured, transported, used, and stored by industries and account by its fossil, biogenic or atmospheric origin by 2028. The European Commission has announced that it will publish an industrial carbon management strategy in the fourth quarter of 2023. The strategy will focus on 1) the role carbon capture, utilization and storage (CCUS) can play in decarbonizing the EU economy by 2030, 2040 and 2050 and 2) measures needed to optimize their potential.

Until now, there has been limited regulatory focus directed directly towards CCS-based CDR in the EU. Projects and infrastructure can be supported through e.g., the Innovation Fund, Connecting Europe Facility, and Horizon Europe, and state aid guidelines enable Member States to provide support to some extent. Today, public funding varies considerably between Member States.

In parallel to public funding, there is also EU legislation establishing some of the conditions around BECCS and DACCS. This includes the CCS Directive establishing a legal framework for the environmentally safe geological storage of CO_2, the Environmental Liability Directive establishing a common framework for the prevention and remedying of environmental damage[1], and the recent proposal on a Net-Zero Industry Act setting an EU objective and obligations to reach an annual 50 million tonnes injection capacity in CO_2 storage sites by 2030.

The European Commission has proposed a voluntary regulatory framework for the certification of carbon removals (CRCF) in November 2022. The aim is to establish an EU-wide certification framework to assure the quality of carbon removals activities and to increase transparency and credibility of carbon removal activities in the voluntary carbon markets. The framework will facilitate private funding of carbon removal activities across the EU. The voluntary carbon markets are generally expected to play a greater role in the business case for BECCS and DACCS projects in the future.

Some actors in the European Parliament and in some Member States have also put pressure on the European Commission to integrate CCS-based CDR in the EU Emissions Trading System (EU ETS). As part of the recent agreement on the reform of the EU ETS, the European Commission is obligated to carry out a report and possibly a legislative proposal in July 2026, which must examine how CCS-based CDR could be covered by emissions trading, whilst making sure it does not lead to offsetting of necessary emissions reductions.

1 E.g., the Directive addresses compensation claims in case of leaks caused by non-compliance.

Potential for BECCS and DACCS in the EU

In this chapter, the report will address the potential for BECCS and DACCS in the EU with a specific focus on biomass resources by investigating the 1) current sources of biogenic CO_2, 2) limitations on biomass use and 3) deployment of BECCS and DACCS towards climate neutrality in the EU.

1. Current sources of biogenic CO_2 in the EU

CONCITO estimates that 209 million tonnes of biogenic CO_2 per year is currently emitted at large scale industrial installations and biogas facilities in the EU. It is important to underline that this estimate does not give an insight into the economical or sustainable potential for BECCS, which is restricted by several factors, including costs, infrastructure, and limited availability of sustainable biomass.

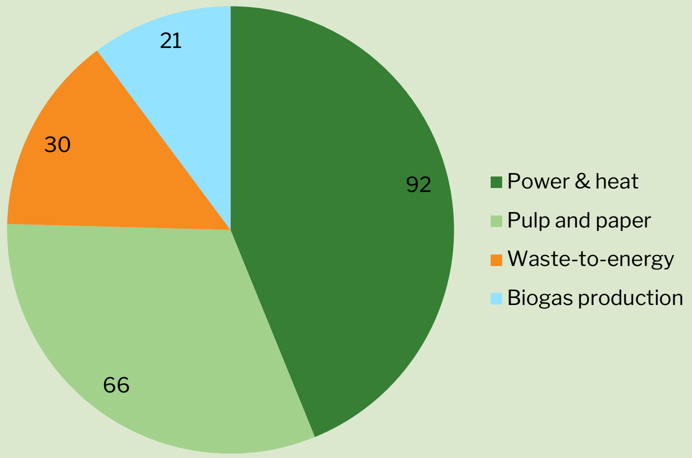
Box 1 gives an overview of the biogenic CO_2 emissions distributed among sources. The origin of biogenic CO_2 can be divided into two overall categories – combustion at industrial point sources and biogas production. Currently, 188 million tonnes of biogenic CO_2 is emitted at large industrial point sources, and 21 million tonnes is emitted from biogas facilities[1].

The largest emissions of biogenic CO_2 from industrial point sources come from the power and heat sector followed by the pulp and paper sector. Northern and Western European countries account for the majority of biogenic industrial point source emissions, while South and Eastern European countries have fewer industrial point sources emitting biogenic CO_2. Notably, Sweden and Finland are the largest and second largest industrial emitters of biogenic CO_2 due to their substantial pulp and paper industries. Biogenic CO_2 emissions from biogas production is more evenly spread out across Europe and is currently dominated by Germany, Italy and France.

