Building the case for *in-value chain action on carbon dioxide removal*

World Business Council for Sustainable Development

Table of contents

Executive summary

Carbon dioxide removal (CDR), the set of human-induced activities through which carbon dioxide is removed from the atmosphere and durably stored, will play an increasingly important role in businesses' net-zero pathways. In fact, while it remains imperative to reduce greenhouse gas (GHG) emissions to tackle the climate crisis, estimates show that we will also need to remove anywhere between 5 to 15 gigatons per year of carbon dioxide ($GtCO_2$/year) from the atmosphere by 2050 to successfully limit global warming to 1.5°C above pre-industrial levels.[1] CDR deployment will need to scale four-fold to achieve this target – with some novel methods even needing to scale by several orders of magnitude.[2]

There are drivers and opportunities for in-value chain action on CDR to meet this growing need. These actions will complement those beyond the value chain – actions or investments outside a company's physical value chain that contribute to societal targets in climate, nature and equity. The World Business Council for Sustainable Development (WBCSD) encourages businesses to map out their trajectory to neutralize unabated emissions, including planned milestones and near-term investments. In the forest, land and agriculture (FLAG) sector, CDR presents a well-established scope 3 emissions reduction pathway. Subsequently, there are opportunities to grow demand for in-value chain action in other emissions-intensive sectors, including the built environment, energy, mining, chemicals and the mobility sector.

Currently there is a lack of clarity on internationally agreed approaches to certification and accounting of carbon removals. Yet there are high-level GHG accounting principles that can help companies navigate this complex environment for investments. This builds on WBCSD's Carbon Dioxide Removal Call to Action for Business and Removing carbon responsibly: A guide for business on carbon removal adoption in which we clarify that companies must deploy CDR responsibly as part of a comprehensive net-zero strategy in parallel with deep emissions reductions. Companies should act today to evaluate the business case for in-value chain carbon removal opportunities.

Introduction

The urgency of accelerating carbon dioxide removal

Scientific consensus is clear that it is not possible to meet the goals of the Paris Agreement without widespread carbon dioxide removal (CDR), the set of human-induced activities through which humans remove and durably store carbon dioxide.[3] Although deep and sustained emissions reductions are the core of any Intergovernmental Panel on Climate Change (IPCC) 1.5°C-aligned scenario,[4] CDR ultimately puts the "net" in net-zero by neutralizing any emissions that are hard, impossible or take time to abate. CDR can also complement short-term climate action on the transition to net-zero emissions and help the world achieve net-negative emissions thereafter to mitigate the effects of a potential temperature overshoot.[5] The IPCC predicts that the world will need to attain between 6 and 16 $GtCO_2$/year of CDR by 2050 to successfully limit global warming to 1.5°C above pre-industrial levels.[6]

However, in 2023, the global removal capacity only amounted to roughly 2 $GtCO_2$/year.[7] The limited uptake to date is largely due to a lack of awareness about the broader need for CDR, insufficient investment incentives and high costs. There are also concerns about the integrity of corporate claims and the projects themselves. Even so, there has been some notable progress in building a pipeline of CDR projects over the last two years, spurred mostly by the development of policy incentives, such as the 45Q tax credit scheme in the United States.

There is a diverse variety of promising conventional land-based activities such as reforestation and soil carbon sequestration and novel CDR activities such as biochar carbon removal (BCR), bioenergy with carbon capture and storage (BECCS), direct air carbon capture and storage (DACCS) and enhanced rock weathering, among others. Each activity comes with a wide array of attributes and potential environmental, societal and economic impacts. The primary attribute that defines an activity with a climate impact is durability – a measure of the permanence of stored carbon with respect to the risk of re-emission into the atmosphere (reversal). Those activities that involve biological storage typically have the highest risk of reversal, generally leading to characteristic durability of decades to centuries.[8] Some novel activities have the potential to store carbon for geological timescales. For this paper's purposes, we refer to durable CDR as activities with characteristic durability greater than 100 years.[9]

All high-integrity forms of CDR can have an important role to play in achieving global CDR targets. Projections show that conventional land-based activities will make up 78-100% of CDR capacity by 2030 due to their higher near-term techno-economic feasibility and wide range of core benefits.[10] The proportion of novel activities will continue to increase towards mid-century. Ultimately, those activities that have potential durability on geological timescales will be pivotal in fully neutralizing fossil emissions to achieve a state of long-term climate stability, though only representing 0.002 $GtCO_2$/year of current CDR capacity.[11]

CDR does have great potential to bring significant environmental, social and economic core benefits.[12] CDR deployment strategies based on a range of methods in diverse geographies and at different scales will help maximize climate benefits, minimize trade-offs and maximize contributions to a range of sustainable development goals. Despite the critical role of CDR, overreliance could delay other decarbonization efforts and bring about high resource dependencies. It is therefore critical to deploy CDR in a way that complements emissions reductions and does not provide an excuse for business-as-usual.

The role of in-value chain CDR in corporate climate action

Removals are a critical element of corporate climate strategies. The Science Based Targets initiative (SBTi) Corporate Net Zero Standard recognizes that in most sectors, a proportion of emissions will be hard or impossible to abate: these are called "residual emissions". When a company has reduced scope 1, 2 and 3 emissions to the extent possible by their net-zero target year, SBTi calls on companies to use permanent CDR to neutralize residual emissions (typically around 10% of the base year footprint – differing by sector).[13]

CDR plays an important role in the emissions reduction pathway for forest, land and agriculture (FLAG) sector companies. SBTi has stated that "Removals are included in FLAG targets because they account for around 50% of the global land-related mitigation opportunity". Science Based Targets initiative (SBTi) has built its FLAG sector pathway on the expectation that about a third of mitigation will come from CDR.[14] This must come from conventional land-based (or biochar) CDR occurring directly in the value chain. CDR does not count as reductions toward meeting near-term or long-term science based targets for companies outside FLAG sector under SBTi's current guidance.[15]

Net-zero targets provide a clear, long-term need for CDR. However, companies also need to develop short-term CDR strategies. For those companies in the FLAG sectors, in-value chain removals can contribute significantly to achieving interim scope 3 emissions reduction goals. As such in-value chain action is increasingly becoming the focus for scaling carbon removal in the FLAG sectors.[16] This is in part due to the contribution they can make to interim scope 3 emissions reduction goals but much of the focus goes beyond the carbon impact. Companies can retain core benefits in the value chain, where projects can improve community livelihoods and contribute to nature-related outcomes.[17] However, in-value chain action in other sectors remains nascent.

Companies outside the FLAG sector should not delay implementing a CDR strategy to achieve their net zero commitment. If they do, the market is unlikely to grow sufficiently and early movers will likely already have secured the limited supply of quality removals. SBTi recommends that companies “disclose information such as planned milestones and near-term investments that demonstrate the integrity of commitments to neutralize unabated emissions at net zero.”[18]

Up to the first half of 2023, CDR represented only 3% of credit purchases on the Voluntary Carbon Market (VCM), although projections show this proportion will grow rapidly. The vast majority presently are from afforestation and reforestation projects, with only 1% relating to durable methods – predominantly biochar.[19] WBCSD has published a How-to guide for voluntary carbon credit portfolio design which outlines the business case for a balanced approach and investments in carbon removals. Durable CDR will be core to companies satisfying their net-zero emissions pledges but this has not yet translated into a predictable demand signal since there are no formal requirements that commit companies to purchasing CDR. By the end of 2023, only 0.5% companies with an SBTi-endorsed net-zero target had made any purchases in durable CDR.[20]

While projections show the integration of CDR into compliance markets, for instance as announced by the Government of Japan within their GX-ETS or within the European Union Emissions Trading System (EU ETS), will drive significant additional demand, potentially reaching up to 15% of total demand for carbon removal credits by 2040, voluntary purchases are likely to remain key for the coming decades. However, since so few corporate investors are currently financing the growth of the durable CDR market, there is likely to be a significant shortfall in supply by 2040, when demand will pick up as companies attempt to meet their net-zero targets.[21]

A key barrier to overcome in closing the supply gap is the successful financing of early-phase projects. Companies can help address this barrier by:

- Providing clear and tangible near-term demand signals;
- Direct private investment into CDR projects, such as those in the value chain.

Not only can direct investment de-risk project development, companies can also unlock additional near-term demand for CDR if they consider in-value chain action due to the wide range of benefits this can provide. This paper aims to advance the case for in-value chain action by exploring strategic opportunities in different sectors and identifying business drivers.

For the purposes of the paper, we use the following definition of in-value chain removal:

> *Direct and in-direct removals from activities associated with the reporting company's operations.* [22]

Routes to in-value chain CDR action

There are a variety of routes to promote the development of in value chain removals. These can be grouped into either efforts that support the development of in-value chain removals, summarized as collaboration or direct project financing.

Collaboration

The first level of action is collaboration with value chain partners to collectively identify opportunities, set collective targets, support each other with the research, design and development of emerging technologies and ensure a robust and transparent data exchange process is in place. These activities develop the infrastructure for CDR and nurture the development of the CDR ecosystem. Such activities will demand company resources including financial and time commitments but stops short of directly financing CDR projects.

Project Financing

For companies wishing to move beyond collaboration and more actively contribute to the financing of projects in their value chain, the two main categories of action are:

- In the supply chain or clients of the company;
- Acquisition of ownership or operational control of a project in the company's operational footprint.

