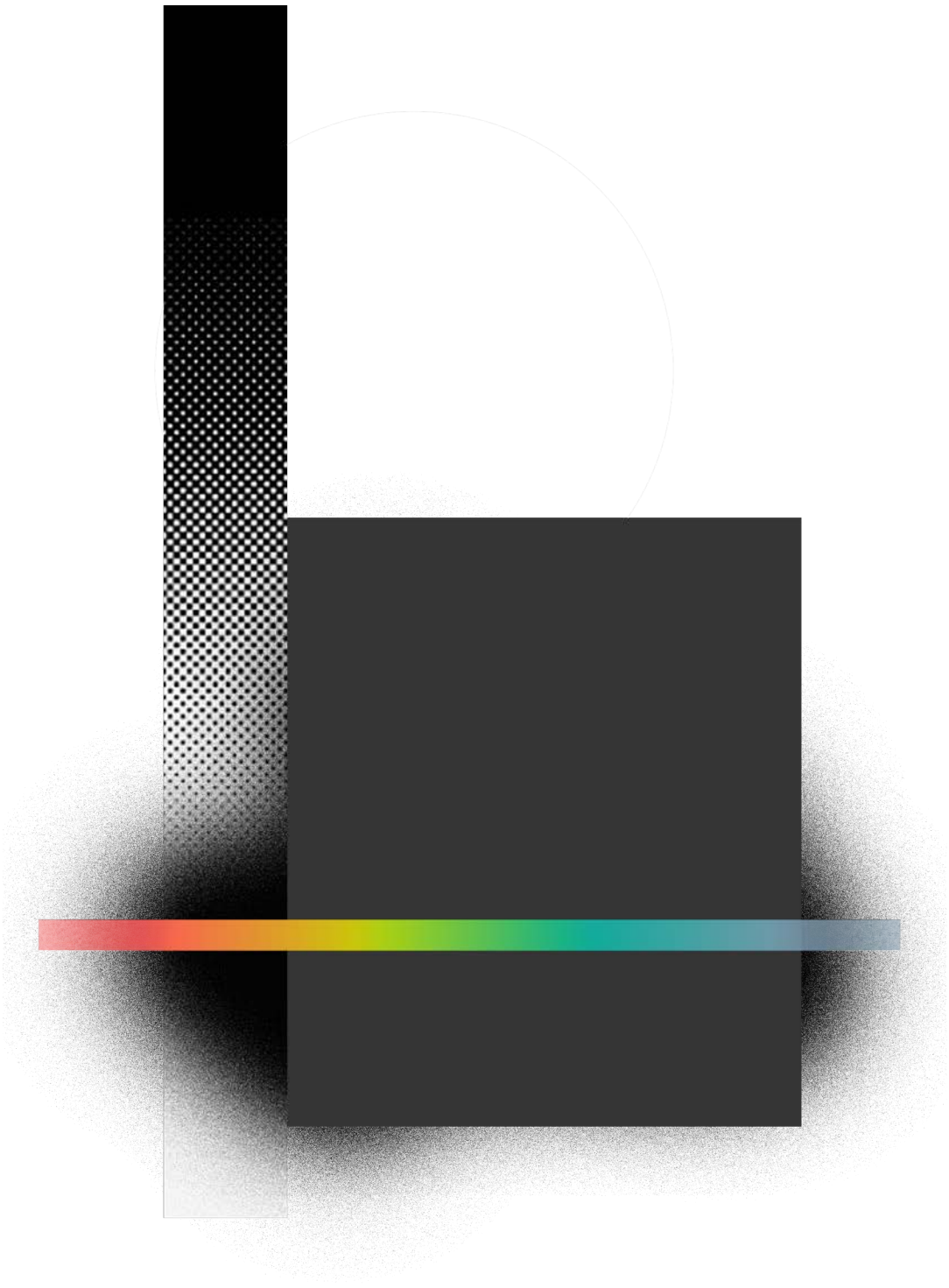
THE ENGINE
Built by MIT



2019 Tough Tech Landscape

Data provided by PitchBook

CONTENTS

Foreword

Across the world, innovators are applying their technological ingenuity and expertise to solve some of our most urgent challenges. Through the development of technologies that seek to mitigate the strain of climate change, enrich human health and develop the systems infrastructure that supports broad economic activity, Tough Tech founders are building a better world for us all. However, the development of Tough Tech—technology that sits at the intersection of frontier tech and breakthrough science—often requires years of R&D before coming to fruition. Accordingly, venture investment in these technologies has lagged, leaving many potential breakthroughs stuck on the laboratory shelf.

Our experience at The Engine over the last few years is emblematic of a tectonic shift in this reality. The growth and traction in Tough Tech has been remarkable and inspiring. First-time founders are committing their lives to solving previously intractable technical challenges in order to create enormous new markets. Experienced entrepreneurs are forgoing opportunities to launch the next software app to take on the planet's most pressing problems. Additionally, through the availability of a diverse capital stack, access to flexible infrastructure and strong institutional support from academic, corporate and government organizations, the Boston ecosystem has evolved into a blossoming Tough Tech community that enables innovators to accelerate their work.

It is with this traction as a backdrop that we have partnered with PitchBook to shed light on Tough Tech investment, assess the trajectory of VC investment in the field over the last few years, identify areas of particular excitement and highlight verticals that may need further support from investors, policymakers and strategic engagement.

So, what is Tough Tech? Tough Tech is transformative technology that solves the world's most important challenges through the convergence of breakthrough science, engineering and leadership. These technologies often involve longer cycles of experimentation and development timelines. Tough Tech includes game-changing technologies that span advanced manufacturing, energy, materials science, biotech, robotics, space, micro-electronics, quantum computing, deep software & AI and the intersections of other new technologies.

In this report, we have worked with PitchBook to identify over 4,000 Tough Tech companies that have received over $105 billion in funding since the start of 2015. We will be hosting the 2nd annual Tough Tech Summit in Boston this week to celebrate this progress. The Summit strives to gather founders, entrepreneurs, investors, academics, business leaders and government officials together to explore the challenges and opportunities of bringing Tough Tech to market. It is in gathering together that we can learn from one another, share key lessons and help founders change the world. We hope you will join us next year.

In the meantime, we look forward to continuing our work with you to build upon this vibrant Tough Tech community through our support of founders on a mission to build massive businesses and change the world.

Katie Rae
CEO and Managing Partner
The Engine

Overview

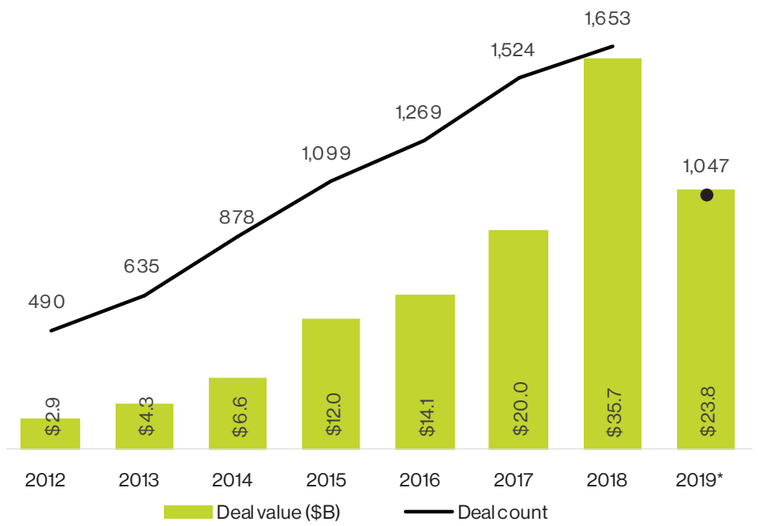
Tough Tech has had a remarkable run this decade. From just shy of 500 venture transactions closed in 2012 across $2.9 billion in aggregate VC, funding of companies tackling myriad Tough Tech arenas has soared to a mammoth $35.7 billion in 2018 across over 1,600 deals. Quarterly deal flow further reveals that such sums aren't due to outlier quarters; rather, since the middle of 2017, quarterly VC invested has been robust, while Tough Tech financing volume has held steady across the board.

This pace of dealmaking and its degree of sustention in 2019 suggests that as Tough Tech segments have matured, more and more investors are piling into diverse categories to varying degrees, seen by the breakdown of VC deal flow by Tough Tech segments. Advances in multiple underlying technologies (e.g. new understandings of particle interactions at the nano scale or the rapid development of our understanding of neural networks and AI systems) and lowered costs of input materials are two key macro factors to which the vigor in deal flow can be ascribed, but it is also worth noting the classic technological cycle's progression throughout the 2010s in particular, and how it contributed to not only these new highs but also the thriving of the overall startup and venture industry. The convergence of technological breakthroughs in Tough Tech (e.g. batteries, materials) paved the foundation for the accelerated pace of innovation experienced in the past decade, especially with regard to the smartphone ecosystem. Development of such communications technology enabled the infrastructure upon which the mobile revolution was built. Many of the most prominent VC-backed startups over the past decade consequently leveraged that tech to massive, lucrative ends, from social media to imagery. Now, especially as many of the most prominent unicorns are exiting or being acquired, more founders and VCs are once again exploring other frontiers, Tough Tech among them, as the technological cycle shifts into its next phase of core technologies' advancement. Although undeniably more difficult in terms of technical challenges, entrepreneurs have more tools and resources than ever before—especially given unprecedented levels of capital pledged to venture funds worldwide—to tackle various segments in Tough Tech. With that said, an important advantage to proving out an effective solution to a technically complex business problem, especially where hardware is concerned, is that barriers to entry can be erected by first solvers and/or movers via intellectual property safeguards and the sheer difficulty of replication. As can be assessed from Tough Tech VC financing volume by stage, gradually, more companies are able to achieve late-stage capital by following such paths given the increasing proportion of late-stage rounds in overall deal volume. As the global venture environment is awash with capital, Tough Tech median financing sizes and valuations have also inflated somewhat, while not as dramatically as observed elsewhere. Deal sizes have remained somewhat more reasonable, with only the early stage experiencing an unceasing rise. Given the nascency of some Tough Tech segments and the maturation of others, it is reasonable to expect fiercer competition for deals and potentially larger financing sizes as a result.

Maturation by stage is readily deduced by employing venture activity rates across Tough Tech segments as a proxy for increasing competition. While VC investment has varied more considerably due to disproportionate outliers in prominent Tough Tech segments like autonomous vehicles and life sciences, the proportional volume of financings within some segments has grown significantly in the past five years. Artificial intelligence (AI) and machine learning (ML), as well as agtech have grown the most, while other segments either held steady or exhibited more modest rates of growth. Numerous factors are driving those arenas in particular; chief among them have been significant advances in ML use-case provability and technical advances in hardware required in the arena. In addition, broader macro drivers such as shifts into alternative protein sources and demonstrated efficacy of immunotherapies in applications for multiple cancers have helped bolster these growing industries.

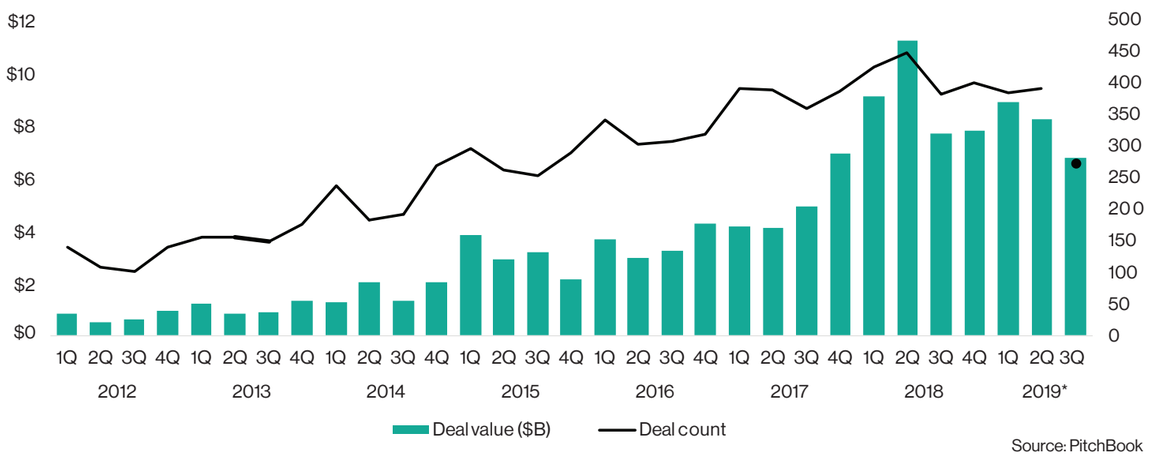
Finally, a key driver behind the surge in VC invested across Tough Tech is the positive turn in the exit cycle for Tough Tech backers. Although the life sciences segment stands out in terms of overall exit value, there has been a surge in exit value and volume across multiple other Tough Tech segments in the past few years. While life sciences still dwarfs other Tough Tech segments due to well-established pathways to liquidity via IPOs, and competition among pharmaceutical giants plus expiration of key intellectual property boosting M&A, the upticks in multiple other Tough Tech segments are encouraging and will continue to fuel investor interest in the coming years.

