NEGATIVE EMISSIONS AND CARBON DIOXIDE REMOVAL (CDR)

Technologies, international policy environment and business models

BRIEF

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CONTENTS

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Steve Freeman, Schlumberger
Hans Petter Kildal, Becour
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INTRODUCTION AND BACKGROUND

From UNEP Emissions Gap Report 2020's Executive Summary:

"Are we on track to bridging the gap? Absolutely not."

The task ahead of us is gigantic.

Most scenarios and pathways that brings us to a net zero society rely on our ability to remove carbon dioxide (CO_2) from the atmosphere from around 2040 and onwards. This is an underexplored area that will need collaboration, power, incentives, and endurance to unlock the potential required.

This policy brief summarizes highlights from the workshop on Negative Emissions and Carbon Dioxide Removal (CDR) held 28 April under the NTNU Energy Transition Week 2021. It was the first in a series of workshops on the topic that aim to outline the main challenges related to:

1. How should businesses approach a situation where negative emissions becomes a necessity?
2. What is the role of governments in making this happen: for example, reducing risk, building markets, and providing regulation – and what is the right timing?
3. What are the knowledge gaps that the academic society should address?

This first workshop was primarily used to shed light on the topic of negative emissions and CDR by taking a closer look at negative emission technologies, the international policy environment, and some selected companies' business models for negative emissions.

This summary should not be used as scientific facts and conclusions, but rather as a summary of important issues and aspects discussed at the workshop.

RECOMMENDATIONS AND WAY FORWARD

Negative emissions and CDR at scale can offset hard to reduce emissions streams and remove historic emissions from the atmosphere. Hence, both will become important and required means to fulfil the Paris Agreement.

A number of solutions will be relevant and necessary in the future depending on both social aspects and policy regimes as well as technological capabilities.

To ensure fulfilling the Paris Agreement, we:

- **Need more modelling work and more facts** on how the nature takes up and release carbon;
- **Need more engineered solutions / projects** at significant lower cost, meaning massive technology development and at scale use. Partnerships will be key;
- **Need stronger national and international commitments** to drive CDR and development of harmonized regulations including sustainable supply chains;
- **Need standardized, long-lasting, flexible, and transparent concepts of certificate** on carbon removal and removal counting including technologies to ensure reliability;
- **Need marketplaces** where those willing to pay for CDR can meet those that are able to implement CDR actions with third party verification;
- **Need to bring together actors across all industries.** Those willing to share and contribute, to bring up opportunities and solutions, and develop credible business models for actors willing to pay or have an obligation to create negative emissions.

And finally, we **need willingness to put pressure behind and speed up the process.**

The above are also areas where research is required to improve the knowledge base for future decisions. Future workshops in the series will dive deeper into selected recommended topics.

OVERVIEW OF NET NEGATIVE EMISSION TECHNOLOGIES AND APPROACHES

Carbon dioxide (CO_2 or "carbon") removal (CDR) technologies play an important role in strategies to reach a key goal of the Paris Agreement of 2015, limiting climate change to well below two degrees, and even more so in scenarios that limit climate change to 1.5°C. CDR technologies provide negative emissions that can offset hard to reduce emissions streams. While global emissions reach negative levels near 2050, CDR technologies begin deploying well before 2050.

The term CDR refers to a wide range of technologies, some of them quite familiar, e.g., afforestation, and some of which are less familiar, e.g., direct air capture. For the purpose of this overview, we will bundle technologies into six sets (Figure 1):

1. Coastal blue carbon,
2. Soil carbon and biochar,
3. Afforestation ,
4. Bioenergy with CO_2 capture and storage (BECCS),
5. Direct air capture (DAC), and
6. Mineralization and enhanced weathering.

These are briefly described below.

1. **Coastal blue carbon** refers to carbon captured and stored by the world's coastal ecosystems. The technology consists of protecting and restoring coastal regions' natural ecosystems. Cost estimates range from 0-20 $/t$CO_2$ with cumulative global storage potential of ~50-85 Gt CO_2 (Siikamäki J. et.al., 2013) i.e., roughly one-two years annual global CO_2 emissions.