Box 1 – Biogenic CO_2 emissions from biogas facilities and large industrial point sources in the EU

CONCITO estimates that 209 million tonnes of biogenic CO_2 is currently emitted at large scale energy and industrial facilities as well as biogas facilities in the EU (see Figure 1). Some industries (incl. cement and bioethanol) were excluded due to lack of data.

Figure 1: Biogenic CO_2 emissions currently emitted from biogas production and large industrial point sources (million tonnes of CO_2)



1 In practice, the CO_2 is not emitted from the biogas production facilities themselves. It will be emitted either at upgrading facilities or when combusted in biogas boilers.

The estimates are based on the European Environment Agency's (EEA) E-PRTR database, UNFCCC inventory submissions alongside sector specific data on capacity size and Eurostat data. A detailed description of the methodology can be found in Annex 1. While the EEA data could have been a valuable resource for estimating all industrial point source emissions, it unfortunately has limitations[2]. Therefore, UNFCCC data alongside capacity sizes were used for the majority of the sources. CONCTO has not been able to provide estimates for industries beyond those depicted in Figure 1 for two main reasons: 1) inadequate reporting in the EEA database and 2) a lack of sector-specific data on capacity size for other industries. In this light, CONCITO underestimates the current biogenic CO_2 emissions to some extent and recommends that the European Commission proposes obligations for all industrial emitters to report and account all biogenic CO_2[3].

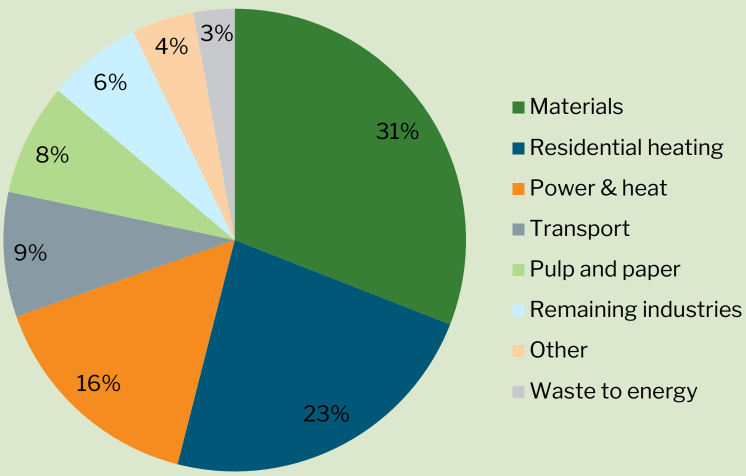
To put this into context, it is important to consider the overall consumption of biomass in the EU and the types of feedstocks used. Currently, the EU consumes 5,6 EJ of biomass for energy purposes, as well as an additional 2,5 EJ for materials. Further, biomass is also utilized for plant-based food production and animal feed and bedding, the latter representing the single biggest category of biomass use. Biomass use in the EU has been on an increasing upward trend primarily driven by significant growth in biomass uses for energy followed by material use.

Box 2 provides an overview of biomass consumption in the EU for energy and material use. The consumption is further classified into two categories, 1) industrial combustion and 2) non-industrial combustion, as BECCS is only feasible at industrial point sources. Industrial combustion of biomass accounts for one third of the EU's biomass consumption for energy and material use – half of which is consumed at conventional biomass-fired or biomass-co-firing power and heating facilities. The remaining portion is combusted at pulp and paper mills, waste-to-energy facilities and other industries.

Box 2 – Current biomass consumption for energy and materials in the EU

Based on the energy content of the fuels and materials, the consumption of biomass for material and energy purposes are shown below*. Figure 2 shows total consumption in materials and final energy-use, while Figure 3 depicts the biomass consumption at industrial point sources.

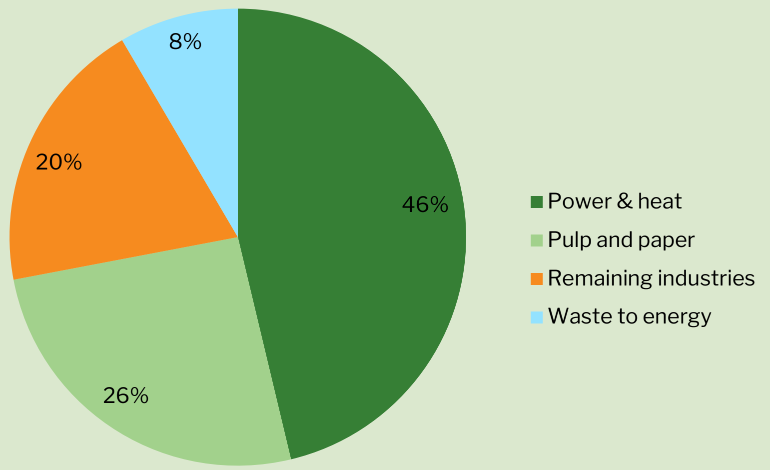
Figure 2: Biomass consumption for energy and materials (percentage)



* Biomass consumption for energy purposes is categorized based on 2023 UNFCCC national inventory submissions, while material-use is based on the JRC report on biomass.

