PitchBook

EMERGING TECH RESEARCH

Introduction to Climate Tech

A Taxonomy Overview

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Vertical overview

Decarbonizing the planet is a transformational process that won't leave any sector of the economy untouched. To be sure, successfully reducing carbon in the atmosphere presents numerous challenges, but also unprecedented opportunities as the burgeoning climate tech industry attracts entrepreneurs and investors. Key to understanding climate tech is recognizing that it's not a standalone segment of opportunity, but rather a continuous process of reinventing many aspects of modern life and reconstructing entire industries to avoid alarming climate scenarios for future decades. This last point represents another unique feature of the climate tech industry: The fusion of private and public interests—and subsequent levels of adherence to the United Nations' Paris Agreement to limit global temperature increase by 1.5 degree Celsius compared to pre-industrial levels—is likely to be central to its development.

Appetite for climate tech among venture investors is high, with record investments of $30.8 billion poured into startups through Q3 2021. This reflects expanding market opportunities for new and existing climate-related technologies, as well as expectations the industry could give rise to 500 to 1,000 unicorns in the coming years.[1] Economic incentives behind climate finance are mixed, with some predicting that decarbonization could reduce economic output in terms of GDP by more than 20% by 2100, implying the US economy could be as much as 7% smaller in comparison to a world with no climate change.[2] This type of mixed-return potential (for example, saving the environment at the expense of the economy) has given rise to impact and ESG investing strategies and the concept of the "**double bottom line**," where climate objectives may or may not align with economic objectives. Yet, with many lessons learned from the clean tech 1.0 flop a decade ago—and the need for climate saving technologies more dire than ever before—venture capitalists increasingly view the climate tech opportunity as one that can be sustainable, good for the world, and profitable.

1: "The Enormous Challenges and Abundant Oppoortunities in Climate Tech," TechCrunch, Kirsten Korosec, September 27, 2021.
2: "The Economics of Climate Change," Swiss Re Institute, April 22, 2021.

Climate tech versus clean tech 1.0

The roughly $25 billion in venture flowing into clean energy technologies between 2006 and 2011 marked the Clean Tech 1.0 boom that sought to address energy price volatility and reduce global greenhouse gas emissions. Most investments were dedicated to nascent technologies such as thin-film solar, biofuels, and battery technology which needed extensive research and development (R&D) and were largely unable to deliver the anticipated large short-term returns, particularly as advances in fracking technology and China's leap in manufacturing bandwidth resulted in lower energy and solar photovoltaic (PV) prices. With economic incentives effectively curtailed, the industry ground to a sudden halt, and more than half of the money invested was lost. However, despite the failure of this cycle, investments made during Clean Tech 1.0 paved the way for the current climate tech boom.

Factors driving the current clean tech cycle

Climate change has become more apparent and urgent: Extreme weather events have increased over 5x in the last decade and have cost the US more than $1.9 trillion since 1980.[3]

Climate tech is broad and holistic: While clean tech exclusively focused on the energy sector, climate tech is concerned with decarbonizing all sectors.

Advanced technologies creating new opportunities: Since the Clean Tech 1.0 era, the cost for renewable energy sources has declined substantially (for example, the cost of solar PV systems has declined by 71% across residential, commercial-rooftop, and utility-scale PV systems over the last 10 years),[4] and emerging technologies are being applied to energy generation in new ways.

Global climate change policy has progressed: Many countries have committed to a net-zero economy by 2050 as part of the historical Paris Agreement, which puts private markets in a more advantageous place than in the Clean Tech 1.0 era. On a national level, climate policies are more ambitious, with a proposed $1.7 billion allocated to climate change over the next 10 years under the Biden administration.[5] Carbon trading markets and clean energy tax credits are more established and integrated into the economy. A new master plan to tackle climate policy in the European Union is currently undergoing its finalization to stand as one of the most ambitious climate policy agendas globally. The "Fit for 55" plan aims to cut carbon emissions by 55% by 2030 and to reach net zero by 2050 in alignment with the Paris Agreement.

Strong demand for ESG Investing: Institutional investors' demand for ESG has more than doubled over the past five years. Top asset managers such as BlackRock, UBS, and TPG are incorporating ESG rating systems into portfolio management and investment decisions. From 2019 to 2020, new net money invested into funds that are concerned with environmental, social, and governance (ESG) principles has more than doubled to a total of $51.1 billion.[6]

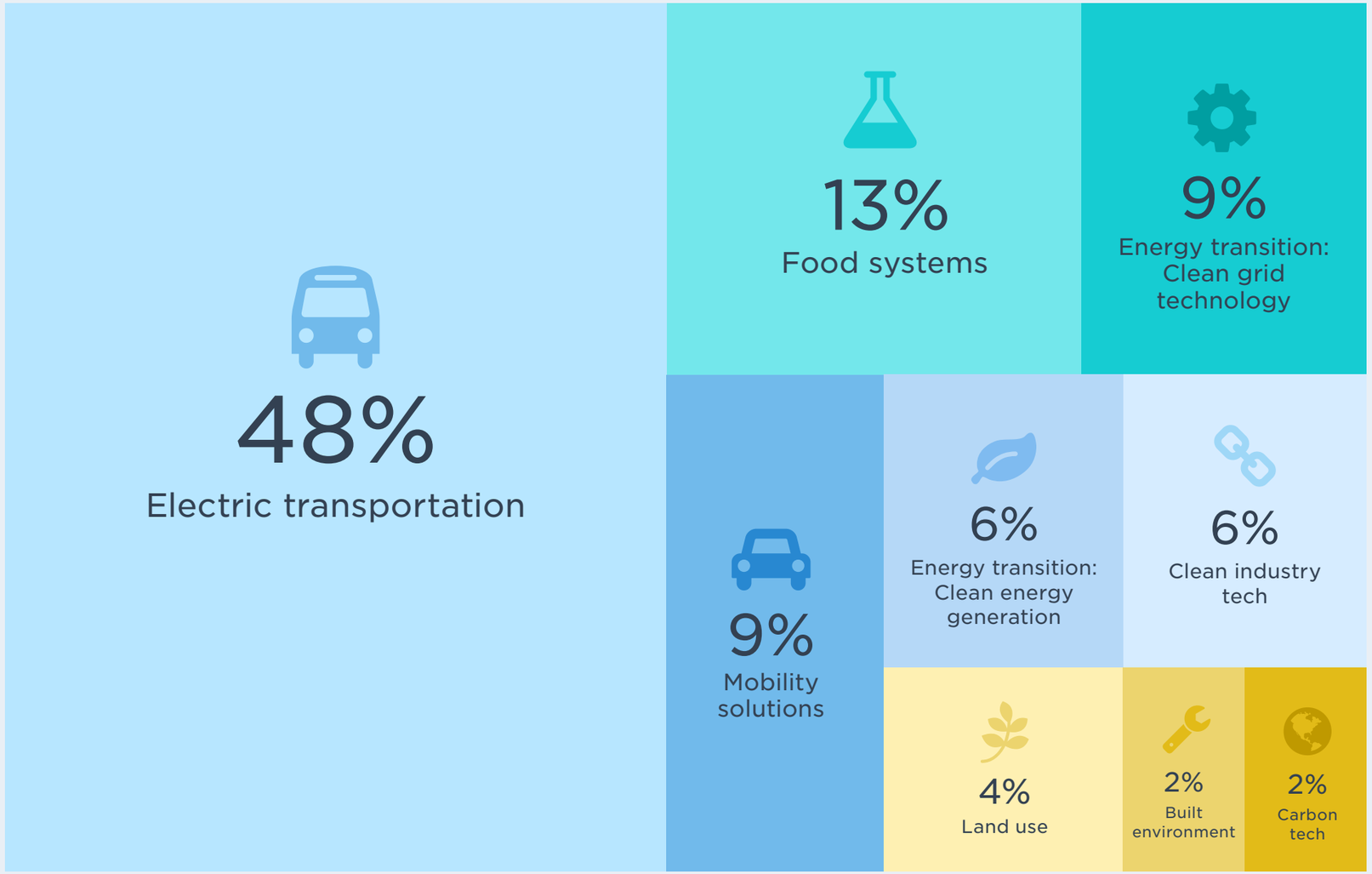
Corporate commitments: To date, more than 200 companies have voluntarily pledged to honor commitments to reach net zero by 2040, (10 years earlier than anticipated by the United Nations) through the **Climate Pledge**.[7]

3: "US Billion-Dollar Weather and Climate Disasters (2021)," NOAA National Centers for Environmental Information, National Oceanic and Atmospheric Administration, 2021.
4: "US Solar Photovoltaic System and Energy Storage Cost Benchmark Q1 2021," National Renewable Energy Laboratory, David Feldman, et al., January 2021.
5: "The Biden Plan for a Clean Energy Revolution and Environmental Justice," Biden Harris Democrats, 2021.
6: "Sustainable Funds US Landscape Report," Morningstar, Jon Hale, February 10, 2021.
7: "Net Zero Carbon by 2040," The Climate Pledge, n.d.

Climate tech taxonomy

As a nascent and somewhat nebulous industry, it can be challenging to draw a hard line between what is and is not climate tech, and we can expect a long-lasting debate to coin the terminology, especially between climate and clean tech. While there is no right or wrong answer, PitchBook's climate tech taxonomy includes any new business model and technology which has a core focus to mitigate the impacts and drivers of global greenhouse gas emissions. We organize the climate tech vertical into nine segments, each with up to six categories.

Climate tech share of VC deal value*



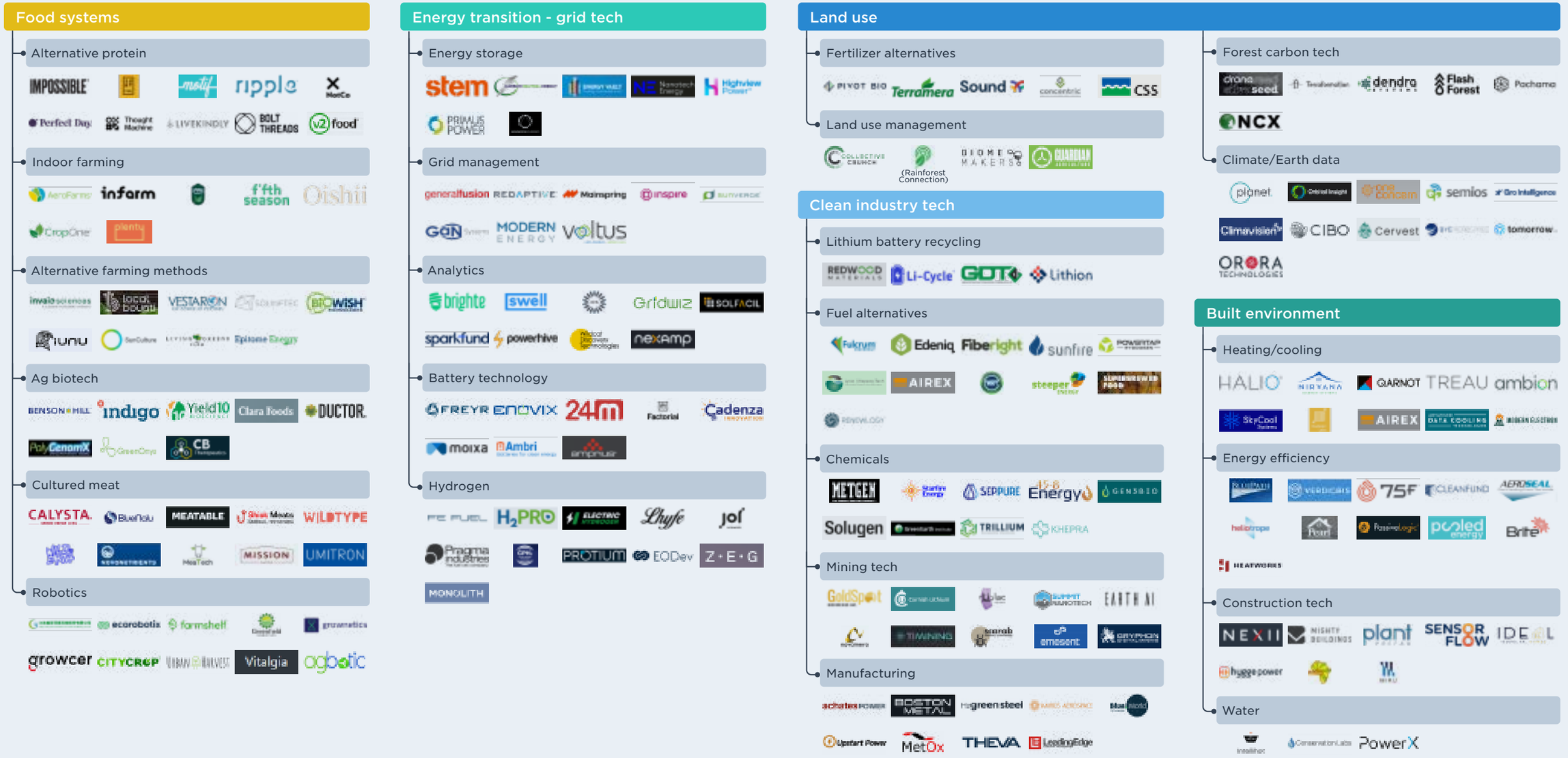
Source: PitchBook | Geography: Global | *As of September 30, 2021

Climate tech VC ecosystem market map

Click to view 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.