Tough Tech VC deal activity



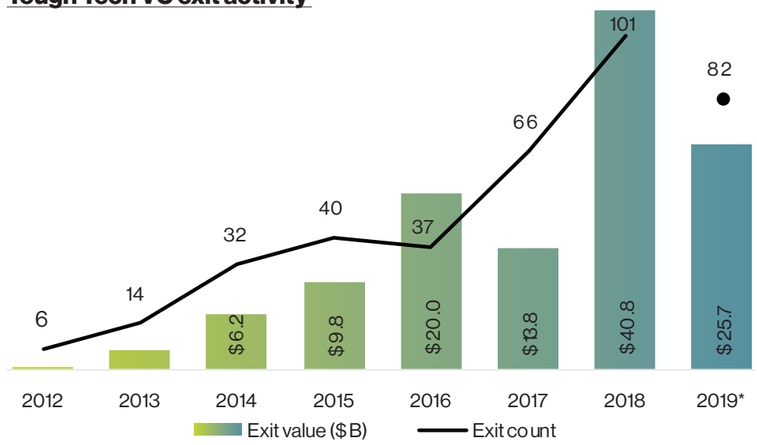
Source: PitchBook
*As of September 25, 2019

Tough Tech VC deal activity by quarter



Source: PitchBook
*As of September 25, 2019

Tough Tech VC exit activity



Source: PitchBook
*As of September 25, 2019

$66B
total deal value
in 2018 and 2019

Tough Tech by the numbers

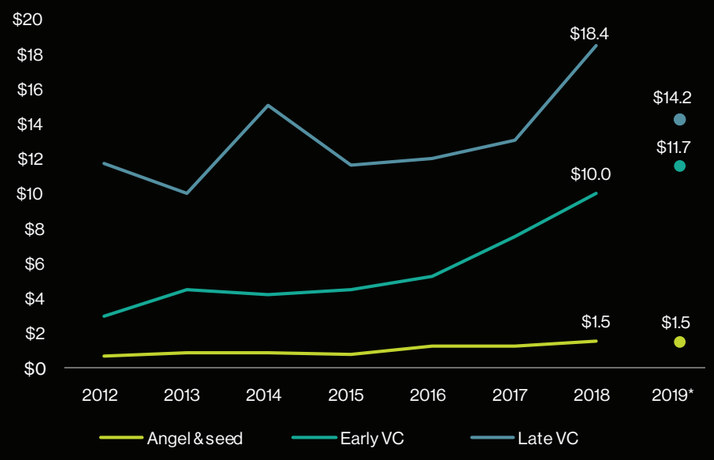
Life sciences at nearly **$31B** in deal value since 2018

Late-stage activity hits **27%** of 2019 volume

Record **101** exits for Tough Tech in 2018

1,653 transactions across $35.7B in 2018

Median VC deal size ($M) by stage



Source: PitchBook
*As of September 25, 2019

Most active global VC investors in Tough Tech in 2019*

Investor Name	Deal count
OrbiMed	15
GV	15
Alexandria Venture Investments	13
New Enterprise Associates	12
The Engine	11
ARCH Venture Partners	11
Prelude Ventures	9
Kleiner Perkins	9

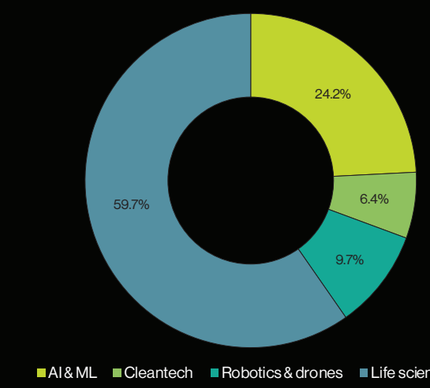
Investor Name	Deal count
Johnson & Johnson Innovation - JJDC	9
Deerfield Management	9
Osage University Partners	8
Intel Capital	8
Keiretsu Forum	8
Khosla Ventures	8
Cambridge Innovation Capital	8

Source: PitchBook
*As of September 25, 2019

VC deals (#) by select subvertical

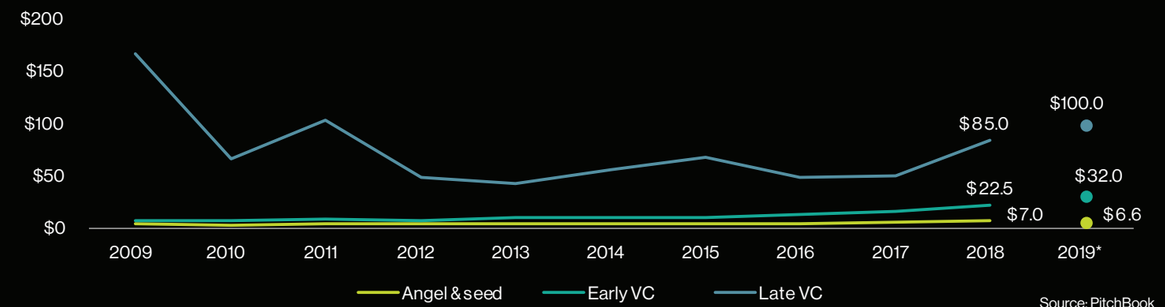
Source: PitchBook
*As of September 25, 2019

VC deals ($) by select subvertical in 2019*



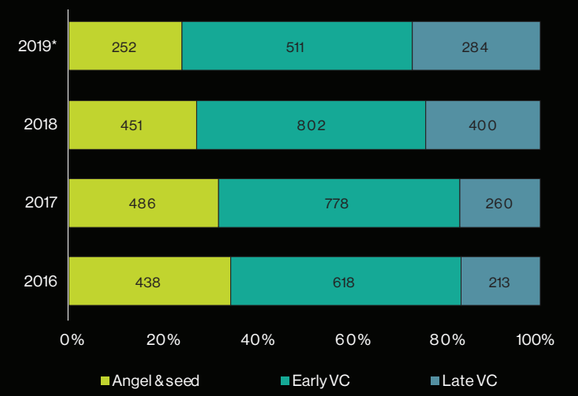
Source: PitchBook
*As of September 25, 2019

Median VC pre-money valuation ($M) by stage



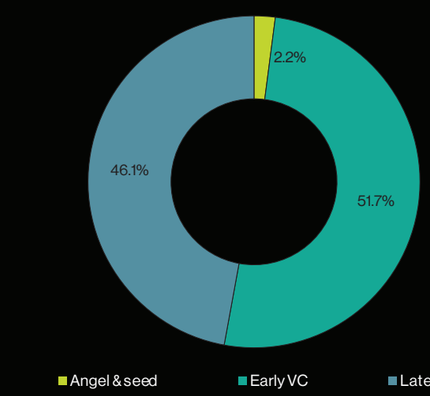
Source: PitchBook
*As of September 25, 2019

VC deals (#) by stage



Source: PitchBook
*As of September 25, 2019

VC deals ($) by stage in 2019*

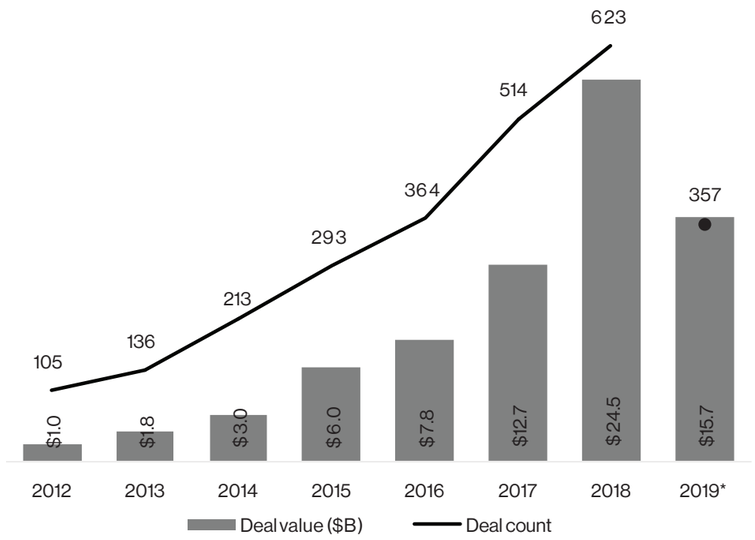


Source: PitchBook
*As of September 25, 2019

Cross-border

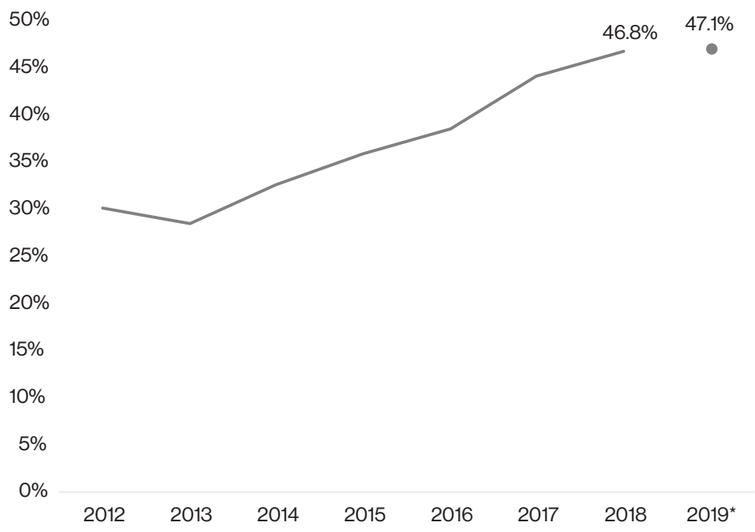
Given the increasingly global nature of the venture industry, analysis of how cross-border investment within Tough Tech has helped accelerate aggregate funding flows seemed warranted. Since 2012, the volume of venture financing in Tough Tech with cross-border participation has increased six-fold, while deal value has soared to over $24 billion. Moreover, after multiple years registering a proportional participation rate between around 30% and 47%, cross-border investors have ratcheted up their participation rate to 89% in 2019 to date. The implications of this sharp increase are potentially numerous, yet its primary drivers are most likely the uptick in the globalization of VC on the whole, the historical development of Tough Tech and the flourishing of regional venture ecosystems. To expand on the latter, Tough Tech lends itself to not only common domestic policy initiatives on the part of governments—for example, government programs to foster advanced manufacturing and provide stimulus to their local economies—but also to comparative advantages boasted by particular regions given their unique history, cost of raw material inputs and talent. For example, given advances in military technology developed at the behest of government imperatives, entrepreneurship in Israeli cybersecurity has flourished at the convergence of hardware and software. More broadly, governments and local businesses in multiple regions have sought to imitate the Silicon Valley model in order to reap its various benefits. Tough Tech, in turn, has benefited as large investment firms, particularly in the US, broadened their geographical scope. It is unlikely that this trend will desist; if anything, it may intensify as an abundance of capital in traditional hubs such as the US Bay Area leads to investors diversifying beyond high-price environments and into new technical arenas.

Global Tough Tech VC deal activity with cross-border participation

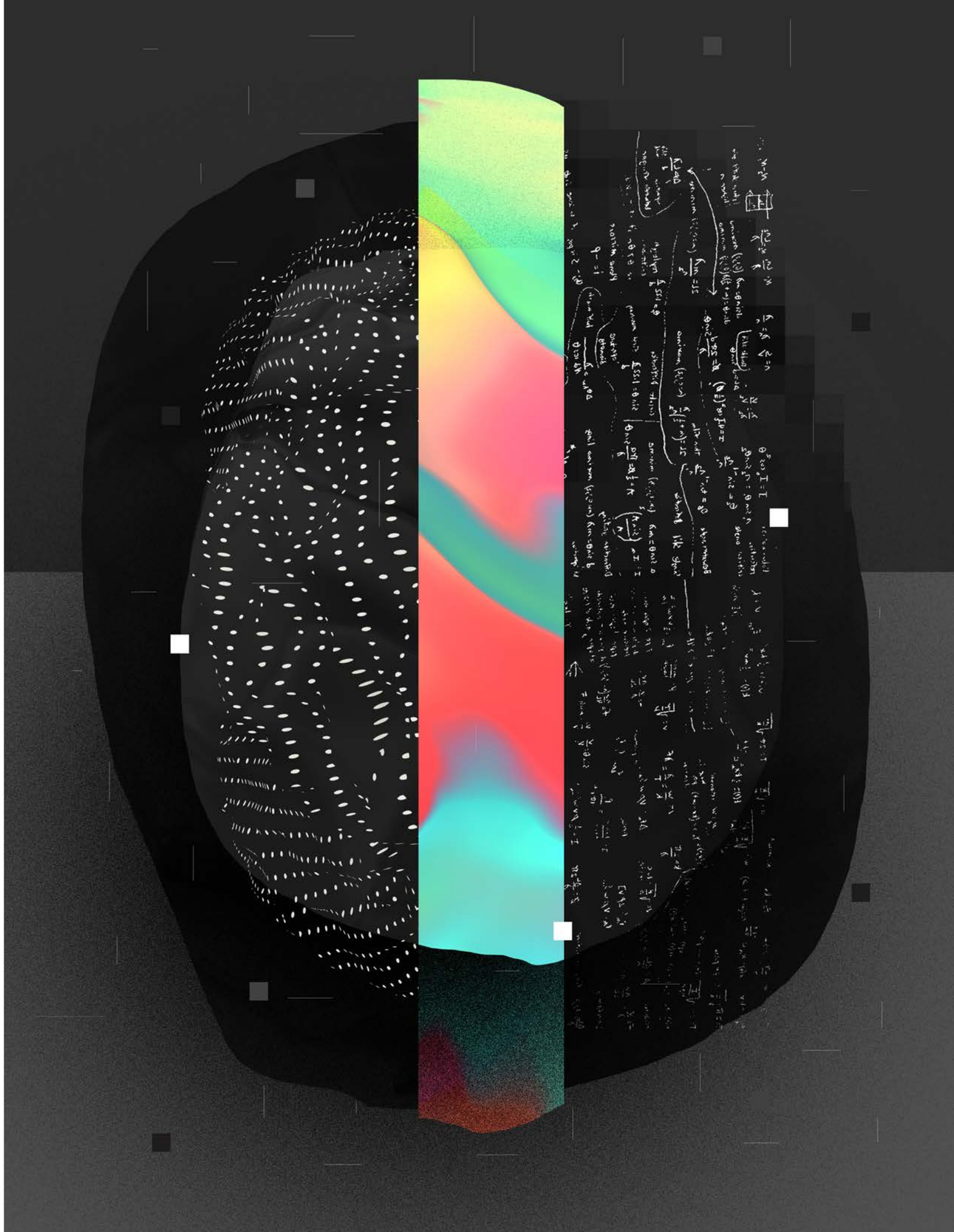


Source: PitchBook
*As of September 25, 2019

Cross-border participation % of global Tough Tech VC deal count



Source: PitchBook
*As of September 25, 2019



Q&A

What is the Engine?

