PitchBook

EMERGING TECH RESEARCH

Carbon & Emissions Tech Launch Report

VC trends and emerging opportunities

Q2 2022

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This new report series provides an overview of the carbon & emissions tech vertical and includes a market analysis, industry segmentation, and venture data tracked through Q2 2022.

Vertical overview

The carbon & emissions tech vertical is growing rapidly. It is somewhat small relative to other verticals attracting venture capital (VC) but is poised for strong continued growth thanks to increasing global focus on aggressive emissions targets and consumer interest in emissions reduction.

The vertical contains a diverse group of technologies that broadly fall into one of two categories:

- Removal of emitted carbon dioxide (either from the point of emission or from the atmosphere, post-emission). This includes emissions from power generation plus generation and use of process heat for industrial and chemical applications.
- Using alternative processes that produce lower levels of emissions relative to conventional approaches, including low-carbon pathways for cement production, fertilizer production, mining, and resource extraction.

Significant investment has also been seen in carbon fintech and carbon monitoring, which enable entities to trade carbon offsets through voluntary carbon markets, engage consumers to reduce their carbon footprint, and provide monitoring services to calculate carbon emissions from an entity, and validate the effectiveness of carbon offsets. Carbon & emissions tech includes all greenhouse gas (GHG) emissions but largely focuses on carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Factors driving growth and investment opportunities.

Only in recent decades has there been any significant push toward GHG emissions reduction. This push manifests as legislation and policy (including the recent Inflation Reduction Act of 2022, signed on August 16) that apply a fiscal value to carbon emissions, serving as the primary driver of growth in the carbon & emissions tech vertical. Historically, governmental action has been disproportionately focused on certain sectors—typically those that are easiest and cheapest to decarbonize, such as power generation and transport[1]—but the increase in overall net-zero emissions pledges means that there is growing action to decarbonize other sectors such as construction and heavy industry. The EU, for example, largely manages carbon emissions reduction through its Emissions Trading System (ETS)[2] and is broadening coverage by phasing out free carbon emission allowances for industrial sectors and creating the "ETS II," which will cover the road transport and building industries from 2024.[3]

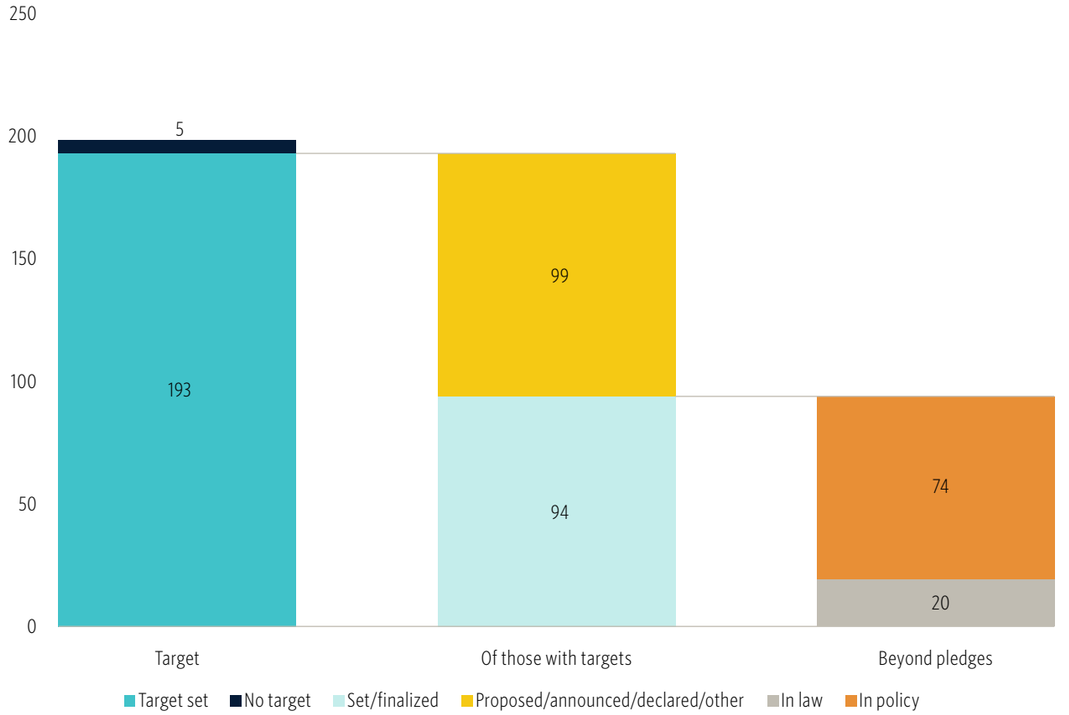
The growth in legislation and policy is coupled with substantial global growth in emission reduction pledges from a combination of countries, regions, cities, and companies. As recently as mid-2019, only 16% of global GDP was covered by net-zero pledges, but this has increased to 91% as of June 2022 (representing 83% of GHG emissions), although some notable countries have later targets (China and India target 2060 and 2070, respectively).[4] Further, interim 2030 targets are common, increasing pressure to implement technologies immediately rather than waiting until

1: Power generation (and grid infrastructure) will be covered in the dedicated Clean Energy Tech Report, which will launch in Q4.
2: A "cap-and-trade" system under which a decreasing number of carbon emission allowances are available each year, which can be purchased via auction. This provides an increasing fiscal incentive for emitters to decarbonize.
3: "Review of the EU ETS 'Fit for 55' Package," European Parliament, Greg Erbach and Nela Foukalová, July 2022.
4: "Net Zero Stocktake 2022," Net Zero Tracker, June 2022.

cheaper or more effective options are available. The increase in pledges from states, cities, and companies provides a buffer from shifts in governmental policy, as seen in the US, for example. At present, though, the pledges' potential influence varies, and over the next few years we expect to see more of these pledges move from the "proposed/announced/declared" status toward being codified in law (See illustration at right). Further, the degree to which action is taken—even based on pledges incorporated into policy or law—will vary greatly between entities (country, region, city, company) based on their commitment to decarbonization, economic situation, and ability to decarbonize.

Technological advancement is also driving growth in carbon & emissions tech, particularly around carbon removal approaches. Technologies such as amine gas scrubbing—having been historically developed to scrub gas streams of acidic components—have matured as CO_2 removal technologies, and novel approaches such as metal organic frameworks and ion-exchange resins offer potential improvements to performance or longevity. The technology landscape for CO_2 removal is broad, containing approaches with varied strengths and weaknesses; this is beneficial considering different implementations have different requirements for energy use, temperature range, CO_2 capacity, and more. Growth in carbon capture technologies also provides raw materials for carbon utilization firms, including provision in new forms such as pure carbon from methane pyrolysis.

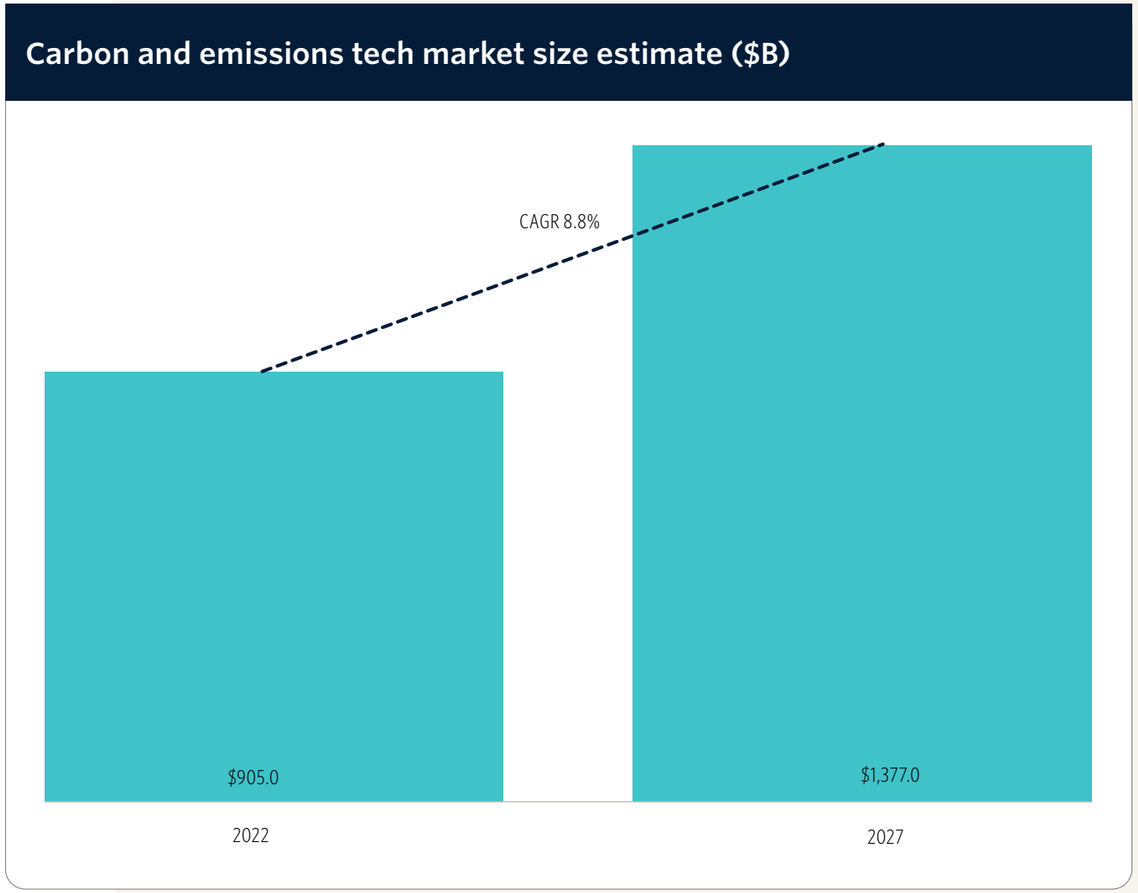
Number of country-level carbon reduction pledges by status*



Source: PitchBook Data, Net Zero Tracker | Geography: Global | *As of June 30, 2022

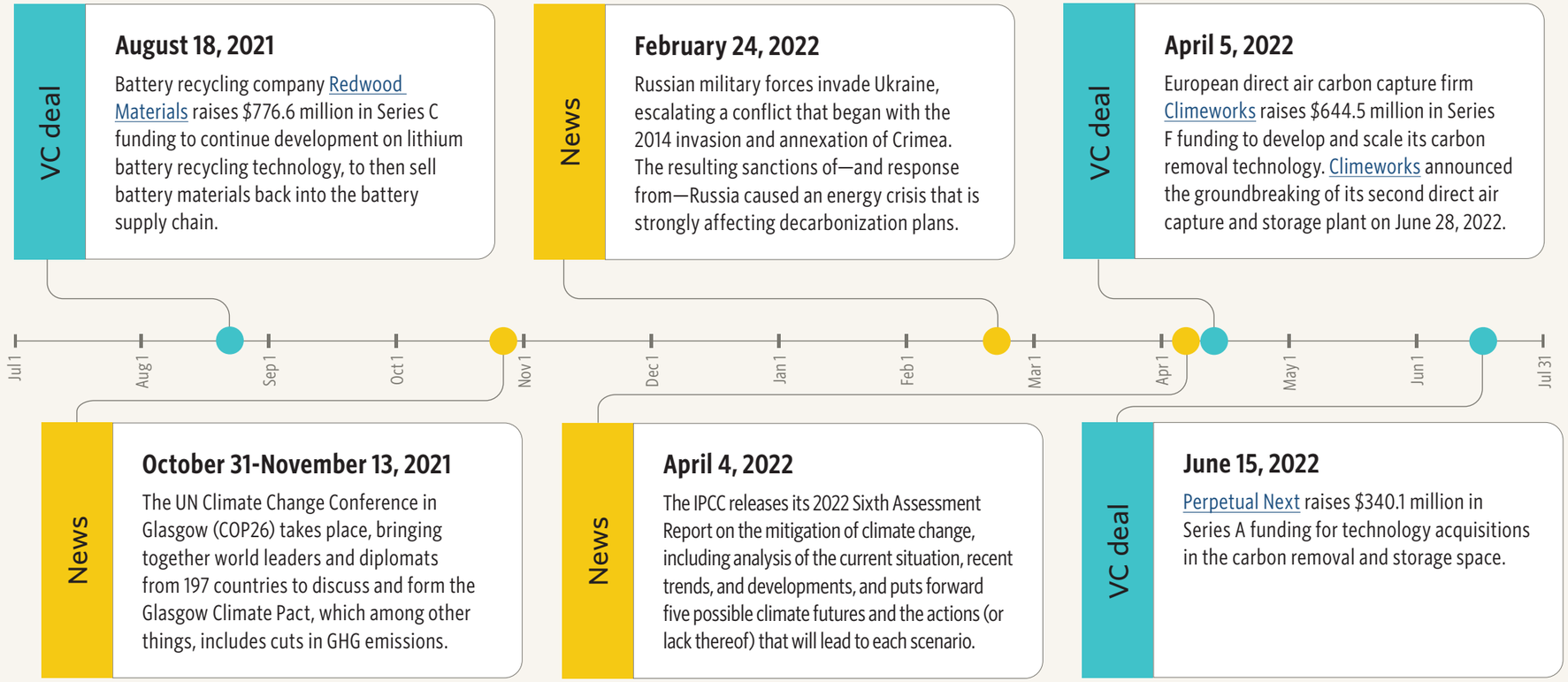
The estimated market size and expected growth rate

We estimate that the overall market for carbon & emissions tech will reach $905.0 billion in 2022 and forecast that it will reach $1,377.0 billion in 2027, representing a CAGR of 8.8% (excluding dramatic regulatory change or technological innovation). Current interest in emissions capture and reduction is high and likely to continue considering the rapid growth in carbon reduction pledges at various levels. This market size reflects carbon capture and removal technologies; carbon accounting software; green chemicals; fertilizer; manufacturing, mining, and general resource origination; green construction; building efficiency improvements; and ecosystem and land monitoring (plus some smaller adjacent sectors). The market for carbon credits is much larger than the technology market. The bulk of the vertical's market size is represented by the industry and built environment segments, as they are well established and provide an alternative for extremely large conventional markets, producing products that have long been considered vital in all regions. Carbon tech (covering carbon capture and removal) is one of the smaller segments, partly due to its relative newness and historically low incentivization. Despite this, it is also the fastest growing segment, and we predict this growth will continue, particularly given recent supporting governmental action and growing consumer demand.