In the value chain of the company

Companies can invest in CDR projects deployed by other companies or stakeholders in their value chain. This type of activity is, commonly called either insetting or scope 3 removals, has no universally recognized definition.[23] Companies can realize insetting through a variety of approaches, including:

- Purchasing and retiring carbon credits generated by third party companies in the value chain. If these credits are re-sold beyond the value chain, then all companies in the value chain must then surrender any claim to the CDR activity.[24]
- Providing CDR project finance or in-kind support to companies in the value chain.
- Purchasing products with an attributed carbon removal, such as biochar in concrete. The company can generate the attribution of a carbon removal in a product without the sale of carbon credits or where it immediately retires any credits in the value chain.

In ownership or operational control of the company

Companies wishing to play a more active role in the development or deployment of CDR projects can make investments to give them operational control or equity. They can achieve this through the following mechanisms:

- Providing equity finance to CDR projects in the value chain;
- Financing and deploying a project directly in the company's operational footprint.

Opportunities for in-value chain CDR in selected industries

Key to integrating in-value chain action into a broader CDR strategy is to holistically assess strategic links between the value chain and specific CDR activities. This section explores key synergies, dependencies and opportunities within selected sectors. For more details on CDR methods, including side impacts, refer to WBCSD's work on Removing carbon responsibly: A guide for business on carbon removal adoption.

Agriculture & food

There are several in-value chain CDR activities that companies can leverage related to agricultural activities, including agroforestry, soil carbon sequestration and biochar production from agricultural residues and re-applied to the land in the supply chain, if there is full traceability of the source of biomass.[25]

Soil carbon can be sequestered through a range of regenerative agricultural practices, such as use of cover crops, crop diversity and reduced soil disturbance that enhance the carbon content of soil through natural processes. Soil carbon sequestration offers one of the most rapidly scalable and cost-effective opportunities to remove carbon at scale, with a potential for 4 $GtCO_2$/year by 2030.[26] There are challenges in preventing the early reversal of carbon storage in the soil and the quantification of net carbon sequestered to satisfy integrity standards. The development and application of innovative technologies can help overcome these challenges, for instance the use of fungus to fix carbon and improve durability and development of robust, cost-effective and scalable soil sampling practices to provide trusted soil carbon measurements.[27]

Agroforestry, the growing of both trees and agricultural or horticultural crops on the same piece of land, is a low-cost sustainable approach with a global CDR potential of 0.3 $GtCO_2$/year.[28] The biomass and improved retention in the soil sequester the carbon. Agroforestry and soil carbon sequestration offer a wide range of additional sustainability benefits and positive impacts on nature, including improving crop yields, the creation of habitats to improve biodiversity and improved climate adaptation and resilience for food systems.[29]

Biochar carbon removal (BCR) is a rapidly growing CDR activity, with at least 600,000 metric tons of CO_2 removed in 2023 and a 2050 potential of 6 $GtCO_2$/year.[30] It involves the pyrolysis of biomass residues to form stable char, which the company can then spread on the land or bury. This can contribute to improved soil health, improved water retention and reduced soil erosion.[31] Its use can also lead to reduced fertilizer demand. BCR is unique as it is the only method that the FLAG sector can use to contribute to interim net-zero targets that can potentially achieve a storage durability of thousands of years.[32] Some recent evidence suggests that a high proportion of high-temperature biochar could be geologically permanent.[33] The durability of biochar explains much of its interest from early moving companies outside the FLAG sectors.

These activities can strongly contribute to reducing the scope 3 emission footprint of the entire agriculture value chain. Companies deploy them at the farm level, hence offering opportunities for community-led deployment of projects that empower and incentivize farmers to deploy more sustainable farming practices and restore ecosystems.

Collaborative opportunities for the agriculture and food sectors

The agriculture and food sector also has significant potential to provide a source of sustainable biomass residues for use in other value chains, such as biochar used in other sectors, bio-based building materials, BECCS projects (and other biomass carbon removal projects, such as biomass with carbon removal and storage (BiCRS)). These offer revenue generation opportunities for the valorization of agricultural wastes.

While not classed as FLAG removal, enhanced rock weathering is another highly promising activity that companies can deploy on agricultural lands. This involves spreading pulverized alkaline rock on lands, rapidly accelerating the natural weathering process of the conversion of atmospheric CO_2 to carbonate minerals.[34] Enhanced weathering offers potential storage of carbon for geological durations, with additional potential benefits of reduced soil acidity, improved release of nutrients and micronutrients and ultimately potential crop yield improvements.[35] These may result in reduced costs and scope 3 emissions reductions from the reduced use of fertilizer and lime for acidity management. As the removal cannot count towards FLAG targets, the main FLAG impact would be through these secondary effects. Enhanced weathering has had limited deployment to date, though it offers significant global potential to remove 2 $GtCO_2$/year by 2050.[36] Unlocking the full potential of this method will require additional research to understand the long-term side effects, such as on ocean alkylation. The durability of these methods is such that they can demand high market prices and demand from outside the FLAG value chain.

Forestry

The forestry sector, like the agriculture and food sectors, is in a unique position to achieve significant in-value chain CDR deployment. The sector already contributes most of all current CDR activity[37] through improved forest management activities, such as afforestation and reforestation.[38] These also have some of the largest global potential, with estimates reaching up to 10 $GtCO_2$/year by 2050.[39] These projects involve the conversion to forest of land that historically has not contained forests and replanting of trees in previously forested land for afforestation and reforestation respectively. Afforestation must be responsibly designed and executed to ensure that there is no loss of biodiversity or unintended consequences from the planned land use change. Yet if projects are well-designed and implemented, such as by avoiding mono-culture plantations, both can provide significant additional benefits. Reforestation in particular can help improve biodiversity, improve climate resilience and offer substantial societal benefits.[40]

Just as with the agriculture and food sectors, there are also several other opportunities for the forestry sector to connect with other value chains through CDR by supplying sustainably sourced forestry products and residues for use in other sectors, such as in construction, BCR and BECCS projects. Additionally, the pulp and paper industry represents further opportunities to develop in-value chain carbon removals. This industry represents a sizable opportunity for BECCS and resulting carbon removals as it accounts for roughly 2% of global industrial emissions, with US- and EU-based pulp mills emitting 150 $MtCO_2$/year and 62 $MtCO_2$/year respectively. The permanent capture and storage of biogenic CO_2 emissions, which typically represent over two-thirds of total greenhouse gas (GHG) emissions from such mills, makes it possible to achieve negative emissions.[41] An example demonstration project selected for funding by the U.S. Department of Energy sees Amazon collaborating with RTI International, SLB and International Paper to deploy novel amine-based liquid solvent technology that targets a capture of up to 120,000 metric tons of CO_2/year by 2029.[42]

Energy

The power sector has a GHG emissions reduction target of 97% by 2050.[43] As such, SBTi recognizes that the power sector will not have significant dependency on CDR to achieve net-zero emissions compared to other sectors. However, there is significant opportunity in the value chain to deploy BECCS projects, including waste-to-energy facilities, as these have the potential to generate carbon-negative electricity, district heating or other energy vectors for use along the value chain. Power-BECCS or power-BCR have significant scalability potential – up to 8.5 $GtCO_2$/year by 2050, limited by the availability of sustainable biomass.[44] There are significant investments and developments in commercial scale power-BECCS projects around the world, such as the UK-based Drax power station that could remove 8 $MtCO_2$/year by 2030.[45] Dedicated biomass and waste-to-energy facilities already exist today and a company could generate a BECCS project through a retrofit to install carbon capture and storage (CCS).[46]

There are also strong links with biochar production and the energy sector. Companies often combust the off gas produced during pyrolysis to generate electricity, district or industrial process heating.[47]

There may also be indirect links from the energy value chain to DACCS. DACCS projects will require significant quantities of renewable energy. The heat requirements for sold-adsorbent and liquid-adsorbent processes are the majority of energy demand, with over 9GJ/metric ton of CO_2 removed for solid-adsorbent systems and just over 6GJ/metric ton for liquid-adsorbent systems.[48] New projects will likely require construction of additional energy generation capacity and grid infrastructure to supply renewable energy to sites, which may result in emerging partnership opportunities between DACCS project developers and energy infrastructure developers.[49]

Integrated energy companies may see opportunities in these various methods to integrate CDR into their growing alternative energy portfolios. They also have a significant opportunity to use their expertise with financing and developing large-scale infrastructure projects to enable commercial scale DACCS and BECCS projects by transporting and geologically storing captured CO_2.

Built environment

The built environment has a large emissions footprint, with 8%, 18% and 4% of global emissions in 2022 coming from fossil fuel use in buildings, the generation of electricity used in buildings and embodied emissions from building materials respectively.[50] The production of materials used in the construction process for cement, steel and aluminum generated 2.5 $GtCO_2$, with brick and glass production contributing around 1.2 $GtCO_2$ in 2023.[51] We explore the opportunities for CDR to complement the decarbonization of the operational emissions of buildings through energy efficiency and renewable energy in the Energy sub-section. Projections show these sectors will require carbon removal[52] to achieve net-zero emissions but there are also multiple opportunities to integrate CDR into the various production processes and products used in the construction industry.