2 E.g., the database is lacking behind in reporting, only obligates larger installations to report and does not include facilities that only produce heat.
3 The use of biomass among smaller industrial installations and heat producers should be documented as well.

Figure 3: Bioenergy consumption at industrial point sources (percentage)



Regarding non-industrial combustion of biomass, the vast majority can be attributed to heating in residential buildings and the use of biofuels in the transport sector.

2. Limitation on biomass globally and in the EU

Biomass is a limited resource, and the availability of sustainable biomass is one of the major limiting factors for the deployment of BECCS. Multiple factors determine the supply of sustainable biomass such as land productivity, land and water availability, and competition with food production and land conservation. The IPCC found that negative impacts on biodiversity and food security through land competition might arise if BECCS is deployed globally at large-scale.

The European Commission acknowledges that BECCS deployment should be approached in full consideration of the limits and availability of sustainable biomass in order to avoid excessive demand for biomass for energy that would have negative effects on carbon sinks and stocks, biodiversity and air quality.

The global availability of sustainable biomass has been a subject of heated intellectual debate over the last several years. The IPCC has previously found high agreement among experts that the sustainable bioenergy potential on a global scale would be restricted to approximately 100 EJ per year for energy purposes in 2050[4]. This same restriction is used in the IEA's Net Zero by 2050 scenario, where global bioenergy use is restricted to 100 EJ per year.

However, there is still high uncertainty around the exact level of sustainable bioenergy use and other studies by Wu et al. (2019) and Frank et al. (2021) indicate availability between 150-170 EJ per year, but this entails great transformation of the use of land including diet-shifts. Global availability of sustainable bioenergy of 100 EJ or 170 EJ per year corresponds to a range of 10 to 17 GJ of bioenergy per capita by 2050[5].

It is crucial to be aware of the share of the global bioresource that the EU is occupying. Currently, the EU consumes on average 15 GJ of bioenergy per capita with significant variations between the different Member States[6]. In this light, the biomass consumption for energy purposes is already at a level that could be considered at odds with the sustainable level of bioenergy use, assuming an equitable distribution of bioenergy globally.

In this light, an increase in the biomass consumption for energy purposes in the EU is likely to push the boundaries of sustainable use.

4 In subsequent reports, the IPCC has not mention 100 EJ per year as the ceiling for sustainable biomass use.
5 Based on the UN's projection of world population in 2050.
6 Based on current EU-27 population and biomass feedstock modelling for 2020, which can be found in the staff working document for the Communication on Sustainable Carbon Cycles.

Other political priorities in the EU related to food production, biodiversity protection, and carbon sinks[7] could limit available biomass for energy. In the next section, the report looks into the future development of biomass consumption if regulation in the EU remains unchanged.

3. Deployment of CCS-based CDR towards climate neutrality

Looking forward, the potential of CCS-based CDR to reach climate neutrality and net-negative emissions hereafter remains unclear. According to the European Commission, the potential for BECCS in 2050 ranges from 5 to 276 million tonnes, while potential for DACCS in 2050 ranges from 83 to 264 million tonnes. These wide ranges reflect the considerable uncertainty surrounding factors such as residuals emissions, technology costs, infrastructure development, and the availability of sustainable biomass.