2. **Soil carbon and biochar** are technologies for accumulating carbon in soils. Soils contain roughly twice as much carbon (5.800 Gt CO_2) as the atmosphere (2.750 Gt CO_2). Over time farming practices and other land transformations have exposed soil carbon to the atmosphere where it has oxidized to form CO_2. Roughly 440 Gt CO_2 have been lost cumulatively from soils as the result of human activities (Sanderman J. et al., 2017). By changing land practices, for example employing low- and/or no-till cropping practices, soil carbon loss could be stopped or reversed. Natural processes would restore carbon to soils, but that process could be accelerated by employing other technologies such as pyrolyzing biological feedstocks and adding the resulting carbon to soils. Though there is limited pyrolysis capacity installed globally now and the process is fairly energy demanding. The restoration of carbon to soils not only provides a CDR opportunity, but also enhances soil productivity. Cost estimates range from 0-100 $/t$CO_2$ (IPCC SR15) with cumulative potential of 90-440 Gt CO_2.

3. **Afforestation** refers to expanding the extent of land area covered by forests. The afforestation potential is highly geographically specific and certain countries have significant amounts of abandoned agricultural land possible for afforestation. Studies show that the total areas may be as large as or even larger than the different countries' own statistics on abandoned land. The technology is cheap compared to other negative emission technologies. Forests and other above ground biomass hold carbon in the plant structure. Above ground biomass contains roughly 2.200 Gt CO_2, somewhat less than the atmosphere's 2.750 Gt CO_2. Anthropogenic land use change has released roughly 900 to 1.100 Gt CO_2 to the atmosphere (Olofsson J. et al., 2008). Deforestation is a current source of emission rather than a sink. Changing land-use patterns to restore forest carbon stocks provide a potentially large opportunity to deliver CDR services but is subject to permeance and leakage between afforesting and deforesting regions through international trade pressures. The competition with agricultural land use is a significant tradeoff. Afforestation could also lead to a warming of temperatures due to changes to the land surface properties, even though more carbon is stored in the trees. Cost estimates range from 0-50 $/t$CO_2$ (IPCC SR15).

4. **Bioenergy with CO_2 capture and storage (BECCS)** refers to technologies that use bioenergy in combination with CO_2 capture and storage. Bioenergy fuels obtained their carbon from the atmosphere, so that if it is combusted and returned to the atmosphere no net change in atmospheric carbon occurs. If, however, the carbon is captured and not returned to the atmosphere then the process generates energy and net carbon removal. Potential bioenergy sources include recycled waste streams of wood, paper, land-fill methane, crop residues, and purpose-grown crops such as corn, rapeseed, sugarcane, switchgrass, or woody poplar. Energy production is limited by competition for productive lands. Competition with food and unmanaged ecosystem land uses creates significant tradeoffs for purpose-grown bioenergy, though the demand for land for bioenergy is smaller in scenarios with BECCS than in scenarios that do not allow for BECCS. It also matters if irrigation is required or not to grow the bio feedstock.

[1] Indirect emissions will affect these net calculations but become less relevant as systems in the economy approach zero or negative emissions. Increasing the velocity of biogenic carbon can in itself, for some time, increase the CO_2 concentration in the atmosphere.

Once captured CO_2 must be transported to its storage location. CO_2 can be stored in deep saline formations (on and offshore) depleted oil and gas reservoirs, un-minable coal seams and basalt formations. The cumulative storage potential substantially exceeds current estimates of potential cumulative CO_2 capture in the 21st century. BECCS capture costs are estimated to range from 100-200 \$/tCO_2 (IPCC SR15).

5. **Direct Air Capture (DAC)** employs CO_2 capture technology to extract CO_2 directly from the atmosphere. Several pilot facilities are currently in operation. Once captured the CO_2 would be stored in a reservoir in the same way as captured CO_2 from other sources as discussed above. The total suite is often referred to as DACCS – Direct Air Carbon Capture and Storage. Tradeoffs include water use, capital intensity, and energy use. DAC cost estimates range from 100-600 \$/tCO_2 (IPCC SR15).

6. **Mineralization** of CO_2 refers to the utilization of materials that react with CO_2 to form stable chemical bonds. Mineralization is both a capture and storage mechanism. As example, limestone could be ground up and spread in soils or the ocean to bind up carbon. Cost estimates range from 50-200 \$/tCO_2 (IPCC SR15).