CLIMATE TECH VC ECOSYSTEM MARKET MAP



Segment overview

Energy transition: Clean energy generation

Energy transition

Energy transition is one of the major industries that needs to be reconstructed to reach net zero by 2050 as energy consumption is responsible for more than two thirds of global greenhouse gas emissions.[8] We divide energy transition into two smaller segments—clean energy generation and clean grid technology—to provide the most precise data possible and gain better financial insights between the two categories.

Definition

To reduce the climate impact of the energy sector, it is essential to find reliable and affordable ways to generate clean energy from renewable, zero emission, non-polluting sources. Even though mature clean energy technologies are affordable, efficient, and increasingly competitive, fossil-fuel-based electricity and heat energy generation is still responsible for about one-third of global greenhouse gases emissions every year.[9] The main technologies to generate clean energy are solar and wind, while other technologies, especially around generating energy from waste, are emerging. Clean energy generation accounts for around 6% of total climate tech investment in 2021 YTD, the equivalent to $1.9 billion across 103 deals. The top deals are made across solar and nuclear energy, while wind and waste-to-energy deals are gaining more traction.

Disruptive technology: Advanced solar analytics

Solar energy is a major source of clean energy generation and one of the most mature technologies within the segment. Many solar hardware startups have begun to phase out of the VC ecosystem as they are mature enough for traditional investors to provide financing. In a new wave, numerous startups are exploring innovative technologies to further advance solar panels' efficiency and applicability. Several startups focus on automated processes for solar panel installation through 3D modeling, solar design, software, and advanced sensor technology. In particular, advanced analytics will become increasingly important as the clean electricity grid expands. As solar plants generate vast amounts of real-time data, artificial intelligence (AI) can advance predicting capacity levels and improve the accuracy of solar forecasting by 30%.[10]

Categories

Solar

Solar energy is one of the two major sources of clean energy generation, and the technology has reached relative maturity. The solar market is predicted to quadruple in the US over the next decade.[11] Emerging technologies in this segment include improved solar panel technologies (for example, solar panel robotics), automated solar panel installation, and solar financing. Startups are also working to utilize AI to increase performance in solar power systems.

Wind

Wind energy is the second major source of clean energy generation and has reached relative maturity in the market. Wind energy refers the process of creating electricity using the wind or air flows that occur naturally in the earth's atmosphere. Emerging technologies in the space include offshore floating wind concepts, smart rotors that can adjust themselves to non-homogeneous wind flow.

8: "4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors," World Resources Institute, Mengpin Ge, et al., February 6, 2020.
9: Ibid.
10: "The SunShot Initiative," Solar Energy Technologies Office, Office of Efficiency and Renewable Energy, n.d.
11: "US Solar Market Insight," Wood Mackenzie, 2021.

ENERGY TRANSITION: CLEAN ENERGY GENERATION

Nuclear

Even though it is the second largest source of low-carbon electricity today, providing 10% of global electricity supply,[12] nuclear is seen as controversial and often gets left out of the "clean energy" conversation due to safety issues and unresolved questions about permanent nuclear waste storage. Nuclear energy can provide a safe and clean alternative through either fission or fusion energy. Fission technology is the splitting of a heavy, unstable nucleus into two lighter nuclei, while fusion technology is the process where two nuclei fuse to produce energy. Emerging technologies in the segment are small modular and microreactors, while fast neutron reactors that operate through closed nuclear fuel cycles are seeing a comeback as they can increase efficiency of nuclear energy while decreasing radioactive waste.

Waste-to-energy

Waste-to-energy (WtE), or energy-from-waste, is the process of generating energy in the form of electricity and/or heat from the primary treatment of waste. Waste-to-energy technologies include thermal processes such as mass-burn incineration and gasification along with nonthermal processes such as anaerobic digestion or landfill-gas recovery.

Ocean and hydro

Ocean energy is power produced by the surge of ocean waters during the rise and fall of tides, while hydro energy uses the power of moving water to generate electricity. Emerging technologies in ocean energy include wave energy converters to generate power from surface waves, tidal energy converters to generate power from the movement of tidal currents, and ocean thermal energy converters to generate power from thermal differences between warm surface seawater and cold deep seawater. Ocean energy has the potential to power offshore activities and remote islands or coastal regions.

Geo-thermal energy

Thermal energy refers to the energy derived from heat flows in various settings. Traditionally, geothermal technology has used the heat from the earth's crust to generate electricity. Now, geothermal plants must be situated in locations where hot water is trapped under the surface to pump the hot water to the surface to collect heat. Emerging technologies in the segment use advanced mapping to find geothermal activity and carbon dioxide (CO_2). For example, Plume Geothermal uses a novel technology that simultaneously collects heat and stores CO_2 underground.

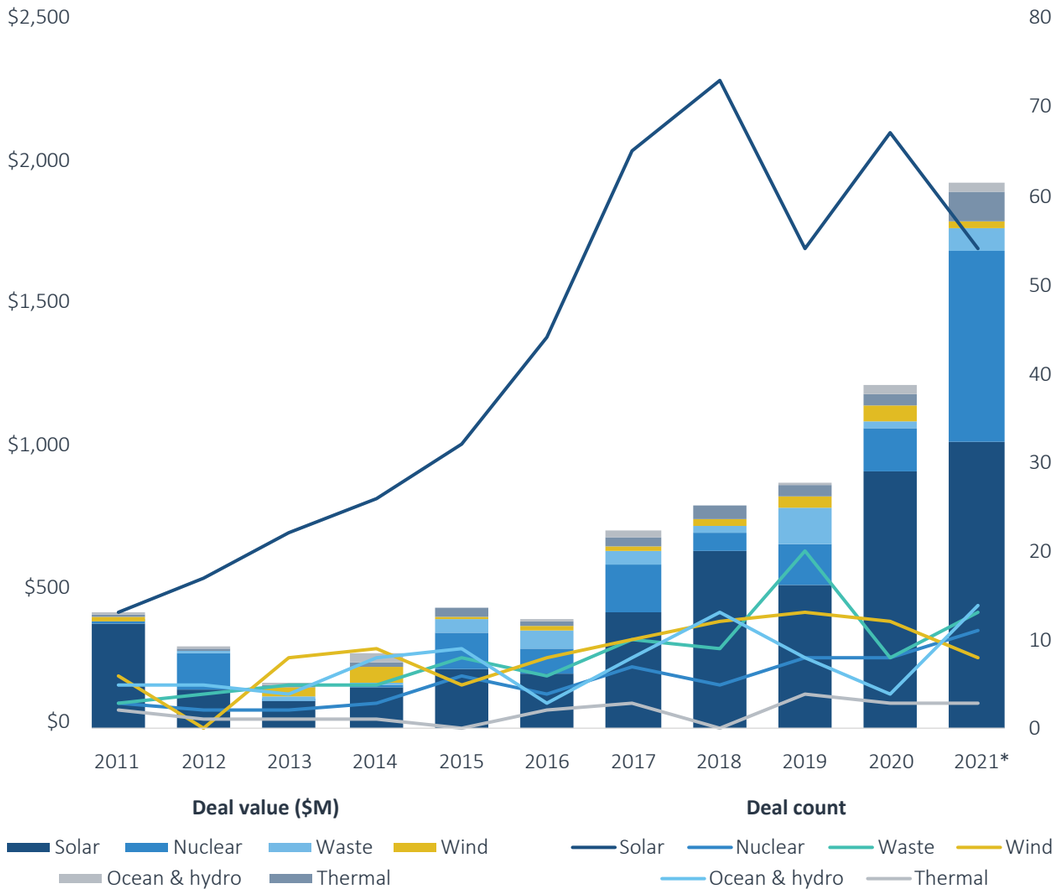
VC activity

VC activity into clean energy generation continued to grow in 2021. Startups in clean energy generation raised $1.9 billion in VC investment across 103 deals through Q3 2021, an increase of 58.8% YTD in comparison to 2020 total investments. As in previous years, solar and wind companies received most VC investment. VC investments into early- and late-stage clean energy generation startups increased in 2021 compared with 2020 from $134.0 million to $189.4 million and $1.0 billion to $1.7 billion, respectively. Consistent over the years, more than half of the deals—54 deals—took place in solar, accounting for 52.4% of the funding in this category ($1.0 billion). Nuclear energy raised 35.2% of 2021 YTD funding, followed by waste and wind with 3.9% and 1.5%, respectively.

12: "Nuclear Power in a Clean Energy System," International Energy Agency, May 2019.

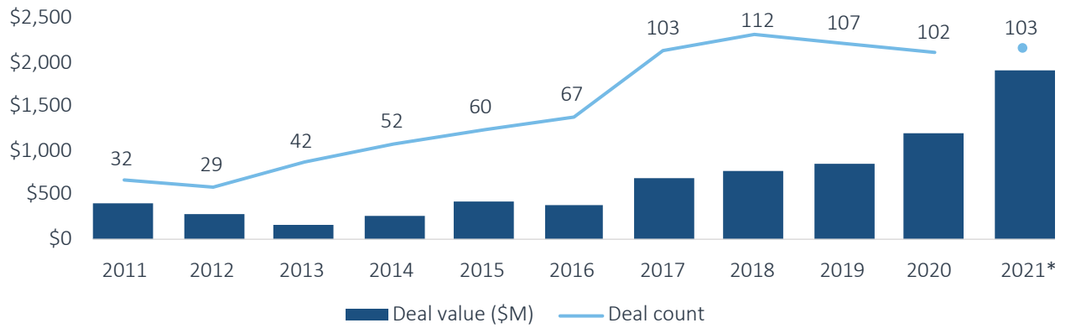
ENERGY TRANSITION: CLEAN ENERGY GENERATION

Figure 1. CLEAN ENERGY GENERATION VC DEAL ACTIVITY BY CATEGORY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 2. CLEAN ENERGY GENERATION VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 3.

Key clean energy generation startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
TAE Technologies	Nuclear	1998	$1,094.8
Aurora Solar	Solar	2013	$323.7
Solaria	Solar	2000	$303.7
Sunseap	Solar	2011	$285.5
NuScale	Nuclear	2007	$245.2

Source: PitchBook | Geography: Global | *As of September 30, 2021

Energy transition: Clean grid technology

Definition

Clean grid technology is the second component of energy transition. Grid technology is essential to reaching a clean energy grid, which relies on transmission lines and smart grid technologies. To successfully develop utility-scale solar power projects, for example, access to high-voltage transmission lines is key to move power from the project site to the consumer. Smart grid technologies include devices and controlling systems that deliver and utilize digital information to optimize the delivery efficiency, reliability, and security of renewable power. Hardware such as long-duration energy storage and battery technology are also key components of this segment.

Key growth drivers

- Supportive political frameworks
- Demand driven
- Improved technologies for energy transmission and storage

Disruptive technologies

Efficient, long-duration energy storage is a significant bottleneck in clean grid technology, yet it is necessary for the year-long supply of renewable energy and the replacement of mid-range and fossil fuel power plants. Sodium-based energy storage systems that substitute fossil baseload generation with renewable energy could present a cost-effective multi-day energy storage technology. Grid management and analytics have become essential for clean energy grids, particularly energy storage. We have seen the highest growth in VC deals in energy storage, reflecting the challenges inherent to providing the grid with consistent energy amid variabilities in energy generation. Two major deals in the segment include a $200.0 million Series D raised by **Form Energy**, a developer of sodium-based energy storage. The deal was led by ArcelorMittal and Breakthrough Energy Ventures and valued the company at $1.1 billion. **SVOLT**, a developer and manufacturer of electric batteries, raised a $1.6 billion Series B, attaining a valuation of $5.0 billion. (For more information on **Form Energy**, see our **Q3 2021 Climate Tech VC Update**)

Categories

Energy storage

Low-carbon grids need long-duration storage, and startups are developing several technologies to meet the demand for growing renewable energy storage—especially from wind and solar. These include pumped hydro, stacked blocks, liquid air, underground compressed air, and flow batteries.

Grid management

Smart grid management systems are essential for modernized and low-carbon grids to provide solutions that address the increasingly complex distribution environment of renewable electricity. Startups in this category work on technologies including devices and controlling systems that deliver and utilize digital information to optimize the efficiency, reliability, and security of renewable power. VC investment has almost tripled since 2018, from $209.0 million to $606.0 million.