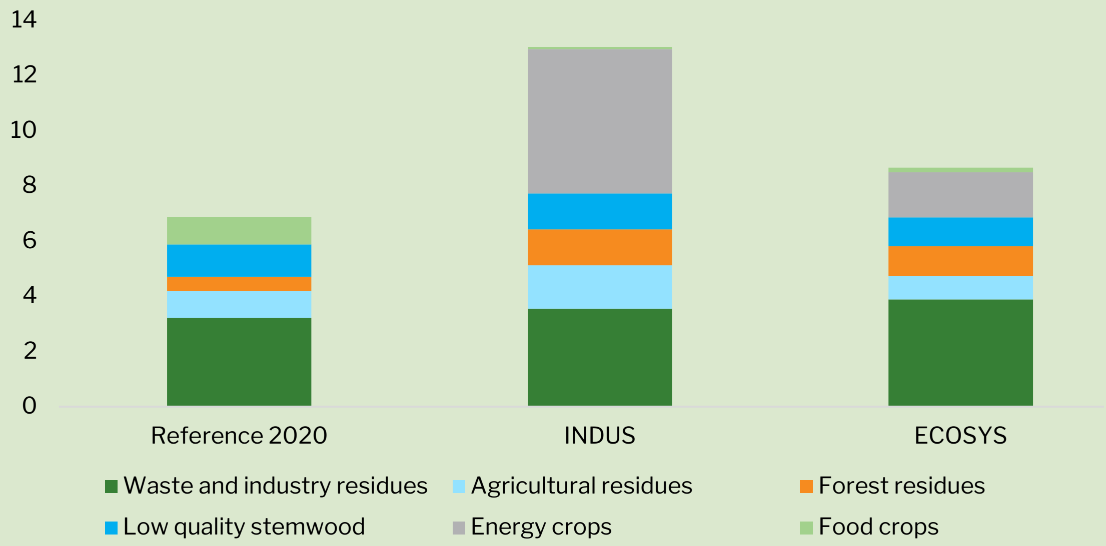
The future BECCS deployment should be approached in full consideration of the expected increase in the use of biomass moving forward. The European Commission indicates that the use of biomass could increase around 25-90% towards 2050 depending on how much priority is given to changes in lifestyle as well as ecosystem restoration and carbon removals. As shown in Box 3, energy crops and forest residuals are expected to significantly increase to meet the demand of bioenergy putting pressure on carbon sinks and stocks, biodiversity, and food security both inside and outside the EU.

The European Commission's modelling for the 2030 Climate Target Plan and the Joint Research Centre (JRC) Energy Scenarios shows that use of biomass could more than double towards 2050 if regulation in the EU remains unchanged.

Box 3 – Bioenergy feedstock in 2050

The European Commission has established two illustrative scenarios – INDUS and ECOSYS – regarding the management and use of carbon by 2050. The two scenarios have different reliance on large scale deployment of industrial solutions, changes in lifestyle, ecosystem restoration and carbon removals. To meet the demand for bioenergy, fast growing energy crops increase by approximately 1,6 EJ in ECOSYS and more than 5 EJ in INDUS. Meeting the energy crop demand of the INDUS scenario would necessitate cultivating an area larger than Italy*.

Figure 4: Bioenergy feedstocks in 2050 according to illustrative scenarios (EJ)



* Material Economics estimate that a land area the size of Germany, 350.000 km², can produce 5,6 EJ biomass from dedicated energy crops. The INDUS scenario estimates a biomass requirement of approximately 5.2 EJ from energy crops, which would necessitate an area of 327,000 km². This area is slightly larger than Italy's land area of 301,000 km².

7 Especially, the achievement of the EU's ambitious land-use sink target of 310 million tonnes by 2030 under the revised LULUCF Regulation.

In these scenarios, the power and heating sector drives over 50% of increased biomass use, while the transport sector accounts for just over 20%. This is consistent with other climate mitigation scenarios, which also project substantial increases in future demand for bioenergy by the power and heating sector and transport sector in the EU. This development has been criticized by causing the EU to possibly divert twenty percent of its cropland to energy crops, increase the import of wood for bioenergy four-fold and outsource deforestation.

These modelling results have a high degree of uncertainty and do not take into account the most recent political development such as targets and policies set in the REPowerEU plan (e.g. an increased political target for biomethane in 2030), which could create even higher demand for biomass. The modelling can also be affected by the current lack of robust data. For instance, JRC has found that 12% of woody biomass use stems from unaccounted sources.

Prioritization and stronger regulation of biomass use is needed prior to further incentivizing the deployment of BECCS to avoid lock-in of high biomass use for purposes that could be served by other means e.g., electrification. BECCS entails a risk of lock-in as the capital cost has been incurred, and the operating hours could possibly increase compared to a scenario without BECCS. The EU should prioritize biomass for high-value purposes, such as hard-to-abate industry, material in buildings, and food production, on the path towards climate neutrality.

Policy interventions to sustainably deploy BECCS and DACCS in the EU

In this chapter, the report presents possible policy interventions to sustainably deploy CCS-based CDR in the EU. Importantly, the report does not assess the political feasibility and social acceptance of BECCS and DACCS, which will be important to the deployment in the EU[1].

1. Economic incentives and infrastructure for BECCS and DACCS are needed in the EU

Currently, there is a lack of economic incentives to establish BECCS and DACCS projects in the EU. Developers are unlikely to carry out necessary investments and engage in projects without public funding. The voluntary carbon markets are expected to play a greater role in the business case for BECCS and DACCS projects in the future (see further below).