The first three technologies, coastal blue carbon, soil carbon enhancement, and afforestation are technologies that employ nature-based CDR. All three have issues with permanence, but more importantly they all have cumulative limits. The second set of three technologies, BECCS, DAC and mineralization, all could be deployed to remove carbon from the atmosphere on an effectively permanent basis hence, unlimited capacity. The first three technologies tend to have lower costs per ton of CO_2 uptake than the latter.

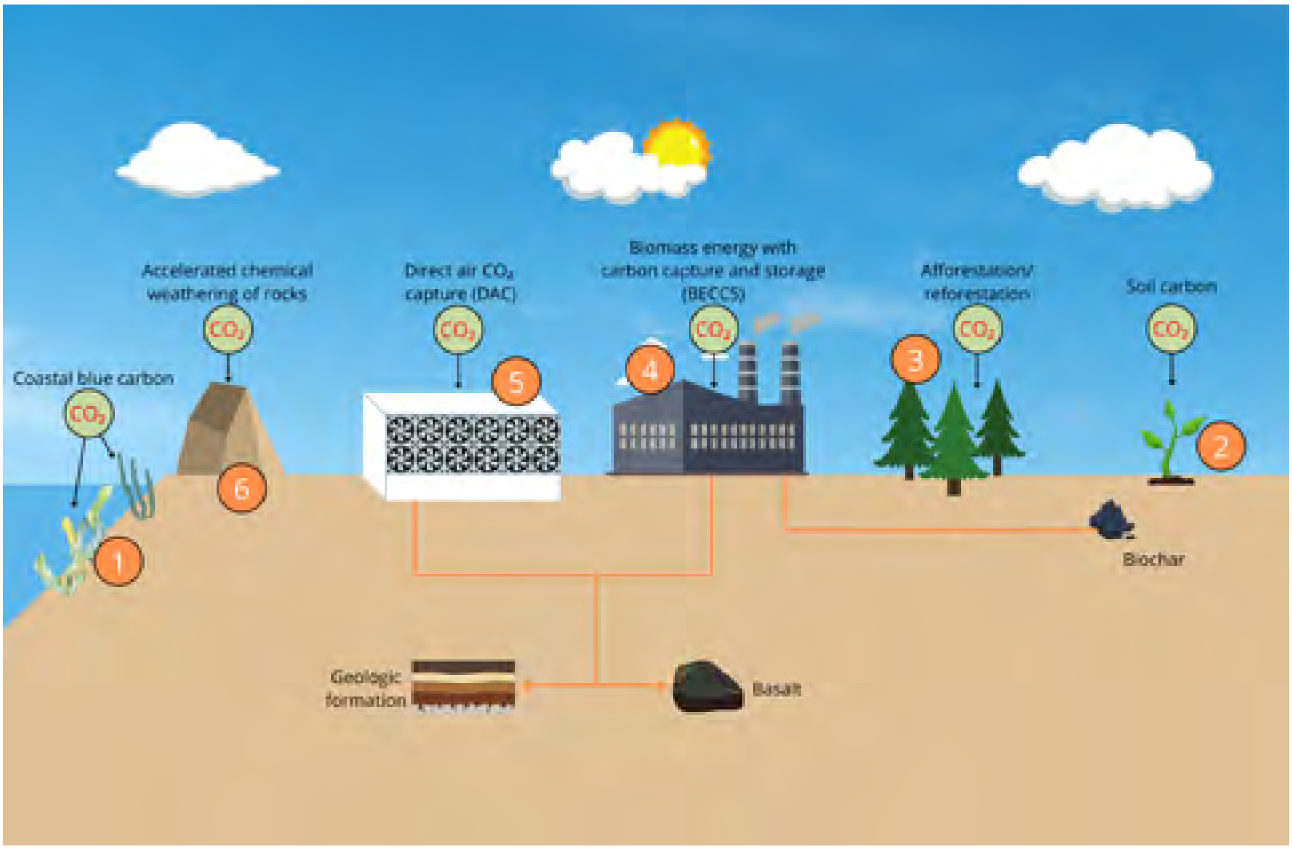

Figure 1: The six main groups of negative emission technologies and reliable sequestration.

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Biogenic carbon to mitigate climate change – utilization and societal / environmental impacts

In general, there are two main routes for utilizing biogenic carbon to mitigate climate change: i) Engineered solutions like BECCS and ii) nature-based solutions like afforestation etc.