ENERGY TRANSITION: CLEAN GRID TECHNOLOGY

Analytics

Startups in this category develop software solutions to optimize and accelerate the performance of low-carbon grids, including cloud-based intelligence and analytics platforms, energy consultancy services, data modeling, and ultra-high-density smart grid technology. VC employed in this category has increased by 266.3% since 2018 and is expected to gain further traction through applications such as AI and Big Data management.

Battery technology

The expansion of electricity generated from renewable resources in the supply matrix has driven the clean energy transition. Unlike fuels, this type of energy expires, and temporal balancing has become a significant challenge. Based on the Sustainable Development Scenario (SDS) of the International Energy Agency (IEA), nearly 10,000 GWh battery storage will be required across the grid annually by 2040—the current capacity is limited to 200 GWh.[13] This is a major technology gap, and considerable progress is needed to store large quantities of electricity at a competitive price. Technologies in this category focus specifically on battery technologies designed to improve the operational reliability, economics, and efficiency of electric power systems, as opposed to battery packs for automotive applications.

Clean hydrogen

Clean hydrogen technology intends to eliminate harmful emissions produced by carbon-based technologies; however, around 76% of hydrogen is currently produced from natural gas, and the remainder of 23% almost entirely from coal. Hydrogen generated from water (electrolysis) makes up 2% of global hydrogen production while hydrogen from renewable energy sources is currently being deployed on a small scale, mainly in European countries. Through further advancing clean hydrogen technologies, various clean energy challenges can be addressed by decarbonizing sectors such long-haul transport, chemicals, and iron and steel. Clean hydrogen can also strengthen energy security and increase flexibility in clean power systems. The **Q3 2021 Climate Tech VC Update** analyzes the novel technology of turquoise hydrogen as an emerging opportunity.

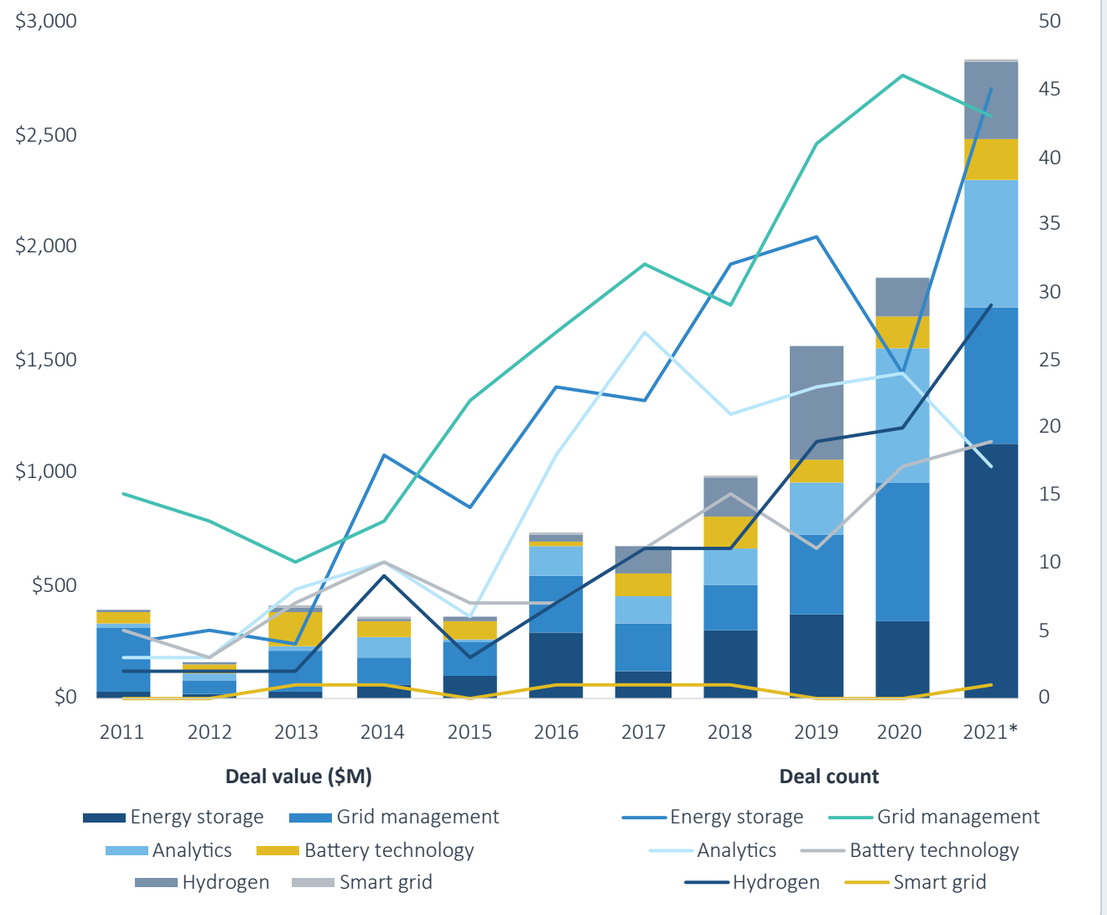
VC activity

VC activity into clean grid technology has skyrocketed in 2021 to $2.8 billion in VC investment across 148 deals YTD, an increase of 50.7% investment value in comparison to 2020. As in previous years, grid management technology has received consistent funding, while the energy storage subsegment has seen the highest increase in proportion of VC invested in the space, from 18.2% to 40.2% of total VC invested in grid technology from 2020 to 2021, respectively. Total deal values for angel & seed, early-stage, and late-stage clean grid technology startups have increased in 2021 from $70.3 million to $75.6 million, $375.0 million to $520.7 million, and $1.4 billion to $2.2 billion, respectively.

13: "Innovation in Batteries and Electricity Storage," International Energy Agency and the European Patent Office, September 2020.

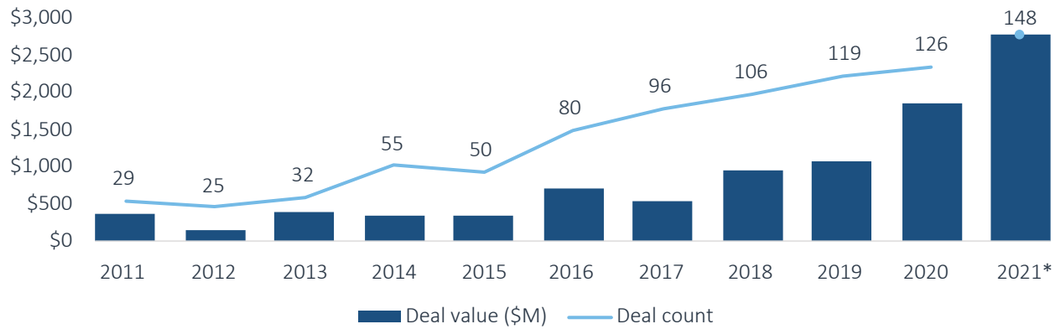
ENERGY TRANSITION: CLEAN GRID TECHNOLOGY

Figure 4. **GRID TECH VC DEAL ACTIVITY BY CATEGORY**



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 5. **GRID TECH VC DEAL ACTIVITY**



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 6.

Key grid technology startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
Swell	Analytics	2014	$468.0
Form Energy	Energy storage	2017	$366.0
Stem	Energy storage	2009	$345.3
Monolith Materials	Hydrogen	2012	$325.0
Energy Vault	Energy storage	2017	$288.2

Source: PitchBook | Geography: Global | *As of September 30, 2021

Electric transportation

Definition

Transportation has been a fast-growing and major contributor to global carbon emissions, with an increase of 79% since 1990.[14] Accounting for 16.2% of global carbon emissions,[15] electrifying transportation has been a favored tool to tackle climate change. Electric transportation technology has received around 50% of total climate tech VC funding through Q3 2021. The segment includes software and hardware solutions for electric road vehicles, electric aviation solutions, and electric maritime vessels, along with the supporting infrastructure such as charging stations and battery technology. In 2020, more than 2 million electric vehicles populated US roads, while more than 50 electric vehicle models are available today. Around 140 models are expected by 2024, and the market is expected to grow as electric vehicle infrastructure expands.[16]

Key growth drivers

- Ongoing OEM investment
- Improving technology and affordability
- Favorable regulations and scale

Disruptive technologies

Electric mobility adoption is growing fast, with 18.7 million electric vehicles expected on the road by 2030,[17] making it necessary to drastically expand the electric vehicle charging infrastructure through technological innovation and multiple charging scenarios. Statistically, the average car is parked for around 95% of the time,[18] which makes cars a promising resource for decentralized energy storage without added operating costs. Vehicle to grid charging (V2G) is a novel technology that allows for a bidirectional exchange between the vehicle and the grid. Through this two-way exchange, energy stored in electric vehicles can be pulled back into the grid when the demand peaks and stress loads on the grid are high. This helps optimize grids by leveraging millions of electric vehicles as decentralized energy storage. Several startups have pushed through the R&D phase in this area—such as Fermata Energy, Nuvve, and Connect California—and the technology is ready to scale.

Categories

Electric aviation

Prior to the COVID-19 pandemic, air travel accounted for 2.5 % of global carbon emissions,[19] a number that could triple by 2050. To reduce carbon emissions in this sector, the nascent electric aviation space provides a novel alternative. VC activity in this category grew to 5.4% of total investment in 2021 YTD—accounting for $801.3 million.

Road consumer (Passenger travel)

Road travel—consumer and commercial—accounts for about 75% of total transportation emissions, while passenger travel is responsible for about 60% of all road transport emissions.[20] The number of electric vehicles in the US is expected to more than triple between 2016 and 2020—from 300,000

14: "4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors," World Resources Institute, Mengpin Ge, et al., Februrary 6, 2020.
15: "Emissions by Sector" CO2 and Greenhouse Gas Emissions, Our World in Data, Hannah Ritchie and Max Roser, 2020.
16: "Electric Transportation," Edison Electric Institute, n.d.
17: Ibid.

18: "95% of a Car's Lifetime is Spent Parked," Milita Technology, November 20, 2017.
19: "Climate Change and Flying: What Share of Global CO2 Emissions Come From Aviation?" Our World in Data, Hannah Ritchie, October 22, 2020.
20: "Emissions by Sector" CO2 and Greenhouse Gas Emissions, Our World in Data, Hannah Ritchie and Max Roser, 2020.

to 1.1 million—and by 2030, there may be close to 19 million electric vehicles on the road.[21] Companies in this category develop scalable electric road vehicles to meet growing customer demands, needs, and budgets.

Road industry (Freight)

Road freight transport is responsible for around 40% of road transportation emissions which is why fleet and truck electrification becomes more important as corporations pledge to go carbon neutral by 2050 or earlier. Road industry refers to electric trucking, electric hauling, electric buses, and electric fleet solutions with relatively stable investments of $338.5 and $338.3 million in 2020 and 2021 YTD, respectively.

Electric maritime vessels

The carbon footprint produced by the international shipping industry amounts to about 940 million tons of CO2 per year,[22] which accounted for approximately 2.5% of global GHG emissions in 2020.[23] Alternatives are electric vessels powered by lithium-ion batteries with capacities of up to 50,000kWh. Those are novel technologies, and investors have been supportive over the past two years with a total of around $75 million in VC across five deals.

Electric vehicle infrastructure

Electric infrastructure will be necessary to support the growth of electric road transport. This category includes electric vehicle charging stations and software infrastructure to support the increasing demand for battery charging. The growing market share of electric vehicles is expected to further drive the expansion of the electric vehicle charging infrastructure market. Other growth drivers include increased investments from car manufacturers into charging infrastructure and related technologies such as radio frequency identification and near-field communication (NFC), which allow for self-operated charging stations.

Electric vehicle battery tech

After electric vehicle infrastructure, electric vehicle battery tech is the second largest category in the electric transportation space. Demand for lithium-ion batteries is expected to grow 1,700% by 2030[24] in response to the electrification of the grid and transportation system. Innovative startups in this category focus on technologies to advance cell components through novel electrolyte formulations, electrode architectures, or chemical composition to improve performance. Investments employed in this category have grown exponentially since 2018, from $1.1 billion to $6.1 billion in 2021 YTD.

