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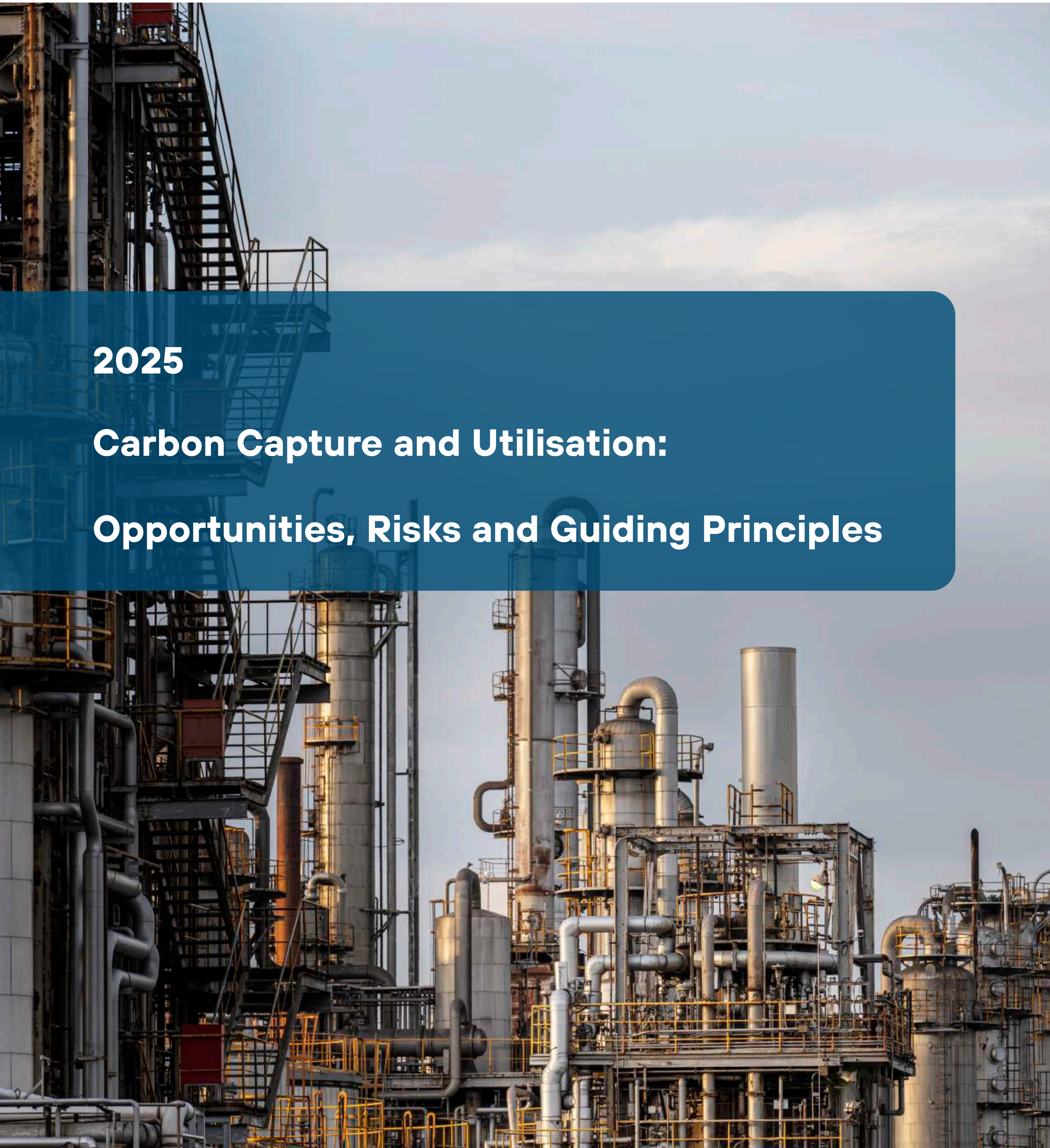

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Carbon Capture and Utilisation: Opportunities, Risks and Guiding Principles

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About Bellona Deutschland

Bellona Deutschland is an international, independent and non-profit organisation that meets environmental and climate challenges head on. We are solutions-oriented and have a comprehensive and cross-sectoral approach to assess the economics, climate impacts and technical feasibility of necessary climate actions. To do this, we work with civil society, academia, governments, institutions, and industries.

