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CIRCULAR CARBON INNOVATION:

An Unrealized Investment Opportunity

An Analysis of Investor and Industry Perspectives by the Circular Carbon Network

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INTRODUCTION

The urgent need to address climate change is usually framed in terms of opportunity costs and the risk of doing nothing. However, an emerging approach among a widening circle of investors focuses instead on market potential and investment opportunity. The market success of renewables is proving that there are ways to address climate change that are also profitable.

Another important and complementary emerging solution is turning excess carbon dioxide (CO_2) into valuable products, like building materials, fuels, and chemicals. There is substantial technology innovation occurring in this area and early commercial efforts are underway to achieve scale. However, the industry will require a significant amount of capital to reach its full profit and impact potential. Like other emerging clean energy sectors, catalyzing further investment requires tackling commercialization challenges as well as financial gaps, which are inextricably linked.

This report has been developed for investors and industry stakeholders with the objective of outlining the market opportunity, framing the commercial and impact investment potential, and presenting practical solutions for mobilizing new capital into the sector. There is an urgent need to better understand how to effectively capitalize and scale this massive CO_2 market opportunity.

For purposes of this publication, the term circular carbon refers to technologies and pathways that seek to generate economic value from the reduction or use of atmospheric CO_2. This umbrella terminology is inclusive of sectors including carbon capture and utilization (CCU), carbon dioxide utilization (CDU), carbon capture, use, and storage (CCUS), CO_2 products, air capture, land use management, ocean sequestration, and reforestation.

This report has a particular focus on commercial product pathways that convert or directly utilize CO_2 including:

- Chemicals
- Fuels
- Polymers
- Industrial gases
- Food and agriculture

Many of these solutions can be carbon-neutral or carbon-negative, depending on their production lifecycle and implementation. Analysis regarding net CO_2 impact is already ongoing for many processes and products.

The Circular Carbon Network (CCN), an initiative of the NRG COSIA Carbon XPRIZE, is designed to bring together diverse industry leaders and stakeholders to share knowledge, build relationships, and increase the flow of capital and deals. During 2016 and 2017, CCN conducted an extensive set of surveys and interviews with investors and facilitated two investment-focused workshops to determine how to best rapidly accelerate new capital into circular carbon innovation.

Several key questions emerged from those discussions, including:

- What is the economic potential of carbon utilization?
- How much can it contribute to climate mitigation?
- What are some of the most promising pathways?
- What is the realistic timeframe for their commercialization?
- How much capital will be required?
- Where will follow-on capital come from?
- How can we mitigate the risks?
- Does this industry depend on a national/global climate policy?
- How do I get access to good deals?

This report begins to answer these questions and is designed to spur further engagement and discussion among key players in the industry. Key takeaways from our engagement and analysis include:

- CO_2 products present diverse and significant opportunities for investors. CO_2 is a building block for a wide diversity of products and materials with both B2B and B2C applications. The Global CO_2 Initiative and CO_2 Sciences have estimated that by 2030, CO_2 products could generate between $800 billion and $1.2 trillion annually and reduce CO_2 emissions by 10% to 15%.
- Capital providers in each development stage (early stage, scaling, and commercialization)—including large corporates focused on minimizing climate change risk and identifying sustainability solutions that are tangible and additive—are increasing engagement and investment.
- There are critical gaps and barriers in the capital ecosystem that have slowed capital flows into circular carbon technologies. These include questions around policy and regulatory risk; capital intensity compared to other sectors; the potential impact of any single solution; availability of data; physical and virtual infrastructure and networks; and standard financing models.
- Investors and industry stakeholders believe that these gaps and barriers can be addressed through new financing tools, market services, and technology development support, many of which are described in Section III.
- Continued discussion and action focused on accelerating investment in circular carbon innovation is necessary to ensure that solutions are smartly implemented and widely adopted.

THE BUSINESS CASE FOR CIRCULAR CARBON TECHNOLOGIES

The world must avoid approximately 200 billion tons of carbon dioxide (CO_2) emissions over the next five decades to avoid the most drastic climate change scenarios.[1] CO_2 concentration in the atmosphere has risen rapidly in recent years even as reported emissions globally have stabilized. While analysis is incomplete, this linkage between current emissions and CO_2 concentration may signal a potentially more ominous scenario for climate change than current consensus. This data only serves to further enhance the urgency—and the opportunity—for solutions that can not only help reduce emissions, but also remove existing CO_2 from the atmosphere.

In addition, media and policy attention to climate change has typically focused on emissions reduction from the power and transportation sectors. Yet for the world to remain below the International Energy Agency's (IEA) 2DS scenario[2], significant reductions are necessary from a much broader swath of the economy—including agriculture, buildings and homes, and heavy industry. The breadth of required reduction and removal underscores the size of the current market opportunity.

A particularly promising set of technologies within circular carbon innovation poised to help address these issues focuses on converting CO_2 into valuable products. The Global CO_2 Initiative and CO_2 Sciences have estimated that by 2030, CO_2 products could generate between $800 billion and $1.2 trillion annually and reduce CO_2 emissions by 10% to 15%.

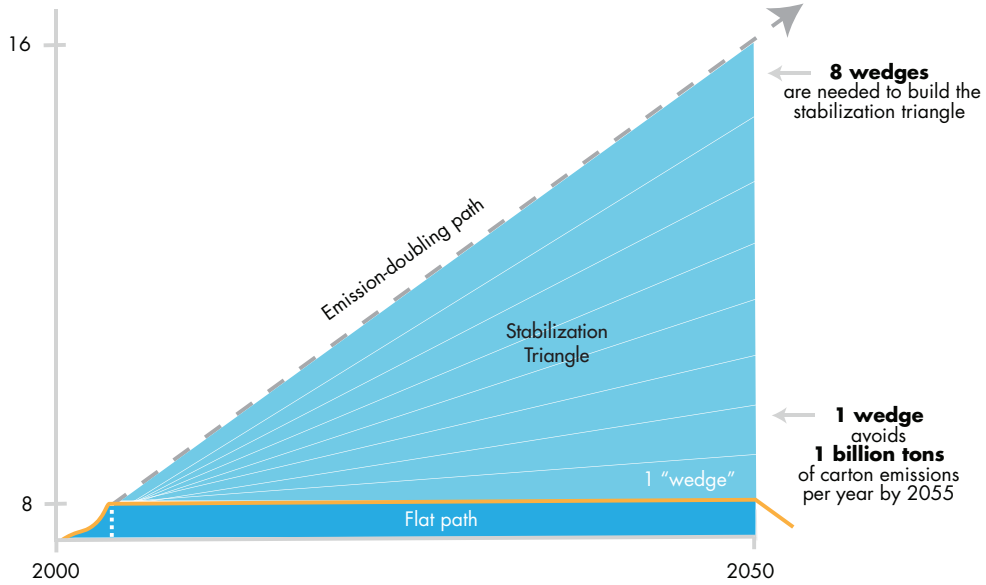


Figure A. Princeton University Carbon Mitigation Initiative Emission Wedge Visualization