Cement and steel

Both the cement and steel sectors are currently dependent on fossil fuels to provide heat to run kilns and blast furnaces respectively. CCS is a key decarbonization lever in both sectors, particularly in reducing process emissions.[53] There are emerging alternative decarbonization technologies to provide high-temperature heat, though some companies may also deploy CCS to reduce fossil fuel emissions from heating as an interim solution if other options, such as hydrogen, are not yet commercially viable. This offers an opportunity to use alternative fuel sources, such as biogas or solid biomass, combined with CCS to create BECCS projects. According to the International Energy Agency (IEA), 50% of cement production by 2050 will use CCS to decarbonize fuel usage, with 19% through BECCS facilities.[54]

It is also possible to use biochar to generate negative emissions in the steel sector. In addition to its use to provide auxiliary low-carbon heating, the sector can use high-quality biochar as a reductant in place of fossil coke. Not only will this significantly reduce process emissions but steel products also sequester a small portion through carburization.[55]

The cement and concrete industries have several other opportunities for durable, product-based CDR that enables carbon circularity in building material products that could equate to between 0.1 and 1.4 $GtCO_2$/year by 2050.[56] A promising, emerging method is that of ex-situ mineralization, which uses captured CO_2 to react with alkaline materials to produce carbonated building aggregates for use in concrete. This method is still in the early stages of development and needs further research, development and demonstration (RD&D) before commercial deployment. The use of fossil-derived CO_2 for this process may initially be important for early-stage development; however, for this to result in a removal, the captured CO_2 must be of biogenic or atmospheric origin. Companies can source the alkaline materials from mined rocks, mine tailings and industrial waste, including steel slag and kiln dust – further improving circularity and cost efficiency.[57]

Cement, by its nature, can capture carbon dioxide over the lifetime of a building through ongoing carbonation reactions. However, it is possible to rapidly accelerate this process at the point of manufacturing through curing carbonation processes, such as those patented by CarbonCure or Neustark. This can use captured fossil, biogenic or atmospheric CO_2 to rapidly cure fresh concrete. The use of captured fossil CO_2 from the cement production process can reduce the life-cycle emissions of the product by 4-6%, while offering rapid strength gain in products.[58] The use of biogenic or atmospheric CO_2 could offer limited opportunities for removal with the carbon durably sequestered into this stable concrete.

A more technologically mature and established method is to mix biochar into the concrete mix as an additive. Not only can this reduce the amount of cement required, it also offers long-term storage potential for the biochar, with potential improvements to the mechanical properties, durability and weight of concrete, depending on the mix.[59] Biochar has many other potential applications in the built environment, such as an additive into asphalt, bricks and plaster. Adding biochar into asphalt can displace the need for more carbon-intense materials and offer additional improved mechanical properties, including high-temperature resistance and improved resistance to deformation.[60] Companies can also use biochar in high proportions in bricks, plaster or render. The porous nature of biochar is such that it can help provide thermal insulation and maintain humidity levels in buildings through these applications.[61] At present, these only represent 10% of the total biochar market but are some of the many promising end-uses for biochar.[62]

While these are promising methods, they require further work to address concerns regarding verification of the permanence of stored carbon, particularly beyond the lifetime of buildings and other infrastructure.

Bio-based building materials

In addition to biochar additives used in construction materials, other bio-based building materials can replace carbon-intensive materials, such as steel, cement and masonry. Timber is the most established form of bio-based building material. Emerging regulations, design innovation and the development of engineered timber are helping to promote more widespread application, with efficient use able to greatly contribute to reducing the life-cycle emission footprint of buildings. Other innovative bio-based building materials are emerging, such as bamboo and hemp bricks for structural materials, offering further opportunities in the future. There are also a wide range of emerging bio-based insulating materials, such as hempcrete, rice panels, wood fiber and sea grass.[63] As with any carbon removal reliant on biomass, companies should apply rigorous due diligence of the sourcing of bio-based materials to ensure net-positive benefits. The carbon accounting of bio-based building materials is challenging and the reporting of removals from these activities will require the development of robust, science-based methodologies. The extent to which bio-based building materials can lead to net carbon removal depends entirely on the sustainability of sourcing practices, the life of the building and end-of-life treatment.[64]

The use of bio-based building materials offers opportunities for circularity and the cascading of CDR by recycling materials at end of life. Companies can convert these into biochar or bioenergy through BECCS for use in other BiCRS projects.[65]

In addition to the carbon sequestration potential and the displacement of carbon-intense building materials, these materials can contribute to a healthier indoor environment due to low emissions of volatile organic compounds (VOCs) and humidity regulation. The use of these materials may also offer safer working conditions due to lower quantities of contaminants.[66]

Mining

On an average mine site, around half of energy consumption is electricity and the rest comes from the use of fossil fuels, mainly diesel. The mining sector generates most CO_2 emissions via diesel-fueled haulage of ore and waste products during active operations. For example, there are around 28,000 large mine hauling trucks in operation – collectively emitting over 68 $MtCO_2$ of CO_2 every year.[67] Electric and hydrogen-fueled trucks offer alternatives to more traditional diesel-powered transportation and equipment manufacturers like Caterpillar and Komatsu are innovating and testing alternative vehicles. Mining companies are increasing operational readiness to be able to adopt zero-emission solutions at a faster pace, including enabling infrastructure, capacity building and clean energy procurement.

Mining companies are providers of the raw materials needed to create sustainable infrastructure and low-carbon technologies and electrify transportation; therefore, mining and metals companies supply critical components to CDR industry, specifically when it comes to critical minerals required for advanced technologies. Specifically, the mining sector has a significant role to play in the development and scaling up of enhanced rock weathering and other forms of mineralization CDR deployed in other sectors. Carbon mineralization accelerates reactions between CO_2 and certain minerals, effectively removing CO_2 from the atmosphere and permanently storing it as a mineral in the rock. This process naturally occurs over hundreds or thousands of years but it is possible to accelerate it in various ways to remove significant amounts of atmospheric CO_2 in decades. The chemical reaction works best with mafic or ultramafic rocks, which contain alkaline minerals like magnesium or calcium-bearing silicates. Through natural sink processes, carbon mineralization permanently removes about 0.3 $GtCO_2$/year from the atmosphere. While carbon mineralization presents significant carbon removal potential, it lacks sufficient research and demonstration funding to achieve mainstream use.

In addition to natural ore providing a sink for carbon dioxide, mining companies can also generate revenue from waste products and become a supplier of alkaline rock from nickel, cobalt, diamond or asbestos mine tailings.[68] To avoid potential unintended negative side impacts in the application of enhanced weathering, it is necessary to assess these tailings for potential heavy metal contamination and treat them accordingly.

Chemical

A wide range of product and material value chains ensure the deep embedding of the chemical sector involving a range of processes. Circularity is a key transition lever for the sector but CDR can play an important and complementary role. There are significant opportunities for embedded CDR in the chemical system, with the potential for sequestration of 0.5 $GtCO_2$/year by 2040.[69]

End-of-life

Scope 3 emissions represent at least 64%[70] of emissions from the chemical sector, mostly driven by upstream fossil fuel emissions and end-of-life emissions from non-ammonia chemicals, which rely on fossil fuels as a feedstock.[71] As a result, the conversion of this feedstock represents the greatest opportunity for the decarbonization of scope 3 emissions. However, feedstock availability will limit the extent of the role it will play prior to 2050. CCS will have to address the residual process emissions. The greatest opportunity for CDR in the chemical sector is in applying CCS to end-of-life waste incineration.[72] This offers opportunities to recycle carbon into production processes and sequestration. The conversion of the feedstock to biogenic or atmospheric sources ensures that the sequestration from waste incineration will generate a BECCS removal in the chemical value chain. As a result, there are synergies and opportunities for cooperation with the energy value chain in the development of waste incineration facilities with CCS.

Production

Methanol- and ammonia-based pathways require significant quantities of hydrogen. At present, the reformation of fossil fuels – so-called gray hydrogen – produces the vast majority – 43Mtpa – of hydrogen. The production of hydrogen through electrolysis, powered by renewable electricity – green hydrogen – will ultimately be the primary long-term driver for the decarbonization of hydrogen production. However, the application of CCS onto fossil-derived hydrogen generation – blue hydrogen – will still have a significant, transitionary role to play, particularly as a retrofit to existing facilities. The International Energy Agency (IEA) predicts that blue hydrogen production may amount to 9-12Mtpa by 2030.[73] A credible option to reduce the carbon intensity of blue hydrogen is to use biogas as a feedstock in these facilities. This, coupled with pre-combustion CCS, is a BECCS pathway.[74] Other opportunities for CDR in the production of hydrogen involves the gasification of biomass, coupled with pre-combustion CCS.

Many chemical processes are endothermic and require process heat. Analysis of European chemical parks suggest it is possible to achieve a reduction of 25% to 30% of scope 1 emissions until 2030 through the decarbonization of steam generation. There are a wide range of technological solutions to decarbonize heat, such as electrification, hydrogen, biomass and biogas. Their commercial availability will limit the use of these solutions. Biomass and biogas offer some of the most commercially viable low-carbon heating solutions and can offer opportunities for CDR through the application of post-combustion CCS. It is also possible to couple heat supply with the production of biochar, with the pyrolysis gas combusted for heat.

Technology supply

The chemical sector has unique opportunities to be a key enabler for CDR by creating innovative chemical absorbents used in the capture processes for BECCS and DACCS facilities.

Mobility

The decarbonization pathways of much of the mobility sector, particularly shipping and aviation, will involve the use of alternative, low-carbon fuels, such as sustainable aviation fuel (SAF), methanol and ammonia. In the aviation sector, up to 65% of the decarbonization potential by 2050 alone will come from SAF, although at present companies are producing only 300 million liters per year – compared to the 5 billion required by 2050. The nascency of alternative fuel supply chains and projected residual emissions from the production of SAF leads to a high dependency on CDR to achieve net-zero emissions by 2050. There are, however, several ways to deploy CDR in the value chain, primarily within the SAF production process.