About Germanwatch

Following the motto of Observing. Analysing. Acting. Germanwatch has been actively promoting global equity and livelihood preservation since 1991. We focus on the politics and economics of the Global North and their worldwide consequences. The situation of marginalised people in the Global South is the starting point for our work. Together with our members and supporters, and with other actors in civil society, we strive to serve as a strong lobbying force for sustainable development. We aim at our goals by advocating for prevention of dangerous climate change and its negative impacts, for guaranteeing food security, and for corporate compliance with human rights standards.

Germanwatch is funded by membership fees, donations, programme funding from Stiftung Zukunftsfaehigkeit (Foundation for Sustainability), and grants from public and private donors.

About NABU

NABU has been committed to advocating for people and nature since 1899. With around 960,000 members and supporters, NABU is the environmental organization with the largest member base in Germany.

NABU's most important missions include the preservation of habitat and species diversity, the sustainability of agriculture, forestry and water management and, last but not least, climate protection. One of NABU's central concerns is to provide access to experiencing nature and promote environmental knowledge.

In the approximately 2,000 NABU groups and around 70 information centres throughout Germany, practical nature conservation is just as much a part of our work as lobbying, environmental education, research and public relations.

Preamble

The defossilisation of energy-intensive industries in Germany is a decisive lever for achieving climate targets and, at the same time, essential for securing the future of Germany as a centre of industry. It offers the opportunity to create new jobs in high-growth sectors with a broad supplier network, to promote regional value creation and to increase innovative strength. It is therefore important to modernise the German industry, strengthen its resilience and actively shape its transformation.

Even in a climate-neutral future, carbon will be needed as an important raw material in industrial processes where it cannot be replaced by electrification. This is particularly the case in parts of the chemical industry or for the production of sustainable fuels for shipping and aviation (see box on aviation). In this context, Carbon Capture and Utilisation (CCU) is increasingly being discussed as a potentially promising approach for a climate-neutral industry. CCU refers to technologies and processes for capturing and utilising carbon dioxide (CO_2), for example from fossil fuels, industrial processes, biogenic installations or directly from the atmosphere, in order to reuse it as a raw material. Fuels, building materials or other products based on CCU can be part of the solution, but only if the right framework conditions are in place.

A realistic look at the potential of CCU as a climate protection measure, taking into account the overall impact, shows that there are significant dilemmas and trade-offs associated with the use of CCU. Chemically speaking, CO_2 is an inert molecule. If it is to be converted back into raw materials, large amounts of energy and additional hydrogen are required (see box on CCU energy requirements). Both resources will remain limited commodities in their green form in the medium term, especially in the existing European industrial centres. The opportunities in other regions of the world with greater renewable energy potential must be taken into account in a global approach. However, the recommendations in this paper relate primarily to Central Europe and the challenges here, particularly with regard to energy and feedstocks.

Under the current regulatory framework in Germany and Europe, CCU is generally not a business case. Currently, such a case would only arise where CCU applications are recognised as emission reductions, for example where CO_2 is permanently chemically bound under normal use and end-of-life as part of the European Emissions Trading Scheme (EU ETS), and thus given value.

In a Delegated Regulation adopted in July 2024,[1] the EU Commission stipulates that the CO_2 must be chemically bound for "at least several centuries" in order for CCU to be recognised as an emission reduction in the context of EU emissions trading,[2] more or less on par with the treatment of CCS. It thus focuses on those building materials for which such a long sequestration period is possible. As

1. EU Commission Delegated Regulation of 30 July 2024 supplementing Directive 2003/87/EC of the European Parliament and of the Council with regard to the conditions for greenhouse gases to be considered as permanently bound in a product. https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14135-Emissionshandelssystem-EHS-dauerhafte-CO2-Speicherung-durch-CO2-Abscheidung-und-Nutzung_de

2. Art 3, 1 b) "It shall remain permanently chemically bound in a product so that it does not enter the atmosphere for a period of at least several centuries during normal use and/or during the disposal phase of the product, including normal end-of-life activities"

a rule, these are mineral compounds and not hydrocarbons. However, statements from companies and industry associations on this legislation suggest that pressure will remain high for a shorter sequestration period to be recognised as a climate protection measure, which should be critically and carefully evaluated.