1 Carbon Mitigation Initiative, "Stabilization Wedges" (Princeton University, 2015); http://cmi.princeton.edu/wedges/

2 IEA's 2°C Scenario (2DS) lays out an energy system pathway and a CO_2 emissions trajectory consistent with at least a 50% chance of limiting the average global temperature increase to 2°C by 2100. https://www.iea.org/etp/explore/

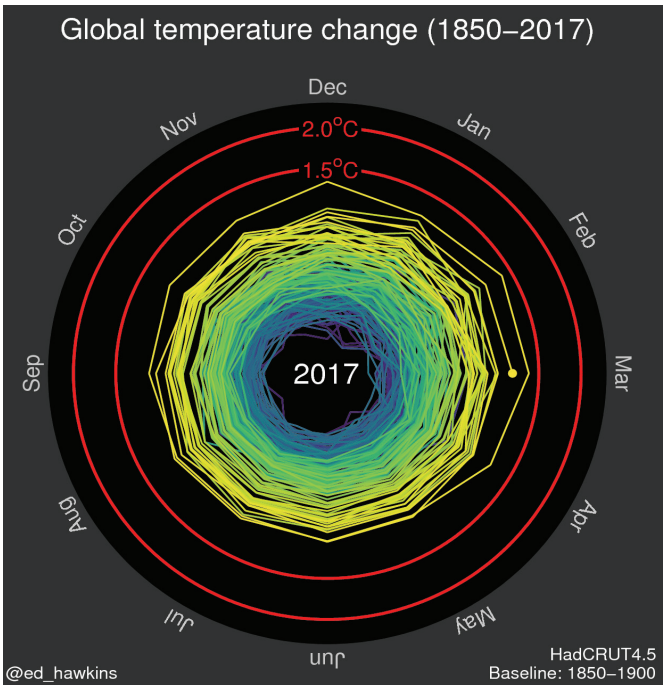


Figure B. Global temperature change (1850-2017)[3]

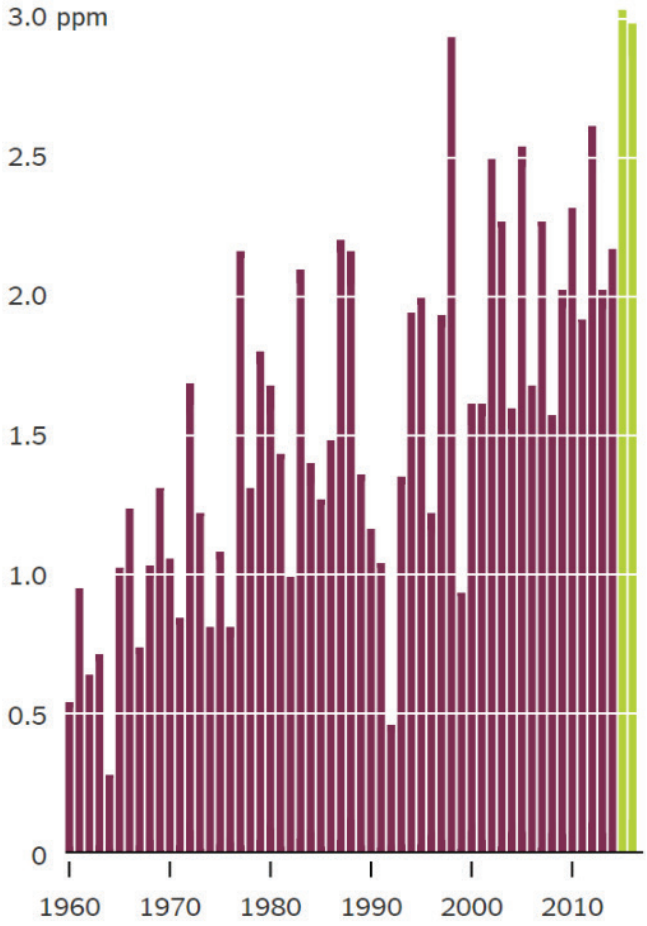


Figure C. Annual mean growth rate of CO_2 concentration at Mauna Loa[5]

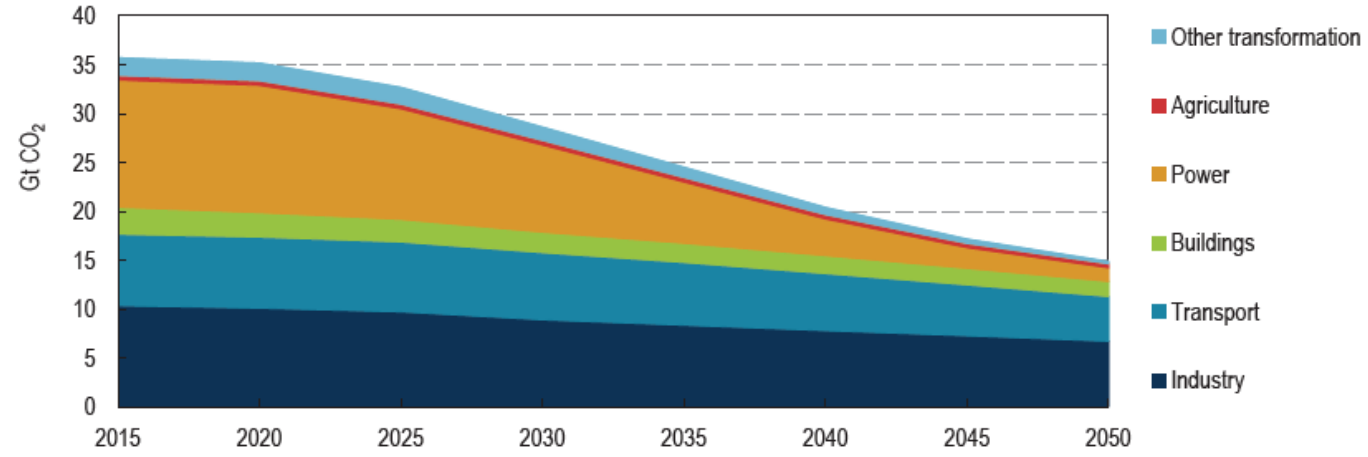
CO_2 product pathways being explored today, including key verticals with near-term commercial potential, are outlined in greater detail in Section III. The carbon used in many of these new product verticals is replacing carbon typically sourced from fossil sources, namely crude oil, natural gas, or coal. For example, over 90% of organic chemicals are derived from fossil carbon and 5% to 10% of global crude oil production is used in the manufacturing of these products.[4] Thus, in addition to beneficial reuse, scaling these technologies further serves to reshape traditional fossil fuel supply chains and avoid additional CO_2 emissions from fossil sources.