As mentioned, the costs of BECCS and DACCS projects will vary significantly according to site-specific factors, relative access to finance, and economies of scale. The IPCC estimates a cost range of 100 to 200 EUR per tonne for BECCS and 100 to 300 EUR per tonne for DACCS in 2050. For DACCS, large amounts of air need to be filtered to purify one tonne of CO_2 requiring high energy consumption due to the low concentration of carbon in the air. Combined with low technological maturity, the process is consequently more expensive than BECCS.

Infrastructure for the transport and storage of CO_2 is another bottle neck to a large-scale deployment of BECCS and DACCS. BECCS projects in the EU may be located far away from possible storage sites, whereas DACCS projects have the flexibility to be built near the storage site. The current lack of transport and storage capacity can deter investors in BECCS and DACCS projects. However, a number of storage projects is under development, most notably in Norway, Denmark, United Kingdom, and the Netherlands. Announced projects leave some inland regions with poor access to CO_2 storage, particularly in Central and Eastern Europe. It underlines the need of ensuring adequate and coordinated development of an EU-wide CO_2 transportation and storage site network.

This is only just getting started through possible financing through the Connecting Europe Facility, the injection capacity in CO_2 storage sites objective and obligations in the Net Zero Industry Act as well as bilateral infrastructure projects. Shared infrastructure, including CO_2 pipelines and storage sites both onshore and offshore, could bring down costs and reduce the long lead time for CCS projects in general.

To further ensure proper economic incentives for BECCS and DACCS, the following policy interventions could be considered:

- **Careful integration of CCS-based CDR in the EU ETS:** Today, there are only incentives for CCS and CCU on fossil installations in the EU ETS for stationary installations, aviation and maritime transport, but no incentives for BECCS and DACCS[2]. There are several policy options for including BECCS and DACCS in the current EU ETS. For example, BECCS and DACCS could be included in the EU ETS by 1) awarding free allowances for generating CDR, or 2) allowing the use of CDR certificates

1 E.g., the NEGEM project are looking systematically into these aspects.
2 This is partly because the EU ETS does not allow for the generation of allowances corresponding to the amount of carbon removals generated through DACCS. Biomass facilities are not included in the system, and the emissions factor for biomass that complies with the sustainability criteria and greenhouse gas emission saving criteria for the use of biomass established by Renewable Energy Directive is counted as zero.

either directly for compliance obligations (with possible limitations) or through the establishment of an intermediary Carbon Central Bank. The different policy options would require big and systemic changes to the EU ETS, and it would be necessary to mitigate risks concerning BECCS and DACCS. For instance, prioritization and stronger regulation of biomass use is needed prior to further incentivizing the deployment of BECCS. Furthermore, limitations or restricted use of allowances or certificates generated from CCS-based CDR should be carefully analyzed and considered to ensure emission reductions and take into account the limited availability of sustainable biomass. Companies should not be allowed to use certificates from less permanent CDR methods – such as carbon farming – as a means of reducing compliance obligations and avoiding carbon pricing, since it could compromise the environmental integrity of the EU ETS. Generally, fossil emissions which stay in the atmosphere for millennia should not be balanced out by CDR in the biosphere, where huge permanence, measurement and additionality issues exist. CONCITO will further investigate policy options for including BECCS and DACCS in the EU ETS in a separate report taking into account the growing research and analyses on this issue[3].

- **Additional funding in the EU (especially for DACCS)**: A combination of policies and financial mechanisms will be necessary to support the deployment of CCS-based CDR. A careful integration into the EU ETS will likely occur post-2030 and may not be sufficient on its own. This is especially true for DACCS considering the disparity between the significant project costs and the allowance price. In the early development and deployment stages, DACCS is likely to require additional public funding – e.g., in the form of "top ups", such as contracts for difference, that complement the allowance price and provide a higher and more predictable price signal. In the longer run, the cost of DACCS could decrease, and economic incentives created by an EU ETS could potentially be sufficient. BECCS might not require additional public funding if included in the EU ETS due to the expected increase in the allowance price.

2. The relationship between emission reductions and carbon dioxide removal

CCS-based CDR is needed to counterbalance some hard-to-abate greenhouse gas emissions to reach net-zero and subsequently to achieve net-negative emissions - both globally and in the EU. At the same time, CCS-based CDR is by no means a substitute for rapid and deep emission cuts that must take highest priority. For example, CCS-based CDR would be constrained by timely implementation, be exceptionally expensive compared to the majority of emission reductions and further constrained by limited resources such as biomass.