Important decisions are also being made in other areas. The 'Industrial Carbon Management Strategy' and the 'Clean Industrial Deal' respectively engage directly and indirectly with CCS and CCU, seeking to create a European market for CO_2 and enabling large-scale investments in necessary capture, transport, and storage infrastructure, often treating CCS and CCU on relatively equal footing despite the significantly variable climate impact of CCU. The EU ETS already recognises the emission reduction generated by capturing and permanently storing CO_2 in geological formations, as well as from certain types of CCU where the CO_2 is permanently chemically bound. Nevertheless, the European Commission has been tasked with identifying ways in which CCU approaches which do not meet these conditions may be recognised in the EU ETS even though the captured CO_2 is to be released at a later stage. It is vital that if CO_2 is emitted to the atmosphere, even if it has been previously captured from another installation, this be penalised appropriately such as to disincentivise the emission of CO_2.

In Germany, a Carbon Dioxide Storage and Transport Act (KSp(T)G) has yet to be passed. While the focus is rightly on the capture and geological storage of CO_2, i.e. CCS (Carbon Capture and Storage), in terms of industrial and climate policy, CCS and CCU are de facto equated at one point of the draft.[3] This is a dangerous fallacy that can unfortunately be observed quite often in the current climate policy debate: while CCS is intended to permanently store CO_2, CCU converts the captured CO_2 into products with very different lifetimes, which does not necessarily lead to a permanent, complete or even predominant reduction in emissions. The long-term strategy for negative emissions (LNe), with which the Federal Ministry for Economic Affairs and Climate Action (BMWK) is to create guidelines for dealing with unavoidable residual emissions, will also be relevant for dealing with CCU. In addition, it is urgently necessary to resume the creation of a National Biomass Strategy (NABIS).

In these and other CCU-related regulations, it must be ensured that CCU applications are only recognised as climate protection measures to the extent of their actual and verifiable contribution to reducing emissions. This paper sets out important guidelines for the development of this regulatory framework.

3. Section 4 of the KSpTG draft law adopted by the federal government states with regard to infrastructure construction that, in addition to the permanent geological storage of CO_2, a project also serves the public good "if it transports carbon dioxide to cover a proven need for the use of carbon dioxide as a raw material source for carbon compounds in order to permanently reduce carbon dioxide emissions in Germany for the purpose of climate protection".

The high energy requirements of CCU

Converting CO_2 into a raw material requires considerable amounts of energy. Direct air capture (DAC) requires around 1.8 to 6.5 GJ of energy per tonne of CO_2, depending on the technology and energy sources.[4] According to the Federal Environment Agency, the conversion of CO_2 into higher-value organic chemical products requires around 36 GJ of energy per tonne of CO_2, i.e. five to 20 times the energy required for DAC.[5] Particularly the amount of hydrogen required to be produced by electrolysis, contributes to the high energy requirement.

The energy-intensive CCU processes can only be realised in an ecologically sensible way if there is a sufficient supply of renewable energies. CCU therefore requires an additional expansion of renewable energy (additionality). Furthermore, CCU should only be used where hydrocarbons are still required (such as in parts of the chemical industry and modes of transport that are difficult or unviable to electrify) and where these cannot be provided by other means with a better climate and environmental balance. The additional demand for renewable energy in turn increases the demand for raw materials, including critical raw materials.[6]

At the same time, it is evident that large-scale CCU with a net-zero greenhouse gas balance is not feasible in Central Europe in the short to medium term. So far, CCU does not usually constitute a business case and will remain very expensive for the foreseeable future. Due to the high demand for renewable energies and hydrogen, other regions of the world will offer significantly better location specific conditions.[7]

4. International Energy Agency, 2022, Report on Direct Air Capture

5. Federal Environment Agency, 2021, Discussion paper on the assessment of carbon capture and utilisation

6. Zelt, O. et al., 2020, Multi-criteria evaluation of synthetic fuel supply technologies Fuels. MENA-Fuels: Partial Report 3 of the Wuppertal Institute and the German Aerospace Centre (DLR) to the Federal Ministry of Economics and Technology (BMWi) and Climate Protection (BMWK)

7. Verpoort, P. C. et al, 2024, Impact of global heterogeneity of renewable energy supply on heavy industrial production and green value chains. Nature Energy, 9(4), 491-503. https://doi.org/10.1038/s41560-024-01492-z

Guiding Principles for the utilisation of CO_2 within a climate-friendly framework

In order for CCU to make a meaningful contribution to the climate-neutral transformation, it must be regulated on the basis of the following principles:

What must apply to the CO_2 source?