The engineered solutions typically have fewer co-benefits with social aspects and other sustainable development goals (SDG) than climate, whereas the nature-based solutions more often can strengthen other SDGs. However, this is not always the case. Ocean alkalinization for example could be beneficial for local ecosystems, but this is still uncertain (Bach L.T. et al., 2019). Very large-scale afforestation could adversely impact biodiversity depending on how the land is used otherwise.

Some additional comments to potential technologies:

- Blue carbon – especially mangroves – have the possibility to store the double amount of carbon per km^2 than land forest and will in addition improve the local ecosystem. Restoration is important as 25-30% of original mangroves are already lost, which can be part of a nation's contribution to climate mitigation. ~4Gt C are stored in mangroves today (Hutchison J. et al., 2013).

- Green carbon through afforestation – especially in tropical areas as trees in such areas will increase the hydrological cycle, hence increase cloud formation and thereby increase heat reflectivity in addition to the effect of carbon uptake.

- Blue BECCS (e.g., the use of seaweed for fuels) – can reduce the land-conflict. It does not use fresh water nor fertilizer but comes at higher costs. The solution is not studied enough, and there is uncertainty about side-effects on i.e., local ecosystems and halogen emission. The interest in this solution is, however, growing.

- Green BECCS (a technology that the IPCC relies upon heavily) – comes with a range of challenges such as use of land for food production, water control, biodiversity threats, and decreased surface reflectivity. Therefore, BECCS is not a silver bullet to the climate crisis. It is largely a possibility in combination with energy production and soil carbon. The largest possibility for bio-crops is to use abandoned land for re-agriculture, while using tropical forests (deforestation) and use for bio-crops will have a net negative climate effect. "Land management" is therefore a key aspect to reduce land-conflict and thereby avoids negative effects on other SDGs.

- Afforestation – effects depend on location; Afforestation in boreal areas (with cold winters) e.g., will increase heat reflectivity as trees absorb more heat than snow covered landscapes – and may outweigh the effect of carbon uptake. Although large possibilities are related to afforestation, the effect of afforestation is essentially a medium-term solution due to inherent dangers of forest fires, insects, plagues, droughts etc. Afforestation could focus more on areas where forest fires have occurred – and identify what type of trees should be planted to take up the most CO_2, protect against new fires etc.

- Restoration of ecosystems (beyond afforestation) – has a huge potential and may give many additional CO_2 sequestration effects in addition to many positive social effects.

- Direct Air Capture and CCU in combination – can be used to complement the other climate solutions to reduce the pressure on land conflict. These can be viewed as a system for "carbon management" interlinking carbon recycling, carbon sequestration and renewable energy. Creating a value chain for carbon neutral/negative products will be important.

The CO_2 uptake in green and blue carbon is uncertain, as effects are complex and not fully understood yet. Estimates for expectations of BECCS vary to a high degree between scientific papers and grey literature, and there is a great split related to business models to realize carbon negative emissions. Reliable business models for all CDR solutions are missing, not only for BECCS.

There will be significant trade-offs between repair of ecological systems and avoidance of climate change in addition to other SDGs like food, water etc. This will be even more challenging when we remove fossil carbons used for different materials, food, chemicals etc. – as more fossil than biogenic carbons are used for these purposes. As the need for materials, chemicals and food will increase over time the challenge will be even greater and it remains unclear how this can be unified with ecosystem preservation. There is also a significant uncertainty about complex side-effects from both blue and green BECCS.

There is an untapped potential for BECCS on waste and forest / agricultural residues. On the other hand, over time more and more waste and residues have found alternative use. "Engineered food", in the sense of produce "eggs without chicken", "solar food" are also brought to the market and crop yield improvement will be important going forward as well.

Continued reading

IPCC special report on Global warming of 1.5°C (2018) with attention to Chapter 4 "Strengthening and Implementing the Global Response".

INTERNATIONAL POLICY ENVIRONMENT

The policy environment is in many ways the key contributor to the future development and sets the scene through establishing ambition, introducing regulations, and supporting the development of new markets. This has a huge impact on society, academia, and citizens. Policy plays, as such, a key role in enabling a fair, just, and efficient transition.