Source: PitchBook Emerging Tech Research | Geography: Global

Q3 2021–Q2 2022 timeline



Deal count

142
total deals in Q2

15.4%
QoQ growth in deal count

-18.9%
YoY growth in deal count

Deal value

$3.4B
deal value in Q2

58.1%
deal value growth QoQ

-25.6%
YoY growth in deal value

5: The Glasgow Climate Pact," UKCOP26.ORG, 2021.
6: "Climate Change 2022: Mitigation of Climate Change," Intergovernmental Panel on Climate Change, 2022.

Climate tech landscape

1. Carbon tech
2. Industry
3. Built enviroment
4. Land use

Carbon & emissions tech VC ecosystem market map

Click to view the interactive market map on the PitchBook Platform.

Market map is a representative overview of venture-backed or growth-stage providers in each segment. Companies listed have received venture capital or other notable private investments.

Carbon tech

Direct air capture

Point-source carbon capture

Biological carbon removal

Carbon accounting/analytics

Carbon fintech & consumer

Carbon utilization

Green industry

Green mining

Lithium battery recycling

Manufacturing and chemicals

Recycling - metals

Recycling - polymers

Recycling - analytics

Carbon & emissions tech VC ecosystem market map

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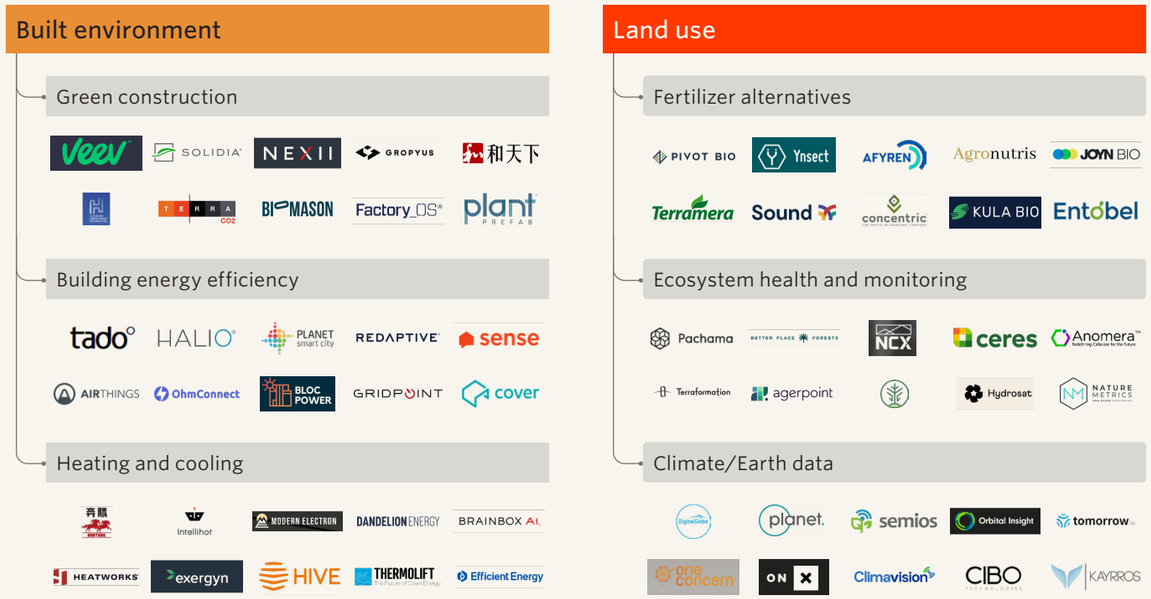
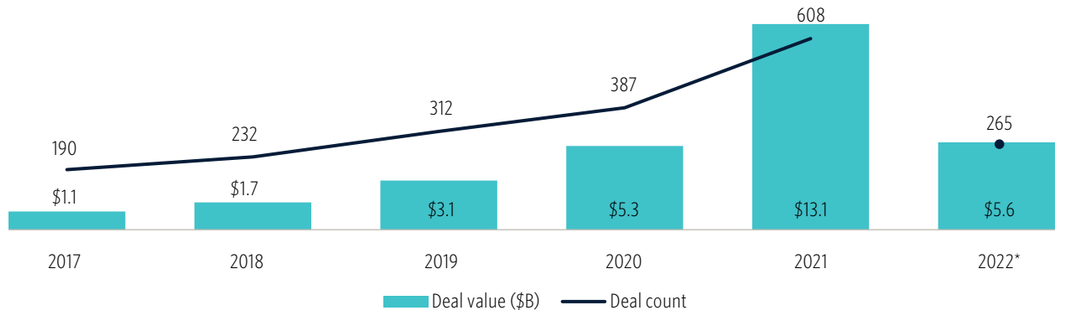


VC activity

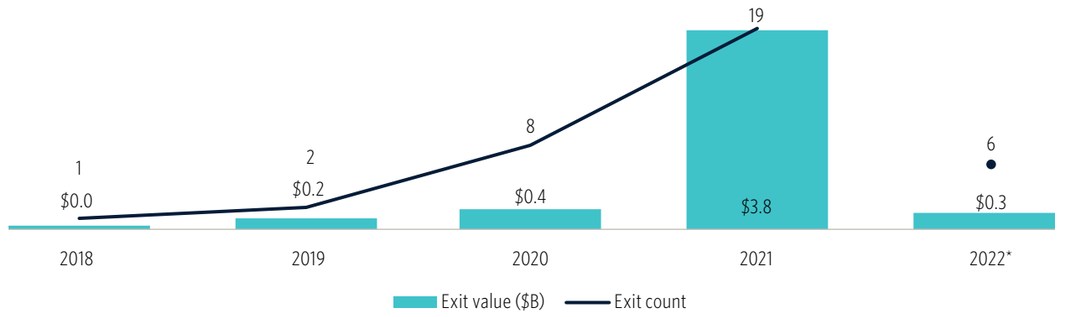
2021 represented a strong year for private markets overall, with higher deal and exit value. Carbon and emissions startups raised $5.6 billion in the first half of 2022, which is very similar to H1 2021's $5.8 billion. 2021 saw elevated investment, which should reset lower in 2022. That said, deal value in H1 2022 is still higher than the fiscal year (FY) value for all prior years except 2021, and with the growth drivers affecting the vertical, it is likely that 2021 will be considered an outlier year for VC deals. The average value per deal has been rising since 2017, from $7.1 million per deal to $23.6 million per deal in 2021 and 2022 (which have very similar average value per deal). Exit activity mirrored the trend seen in deal value and deal count, with a very strong 2021 (relative to other years), but exits in the carbon & emissions tech space are infrequent at present—in H1 2022, we have seen only six exits in the carbon & emissions tech space compared to 19 in FY 2021 (which is still low relative to other verticals).

Carbon & emissions tech VC deal activity



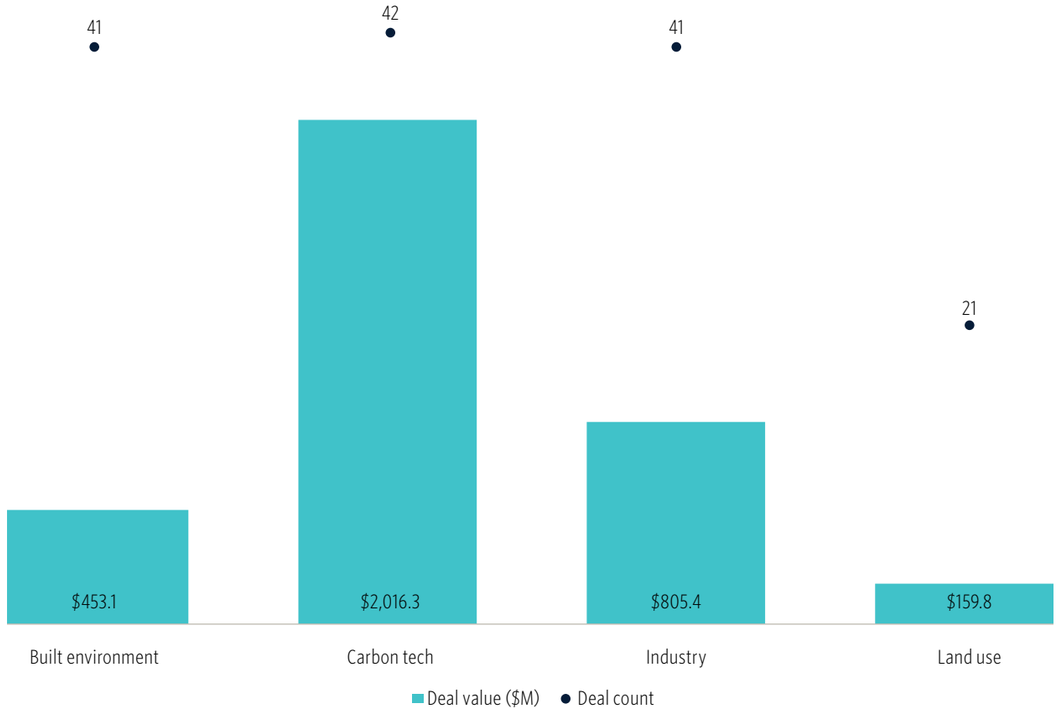
Source: PitchBook | Geography: Global | *As of June 30, 2022

Carbon & emissions tech VC exit activity



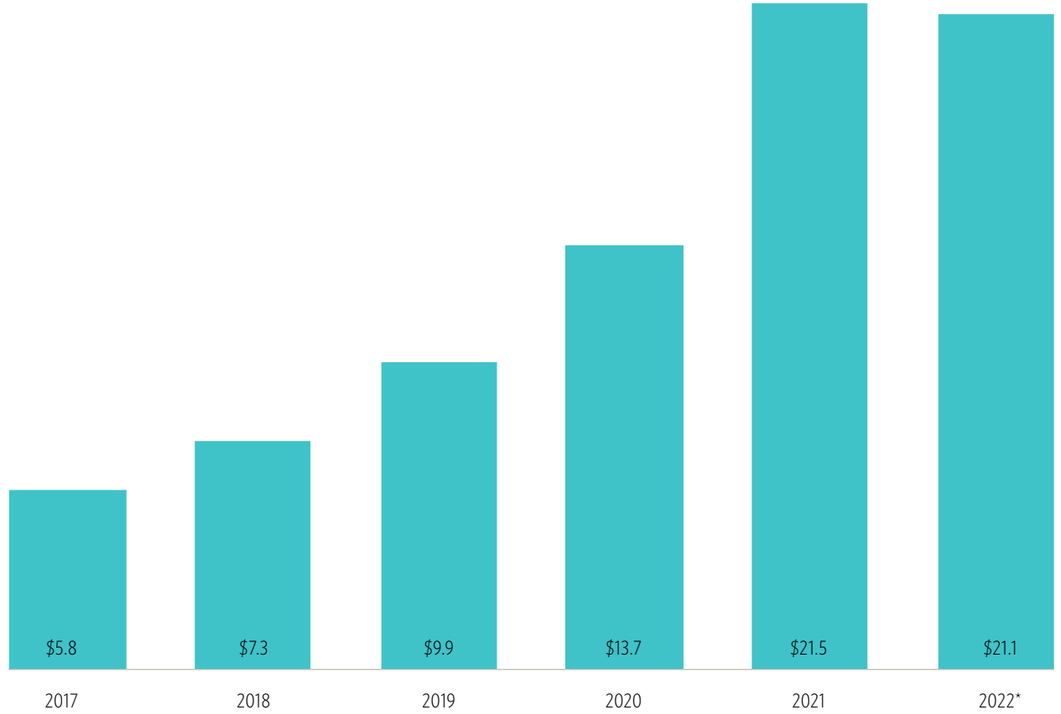
Source: PitchBook | Geography: Global | *As of June 30, 2022

Carbon & emissions tech VC deal activity by segment*



Source: PitchBook | Geography: Global | *As of June 30, 2022

Average carbon & emissions tech VC deal value ($M)



Source: PitchBook | Geography: Global | *As of June 30, 2022

Segment overview

Carbon tech

Zero-carbon pledges require a combination of carbon removal approaches.