1. **Differentiation by carbon source in regulation and accounting:** In principle, a carbon dioxide molecule from fossil sources contributes to net greenhouse gas emissions as soon as it is emitted into the atmosphere. Emissions into the atmosphere can thus only be approximately climate-neutral if the carbon is of atmospheric origin. With biogenic sources, it is important to take a closer look.

1.1 Utilisation of fossil carbon sources only under certain conditions: CCU with a fossil carbon source would only be compatible with climate neutrality if:

1.1.1 CO_2 storage in the product is achieved as completely and permanently as possible. This means that the CO_2 must be stored for the long term and thus remain bound for several centuries (e.g., through geological storage or the carbonation of building materials).

1.1.2 The permanent circular use of CO_2 is guaranteed. It should be noted that even a circular economy always requires a certain amount of energy as input and possibly additional resources; i.e. even closed-loop CCU would have to compensate for any residual emissions by natural or other technical sinks. It should be noted that a large proportion of chemical production is released into the sewage system or the environment as abrasion, lubricants or cleaning agents or through littering. Additional amounts leave the system through exports.

1.1.3 A complete net return to geological storage is ensured at the end of life.

1.2 Suitability of direct atmospheric carbon sources (Direct Air Carbon Capture and Utilisation): Direct atmospheric carbon sources offer the potential to contribute to reducing emissions by removing CO_2 from the atmosphere. Ideally, this effect is maintained in the long term through downstream utilisation of the sourced carbon, such as permanent storage in products or its final return to the lithosphere (sink). For a climate-neutral or even negative-emission-capable process, however, the provision of energy and resources for DAC must not ultimately cause any net additional emissions. However, DAC is associated with considerable challenges, particularly due to the high energy and resource requirements and the associated costs, which currently severely limits its large-scale application.

1.3 The ambivalent role of biogenic carbon sources: In the context of CCU, the utilisation of biogenic carbon sources is particularly relevant due to their capture from waste incineration or biomass-based industrial processes. Theoretically, the utilisation of carbon that was previously removed from the atmosphere by sustainably cultivated plants can contribute to negative emissions if the effect is maintained through downstream utilisation and - of course this also applies here - the provision of energy and resources to utilise the carbon does not lead to net-positive emissions. In principle, however, the use of biogenic carbon requires particular caution, as sustainable biomass is a limited resource that should only be combusted in respect of the cascading principle if possible. In addition, numerous secondary effects can be associated with its utilisation, such as impacts on biodiversity and ecosystems. Furthermore, competing uses must be resolved, for example through cascading use that follows the food-first principle and prioritises the necessary renaturation of ecosystems. In principle, the use of biomass must not lead to the cannibalisation of climate protection goals in the LULUCF sector, such as carbon storage in soils and forests.

In the current EU ETS, which utilises downstream pricing (CO_2 certificates are due when CO_2 is emitted), it must be ensured that CCU does not create any loopholes that allow fossil CO_2 to enter the atmosphere unpriced and unaccounted for. In contrast to today, in a climate-neutral future, the carbon that goes into material utilisation in the chemical industry must also be fully recorded and addressed. The principle should be: The responsibility for CO_2 ultimately lies with the last actor to whom it can still be transferred to in terms of the current regulatory framework. At the same time, double pricing of the same CO_2 molecule must be ruled out (e.g. in the case of waste incineration, only the CO_2 that is released into the atmosphere should be priced. The part that is transferred via CCU into a product which then ends up in aviation fuel or chemical products, for example, would be priced there instead.

What needs to apply to the process?

2. Almost 100% renewable energy as a prerequisite for CCU processes: CCU can only be considered climate-neutral if the entire process is climate-neutral, which includes capture and processing, transport, synthesis of new molecules and end-of-life treatment. Overall, CCU thus generates a large demand for renewable energies and additional green hydrogen - both resources will be a scarce and expensive commodity in the future (see Energy box). It should also not be forgotten that the industrial plants for all these processes are resource-intensive and also affect scarce resource types. Issues of priority in access to sustainable energy from CCU over other industrial applications and the potential for flexibilisation of DAC technologies, e.g. with regard to their adaptation to the renewable's electricity market, still need to be clarified.

What needs to apply for the use of CO_2?