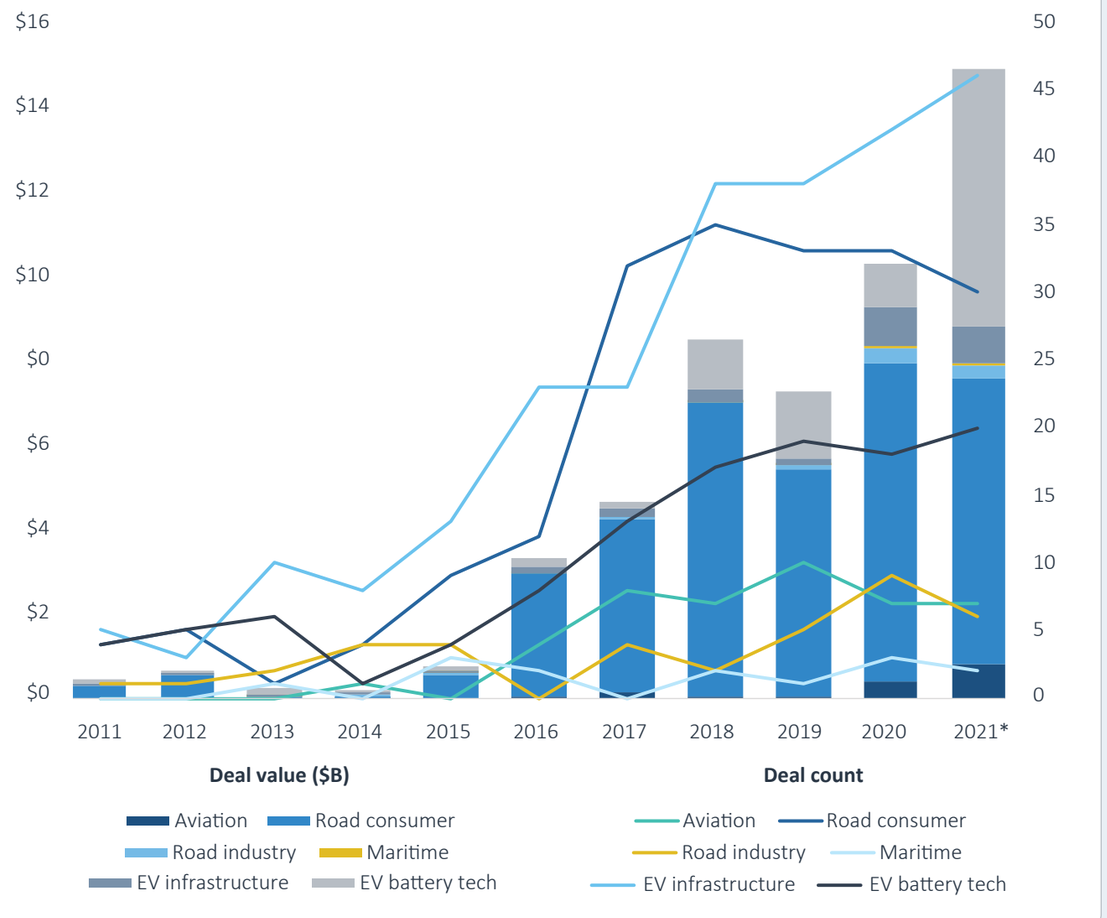
VC activity

VC activity into electric transportation continued to dominate in 2021, with startups raising almost 50% of all VC invested in climate tech: $14.9 billion across 111 deals through Q3—44.6% more investment value YTD than in 2020. Following the trend of previous years, consumer road vehicles received the most funding, while the electric aviation space almost doubled from $ 415.5 million in 2020 to $801.3 million in 2021. Battery tech put up the strongest numbers, increasing VC funding by 485%, from $1.0 billion to $6.1 billion. Total deal values of angel & seed startups decreased from $67.4 million in 2020 to $62.5 million in 2021 YTD. Both, early- and late-stage VC have already exceeded 2020 investments by 132.7% and 32.7%, respectively.

21: "EEI Celebrates 1 Million Electric Vehicles on US Roads," Edison Electric Institute, November 30, 2018.
22: "CO2 Emissions Reduction Measures for RO-RO Vessels on Non-Profitable Coastal Liner Passenger Transport," MDPI, Sandro Vidas, et al., 2021.
23: Ibid.
24: "This is the Drawing Age of the Battery," Bloomberg, Nathaniel Bullard, December 17, 2020.

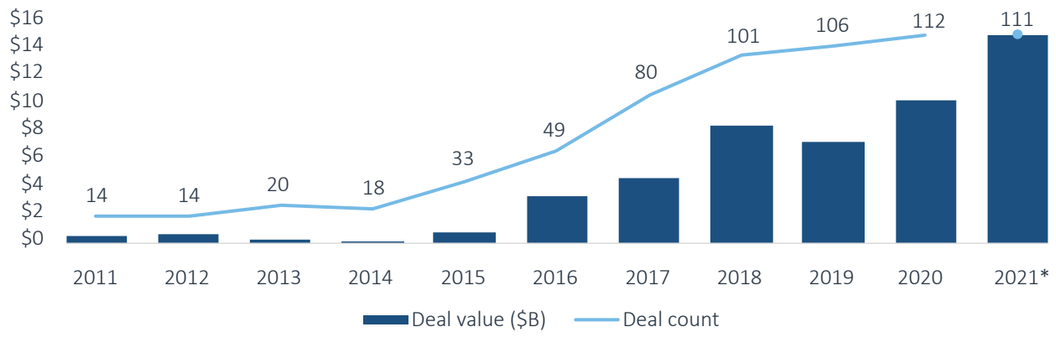
ELECTRIC TRANSPORTATION

Figure 7. ELECTRIC TRANSPORTATION VC DEAL ACTIVITY BY CATEGORY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 8. ELECTRIC TRANSPORTATION VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 9.

Key electric transportation startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
Rivian	Road consumer	2009	$8,951.3
Northvolt	EV battery tech	2016	$4,410.1
Weltmeister	Road consumer	2012	$3,915.5
SVOLT	EV battery tech	2018	$2,268.9
Enovate Motors	Road consumer	2015	$1,409.9

Source: PitchBook | Geography: Global | *As of September 30, 2021

Mobility solutions

Definition

While revenue streams from transportation are set to grow significantly, they will also diversify toward mobility solutions such as on-demand mobility, analytics, and data services, adding a 30% revenue potential—up to $1.5 trillion.[25]

Technologies that decarbonize transport through efficiency and decentralized ownership, such as transit infrastructure, multi-modal usage, shared mobility, clean hydrogen, and electric micro mobility solutions, will transition the car into a shared good, and shared-mobility solutions are expected to grow by more than 20% through 2030.[26]

Key growth drivers

- Growing urbanization
- Traffic congestion driving inefficiency
- Growing shared mobility infrastructure

Disruptive technologies

As a result of the increasing number of internet of things (IoT) sensors on vehicles, data volumes from bus schedules, speed, passenger numbers, environmental conditions, and traffic congestion are increasing as well. This data can help maximize capacity and accessibility as well as provide opportunities for other analytics. Solutions to these data challenges include machine learning (ML), which has grown tremendously across most sectors, and quantum computing. The latter is well suited for data problems that are too complex for conventional computers to solve, such as route planning in public transport. As demand-responsive services gain traction to decarbonize mobility, traditional binary computing is unlikely to meet the demand for real-time optimized scheduling for a growing number of first-mile and last-mile pickups and drop-offs. Quantum computing offers a way to generate data outside of a binary model and has the potential to solve complex data queries such as point-to-point journeys across an entire city.[27] Quantum computers are already operated by large software providers, and we expect transport operators will be able to leverage quantum computing to optimize route planning within the next few years.

Categories

Shared mobility

Shared mobility includes ridesharing, often via a mobile app or software for personal use. Especially in urban areas, shared mobility has achieved widespread adoption as it solves the cost and convenience issues around individual car ownership. A recent OECD study estimates that a reasonable utilization of shared mobility services can decrease 6.3% of urban passenger transport emissions by the end of 2050 across 247 cities.[28] However, shared mobility services, such as ridehailing providers, must invest in fleet electrification and incentivize customers to take pooled rides. While shared mobility services accounted for only 9.6% of investment value in 2020, that share has risen to 23.4% in 2021 YTD.

25: “Automotive Revolution—Perspective Towards 2030,” McKinsey & Company, Paul Gao, et al., January 2016.
26: “Shared Mobility,” McKinsey Center for Future Mobility, McKinsey & Company, n.d.

27: “The Transport Network of Tomorrow,” Trapeze Group, n.d.
28: “Exploring the Impact of Shared Mobility Services on CO2,” Environment Working Papers, OECD Publishing, Ioannis Tikoudis et al., 2021.

MOBILITY SOLUTIONS

Autonomous cars

On their own, autonomous cars will not significantly reduce transport-related carbon emissions. However, shared electric autonomous transportation has the potential to reduce the amount of vehicle CO2 emissions by 50%, cut global energy use from passenger transportation by 70%, and cut transportation operation system costs by more than 40% by 2050.[29]

Autonomous vehicle technology refers to software and hardware solutions that enable self-driving or driver assistance for cars, trucks, and other vehicles with the potential to reduce emissions through efficiency. (Link paper Asad)

Smart infrastructure

The sustainability of cities plays a major role in meeting climate targets. According to the UNDP, urban spaces are responsible for 70% of GHG emissions, and 28% of the global population will be concentrated in cities with more than a million inhabitants by 2030. Making infrastructure and logistics more efficient through smart solutions will be key in reducing emissions. With mainly software solutions—such as big data system analysis and artificial intelligence technologies to make delivery processes, route planning, and other logistical processes more efficient—this category is diverse and consistent over the past four years, with around $30 million of investment annually.

Clean hydrogen

Hydrogen is a clean fuel that produces electricity when water combines with oxygen in a fuel cell, leaving only water and heat as byproducts. Hydrogen's many colors result from the inputs used, such as natural gas, nuclear power, biomass, and renewable power such as solar and wind. Clean hydrogen usually refers to the solar and wind varieties. The potential to produce carbon-neutral hydrogen makes it an attractive fuel option and input for transportation, electricity generation, and industrial applications, such as in trucks, buildings, and manufacturing.

Clean hydrogen transportation refers to software and hardware solutions around hydrogen mobility infrastructure. Investments in this category have been unsteady, but recent policy initiatives and maturing technologies are promising for the future of clean hydrogen-fueled transportation.

Micromobility

Micromobility has been exponentially growing in the urban transport sector, addressing the "last-mile" problem for personal transportation through light electric vehicles, such as e-bikes, and the fastest-growing mode of transport in history: electric scooters.[30,31] Technologies in this category are in different stages of development and include hardware and software innovations, vehicle suppliers, shared platforms, and enablement technologies.

VC activity

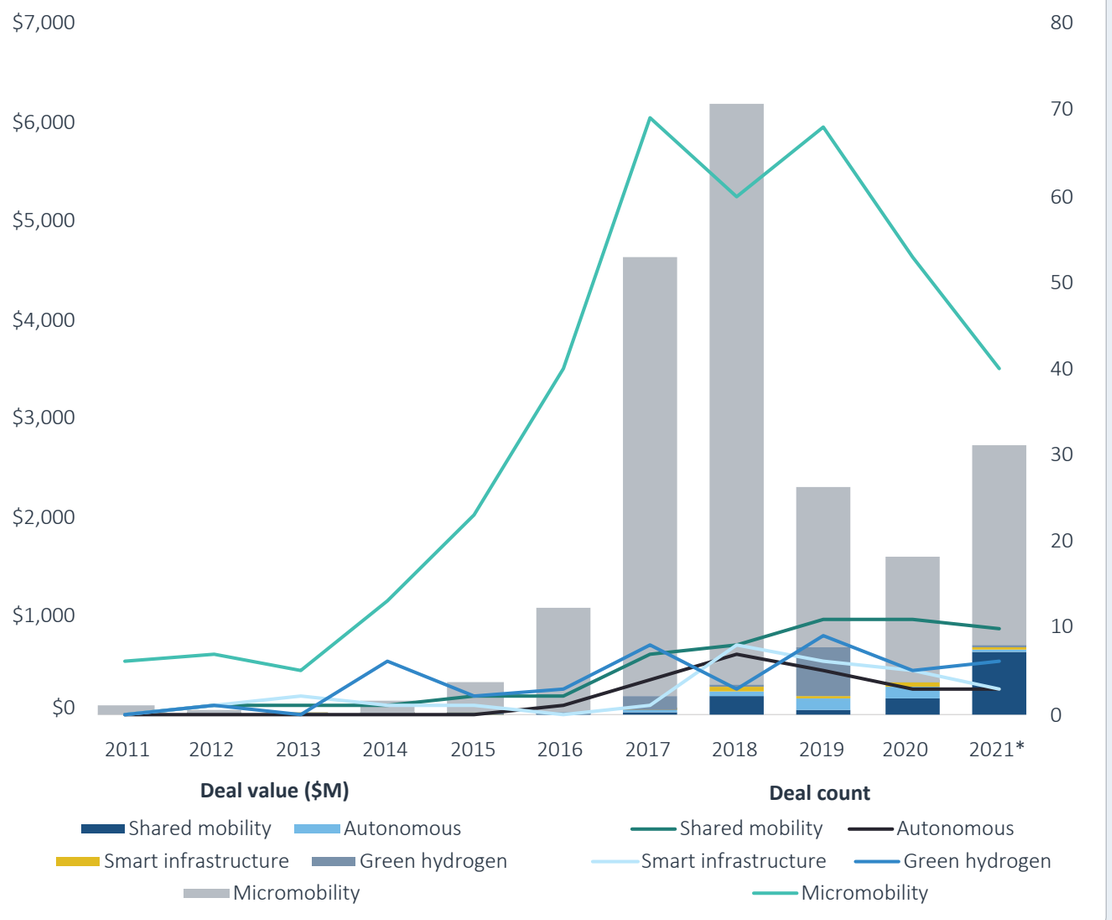
VC investment values in mobility solutions grew for the first time since 2018 by 71.8% between 2020 to 2021 YTD. Startups in mobility solutions raised $2.7 billion in VC across 62 deals in through Q3 2021. Just as in previous years, autonomous driving technology received the most funding in the space, while shared mobility almost quadrupled from $152.3 million in 2020 to $636.7 million in Q3 2021. Total VC investments for angel & seed startups decreased in 2021 from $48.7 million in 2020 to $18.8 million in 2021 YTD. However, capital raised by early- and late-stage VC already exceeded 2020 amounts by 34.2% and 114.6%, respectively.