The Engine, built by MIT, is a VC firm that invests in early-stage companies solving the world's biggest problems through the convergence of breakthrough science, engineering and leadership. It's mission is to accelerate the path to market for Tough Tech companies through access to a unique combination of investment, infrastructure and a vibrant ecosystem.

How has your investment thesis around Tough Tech evolved given the past few years' developments in the space?

The Engine launched its portfolio in 2017 with investments in seven Tough Tech companies. We have since invested in a total of 19 companies. As we launched, we acknowledged that the depth of the capital stack available to Tough Tech companies would be pivotal to the success of our portfolio. We have been impressed by the amount of support they have received from investors across the capital stack, from traditional VC firms to strategic corporates and later-stage institutional investors.

While there certainly is momentum building around the potential of Tough Tech to transform markets, the most encouraging lesson we learned over the last couple of years is the presence of talented and motivated technical leaders fully committed to willing their companies to success. There is no shortage of them and they are the real story here.

More generally, what are the key factors/developments in Tough Tech on the industry side that you are watching most closely?

Skeptics of investment in Tough Tech point to long technology-development timelines and capital intensity as barriers to successful returns. Yet, as this report illustrates, the biotech investor pipeline and associated returns remain strong, perhaps more than the rest of Tough Tech. The common trope of long technology-development timelines and capital intensity does not account for the success of the biotech investment pipeline. Rather, this success accrues in part due to an increase in the degree to which strategics compete on innovation. For this reason, we are actively working with many corporate partners as they begin to transition to open innovation frameworks. The depth of their interest in partnering with The Engine and working with our portfolio is an encouraging sign moving forward.

In your view, what are the key differences for investing in Tough Tech as opposed to the broader VC space?

Part of what makes Tough Tech tough is that an investment in the space entails a more diverse combination of risks than, for example, a software investment. When commercializing Tough Tech, a founder has to manage risk across four dimensions: technical, market, scale and regulatory. Assessing those risks ex ante requires deep expertise in the specific technical fields, an understanding of intricate market structures and engagement with the policy community, a combination of knowledge that is difficult to assemble in the time period allotted for company diligence. At The Engine, we have worked to build a network of technologists, investors, corporates and academics that provide important feedback during our diligence process, and we work closely with our portfolio companies as they move forward.

Of the many segments that make up Tough Tech, which segments are the most interesting to you at this moment and why?

We see tremendous opportunities across Tough Tech verticals, so by no means is our excitement limited to these areas. However, here are some interesting highlights from a few key segments:

Advanced Manufacturing

The way we make things is changing. Essential things like steel and chemicals. Everyday things like shoes and tools. Complex things like rockets, biological organisms and semiconductors. This change is thanks to a unique convergence of materials, technologies and processes maturing in unison. These new technologies and processes are not simply different from the status quo. They are, in almost all cases, more efficient, less expensive and far less polluting than their traditional counterparts. In short, we are witnessing a new industrial revolution, one hidden from the public eye. These are technologies and processes that are the foundation on which the necessities of life are built.

Agtech

There is tremendous economic opportunity for those bold enough to attempt to transform humanity's relationship with food and agriculture. The sector can be subdivided into categories of technological discipline, including: robotics & drones, sensors, crop & food science, agricultural chemicals/biologics, mechanical & manufacturing, analytics, platforms, synthetic environments and services. All of these technologies benefit from shared innovation with other industrial sectors—the biotech sector, for example, benefits from many of the same fundamental breakthroughs in biology, chemistry and computing (CRISPR can edit the DNA of a tomato or a liver cell, silk proteins can ensure the freshness of a head of lettuce or blood sample, algorithms can optimize harvests and discover new molecules, etc). Entrepreneurs recognize that the food and agriculture system, strained to feed a growing world, is a welcome place for innovation.

Biology

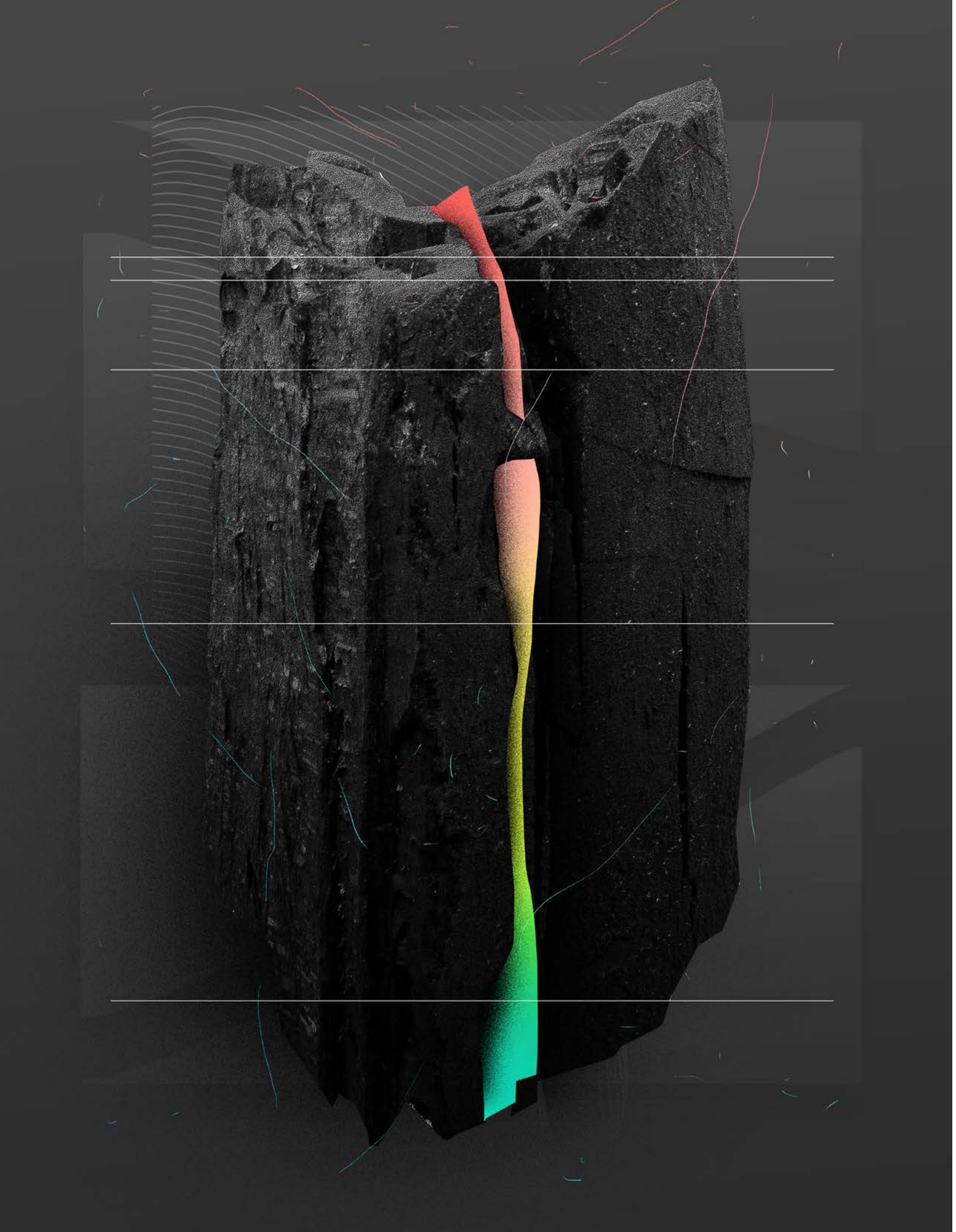
The story of innovation in biology is one of convergence. Discoveries and breakthroughs at the forefront of the sector are increasingly powered by technologies that are, in their own right, transformative. For example, advances in machine learning, image processing, microfluidics, photonics, high throughput screening and advanced manufacturing, combined with our increasing knowledge of biological pathways, products and our expanding understanding of environmental factors, can usher in a new era of biology and medicine. Moreover, processes that were once dependent on repetitive lab work can be automated to achieve higher production speeds and reproducibility. When combined, these advances can lead to novel and more effective gene, cell and tissue therapies, new antibiotics and vaccines, point-of-care diagnostics that can be quickly developed in response to outbreaks and innovative curative therapeutics for multifactorial diseases.

Energy

Opportunities are rising in the energy industry as the sector evolves, primarily driven by two realities. The first is an increasing awareness of climate constraints, and, in some places, strict policy around emissions. The second simultaneous shift involves the industry transitioning from a resource-based footing to a technology-based footing. This is clearly evident in electricity and transportation, but exciting new innovations are emerging in building materials and industrial energy, as well.

Computing

In our increasingly data-heavy world, advances in computational power and speed are more relevant than ever. Innovations on both the algorithm front and the hardware front will lead to a whole new wave of breakthroughs in areas ranging anywhere from drug discovery to distribution planning, traffic optimization, utilities management, worker shift management, inventory management, financial portfolio management, data encryption, cybersecurity and robotics. In addition, remote access to the cloud is not always practical due to limited connectivity or the need for real-time data processing (e.g. for autonomous vehicles). Therefore, edge computing devices will require specialized small, energy-efficient, low-power and high-performance computing capabilities.

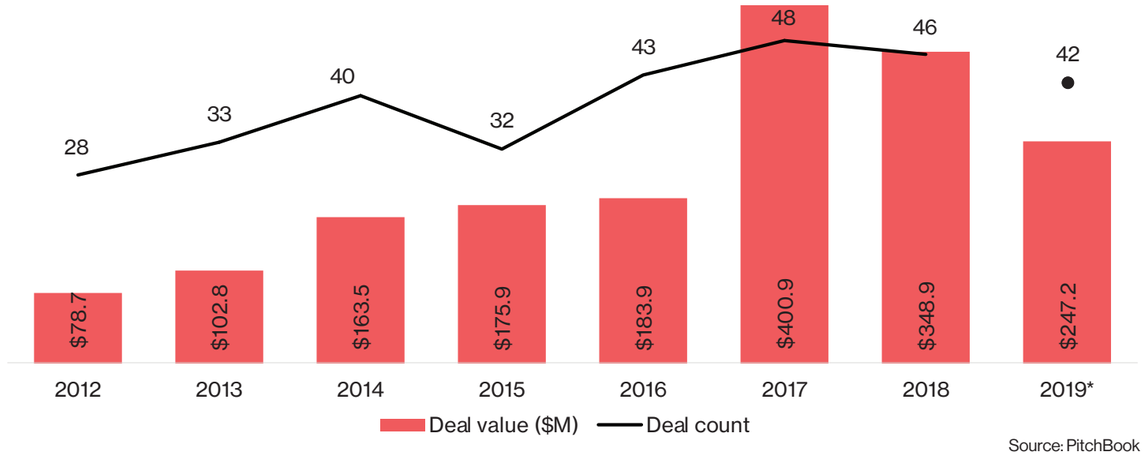


Materials

A foundational segment, materials is also one of the smaller arenas within Tough Tech. This is unsurprising given its overall economics and place in the value chain. Incumbency advantages are massive and R&D costs plus scaling in materials can be expensive, among other factors. However, those hurdles don't preclude innovation within materials—the entry point within established value chains for materials startups and a suite of potentially beneficial industry applications have begun to emerge and advance throughout this decade. Close to $1 billion in VC has flowed into materials startups since 2017's start, in a promising sign for companies within the space. Moreover, there has been a consistent trickle in late-stage funding over the past several years—another telltale sign of materials companies' survival and maturation. When observing the population of materials companies and their associated keywords, we can see that nanotechnology, cleantech and microelectronics all share strong relationships to the industry. Moreover, the companies that have raised the most VC since the beginning of 2012 all dwell within or at the nexus of those Tough Tech segments, especially as the implementation of AI and machine learning aids in materials development. Focused on sustainable fabrics developed via bioengineered proteins and fermentation, *Bolt Threads* has raised more than $200 million; *Ionic Materials*—which makes a polymer electrolyte material for solid-state batteries—has closed on $85.1 million overall. In addition, precision nanocoating developer *Forge Nano* closed on about $41 million in January of 2019. Of the top 20 companies by VC raised within this population, two underwent distressed acquisitions in July 2019, illustrating the challenges inherent in not only VC but also Tough Tech. However, as capital continues to flow unabated and technical advances are made—for example, deployment of machine learning techniques to uncover novel compounds with unique properties as areas for research and prototyping—further advancement and VC investment is to be expected.