3 Hawkins, Ed. "Visualization Resources." Web blog post. Climate Lab Book. Ed Hawkins, 2016. Web. July 2017.

4 A Strategic European Research and Innovation Agenda for Smart CO_2 Transformation in Europe (Smart CO_2 Transformation (SCOT), 2016).

5 Gillis, Justin. "Carbon in Atmosphere is Rising, Even as Emissions Stabilize." The New York Times 26 June 2017. www.nytimes.com Web. 20 July 2017.

6 Energy, Environment & Climate Change, "2016 Insights" (International Energy Agency, 2016).



Source: Derived from 2DS modelling results in IEA (2016a), Energy Technology Perspectives 2016.

Figure D. Energy-related CO_2 emissions under IEA's 2DS scenario

The viability of each utilization pathway will depend on incumbent industry dynamics and will also require a portfolio approach by the market. Altogether this will create a range of opportunities for investors in a multitude of areas. In addition to the products themselves, enabling innovation in underlying technologies and components—such as catalysts, genetic engineering, and inexpensive sources of CO_2—has supported recent market growth. Additional development work in these supporting verticals is necessary to fully scale these pathways. A detailed discussion of these issues can be found in Section III.

The NRG COSIA Carbon XPRIZE has been a major catalyst of action, but broader engagement by the investment community is needed for emerging solutions to scale. Prior to 2011, innovation and research in circular carbon solutions was happening in a diffuse manner across the globe. The prize and associated test centers (Wyoming Integrated Test Center and Alberta Carbon Conversion Technology Centre) serve as magnets for innovators and a budding community. In parallel, large organizations and policymakers have started pursuing strategies related to circular carbon innovation. First-movers are proving business models and markets, attracting further investment and competition. The industry is maturing in real time.

CURRENT MARKET OVERVIEW

Enhanced oil recovery (EOR) has historically represented the highest value end-use for CO_2 in the market. However, EOR represents only a small slice of the future CO_2 market opportunity, and it remains limited in net CO_2 impact. The IEA has estimated that for every barrel of oil produced from EOR using manmade CO_2, there is a net CO_2 storage of only 0.19 metric tons.[8]

An August 2016 report by the National Coal Council estimated the total commercial market for CO_2 at 650,000 to 700,000 tons/year (excluding oil and gas applications). Carbonation for consumer beverages was said to represent roughly 50% of that total as of 2015. There is plenty of additional low-hanging fruit on the supply side: U.S. Department of Energy (DOE) analysis has identified approximately 30 million metric tons/year of pure CO_2 currently being produced at industrial facilities located within 50 miles of existing CO_2 pipeline networks.[9] The conditions and opportunity for commercial facilities exists today. As shown in Figure F, the potential annual revenue for certain market segments is significant. There is substantial opportunity for growth industry-wide and first-movers today face a near-term addressable market with limited competition.

Classifying Products and Key Verticals

The following circular carbon product verticals have been identified by market analysts as having the nearest-term commercialization potential. All market size estimates reflect the middle-road scenario outlined in the CO_2 Sciences and the Global CO_2 Initiative's "Global Roadmap for CO_2 Utilization." Markets are not static, however, and these are merely snapshots of potential market size.

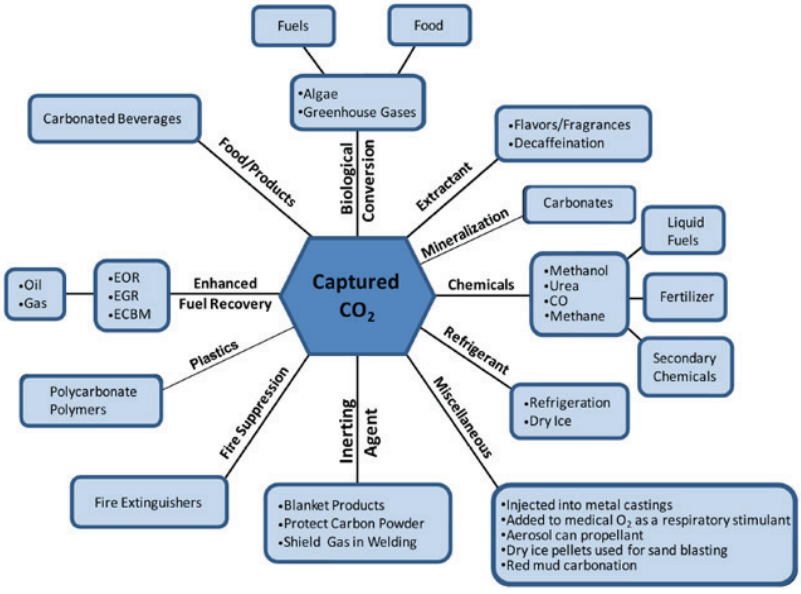


Figure E. Potential product pathways for CO_2[7]

7 U.S. Department of Energy, "CO_2 Utilization Focus Area". https://www.netl.doe.gov/research/coal/carbon-storage/research-and-development/co2-utilization. Web. 18 August 2017.

8 Storing CO_2 Through Enhanced Oil Recovery (International Energy Agency, 2015).

9 Gerdes, Kristin. "Incentivizing Carbon Capture Retro ts of the Existing PC and NGCC Fleet." Office of Program Performance and Benefits, National Energy Technology Lab. 29 July 2014. Web. 20 July 2017.