29: "You Say You Want a Transportation Revolution? How about Three of Them?" Science & Climate, Kat Kerlin, May 2, 2017.

30: "How Micromobility is Moving Cities into a Sustainable Future," EY, Martin Cardell and Thomas Holm Moller, August 14, 2020.
31: "Micromobility: Moving Cities to a More Sustainable Future," EY, August 2020.

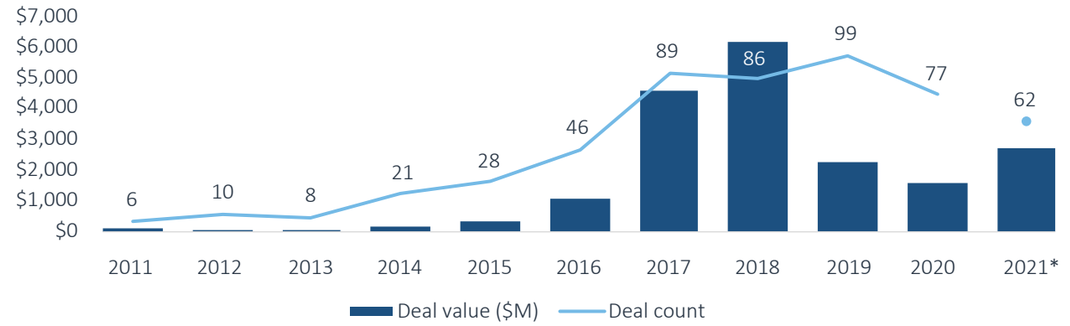
MOBILITY SOLUTIONS

Figure 10. MOBILITY SOLUTIONS VC DEAL ACTIVITY BY CATEGORY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 11. MOBILITY SOLUTIONS VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 12.

Key mobility solutions startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
BAIC BJEV	Micromobility	2009	$2,112.2
Youxia Motors	Micromobility	2014	$1,326.5
Caocao Mobility	Micromobility	2015	$739.7
OLA Electric	Micromobility	2017	$622.2
Voi	Micromobility	2018	$404.0

Source: PitchBook | Geography: Global | *As of September 30, 2021

Food systems

Definition

Food systems account for approximately 20% to 30% of global emissions[32]—with an anticipated steep upward trend given that the global population is predicted to grow 25% by 2050.[33] More people means an inevitable need to transport more food, which will invariably increase carbon emissions if this industry is not transformed through climate innovation. Startups in the food systems space focus on emerging technologies to decarbonize agriculture and food supply through efficiency, protein alternatives, and farming methods that reduce the carbon footprint of agricultural practices. This segment is the second-largest category in the climate tech ecosystem, with $4.1 billion in total investment in 2021 YTD—13.2% of the total VC through Q3 2021. Alternative protein and indoor farming make up a large proportion of investment. Deal count in these two subsegments has risen steeply from just 12 in 2011 to 173 in 2021 YTD.

Key growth drivers

- Improving technologies and affordability
- Favorable regulations
- Informed consumer choices

Disruptive technologies

Monocropping and climate change both negatively impact soil health in ways that can negatively impact productivity over the long term. Growing the same crop repeatedly on the same land, combined with increased heat and drought due to climate change, can decrease the number of beneficial microbes in the soil and increase susceptibility to soil pathogens. Ag biotech plays a major role in improving soil health and plant resiliency. (Our Q3 2021 Climate Tech VC update dives deeper into this technology, highlighting the startup **Avalo** and its approach to AI-powered genome analysis.)

Categories

Alternative proteins

Alternative proteins encompass meat, seafood, dairy, and egg products that are synthesized in factories from plants, animal cells, microbes, or fungi. Alternative proteins are a $290 billion market and will potentially cover approximately 11% of global protein consumption in 2035, with the prospective to reach around 22% through novel technologies and supportive policy regulations.[34] Reaching these market shares can significantly contribute to a more sustainable food system. In recent years, VC investment has surged, with record deal investments of $2.4 billion in 2021 YTD.

Cultivated protein

Cultivated protein refers to meat (terrestrial), seafood (marine), dairy, and egg products manufactured by growing live animal cells in labs rather than through slaughtering, harvesting, and fishing. Cultivated protein has emerged as a field of synthetic biology that aims to develop viable food alternatives to the traditional, live-animal-based meat and dairy production industry.

32: "The Food System and Climate Change," Princeton Student Climate Initiative, Audrey Watson, March 23, 2020.
33: "World Population to Reach 9.9 Billion by 2050," SDG Knowledge Hub, IISD, August 6, 2020.

34: "Food for Thought: The Protein Transformation," BCG, Ben Morach et al., March 24, 2021.

FOOD SYSTEMS

Early regulatory approval for some cultivated meat products continues to drive investments into this emerging industry. In recent years, VC investment has spiked, with a record $668.3 million raised in 2021 to date.

Indoor farming

Indoor farming offers an attractive alternative to conventional outdoor farming due to more efficient use of natural resources. By bringing farming operations indoors, farmers can utilize water-efficient growing methods such as hydroponics and aeroponics. In addition, indoor farming more easily adapts to worsening climate change effects such as extreme weather events and water scarcity. Over the past three years, VC investment has grown, with a record $706.1 million in deal value in 2021 YTD.

Alternative farming methods

This category includes farming methods that challenge the status quo of traditional farming and reduce the carbon footprint through efficiency or innovation such as digital agricultural services, smart irrigation systems, efficient lighting technologies, 3D-printed growing kits, and supplements to cut methane emission from animal livestock.

Ag biotech

Ag biotech plays a crucial role in mitigating climate change and adaptation challenges in our food system. Plant biotech focuses on biological or chemical products such as custom plants, organisms, and fertilizers. Animal biotech providers develop solutions to address animal genetics, nutrition, and breeding to create health-optimizing products.

Robotics

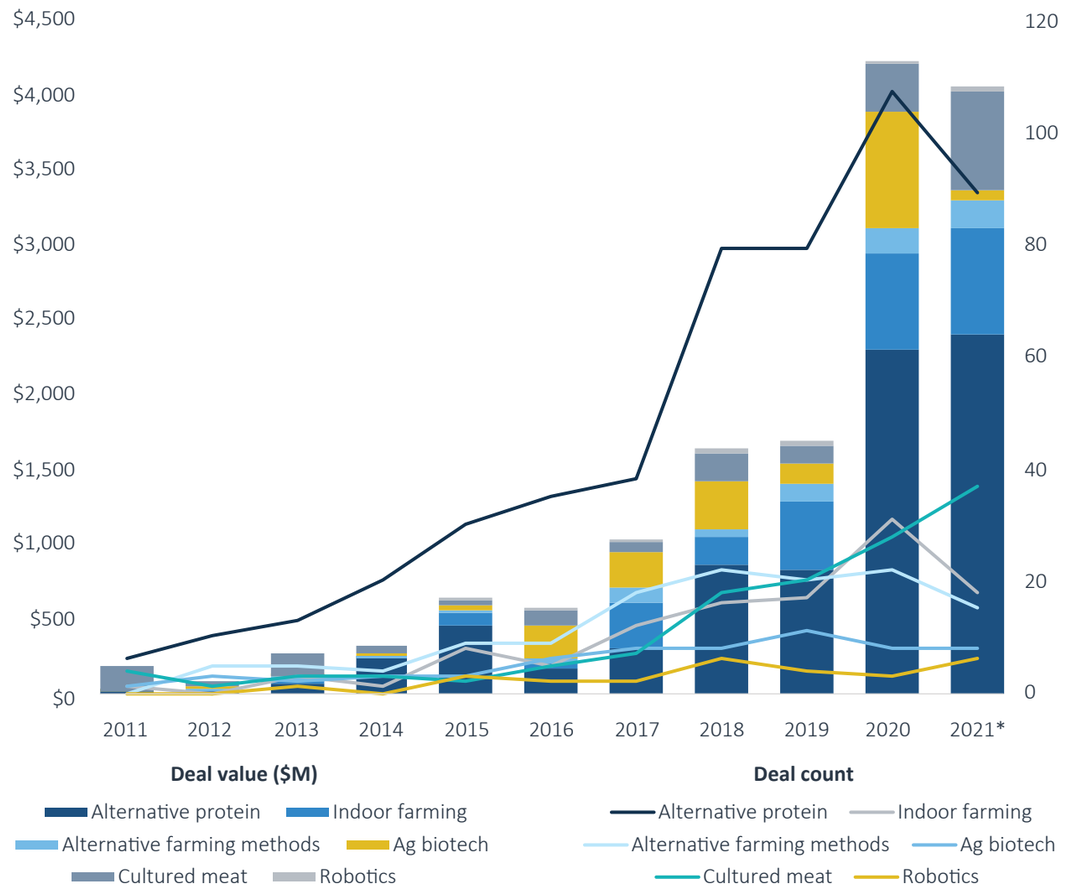
Robotics in agriculture refers to farm machinery that addresses labor challenges, facilitates precision farming, and alleviates climate concerns such as soil compaction and greenhouse gas emissions. We segment this category into two groups: agricultural drones (for seeding, spraying, and surveying), and smart field equipment.

VC activity

VC activity into the food systems segment slightly decreased for the first time by 3.6% between 2020 to 2021 YTD. Startups in food systems raised $4.1 billion in VC investment across 173 deals through Q3 2021. Just as in previous years, alternative proteins received the most funding, while investment into cultured meat more than doubled from $330.4 million in 2020 to $668.3 million YTD. Total investments for angel & seed startups increased in 2021 from $130.0 million in 2020 to $139.2 million YTD. Capital raised by early-stage VC has already exceeded 2020 investments by 39.1%.

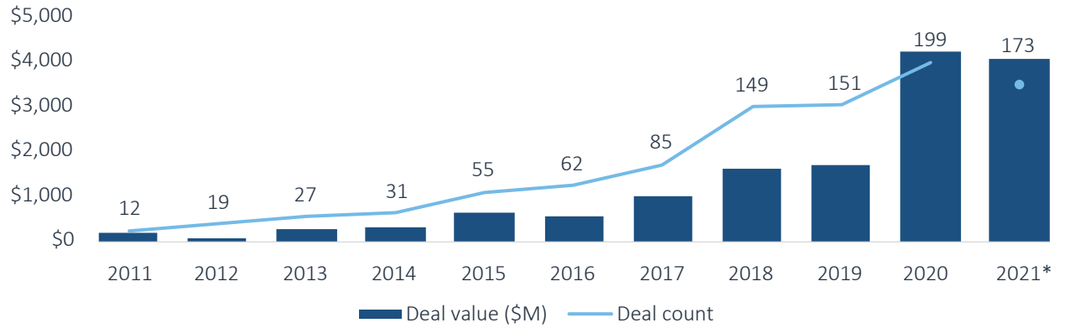
FOOD SYSTEMS

Figure 13. FOOD SYSTEMS VC DEAL ACTIVITY BY CATEGORY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 14. FOOD SYSTEMS VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 15.

Key food systems startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
Indigo Agriculture	Ag biotech	2013	$1,160.0
Eat Just	Alternative protein	2011	$839.5
Perfect Day	Alternative protein	2014	$711.5
Plenty	Indoor farming	2014	$541.0
Bowery	Indoor farming	2014	$532.2

Source: PitchBook | Geography: Global | *As of September 30, 2021

Land use

Definition

Human economic activities have altered more than 75% of the world's land surface,[35] often resulting in significant degradation of the ecosystem and natural resources our economy depends on. The land use segment encompasses agricultural practices, such as alternative fertilizer, and land use management practices, such as soil management as well as nature-based carbon solutions and climate analytics. Voluntary carbon markets have drawn much attention to their ability to tackle climate change by assigning a monetary value to stored carbon and by leveraging this value to advance conservation efforts through market forces (see Figure 16).