The risk of mitigation deterrence[4] is an important part of the policy debate on the development, deployment and future reliance of BECCS and DACCS in the EU. It is a question of potential moral hazard, where efforts, or even potential efforts, to deploy CDR methods could result in the delay or reduction of mitigation efforts. There is disagreement in scientific literature regarding the magnitude of the risk, but, even so, it remains critical to ensure that emission reductions remain at the forefront of climate action in the EU.

To remedy these risks certain guardrails could be considered in the EU climate policy regime going forward:

- **Separate reduction and removal targets:** To ensure that CDR do not distract from emission reductions, one potential avenue would be to establish clear and separate targets and frameworks for emission reductions and CDR. Separate targets could establish the basis for a policy and obligation

3 E.g. Rickels, Proelß, Geden, Burhenne and Fridahl (2021), Rickels, Rohtenstein, Schenuit and Fridahl (2022), La Hoz Theuer and Olarte (2023), Meyer-Ohlendorf (2023) and Edenhofer et al. (2023).
4 The idea that promises of future carbon removal might act as an excuse for avoiding the need to reduce emissions today.

regime that improves the likelihood that targets are achieved, which is the case for CDR in soils and forests in the LULUCF regulation, but not for CCS-based CDR. Alternatively, a minimum target for emission reductions could be established in order to signal to emitters that most emissions can and should be reduced, while still allowing CDR to play a role. On the other hand, a 'net target' including both emission reductions and CDR could in principle achieve climate targets more cost-effectively, since sub-optimally set CDR targets could prevent cost-efficient removal quantities as marginal removal costs in general would not equal the price for reducing emissions depending on the current and future shape of the marginal abatement cost curve and removal cost curve. The current 2030 climate target has a limit on the contribution of CDR to achieving the target of 225 million tonnes of CO_2 equivalent. In the public consultation on the 2040 climate target, the European Commission explicitly poses the question if it is better to set a separate target for emission reductions and another target for CDR, or even one target for reducing emissions, a target for nature-based CDR and a target for industrial CDR.

3. Climate effect and availability of biomass

Today, harvesting of wood and other types of biomass is accounted for as an emission in the country where the biomass is harvested as part of LULUCF accounting based on UN guidelines. If biomass is burned in an electricity or heating facility, the emissions are not attributed to the power and heating sector to avoid double counting, as the emission has already been accounted for in the LULUCF sector.
This accounting principle has provided a strong incentive for companies to increase their consumption of bioenergy, because it is perceived as carbon neutral if sustainability requirements are met, and therefore not subject to carbon pricing. In principle, countries inside and outside the EU pick up the bill in terms of lower carbon stocks and net-removals in their LULUCF accounts[5], but this has so far not translated into effective incentive structures in the EU.

In practice, burning biomass is not carbon neutral, as the biomass would alternatively not have been converted into CO_2 immediately. When energy is produced from e.g. woody biomass, the wood is burned, and the carbon content is released as CO_2 into the atmosphere. The woody biomass could alternatively have been left in the forests for natural decay or used for other purposes such as harvested wood products. The amount of CO_2 in the atmosphere, the net-emissions, associated with burning biomass will decrease over time, if the biomass is replanted in the same way, but it will be high for the first many decades.

The temporary shift of the carbon pool from forest to atmosphere will negatively affect the climate, and the short to medium term increases in emissions may lead to climate tipping points being passed.

In a recent publication, the Danish Energy Agency estimated that the emissions factor of burning wood pellets and wood chips in Denmark is 121 kilogram of CO_2/GJ after 1 year, 27,5 kilogram of CO_2/GJ after 30 years and 8,6 kilogram of CO_2/GJ after 100 years[6]. In comparison, the emissions factor for coal is 107 kilogram of CO_2/GJ and natural gas is 64 kilogram of CO_2/GJ in Denmark. Other sources[7], including a report from CONCITO, have also estimated emissions factors and relative emissions savings of burning biomass with results depending on the type of biomass, country/region, data, methodologies, and assumptions. For example, the climate impact of burning

5 The UN accounting principle does not make it accurate to count biomass burning as carbon neutral. This is partly because the EU has little control over the extent to which countries outside the EU count emissions accurately and whether they have binding and sufficient climate targets that mean emissions are offset by reductions elsewhere. If this is not the case, EU's import and consumption of biomass from those countries will result in additional global emissions. Furthermore, estimation of emissions and removals from the LULUCF sectors are highly uncertain.
6 The emissions factor includes both the biogenic emissions from energy production, process emissions (transport and production), and indirect emissions (emissions associated with indirect changes in land use).
7 E.g. Danish Council on Climate Change (2022), CONCITO (2021), IPCC (2018), Cherubini et al. (2011) and IPCC (2006).

different types of biomass varies (e.g. for wood, agriculture and waste residuals) and depends on the time perspective.