3. Clear accounting of CCU based on long-term sequestration or closed-loop management of CO_2: In order for a CCU product to be recognised as climate-neutral, it must be ensured that no GHG emissions are released into the atmosphere through its use.[8] Balance sheet GHG-neutral therefore means that either no emissions are actually produced or that the only

8. CO_2-neutral does not equal GHG-neutral. The use of CCU products often results in further compensation requirements for other climate-relevant gases (e.g. in air traffic through non-CO_2 emissions, when using chemical products such as lubricants or cleaning agents or through tyre abrasion), which must also be compensated for in order to achieve GHG neutrality

emissions are CO_2 that was previously removed from the atmosphere (e.g. by DACCU). However, we do not consider it to be a sufficiently reliable measure per se to serve as a basis for carbon credits or trading on carbon markets. For accounting purposes, stringent sustainability and accounting criteria must be met under a clean monitoring and compliance system. This principle applies not only to the main process of CO_2 utilisation, but also to all accompanying processes such as energy provision and transport.

Concepts for CCU process chains must ensure long-term CO_2 capture or closed-loop recycling. However, closed-loop recycling cannot yet be guaranteed. Such concepts should be developed by the industry and critically examined for technical feasibility, energy efficiency and life cycle emissions. CCU can only make a meaningful contribution if the entire life cycle is compatible with the goals of climate neutrality and ecological sustainability.

CCU for aviation

Climate neutrality in air travel is particularly difficult to achieve due to the particularly high energy requirements and the additional non-CO_2 effects such as contrails and water vapour. A direct switch to electric or hydrogen engines is not technically or physically feasible, especially for long-haul flights. There is a growing realisation that climate-neutral flying can only be achieved through a ramp-up of E-SAF (Electricity-based Sustainable Aviation Fuels) based on renewable energies. So far, however, there are no large-scale plants available for this, nor is it clear in what form the necessary renewable energies can be secured. There is also no agreement yet on the carbon sources required for the synthesis of E-SAF.

The prerequisite of the CO_2, which is emitted by the aircraft, being transferred to a climate-neutral cycle or compensated for in some other way, is currently not feasible without the use of direct air capture (DAC). When CO_2 from fossil industrial point sources is utilised, the CO_2 is released into the atmosphere during use in flight. In carbon accounting terms, this only halves CO_2 emissions (through "double use"); net zero would still be a long way off, even for pure CO_2 emissions. The non-CO_2 effects, which account for up to two thirds of the total greenhouse effect caused by air traffic (particularly through contrails), must also be taken into account.

Ultimately, the CO_2 would therefore either (1) have to be removed directly from the atmosphere via DAC and then converted into e-SAF or (2), if no climate-neutral CO_2 sources were used for fuel production, subsequently offset via DACCS (Direct Air Carbon Capture and Storage). In both cases, the non-CO_2 effects would also have to be offset by DACCS.

9. A good overview is provided by atmosfair

Conclusion

If the aforementioned guiding principles are met, CO_2 can theoretically be used in a climate-neutral way. However, it is also clear that strict requirements are needed to ensure that CCU does not become a loophole. Most CCU applications are not suitable per se as a permanent CO_2 sink, nor can they be fully acknowledged as a CO_2 reduction measure. Apart from use cases which guarantee long-term sequestration and are less energy-intensive, such as binding CO2 in building materials, only a few products are suitable for a GHG-neutral strategy without further measures. If CCU were to be integrated into the existing emissions trading system, it would have to be ensured that the emissions released during the life cycle are accurately priced - while also preventing double pricing. Regulatory incentives must continue to lead to a reduction in emissions and must not undermine climate protection measures.

Nevertheless, CCU can be a building block for the climate-neutral supply of carbon in the future, for example for feedstock replacement in the chemical industry or for the production of e-kerosene for aviation. Although research and development of this technology will probably not be used on a large scale in Europe, its development can still be advanced. However, as CCU is associated with considerable energy, resource and sustainability challenges, alternatives such as electrification strategies and carbon sequestration in natural sinks are generally preferable.

Nonetheless, CCU should not only be seen as a technical solution to the carbon issue. Rather, CCU offers a starting point for discussing fundamental questions about the future of industry, especially the chemical industry, in Europe.[10] The path to implementing CCU in a way that makes sense from a climate policy perspective requires a broad reframing with regard to the utilisation of resources, the design of production processes and the responsibility of industry in a climate-neutral economy.

10. Verpoort, P. C. et al., 2024, Transformation of energy-intensive industry - competitiveness through structural adaptation and green imports. Potsdam Institute for Climate Impact Research.

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