Key growth drivers

- Growing voluntary carbon markets
- Cross-industry climate analytics and intelligence demand
- Growing demand for organic farming

Disruptive technologies

Nitrogen cycles are off-balance due to modern agricultural practices, such as monocropping and the excessive use of nitrogen fertilizer. Prior to the era of monocrop agriculture, compost, manure and nitrogen-fixing microbes supplied most of the nitrogen available to plants. This has been largely replaced by an industrial method to create vast amounts of ammonia fertilizer. The environmental impact of those fertilizers is immense as nitrogen is a greenhouse gas 300 times stronger than carbon dioxide. However, there are several technologies to tackle this problem, including engineering plants to fix their own nitrogen and developing microbial fertilizers that supply crops through natural nitrogen cycles. One startup—**Pivot Bio**, which develops microbial nitrogen fertilizers to replace synthetic fertilizers—recently raised a $430.0 million Series D led by DCVC and Temasek Holdings.

Categories

Fertilizer alternatives

The use of synthetic fertilizers is the main source of nitrous oxide emissions in our atmosphere. Startups that develop alternative fertilizers focus on technologies to help farmers grow crops that can capture and metabolize nitrogen from the atmosphere, reducing the need for petrochemical fertilizers and therefore offering environmentally friendly alternatives with lower emissions. Alternative fertilizers make up 40.1% of VC investment in the land use segment, with a steep growth of investment backing it—growing by 900.0% between 2019 and 2021 YTD.

Land use management

Land use management refers to sustainable practices such as biodiversity platforms, microbiome technology to better understand soil health, or acoustic systems to monitor rainforests. A variety of emerging solutions focuses on improving or mitigating damage to soil as well as collecting and analyzing field data. While they represent a small category, AI technologies and robotics are improving data and helping drive growth.

35: "World Population to Reach 9.9 Billion by 2050," SDG Knowledge Hub, IISD, August 6, 2020.

Figure 16. VOLUNTARY CARBON MARKETS

The general goal of carbon markets is to tackle climate change by assigning a monetary value to stored carbon and by leveraging this value to advance conservation efforts through market forces. Hence, carbon markets allow both governments and the private sector to contribute to emission reductions by financing projects globally that reduce CO_2. Carbon markets are becoming increasingly important not just for governments but also for corporations. Many political entities, such as the EU, the UK, and the state of California, have instated mandatory carbon markets (compliance carbon markets) to cover specific industry sectors and gases. Other sectors have become increasingly involved in carbon markets as well, through so-called voluntary carbon markets, which allow carbon emitters to offset unavoidable emissions by purchasing carbon credits. These credits are the currency of voluntary carbon markets and are produced through projects that remove or reduce GHG from the atmosphere. However, nature-based carbon solutions are currently the most feasible solution.

Compliance carbon markets are heavily regulated though government mechanisms and are geographically limited. On the other hand, voluntary carbon credits are more flexible and not restrained by national policy or multilateral agreements. Voluntary carbon markets were formed to drive corporate finance into projects that reduce greenhouse gas emissions. To date, more than 200 companies have pledged to reach net zero by 2040 (10 years earlier than anticipated by the United Nations) through the Climate Pledge. In an analyst note released in August, the currently most liquid carbon credits exchange, **Xpansiv** CBL, shared a number that makes it clear: In comparison to last year, carbon volumes are up 393%, with total transactions of 25.8 million tons of carbon traded in Q2 2021.[36]

The main challenges of voluntary carbon markets are:

- **Insufficient governance:** The absence of governance entails difficulties in legal qualification of voluntary carbon units.
- **Distrust:** Difficult for market participants to verify the quality of a given carbon credit.
- **Missing link to compliance market:** Voluntary carbon credits are purely private in nature and cannot be used to comply with any regulatory requirement.

The main certification mechanisms:

Voluntary carbon credits are issued through a given standard and then stored in the according registry. The two main issuers of voluntary carbon credits are VERRA and the Gold Standard, and credits cannot be transferred to a registry of a different standard.

36: "Xpansiv Market CBL Sets Quarterly Record, Trading More than 25M Tons of Carbon and 66B Litres of Water," CBL, July 1, 2021.

LAND USE

Forest carbon tech

Annually, forests sequester around one-third of all human-caused carbon dioxide emissions from the atmosphere. Ending deforestation could allow forests to double that capacity. While there are both natural and mechanical ways to diminish carbon dioxide in our atmosphere, nature-based carbon solutions represent the lowest-cost option. Through mass reforestation, drone planting, and advanced AI to monitor carbon credit markets, startups are turning forests into growing carbon sinks. Investments in this category have been increasing from just below $5 million in 2019 (across three deals) to $111.0 million in 2021 YTD (10 deals). Novel technologies are relying on AI to simulate forest data, which we discuss in more detail in our Q3 2021 Climate Tech VC update.

Climate analytics: Climate & earth data

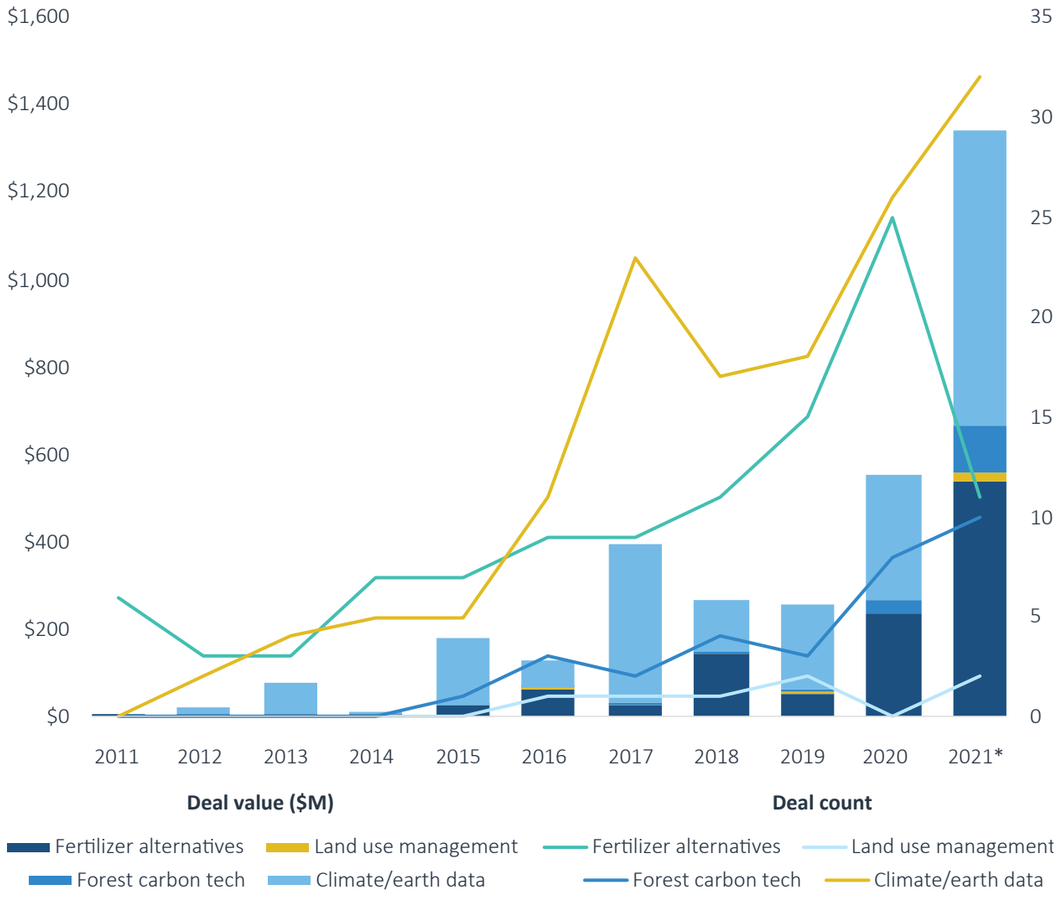
Climate intelligence (CI) or climate analytics represents the practices of collecting climate information data in order to improve our ability to track changes in the climate, understand how climate change affects human and economic activities, and improve climate change mitigation and adaptation. Companies in this category focus on technologies that can derive insights from earth- and climate-related data to generate climate solutions. The category received slightly more than half of the investment in the land use segment, with $675.4 million in VC invested as of Q3 2021.

VC activity

VC activity in the land use segment grew by 142.1% between 2020 to 2021 YTD. Startups in the space raised $1.34 billion in VC investment across 55 deals through Q3. Just as in previous years, climate and earth data received the most funding ($675.4 million), followed by alternative fertilizers ($539.2). Forest carbon performed the strongest with an increase of 265.1% in value—from $30.4 million in 2020 to $111.0 million in 2021 YTD (see our Q3 2021 Climate Tech VC update for a more in-depth analysis).Capital raised by angel & seed startups decreased slightly from $55.3 million in 2020 to $52.1 million in 2021 YTD while early- and late-stage VC has already exceeded 2020 investments by 305.25% and 135.8%, respectively.

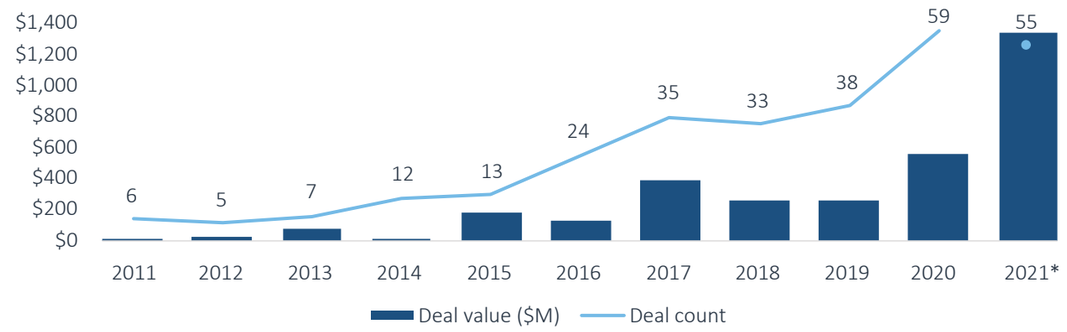
LAND USE

Figure 17. LAND USE VC DEAL ACTIVITY BY CATEGORY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 18. LAND USE VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 19.

Key land use startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
Pivot Bio	Fertilizer alternatives	2010	$691.75
Semios	Climate & earth data	2010	$205.5
Orbital Insight	Climate & earth data	2013	$203.65
Tomorrow.io	Climate & earth data	2016	$185.0
One Concern	Climate & earth data	2015	$152.3

Source: PitchBook | Geography: Global | *As of September 30, 2021

Clean industry tech

Definition

Industrial processes account for roughly 20% of greenhouse gas emissions globally and are expanding rapidly, driven largely by activities in emerging economies and rising consumer demand.[37] Viewed as the most challenging area to decarbonize, industrial processes attracted $1.85 billion in 2021 YTD, or 6% of total climate tech investment, making it one of the smaller segments in the taxonomy. Traditionally, investments have been directed toward fuel alternatives, which represented between 60% to 100% of total investment in the space until 2019. However, investments in the segment have grown considerably, largely driven by increased VC focus on lithium-ion battery recycling, which accounted for almost 50% of the total investment in 2021 YTD.

Key growth drivers

- New technological breakthroughs
- Consistent growth of investment
- Increasing demand from corporations to become carbon neutral throughout the entire supply chain

Disruptive technologies

As the automotive industry continues to shift toward electric means of propulsion, **battery recycling provides a new market opportunity** for startups to enable environmentally sustainable electric vehicle supply chains. Lithium-ion (li-ion) batteries hold valuable materials such as lithium, nickel, and cobalt that can be extracted, processed, and reused for new batteries. As of now, fewer than 5% of lithium-ion batteries are recycled, a result of logistical challenges and the high price of getting batteries to processing facilities.[38] So far in 2021, VC investors have allocated $877.1 million toward battery recycling companies such as **Redwood Materials**, Battery Resourcers, and Nth Cycle, a significant step-up from the $72.2 million invested in 2020.

Categories

Lithium battery recycling

Startups in this category develop technologies to automate, streamline, and clean up the labor-intensive, inefficient, and currently unsustainable process of lithium battery recycling. Traditionally, battery recycling involves either burning them to recover some of the metals or grinding the batteries up and treating the resulting “black mass” with solvents. VC activity in this category makes up close to 50% of the entire clean industry tech segment and has been growing exponentially since 2019 from $0.9 million to $877.1 million in 2021 YTD.

Fuel alternatives

Reaching net zero by 2050 will be impossible without reducing transport systems’ reliance on fossil fuels. Fuel alternatives are especially relevant for industries such as manufacturing, construction, and shipping, which are harder to decarbonize. Alternative fuels refer to any non-petroleum-based fuel, such as biodiesel, ethanol, electricity from renewable sources, and clean hydrogen. This category lists clean fuels such as renewable methanol, hydrocarbon fuel, and ethanol from non-recyclable waste and other materials. Fuel alternatives are the most mature category in the segment, with VC activity accounting for around 10% of total investments.