The emission factors of burning biomass are important to take into account when upscaling the potential for BECCS. BECCS deployment should be approached in full consideration of the risk of increasing use of biomass as well as the net-emissions from burning biomass and limited availability of sustainable biomass. Economic incentives reflecting the loss of carbon stocks in the LULUCF sector should be included in order not to distort the market by having strong incentives for BECCS that are not mirrored by similar incentives to store carbon in biomass.

To properly address these issues, the following policy interventions can be considered:

- **Including net-emissions from biomass in the EU ETS:** To establish more accurate incentives for the use of biomass in the EU, and at the same time ensure that subsidies for BECCS are allocated where they have the greatest climate effect, net-emissions from burning biomass could be covered by the EU ETS. This would more accurately incentivize a sustainable deployment of BECCS by limiting lock-in of biomass use for purposes that could be served by other means e.g., electrification. The European Commission could adopt delegated acts establishing the emissions factors based on the best available knowledge. This policy intervention will require big changes to the EU ETS and should be carefully analyzed, including changes to the emissions cap, effects on the allowance price and carbon leakage. For example, it would require new installations to be included in the EU ETS, since installations exclusively burning biomass are not included in the system today. Furthermore, it should be analyzed if biomass consumed in residential heating could be covered by emissions trading.
- **Limit the role of biomass and biofuels in the Renewable Energy Directive:** Biomass is counted as renewable energy in the Renewable Energy Directive. Therefore, the increasing renewable energy targets can encourage Member States to increase their consumption of biomass. To mitigate this trend, the European Commission could introduce a ceiling for how much biomass can be counted towards the renewable energy targets as well as getting the metrics for renewable heating and cooling right. Another option moving forward is to define new renewable energy targets based on other technologies than biomass, e.g., GW targets for wind and solar deployment. In parallel, it will be necessary to lower the consumption of biofuels in the EU. CONCITO has previously estimated that the energy content in the food crops used as feedstock for biofuels consumed in the EU is equivalent to the energy content in food that could feed approximately 150 million people. Moving forward, the EU should exclude the use of crop-based biofuels in all legislation.
- **Phase-out subsidies for biomass consumption**: Today, the use of bioenergy is typically not subject to carbon or energy taxes and often receives significant subsidies to compete against fossil fuels. For instance, many Member States in the EU provide massive subsidies for electricity generation and combined heat and power (CHP) from solid biomass. The European Commission should seek to limit and phase-out subsidies for biomass consumption.
- **Phase-out of biomass boilers in residential heating**: The European Commission could introduce regulation to reduce and avoid lock-in of biomass consumption in residential heating by introducing a phase-out of individual biomass boilers (e.g. through ecodesign requirements). Incentives for switching to other heating sources (e.g. heat pumps, wood-burning stoves) should be carefully analyzed.

4. Voluntary carbon markets and robust certification

In parallel with public funding, voluntary carbon markets are expected to play a greater role in the business case for BECCS and DACCS projects in the future. Globally, the current market is primarily dominated by avoided emissions and carbon farming projects, and CDR in these markets is typically of low quality, undocumented and at a very low price. However, there is also an increasing amount of capital earmarked for the development of BECCS and DACCS project. As an example, Microsoft has recently committed to purchase certificates from future BECCS facilities by Ørsted in Denmark, which was important for the business case and the award of state subsidies for the facilities. The voluntary market can thus play a role in providing risk capital for the realization and development of BECCS and DACCS projects.

However, there is a need for further clarification on how the EU and Member States integrate voluntary carbon markets, including BECCS and DACCS projects, into climate targets. For example, Sweden plans to allow support from voluntary markets to CDR projects, which also receive public funding. The Swedish Energy Agency proposes to address concerns about double counting, so when certificates for CDR are sold, it should be stated that the buyer has provided a contribution to the Swedish climate targets, and that double claims are made, if the certificates are used to compensate the buyer's emissions.

Currently, there is a risk that BECCS and DACCS projects, which have a high degree of permanence, are conflated with various other CDR methods under categories such as 1) carbon farming (e.g. CDR through soils and forests) and 2) carbon storage in long-lasting products and materials (e.g. CDR through wood-based materials in buildings). Clear delineation between the different types of CDR methods is needed, since there is a big difference in their permanence, scalability and sustainability. For example, storing carbon in soils and forests has significant issues with permanence (including risk of reversals through e.g. changes in land-use, droughts, pests, and forest fires) and monitoring (such as lack of quality data and great uncertainties establishing trustworthy baselines) as well as risks of carbon leakage and impairment of biodiversity.