There are several accepted pathways to do so, including the hydro-processing of esters and fatty acids, as well as the production of fully synthetic fuels using Fischer-Tropsch[75] processes with biomass gasification or power-to-liquids.[76] Those pathways that use biomass gasification offer opportunities for embedded CDR through the application of CCS to capture any residual CO_2 emissions from the facility.[77] Power-to-liquid approaches can use imported biogenic or atmospheric CO_2 captured through other BECCS or DACCS facilities, although the use of this carbon itself will not lead to a removal due to the short storage duration of the fuels. BECCs and DACCS are therefore crucial in both neutralizing residual emissions and providing a robust feedstock for power-to-liquid SAF production.[78]

SAF production pathways require the supply of hydrogen. As covered in the Chemical section, there are a variety of ways to embed CDR into the production of hydrogen that can translate into the life-cycle emissions of SAF. The Chemical section also described the opportunities for CDR in ammonia and methanol production that will be key to the shipping sectors.

Due to its nature, shipping is a hard-to-abate sector. Onboard Carbon Capture (OCC) is, therefore, widely seen as indispensable in reaching goals set for 2030 and beyond. A net zero shipping industry shall require low-carbon fuels in combination with other decarbonization measures such as wind-assisted propulsion and OCC. The post-combustion OCC-technology is mature and based on the same CCS technology as used for on-land applications. OCC results in a CO_2 emission reduction when compared to an existing fossil-fueled vessel without OCC. Yet new applications focus on the combination of OCC for vessels fueled by alternative, low carbon fuels such as green methanol. This provides opportunities for CDR through sequestration of the captured biogenic or green CO_2. This is a BECCUS pathway, making the usage of low carbon fuels more economically viable.

The mobility value chain is a significant consumer of steel and plastic products; as such, there may be strategic opportunities to invest in CDR in those sectors where it is possible to embed negative emissions into product life-cycle emissions. Refer to the Cement and steel and Chemical sections accordingly.

Accounting for in-value chain CDR

A critical part of assessing whether to act in the value chain is understanding whether and how a company can report it as part of their GHG inventory and thereby whether and how it can contribute to a net-zero target. The following section provides an overview of the key principles in the *GHG Protocol Land Sector and Removals Guidance*.[79] We do not intended for it to replace or supersede it. For more details, refer to that guidance.

High-level GHG accounting principles

CDR involves two distinct processes:[80]

1. The transfer of GHGs from the atmosphere via sinks, such as photosynthesis or through technological means;
2. The storage of the GHG in pools, including land-based, geologic or product storage.

Under the *GHG Protocol Land Sector and Removals Guidance,*[81] if a company owns or controls both processes, it may be able to report a scope 1 (direct) removal. Where a removal occurs because of a company's activity but where it does not own or control both the sink and the pool, it may report a scope 3 (indirect) removal. For land management removals, accounting for scope 3 removals depends on full traceability to associated lands. Care should also be taken to follow guidance on characterizing organizational boundaries. Note that there may be exceptions to this through specific contractual agreements. There is no scope 2 removal category.

Reporting removals is voluntary, however, if companies wish to account for CDR in the value chain, they must:

- Report all life cycle emissions in the value-chain of the CDR pathway, across scopes 1, 2 and 3;
- Account for CDR based on annual or annualized net carbon stock changes in the reporting year;
- Separately account for and report scope 1 and 3 removals, in line with guidance to determining organizational boundaries;
- Separately account for and report land-management net removals and net removals with geological storage, with separate reporting of biogenic or technological removals, if relevant;
- Separately report removals by gas, if applicable.

There are also additional requirements that companies will need to adhere to be able to report a removal. Companies must:

- Use empirical, primary data to account for net carbon stock changes. Companies must detail the methodology, data sources and assumptions used to calculate scope 1 and 3 removals.
- Have traceability throughout the full removal pathway and provide information on traceability systems.
- Detail the systems and procedures for long-term monitoring of carbon pools owned or controlled by the reporting company to ensure the permanence of removal.
- Detail the uncertainty ranges for reported removals and methods used to determine this.
- Separately report reversals from previously reported removals, disaggregated by reversals from land-based storage and from geologic storage.

Accounting for net removals in an inventory relies on inventory accounting approaches that track removals in a defined inventory boundary over time, relative to a base year. This is, however, fundamentally different to intervention accounting approaches, such as those used in generating carbon credits. Intervention accounting methods estimate the impact of actions, without regard to a defined GHG inventory boundary, relative to a counterfactual.

A challenge for companies is that it is not possible to reconcile these approaches at present.[82] If a company retires a carbon credit purchased from an entity in the value chain and wishes to include a net removal in their GHG inventory, it will need to re-calculate the net removal based on inventory accounting approaches instead. It must report retired carbon credits purchased from outside the value chain separately from the removals inventory.

The *GHG Protocol Land Sector and Removals* guidance provides more information on how these different requirements may apply for land management removals and removals with geologic storage. For example, for land management removals, whether companies have full traceability to specific land management units or to sourcing regions will lead to the mandating of different safeguarding.[83]

Identifying the scope 3 boundaries

CDR methods often rely on multiple steps and companies involved in the sinks, pools and other activities. Involvement in a CDR pathway can create business activities with new sets of companies, across different value chains. As such, CDR pathways don't always align with existing value chains, which makes identifying the scope 3 boundary challenging. We provide several examples below, based on the *GHG Protocol Land Sector and Removals* guidance, to demonstrate which value chain actors can report a removal against a particular scope, **assuming they meet all the reporting requirements set out in the guidance**.[84]

In any of these cases, if the reporting companies sell carbon credits generated by the CDR activity to an entity outside the value chain, they must report an adjusted inventory that includes the removal of the contribution from the credited removal.

Is there double counting of scope 3 reductions among multiple entities in a value chain?[85]

It is worth noting that multiple entities in a value chain influence both emissions and reductions, including raw material suppliers, manufacturers, distributors, retailers, consumers and others. As a result, changes in emissions are not easily attributable to any single entity.

Double counting in scope 3 occurs when two entities in the same value chain account for the scope 3 emissions from a single emissions source – for example, if a manufacturer and a retailer both account for the scope 3 emissions resulting from the third-party transportation of goods between them. This type of double counting is an inherent part of scope 3 accounting. Each entity in the value chain has some degree of influence over emissions and reductions. Scope 3 accounting facilitates the simultaneous action of multiple entities to reduce emissions throughout society.

Companies may find double counting in scope 3 to be acceptable for purposes of reporting scope 3 emissions to stakeholders, driving reductions in value chain emissions and tracking progress on a scope 3 reduction target. To ensure transparency and avoid misinterpretation of data, companies should acknowledge any potential double counting of reductions or credits when making claims about scope 3 reductions. For example, a company may claim that it is working jointly with partners to reduce emissions, rather than taking exclusive credit for scope 3 reductions.

Unlike the cases above, double counting is a problem when it comes to the use of carbon credits to offset emissions or other market instruments that convey unique claims to GHG reductions or removals. If GHG reductions or removals take on a monetary value or receive credit in a GHG reduction program, it is necessary to avoid double counting of credits from such reductions or removals. To avoid double crediting, companies should, for example, specify exclusive ownership of reductions through contractual agreements.

Soil carbon sequestration

One of the most straightforward examples of where a CDR pathway aligns closely in existing value chains is soil carbon sequestration. Farmers can deploy this as they control both the sink and the pool and can therefore report a scope 1 removal. The rest of the value chain can report a scope 3 removal.

Table 1: Example in-value chain soil carbon sequestration GHG reporting

Value chain actor	Location of sink and pool	Reporting category
Agricultural input (e.g., seed and fertilizer suppliers)		Scope 3 land management removal
Agricultural production (e.g., farms)	Sink and pool	Scope 1 land management removal
Downstream activities (e.g., food processing, distribution and consumption)		Scope 3 land management removal

Biochar carbon removal (BCR)

As shown, there are many potential iterations of BCR, depending on the source of the sustainable biomass and the storage pools, such as in farmland or building material products The most straightforward example is biomass residues sourced directly from farms and the application of the biochar on the same farmland. In this case, the farm controls both the sink and pool and can therefore report a scope 1 removal. The rest of the agriculture value chain and any other companies involved in producing biochar can report a scope 3 removal.

Table 2: Example in-value chain biochar carbon GHG reporting

Value chain actor	Location of sink and pool	Reporting category
Agricultural input (e.g., seed and fertilizer suppliers)		Scope 3 land management removal
Agricultural production (e.g., farms)	Sink and pool	Scope 1 land management removal
Companies involved in the production of biochar from agricultural residues		Scope 3 land management removal
Downstream activities (e.g., food processing, distribution and consumption)		Scope 3 land management removal

Cases where an agricultural value chain takes biomass residues but stores them in pools controlled by other value chains is very important to BECCS, as explained in the example below.

Mineralization in concrete products

A mineralization removal pathway is a unique case where a product stores the carbon, captured through technological means, in a product. As an example, a company produces concrete using inputs, including cement, water and aggregates produced through mineralization. The mineralization requires a supply of alkaline rock, such as from mine tailings, as well as atmospheric CO_2, such as from a DAC facility.