CDR is not yet well accounted for in regulatory frameworks and substantial changes are needed to roll out negative emissions at scale. The following points to what such policy needs to provide:

- More policies on technology and innovation that stimulate development of engineered solutions / projects at significant lower cost, meaning massive technology development, demonstration, scaling up, monitoring and evaluation,
- Broad based carbon price incentives; private schemes for offsets or public schemes such as emission trading system (ETS),
- Specific incentives for DAC, BECCS, auctions, land use and nature-based solutions,
- Stronger national and international commitments to drive CDR and development of harmonized regulations including sustainable supply chains,
- Policy agility: keep evaluating as we go along, and not locking ourselves into pathways that are not going to deliver. Evaluate through demonstration, and
- Policies covering responsibility for current and past emissions.

In addition, there will be a substantial need for monitoring addressing at least the following points: Are initiatives working as they should? How long is the carbon locked away for? Transportation and storage leak monitoring? Are people clearing land to get payed to plant trees?

Below we briefly look at one international and two national examples for stimulating net negative emissions and CDR, all three demonstrating being at an early stage.

International example: Policy framework for sustainable carbon cycles in a climate-neutral EU

EU has, through their Climate Law, committed to be climate neutral by 2050 and net negative beyond 2050. A key milestone on their way is 55% emission reduction in 2030 compared to 1990. To be carbon neutral in 2050, carbon removals from both ecosystems and engineered solutions are required to offset hard and expensive to remove emissions from agriculture, industry, transport, and a few other sectors.

The pathway to neutrality goes via «sustainable carbon management» relying on three pillars:

- Reducing reliance on carbon; through energy and resources efficiency and replacement of carbon by electrification, hydrogen, and new industrial processes,
- Recycling carbon; by phasing out the use of virgin fossil carbon and recycling carbon from waste streams, biomass or directly from the atmosphere. Here, circular economy, bio-economy and innovative other processes will be encouraged, and
- Removing carbon from the atmosphere; hence reversing the process of releasing fossil and biogenic carbon to the atmosphere and store it using ecosystems and engineered solutions.

In its Fit-for-55 package the EU has revised their key climate and energy policies including ETS and land use, land use change and forestry (LULUCF).

Since, removing carbon today is mainly through eco systems, the EU has started to support engineering solutions such that at scale solutions shall be available for the 2050 goal. Two new policy initiatives to promote CDR are launched:

- Innovation Fund funding clean technology solutions, including carbon removals, with ongoing calls for projects, and
- Carbon Farming, which is a new way to develop a business model for new farming practices and ecosystem conservation.

In addition, the EU is preparing a concept of Certification of carbon removal to support at scale solutions. The aim is a robust, long-lasting, and still flexible solution including robust and transparent carbon accounting to monitor authenticity of carbon removals through a set of common rules across EU. The proposal is expected to be ready by 2023, and optimistically effective no later than 2025.

As of today, there is no business case for negative emissions in the EU. A certificate of carbon removal will be an important starting point to achieve an environment, which enables trading of negative emissions between companies and countries. If found successful, several options exist thereafter to further stimulate negative emissions, including public procurement, compliance markets and voluntary markets.

National example: The proposed support scheme for Bio-CCS and DAC in Sweden

In June 2017, the Swedish Parliament decided by a large political majority to introduce a climate policy framework with a Climate Act as a key component to comply with the goals of the Paris Agreement.

By 2045, Sweden is to have zero net emissions of greenhouse gas (GHG) into the atmosphere and should thereafter achieve negative emissions.

Sweden then launched the Industrial Leap to accelerate and support industries. The initiative supports huge and complex technology leaps to significantly reduce process related emissions in industries as cement, iron / steel and refineries and runs from 2018 to 2040. From 2019 negative emissions, i.e., bio-CCS (BECCS) and DAC, are included in the programme.

A supplementary agreement, the Public Inquiry on negative emissions / supplementary measurements, was launched in 2019 after realising that both emission mitigation and supplementary measures are needed to meet the climate goals and Paris Agreement. The inquiry focuses on i) increased carbon sink in forest and land (LULUCF), ii) verified emission reduction in other countries and iii) Bio-CCS and DAC.