- *2019 is on pace to reach a decade high in financing volume.*
- *Since 2017's start, there has been close to $1 billion in VC invested.*
- *Later-stage deal volume has slowly crept into double digits in past five years.*
- *Popular avenues range from sustainable materials (e.g. biodegradable packaging) to ongoing application of carbon fiber and graphene.*

Materials VC deal activity



Source: PitchBook
*As of September 25, 2019

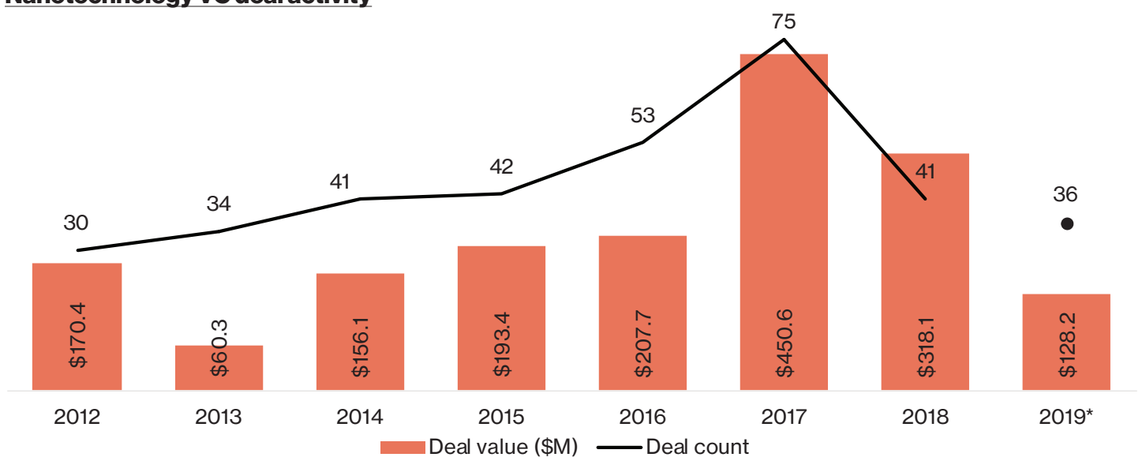
Nanotechnology

- *Since a peak of volume in 2017, financing flows have returned to historical medians.*
- *VC volume remains largely concentrated at the angel, seed and early stages.*
- *Key areas of development across the segment include: therapy delivery in healthcare, materials development at the nanoscale to endow novel properties or expedite processes and additional healthcare avenues (e.g. utilizing nanoparticles in imaging).*

Intriguingly, nanotechnology's heyday in terms of venture funding was in 2017, where 75 financings for a cumulative $451 million occurred. Since then, capital flows have returned to historical norms, with 41 transactions for over $300 million in 2018 and 2019 seeing a somewhat lower $128.2 million across 36 deals thus far. As perhaps can be expected, the bulk of financing has been among angel, seed and early-stage ranges of the capital stack. Nanotechnology's wide diversity of potential applications and processes contribute to the presence of outliers that skewed 2017 to such heights. One financing accounted for a large chunk of the $451 raised that year—carbon nanomaterial developer *Susn's* $157.8 million Series C round. However, reviewing the dominant industries of the nanotechnology segment, three primary areas emerge: drug discovery/delivery/biotechnology as a cluster, generalized hardware and materials and electronic components/equipment/instruments.

The middle cluster is illustrated by companies such as *StoreDot*, which utilizes nanoparticles of active materials with organic compounds to create faster-charging batteries; the former by *Clene Nanomedicine*, which focuses on a novel electrochemical method of producing nanocrystals without surface coatings to catalyze cellular reactions; and the latter by *Nanoramic Laboratories*, a maker of ultracapacitors utilizing carbon nanotubes on a conducting substrate to improve energy storage. It is reasonable to expect these areas to remain primary avenues of overall nanotechnology development going forward, given the concentration of capital thus far and macro industry drivers. In the meantime, nanotech will also continue to proliferate given that founders across multiple Tough Tech segments are utilizing or tackling nanotechnology; this ubiquity will aid in spurring more venture investment in coming years as nanotech-related solutions become more mainstream.

Nanotechnology VC deal activity



Source: PitchBook
*As of September 25, 2019

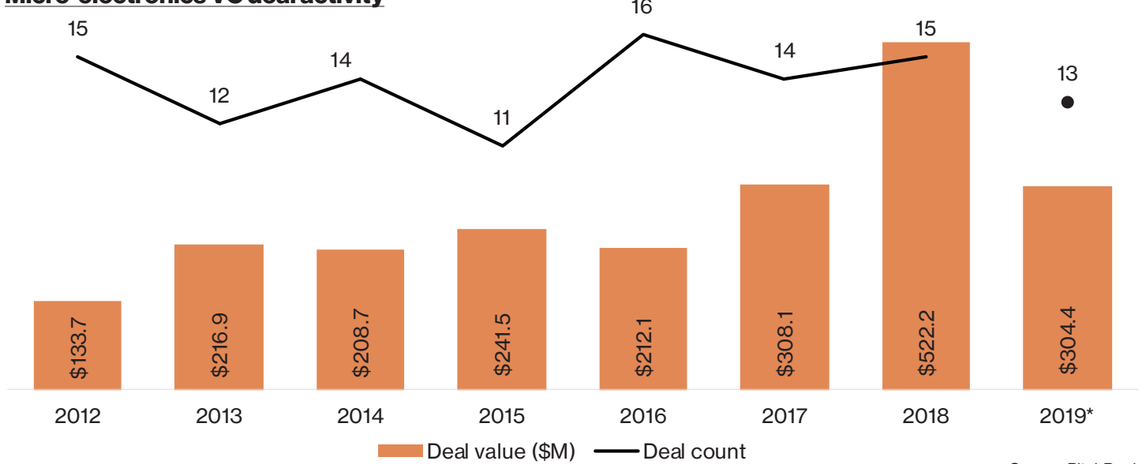
Micro-electronics

Maybe even more so than other small segments within Tough Tech, micro-electronics is impacted by the broader semiconductor industry's cycles and incumbency effects. However, VC investment within the space keeps chugging along, albeit at a smaller, steady trickle relative to other segments. In fact, an expanding diversity of applications-focused micro-electronics is a defining theme for the segment overall, especially in recent years, as the key challenge of developing a brand-new semiconductor material beyond silicon becomes a primary focus. From fabless semiconductor arrays intended to aid in high-bandwidth applications to processors exclusively dedicated to machine learning use cases, diversification into a plethora of industries and myriad applications are characteristics of the segment over the past several years, often utilizing a blend of novel materials upon which to build chips beyond traditional silicon, given the unique needs of specific applications.

Around that broad theme, three primary clusters around which the bulk of companies reside should be noted: specialized semiconductors (e.g. *Graphcore*, which develops chips exclusively for machine learning), alternatively built chips (e.g. *GaN Systems*, which has garnered $45.5 million in VC and builds semiconductors with gallium nitride) and advances beyond traditional chip design and manufacture (as exemplified by *SiFive*, which proffers custom chip design, prototyping and creation). The bulk of VC invested thus far appears to be within the realm of specialized applications. With key subsegments like microbatteries estimated to grow in market size at a CAGR of 30.4% between 2019 and 2025 and hit $631.2 million, further growth in multiple specialized applications is likely.

- *Diversification and expansion of semiconductors into multiple facets is a major theme (e.g. electromagnetic interference shielding, e-textiles).*
- *2018 saw a record $522.2 million in VC invested globally in micro-electronics, largely due to outlier financings such as Graphcore's $200 million Series D round.*
- *Interestingly, the bulk of dollars invested and volume are both concentrated in the late stage.*

Micro-electronics VC deal activity



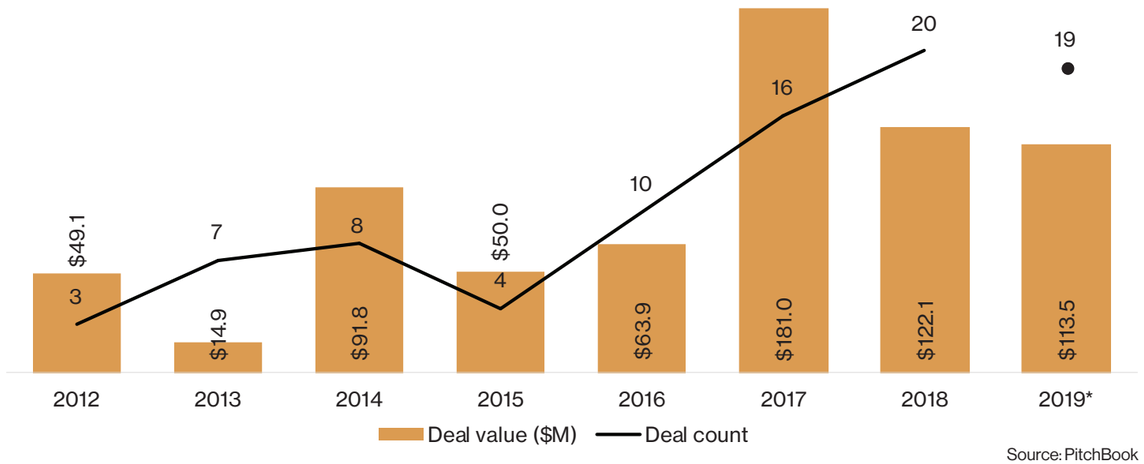
Source: PitchBook
*As of September 25, 2019

Quantum Computing

- *VC activity has risen sharply since 2015 and intensified further in 2019 after a high of 20 transactions completed in 2018.*
- *Overall funding amounts remain relatively small compared to other Tough Tech segments, but these amounts are growing.*
- *Few clear outliers (aside from D-Wave Systems) are contributing to the surge in dealmaking.*

Any review of venture funding in quantum computing in fall 2019 must note that news leaked recently that *Google* reportedly achieved a solution on a quantum computer at a rate dwarfing classical computers' speed. As multiple news outlets rushed to note, the achievement shouldn't be overinterpreted as grounds for 'quantum supremacy,' as it was an experimental demonstration for research purposes and real-world application is some distance in the future. However, the fact that *Google* could demonstrate such a solution underscores the growth in discussion of potential applications of quantum computation and commensurate growth in venture funding. While the recent growth rate of quantum computing VC activity has been significant, it still is dwarfed by other Tough Tech segments, emphasizing the area's nascence. Only one company—early mover *D-Wave Systems*—has emerged as a sinificant outlier in terms of VC invested over the years, amassing a total of $163 million over the past several years, while the bulk of companies raking in tens of millions of dollars in VC all raised in the past two years. The sheer youth of the arena makes it difficult to tease out any clear emergent trends—namely, which areas of quantum computing are garnering the most stable and significant interest. However, software plays seem to outnumber most others (for example, The Engine's portfolio company *Zapata Computing*, which develops quantum algorithms aiming to commercialize the tech for a variety of applications). Interesting other potential avenues that some startups are pursuing illustrate once again the youth of the segment, for example, startup *ionQ's* development of an atomic quantum computer utilizing trapped ions to replicate qubits. As funding is still flowing strong in 2019 relative to prior years, it is likely that funding to a handful of these avenues of development will deepen as key players begin to emerge and achieve deployment stages; all in all, the space is still quite fluid so the prime pathways toward realization of applicability have yet to be mapped out.