Green industry

Growth in green chemicals investment focuses on optimization through biological approaches.

Built environment

Construction and built environments are increasingly exposed to carbon reduction obligations.

Land use

Restrained investment in land use tech follows a strong 2021.

Carbon tech

Overview

Carbon tech firms cover the entire technology landscape for carbon dioxide measurement; removal; storage; utilization; and trading, essentially, the capture of carbon; and processes that support this activity. Users of carbon tech are extremely broad, due to almost universal need for sectors to decarbonize (and the growth in regulatory pressure to reduce GHG emissions). This breadth shapes the technologies in the space. Carbon capture hardware is enabling continued use of high-carbon processes (such as chemical production and power generation), which currently cannot be replaced economically either through retrofit of carbon-emitting assets or direct air capture (DAC) approaches. DAC is experiencing particularly strong growth, driven by technological innovation and a supportive carbon pricing environment. Carbon utilization technologies are also rising in prominence, although many of these have high energy requirements and require clean energy to be considered viable.

The carbon tech space is relatively young due to low-carbon prices in recent history. Additionally, the industry is not dominated by large companies, providing opportunities for startups, who also benefit from the breadth of the space. There is also both competition and funding opportunity from large oil and gas firms as they seek to diversify and adapt to a low-carbon economy. Occidental Petroleum (NYSE: OXY), for example, formed a subsidiary in 2020 to develop and finance DAC approaches and carbon sequestration. Similarly, carbon tech development and investment involving large oil and gas firms is common, as seen in the Northern Lights project,[7] a joint venture between Equinor (OSL: EQNR), Shell (NYSE: SHELL), and TotalEnergies (PAR: TTE).

Carbon tech contains the following subsegments:

- **Point-source carbon capture and storage (CCS):** Technologies for removing carbon from flue (exhaust) gas streams caused by power generation and industrial gas streams, which can often be retrofit to existing infrastructure. The category includes several CO2-removal approaches including chemical absorbents (for example, amine gases), solid adsorbents, and separation membranes. The approaches include those that bind to CO2 and later release it into storage when heated, thus recharging the chemistry.
- **Direct air capture:** Technologies similar to point-source carbon capture in that they involve exposing CO_2-laden gas (in this case air) to chemical or mechanical technologies to either absorb, adsorb, or otherwise remove the CO_2. They often include additional hardware to increase air flow to the removal technology to compensate for the relatively low CO_2 concentration in the atmosphere. The chemical and mechanical approaches used are often the same as those used for point-source CCS.
- **Biological carbon removal:** Biological approaches to CO_2 removal tend to divide into two groups: forestry approaches (reforestation or afforestation), and soil carbon approaches (using either microbial approaches or biochar integration). Less commonly, some firms use algae to capture carbon.
- **Carbon utilization:** Companies in this area use captured carbon as an input into a valuable physical product, such as construction materials, fiber-reinforced plastics, and soaps.
- **Carbon fintech & consumer:** A broad category including integration of carbon and emissions into

7: "What We Do," Northern Lights, n.d., Accessed August 23, 2022.

financial products. This includes integration of carbon offsets and monitoring into banking products, marketplaces for carbon trading, and selling of tokenized carbon products.

- **Carbon accounting/analytics:** Services that monitor either the carbon footprint of an entity (individual, project, or company) or monitor the carbon sequestered by carbon removal approaches. Includes measurement, reporting, and verification companies. Analytics are often included to provide management the option to integrate with carbon offsetting offerings.

Industry drivers

- **Net-zero emissions pledges.** The number of countries, regions, and companies making net-zero emissions pledges (plus emissions reduction pledges in general) has grown in recent years, and the end dates for these pledges tend to be between 2030 and 2050, although some significant regions have target dates beyond 2050—notably China and India. To successfully hit these target dates, decarbonization efforts are considered a key area of investment, contributing to growth in the sector.
- **Increasing carbon prices.** In the US, the 45Q tax credit provides a financial incentive for carbon capture, utilization, and storage, and this incentive has been greatly expanded by the recent signing of the Inflation Reduction Act of 2022, which increases the per-ton value to $85 (from $50) and sets a specific value for DAC, which was formerly not given special status, and thus the tax credit available will rise from the $50 base amount to $180. Coupled with this value increase, the thresholds to become eligible for the tax credits have been relaxed, and the payment of the credits is changing to make it easier for small firms to take advantage of the credits.[8] In Europe, the ETS will gradually reduce the maximum number of allowances available to various industries, thereby increasing the cost of these allowances over time. Both examples increase the cost of emitting carbon, pushing firms to reduce their emissions and increasing the value of carbon removal.
- **Growing commercial and consumer demand for offsets.** Consumers are increasingly seeking options to reduce their emissions, and the voluntary carbon market is a low-effort way to reduce emissions in hard to abate areas. Corporations' desire for offsets is similarly high—many have pledged emission reductions, and the low cost of carbon offsets allows these targets to be achieved quickly and with little impact to the business. AstraZeneca for instance, has committed to net-zero carbon by 2025 and negative carbon emissions by 2030.[9] Similarly, Microsoft has taken action to become carbon negative by 2030.[10]

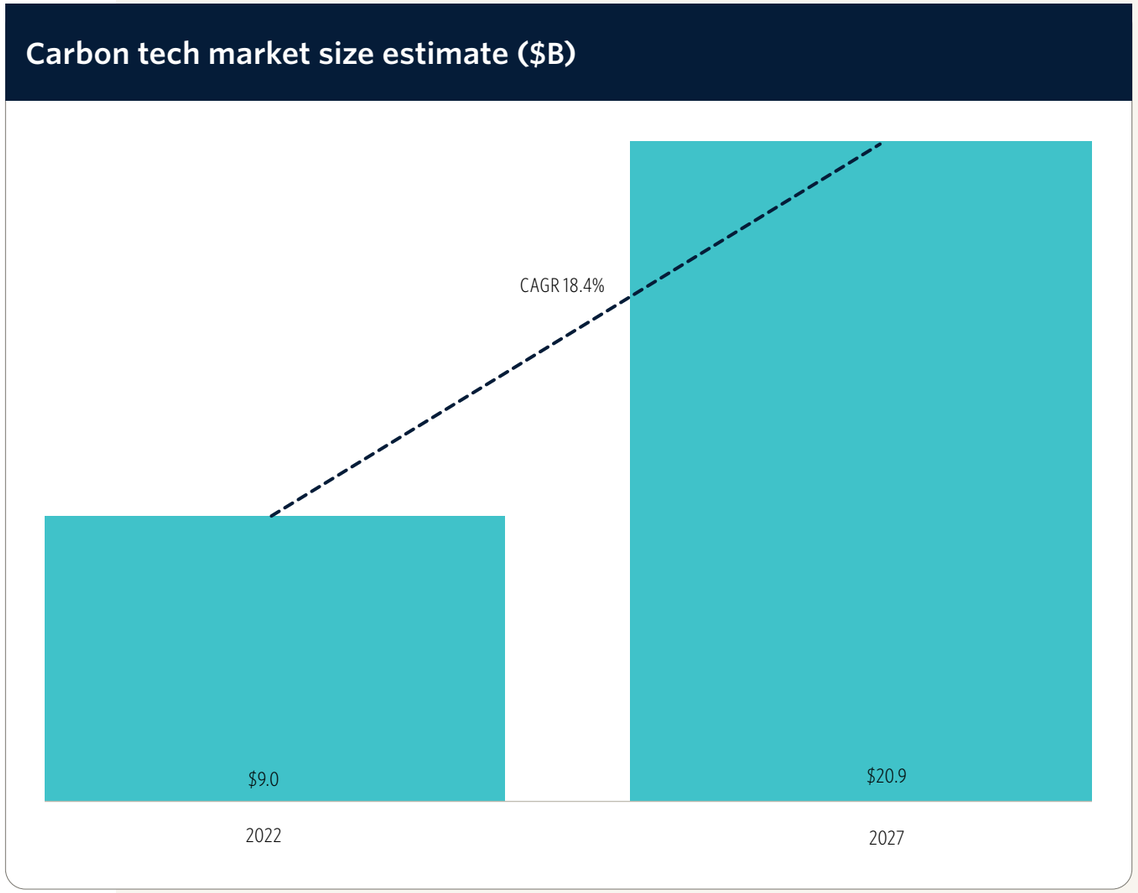
8: The 45Q tax credit will now apply through direct pay rather than as a reduction in paid tax (It will essentially count as tax overpayment), reducing the tax liability required to benefit from the credit.
9: "Ambition Zero Carbon," AstraZeneca, January 22, 2020.
10: "Operating to Drive Global Change," Microsoft, 2022.

Market size

We predict that the market size for carbon tech will reach $9.0 billion in 2022 and increase to $20.9 billion by 2027, representing a CAGR of 18.4%. This is a smaller segment, but it is growing quickly, and recent carbon pricing increases introduced in the US will contribute to increased investment in the space. DAC in particular is likely to see higher growth than the rest of the segment, while carbon accounting is in demand to allow companies to validate and publicize their progress toward climate pledges. Point-source carbon capture is likely to grow steadily, supported in part by oil and gas companies looking to extend the life of their high-carbon assets.

Business model

Companies in this space largely generate revenue through a combination of selling hardware for GHG scrubbing, creating and selling carbon offsets from carbon removal projects, and providing marketplaces for trading these offsets. Additional revenue sources include selling products made from captured carbon and providing monitoring services to businesses or individuals to calculate their carbon emissions. These monitoring approaches can also be provided as a service to those selling carbon offsets to validate the permanence, additionality, and exclusivity of their offsets. Some carbon fintech firms are emerging that sell tokenized carbon products, but at present this is limited, and it remains to be seen how popular this approach will be.



Source: PitchBook Emerging Tech Research | Geography: Global

VC activity

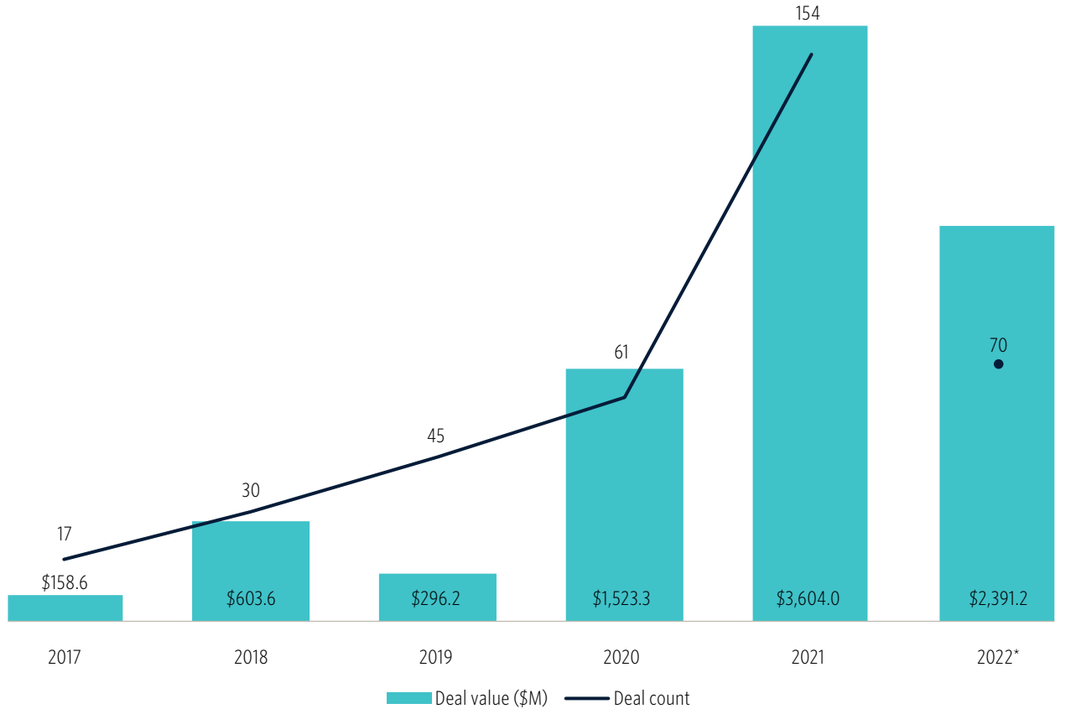
VC activity was strong in Q2, and we expect this to continue as interim and end net-zero targets approach. In Q2, carbon tech attracted $2.0 billion of VC funding across 42 deals, tied with Q2 2021 for the highest deal count, and the second highest deal value of any quarter on record (after Q3 2021, at $2.5 billion). The largest deal of the quarter was the $644.5 million Series F for European DAC company Climeworks, which began development of its second commercial DAC and storage plant in June 2022.