The Swedish Energy Agency were assigned to design a support system for bio-CCS, prepare a proposal for a treaty with Norway (UK and the Netherlands) for storing the carbon and finally create a centre for CCS within the agency. On their search for the fit for purpose support scheme, two main questions were addressed: i) should it be reverse auction or a fixed sum for a given volume of CO_2 (feed in tariff) and ii) should biochar be included in the support scheme? Since biochar was deemed not a good carbon sink in this context, it was excluded.

Reverse auctions were the chosen support scheme. It stimulates a marketplace for removals, it gives the state better control of the costs with less risk of overcompensation of the actors and it complies with state aid rules within the EU.

Three auctions will be planned. The first is scheduled for 2022, with allocation in 2023 and winning bid storage from 2026. The support period is 15 years and a total volume of 600.000 tons CO_2/yr. The

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Photo: Orjan Ellingvag / Alamy Stock Photo

second auction with a volume another 600.000 tons CO_2/yr will take place in 2026 and the third is scheduled for 2029 with a volume of 1 million tons CO_2/yr. This brings Sweden in line with the Public Inquiry of 2 million tons CO_2/yr in 2030. Each bid must cover post 50.000 tons CO_2/yr and will be adjusted for any previous state aid or EU aid to ensure fair competition.

Stakeholders from industry argue strongly in favour for the possibility to trade negative emission rights in such a marked-based system. However, this does not affect the design of the support scheme.

National example: Finland – target net negativity by 2035 without any offsets

Finland has targeted to become net carbon neutral by 2035. And this is expected to be reached without any offsets. Until now, CO_2 removal is not discussed too much.

LULUCF is the key to reach the net zero target and to compensate the remaining GHG emissions. 70% of Finland's land area is covered by forests and forest industries are important for Finland's economy and employment. Therefore, a lot of discussions are going around the use of forest resources and the impacts of forest sinks. Another discussion is related to peat and peat lands. Peat is the only domestic fossil fuel, and it needs to be phased out very quickly. Afforestation and reforestation will probably be one of the solutions for the abandoned peat lands.

BECCS could be expected to become another part of the solution. However, no policy incentives have been launched yet. The BECCS potential is anticipated to be significant because of the substantial forest industries, and hence associated potential for bio energy. Current annual total GHG emissions are about 50 million tons CO_2e and by 2050 the BECCS potential is estimated to be about 10 million tons CO_2.

DAC is also on the table for producing synthetic fuels or even food with renewable electricity and hydrogen. However, CO_2 utilization is easily misunderstood to represent negative emissions even though CO_2 is typically released back to atmosphere. As an example, companies could have a strategic target to become net negative in their operations by buying emissions compensations or investing in their own "net-negative" projects, which would lead at maximum to net zero. A better understanding and more clear communication are needed to increase the knowledge – what is really happening around CO_2 removal and net negative emissions and practices.

Most integrated assessment models (IAMs) expect global and/or regional emissions trading, including trade of negative emissions. IAM scenarios for Finland showcase that it could become a net exporter of (negative) emission allowances and thus help other countries to reach their climate negative targets. However, sustainable use of forest resources will limit the potential for BECCS to ensure the growth of forest sinks and biodiversity.

BUSINESS MODELS FOR NEGATIVE EMISSIONS

Companies are starting to realise the need to include negative emissions as measures to reach their net zero ambition in due time.

To succeed with CDR, credible business models are needed as well as safe and long-lasting storage of CO_2 and acceptance by citizens. The challenge in the offset market is huge and scale up of CCS to giga tons is needed and will come with huge cost. It remains completely open on who will bear these costs, but it is clear that no single company or country can pay the whole bill alone.

One of the more promising developments is that some companies with ambitions to reduce their carbon footprint are willing to pay for CDR. Also, developments in distributed ledger technologies and other digital systems that could be used to track origin along value chains make it possible to trade negative emissions. A key to successful business models for CDR will be the ability to bring together those who are willing to pay for carbon removal with those who are able to do it in markets and transactions where this can be documented and tracked.

Below we summarize the highlights from some selected companies' business models including key challenges and what is needed as they see it.

Microsoft – the IT giant on a fast ramp up as purchaser of carbon removals

The IT giant Microsoft has shown to be one of the most aggressive companies when setting climate goals. It launched its first net zero target in 2009 for scope 1 and 2 emissions, which was further accelerated. The company became carbon neutral in 2012 in scope 1 and 2 and business airline travel scope 3 through offsets and in the voluntary market. Microsoft has recently sharpened its target and shall become carbon neutral and net negative scope 1, 2 and 3 by 2030 and beyond that remove all historic emissions by 2050. Most of its emissions come from data centre operations.