The mine tailings are by-products of the mining value chain; hence any company downstream of the tailing production will not be able to report the scope 3 removal in this case. Any other company will also be able to report a scope 3 removal, including those involved in the DAC facility, the production of concrete and its use in buildings. Removals with product storage involve the transfer of the product between multiple entities, so it is not possible for a single company to control both the sink and the pool. No company can report a scope 1 removal in this case.

Table 3: Example in-value chain mineralization in concrete products GHG reporting

Value chain actor	Location of sink and pool	Reporting category
DAC facility owner	Sink	Scope 3 technological carbon removal with product storage
Mine and processing facility owner, supplying alkaline rock tailings		Scope 3 technological carbon removal with product storage
Downstream companies in the mine to market value chain		None
Companies providing other inputs to concrete production	Pool	Scope 3 technological carbon removal with product storage
Owner of facility producing carbonated concrete through mineralization	Pool	Scope 3 technological carbon removal with product storage
Companies downstream in the built environment (construction, use phase and end-of-life)	Pool	Scope 3 technological carbon removal with product storage

BECCS

Pathways that involve the supply of raw materials, such as biomass residues, from one value chain, with the removal generated through another value chain are much more complex. For example, a BECCS project could involve burning forestry residues from existing forestry operations to produce electricity.

Table 4: Example in-value chain BECCS GHG reporting

Value chain actor	Location of sink and pool	Reporting category
Companies involved in the generation of forestry residues (e.g., harvesting and processing)	Sink	Scope 3 biogenic removal with geological storage*
Companies downstream in the forestry value chain (e.g., manufacturing and use of forestry products)		None
Companies involved in the processing and transportation of forestry residues		Scope 3 biogenic removal with geological storage
BECCS facility owner		Scope 3 biogenic removal with geological storage*
The storers of the captured CO_2	Pool	Scope 3 biogenic removal with geological storage*
Companies in the energy value chain downstream of the BECCS facility (e.g., transmission, distribution and consumption)		Scope 3 biogenic removal with geological storage

*These companies may be able to report a scope 1 biogenic removal with geological storage through a specific contractual agreement.

As the biomass is a waste product, any company in the forestry value chain, downstream of the source of the residue, cannot report a removal from this BECCS activity. The removal does not exist because of their activities. On the contrary, any company in the energy value chain can report a scope 3 removal, as the use of the electricity generated through the project is key to the removal occurring. Lastly, the BECCS removal pathway requires the transportation and storage of the carbon in a geological pool. Companies controlling these processes will also be able to report a scope 3 removal.

Under a BECCS pathway, it is conceivable that different companies will control or operate the sinks and stores. However, one company, such as the BECCS facility controller, may be able to report a scope 1 removal through a specific contractual agreement.

In-value chain carbon removals under the SBTi frameworks

During the transition to net-zero emissions

Under SBTi's FLAG guidance, carbon removals generated through land-based activities in the sector, such as biochar and reforestation, can contribute to interim net-zero targets for FLAG emissions.[86] Typically, companies with non-FLAG emissions can only invest in these activities as part of their beyond value chain mitigation actions, such as by purchasing carbon credits. In this situation, any other company in the FLAG value chain must surrender any claim to this credited removal.

The SBTi FLAG guidance explicitly prevents the transfer of a FLAG-based mitigation activity into non-FLAG emissions pathways. As a result, companies that have both FLAG and non-FLAG emissions and separate SBTi-endorsed net-zero targets, cannot use any removals generated by its FLAG activities to contribute to its own non-FLAG net-zero targets.[87]

The extent to which these activities can contribute to the neutralization of non-FLAG emissions is still unknown, pending further guidance from SBTi. An interesting potential exception could be related to biochar, as recent scientific evidence suggests that high proportions of carbon stored in biochar could be permanent up to geological timescales.[88]

Neutralizing residual emissions

SBTi has not yet issued detailed guidance on neutralizing residual emissions with permanent removals. It is, however, clear that this can be achieved through both in-value chain CDR and purchased CDR beyond the value chain, if it can be demonstrated that the carbon removals are permanent, to the extent that they meet standards to be defined in upcoming guidance.[89] After accounting for the contribution from in-value chain removals, any remaining residual emissions will need to be neutralized by purchasing and retiring high-integrity carbon removal credits that meet equivalent permanence standards.

Worked example: Biochar carbon removal

A company in the agriculture and food sector owns and manages a forest as well as numerous farms within a landscape. It uses residues produced from forestry operations to produce biochar, which it then uses as a soil amendment in one of its farms.

As the company owns both the sink and the pool, it can report this a scope 1 removal, subject to the requirements of the GHG Protocol such as traceability. This can therefore contribute to interim net-zero targets by netting against combined scope 1 and 3 emissions in line with SBTi FLAG guidance.

This company also has industrial emissions but cannot use this removal to claim any progress towards its non-FLAG emissions targets.

Business drivers for in-value chain carbon removal

It is important that an in-value chain carbon removal action can contribute to a company's climate targets, though there are many additional drivers that companies should consider.

Business opportunities

Many novel CDR methods are at low levels of technological readiness and still require significant research, development and deployment (RD&D) to reach commercial scale. Equity investments are particularly crucial in this market to help nascent methods continue to develop and early-stage projects overcome financial hurdles. This presents an exciting opportunity for companies in the value chain or new investors to help meet growing demand for CDR and thereby capitalize on the significant market growth opportunities.[90]

Investment in CDR in the value chain offers opportunities for companies to generate revenue through the sale of credits from some or all the removals produced for companies outside of the value chain. The company must surrender any claim to the sold removal credit to avoid double counting, Companies can thereby satisfy their own demand for CDR while also benefiting from the additional revenue, particularly during periods of high credit prices. Companies will need to engage external crediting agencies to certify the removal for sale on the VCM.

Some methods provide opportunities for creating value though the supply of waste products, such as the valorization of waste biomass from FLAG sectors to supply sustainable biomass to biochar, BECCS and BiCRS projects. Similarly, they could valorize waste process heat to meet the process heat demand for DACCS projects.

As well as revenue generation potential, investing in CDR directly in the value chain offers opportunities to reduce costs. Despite upfront capital expenditure (CAPEX) costs potentially being higher than through purchasing carbon credits beyond the value chain, there may be opportunities for significant longer-term operating expenditure (OPEX) savings. The reduced need for intermediates in managing the transaction of carbon removal credits externally is driving this.[91] The developer and investor receive greater long-term value while also reducing exposure to high or volatile carbon credit prices.

There may also be opportunities to develop synergies between multiple removal activities, such as forest management and the production of sustainable biomass for BiCRS.

Security of supply of carbon removal

With the carbon removal market predicted to have limited supply up until 2050, not being able to secure access to the removals needed to satisfy net-zero commitments, either voluntary or through compliance mechanisms, is a significant risk.[92] Not achieving this may result in significant financial penalties, directly and indirectly through adverse stakeholder impacts.

Companies can achieve long-term access to carbon removal credits purchased outside the value chain by setting up long-term purchasing agreements but these are often still of limited duration and risks of failure to deliver remain. Deploying projects directly in the value chain may provide a more secure long-duration pipeline of carbon removal. In addition, companies will not have to purchase credits through open carbon markets with this approach, where they may be at risk of significant price fluctuations. In-value chain investments negate these uncertainties and provide more predictable longer-term cost projection.

Additional benefits

Carbon dioxide removal comes with a wide variety of different environmental, social and economic benefits across different methods. WBCSD's Removing carbon responsibly: A guide for business on carbon removal adoption provides an in-depth description.[93]

The delivery of removal projects in value chains can provide multiple, direct sustainability and commercial benefits to the entire value chain. The retention of these benefits can provide the following broad opportunities:

- Empowering local workforces with skilled jobs and improving living conditions of communities.
- Improved soil health, water retention and other agronomic benefits associated with agroforestry, soil carbon sequestration, biochar and enhanced weathering that can lead to improved crop yields, reduced fertilizer consumption and reduced soil erosion.
- Restoration of natural habitats in landscapes local to the operations of companies in the value chain, providing significant biodiversity benefits and climate resilience.
- Generation of additional co-products, such as heat from biochar production and high-premium, negative-emission energy through BECCS projects, for use throughout the value chain.

Some CDR methods offer opportunities for synergies, such as deploying a combination of biochar and enhanced weathering on agricultural lands. This offers opportunities for increased carbon removal density and the stacking of multiple core benefits in the value chain.

Creating or joining new value chains

It is possible to contain some CDR methods entirely in the value chain, whereas other more complex cases involve multiple value chains in generating the removal pathway. The emergence of a carbon removal industry will therefore provide many opportunities to connect different value chains through the supply of feedstocks needed for a removal pathway or to deploy the removal and yield the resultant benefits. Primary examples of this include:

- The supply of sustainable biomass residues from forestry and agricultural sectors to biochar, BECCS and other BiCRS projects.
- The use of waste heat from industrial processes to satisfy the process heating demand for DACCS projects installed nearby.[94]
- The supply of carbon negative electricity or other energy vectors from BECCS projects to large consumers, enabling them to reduce their scope 2 emissions and claim scope 3 removals.
- The use of biogenic or atmospheric carbon dioxide captured from BECCS or DACCS projects as a feedstock for chemical production and sustainable aviation fuel. These activities would not result in a removal, as the carbon is stored in short-lived products but the chemical and SAF supply chains and end-users will become dependent on DACCS and BECCS removal technology to deliver the required CO_2 – ultimately enabling the circular carbon economy.

Investment on the demand side of these new value chains will help secure access to future supply chains, whereas investment on the supply side will help create new business opportunities. The preceding section explores the degree to which companies in different value chains can make claims to a removal.