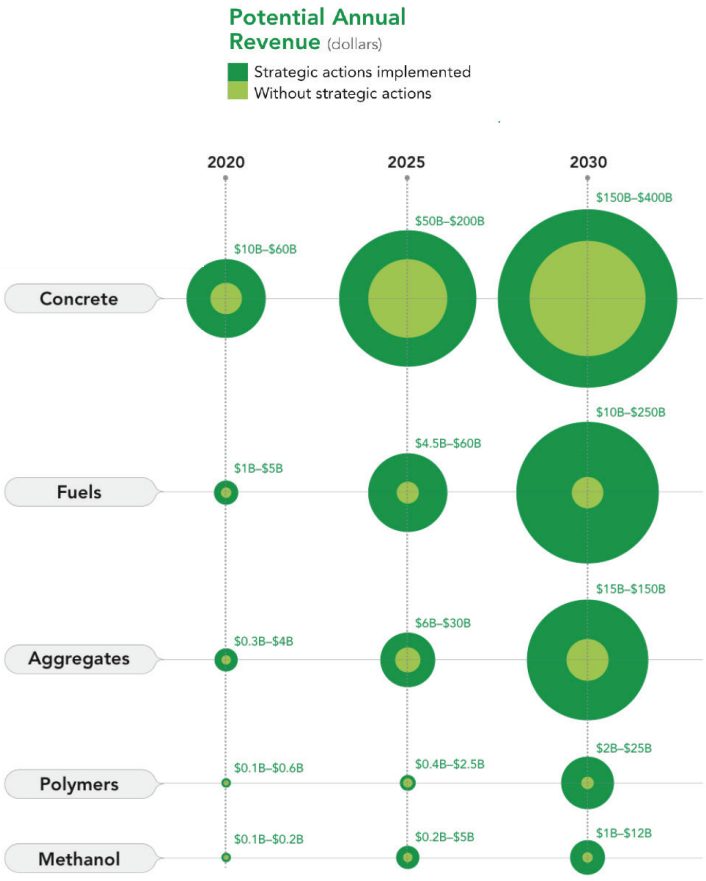


Figure F. Annual revenue potential for select CO_2 utilization pathways[10]

Today, some categories are projected to have vast markets, while others are estimated to be potentially high value but niche.

What follows is a closer look at each of these categories of CO_2 products, from the perspective of market opportunity. There are also a wide range of agricultural practices and products that utilize CO_2 and represent significant markets which are not addressed in this report.

10 Global Roadmap for Implementing CO_2 Utilization (CO2 Sciences and The Global CO_2 Initiative, 2016).

Chemical Intermediates

Forecasted 2030 Market Size (for carbon-based products):

- Methanol: 9.3 million metric tons of product; 12.7 million metric tons of CO_2
- Formic acid: 50,000 metric tons of product
- Syngas: 110 GW thermal/year

Conversion of a CO_2 molecule into a useful chemical typically requires significant energy inputs due to thermodynamic challenges. Specifically, breaking the chemical bonds that bind oxygen to carbon within the CO_2 molecule requires significant energy. The need to add energy, a potentially costly input, to a CO_2 conversion process has often blunted the economics and net CO_2 impact of otherwise promising solutions. However, recent innovations in catalysis have helped improve the efficiency and/or reduce the energy needed for some processes. Chemical pathways with promising commercialization trajectories are mainly those with a diversity of end-use products—including uses in fuels or fuel production—as these multi-use pathways address larger market opportunities and a wider range of customers. Methanol, syngas, and formic acid represent the majority of focus among emerging developers. From a net emissions perspective, the profile of these solutions improves with lower-emission energy inputs.

Beyond use as a transportation fuel or in a fuel blend, methanol is a significant chemical intermediate and, by volume, one of the top five commodity chemicals. CO_2 can be hydrogenated in the presence of a wide range of catalysts to form methanol—though a source of hydrogen with a low carbon footprint is necessary to ensure positive net CO_2 impact.[12]

Formic acid is used as a chemical intermediate in adhesives, preservatives, and dimethylformamide (DMF), among others. Major applications include silage and animal feed preservation, leather and tanning, textiles, formate salts, pharmaceuticals and food chemicals, rubber chemicals (antiozonants and coagulants), catalysts, and plasticizers.[13]

Syngas has a wide range of pathways as an intermediate. Biomass gasification, gas fermentation, and thermochemical syngas conversion routes can produce fuels and chemicals such as alcohols, olefins, and fuel-grade hydrocarbons.

In many cases, low-carbon or near-zero-carbon energy inputs may be required for these pathways to show carbon-neutrality at scale. Many technology developers perceive the emergence of low-carbon renewables, like wind, solar, and geothermal, to be a promising development since these technologies could be integrated with circular carbon solutions.

Fuels

Forecasted 2030 Market Size:
45 billion gallons/year of product; 135 billion metric tons of CO_2

Figure G. Carbon-neutral/negative diesel and jet fuel

A number of fuel pathways are being considered by emerging startups. Catalytic hydrogenation of CO_2 is being developed for the production of drop-in fuels from CO_2 for the transportation fuels market. CO_2 is also being used to make syngas, which can then be used in either Fischer-Tropsch synthesis for making ultra-clean diesel and jet fuels, or methanol synthesis for other transportation fuel products. Algae-based biofuels remove CO_2 from the atmosphere during photosynthesis as the algae grow.

12 A Strategic European Research and Innovation Agenda for Smart CO_2 Transformation in Europe (Smart CO_2 Transformation (SCOT), 2016).
13 IHS, "Chemical Economics Handbook." December 2016. https://www.ihs.com/products/formic-acid-chemical-economics-handbook.html. Web. 31 August 2017.

Building Materials

Forecasted 2030 Market Size:

- Concrete: 10.5 billion tons/year of product; 890 million metric tons of CO_2
- Carbon Aggregates: 3.5 billion tons/year of product; 1.2 billion metric tons of CO_2

Building material producers are facing increasing demand for more sustainable and higher performing materials worldwide. CO_2 is being utilized to produce both cements (binders) and aggregates to replace the conventional gravel and sand that give concrete its strength. The process of converting CO_2 into mineral carbonates requires a source of metal ions (e.g., iron, calcium, magnesium), alkalinity, and water.[14]

These products have perhaps the greatest potential to sequester CO_2 for a long period of time and require lower energy inputs relative to the other product categories. In particular, many mineralization pathways do not suffer the same thermodynamic challenges that chemical pathways face. The need for external energy inputs for mineralization is often dramatically reduced. In some cases, the mineralization reactions are exothermic, meaning the mineralization process runs "downhill" rather than needing to be pushed "uphill" using external energy inputs.