Quantum Computing VC deal activity



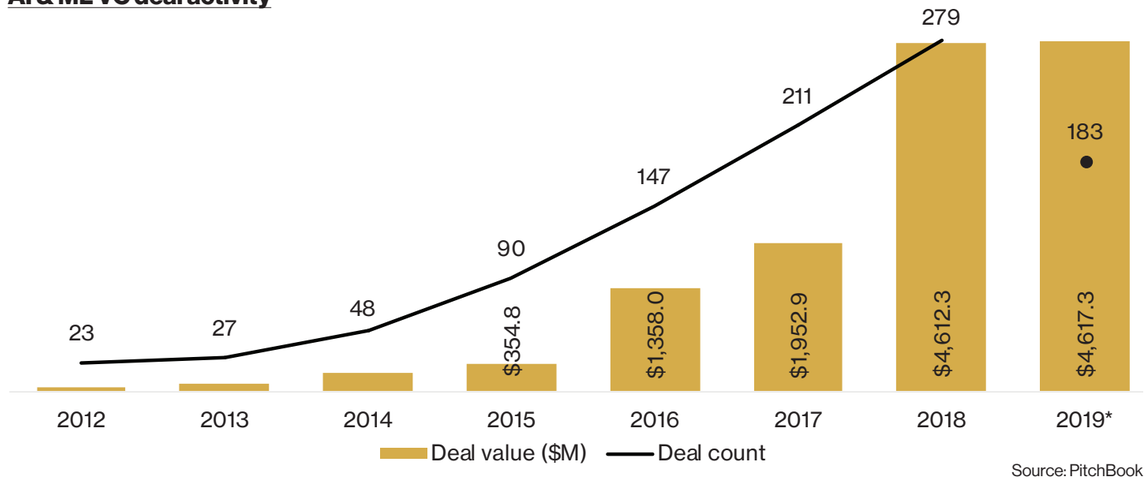
Source: PitchBook
*As of September 25, 2019

AI & ML

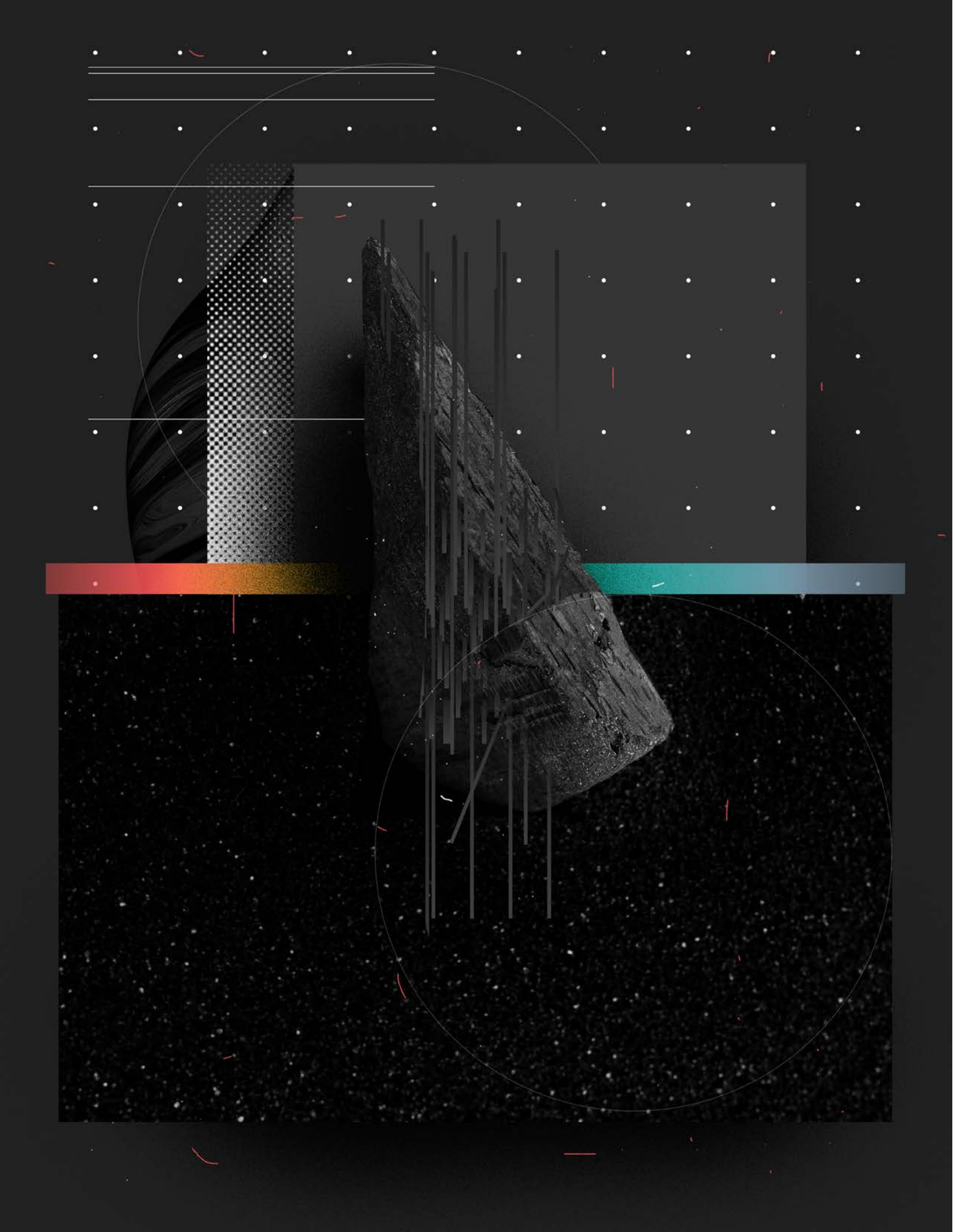
- *Strong growth rates in both VC invested and volume across all AI & ML since 2014.*
- *Well over $9 billion invested since the start of 2018 to now.*
- *Increased expansion of applications both commercial and theoretical, with transportation, logistics and healthcare dominant yet automation of repetitive tasks and business processes also growing apace.*

AI & ML have suffered the fate of over-hype, leading to much discussion as to the true efficacy of ML in key areas plus the actual utility of AI systems. Although their application has been more incremental than first supposed, there are significant advantages to deploying AI systems in arenas requiring significant computations to unearth actionable data and/or results with greater efficiency. The numbers speak for themselves—from 48 financings for $253.1 million in VC in 2014, the cycle of venture investment in AI & ML has reached a new high of $4.6 billion invested across 183 transactions in 2019 to date. More volume is concentrating in the late stage, signifying the maturation of the space overall. Significant numbers of startups and maturing businesses are tackling arenas armed with custom applications of AI & ML, most notably in a handful of avenues that encompass the bulk of funding since 2012: drug discovery, resource management, autonomous vehicles and systems and business process automation. Autonomous vehicles and systems admittedly dominate the top 10 businesses by VC raised within this Tough Tech segment, from *Cruise's* multiple billions to *Aurora Innovation's* platform for self-driving cars. However, healthcare applications also account for a significant chunk of VC invested and volume, exemplified by businesses such as *HeartFlow*, which has created a product suite for healthcare professionals to identify and model diseases and treatments, or *BenevolentAI*, which has partnered with companies such as *Novartis* to aid drug discovery by leveraging patient-level data to account for patient heterogeneity. It is likely that transportation, logistics and healthcare applications will continue to dominate the burgeoning field of AI & ML applications given their dynamics and economics; however, multiple other avenues are cropping up, particularly in the realm of business or repetitive process automation. Take *DropWise*, which is leveraging ML to develop a hydrophobic coating material, or *Cobalt Robotics*, which makes patrolling robots that utilize ML in detection of anomalies to reinforce more accurate recognition over time. These areas will likely grow significantly in coming years.

AI & ML VC deal activity



Source: PitchBook
*As of September 25, 2019

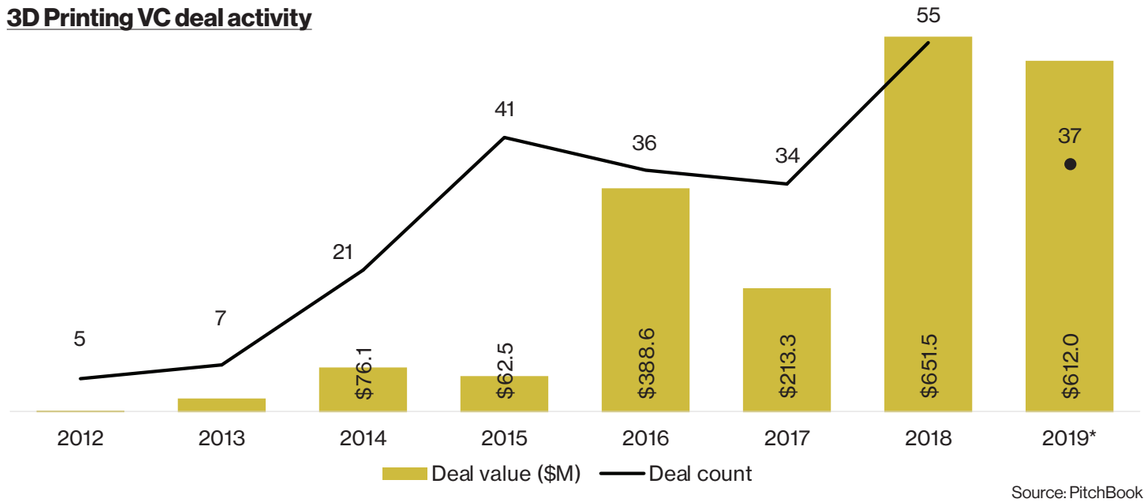


3D Printing

The VC financing cycle for 3D printing aligns well with the classic framework for a novel technology. After a surge in interest from 2014 to 2015, there was a dip followed by a plateau in volume before VC invested ratcheted up in the past two years. Previously, only outlier financings drove the surge in aggregate deal value in 2016. In a broader industry analysis, 3D printing has undergone significant hype at different times for various reasons, but now more significant sums are being bet on its increasing viability. The top three 3D printing companies in VC raised over the past several years—*Carbon, Desktop Metal* and *Formlabs*—exemplify the primary avenues within the industry that are currently at the forefront of viability and entry into extant manufacturing and supply chains, all centered around novel processes of manufacturing for more efficient suites of applications. *Carbon* has closed on nearly $700 million in funds, applying a novel process—combining digital light projection with programmable liquid resins—to produce parts. *Desktop Metal*, on the other hand, has raised nearly $457 million to fuel its making of 3D metal printers for both studio and scale production. Finally, *Formlabs* produces a variety of 3D printers for multiple digital fabrication purposes across different industry settings. However, 3D printing use cases are slowly proliferating into other avenues, as seen by the array of businesses recently raising, like *Structo*, which offers 3D printing for general dentistry (e.g. the manufacturing of denture bases, crown models). This trend toward more rapid prototyping, especially for customized products produced in batches, is likely advancing due to the evolution of consumer and healthcare industries toward individuation and on demand. Hence, it is reasonable to expect further growth in that arena of 3D printing, while larger extant industry giants in transportation and manufacturing either develop their own solutions to mimic innovation or partner/acquire to realize such capabilities. Perhaps the primary frontier for companies now is investigating the 3D printing of new materials; innovation is occuring mainly within this realm, e.g. *Modern Meadow's* biofabricated leather products made using collagen protein as a core building block.

- *A record high of 55 financings in the 3D printing segment closed last year, for a record $651.5 million total.*
- *2019 could eclipse the record for VC invested in 3D printing, signaling an increase in viable applications.*
- *Late-stage volume is also ramping up and accounting for a record proportion of dollars invested.*
- *Markets and Markets estimates a growth in the overall 3D printing market of 23.25% CAGR from 2018 to 2024, hitting $34.8 billion.*

3D Printing VC deal activity



Source: PitchBook
*As of September 25, 2019

Advanced Manufacturing

- *Benefiting from favorable policies and increased investment in educational programs aiming to foster talent, advanced manufacturing is slowly innovating on its path to commercialization.*

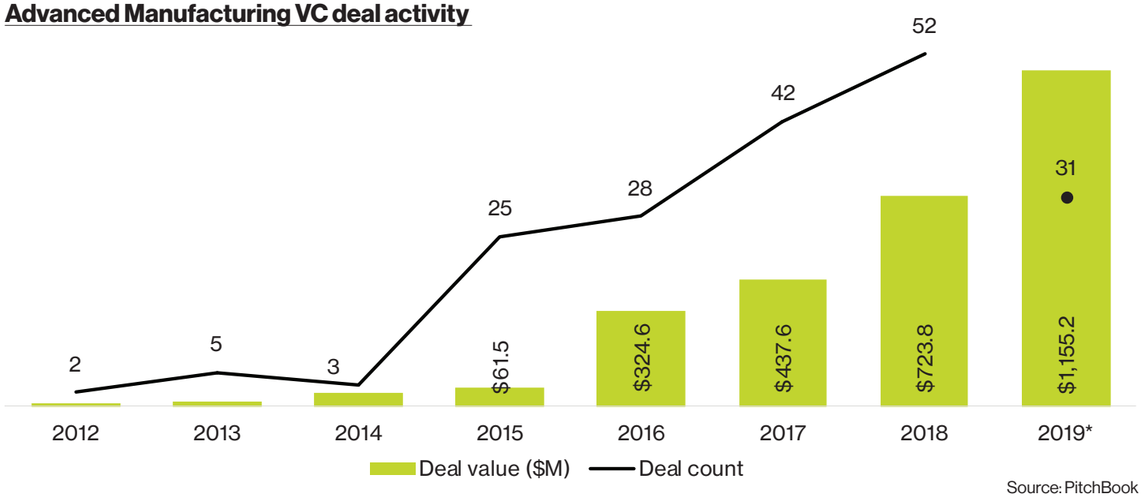
- *2019 has already set a record in VC invested across only 31 transactions, signifying the emergence of leaders in key spaces.*