Future-proofing supply chains

Investing in CDR in the supply chain can help improve a company's commitment to climate goals. It may also improve the value chain's resilience to changing stakeholder expectations and regulatory landscapes.[95] As well as removing carbon, these activities may often build climate resilience in the supply chain and help restore ecosystems on which suppliers depend, particularly through land-based activities such as reforestation, soil carbon sequestration and biochar. As such, in-value chain CDR investments can provide powerful incentives to provide financing for climate change adaptation measures led locally and enhance stakeholder livelihoods.[96]

Rather than seeing these investments as a purely financial transaction, working with value chain partners to deploy carbon removal can enhance trust and transparency and maximize the collective benefit.[97]

Control over the removal project

Direct involvement in the removal project also offers a unique opportunity to shape the execution of the project, including where and how, such that their customization delivers maximum benefit to the company and value chain partners.[98] Additionally, regulators are still shaping CDR market policy and participation in the market will provide opportunities to engage and shape policy outcomes.

Green product claims

Companies may incorporate the negative emissions of in-value chain carbon removals into the life-cycle emissions associated with a product. Consumer protection regulation, such as the EU Empowering Consumers Directive, has banned claims based on unverified GHG emissions offsetting for goods and services.[99] As such, there is likely a key role for the accounting of high-integrity carbon removal in product life-cycle emissions, which will be of particular importance to business-to-business (B2B) companies. This will naturally lead to the potential for greater product premiums, thereby incentivizing in-value chain action.

Enhanced brand identity

Deploying carbon removal directly in the value chain creates opportunities to incorporate the role of carbon removal in the corporate sustainability narrative and brand identity more strongly than if the company were to make investments beyond the value chain. If the reporting company can demonstrate that it has applied rigorous accounting methodologies, used third-party verification and published the removal in a registry, it may have a stronger case for any claims made about the role of carbon removals.

Some sectors have stronger synergies with certain carbon removal methods, such as the cement sector and mineralization, as described in a subsequent section. Companies that embrace these synergies and opportunities may be able to demonstrate significant climate leadership among their peers by playing a key role in developing solutions.

Unique considerations of in-value chain CDR

Despite the significant opportunities from in-value chain carbon removal investments, there are also some unique challenges to consider and address.

Quantification and MRV

There should be little difference in the key steps needed to deliver a high-integrity removal in the value chain, compared to suppliers delivering carbon credits to the market. In all cases, companies should:

- Follow the guiding principles of the ICVCM's Core Carbon Principles to deliver a high-integrity removal. A notable exception is that of additionality, as some in-value chain action will not involve the sale of carbon credits and thus will not need to demonstrate that the project would not have occurred without the sale of credits.
- Ensure the sustainable sourcing of any biomass used and that it satisfies the appropriate sustainability standards. A useful guide to Biomass Sustainability in CDR is Carbon Direct's buyers guide.[100]
- Use science-based and multi-stakeholder evolved methodologies to quantify the removal.
- Conduct monitoring, reporting and verification (MRV) activities to track the removal performance over time, ideally aided by third parties.
- Conduct due diligence, aided by third-party verification, to ensure robust and accurate quantification and the assessing and management of any associated side impacts. This should take place for the duration of the reporting of the removal.
- Register the removal in a reputable registry.

Companies that deploy CDR directly in the value chain will need to be more acutely aware and actively involved in these steps than they may otherwise have been by purchasing equivalent credits, where these are supplier-driven activities. An additional difference is the role of certification agencies, which will generate a certified removal certificate, that value chain entities can then sell on the VCM as a credit. This may expose the value chain to greater scrutiny over the integrity of the removal.

A particular challenge is to ensure data traceability among the many organizations involved in the full removal pathway and value chain. Traceability is a fundamental aspect of high-integrity carbon removal and is a key requirement from the GHG Protocol to report a removal in a GHG inventory.[101] To enable seamless tracking, third-party verification and data transfer, digital solutions for MRV are emerging, such as Carbonfuture MRV+[102] or the application of distributed leger technologies, including public blockchains, to manage these challenges.

Liability

There are several key risks associated with carbon removal projects, regardless of their deployment in the value chain or purchased through carbon credits beyond it. The extent to which companies are liable for the impact of these risks manifesting may, however, vary. The main liability differences include the following.

Delivery risk

Any company looking to a make claim from any removal activity risks exposure to failure to deliver the project. If carbon credits are supplied and purchased ex-post, there is no risk to delivery. If a company purchases them ex-ante, such as with long-term pre-purchase agreements or if the removal claim results from in-value chain activity, the risk of delivery can be significant. Although certain contractual terms in credit pre-purchase agreements may mitigate this to an extent, emerging carbon insurance products may mitigate any residual liability concerns.[103]

Invalidation risk

Stakeholders can invalidate a CDR activity through premature reversal of carbon storage or because of other unintended side impacts on the environment, communities or the economy.

For CDR projects generated through a crediting approach, the reversal liability typically lies with the supplier and the risk of reversal buffer pool mechanisms may cover them, thereby pricing them into the carbon credit.[104] This will not be possible for in-value chain carbon removals. Carbon insurance products will likely be a critical tool in managing the liabilities related to reversal.[105]

A key task in delivering a high-integrity removal is to report all certification-related data into a reputable registry to demonstrate that a reversal has not occurred. The two main activities involved in generating a removal are to capture the carbon and guard the stable carbon pool to deliver a removal. Deciding which company is liable for reporting and registering all certification-related data from these two processes can be challenging and will typically vary based on different removal activities. Carbonfuture recommends this be the last wholesaler in the chain of custody, where it may have contributed most to the delivery of the removal itself and is best able to carry accountability. As an example, this would mean the following for different methods:

- Biochar: This will typically be the pyrolysis operator as the project developer.
- Enhanced weathering: This will typically be the organization spreading the particles on the land, rather than the supplier of rock.
- Mineralization in building materials: This will typically be the company that produces the building materials, particularly because the risk of re-emission from the material is very low in this context.

Some CDR projects have the potential to lead to unintended environmental, societal or economic consequences if stakeholders do not identify and manage risks effectively. Companies that purchase carbon credits from beyond the value chain may have some reputational exposure and incur costs to replace credits if there are unintended consequences. Carbon insurance may be able to play a role in mitigating the replacement costs. The main liabilities will, however, fall with the supplier. If, however, companies have acted to deploy CDR projects in the value chain, then these liabilities will fall in the value chain. Companies making investments in the value chain will need to be more involved in identifying and managing any associated risks.[106]

Skillsets and resource

If investment into carbon removal is a new business venture it will require a new degree of expertise and resource from companies, much more than expected through credit purchases. Companies will require much of this to carry out in-house due diligence assessments of projects.

In addition, there will be a significantly greater administrative burden on companies to manage the complex value chain interactions to deliver projects and trace carbon data.[107] Therefore, companies need to invest early in developing this knowhow and skillset in house, which may take time and resource investment.

Retaining the benefits of carbon removal in the boundaries of the value chain

A challenge that is mostly unique to the agriculture and food sectors is that the dynamic nature of supply chains can make the boundary of the value chain difficult since it is liable to change rapidly. There is a significant opportunity to develop land-based removal methods in agricultural value chains, particularly in farms themselves. These can be significant investments; therefore, it is key to have confidence that the value chain will retain these removals within its boundary for a significant duration. Companies should continue to invest in traceability to better map supply chains, to focus interventions on farmers and growers the company sources from.

This, however, may not always be feasible. In this case, companies may need to take a landscape or supply-shed approach where projects don’t necessarily take place on land owned or controlled by value chain partners but rather in the immediate sourcing landscapes in the supply chain. This presents a big opportunity for shared investment from different value chain partners who source from the same landscape. This does, however, place additional challenges in translating the outcomes into a GHG inventory and counting towards an SBTi target, though there is ongoing work to assess the incorporation of these approaches.

Conclusion and call to action

Achieving gigaton scale CDR by 2050 is critical to meeting the goals of the Paris Agreement. While it is necessary to avoid overreliance and mitigate any associated risks, CDR offers significant opportunities to contribute to a wide range of sustainable development goals. Despite recent positive progress in developing the market, there is still a significant projected supply shortfall to meet demand for 2030 and beyond. Clear and tangible short-term demand signals will help early-phase projects access the financing needed to start deploying at scale. Much of this early demand comes from voluntary commitments to purchase carbon removal credits from the VCM. While projections show this will provide much of the financing needed, there remains significant untapped demand opportunities from companies taking action to deploy CDR in their value chains.

Call to action:

- Set clear short-, medium- and long-term targets for high-quality CDR that complement science-based emissions reduction pathways and demonstrate commitments to neutralize residual emissions at net-zero.
- Assess the possibility of satisfying a proportion of the CDR requirements through in-value chain action by reviewing strategic opportunities and additional business synergies for these actions.
- Seek opportunities for collaboration with value chain partners in the first instance, then assess other investment approaches, including project finance, in-kind support or equity finance.
- Ensure that any biomass sourced for use in CDR projects satisfies sustainable sourcing standards and that there is full traceability of the source.
- Ensure that robust plans for MRV and risk management are in place to substantiate any in-value chain removals and that liability ownership is clear.
- Invest early in resourcing the development of in-house CDR expertise to enable reputable in-value chain action on CDR.