Polymers

Forecasted 2030 Market Size:

1.7 million metric tons/year of product; 500,000 metric tons/year of CO_2

Over 322 million tons of plastics—thermoplastics, polyurethanes, thermosets, adhesives, coatings, and sealants—are produced annually.[15] Low-carbon plastics can be made by direct polymerization of CO_2 or by polymerizing CO_2-sourced monomers. Common product pathways in development include ethylene, propylene, or cyclohexene oxide for developing commodity plastics for packaging applications or foams, which are commonly used for packaging medical materials, among other applications.[16]

A handful of companies, namely corporates Covestro and Asahi Kasei, have begun commercial production of flexible foams. However, global production capacity of low-carbon polymers remains less than 1% of the current capacity available to develop polymers from conventional feedstocks.[17] There is significant room for this segment to grow.

Figure H. Applications of low-carbon plastics

14 CO_2 Building Blocks: Assessing CO_2 Utilization Options (National Coal Council, 2016).
15 Plastics - The Facts, 2016. "An analysis of European plastics production, demand and waste data." (PlasticsEurope and European Association of Plastics Recycling and Recovery Operations, 2016).
16 A Strategic European Research and Innovation Agenda for Smart CO_2 Transformation in Europe (Smart CO_2 Transformation (SCOT), 2016).
17 Global Roadmap for Implementing CO_2 Utilization (CO_2 Sciences and The Global CO_2 Initiative, 2016).

Food and Agriculture

Forecasted 2030 Market Size:
1 million metric tons/year of CO_2

Carbonation of consumer beverages represents the largest non-EOR commercial use for CO_2 by volume today, although it is a small overall market: approximately 325,000 metric tons/year of CO_2. The production of dry ice and baking soda are the next most significant uses. Assuming a continued 3% to 4% compound annual growth rate in these existing verticals, the total market will reach 1 million metric tons by 2030. Should new products and uses become commercially viable, this market could grow exponentially.

Industry Participant Landscape

Relative to other technology sectors, the community of investors active in the circular carbon space today is small. But there is growing interest and momentum. Following the massive growth and subsequent collapse in investments allocated to cleantech over the past decade, the cycle has begun to shift toward resource efficiency plays again, even if they are no longer called 'cleantech.' The emergence of newly branded categories such as "sustainability tech," "natural resource innovation," and "circular economy" signal the emergence of renewed interest and fresh approaches. More realistic expectations for exit timelines, capital intensity, and policy risk are common features of these new models. Shifting attitudes among limited partners (LPs) are crucial for investors (new and old) to raise capital in support of these ventures. Multiple recent fundraising announcements reflect this new reality.[18]

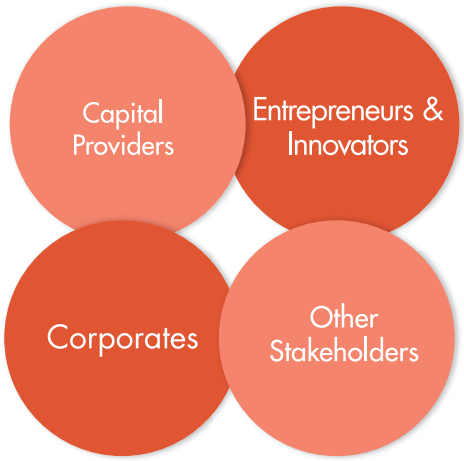


Figure I. Industry Participants in Circular Carbon

The circular carbon ecosystem is benefitting. Many of the new investment approaches are being implemented by cleantech veterans. Many are applying lessons learned in hard science-based solutions and capital intensive models, in which long development cycles are often essential. Yet not all investment vehicles, nor models from other tech verticals, will fit circular carbon technologies. Investors must continue thinking carefully about which types of investments are required and when. An acceleration of corporate involvement and participation from family offices, philanthropy, and other patient capital sources have helped fuel the emergence of innovative and hybrid funding mechanisms. New, creative structures are still required, but the ecosystem is growing and new entrants are providing more flexibility and available dollars for these emerging solutions.

18 Including Energy Impact Partners, Congruent Ventures, and KPCB spinning out of its green growth fund, among others.

Figure I below is a landscape map of some of the key relevant entities, including early- and growth-stage investors, corporations, emerging startups, and the semifinalist teams for the NRG COSIA Carbon XPRIZE.

This list is not exhaustive, but rather representative of a growing global community—there are numerous companies actively raising capital and potential co-investors monitoring opportunities.