- *Venture funds' interest has ramped up steadily since 2015, in tandem with advances in materials and 3D printing.*

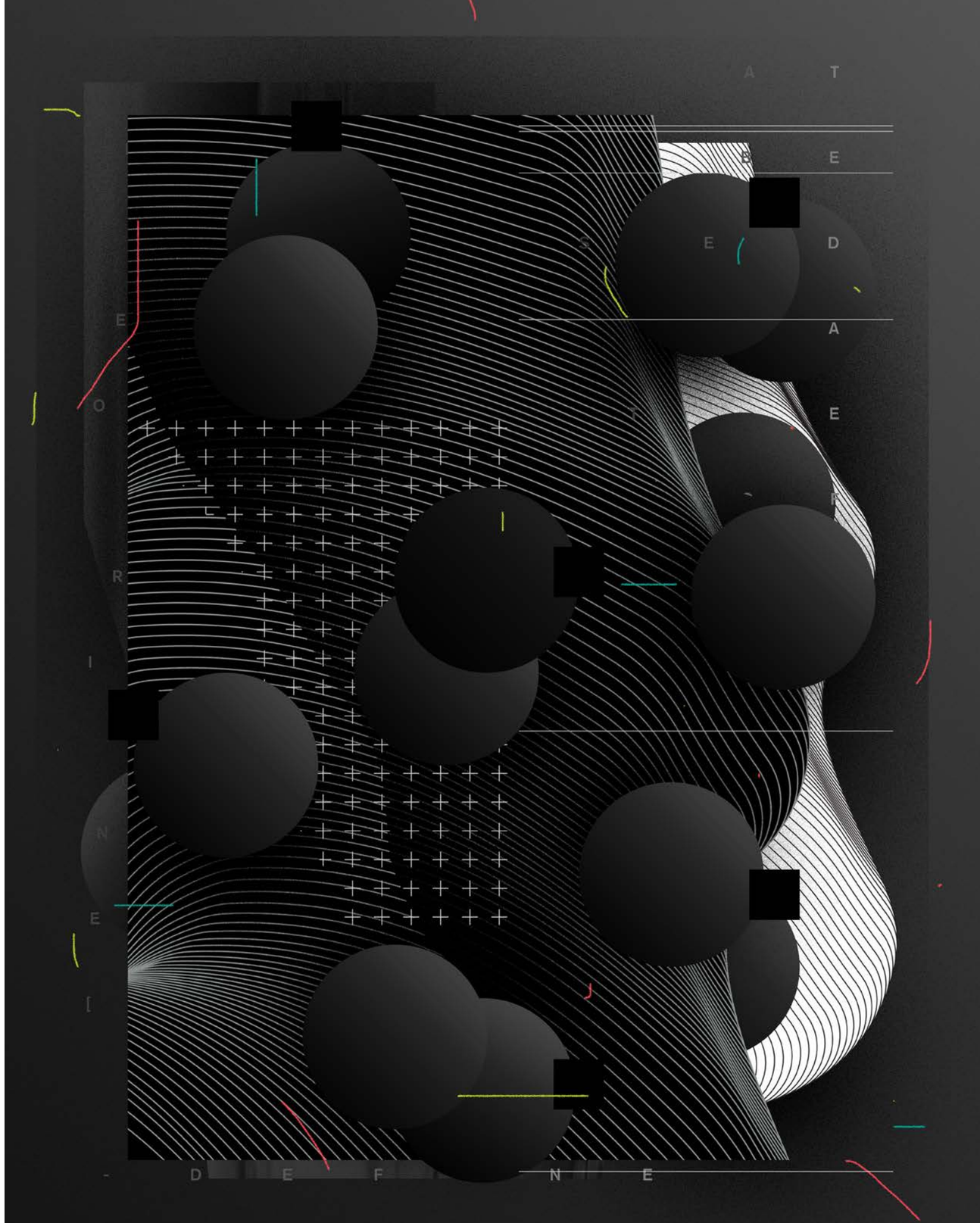
Intertwined with the growth in 3D printing and materials, advanced manufacturing is downwind of those narrower segments, unifying advances and innovations in both segments. Its steady rise in venture funding is to be expected, as more companies can establish advanced manufacturing operations by leveraging incremental to significant advances in both raw materials and 3D printing capabilities. Moreover, the broader smart manufacturing market size is expected to grow given increased adoption by traditional players; Grand View Research estimates the global market size at $395.2 billion by 2025.[1] The vast bulk of activity is still at the angel, seed and early stages, hinting at the field's youth and overlapping with other Tough Tech segments (as well as, it should be noted, robotics). However, more purely advanced manufacturing-focused startups are accruing interest and dollars from VCs, albeit in a scattering of areas across the segment. Businesses such as *Fast Radius* and *SuitX* exemplify these emergent advanced manufacturing niches; the former unifies 3D printing, metal printing, machining and external production from partners to proffer on-demand parts, while the latter has created an exoskeleton for workers in plants and other physically demanding occupations. Perhaps one of the more novel avenues is showcased by *Ginkgo Bioworks,* which produces custom microbes across multiple markets. Given advanced manufacturing's close overlap with both materials and 3D printing, steady growth in VC funding is likely, especially should significant liquidity be realized in the space as larger industry players engage in M&A across all three arenas. Ongoing emphasis at multiple governmental levels about fostering domestic manufacturing, especially in the US, could also continue to cultivate talent pipelines and incubator inception within the segment.

(1) https://www.grandviewresearch.com/press-release/global-smart-manufacturing-market

Advanced Manufacturing VC deal activity



Source: PitchBook
*As of September 25, 2019



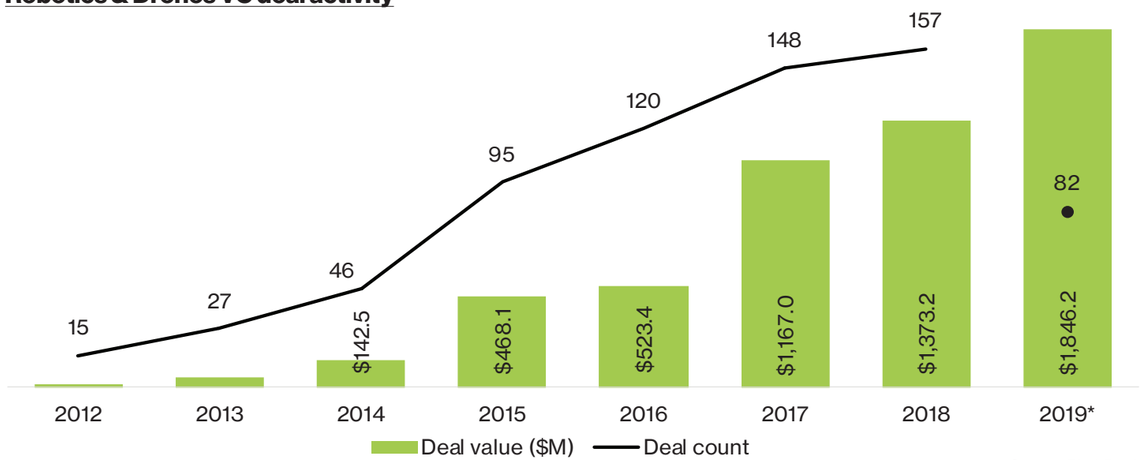
Robotics & Drones

- *The robotics & drones segment hauled in a record $1.8 billion thus far in 2019 and 2018 saw a record volume of 157 completed transactions.*
- *Growth in robotics & drones investment has paralleled advances in computing applications and diversification in hardware.*
- *Proliferation into multiple fields is driving investment as adoption increases overall.*
- *According to BIS Research, the global market for agriculture drones & robots alone is expected to hit $23.06 billion by 2028.*[2]

Robotics & drones has benefited significantly from the advances made in other related segments, whether those segments are included in Tough Tech or not. Significantly more powerful and application-specific computational capabilities paired with swift iteration in hardware platforms—especially as civilian industries picked up on military deployment of drone technologies—have been instrumental to the proliferation of robotics into multiple industries and the associated ecosystem of inputs, from chip design to general parts to fuel cells. More so than other Tough Tech segments, robotics & drones saw swifter expansion into multiple other industries from the beginning; the top companies by VC raised or even prominent exiters in the past several years illustrate this handily—from *Auris Health's* microsurgical devices to *Rise Robotics'* electrification replacement technology for hydraulics. Drones are now proliferating into a nigh-bewildering variety of consumer and commercial applications, as the sheer extent of useful leveraging of high-quality aerial data is now becoming apparent, as well as low-cost, rapid delivery. Companies such as *Zipline International*, which has developed a fleet of drones to deliver medications to health facilities worldwide, exemplify how delivery solutions could proliferate in the future, based upon drones. All these are areas attracting a stronger flow of venture dollars as business use cases and implementation proceed apace. It's easy to envision additional arenas or increasing intensification of usage of both robots and drones in multiple scenarios: search and rescue, inhospitable environments or logistics scenarios that are highly repetitive and simple. As input costs continue to decline, more utility of robots and drones is likely; VC funding of newer avenues for deployment of such is equally likely, as investors look to gain early footing in novel use cases. Key hurdles that will incur increased focus are more autonomy and energy expenditure, both in terms of batteries/fuel and computation.

(2) https://www.prnewswire.com/news-releases/global-agriculture-drones-and-robots-market-to-reach-23-06-billion-by-2028--300845088.html

Robotics & Drones VC deal activity



Source: PitchBook
*As of September 25, 2019

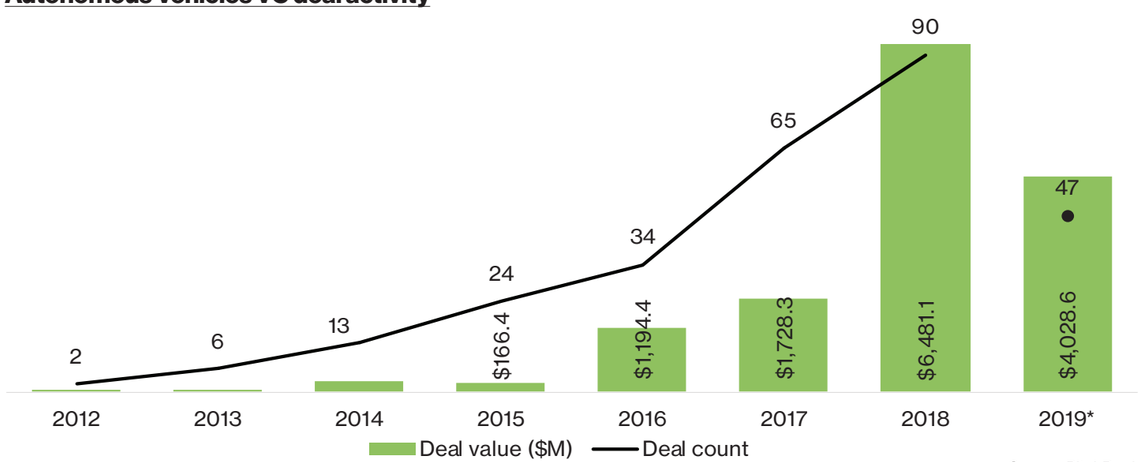
Autonomous Vehicles

- *Autonomous capabilities are now widespread, but still-critical hurdles remain intact for a tipping point to be reached.*
- *The broader ecosystem surrounding autonomous cars (e.g. novel parts, software required for true autonomy) is beginning to burgeon.*
- *There has been remarkably quick growth in VC invested and volume tapering in 2019, however, deal activity remains strong overall.*

Autonomous vehicles capture dollars, headlines and investor interest like no other segment of Tough Tech, barring perhaps only life sciences. Multiple aspects of transport are subject to potential autonomy; it's the entire unified array of capabilities required for many modes of transport that are only now slowly being adequately addressed. The potential for productivity improvements as well as advancement in human quality of life is immense enough it is merely a matter of time, especially given market research reports detailing a potential global autonomous vehicle market of well over $500 billion by 2026.[3] However, critical hurdles still need to be addressed. The massive flow of funding—10 companies within this population have raised $1 billion or more in various types of funds—have gone to more generalist approaches, such as *Cruise's* vehicles produced in partnership with *GM* or *Byton's* development of smart electric cars. Nearly all autonomous vehicle makers are anticipating industry shifts toward renewable energy sources, and thus are developing autonomous and sustainable capabilities hand in hand. In addition, the broader ecosystem around autonomous vehicles is beginning to take shape, attracting more dedicated investor funds and focus as teams realize the need for additional or specialized technologies. For example, although much has been achieved with the typical four-input array of sensors, it may take additional types of sensors to finally achieve full monitoring capabilities for autonomous vehicles. Businesses such as *Roadstar.AI* and The Engine portfolio company *ISEE* are working on more robust autonomous driving software to leverage existing hardware more efficiently or are tapping into augmented and virtual reality simulations to improve human driver reactions—a model that could help inform future autonomous driving solutions. As dominant market players, such as *Cruise*, continue to refine full vehicles, the ecosystem around autonomous vehicles is likely to become a key destination for future VC dollars and startups.