37: “Decarbonization of Industrial Sectors: The Next Frontier,” McKinsey & Company, June 2018.

38: “Most Lithium Batteries End Up in a Landfill. A New Bill Aims to Change That,” Grist, Maddie Stone, March 17, 2020.

CLEAN INDUSTRY TECH

Chemicals

Chemicals represent the most polluting components of this segment—accounting for around 6%[39] (from direct industrial processes and energy-related emissions) of total global emissions. Chemical processes are extremely polluting since they emit nefarious emissions such as methane and NOx. Chemicals also have high transport and supply chain dependencies, reflecting the decentralized and widespread nature of production facilities. Synthetic biology is increasingly viewed as a potential de-carbonizer of the petrochemical industry, with plant-derived substitutes being created via emerging technologies such as oxidase enzymes and fermentation. Investments have risen almost tenfold between 2020 and 2021 YTD, mainly due to a $357.0 million Series C raised by **Solugen** in 2021.

Mining technology

The production of minerals, such as graphite, lithium, and cobalt, is expected to grow approximately 500% by 2050 in response to the growing demand for climate technologies.[40] Estimates predict that more than 3 billion tons of minerals and metals will be needed to supply the clean energy sector. This trend implies immense economic opportunities exist for resource-rich (often developing) countries and the private sector alike. Emerging approaches to smart mining can help integrate renewable energy practices into the mining industry, promoting decarbonized mining processes that can expand and strengthen the mineral value chain. Startups in clean mining tech developing technologies to reduce the carbon footprint of mining processes have experienced a 10x increase in investment since 2019, reaching $170.0 million in 2021 YTD.

Manufacturing

The manufacturing sector is responsible for 19% of domestic direct emissions and indirectly responsible for an additional 11% of emissions through electricity use.[41] Given the sector's carbon intensity, emerging technologies focus on resourceful manufacturing processes through software and hardware solutions. Technologies include AI, sensors, and drones to make processes more energy efficient as well as robotic solutions to reduce waste and automate processes. Startups in the space are focused on the steel and metal industry, fuel cells, power trains, activated carbon products, industrial remediation services, and others.

VC activity

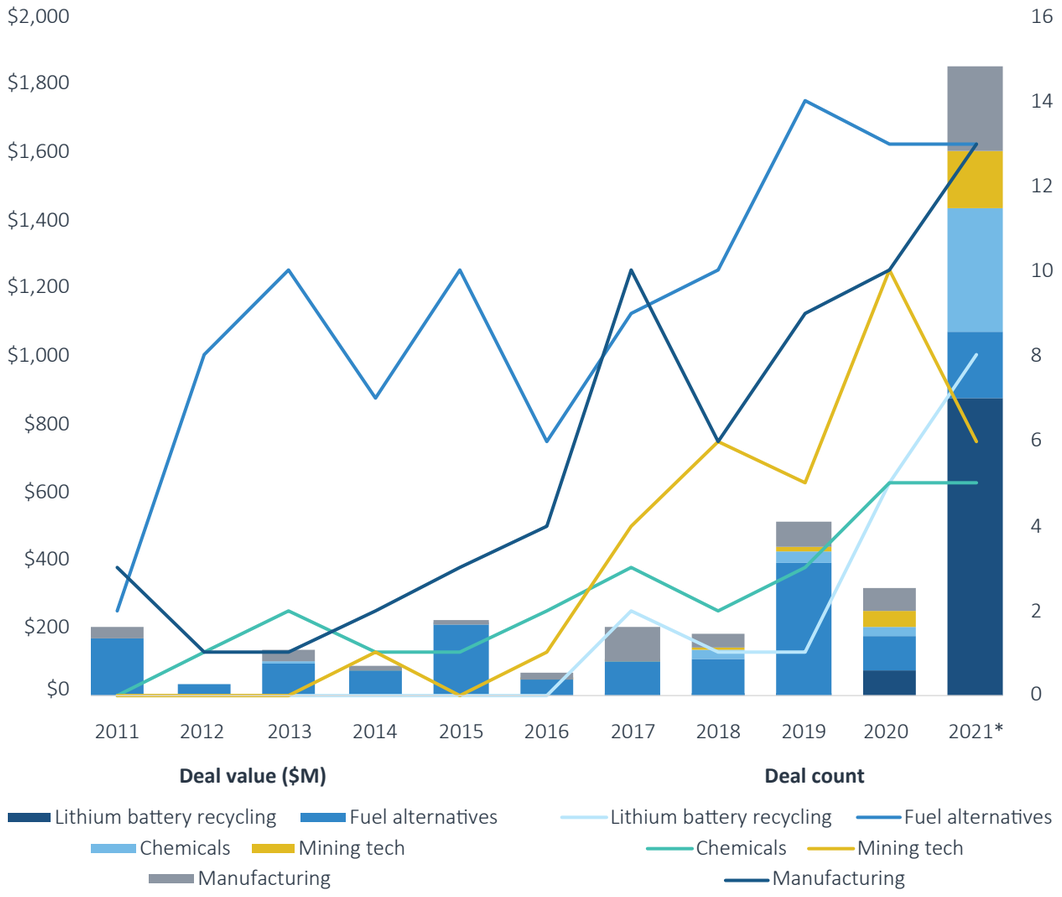
VC activity in the clean industry tech space grew by 484.1% between 2020 to 2021 YTD. Startups in the segment raised $1.85 billion in VC investment across 45 deals in 2021 YTD. Lithium-ion battery recycling performed the strongest with a 1,114.8% increase in funding from the previous year until 2021 YTD, followed by chemicals, manufacturing, and mining tech, which grew by impressive 1,028.2%, 254.8%, and 302.8% funding totals, respectively, in 2021 YTD compared to 2020. All stages in the industry segment increased VC deal value in 2021 YTD: Angel & seed deal value grew from $22.6 to $38.3 million, early-stage VC from $153.4 to $283.6 million, and late-stage VC from $140.7 million to $1.5 billion.

39: "Emissions by Sector," CO2 and GHG Emissions, Our World in Data, Hannah Ritchie and Max Roser, 2020.
40: "Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition," The World Bank Group, Kirsten Hund, et al., 2020.

41: "A Climate of Change: Manufacturing Must Rise to the Risks and Opportunities of Climate Change," Center for Climate and Energy Solutions, n.d.

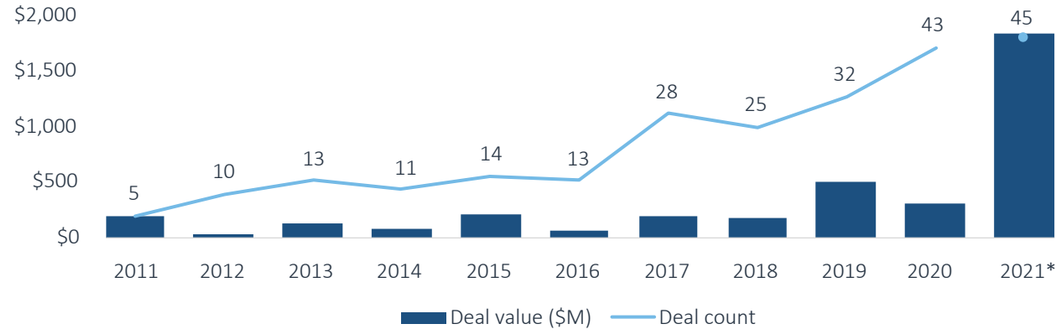
CLEAN INDUSTRY TECH

Figure 20. CLEAN INDUSTRY TECH VC DEAL ACTIVITY BY CATEGORY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 21. CLEAN INDUSTRY TECH VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 22.

Key clean industry tech startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
Redwood Materials	Lithium battery recycling	2017	$824.6
Solugen	Chemicals	2016	$440.5
Fulcrum BioEnergy	Fuel alternatives	2007	$396.9
Lilac Solutions	Mining tech	2016	$153.6
Achates Power	Manufacturing	2004	$139.8

Source: PitchBook | Geography: Global | *As of September 30, 2021

Built environment

Definition

Construction and building operations account for 39% of energy-related GHG emissions, while operational emissions from heating and cooling buildings are responsible for almost two-thirds of that amount.[42] Climate friendly built environments entail high-efficiency fittings, heating and cooling for residential and commercial buildings, and efficient construction technology, which utilizes low-carbon materials. Smart building management addresses energy efficiency through sensors, AI analysis, and automated processes. The built environment space is a small segment, only accounting for 2.0% of total climate tech VC investment in 2021 YTD, with linear (rather than exponential) growth over the years. Construction technology is the largest category in the segment, accounting for nearly 50% of the total investment.

Key growth drivers

- Cross-sector coordination to revolutionize the space
- Growing demand in industrial sector due to low operating and maintenance costs
- Growing urbanization and rising concerns over environmental deterioration

Disruptive technologies

VC investments in construction tech have grown steadily since 2019, with a 272.2% increase over the past two years. It is imperative to decarbonize building materials to reach national and global emission targets. For example, the global carbon footprint of cement (the binding substance in concrete) used in construction accounts for approximately 7% of global CO2 emissions, which translates to more than 4 billion tons of carbon each year. The energy used to produce cement adds 0.93 pounds of carbon dioxide per pound of concrete produced. This almost 1:1 ratio is highly inefficient and has become an attractive focus area for startups eager to improve the carbon impact of this process.[43] Canada-based **Nexii** uses a cement-like material to construct exceptionally more energy-efficient buildings and offers an environmentally friendly alternative to the use of carbon-intensive concrete in conventional construction.

Categories

Heating & cooling

Decarbonized heating and cooling technologies can potentially reduce CO2 emissions by two gigatons over the next 30 years.[44] Startups in this category are working on advancing technologies around producing active solar thermal, combined heat and power (CHP), and more efficient heat pumps. VC investments in this category were on an upward trend, from $18.3 million in 2016 to $ 143.7 million in 2020, but have declined to $44.1 million in 2021 YTD.

Energy efficiency

“Intelligent efficiency” technologies have significant potential to reduce emissions. The technology is based on the concept of incorporating smarter design processes into the full

42: “New Report: The Building and Construction Sector Can Reach Net Zero Carbon Emissions by 2050,” World Green Building Council, September 23, 2019.

43: “Cement and Concrete: The Environmental Impact,” Princeton Student Climate Initiative, Princeton University, Keegan Ramsden, November 3, 2020.
44: “Technology Roadmap: Energy-Efficient Building: Heating and Cooling Equipment,” International Energy Agency, 2011.

lifecycle of construction, including planning, construction, operation, and retrofits. Startups in this category include hardware and software solutions, along with financial services. Products are focused on improving building envelopes and window insulations, improving air and moisture control, and incorporating LED lighting and high-efficiency light fixtures. VC investment into energy efficiency has grown significantly over the past few years and shows a clear upward trend of 325.0% between 2018 and 2021 YTD.