This high total deal value in Q2 is driving strong H1 2022 figures after a relatively low total deal value in Q1 2022. Thus far, deal values in all subsegments other than carbon fintech & consumer are higher in H1 2022 than deal values for the whole of 2021, with particularly high funding attracted by DAC ($707.7 million in H1). Barring substantial global policy shifts, we anticipate continued high investment in carbon tech companies as carbon targets loom and carbon prices rise.

Opportunities

Increasing value of carbon. The most significant trend in this space is undoubtedly the growth of pledges from governments, cities, and companies that place high value on carbon. In the US, the price of carbon applied upon capture will rise to $85 per ton with the implementation of the Inflation Reduction Act (or $180 per ton for DAC carbon). The EU uses a cap-and-trade system that limits how many carbon allocations are available. Those emitting carbon must pay for allowances; those emitting more than their held allowances must purchase additional allowances from other firms, resulting in market-set pricing that approached €100 this year.

Carbon tech VC deal activity



Source: PitchBook | Geography: Global | *As of June 30, 2022

These pledges—and the legislation that follows—increase the viability of carbon technologies, essentially across the board. Entities face more pressure to measure and manage their emissions, and firms removing carbon post-emission can extract more value from doing so. Some of this benefit has already been realized in that the last two-three years have seen an explosion in net-zero and emission-reduction pledges. The implementation of action driven by these pledges will continue for decades, as interim targets loom and carbon prices steadily climb. In particular, the DAC sector is poised for strong growth, as the carbon price for DAC carbon is set to rise by 260% (from $50 to $180) while the eligibility thresholds will be significantly reduced (from 100,000 tons per year to just 1,000 tons per year). Further, the change to direct pay (in which the tax credits are effectively considered tax overpayment) allows firms with low tax liabilities to take advantage of high levels of tax credits. This is particularly useful considering the maturity of the DAC industry, which tends to be populated by smaller companies in the process of developing and installing their technologies.

High-quality carbon offsets. While the potential for increased scrutiny of carbon offsets is concerning for offset providers that might not meet the requirements; for those that do, this represents a strong opportunity. They will likely find themselves more competitive once they no longer compete against offsets that do not meet the appropriate standards for permanence, additionality, exclusivity, and leakage. Further, companies able to provide measurement, verification, and reporting are well placed to succeed if regulatory scrutiny increases.

Raw materials for carbon utilization. The increase in carbon capture also provides increased availability of feedstocks for carbon utilization. Additionally, new approaches such as torrefaction and pyrolysis[11] produce carbon in novel forms (such as solid pure carbon rather than CO_2) with a different suite of applications. It is worth noting, however, that carbon utilization projects are usually more limited by clean electricity prices than by carbon availability or cost, so the benefits from increased carbon availability are effectively capped.

Risks & considerations

Carbon price volatility. The core risk facing the carbon tech space is in the potential for the value of carbon to shift dramatically due to changes in policy and regulation. The product of carbon tech (removing or reducing carbon) does not directly provide value—outside of some value as a feedstock for carbon utilization—and fiscal value from carbon tech activities is heavily driven by the value that legislative incentives and schemes place on carbon. This exposes carbon tech companies to potential volatility in carbon pricing, although the effects are likely to be muted by emission reduction pledges at the sub-governmental level. Long-lasting swings in carbon prices could reduce the willingness of firms to implement carbon tech offerings, as the value added in their implementation would be more volatile and potentially lower than the cost. For DAC projects in particular, the uncertain price of carbon in the future might limit the willingness of companies to embark on large, capital-intensive construction projects.

Increased scrutiny of carbon offsets. Even for companies providing high-quality carbon offsets, the prospect of increased regulatory scrutiny represents an additional burden and cost. Companies offering offsets may need to implement additional programs to monitor and assess the carbon projects on which their offsets are based, and this can include long-term monitoring for

11: Both torrefaction and pyrolysis are processes in which biomass is heated in the absence of oxygen to release volatiles and leave carbonized matter. They differ in the exact conditions used.

permanence plus broad geographic coverage to ensure that carbon offset projects do not simply shift carbon emitting activity to other locations. For companies offering offsets that are deficient in one or more area (permanence, exclusivity, leakage, additionality), additional work and cost is required to improve the carbon project and then to ensure this improvement is measurable. Somewhat related is the growth in the last few years of tokenized, tradeable carbon credits, which could be at particular risk of "exclusivity" measurements, as some of these tokens are designed to be traded peer-to-peer. This secondary trading of carbon credits is viable, but only if the holder of the carbon credit is entitled to the offsetting value of the token. To the seller of the token, the act of selling is tantamount to emitting the amount of carbon that the token represents, lest two users claim the benefits of the same token.

Lack of carbon removal and storage options. Carbon removal is a growing industry, and with this comes increasing volumes of carbon to be stored. For mineralization technologies (such as Travertine) this is less of a problem, as is the case for solid carbon production (such as that produced as a co-product of Monolith's turquoise hydrogen generation), but for technologies that remove carbon in the form of CO_2 (which is a significant proportion), large-scale additional carbon transportation and storage locations will become increasingly important. Some large-scale storage installations already exist, but these will not be sufficient on their own as volumes increase. Similarly, dedicated CO_2 transportation frameworks and supply chains will be important to overall efforts, and some progress has been made at implementing a geographically broad carbon removal network involving both road and pipeline transport plus storage.[12] Such efforts are needed to lower the post-capture costs of CO_2 removal, thus lowering costs overall.

12: "A Carbon Capture, Utilisation, & Storage Network for Wales," Welsh Government, March 31, 2021.

Key carbon tech VC deals over the past year*

Company	Close date	Subsegment	Stage	Deal size ($M)	Lead investor(s)	Valuation step-up
Climeworks	April 5, 2022	Direct air capture	Series F	$644.50	GIC, Partners Group	N/A
Crusoe Energy Systems	April 20, 2022	Carbon fintech and consumer	Series C	$505.00	G2VP	3.1x
Perpetual Next	June 15, 2022	Biological carbon removal, carbon utilization	Series A	$340.1	N/A	N/A
Carbon Clean	May 11, 2022	Point-source CCS	Series C	$190.72	Chevron Technology Ventures	7.9x
Persefoni	October 27, 2021	Carbon accounting/analytics	Series B	$101.0	Prelude Ventures, The Rise Fund	5.3x
Xpansiv	September 1, 2021	Carbon fintech and consumer	Late-stage VC	$100.0	N/A	N/A
Prometheus Fuels	September 23, 2021	Direct air capture, carbon utilization	Series B	$100.0	N/A	8.1x
Sweep	April 5, 2022	Carbon accounting/analytics	Series B	$71.3	Coatue Management	2.9x

Source: PitchBook | Geography: Global | *As of June 30, 2022

Green industry

Overview

The green industry space essentially covers the low-emissions production of chemicals and raw materials, whether generating them using conventional processes, extracting them from the ground, or sourcing them from existing waste. The outputs are often identical to conventional industry outputs and include raw chemicals such as solvents and detergents, chemical feedstocks for further use, plastics, metals, and fibers. The technologies within the space are highly varied and include biologically derived chemicals (including algal and vascular plant-based), battery recycling technologies, sensing hardware and software, low-carbon mining approaches, and novel approaches to plastics recycling. The plastics recycling space is showing innovation—traditional recycling techniques are effective but eventually cause degradation of the source material—and various new technologies are being developed to increase product quality, including use of enzymes, microwaves, and superheated steam.

The industrial space is dominated by large, conventional chemical, mining, and petrochemical companies, many of which have invested heavily in low-emissions technology to remain competitive as decarbonization efforts spread into additional sectors. This investment from large companies into green industry takes the form of in-house technological development, acquisitions, and partnerships. For example, diversified chemical company Dow (NYSE: DOW) has invested heavily in recycling technologies, including its own REVOLOOP mechanical recycling, plastic-to-fuel company Plastogaz (a March 2022 investment), and a partnership with Mura Technology.

The green industry segment contains the following subsegments:

- **Manufacturing and chemicals:** Technologies and approaches to reduce the emissions generated in creation of chemical feedstocks and products, including petrochemicals. Approaches include novel pathways (including biological alternatives) or improvements to conventional production (improved efficiency or emissions capture).
- **Recycling—polymers:** Technologies to reuse polymers of all kinds, including plastics, plus other polymers such as organically derived textiles.
- **Recycling—metals:** Approaches to reclaiming metals from scrap and waste, including non-lithium battery recycling.
- **Lithium battery recycling:** Hardware to recycle batteries specifically with lithium-based chemistries – due to lithium's rise in importance as the primary cell chemistry for high-energy density applications, recycling approaches specifically focused on lithium batteries has grown significantly in the last 5 years.
- **Recycling—analytics:** Hardware and software to optimize recycling, mostly through sorting and sensing capabilities.
- **Green mining:** Low-emissions mining approaches, including software to improve the efficiency of mining through mine location optimization, and technology to directly reduce or remove emissions from mining activities.

Industry drivers

Carbon targets and pricing. The core factor driving efforts to reduce emissions from the chemicals and manufacturing industry is pressure from carbon targets, pledges, and carbon pricing associated with governmental carbon targets. Carbon pricing in particular is fundamental to increase the ability of cleaner approaches and technologies to compete with conventional processes, which are optimized for economy at the expense of emissions. These pledges and targets have grown significantly in a short time, now covering 83% of GHG emissions, and they tend to be gradually phased in until the end target date, so the level of incentivization will increase over time rather than remain constant. Even without the direct financial incentives provided by governmental emissions reduction legislation, pledges from individual companies provide an additional driving force behind green industry efforts. Increasing use of low-carbon industrial products allows companies with emission-reduction pledges to demonstrate their progress and conviction regarding pledges.

Consumer demand for sustainable products. While the implementation of carbon pricing is critical to allow reduced emissions products to compete with conventional approaches, consumer demand shifts are also relevant. Consumers are now more willing to pay a premium for products with lower environmental impacts, and this raises the demand for low-carbon feedstocks and chemicals.

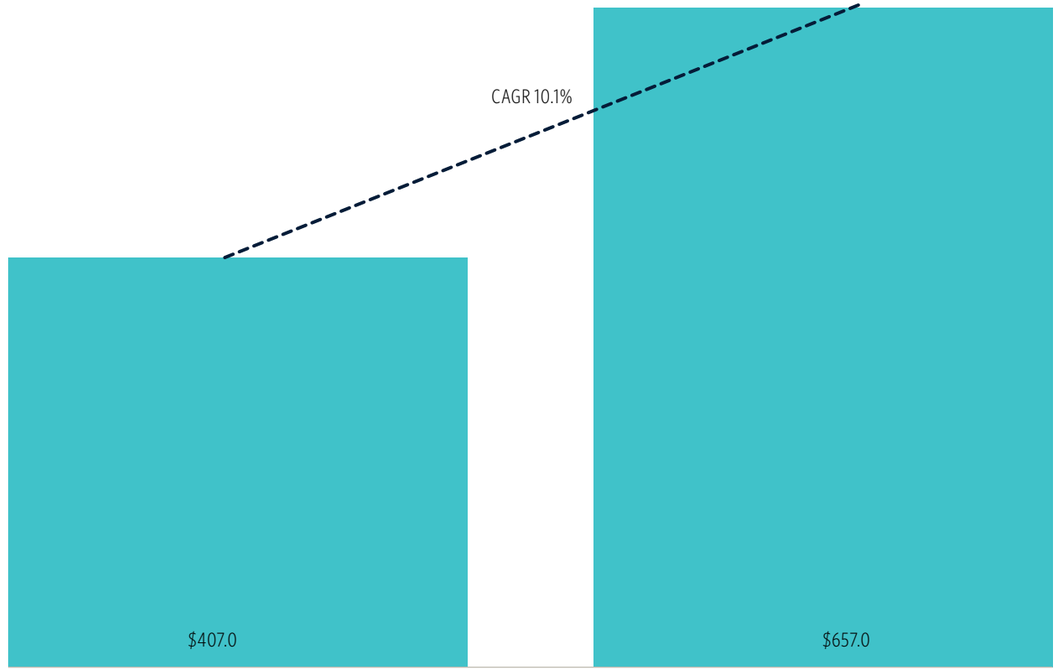
Market size

We predict the market size for the green industry segment (decarbonized industrial production of chemicals, raw materials, and derived materials) will reach $407.0 billion in 2022 and grow to $657.0 billion by 2027, at a CAGR of 10.1%. The market size for conventional chemicals and mining is extremely high (in the region of $5-$8 trillion, depending on source, methodology, and scope covered), reflecting the global need for these chemicals and materials. Over time, incentives and policies will shift where buyers obtain these products toward decarbonized sources—whether these be new companies or existing providers who have switched their production approaches. The implementation of legislation such as the Carbon Border Adjustment Mechanism (CBAM)—which applies a carbon tax on foreign goods imported into the EU—will be critical to ensure that those providing green chemicals and materials are not at a disadvantage against foreign high-emissions products.

Business model

Companies in the space monetize by developing low-carbon-emission approaches to produce chemicals and chemical feedstocks and then selling these products, which compete with conventionally produced chemicals and feedstocks and are priced at a premium relative to their conventional counterparts to compensate for the increased cost of production. Some business models in this segment include a waste disposal element, from which they may generate revenue (although this is usually a smaller component than the products of the processed waste).