Figure J. Potential Circular Carbon Ecosystem

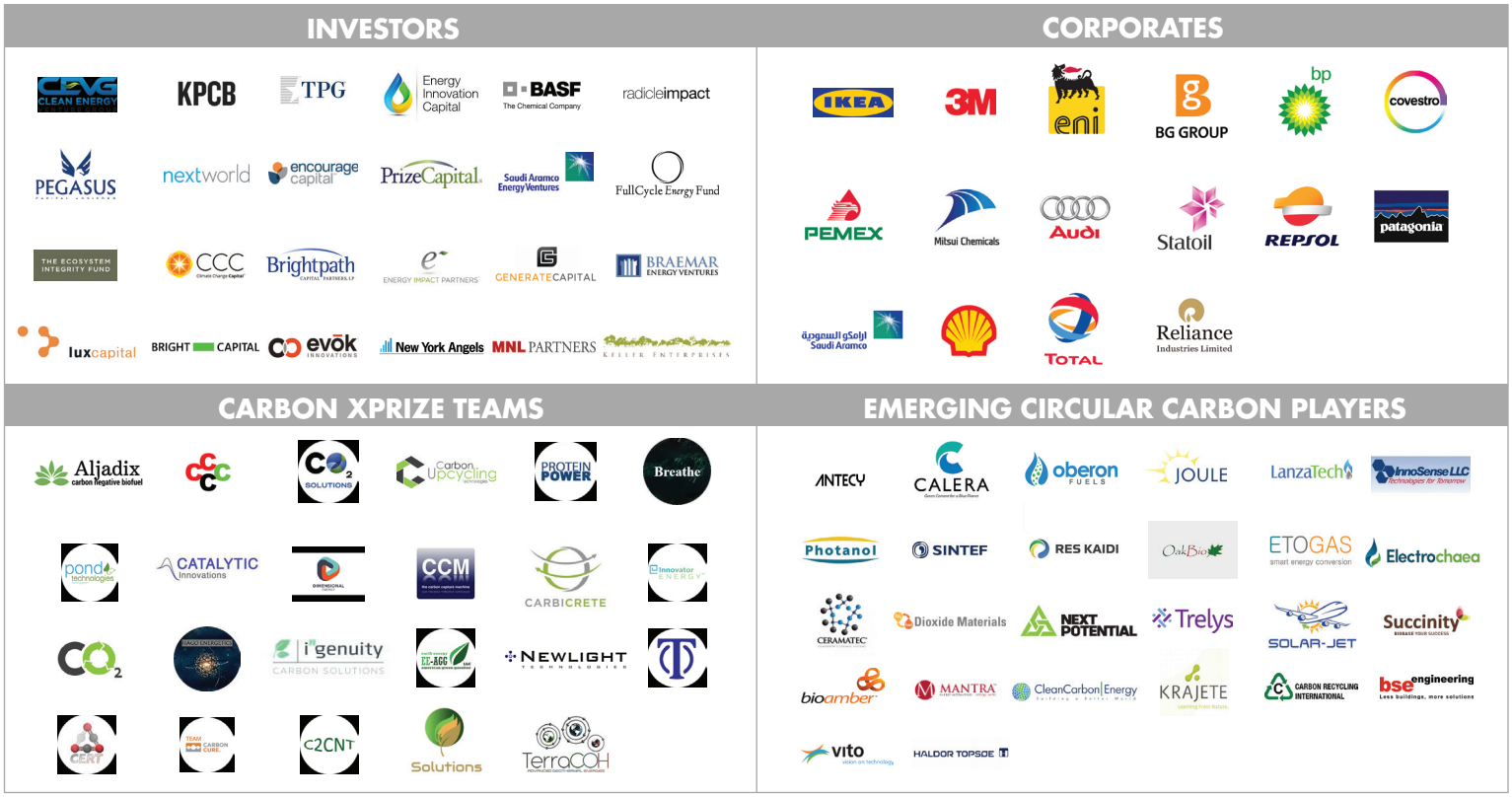


Figure K. Representative landscape of the Circular Carbon ecosystem

CAPITAL LANDSCAPE: KEY BARRIERS AND POTENTIAL SOLUTIONS

Over the past year, CCN has led a discovery process to crowdsource insights around capital investment in circular carbon solutions. We conducted formal market surveys to directly engage leading investors and entrepreneurs and convened stakeholders at two interactive workshops during the NRG COSIA Carbon XPRIZE Team Summit in December 2016 and the Clean Innovation Investor Forum in June 2017.

A set of cross-cutting themes relevant across technology development stages are discussed below, followed by key barriers to investment and potential solutions organized by company development stage (Early Stage, Scaling, and Commercialization). Potential solutions are arranged into three categories: Financing Tools (creative models and mechanisms for structuring deals); Market Services (enabling mechanisms to accelerate the pace to market), and Technology Development Support (approaches for supporting entrepreneurs and innovators).

A core objective of CCN is to support a process to further expand this solution set and implement programming to support it. The ideas below are intended to catalyze further discussion, critique, and refinement. We welcome your feedback and engagement.

Cross-Cutting Themes

Uncertainty about viability and profitability has slowed capital flows into circular carbon technologies. The following are common narratives shared with CCN by investors and industry stakeholders.

Issue: Many investors believe that circular carbon technologies are dependent on new policy to be profitable, and that, in the absence of a price on carbon, regulatory mandates, or direct subsidy support, the economics "don't work." This perception is widely held, but may not be uniformly true across all technologies and product categories. Many circular carbon technologies are too nascent to adequately assess policy and regulatory risk.

Potential Approach: Evidence-based communication, both public and peer-to-peer. Publication of success cases, metrics, and practical illustrations of policy impacts can directly dispel false narratives for investors. Such evidence-based communication can address both capital intensity and policy-dependency misconceptions. To be effective, companies and early-stage investors must be comfortable sharing (potentially confidential) metrics early in the development cycle. Such case studies and metrics may also serve to be useful tools in more targeted communication between potential co-investors, for example. Companies must either be willing to share confidential information or utilize a trusted third-party validator to play this communications role.

Issue: Investors believe that business models in this sector are too capital intensive, and that achieving commercial scale in these segments requires hundreds of millions of dollars. Similarly, many circular carbon technologies are too nascent to adequately estimate the necessary capital expenditure for commercialization. However, leaner, modular manufacturing strategies have proven to minimize capital intensity for other industrial technologies.

Potential Approach: A focus on profit, then climate change. Public demonstration of project and company economics can help shift innovators' primary focus from impact to profitability. For many potential investors, economics are the only factor. Management teams must understand the motivations of their investor base and frame their respective value propositions—profitable enterprises—accordingly. Likely investors in this industry are predisposed to acting on climate; they will seek profitable investments to maximize impact.

Issue: Investors see potential markets for circular carbon technologies as too niche. Outside of enhanced oil recovery (EOR) and beverage carbonation, commercial CO_2 end-uses are not well known and assumed to be small or nonexistent. Early-stage investors seek companies and solutions with large addressable markets. Many will not even engage in meaningful due diligence if initial reactions are that the total addressable market is insufficient or unknown.

Potential Approach: Quantifying the size of the opportunity. Relativity is a useful framing tool to put the problem in terms an audience can better understand. By quantifying and better understanding the scale of CO_2 that could be removed from the atmosphere or mitigated, investors can better grasp the scope of the market potential.

Issue: The carbon problem is too big; one company won't make an impact. Investors are often skeptical that one company tackling CO_2 from point sources will meaningfully affect global CO_2 levels.

Potential Approach: Resetting expectations. Circular carbon solutions are not a silver bullet. The world needs solutions at scale to address the emissions problem, but no single solution will be able to address 36 Gigatons/year of CO_2. Circular carbon solutions should be viewed as a potentially profitable and valuable wedge for global emissions. In addition, investors can consider the exponential impact associated with scale as well as the opportunities for partnerships and industry linkages to support critical mass for change.

Key Gaps, Barriers, and Potential Solutions by Technology Development Phase

1. Early Stage

Circular carbon technologies tend to be based in hard science, carry significant early-stage development risk, and face long pathways to return on investment (ROI). These issues, while not unique to this sector, are particularly acute for it. The following are key barriers for early stages of a company's development cycle, defined herein as from enterprise inception through a typical Series A financing.

Key Gaps and Barriers

Lack of high-quality deal flow. Investors without a track record in these segments are unlikely to have visibility into many of these companies. Without strong deal flow, many investors will not dedicate their team's time and resources to diligence.

Not enough investors to syndicate deals. Many early-stage investors new to the segment do not have visibility into the interest of other investors and believe they are going it alone. This may lead to investors turning down deals based on the belief they will not have co-investors available to fill out a round.

Lack of geographic alignment. Unlike the high geographic concentration in typical technology sectors, many leading circular carbon startups are physically located in non-traditional ecosystems. This dynamic is further amplified later in company development cycles when factors such as project co-location and transportation costs become key to project economics.