Acronyms and abbreviations

B2B – Business-to-Business

BCR – Biochar Carbon Removal

BECCS – Bioenergy with Carbon Capture and Storage

BiCRS – Biomass Carbon Removals

CAPEX – Capital Expenditure

CCS – Carbon Capture and Storage

CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation

CDR – Carbon Dioxide Removal

DACCS – Direct Air Carbon Capture and Storage

ETS – Emissions Trading Scheme

FLAG – Forest, Land and Agriculture

GHG – Greenhouse Gas

Gt/year – Metric Gigaton per Annum

ICVCM – Integrity Council for the Voluntary Carbon Market

MRV – Monitoring, Reporting and Verification

OPEX – Operational Expenditure

RD&D – Research, Development and Demonstration

SAF – Sustainable Aviation Fuel

SBTi – Science Based Targets initiative

VCM – Voluntary Carbon Market

VOC – Volatile Organic Compounds

Endnotes

[1] Intergovernmental Panel on Climate Change (IPCC) (2022). *Sixth Assessment Report, Working Group III. Available at:* https://www.ipcc.ch/report/ar6/wg3/.
[2] International Energy Agency (IEA) (2023). *Credible pathways to 1.5°C.* IEA. Paris. Available at: https://www.iea.org/reports/credible-pathways-to-150c.
[3] Intergovernmental Panel on Climate Change (IPCC) (2022). *Climate Change 2022: Mitigation of Climate Change: Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.
[4] 1.5°C-aligned scenarios with no or limited overshoot.
[5] Intergovernmental Panel on Climate Change (IPCC) (2022). *Climate Change 2022: Mitigation of Climate Change: Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.
[6] Intergovernmental Panel on Climate Change (IPCC) (2022). *Climate Change 2022: Mitigation of Climate Change: Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.
[7] Smith, S. et al. (2023). *The State of Carbon Dioxide Removal.*
[8] WBCSD (2023). *Removing carbon responsibly: A guide for business on carbon removal adoption.*
[9] Boston Consulting Group (2023). *Climate Needs and Market Demand Drive Future for Durable CDR.*
[10] Smith, S., et al. (2023). *The State of Carbon Dioxide Removal.* I
[11] Fankhauser, S, et al. (2022). The meaning of net zero and how to get it right. In: *Nature Climate Change*, Vol. 12, pp. 15-21.
Smith, S. et al. (2023) *The State of Carbon Dioxide Removal.*
[12] WBCSD (2023). *Removing carbon responsibly: A guide for business on carbon removal adoption.*
[13] Science Based Targets Initiative (SBTi) (2024). *SBTi Corporate Net-Zero Standard*.
[14] Science Based Targets Initiative (SBTi) (2022). *Forest, Land Agriculture Science Based Target-Settting Guidance.*
[15] Science Based Targets Initiative (SBTi) (2024). *SBTi Corporate Net-Zero Standard*.
[16] Sylvera (2022). The difference between insetting and offsetting. *Sylvera.* 23 November 2022. Retrieved from https://www.sylvera.com/blog/insetting.
Nestle (2022). Nestle's supply chain (scope 3) and sourcing landscape removals framework. *Nestle.* Retrieved from: https://global-test.factory.nestle.com/sites/default/files/2022-02/nestle-insetting-framework.pdf.
[17] International Platform for Insetting (IPI) (n.d.). Insetting Explained. Retrieved from: https://www.insettingplatform.com/insetting-explained/#1598877186572-be0952f3-90c1.
[18] Science Based Targets Initiative (SBTi) (2024). *Above and Beyond: An SBTi report on the design and implementation of beyond value chain mitigation (BVCM).*
[19] Carbon Direct (2023). *State of the Voluntary Carbon Market.*
[20] CDR.fyi. (2023). Only 0.5% of Companies with SBTi Targets Have Purchased Carbon Removal. 21 September 2023. Retrieved from: https://www.cdr.fyi/blog/SBTi-purchases-analysis.
[21] Boston Consulting Group (2023). *Climate Needs and Market Demand Drive Future for Durable CDR*.
[22] World Resources Institute and WBCSD (2004). *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard.*
World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[23] World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[24] International Platform for Insetting (n.d.). Insetting Explained Retrieved from: https://www.insettingplatform.com/insetting-explained/#1598877186572-be0952f3-90c1.
World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[25] World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[26] World Economic Forum (2023). *Scaling Voluntary Carbon Markets: A Playbook for Corporate Action*.
[27] Loam (n.d.). We're using the world's smallest organisms to solve the world's biggest problems. Retrieved from: https://www.loambio.com/science/.
[28] Leakey, R.R.B. (1997). Definition of Agroforestry Revisited. In: *Agroforestry Today*, 1997, Vol. 8, pp. 5-7.
Hart, T., Drew, E, et al. (2023). Priority science can accelerate agroforestry as a natural climate solution. In: *Nature Climate Change*, 2023, Vol. 13.
[29] Hart, T., Drew, E. et al. (2023). Priority science can accelerate agroforestry as a natural climate solution. In: *Nature Climate Change*, 2023, Vol. 13.
[30] International Biochar Iniative (2024). *Global Biochar Market Report 2023*.

[31] Prabhakar, S. (2024). Biochar application for sustainable soil erosion control: a review of current research and future perspectives.In: *Frontiers in Environmental Science*, 2024, Vol. 12.
[32] WBCSD (2023). *Removing carbon responsibly: A guide for business on carbon removal adoption.*
[33] Sanei, H., et al. 2024. Assessing biochar's permanence: An inertinite benchmark. In: *International Journal of Coal Geology*, Vol. 281.
[34] Beerling, D.J., Kantzas, E.P., Lomas, M.R. et al. (2020). Potential for large-scale CO2 removal via enhanced rock weathering with croplands. In: *Nature*, 2020, Vol. 583, pp. 242-248.
[35] Carbon Business Council (2024). *Enhanced Weathering Policy Primer: Assessing the Opportunity.*
Carbon180 (n.d.). Enhanced Rock Weathering. Retrieved from: https://carbon180.org/pathway/enhanced-rock-weathering/.
[36] WBCSD (2023). *Removing carbon responsibly: A guide for business on carbon removal adoption.*
[37] Smith, S., et al. (2023). *The State of Carbon Dioxide Removal.*
[38] Smith, S., et al. (2023). *The State of Carbon Dioxide Removal.*
[39] Smith, S., et al. (2023). *The State of Carbon Dioxide Removal.*
[40] WBCSD (2023). *Removing carbon responsibly: A guide for business on carbon removal adoption.*
[41] Sagues, W.J, Jameel, H., Sanchez, D.L., Park, S. (2020). Prospects for bioenergy with carbon capture & storage (BECCS) in the United States pulp and paper industry. In: *Energy & Environmental Science*, 2020.
[42] U.S. Department of Energy (2024). Demonstrations, Department of Energy Office of Clean Energy. Carbon Capture Large-Scale Pilot Projects Selections for Award Negotiations. Retrieved from: https://www.energy.gov/oced/carbon-capture-large-scale-pilot-projects-selections-award-negotiations?utm_medium=email&utm_source=govdelivery.
[43] Science Based Targets initiative (SBTi) (2024). *SBTi Corporate Net-Zero Standard*.
[44] WBCSD (2023). *Removing carbon responsibly: A guide for business on carbon removal adoption.*
Science Based Targets initiative (SBTi) (2024). *SBTi Corporate Net-Zero Standard*.
[45] drax. Carbon Emissions (n.d.). Retrieved from: https://www.drax.com/uk/carbon-emissions/#:~:text=Since%202012%2C%20the%20Group%E2%80%99s%20actions%20have%20reduced%20our,helping%20the%20UK%20achieve%20its%20net%20zero%20target.
[46] Stockholm Exergi (n.d.). BECCS - Negative Emissions. Retrieved from: https://www.stockholmexergi.se/en/bio-ccs/.
[47] International Biochar Iniative (2024). *Global Biochar Market Report 2023*.
[48] International Energy Agency (2022). *Direct Air Capture 2022.* Paris.
[49] Climeworks (2023). Climeworks and Great Carbon Valley chart path to large-scale direct air capture and storage deployment in Kenya. Retrieved: https://newsroom.climeworks.com/261860-climeworks-and-great-carbon-valley-chart-path-to-large-scale-direct-air-capture-and-storage-deployment-in-kenya.
[50] International Energy Agency (IEA) (n.d.). Energy System - Buildings. Retrieved from: https://www.iea.org/energy-system/buildings.
[51] Global Alliance for Buildings and Construction (2023). *Global Status Report for Buildings and Construction*. Retrieved from: https://www.unep.org/resources/report/global-status-report-buildings-and-construction.
[52] According to SBTi, the steel and cement sectors will have residual emissions of 9% and 6% in 2050, compared to baselines, respectively. Source: Intergovernmental Panel on Climate Change (IPCC) (2022). *Climate Change 2022: Mitigation of Climate Change: Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.
[53] International Energy Agency (IEA) (2023). *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach.*
[54] International Energy Agency (IEA) (2023). *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach.*
[55] Khanna, R., Li; K., Wang, Z., Sun, M., Zhang, J., Mukherjee, P.S. (2019). Char and Carbon Materials Derived from Biomass. In: *Elsevier*.
[56] Hepburn, C. et al. (2019). The technological and economic prospects for CO2 utilization and removal. In: *Nature*, 2019, Vol. 575, pp. 87-97.
McKinsey (2023). The circular cement value chain: Sustainable and profitable. Retrieved from: https://www.mckinsey.com/industries/engineering-construction-and-building-materials/our-insights/the-circular-cement-value-chain-sustainable-and-profitable.
[57] World Resources Institute (2023). 5 Things to Know About Carbon Mineralization As a Carbon Removal Strategy. Retrieved from: https://www.wri.org/insights/carbon-mineralization-carbon-removal.
[58] The Constructor (n.d.). Curing of concret by carbon dioxide. Retrieved from: https://theconstructor.org/concrete/curing-concrete-carbon-