Green industry market size estimate ($B)



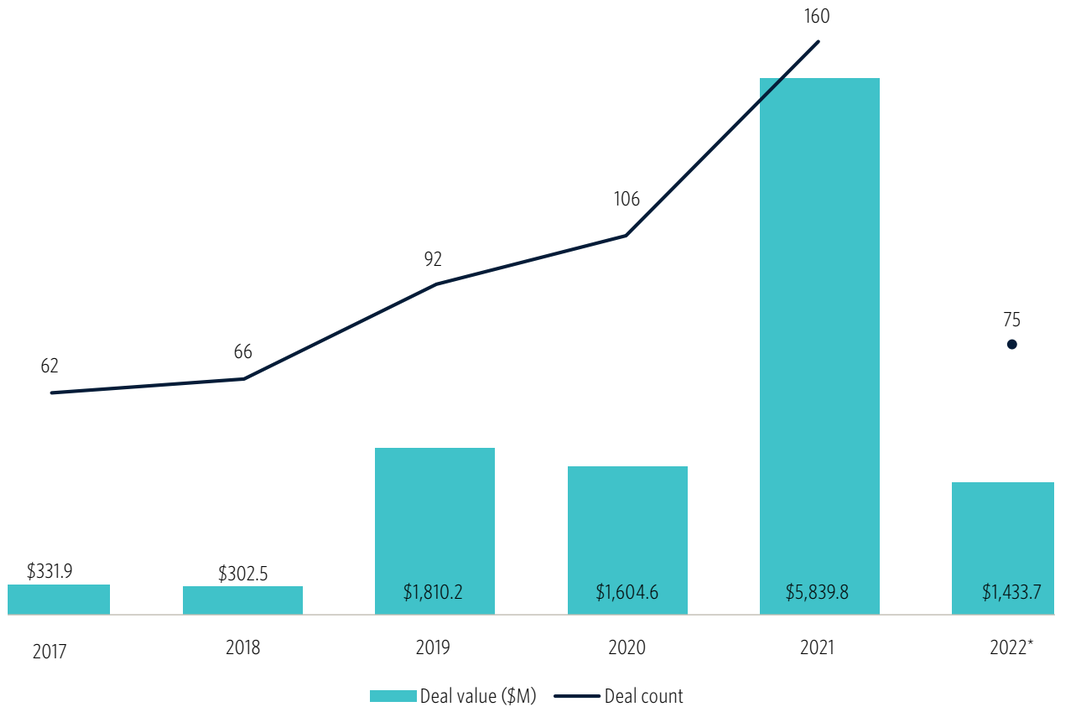
Source: PitchBook Emerging Tech Research | Geography: Global | *As of June 30, 2022

VC activity

VC deal activity has fallen sharply since 2021, although this is in part due to the very large ($2.8 billion) Series E funding secured in June 2021 by Northvolt (lithium battery developer, manufacturer, and recycler), which accounts for nearly half the total deal volume that year. In H1 2022, green industry VC deal activity consisted of $1.4 billion across 75 deals, compared to $3.5 billion across 81 deals for H1 2021. Within the green industry segment, manufacturing & chemicals accounted for the bulk of deal value in H1 2022, at 57.1% of total value, while green mining only saw four deals in H1 2022, for a total just $3.6 million. Lithium battery recycling saw a large decline in VC deal value (but only a minor drop in deal count), even when accounting for Northvolt's Series E funding.

Total deal value in Q2 2022 for the green industry segment was $805.4 million across 41 deals. The largest VC deal in Q2 was waste-to-chemicals/fuels company Enerkem's April 6 late-stage VC round for CAD 255 million ($201.9 million). We anticipate strong investment in the green industry space in the future. Interest in emissions reduction and subsequent action to bring change have been growing strongly in recent years, although the effects of this largely remain to be seen.

Green industry VC deal activity



Source: PitchBook | Geography: Global | *As of June 30, 2022

Opportunities

Waste-to-chemicals: When attempting to reduce emissions associated with chemical production, a core theme is to replace petrochemical feedstocks with something more sustainable. Multiple avenues are available for this, including biomass—either biomass grown and harvested specifically for this purpose (with species chosen for rapid growth and good water/nutrient efficiency)—or waste biomass that otherwise would hold no value. xF Technologies uses any biomass based on cellulose (structural plant matter), sugars, and starches, which are used to create various solvents, plasticizers, and other industrial chemicals. Enerkem uses a wide range of waste material as a feedstock to make chemicals and fuels, including textiles, non-recyclable plastics, food packaging, and wood residues.

Polymer breakdown technologies: Mechanical polymer recycling involves shredding recyclable plastics and melting them into a granulate that can be reused. It is a valuable process that can be improved through advancements to cleaning and sorting of the initial plastic waste, but it still suffers from problems of contaminants and additives to the initial plastics. Dyes in particular will often leave the final product with a dull, uniform color. An alternative that has seen strong recent development is advanced chemical recycling, which involves breaking down waste plastics into more basic chemical feedstocks that can then be used to create new plastics with more flexibility in the choice of color, strength, ductility, and other properties. Several technological approaches are viable for this kind of recycling: Mura Technology uses supercritical water to break plastics into smaller molecules, Pyrowave uses microwaves, and Samsara Eco uses an enzymatic approach.

All these approaches convert plastic waste into the chemical feedstocks needed to create new plastics (including food-grade plastics) rather than waste-derived secondary plastics.

Risks and considerations

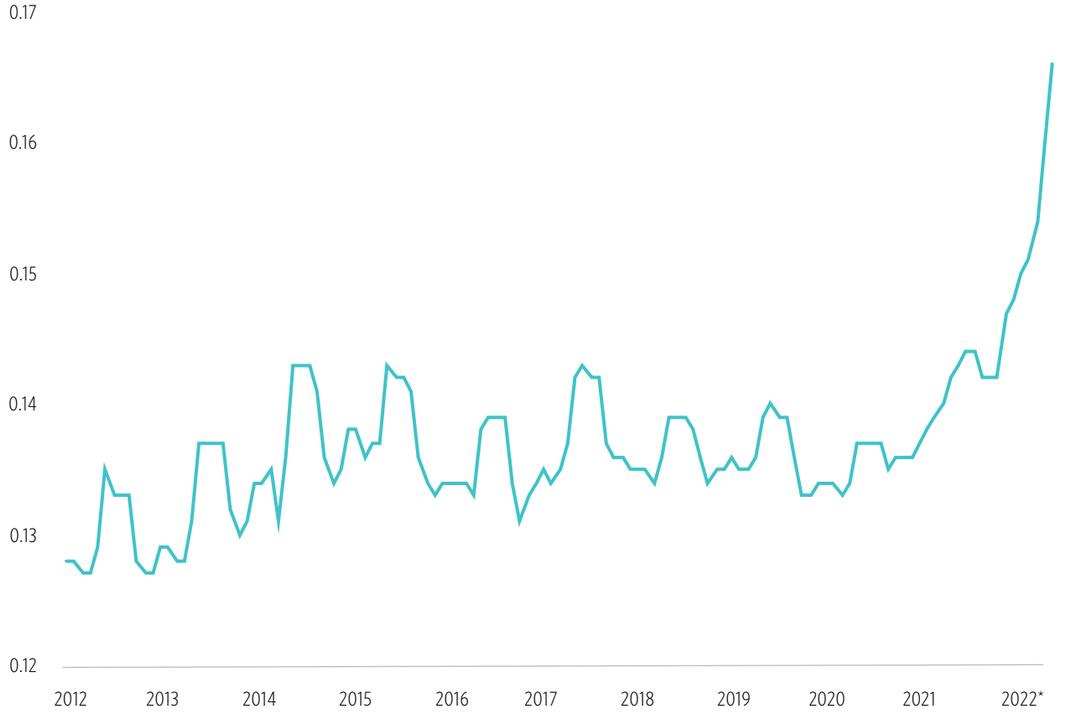
Energy and process costs. Clearly, replacing conventional industrial processes with low-emissions alternatives is technically possible. The core obstacle to implementing this transformation is economics relative to conventional approaches, and this is driven heavily by the energy requirements of greener approaches as well as the additional stages required. Since conventional approaches to chemical manufacture have been developed to be as efficient as possible, modifying these to reduce emissions tends to add processes, inputs (both energy and raw materials), and time. High electricity costs (plus the need for decarbonized energy) increase the spread between raw materials and final products, and this is exacerbated for processes that have high energy requirements. Electricity costs are currently extremely high in both North America (see chart below) and Europe because of high summer temperatures and the need to find alternatives to Russian fuels.

Scaling and output. It is challenging to effectively scale some green industry areas, including recycling and waste-to-chemicals processes. These have limits on how much "raw material" is available without having to import waste from other locations at additional cost. Other decarbonized chemical production approaches (including some blue ammonia production, which are essentially the same as conventional ammonia production, but with additional stages to

remove carbon) tend to be more complex than their conventional counterparts—and thus harder to scale, although not to the extent of resource-limited approaches.

Recycling degradation and sorting. Reaction of plastics to the environment, contamination, and mixing of plastic types during the recycling process all contribute to plastic degradation, and although some emerging technologies are providing solutions, it is challenging to eliminate degradation completely.

Average US city electricity price per KWH



Source: US Bureau of Labor Statistics[13] | Geography: Global | *As of June 30, 2022

13: "Databases, Tables & Calculators by Subject: CPI Average Price Data, U.S. city average," US Bureau of Labor Statistics, Accessed August 23, 2022.

Key green industry VC deals over the past year*

Company	Close date	Subsegment	Stage	Deal size ($M)	Lead investor(s)	Valuation step-up
Redwood Materials	August 18, 2021	Lithium battery recycling	Series C	$ 776.6	T. Rowe Price	13.8x
Solugen	September 9, 2021	Manufacturing and chemicals	Series C1	$ 357.0	Baillie Gifford, Gulf Investment Corporation	N/A
Enerkem	April 6, 2022	Manufacturing and chemicals	Late-stage VC	$ 201.9	N/A	N/A
Vital Thin Film Materials	December 30, 2021	Manufacturing and chemicals	Series A	$188.2	BYD Company, CICC Capital	N/A
Lilac Solutions	September 8, 2021	Green mining	Series B	$150.0	Lowercarbon Capital, T. Rowe Price	7.1x
Britishvolt	May 26, 2022	Manufacturing and chemicals	Early-stage VC	$142.8	Glencore	1.7x
TemperPack	March 22, 2022	Manufacturing and chemicals	Series D	$140.0	Goldman Sachs Asset Management	2.3x
Lithion Recycling	January 24, 2022	Lithium battery recycling	Series A	$125.0	N/A	N/A
Ascend Elements	October 13, 2021	Lithium battery recycling	Late-stage VC	$110.0	N/A	N/A
Mura Technology	June 1, 2022	Recycling—polymers	Late-stage VC	$100.0	N/A	0.7x

Source: PitchBook | Geography: Global | *As of June 30, 2022

Key green industry incumbents*

Company	Subsegment	Holding status	Key products	Enterprise value ($B)
BASF	Chemicals and manufacturing	ETR: BAS	Industrial chemicals, recycling	$65.8
Dow	Chemicals and manufacturing	NYSE: DOW	Industrial chemicals, derived chemical products	$53.5
Waste Management	Recycling—polymers	NYSE: WM	Recycling, waste disposal	$85.6
Veolia Environnement	Recycling—polymers	PAR: VIE	Battery recycling, repurposed engineered materials	$14.3
Glencore	Green mining	LON: GLEN	Base and ferrous metals, metal ores	$98.5

Source: PitchBook | Geography: Global | *As of June 30, 2022

Built environment

Overview

The built environment focuses on companies that reduce GHG emissions from buildings during construction and later in the lifetime of the building. Much of the emissions from the construction process come from the materials used: Cement accounts for approximately 8% of global CO_2 emissions,[14] and steel accounts for 7.2%[15] (although not all of this is structural steel). Many of the technologies in the segment, therefore, focus on producing structural materials with lower emissions profiles, whether through low-carbon versions of conventional products or products such as high-strength polymers or treated timber. Low-carbon cement and concrete companies are one of the most significant and well-represented components of the green construction subsegment, reflecting the size of the cement industry and the demand for low-carbon cement.

Until recently, companies in the conventional (that is, not low-carbon) construction space have not been concerned by their emissions profiles, as the financial incentives were not there, but this situation is changing as more governments bring construction under carbon pricing in one way or another. Looking at the overall construction materials space, there are several large incumbents against whom low-carbon companies will compete, such as LafargeHolcim (SWX: HOLN) and HeidelbergCement (ERT: HEI). Some of these incumbents are developing their own low-carbon offerings. Despite these established firms, the space for low-carbon construction materials is relatively open due to the technical challenges of decarbonization and the youth of the space.