To ensure a robust certification and clarify the role of voluntary carbon markets, the following can be considered:

- **Clarification on the role of voluntary carbon markets in EU climate targets and policies**: The EU should further clarify how voluntary carbon markets are integrated into the EU climate policies. The voluntary market should not be seen as a replacement for additional climate policies in the EU. The EU must meet its climate targets through robust and comprehensive climate policies. If European actors sell certificates and at the same time receive public funding, there will be questionable additionality. There is a strong need to clarify how CDR projects receiving both public funding and finance from the voluntary carbon market can be used for offsetting companies' emissions.
- **Robust definitions and clear rules on the use of different types of CDR certificates**: The proposal from the European Commission on a certification framework for carbon removals (CRCF) does not sufficiently delineate between the different types of CDR activities. The various CDR methods should be labelled in different ways, according to the origin and fate, especially the character and duration of the carbon storage, including its reversal risk, and the proposal needs to clearly distinguish CDR from emissions reductions. In parallel, the Green Claims proposal addressing environmental claims made by organizations or for products must set more clear guardrails. The proposal does not currently provide strict rules on the use of different types of CDR certificates and should provide clear regulation on how and when they can be used by organizations or for products.

- **Establish a robust methodology for BECCS and DACCS:** Methodologies for BECCS and DACCS under the CRCF must be based on the actual carbon dioxide removal of the methods across their lifecycle. The European Commission has pointed to the use of the methodology from the EU Innovation Fund to certify CDR from BECCS and DACCS in the context of the CRCF. However, that methodology lacks clarity on how the origin of the CO_2 impacts the generation of CDR certificates. For instance, industrial facilities using both fossil fuels and biomass for its production will use the fossil CO_2 captured to reduce the surrender of allowances under the EU ETS, while possibly generating carbon removal credits from the biogenic CO_2 captured. To address this, the methodology should be refined to consider variations in CO_2 origin[8]. Additionally, net-emissions from burning biomass should be accounted for, when generating CDR certificates from BECCS on the voluntary carbon market. As mentioned above, this could take into account the emission factors for the use of different biomass feedstock.

8 This should align with the possible implementing acts to specify how to account for the storage of emissions from mixes of zero-rated biomass and biomass that is not from zero-rated sources as agreed in the reform of the EU ETS.

Annex 1 - Methodology to estimate the biogenic emissions in the EU

The report uses both European Environmental Agency's (EEA) E-PRTR database, Eurostat data and UNFCCC inventory submissions alongside sector specific data on capacity sizes to estimate the biogenic CO_2 emissions from biogas production and large industrial point sources. UNFCCC National Inventory Submissions 2023 for the year 2021 and capacity sizes were used for the power and heat sector and the pulp and paper sector. All power and heating facilities that were larger than 20 MW were included, and the distribution was taken from a study by AEBIOM and Basis Bioenergy, which was also used in a revision of the Renewable Energy Directive. However, capacity sizes are only given for plants that are powered by woody biomass. Therefore, CO_2 emissions from biogas-firing in the power and heat plants were excluded. This might lead biogenic CO2 emissions from the power and sector to be underestimated but previous analyses[1] suggest that one of the main uses of biogas is electricity and heat generation at small facilities. Eurostat data was used to estimate the share of biogenic CO_2 emissions from biogas-firing in the power and heat sector.

Capacity sizes for the pulp and paper sector was found in Cepi's key statistics report from 2021, and only facilities producing 50.000 tons of pulp and paper materials per year were included. Previous calculations based on the E-PRTR database found higher biogenic emissions from waste-to-energy facilities than can be observed in the UNFCCC National Inventory Submissions[2]. In light of this, the E-PRTR database was used to estimate these emissions. Eurostat data on indigenous production of biogas and conversion factors was used to calculate biogenic emissions from biogas. Biogenic CO_2 emissions from biogas production are not strictly emitted at the production sites. They are currently released to the atmosphere at either upgrading facilities or simply emitted when biogas is combusted. Biogenic emissions from bioethanol and alcohol production could also have been included. However, a substantial portion of the CO_2 from bioethanol and alcohol production is already being used for other purposes such as carbonization, which makes it challenging to precisely assess how many of these emissions should be included.

1 Analyses by Scarlat et al. (2018), a EU Horizon 2020 funded study and World Biogas Association suggest that biogas-fired power plants are usually small and local as well as having a small average capacity size.
2 Rosa et al. (2021) found that yearly biogenic CO_2 emissions from large incinerators are 36 million tons while UNFCCC data reports only 23 million tons.

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