(3) https://www.globenewswire.com/news-release/2019/07/03/1877861/0/en/Global-Autonomous-Vehicle-Market-is-Expected-to-Reach-556-67-Billion-by-2026.html

Autonomous Vehicles VC deal activity



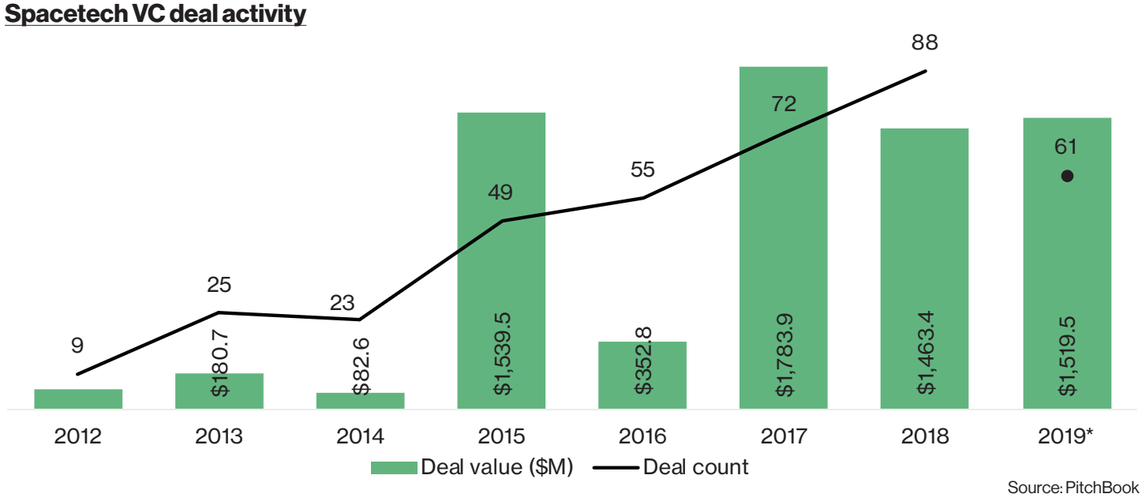
Source: PitchBook
*As of September 25, 2019

Spacetech

- *VC invested is robust in 2019 to date, eclipsing $1.5 billion, and is on pace to potentially set a record sum.*
- *Deal volume has steadily grown over the past several years and is showing no signs of stopping.*
- *The proliferation of the satellite ecosystem has been a primary driver of financing volume.*

Spacetech in general has had a longer tenure across multiple media channels, primarily due to outlier companies such as *SpaceX*, *Planet* or *Blue Origin* that have been active for quite some time. Lately, the trickle of VC financing within the space has intensified into a flood, with the past three years seeing close to $5 billion invested across several hundred rounds. Moreover, 2019 may well set a record for both VC invested and volume, as the next wave of innovation around enabling spacetech infrastructure in general becomes popular. This surge in investor appetite, along with a steady (albeit slow) increase in later-stage funding is primarily attributable to not only that but also to growth in primary areas of the spacetech ecosystem—rocketry and satellites—with the latter especially experiencing a boom. (As more businesses find success by still attracting funding while staying private, further late-stage activity is to be expected.) From micro to nano, satellite companies are pushing into launches in order to pursue the various commercial implications of improved global imagery (e.g. disaster relief and crop productivity tracking). In addition, other businesses such as *Descartes Labs* are building platforms to better derive insights from vast troves of imagery data, while even more niche specializations are also being targeted, such as the methane monitoring via microsatellites that *Bluefield* offers. All in all, the satellite ecosystem has been the primary benefactor of the surge in venture funding in the past decade—although rocketry companies, given their business models and technical requirements, tend to account for the largest single rounds. When reviewing the companies funded most recently, there are not many significant signs of a push by startups or investors into other niches of spacetech, such as nutrition for longer-term human space residency. It is likely that private capital has yet to flow into those ventures due to the significant R&D still required in those arenas. Once commercialization seems within grasp, it is reasonable to expect more niche areas of the industry will be on the frontier for continued spacetech development.

Spacetech VC deal activity



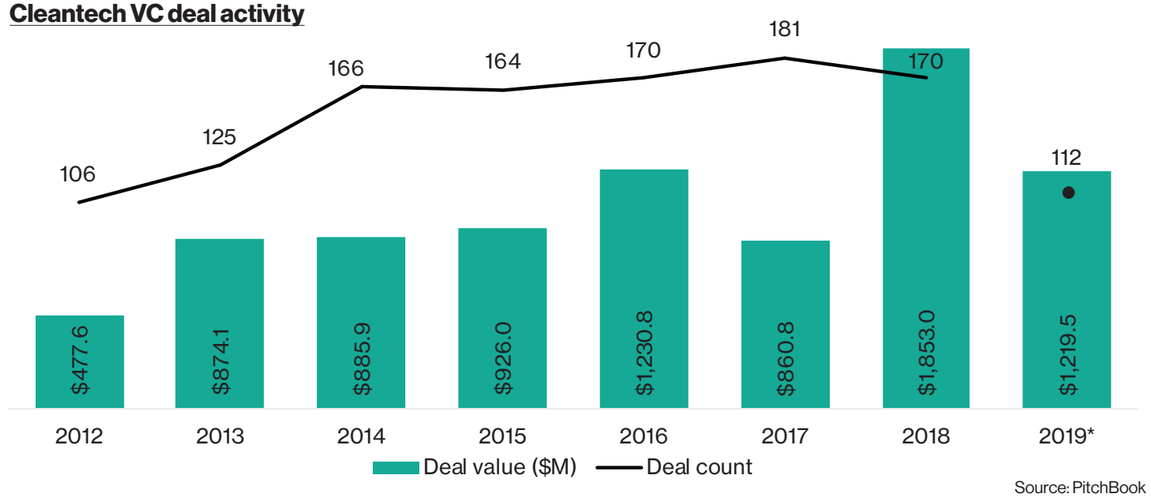
Source: PitchBook
*As of September 25, 2019

Cleantech

- *Since a cleantech boom and bust, a more cautious rise and evening out of funding has occurred as models of investment have evolved*
- *The boom in electric vehicular ecosystems, alternative energy production and energy management and storage has primarily driven the aggregate amount of dollars invested.*
- *Close to $4 billion has been invested since the start of 2017.*

Cleantech is experiencing a renaissance of sorts given increased impetus from not only public policymakers but also a decided shift toward and emphasis on clean technologies from multiple public stakeholders and consumer segments. When reviewing the companies that have raised the most in funding, it is clear that three primary drivers are behind the surge in capital: the electric vehicle ecosystem (e.g. battery innovation), technical advances and greater installation of solar or other alternative-energy production means and overall energy management and storage. Particularly in China, which exhibits broader vehicle industry trends and receives government support, there has been a concerted push into manufacturing both luxury and mass-consumer vehicles. Plenty of capital has been flowing into the broader transport ecosystem as well, from electric scooters to improved battery and energy storage technology. Other companies, such as solar tech providers like *d.light*, which raised a total of $173.4 million across its tenure thus far, or next-generation Li-ion battery maker *Enevate*, which has raised close to $120 million in aggregate, exemplify the energy ecosystem more broadly. It is important to note that public and private policy and sentiment shifts are the primary key factors helping drive the recent growth in investment to a considerable degree. However, many key underlying technical advances have also spurred business opportunities forward into a realm that makes more sense for classic venture models. Thus far, autonomous and electric vehicle ecosystems seem to offer the most promise and make the most sense for VC models, especially those of corporate VC arms. Consequently, it is likeliest that investors and startups alike will monitor the development of this ecosystem and the emergence of viability over the next few years before additional venues of cleantech see any such similar flows of capital. However, that isn't to say that other arenas of cleantech are being neglected; rather, there is still funding of companies such as *Econic Technologies* or *GreenMantra Technologies*, the former of which has developed a catalytic process to make polymers from carbon dioxide waste and the latter a thermocatalytic system that recycles plastics into waxes and fuel.

Cleantech VC deal activity

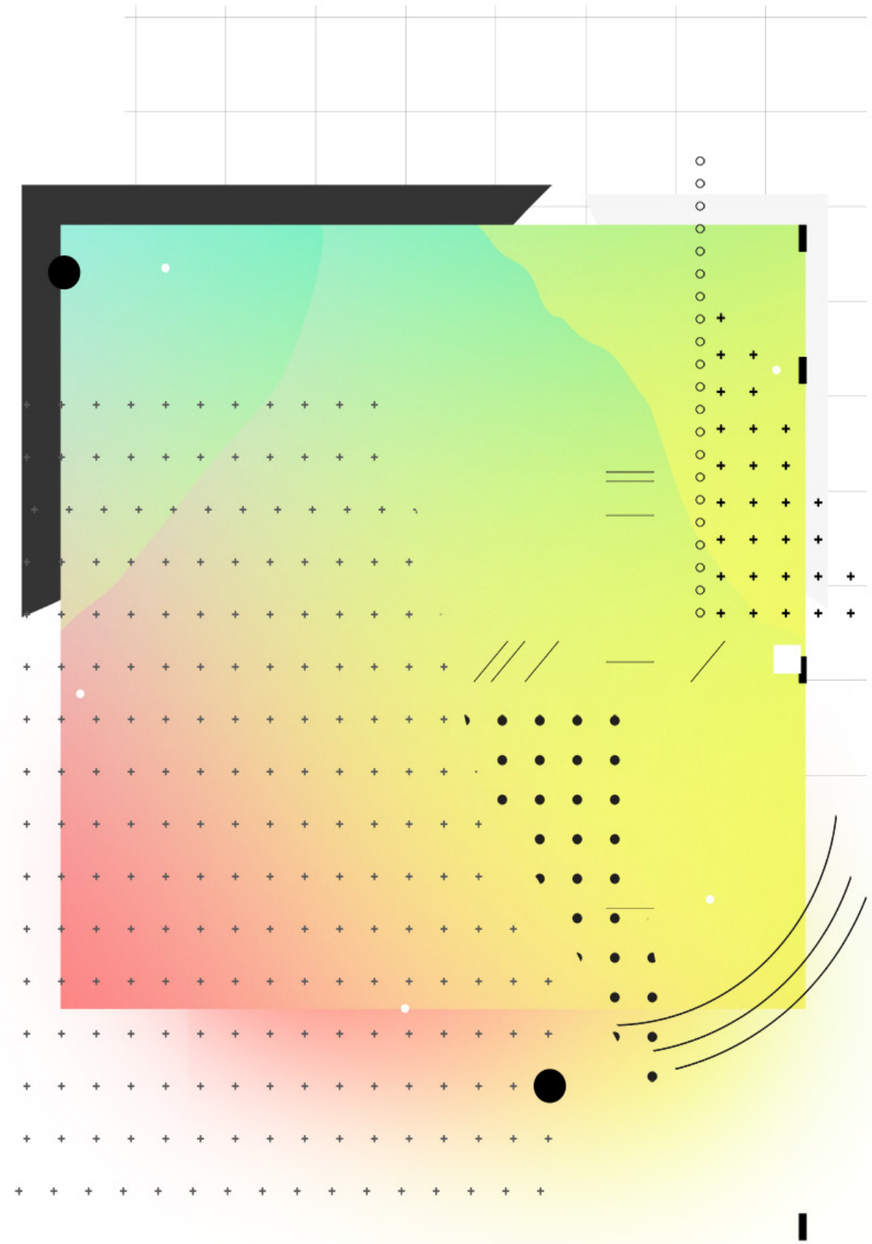


Source: PitchBook
*As of September 25, 2019

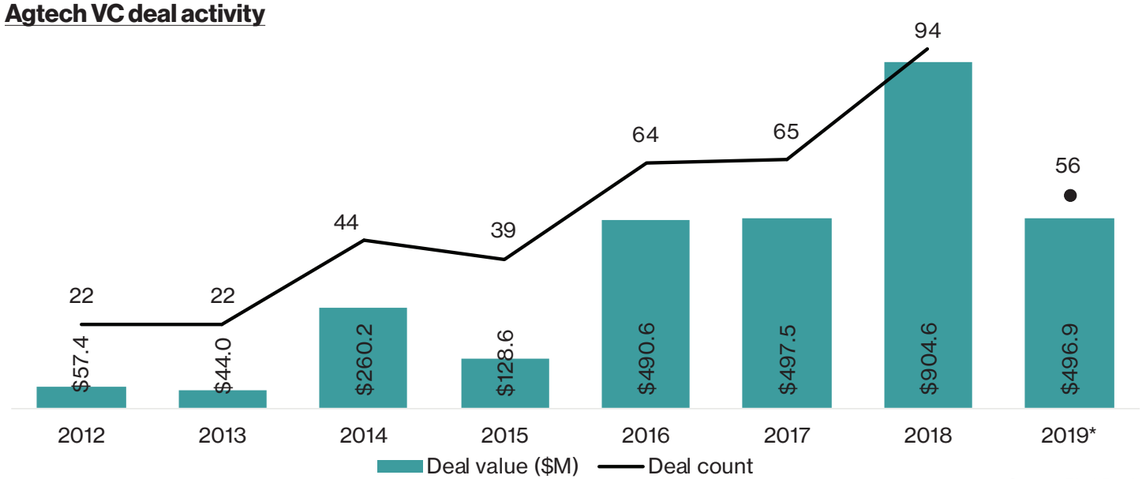
Agtech

- *Agtech saw high of $905 million invested in 2018 across 94 financings—clear records for both.*
- *There has been strong development of multiple agtech avenues, feeding into extant and incumbent agricultural chains of production and supply, as well as tackling brand-new arenas.*
- *A gradual increase in funding across all levels of capital stack signifies maturation of multiple models.*