This cannot be achieved without stimulating a marketplace for negative emissions and support development of removal technologies.

Mid 2020, Microsoft went out to purchase 1 million tons carbon removal. It received close to 200 proposals and decided to purchase from fifteen suppliers delivering twenty-six projects around the world. Almost all projects were short-term, and nature-based due to lack of engineered solutions. Microsoft's scope 3 emissions are likely to go up and its commitment to remove all historic emissions by 2050 will increase the purchase need significantly in the period 2030 to 2050. In other words, Microsoft will be a large purchaser on a fast ramp, hence must invest heavily in the market. Typical challenges that fit for large purchasers are:

- Cost: nature-based solutions are typically in the range 3-25 $/ tons whilst the cheapest engineered carbon removals easily see 150 $/ ton, and
- Project accounting: diffuse and relative new area and with a rather unclear distinction between offset and removal.

Transparency and accountability will be key to succeed on the journey to net zero and beyond. Microsoft is working directly together with voluntaries and certification bodies to create better standards around the clarity on avoidance emission versus removal as well as looking at that in conversations with some governments regarding protocols and verifications of infrastructure.

Technology development and engagement is another area and here IT can make a substantial difference both in providing the infrastructure, but also in the trust and transparency in carbon removal and the endurability of that. Microsoft is already involved in several technology development projects.

As Microsoft sees it, there are five things in combination that make a carbon removal project ideal: i) net negativity, ii) traceability, iii) affordability, iv) costs and v) quality.

It would be very difficult for Microsoft to meet the corporate goals without a rapid acceleration in the carbon removal market. As a purchaser, a technology developer and a company committed to net zero, carbon removal is a necessity.

Aker Carbon Capture – a CCS technology and solution provider

Aker Carbon Capture was spun off in 2020 from Aker Solutions, having then worked with CCS for 15 years. It is a pure-play company delivering ready-to-use capturing plants. It encompasses best-in-class HSE friendly solvent and other patented plant technologies for better all-round plant performance and has validated and certified leading proprietary technology with more than 50.000 operating hours.

- Ambition: “10 in 25”: Secure contracts to capture 10 million tons CO_2 /yr by 2025,
- Mission: Enabling emission free industries and energy solutions through carbon capture.

Achieving the ambition will require speed. Their primary market is northern Europe but also Canada to a certain extent. The markets of interests are power-to-gas (partnered up with Siemens), cement (the world’s first carbon capture project on a cement plant in Brevik), waste-to-energy and bio energy.

Waste-to-energy can be a key in a negative emission market. There are approximately 500 waste-to-energy plants in Europe, emitting ~100 million tons CO_2 /yr (2018 data, CEWEP). There are a significant number of process biogenic waste plants. And there is a strong interest for CCS, particularly in Scandinavia. Aker Carbon Capture together with Ørsted and Microsoft are exploring acceleration of biogenic CCS to realize negative emissions among other.

Getting to net zero will require commercial markets for carbon offset, positive development of ETS and other carbon pricing mechanisms, a well-regulated and transparent market for carbon trading, and cost-efficient transport and long-term storage.

Becour – a tech company focusing on certificates of origin

Becour comes with more than twenty years of dedicated work to track the renewable energy through offering energy attribute certificates (EAC), primarily within electricity, but now also moving into hydrogen and biogas. How electricity is being produced, is essential. By improving and making it more transparent to source the renewable electricity, Becour helps speed the transition. At the marketplace, the customer can choose which powerplant to get the electricity from – i.e., a 24/7 matching solution for documenting renewable energy consumption.

A certificate of origin can be used to offset, but it also tracks attributes that are linked to the product and service. These attributes can follow the value chain from primary stage to final product. The purpose will be to engage the consumer and create incentives. When looking at the energy transition, climate change and sustainability, there are many non-physical attributes. By tracking attributes, one can enable preferences to what project to engage in at a scale. It is technology neutral, hence up to the buyer to decide. It can combine voluntary and compliant systems. Carbon accounting could be a place to utilise this technology.