The building energy efficiency subsegment also includes smart-home technologies to optimize power usage, and this space is somewhat developed, although many of these companies provide smart-home functionality without emissions benefits (such as security, audio/video, smoke detection, etc.). Firms such as Ecobee and Resideo Technologies are the incumbents that represent the energy efficient home automation space, but there is opportunity for new entrants that offer improvements to optimization, incorporation of new hardware, or improvements to user interfaces, including:

- **Green construction:** Low-carbon construction materials, including green cement, timber products, and polymers, plus non-structural materials such as cladding and roofing tiles. Also includes technologies such as 3D printed houses and modular construction.
- **Building energy efficiency:** Technologies to increase the energy efficiency of a building, including passive heat management (novel insulation materials), smart-building power management (and analytics/optimization), and power generation and storage for homes.
- **Heating and cooling:** Energy efficient active heating and cooling technologies, including water heating, heat pumps, air conditioning.

Industry drivers

Expansion of carbon pricing schemes. When cap-and-trade carbon pricing schemes were first introduced, they tended to focus on the sectors that are easiest to decarbonize and emit the highest amounts of CO_2, and the obvious option was the energy sector. As efforts to reduce overall emissions progress, pressure has also been applied to sectors that were not previously targeted (due either to thin profit margins, as for cement and steel, or lack of technological advancement, as for electric vehicles). The EU's cement industry for example, has historically received free

14: "Global CO2 Emissions from Cement Production, 1928–2018," Earth System Science Data, Robbie M. Andrew, September 5, 2019.
15: "Emissions by Sector," Our World in Data, Hannah Ritchie and Max Roser, 2020.

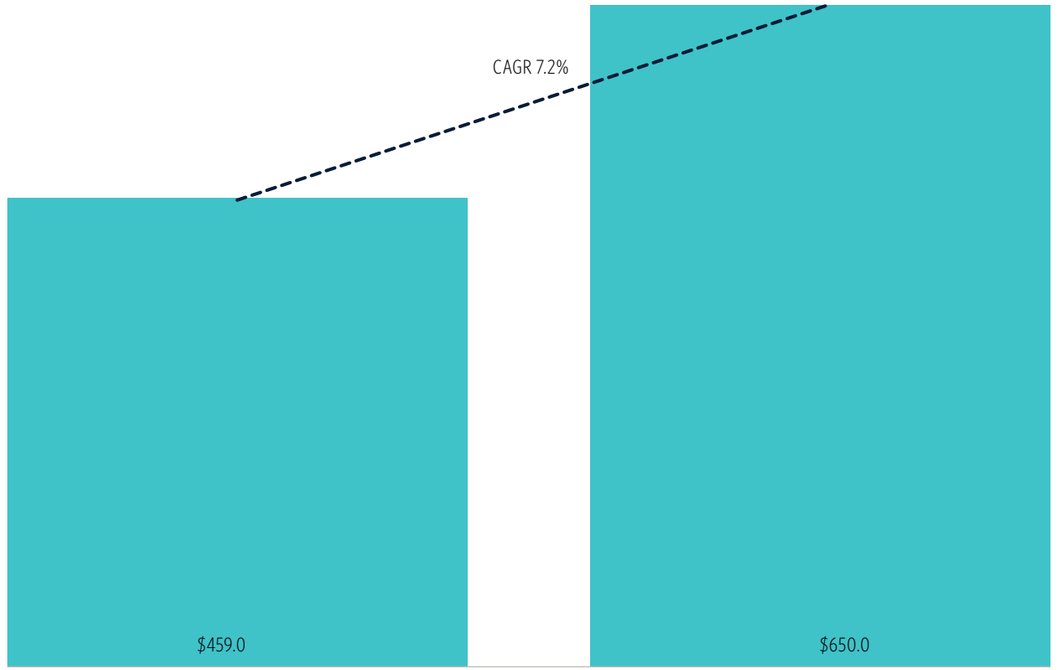
allowances, and carbon released from buildings post-construction has not fallen under the ETS. Both are changing, though, with free allowances being reduced over the next few years, and a new EU ETS being created to cover building energy usage (plus transportation).

High electricity costs. High global fuel prices have elevated electricity costs, and this is pushing owners of real estate to make changes to their homes and commercial properties to reduce energy use. This provides a fertile environment for companies offering post-construction energy efficiency improvements, including insulation, energy optimization hardware and software, and more efficient heating and cooling technologies.

Market size

We predict that the market size for the built environment segment will reach $459 billion in 2022, and grow to $650.0 billion by 2027, representing a CAGR of 7.2%. The built environment is a large space, driven by population growth and the consistent need for new buildings and infrastructure. As with the industry segment, we expect to see a gradual shift from conventional construction materials and building hardware to decarbonized alternatives, alongside energy efficiency gains driven by incentives and technological improvements. We expect strong growth in the green cement space, which is a significant target for decarbonization due to the cement industry's high emissions.

Built environment market size estimate ($B)



Source: PitchBook Emerging Tech Research | Geography: Global

Business model

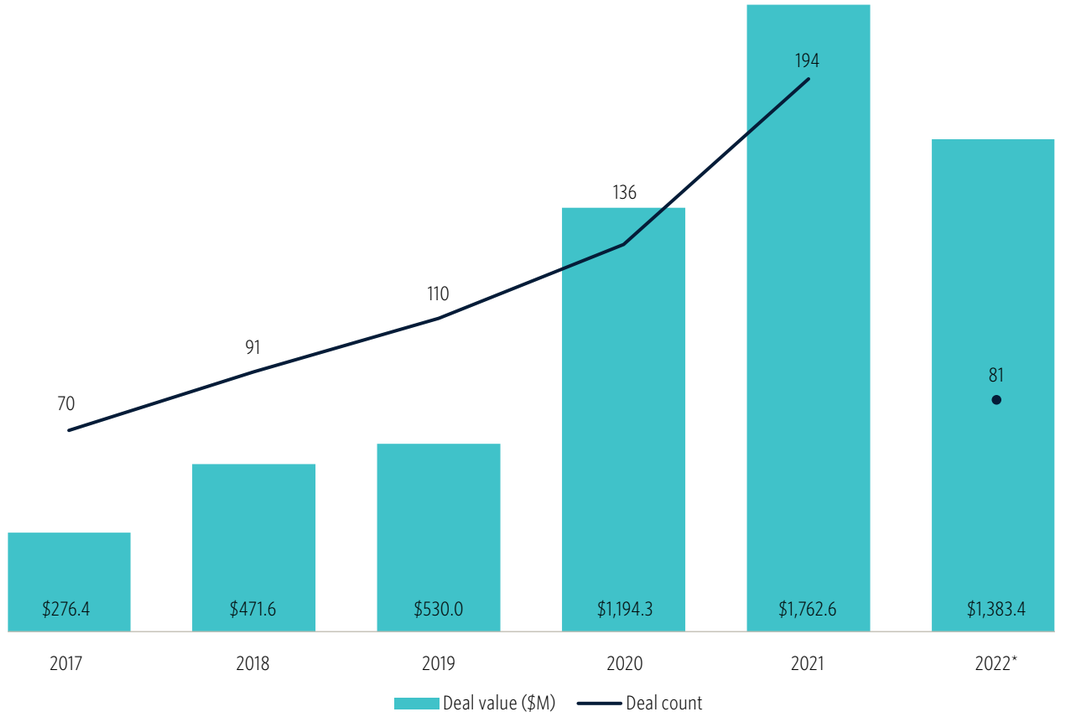
The built environment segment includes technologies for both new construction projects and retrofitting to existing builds. The former is monetized through sales of raw materials (sustainable building materials such as green cement and cross-laminated timber) and the creation and sale of new real estate using sustainable techniques. Retrofitting generates revenue through the sale of energy efficiency hardware, installation services, ongoing maintenance of implementations, and subscriptions to software to optimize power usage or provide control options to users.

VC activity

Q2 for the built environment space follows its strongest quarter on record, with $930.2 million in deal value over 40 deals in Q1 2022. Although deal count is approximately equal (41 deals in Q2), deal value in Q2 was substantially lower at just under half the deal value ($453.1 million). Some of this is due to housing materials company Veev's $400.0 million Series D in Q1, but fewer large deals were seen in Q2. That said, Q2 is broadly in line with the average deal value in 2021—it is Q2 2021 deal value that was abnormally high. The largest deal of Q2 2022 was residential energy use monitoring company Sense's $105 million Series C funding.

Looking at deal value by year, the H1 2022 built environment segment is strong, assisted by a strong Q1. H1 2022 saw 81 built environment deals, compared to 194 deals for FY 2021. Total deal value for H1 2022 is $1.4 billion, compared to $1.8 billion for FY 2021, and higher than the $1.2 billion in deal value for FY 2020.

Built environment VC deal activity



Source: PitchBook | Geography: Global | *As of June 30, 2022

Opportunities

Green cement/concrete. Cement has long been acknowledged as a major emitter of GHGs—releasing emissions from both the energy use involved in production and direct emissions from processing raw materials[16]—but it is only recently that efforts to decarbonize the cement industry have gained traction. A lack of incentives coupled with the historically high production cost of low-carbon cement were the main barriers to wide adoption of green cement, but regulation and policy are providing incentives, and technological improvements to carbon capture are reducing the price gap relative to conventional cement. Technologies to reduce cement/concrete emissions (cement being the component of concrete with the largest CO_2 profile) include the use of "supplementary cementitious materials," an approach used by Terra CO_2, in which low-carbon cement alternatives can replace some of the cement used in concrete mixes. Prometheus Materials similarly aims to replace the cement in concrete with low-carbon alternatives, but uses a biological approach employing biomineralizing bacteria to produce a cement alternative without CO_2 emissions. Aside from alternative materials, the developments in point-source carbon capture can be applied to conventional cement production, providing another avenue to reduce cement-derived carbon emissions.

Residential energy efficiency. Improving residential energy efficiency is a way to service the increasing consumer demand to improve their personal carbon profile while achieving long-term cost savings. High electricity prices further incentivize energy efficiency, and VC-backed companies are providing means to do this. Although approaches such as insulation and energy efficient heating are effective, most of the deals in the space fund platforms that manage and optimize electricity use, usually through a central management hub and connected internet of things devices (heating, appliances, lighting, etc.). To differentiate themselves, some firms are providing additional capabilities on top of smart-home functionality. OhmConnect provides a smart-meter service to optimize electricity use but also provides grid integration so that users' homes can be used as "demand response" to help balance power grid load—for which users are then paid. Sense also provides smart-home energy use optimization and has dedicated capabilities to integrate with residential solar panels.

Risks & considerations

Supply chain disruption. Global supply chain disruption has been a significant factor in recent years, and although the situation is not as problematic as it was in the early days of the pandemic, there can still be problems sourcing some of the exotic materials and feedstocks needed to make low-carbon construction materials. This could impact the ability of VC-backed companies to provide products, but it is also affecting the entire construction industry.

Energy efficiency installation costs. Although energy efficient homes emit fewer GHGs and can provide financial benefits over time due to reduced energy costs, the upfront costs are still often high. Some options are lower cost, such as more effective sealing, insulation, and other passive heat retention approaches, but installing an energy management system often also includes upgrading existing appliances, heating, and lighting, which can increase the cost dramatically. This can place such options out of reach of some potential buyers, particularly if there are limited ways to buy systems incrementally.

16: "CO2 Emissions from Cement Production," Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Michael Gibbs et al., n.d., Accessed August 23, 2022.

Key built environment VC deals over the past year*

Company	Close date	Subsegment	Stage	Deal size ($M)	Lead investor(s)	Valuation step-up
Veev	February 18, 2022	Green construction	Series D	$400.0	Bond Capital (San Francisco)	1.7x
Sense	April 27, 2022	Building energy efficiency	Series C1	$105.0	Blue Earth Capital	2.6x
Benma Graphene	November 22, 2021	Heating/cooling	Seed Round	$101.6	N/A	N/A
Halio	December 6, 2021	Green construction	Series D	$100.0	Capricorn Investment Group, SK Holdings Company	1.0x
Gropyus	January 18, 2022	Green construction	Early-stage VC	$79.4	N/A	N/A

Source: PitchBook | Geography: Global | *As of June 30, 2022

Key built environment incumbents*

Company	Subsegment	Holding status	Key products	Enterprise value ($B)
LafargeHolcim	Green construction	SWX: HOLN	Cement	$47.2
HeidelbergCement	Green construction	ETR: HEI	Cement	$18.6
Saint-Gobain	Green construction	PAR: SGO	Construction materials	$32.8
Resideo Technologies	Building energy efficiency	NYSE: REZI	Smart-home energy optimization	$4.6
Ecobee	Building energy efficiency	Private	Smart-home energy optimization	N/A

Source: PitchBook | Geography: Global | *As of June 30, 2022

Land use

Overview

The land use segment focuses on the management and reduction of GHG emissions from non-industrial or residential land—a space that includes reducing emissions related to fertilizer use and monitoring the health and vulnerability of carbon-bearing land, either natural or otherwise. While the recent focus on decarbonization has tended to focus on reduction of GHG emissions from human sources, there is a vast amount of carbon sequestered naturally in terrestrial ecosystems, and the increased frequency of events such as wildfires threatens to release this sequestered carbon (in addition to destroying valuable ecosystems). Monitoring approaches can identify at-risk natural assets and potentially provide advance warning of imminent threats.