dioxide/39587/#:~:text=Carbon%20cure%20concrete%20or%20concrete%20cured%20by%20carbon-dioxide,reaction%20and%20gains%20strength%20at%20a%20faster%20rate.
[59] Aneja, A. et al. (2022). Mechanical and durability properties of biochar concrete. In: *Materials Today: Proceedings*, 2022, Vol. 65, pp. 3724-3730.
[60] Ma, F. et al. (2022). Biochar for asphalt modification: A case of high-temperature properties improvement. In: Science *of the Total Environment*, 2022, Vol. 804.
[61] Schmidt, H.P. (2014). The use of biochar as a building material. *The Biochar Journal*.
[62] International Biochar Initiative (2024). *Global Biochar Market Report 2023*.
[63] Arup (2024). *City Handboook for Carbon Neutral Buildings*.
[64] Institute of Structural Engineers (2021). Timber and Carbon Sequestration. *The Structural Engineer.* January 2021, pp. 18-20.
[65] Institute of Structural Engineers (2021). Timber and Carbon Sequestration. *The Structural Engineer.* January 2021, pp. 18-20.
[66] Arup (2024). *City Handboook for Carbon Neutral Buildings*.
[67] International Council on Mining and Metals (ICMM) (n.d.). Cleaner and Safer Vehicles. Retrieved from: https://www.icmm.com/en-gb/our-work/cleaner-safer-vehicles#:~:text=There%20are%20around%2028%2C000%20large%20mine%20hauling%20trucks,based%20on%2025%20billion%20litres%20of%20diesel%20fuel.
[68] World Resources Institute (2023). 5 Things to Know About Carbon Mineralization As a Carbon Removal Strategy. Retrieved from: https://www.wri.org/insights/carbon-mineralization-carbon-removal.
[69] SYSTEMIQ (2022). *Planet Positive Chemicals: Pathways for the chemical industry to enable a sustainable global economy.*
[70] This figure is widely understood to be significantly underestimated, particularly if upstream methane and downstream combustion emissions are more accurately assessed.
[71] SYSTEMIQ (2022). *Planet Positive Chemicals: Pathways for the chemical industry to enable a sustainable global economy.*
[72] SYSTEMIQ (2022). *Planet Positive Chemicals: Pathways for the chemical industry to enable a sustainable global economy.*
[73] International Energy Agency (IEA) (2023). *Global Hydrogen Review 2023.*
[74] WBCSD (2023). *A guide to 1.5°C-aligned hydrogen investments.*
[75] Fischer-Tropsch processes involve the catalytic reaction of carbon monoxide and hydrogen to produce synthetic hydrocarbons.
[76] European Union Aviation Safety Agency (2022). *European Aviation Environmental Report*.
[77] Department for Energy Security & Net Zero (2023). *Carbon Capture, Usage and Storage: A Vision to Establish a Competitive Market*.
[78] International Aviation Trade Association (IATA) (2023). *Direct Air Capture (DAC) and Storage (DAC+S).*
[79] World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[80] These two processes can be simultaneous for some methods, such as enhanced rock weathering.
[81] World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[82] Work is underway under the GHG Protocol to provide guidance on reconciling inventory and intervention-based accounting approaches.
[83] World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[84] World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[85] UNDO (2023). Four incredible benefits of enhanced rock weathering. Retrieved from: https://un-do.com/resources/blog/four-incredible-benefits-of-enhanced-rock-weathering/.
[86] Science Based Targets initiative (SBTi) (2022). *Forest, Land Agriculture Science Based Target-Settting Guidance.*
[87] Science Based Targets initiative (SBTi) (2022). *Forest, Land Agriculture Science Based Target-Settting Guidance.*
[88] Sanei, H. et al. (2024). Assessing biochar's permanence: An inertinite benchmark. In: *International Journal of Coal Geology*, Vol. 281.
[89] Science Based Targets initiative (SBTi) (2024). *SBTi Corporate Net-Zero Standard*.
[90] Boston Consulting Group (2023). *Climate Needs and Market Demand Drive Future for Durable CDR*.
[91] Sylvera (2022). The difference between insetting and offsetting. *Sylvera.* 23 November 2022. Retrieved from https://www.sylvera.com/blog/insetting.
[92] Boston Consulting Group (2023). *Climate Needs and Market Demand Drive Future for Durable CDR*.

[93] WBCSD (2023). *Removing carbon responsibly: A guide for business on carbon removal adoption.* Retrieved from: https://www.wbcsd.org/resources/removing-carbon-responsibly/.
[94] International Energy Agency (2022). *Direct Air Capture 2022.* Paris.
[95] Sylvera (2022). The difference between insetting and offsetting. *Sylvera.* 23 November 2022. Retrieved from https://www.sylvera.com/blog/insetting.
[96] International Platform for Insetting (n.d.). Insetting Explained Retrieved from: https://www.insettingplatform.com/insetting-explained/#1598877186572-be0952f3-90c1.
[97] International Platform for Insetting (n.d.). Insetting Explained Retrieved from: https://www.insettingplatform.com/insetting-explained/#1598877186572-be0952f3-90c1.
[98] Sylvera (2022). The difference between insetting and offsetting. *Sylvera.* 23 November 2022. Retrieved from https://www.sylvera.com/blog/insetting.
[99] European Council (2023). Council and Parliament reach provisional agreement to empower consumers for the green transition. Retrieved from: https://www.consilium.europa.eu/en/press/press-releases/2023/09/19/council-and-parliament-reach-provisional-agreement-to-empower-consumers-for-the-green-transition/#:~:text=The%20provisional%20agreement%20maintains%20the,unless%20established%20by%20public.
[100] Carbon Direct (n.d.). *A Practical Guide to Sustainable Biomass Sourcing for Carbon Removal*. https://www.carbon-direct.com/research-and-reports/a-buyer-s-guide-sustainable-biomass-sourcing-for-carbon-dioxide-removal.
[101] Integrity Council for the Voluntary Carbon Market (ICVCM) (2022). *The Core Carbon Principles.*
World Resources Institute and WBCSD (2024). *Land Sector and Removals Guidance.*
[102] Carbon Future (n.d.). The Most Comprehensive MRV Solution for Durable Carbon Removal. Retrieved from: https://www.carbonfuture.earth/products/mrv.
[103] Kita (2024). To insure or not insure? That is the (carbon) question. Retrieved from: https://www.kita.earth/blog/to-insure-or-not-to-insure-that-is-the-carbon-question.
[104] Sylvera (2022). Gui*de to Carbon Credit Buffer Pools*. Retrieved from: https://www.sylvera.com/blog/carbon-credit-buffer-pools#:~:text=In%20simple%20terms%2C%20the%20buffer%20pool%20can%20be,even%20if%20some%20carbon%20stocks%20are%20unexpectedly%20lost.
[105] Kita (2024). To insure or not insure? That is the (carbon) question. Retrieved from: https://www.kita.earth/blog/to-insure-or-not-to-insure-that-is-the-carbon-question.
[106] Integrity Council for the Voluntary Carbon Market (ICVCM) (2022). *The Core Carbon Principles.*
[107] Sylvera (2022). The difference between insetting and offsetting. *Sylvera.* 23 November 2022. Retrieved from https://www.sylvera.com/blog/insetting.

Acknowledgements

Lead authors: Neal Gray-Wannell and Stephen Buskie

This paper was drafted by WBCSD, in collaboration with members of the CCS & Removals workstream. We thank those member companies and the following key partner organizations for their support in developing this paper:

- Rethinking Removals
- Science Based Targets initiative (SBTi)
- International Biochar Initiative
- Carbonfuture
- International Aviation Trade Association (IATA)
- Kita

Disclaimer

This publication is released in the name of the World Business Council for Sustainable Development (WBCSD). It is the result of a collaborative effort between WBCSD and representatives from companies participating in the WBCSD CCS & Removals workstream.

A wide range of members of the CCS & Removals workstream have reviewed the material, thereby ensuring that the document broadly represents a majority view. It does not mean, however, that every company in the workstream agrees with every word.

This publication has been prepared for general informational purposes only and is not intended to be relied upon as accounting, tax, legal or other professional advice.

To contact WBCSD about this report:

Celine Le Goazigo

Senior Manager, Energy

legoazigo@wbcsd.org

Alexander Nick

Senior Director, Climate Action

alexander.nick@wbcsd.org

About the World Business Council for Sustainable Development (WBCSD)

The World Business Council for Sustainable Development (WBCSD) is a global community of over 225 of the world's leading businesses driving systems transformation for a better world in which 9+ billion people can live well, within planetary boundaries, by mid-century. Together, we transform the systems we work in to limit the impact of the climate crisis, restore nature and tackle inequality.

We accelerate value chain transformation across key sectors and reshape the financial system to reward sustainable leadership and action through a lower cost of capital. Through the exchange of best practices, improving performance, accessing education, forming partnerships, and shaping the policy agenda, we drive progress in businesses and sharpen the accountability of their performance.

Follow us on **LinkedIn** and **X**.

www.wbcsd.org

World Business Council for Sustainable Development

Geneva | Amsterdam | Chicago | London | New York City | Singapore | Wuhan City