Agtech has seen an increase in media popularity, as media-savvy and logistically adept businesses like *Beyond Meat* saw remarkable stock surges as well as proliferation of their alternative protein products. Aside from alternative proteins, however, multiple facets of the agtech ecosystem are piquing investors' attention, from advancing robotic systems employed in the field to more robust crop imagery technology to hybrid breeding technologies. For some venues of agtech—e.g. seed coatings or brand-new seeds—incumbents' overshadowing and extant production and supply chains necessitates partnerships and planned acquisitions by the likes of *Bayer* or *Monsanto*. Granted, that did not preclude businesses like *Indigo Agriculture* from raising hundreds of millions and tackling multiple aspects of agtech, but it often requires significant inputs. More commonly, there is a broader spread of capital instead of a concentration in one agtech segment. For example, eight companies have raised $100 million or more since 2012 began, and their products and services range from ag-specific drones to plant breeding to greenhouse farms for local markets. The diversity of agtech niches stands out among Tough Tech in general, although the nature of agtech and its myriad entry points for innovation support that trend. Moreover, this trend also implies the breadth of capital flow will continue, as cost-effective digitization and mechanization continue to demonstrate value. Increased pushes by governments and the industry in general to reduce usage of fertilizers and pesticides in an effort to combat potential pollution will also support investment in more effective, efficient soil cultivation technology and hardier seeds. Increased talent pools are also more proximate than ever before as technical advances bring agtech's purview into confluence with other technical domains. Last but not least, the alternative protein niche appears to have finally found its footing, so a host of additional startups within that realm are likely to begin exploring beyond lab-grown protein into insect and plant sources.



Agtech VC deal activity



Source: PitchBook
*As of September 25, 2019

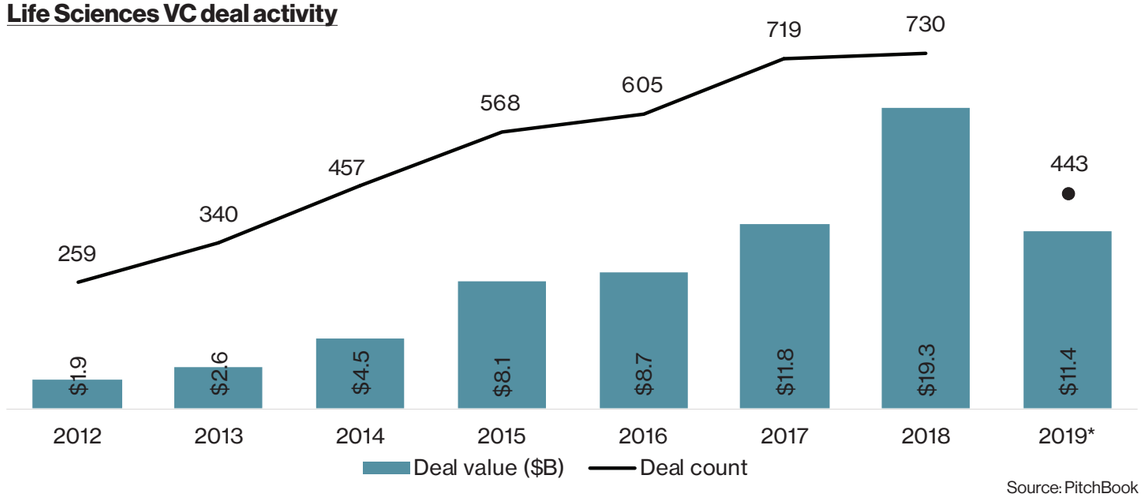
Life Sciences

- *A record $19.3 billion was invested across 700+ financings last year, and despite a dropoff, 2019 figures remain historically robust.*
- *Life sciences is still dominated by pharmaceuticals and biotechnology in general, with oncology-focused immunotherapy plays critical to the recent surge in funding.*
- *Gradually, late-stage funding is ramping up in a sign of the maturation of the privately held company universe within life sciences.*

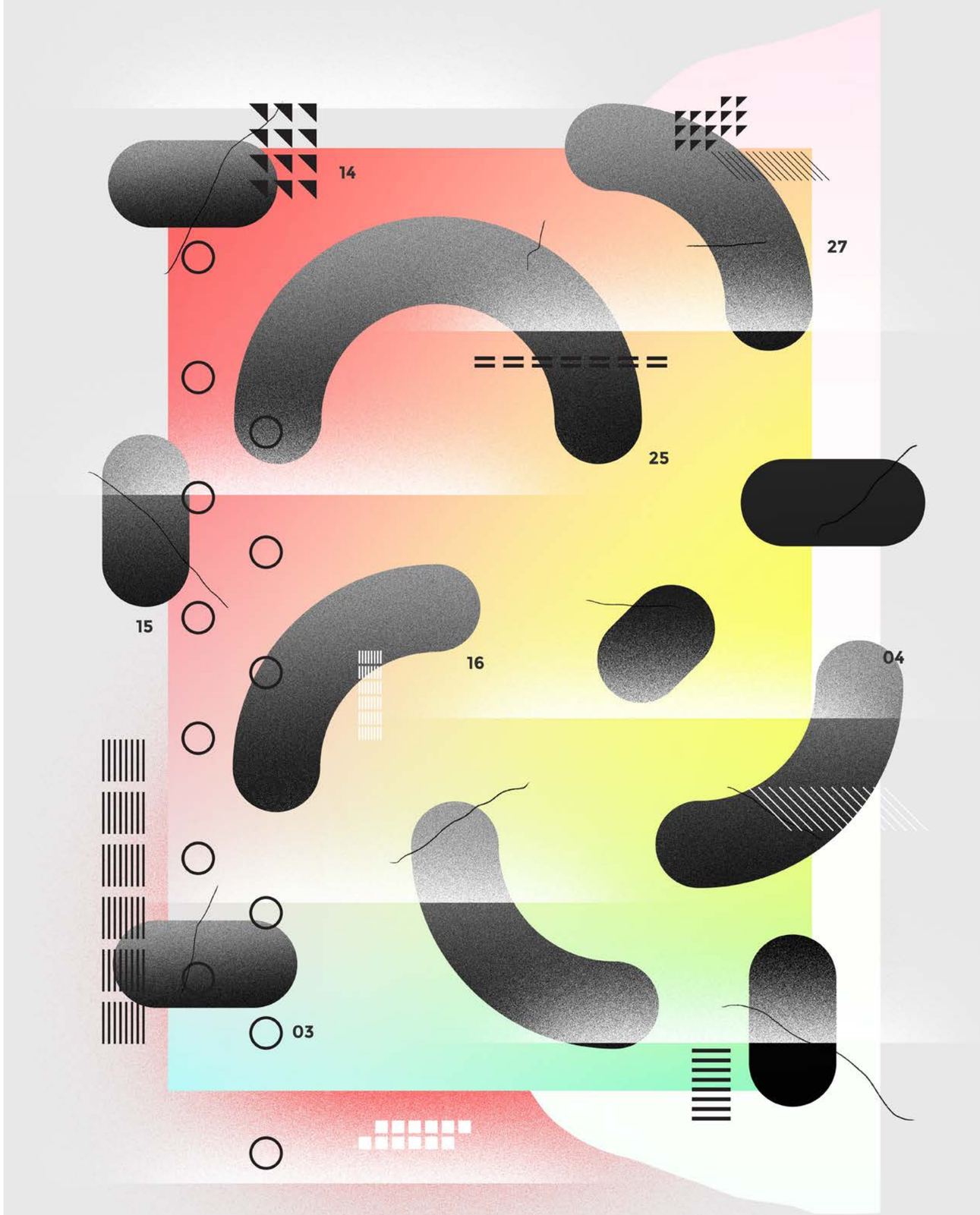
Life sciences is far and away the most dominant of the Tough Tech segments in terms of size, boasting well over 700 transactions in both 2017 and 2018 as well as vast sums invested across that same timespan. Intimately interwoven with the complex healthcare ecosystems of developed nations, the life sciences industry proffers multiple venues for entrepreneurs to start ventures. Interestingly, the average pre-money valuation and deal size for life sciences Tough Tech companies has not succumbed to inflation to the same degree as the broader venture cycle. High barriers to entry—both regulatory and technical—are likely helping combat inflation. The dynamics of the life sciences venture space are also different than most other Tough Tech segments, as the bulk of the companies that raised the most VC since 2012 have already exited. This illustrates the private longevity of life sciences companies isn't as long as other Tough Tech segments, or even VC at large, especially given industrywide prolongation of holding periods. Such relatively swift liquidity pathways allows life sciences to see heavier capital flows.

It is difficult to tease out which key segments propel that inflation due to active investor interest and significant stores of dry powder; however, from review of the past two years' financing flows, primary arenas include immunotherapy, genomics and associated therapeutics, which often focus on a rare disease or disorder. One key example of the boom in immunotherapeutics is *Juno Therapeutics*, which develops chimeric antigen receptor and T-cell receptor tech for specified antibody and immune responses to cancer cells. *Juno Therapeutics* first raised hundreds of millions of dollars and listed on the public markets. It was recently acquired by *Celgene*. Immunotherapies and genomics are likely to remain key areas of focus for companies and investors going forward, although gradually, more niche areas such as genomics-leveraging software and hardware platforms will become more readily available for exploration. One intriguing question that will become increasingly important as an area of exploration is the potential for immunotherapies to proliferate into arenas beyond oncology, which is where the bulk of immunotherapeutic explorations are occurring.

Life Sciences VC deal activity



Source: PitchBook
*As of September 25, 2019



METHODOLOGY

The datasets underlying this report were derived from the PitchBook Platform. In order to define tough tech, The Engine and PitchBook constructed thirteen subverticals that were deemed to comprise Tough Tech in its entirety via custom searches in the PitchBook Platform that employed a combination of keywords, industries and verticals. From there, each custom search was reviewed to add in or exclude companies as well. The full list of thirteen subverticals are as follows: 3D printing, agtech, advanced manufacturing, materials, micro-electronics, life sciences, robotics & drones, spacetech, autonomous vehicles, cleantech, nanotechnology, quantum computing, and artificial intelligence & machine learning. The life sciences vertical includes oncology. In addition, two limiting criteria were utilized: founding date of the company was on or after January 1, 2009 and the date range of the financings included for analysis of overall transactions was between and inclusive of January 1, 2012 and September 25, 2019. Cross-border transactions within this report were defined as deals within Tough Tech that had at least one investor with primary headquarters in a different country participating; in addition, overall Tough Tech datasets, given potential overlap between segments, were deduped to ensure no transaction or company was counted twice. However, given that in reality some companies can exist within two segments, each individual segment's deal flow may include the financing flows of a company that are also included in another Tough Tech segment's dataset. The reason for this is to reflect the reality of the market, in that Tough Tech companies can span subverticals. PitchBook's customary methodology for venture datasets was utilized otherwise. For details, see the full list of PitchBook report methodologies at https://pitchbook.com/news/articles/pitchbook-report-methodologies.

SPONSORS

Army Research Laboratory (ARL) maintains high vigilance in monitoring emerging technologies and corresponding R&D efforts within industry, academia and international markets. ARL accomplishes this through active engagement in the national and international scientific dialog to remain poised to react to developments that make the area a viable approach toward Army capability challenges. The Tough Tech areas embodied in The Engine's long-term portfolio broadly overlap with future Army S&T requirements and will be key enablers in underpinning success.

Breakthrough Energy Ventures (BEV) invests in companies that leverage innovative technologies to help address climate change. Backed by many of the world's top business leaders, BEV has more than $1 billion in committed capital to support bold entrepreneurs building companies that can significantly reduce emissions from agriculture, buildings, electricity, manufacturing and transportation. The fund was created in 2016 by the Breakthrough Energy Coalition.

Tough Tech means solving a human need that will fundamentally make a safer, more efficient, sustainable environment for society, and most importantly, give time back to each individual to enjoy what they like to do the most and see the world. At Hyundai CRADLE, this means we are looking for technologies and business models that enable all-inclusive human mobility so everyone can travel everywhere, unhindered.

As a leader in the ever-evolving financial services sector, PNC Bank recognizes the importance of innovation and transformative technology. As we expand our operations in Boston, we are thrilled to support the leading forum dedicated to Tough Tech. PNC has a long-term commitment to deepening our Boston civic and community involvement. We are excited about the prospect of a growing industry for Tough Tech and look forward to continued engagement in the years to come.

THE ENGINE

Built by MIT

The Engine, built by MIT, invests in early-stage Tough Tech companies.