Natural asset monitoring and protection is not seen as a way to reverse anthropogenic emissions but is rather a complement to reduce the efforts required through other approaches, allowing natural assets to remove carbon from the atmosphere rather than releasing carbon when destroyed. Investment in this space is historically less intensive than it is in other areas, particularly those that provide immediate quantifiable carbon emissions, such as point-source carbon capture or cement alternatives. Similarly, VC investment has slowed in the last two years, although recent government actions include significant incentives and investment for the space, including the recent Inflation Reduction Act, which includes more than $20 billion in investment to support climate-smart agriculture practices, and $5.0 billion in grants to support "healthy, fire resilient forests, forest conservation, and urban tree planting."[17]

New technologies in the space—particularly improvements to sensing capabilities—have increased the ability to monitor large tracts of land, either as an ongoing activity from increasingly cheap remote sensors, or through improvements to drone capabilities that allow fast data capture of large areas without permanent installation of hardware or having to traverse challenging terrain.

- **Fertilizer alternatives:** Low-emissions fertilizer options, either produced conventionally with emissions captured or produced using alternative processes with low emissions. These approaches can include alternative chemical processes or biological approaches such as insect-derived fertilizers or waste-to-fertilizer.
- **Ecosystem health and monitoring:** Sensor, satellite, drone, and other monitoring technology used to assess the ongoing health of land, including forestry projects, and carbon-storing ecosystems.
- **Climate/Earth data:** Technologies generating weather, land, and emissions data (including GHG leak data), either from deployed sensors, satellites, or predictive models.

Industry drivers

Cost and quality of sensing technology. Monitoring technology has advanced rapidly in several fields. Satellite monitoring accuracy has increased and can now incorporate technologies such as lidar to obtain better information and provide more valuable services. Similarly, remote sensors have become cheaper and more effective, allowing providers to cover more area, give better data from deployed sensors, or reduce the amount of human input required (such as for maintenance or power). Drone technology is also now viable for ecosystem health monitoring, driven by improvements to weight capacity, flight distance, and cost, allowing companies monitor all terrain types without increased effort.

17: "Summary of the Energy Security and Climate Change Investments in the Inflation Reduction Act of 2022," democrats.senate.gov, 2022.

High demand for fertilizer. Consumption of fertilizer has been steadily growing, and this causes demand growth. As carbon reduction pledges begin to influence a wider range of industries, alternative fertilizers are expected to make up a larger percentage of overall fertilizer use.

Governmental investment. The Inflation Reduction Act includes more than $25 billion in dedicated investment for both climate-focused agricultural activity and forest health measures (largely to mitigate forest fires, which cause the rapid release of stored carbon).

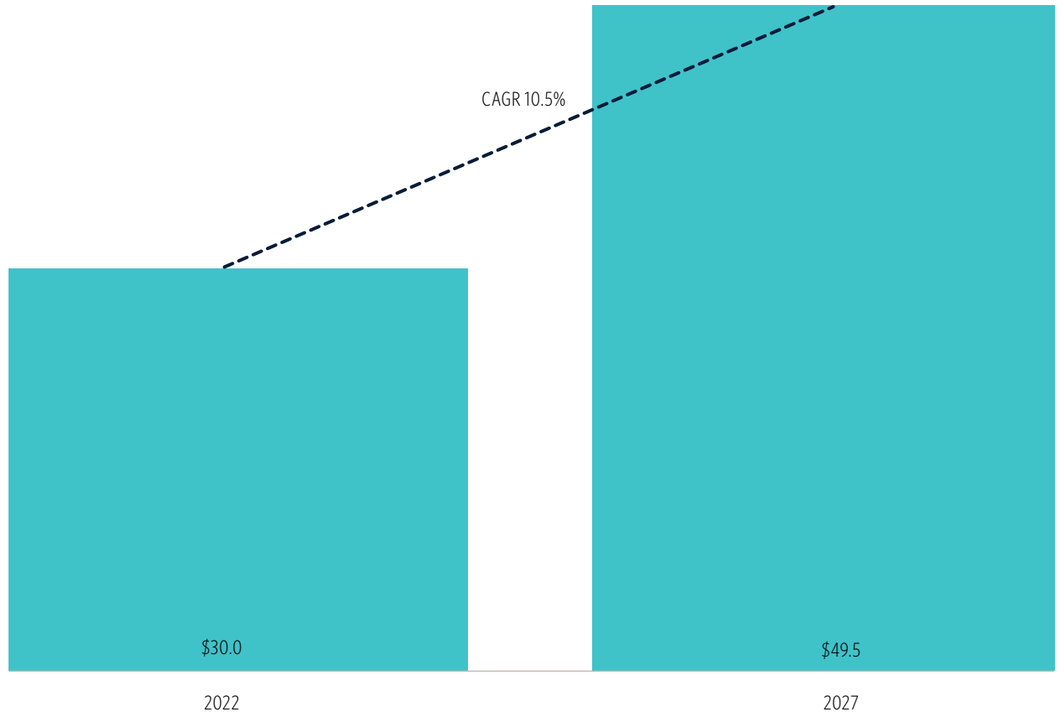
Market size

We predict that the market size for the land use segment will reach $30.0 billion in 2022 and grow to $49.5 billion by 2027, representing a CAGR of 10.5%. The space is varied in the technologies offered and includes both the green fertilizer space and the various levels of environmental monitoring (from low-level plant and soil health monitoring to high-level monitoring of whole landscapes). These markets are very different in how they will grow, with environmental monitoring increasing organically due to demand growth, whereas the green fertilizer space will grow largely through replacement of conventional fertilizers.

Business model

Companies in the land use segment generate revenue through several means: creating and selling low-emissions fertilizers, providing ecosystem health monitoring services to landholders, or providing climate or Earth data—either as collected or with data analysis included. Revenue streams for ecosystem health and monitoring can be one-off purchases of installed sensors or sale of a monitoring service that is performed on a regular or on-demand basis. For the alternative

Land use market size estimate ($B)



Source: PitchBook Emerging Tech Research | Geography: Global

fertilizers, the key element to monetization is to remain as price competitive as possible with conventional fertilizers. Currently, low-emissions fertilizers cost more than equivalent conventional fertilizers, and the price difference must be compensated for by the benefits of the reduced emissions profile of the crop product.

VC activity

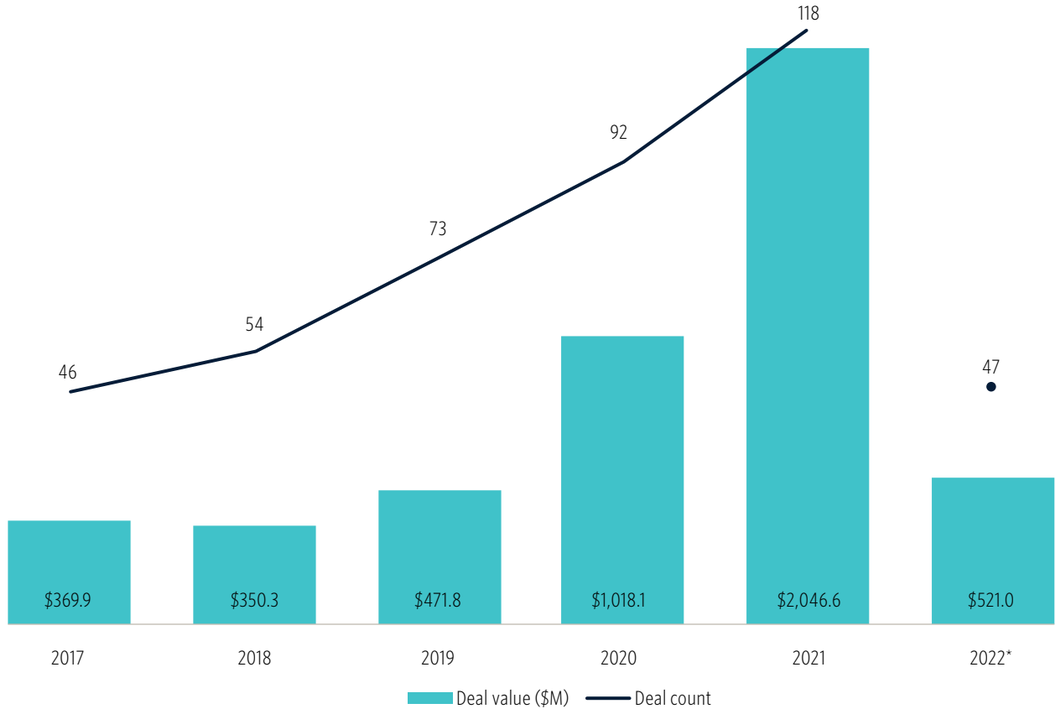
Investment in VC-backed companies in this space has slowed in recent quarters since a peak in mid-2021. Deal count has decreased gradually since Q2 2021 (34 deals) to just 21 Q2 2022 deals, the lowest deal count since Q4 2020. The decrease in deal value relative to Q1 is mostly driven by lower average deal value in Q2, resulting in a total deal value of $159.8 million for Q2 2022 compared to $361.2 million in Q1 2022. Deal values were low in Q2, and no deals above $30 million were seen. Overall, land use deal value was $521.0 million in H1 2022, just over a quarter of FY 2021 deal value ($2.1 billion).

Of the subsegments within land use, ecosystem health & monitoring showed the most consistent VC investment, with $184.5 million in H1 VC funding compared to $270.9 million in FY 2021. Fertilizer alternatives showed much lower total deal value than in recent years but also included the largest Q2 deals in the segment—just with low deal count overall.

Opportunities

Alternative Fertilizers. Beyond carbon capture from conventional ammonia fertilizer production, there are several alternative potential sources of nitrogen-bearing fertilizer. Companies in the space have been developing insect-based fertilizers (a more palatable alternative to insect-based foods), microbial approaches, and waste-to-fertilizer approaches. Some of these approaches have low energy requirements and do not rely on expensive feedstocks, providing some distinct

Land use VC deal activity



Source: PitchBook | Geography: Global | *As of June 30, 2022

advantages over conventional fertilizer production. Switch Bioworks uses a microbial approach, providing dehydrated, modified microbes that produce fertilizers within soil, preventing the possible runoff to which conventionally applied fertilizers are susceptible. Entobel applies an insect fertilizer approach, using the popular option of black soldier flies, which are frequently used for "bioconversion" (conversion of biological matter into useful products) due to their fast and reliable growth and simple nutritional requirements and conditions. Insect-based approaches have additional flexibility in that fertilizers are only one of the potential products they can be used for, with other possibilities such as animal feed production providing an opportunity to either diversify product lines or pivot to more profitable options if needed.

Ecosystem health and monitoring—drone technology. Drone technology has advanced very rapidly, with improvements to range, weight capacity, size, and cost, allowing drones to be used in applications that previously were not viable. Range and weight improvements have been critical to unlocking the potential for drones to be used in ecosystem monitoring applications, enabling drones to cover more ground and hold more capable (heavier) sensors. In addition to monitoring capabilities, drone approaches can be used to improve ecosystem health directly. Flox Robotics uses drones to regularly map geographic areas but also uses an on-board sonic emitter to act as a repellant to protect key assets such as young forest growth or cultivated fields from herbivores and to repel wildlife from areas of high rail or road traffic. Skyseed also uses a drone approach to scan and analyze land and can also be used to distribute seed pellets to replant large areas very quickly, regardless of terrain.

Risks and considerations

Competition for waste. Several companies generating alternative fertilizers use waste matter as a feedstock—often food, agriculture, or manufacturing waste. While this is a viable use for what is otherwise a liability, it is also a somewhat common approach for a variety of products, including chemicals, fuels, and animal feed (including for insect products). This brings the potential competition for what is ultimately a challenging resource to scale—increasing the amount of waste available is only possible to a certain extent (by increasing the percentage of waste that can be utilized) without simply producing more waste. A point could be reached at which waste-to-product approaches become a saturated space, impeding the ability of waste utilizing companies to scale, although some of this would be mitigated by the variation in waste composition preferred by the various waste-to-product approaches.

Competition for green ammonia. Green ammonia presents a potential solution to decarbonizing conventional fertilizer production—one that results in a product with familiar transport and application requirements. Ammonia, though, has been a valuable product in a very wide variety of sectors (including as a chemical feedstock or hydrogen carrier), and thus companies that purchase green ammonia are at-risk of higher prices as demand increases. In the future, it is likely that green ammonia production will be incentivized to scale to meet this demand, but not without delay. A possible response to this risk is for consumers of green ammonia to bring the production in house, although this is not always viable and often includes significant energy inputs.

Higher focus on other decarbonization efforts. Although focus on decarbonization is very high at present, much of the focus is on spaces such as clean energy generation, carbon capture, transport emission reduction, and industrial decarbonization, partly for the high emissions that each sector releases. Next to these industries, protecting existing natural carbon reserves can seem less impactful and thus see lower levels of investment, although there is also strong interest in preserving ecosystems outside their relevance to GHGs.