Gassnova – a facilitator for CCS states the need for a commercial business model to get CCS going

Gassnova is a Norwegian state-owned company facilitating the development of cost-efficient technologies and solutions for capture and storage of CO_2.

CCS has been under development for almost two decades in Europe but so far has not made a difference for climate as hoped for. Lack of credible business models has e.g., hampered, or delayed implementation of CCS for many years. In the US, there is a business to capture CO_2 and store it in the ground, especially when used for enhanced oil recovery (EOR). In Europe, business models do not exist as of today, but rather funding models.

What will be the business model that speeds up CCS? Can blue hydrogen be a game changer? With blue hydrogen, CCS is not only an expensive add-on. It is an integrated and required part of the production process of a valuable product – hydrogen.

BECCS is a type of offset for other emissions. Somebody with an obligation to reduce CO_2 may be willing to pay to a company that can store the corresponding volume of CO_2. But if natural CO_2 sinks are working, BECCS-projects must compete with these lower cost technologies.

Equinor – an energy provider in transformation

Equinor is a global energy provider with the purpose to turn natural resources into energy for people and progress for society. It was founded to develop and produce oil and natural gas from the Norwe-

gian continental shelf and has since then become a global player with a rapid growing renewable portfolio, mainly in offshore wind.
In 2020, Equinor launched its bold ambition to become net zero by 2050 including scope 1, 2 and 3 emissions. That will require the company to avoid and remove 13.5 million tons CO_2e/yr scope 1 and 2 and 250 million tons CO_2e/yr scope 3.

In addition to the use of energy efficiency and low carbon technologies on existing and future infrastructure to reduce emissions from production, Equinor foresees a step up on renewables, CCS and hydrogen (blue and green), and as a supplement to use negative emissions such as natural sinks. A larger share of the oil and natural gas production is also expected to be used for non-energy purposes (not combusted).

Development of CCS and hydrogen at scale is dependent on economic viability and depends on a sufficiently high CO_2 price. On the path, the company, in collaboration with selected companies, is underway with the CCS project Northern Lights and the hydrogen / CCS projects in the Humber industrial region in the UK, among others.

On the journey to net zero, Equinor will rely on both engineered and nature-based solutions, as well as market mechanisms. To stimulate this, it would like to be a company that drives investments into technology that reduces and removes emissions.

A successful transition to net zero depends on policy and a policy framework, customers and markets and a price on carbon providing incentives for investments in low carbon alternatives. And there are dilemmas. How to count CO_2 and what can be accounted for? One example is forest protection versus reforestation / afforestation. Avoiding deforestation may be a more impactful climate measure in the short term, however it does not increase the amount of CO_2 removed from the atmosphere and therefore might not be possible to account for as a carbon neutralisation. Another example is providing CO_2 storage solutions from high emitting sectors such as cement and steel – how are the avoided CO_2 emissions in these product lines, in a scope 3 perspective, accounted for? There will be a need for standardization of how to classify and count negative emissions to ensure consistency, but also providing incentives to invest in required technologies.

Schlumberger – How we can all help drive CCS and BECCS globally?

Schlumberger is a technology company with a deep focus across many energy streams. Over the last 15 years Schlumberger has participated in over 50 CCS projects worldwide and a number of historic and active BECCS projects, working with a wide variety of companies from many different industries including cement and ethanol, agriculture, power and bioenergy industries. The current CCS and BECCS activity level around the world is greater than ever before, and its continued growth is critical to allow the world to achieve its net zero ambitions.

Incentives are currently key to the growth and scaling of CCS and BECCS. Countries such as the US, where government incentives have been well established and reliable, are the main driver behind the growth of CCS projects worldwide. Confidence in the evolution in incentives is key to promote CCS and BECCS growth. In general, for CCS and BECCS to become a global scalable success, driving down costs are key while keeping quality and safety as paramount. Building deep partnerships between key companies and working together across the value chain can greatly drive down project costs and deliver better quality projects, faster. BECCS offers one of the most scalable negative emissions technologies available for the world today.

The key to driving growth in this space is the appropriate incentives to preferentially promote negative emissions technologies, while taking into consideration the sustainability of the feedstocks used and its overall value chain. This overall technology is capable of scaling today if the right companies, incentives, and regulations are put in place.


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