Misalignment of financial valuation expectations between investors and founders. Entrepreneurs tackling big, difficult problems in some cases oversell their solution as a silver bullet to the climate change problem. In the case of climate change, those expectations carry enormous addressable markets and revenue projections. Yet many such company forecasts are not grounded in reality and create a significant gap between company data and potential investor diligence during negotiations. If this gap is too wide, many investors will disengage.

Business models are not aligned to attract investment. Many founders continue to pursue capital-intensive, hardware-focused business models that seek to challenge entrenched incumbents. In some cases, the model is unavoidable, but in many others creative business models can significantly reduce capital requirements. Early in a company's development cycle, investors model its future growth trajectory to determine future capital requirements to get to scale (and ultimately, an exit). Capital-intensive business models at early stages can be challenging because of the perceived scale of those aggregate capital requirements as well as its future availability.

Significant technology risk. Many approaches in development are based on hard science and require

significant development work to prove viability from basic to applied research and development, to lab scale and beyond. While technology risk is typical of early-stage investing, many of these R&D breakthroughs further rely on multiple unproven components, hardware, and processes. This requires investors to get comfortable with a disparate set of technology risks, which can be compounded by the fact that investors may not have a long track record in the segment from which to build.

Potential Solutions

Financing Tools: Creation of blended capital facilities. Hybrid structures that can allow philanthropic entities to draw capital from mission-related allocations, can expand the pool of available dollars by allowing foundations to participate directly in financing circular carbon solutions consistent with their fiduciary obligations. Blended capital facilities can be structured in many ways, but can include features such as first-loss pools to protect certain classes of investors from unwanted risk by matching capital with dollars with different risk/return profiles.

Market Services: Creation of a global deal sharing clearinghouse and community platform. Development of a clearinghouse for companies seeking capital and investors seeking investable opportunities would help minimize transaction costs and timelines for fundraising. A global platform would allow participants to self-identify in terms of profile and needs, which may naturally stimulate dialogue, dealsharing, and new investment. With enough initial critical mass of companies and investors, fundraising would naturally gravitate to such a community platform. Network effects within such an environment would allow for more efficient transactions.

Market Services: Creation of a regional incubator network. Incubators have been a proven model in other capital intensive sectors. Establishment of a connected network of regional entities could provide participating investors access to high-quality deal flow in other geographies. Services at the incubator would further help mentor founders with highly technical backgrounds lacking business expertise. Such a network could provide these founders with the business and management tools necessary to communicate with investors and scale companies.

Market Services: Establishment of a process to leverage philanthropic capital more directly. The PRIME Coalition's model is unique in the market and could help address early stage capital gaps. PRIME is a nonprofit that facilitates investments by working with an ever-expanding group of philanthropic organizations to place charitable capital into early-stage companies. Establishing a similarly structured entity to draw on a larger pool of philanthropic capital, focused on circular carbon technologies, could change the investment dynamics of the sector.

Technology Development Support: Establishment of an independent, third-party validation entity. Many early-stage companies are rightfully concerned about protecting Intellectual Property and confidential metrics on

their process and economics. However, such information is widely useful to potential future investors and the ecosystem writ large. An independent entity structured to manage confidentiality, while communicating metrics to the investment community, would serve the ecosystem needs. A deep and broad community of practice in measurement and verification already exists and is well-known in the environmental, industrial, chemical, and energy sectors. These organizations are increasingly refining their expertise in circular carbon technologies. Southern Research, which validates metrics of XPRIZE competitors, is just one example of an organization potentially positioned to play this role more broadly.

2. Scaling

As a company moves from proven prototype, lab-scale breakthrough, or small pilot facility to larger production facilities and projects, new challenges emerge for investors. There are challenges at each stage of growth, but for purposes of organization these have been aggregated below. This set of gaps is typical of companies seeking—and moving beyond—demonstration scale and first commercial scale financing. These challenges include technical, engineering, and business development barriers to scale.

Key Gaps and Barriers

Limited demonstration capital availability. Moving from lab and small pilot scale production to pre-commercial demonstration is a traditional valley of death for many innovative sectors. For circular carbon solutions, investors with the risk appetite for such demonstration facilities have been rare, further limiting the universe of potential capital providers.

These products and solutions are not bankable. First-of-their-kind production facilities, short operating histories, a dearth of validated performance data, and shallow market penetration combine to create a high cost of capital, which itself can make certain business models uneconomical.

Lack of industry-standard contract structures. Bankable revenue contracts, such as offtake agreements, are essential to leveraging project finance in these sectors, which is a typical model to bring down the cost of capital for commercial scale projects. Customer offtake agreements today are typically bespoke; better standardization may lead to better bankability at scale. Accordingly, today, counterparty creditworthiness is a key issue for many emerging players with one-off contracts.

O&M cost uncertainty. For first-of-their-kind facilities with short operating histories, Operations and Maintenance risk will need to be mitigated for banks and other institutional players. Risks associated with component lifetimes, potential for supply chain disruption, and process operating efficiencies collectively may be too much for investors to bear.

Lack of exits. As investors look at sector performance, a lack of acquisitions and successful IPOs signals challenges for investors to achieve liquidity on their capital investment. Such a macro datapoint for the sector is likely to keep first-time investors away. Early cycles in other, ultimately successful, sectors found ways to overcome this chicken-and-egg hurdle.

Economies of scale are necessary for profitability. Competing against fully commercialized, entrenched incumbents typically requires new entrants to reach full commercial scale to be profitable. Building first-of-their kind commercial facilities requires, in some cases, significant capital commitments that carry higher risk profiles than traditional project or infrastructure investors are comfortable with.

Lack of awareness of product standards and regulations. Companies often lack awareness and understanding of how standards processes work and the timelines involved with certifications and approvals. A lack of visibility from standards bodies and regulators into the suite of new technologies and products in development as well as a lack of engagement between the two parties limits the uptake of new products.

Potential Solutions

Financing Tools: Creation of shared risk pools. Corporates in a given vertical collectively establishing a pool of capital available to finance the scale up and operation of demonstration facilities would leverage portfolio dynamics to diversify risk for the collective ecosystem's benefit. The Oil and Gas Climate Initiative (OGCI) is an example of pooled industry risk that fills the need for demonstration capital.

Financing Tools: Blended capital vehicles. First-loss capital in a blended facility, as defined above, could serve several functions to catalyze additional capital participation. Such vehicles could protect banks from unwanted O&M risk, as well as more generally improve equity returns in the capital stack to a level sufficient to attract meaningful project equity.