Key land use VC deals over the past year*

Company	Close date	Subsegment	Stage	Deal size ($M)	Lead investor(s)	Valuation step-up
Pivot Bio	July 19, 2021	Fertilizer alternatives	Series D	$430.0	Temasek Holdings	3.1x
Agronutris	September 30, 2021	Fertilizer alternatives	Late-stage VC	$117.8	N/A	N/A
onX	October 20, 2021	Climate/Earth data	Series B	$87.4	N/A	5.8x
Semios	September 29, 2021	Climate/Earth data	Late-stage VC	$79.0	Morningside Group	N/A

Source: PitchBook | Geography: Global | *As of June 30, 2022

Key land use incumbents*

Company	Subsegment	Holding status	Key products	Enterprise value ($B)
Honeywell	Ecosystem health and monitoring	NAS: HON	Environmental monitoring	$148.3
Teledyne Technologies	Climate/Earth data	NYSE: TDY	Digital imaging, engineered systems	$22.8
Nutrien	Fertilizer alternatives	TSE: NTR	Low-carbon ammonia	$60.1
Wesfarmers	Fertilizer alternatives	ASX: WES	Low-carbon ammonia	$46.2

Source: PitchBook | Geography: Global | *As of June 30, 2022

Appendix

Top VC-backed carbon & emissions tech companies by total VC raised to date*

Company	Total raised to date ($M)	Segment	Subsegment
Northvolt	$6417.0	Industry	Lithium battery recycling
Generate	$3282.1	Carbon tech	Carbon fintech and consumer
Britishvolt	$2518.4	Industry	Manufacturing and chemicals
Enerkem	$989.2	Industry	Manufacturing and chemicals
Redwood Materials	$824.6	Industry	Lithium battery recycling
Climeworks	$786.7	Carbon tech	Direct air capture
Crusoe Energy Systems	$708.1	Carbon tech	Carbon fintech and consumer
Pivot Bio	$691.8	Land use	Fertilizer alternatives
Tado	$668.9	Built environment	Building energy efficiency
Veev	$652.8	Built environment	Green construction

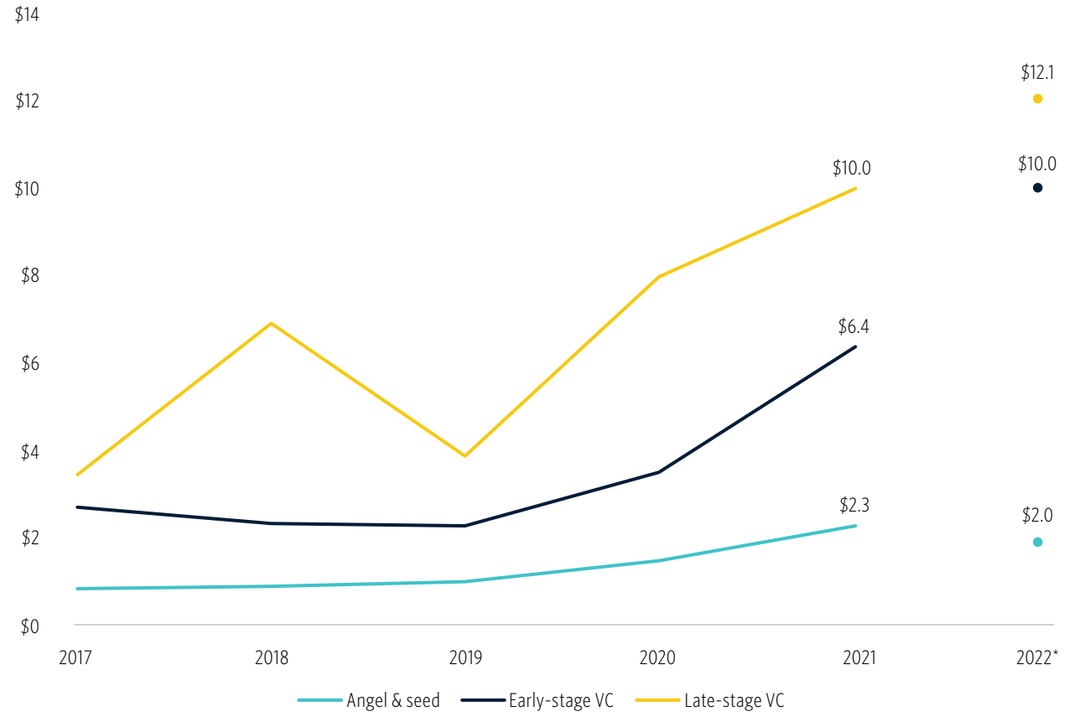
Source: PitchBook | Geography: Global | *As of June 30, 2022

Top VC investors in carbon & emissions tech companies since 2011*

Investor name	Deal count
SOSV	31
Prelude Ventures	30
Cycle Capital Management	28
Enterprise Ireland	25
Keiretsu Forum	23
MCJ Collective	19
Climate Capital	17
Khosla Ventures	17
Clean Energy Ventures	15
Sustainable Development Technology Canada	15

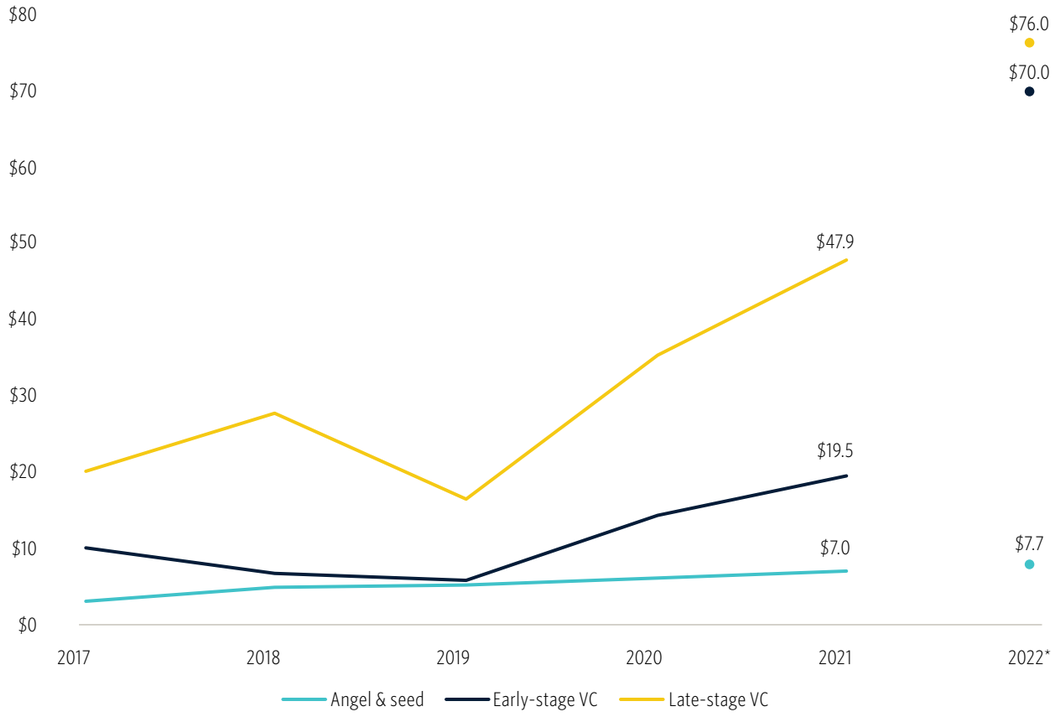
Source: PitchBook | Geography: Global | *As of June 30, 2022

Median carbon & emissions tech VC deal sizes ($M) by stage



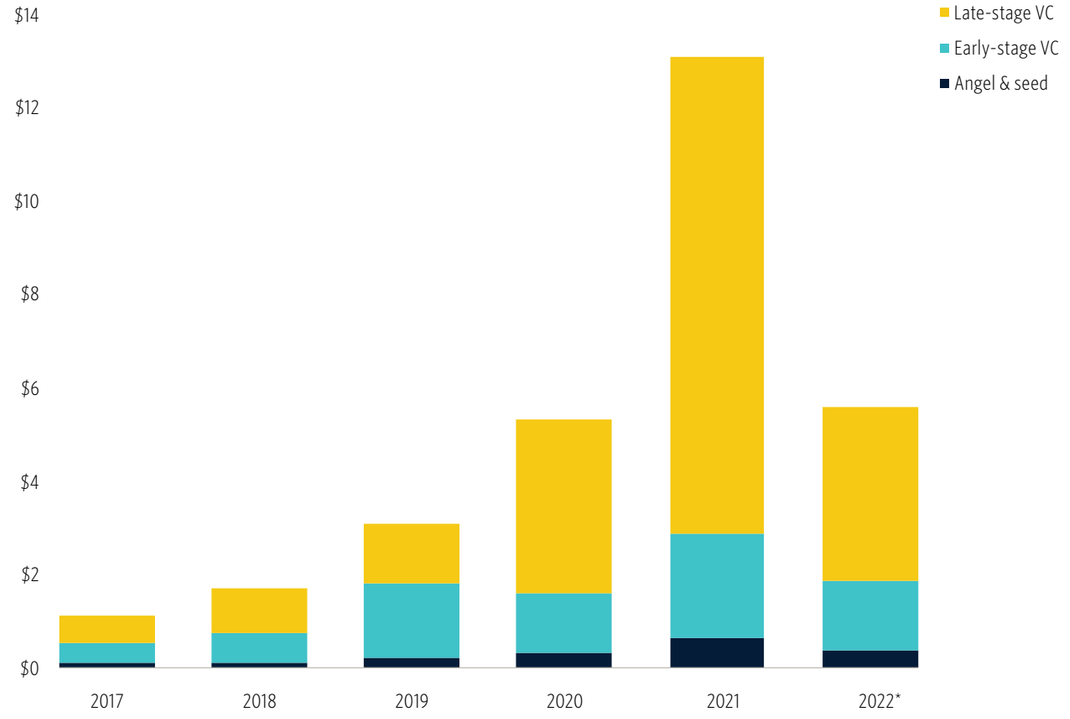
Source: PitchBook | Geography: Global | *As of June 30, 2022

Median carbon & emissions tech pre-money valuations ($M) by stage



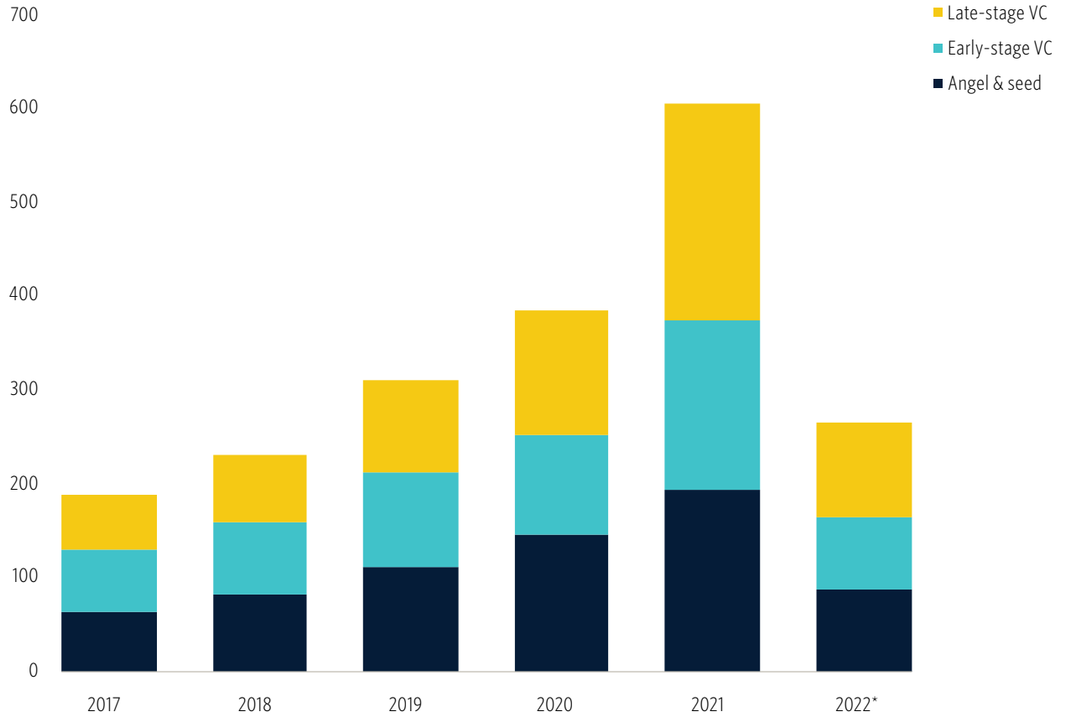
Source: PitchBook | Geography: Global | *As of June 30, 2022

Carbon & emissions tech VC deal value ($B) by stage



Source: PitchBook | Geography: Global | *As of June 30, 2022

Carbon & emissions tech VC deal count by stage



Source: PitchBook | Geography: Global | *As of June 30, 2022

About PitchBook Emerging Tech Research

Independent, objective and timely market intel

As the private markets continue to grow in complexity and competition, it's essential for investors to understand the industries, sectors and companies driving the asset class.

Our Emerging Tech Research provides detailed analysis of nascent tech sectors so you can better navigate the changing markets you operate in—and pursue new opportunities with confidence.

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