Construction tech

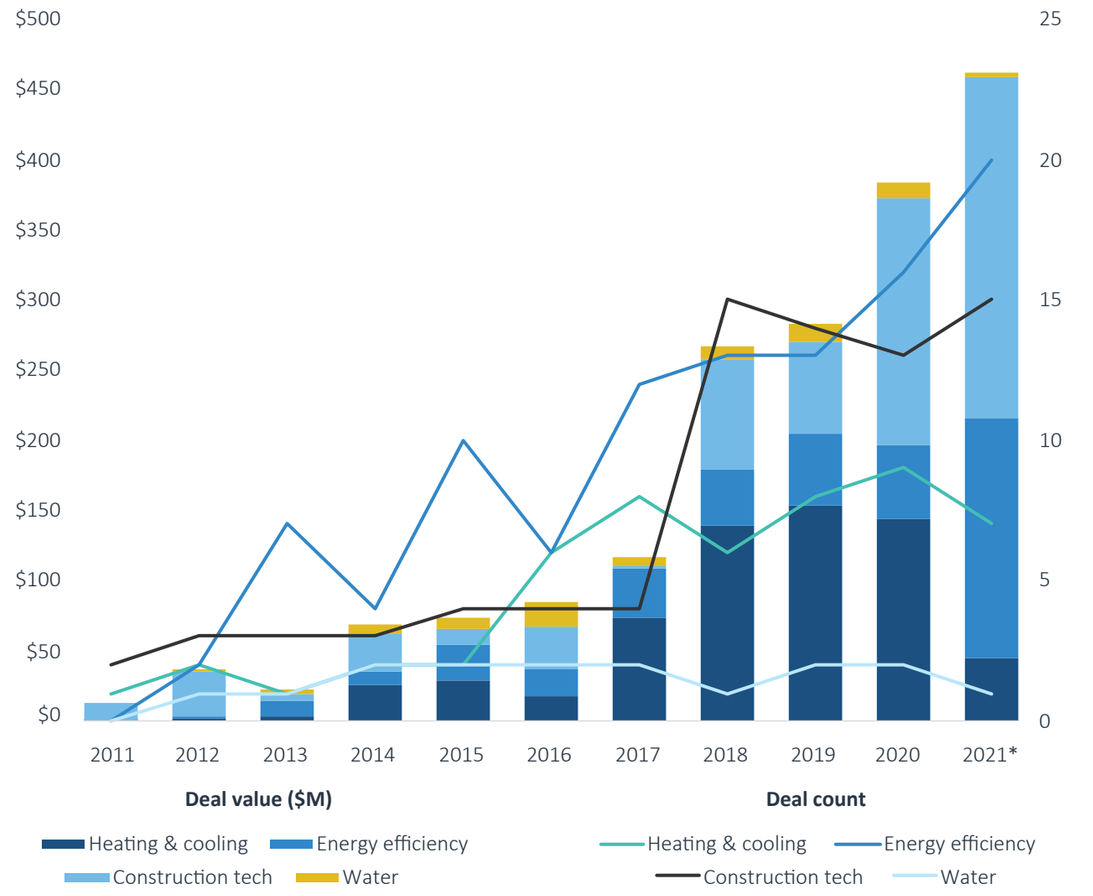
Adaptation and implementation of clean construction technologies will be one of the main drivers of decarbonization within the building sector. The category includes clean construction materials and disaster-resilience features. It also extends into efficient construction processes and methods focused on making construction less labor-, time-, and carbon-intensive. For example, modular construction, 3D printing, and other novel building materials are important approaches to reducing the carbon footprint of cement. Construction tech represents a small category, with only 14 startups in our ecosystem. However, VC investment has grown exponentially over the past three years, with $243.5 million invested in 2021 YTD.

VC activity

VC activity in the built environment space grew by 37.2% between 2020 to 2021 YTD. Startups in the industry raised $525.7 million in VC investment across 44 deals through Q3 2021. Energy efficiency grew the fastest between 2020 and 2021 YTD—by 222.5%—and received $171.1 million in investments YTD.

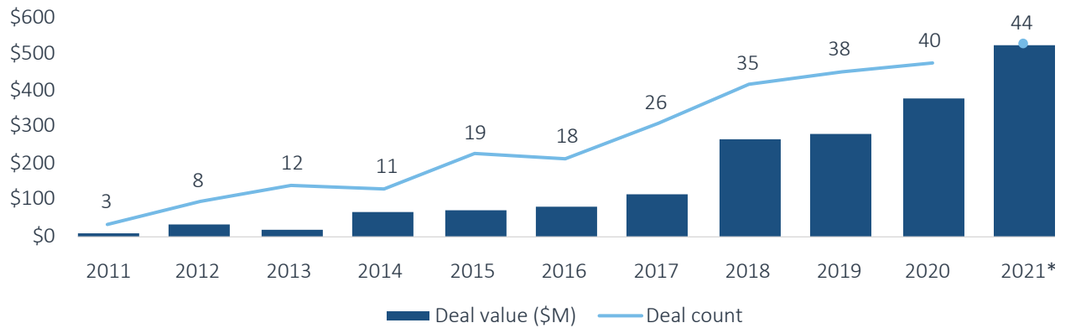
Aggregate deal value across all venture stages is higher YTD than in 2020. Angel & seed deals increased from $16.4 million to $18.8 million, early-stage deals increased from $117.1 million to $164.3 million, and late-stage deals increased from $249.8 million to $342.6 million.

Figure 23. BUILT ENVIRONMENT VC DEAL ACTIVITY BY CATEGORY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 24. BUILT ENVIRONMENT VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 25.

Key built environment startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
Halio	Heating & cooling	2010	$344.2
Chemetry	Construction tech	2007	$223.6
Nexii	Construction tech	2018	$133.2
Mighty Buildings	Construction tech	2017	$94.1
Dandelion	Heating & cooling	2017	$65.9

Source: PitchBook | Geography: Global | *As of September 30, 2021

Carbon tech

Definition

Carbon tech is a nascent and fast-growing category in climate tech, but it requires patient capital to advance technologies through lengthy R&D processes to scale. Technologies in this segment focus on capturing carbon and storing or utilizing it in products through industrial processes. Software innovations in the segment are focused on solutions that help clients with carbon accounting and other financial tools geared toward carbon management. Carbon tech has seen steady growth in VC investment, from $207.6 million in 2018 to $670.3 million in 2021 YTD, accounting for 2.2% of total climate tech investment.

Key growth drivers

- Growing ESG investment strategies
- Policy support
- Voluntary carbon markets

Disruptive technologies: Direct air capture

While direct air capture represents a promising new buzzword in climate tech, the technology is still nascent and requires lengthy R&D commitments with no assurance of scale. Startup ClimeWorks opened the world's largest climate-positive direct air capture plant, named Orca, in September 2021 in Iceland, with a capturing capacity of 4,000 tons of carbon dioxide per year. The plant represents a groundbreaking achievement and helps validate the direct air capture opportunity for both policy makers and investors. The US Department of Energy (DOE) has allocated $12 million in federal funding for six R&D projects that advance direct air capture technology.

Categories

Carbon capture

Carbon capture technologies capture carbon dioxide at the emission sources for safe storage. Technologies include direct air capture, in which carbon dioxide is pulled directly from the air, and point-source capture, where CO2 is captured at the point of production, often in industrial smokestacks. Most technologies in this category are still extremely nascent and require patient capital. VC investment in the carbon capture space started to pick up in 2018 with around $150 million and has peaked in 2020 at $236.9 million with a relatively steady average deal count of 7 deals annually.

Carbon sequestration

Carbon sequestration technologies aim to contain carbon underground, though soil sequestration or ocean minerals. Some of those technologies have beneficial impacts on agricultural practices, especially microbial carbon sequestration, which restores carbon to the soil. It is estimated that a total of 800 gigatons of carbon need to be removed from the atmosphere between now and 2050 to meet emission targets under the Paris Agreement.[45] Leading climate change research has established that soil carbon sequestration is among the cheapest and most scalable methods with the greatest potential to meet these goals.

45: "The Role of CO2 Capture and Utilization in Mitigating Climate Change," Nature Climate Change, Niall MacDowell, et al., April 5, 2017.

CARBON TECH

Carbon accounting

Carbon accounting or greenhouse gas accounting refers to the processes by which organizations or entities measure their carbon dioxide emissions. Startups in this category focus primarily on software solutions designed to streamline, digitize, and automate carbon accounting processes. VC investments have steadily increased between 2018 and 2021 YTD from $7.0 million to $252.3 million.

Carbon utilization

Providers in this category seek to develop means of utilizing captured carbon throughout the supply chain—also referred to as “carbon-to-value.” Examples include carbonized beverages, building materials, enhanced oil recovery, and chemicals. Carbon utilization is a small category and accounted for around 8.5% of VC investments in carbon tech in 2021 YTD across two deals.

Climate fintech

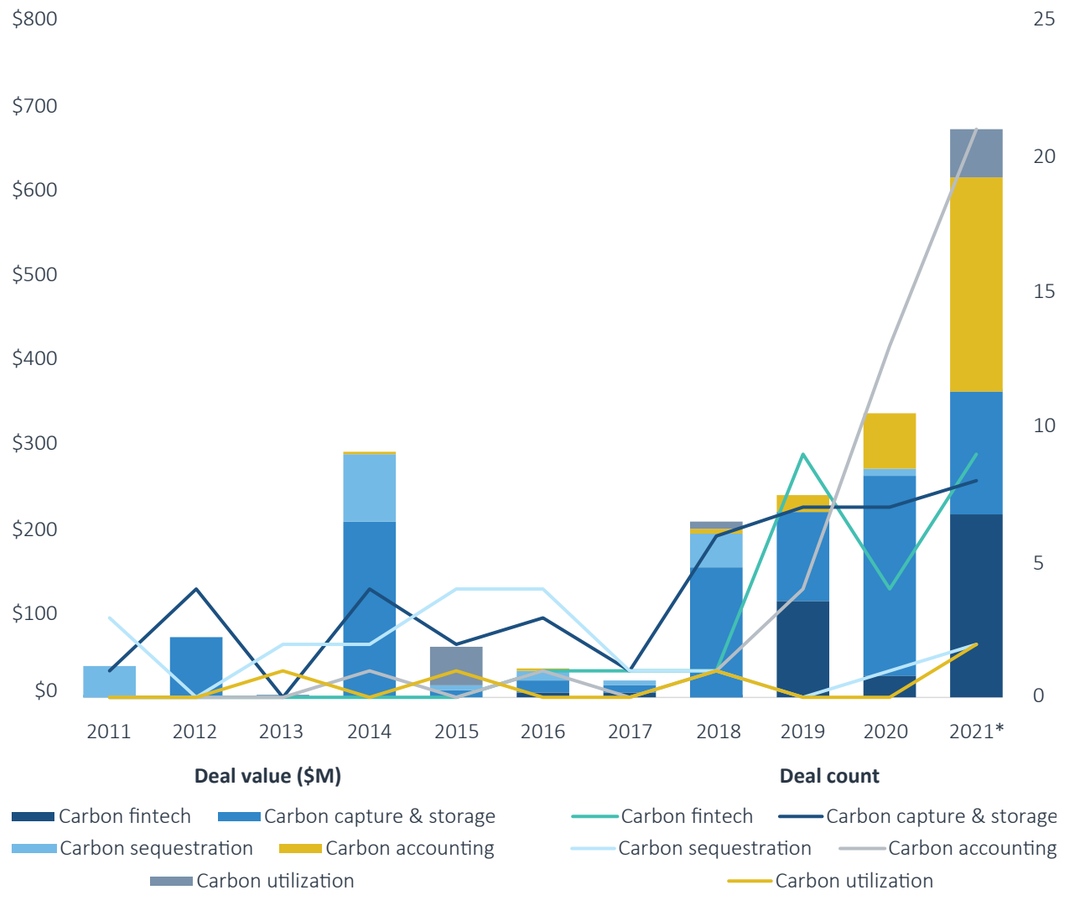
Climate fintech is the junction of climate, finance, and digital technology. Startups in this category develop digital solutions and platforms that link stakeholders across sectors to decarbonize financial transactions. While many of the technologies utilized in climate fintech are relatively mature (for example, Big Data, AI, and blockchain), their application in the context of decarbonization represents a novel approach.

VC activity

VC activity in carbon tech doubled between 2020 and 2021 YTD and raised a total of $670 million in capital across 42 deals. Carbon accounting tech and climate fintech are the largest categories in terms of investment, making up 37.6% and 32.5%, respectively, of the total capital in the segment. Angel & seed total VC investments decreased between 2020 and 2021 YTD from $43.8 to $37.6 million, while early- and late-stage VC deal values increased over the same time from $58.9 to $208.9 million and $232.0 million to $423.8 million, respectively.

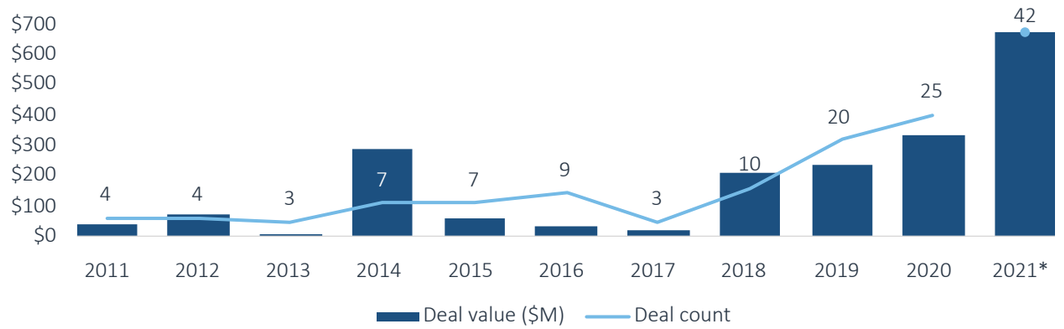
CARBON TECH

Figure 26. CARBON TECH VC DEAL ACTIVITY BY CATEGORY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 27. CARBON TECH VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2021

Figure 28.

Key carbon tech startups

COMPANY	SUBSEGMENT	YEAR FOUNDED	TOTAL RAISED ($M)*
LanzaTech	Carbon capture & storage	2005	$549.5
Crusoe Energy Systems	Carbon fintech	2018	$203.1
Xpansiv	Carbon accounting	2016	$165.0
Climeworks	Carbon capture & storage	2009	$155.6
Svante	Carbon Capture & Storage	2007	$154.2

Source: PitchBook | Geography: Global | *As of September 30, 2021

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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