Financing Tools: Credit enhancement functions. Establishment of a vehicle to backstop weak credit on either side of necessary contracts would serve to mitigate counterparty credit risk and help accelerate lower-cost capital into the sector. In other cases, performance guarantees may be offered but do not have the balance sheet behind them to matter to the capital markets—a credit enhancement or other balance sheet backstop could add meaningful value.

Financing Tools: Performance guarantees. Performance guarantees for CO_2 products, especially those meant to displace conventionally produced products, can provide a backstop for many first-of-their-kind products and production facilities necessary to attract lower-cost capital for financing.

Market Services: Global communications network. Economics of many commercial models are dependent upon local policies and permitting, regional pricing dynamics, and operational logistics costs. A communications network could be established to identify for founders and investors where such favorable environments exist globally, to better inform such strategic decisions.

Market Services: Building a project finance network. Similar to a dealflow vehicle, a centralized platform could help connect projects with financiers and help animate a developer network to find and develop future projects on their own.

Market Services: Business advisory services for founders. Such a function could be tailored to help educate founders on how to communicate to institutional investors. The historical misalignment of objectives and incentives could be mitigated if management was more effective speaking in terms that create better understanding and comfort for infrastructure investors. Media training for executives is a similar function which has a proven bottom line impact.

Technology Development Support: Early education and engagement with standards bodies. Well before commercial products are ready for the market, companies must understand the landscape of standards bodies and regulatory agencies and begin engagement with these entities at all levels of jurisdictions. Understanding the length of the permitting process and regulatory approvals is crucial to minimize time-to-market. A trade association or a new database could be tools in this regard.

3. Commercialization

In parallel to building first-of-their-kind production facilities, companies must also navigate commercial barriers to entry on their respective paths to market. The following commercialization gaps and solutions reflect our ongoing conversation on these topics.

Key Gaps and Barriers

CO_2 price volatility. Commercial sources of CO_2 are limited geographically by existing pipeline networks and point sources of production. In many cases for EOR, contract prices are tied to the price of oil which leads to significant price volatility. Ensuring stable access to supply is a major challenge for companies seeking to build demonstration and commercial facilities outside of these areas and in other industries.

Niche end-use markets. Many CO_2 product pathways result in niche, but high-value markets. These narrow segments collectively provide a large addressable opportunity, but carry significant varied risks among them as well as unique sets of stakeholders, which, in many cases do not overlap. This issue is exemplified by variations in the willingness to pay and pricing for CO_2 as a feedstock between different end products. The fragmented end-use markets make it more challenging for startups and investors to build a cohesive ecosystem.

Inertia in existing markets. Much like utilities for certain cleantech applications, conservatism of the buyer at the end of each new product's value chain is a significant hurdle for startups to overcome. Many incumbents have been established in their supply chains for decades, with little incentive to shift procurement decisions or strategic behavior. Governments and municipal administrations also require significant time to shift procurement strategies.

Pace and scale of market adoption. New products must prove themselves to meet all the purchase criteria of buyers in their respective industries. For circular carbon products, this may mean showing additional value beyond simply meeting credibility thresholds of durability and quality. The pace at which companies can prove such market adoption (by virtue of offtake agreements) may be too slow to finance facilities.

Challenging partnership dynamics. Entrenched incumbents in each vertical maintain a vested interest in protecting their market position, which makes corporate partnerships both challenging to facilitate and a questionable strategy for many startups.

Potential Solutions

Financing Tools: Contracts for differences. Corporate renewable energy procurement has surged in recent years due in large part to contractual innovation. "Contracts for differences" could be utilized for CO_2 procurement as well, with entities stepping in and promising to finance the delta between the cost of CO_2 at the point of supply and the price in another regional market in which they operate. Regional pricing arbitrage opportunities can create financial incentives for traders to enter these markets at scale.

Financial Tools: Making it easy for the buyer. Downstream financial innovation at the point of end-use consumption can help accelerate behavior changes among conservative incumbents. Understanding and communicating procurement decision-making criteria within networks can spur the development of financing toolkits. For instance, upstream concrete manufacturers may be less motivated by a low carbon footprint masonry block than an end-user like an architect, home-builder, or home-buyer. Illustrating robust demand from users can propagate up the supply chain to manufacturers who are

in tune with changing customer needs. Work by the Rocky Mountain Institute (RMI) around corporate renewable energy procurement is a useful analog in this regard.

Market Services: Building community networks. Promoting intervertical collaboration could help solve cross-cutting challenges between niche markets. For instance, fuels and chemicals manufacturers may have much in common on upstream manufacturing challenges, despite different downstream product delivery pathways. General communication channels between founders could also serve to more efficiently share market intelligence.

Market Services: Open innovation challenges offered by potential customers. Industry-wide challenges in key verticals—such as fuels, chemicals, building materials, polymers, proteins, and others—organized by incumbents, could help facilitate matchmaking for strategic partnerships and address traditional communication gaps between strategics and emerging startups.

CONCLUSION: WE CAN HELP CATALYZE THIS INVESTMENT OPPORTUNITY

The circular carbon industry encompasses a potentially massive addressable market (between $800 billion and $1 trillion annually) and has the potential to mitigate risks from climate change at a very significant scale (up to 15% of the reductions required to limit global warming to less than 2 degrees).

There is a strong business case for investors today to leverage the recent expansion of the circular carbon ecosystem catalyzed by the NRG COSIA Carbon XPRIZE and others. Significant technological breakthroughs are happening in companies across the world, led by increasingly capable entrepreneurs. These emerging startups are scaling pathways in markets for CO_2 products as diverse as chemicals, fuels, building materials, polymers, industrial gases, food, and agriculture products. Corporate investment is beginning to accelerate, but additional capital is needed to support continued development and commercialization of these promising solutions and business models. For investors seeking returns combined with impact in energy, climate, and sustainability, the post-Paris world is driving a growing portfolio of solutions that have real potential with the right capital and commercial support structures.

The time to act is now. The Circular Carbon Network welcomes your input and participation. Here's what you can do to help us accelerate this investment opportunity and take the circular carbon sector to the next level of profit and impact.

- Review our report and share your feedback about barriers that must be addressed.
- Share a case study about a creative approach to financing tools, market services, or technology development support.
- Join our network to receive updates about Circular Carbon Network discussions and events.
- Visit us at xprize.org/circularcarbonnetwork or email us at Carbon@xprize.org.