

S³ - Startups for Sustainable Semiconductors

A Model for Ecosystem-Collaborative
Industrial Decarbonization



CONTENTS

Authors.....	3
1. Executive Summary	4
2. Origin, History, Structure of the S³ Program	5
3. Finding the Right Startups by Categorizing the Needs	7
4. Key Performance Indicators for S³	11
5. The Cleantech Startup Landscape	20
6. Conclusions, Takeaways and Calls to Action	24

SPECIAL SECTIONS

• Sustainability Challenges for Semiconductor	10
• Understand Water and Waste Challenges.....	14
• Understand Regulatory Pressures and Market Dynamics.....	15
• Understanding the Emissions Challenge.....	16
• Understand the Energy Challenge	18

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SEMI, the global trade association for the semiconductor and electronics design and manufacturing value chain, provides management of the S³ Program.

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1. EXECUTIVE SUMMARY

Industrial Decarbonization is an urgent challenge facing humanity. While manufacturing and technology sectors drive historic economic and quality of life improvements, it has been achieved by what we now know is harmful rates of consumption (energy, water, metals and materials) and emissions via industrial processes and electricity consumption.



Simultaneously, to produce the chips powering modern life, the challenges associated with high volume manufacturing pose such high barriers to entry that the ability to produce them is limited to only a handful of the largest companies on Earth. These barriers are creating technology islands – of IP, methods, strategies, and knowhow – where one company’s methods demand bespoke (expensive) solutions not easily addressed by start-up innovations.

SEMI, the global industry association connecting companies worldwide across the semiconductor and electronics design and manufacturing supply chain, created the Startups for Sustainable Semiconductors (S³) program in 2021 under the leadership of the corporate venture capital arms of the largest semiconductor sector manufacturers.

The program seeks to ease the friction startups may experience in accessing the industry, with the ultimate goal to accelerate decarbonization timelines of the semiconductor ecosystem as a whole. By collaborating in this way, intensive competition gives way to sector advancement on a larger and more efficient scale to the benefit of the sector and sustainability overall.

With over **150** unique startup teams applying to date, leading to **8** direct VC investments, **34** first-of-their-kind proof of concepts, and **7** sustainability innovations scaled into initial production, we believe S³ offers a viable, successful model for accelerating new sustainability innovations into large industrial ecosystems. This paper provides the framework and metrics of the program as a roadmap to other funders, as well as some background on the sustainability challenges facing the semiconductor industry for potential applicants.



2. ORIGIN, HISTORY, STRUCTURE OF THE S³ PROGRAM

In 2021, an initial group of prominent Semiconductor Corporate Venture Capitalists (CVCs), including Micron, Applied Materials, Intel, and EMD Electronics, convened to explore investment opportunities in semiconductor sustainability. Recognizing that the industry's ambitious sustainability goals could not be achieved through incremental improvements alone, the CVCs devised a grass-root initiative: the Startup for Sustainable Semiconductors (S³) mentoring program and pitch event.

Applied Ventures kicked things off with a virtual Sustainable SEMI Venture Forum in late 2021. The forum featured industry leaders such as SEMI's CEO, Ajit Manocha, corporate executives, CVCs, and prominent sustainability technology innovators. At the end of the forum, the S³ pitch event was officially announced.

In early 2022, a broader planning committee comprised of several top semiconductor CVCs was formed, working closely with SEMI to formally launch the S³ event. Regular meetings were held to iron out the application process, the mentoring program, the qualifying pitching sessions, and the grand finale pitch session to the larger industry at SEMICON West.

A vital component of the S³ program is the mentoring sessions offered to the semi-finalists with the intention of helping startups break into the semiconductor industry. Corporate investors and technology experts are paired with startups to provide guidance on semiconductor-specific technical challenges and prepare them for final pitches to potential Business Unit customers.

The inaugural S³ event attracted 50 applicants across the energy, water, and materials sectors. Nine exceptional finalists were selected to pitch their companies at SEMICON West in July 2022. The startups and CVCs agreed that this was an invaluable opportunity that provided the startups and sponsors alike with awareness, exposure and networking opportunities to drive the innovation and change needed to accelerate the semiconductor sector toward its Net Zero goals.

Now in its fourth year, the program aims to meet promising new technologies where they are at. If the startup wants to redefine their product or solution to better meet the needs of semiconductor customers, then we provide that input directly from our operations teams. If they are looking for funders, our own members plus substantial connection to the VC community is available. The key of the program is finding what the startups need to find mutual success for promising technologies for semiconductor sustainability.

November 2024 Survey Findings

- Past participants show that 3.67/5.0 responded that the mentoring provided by S³ has improved their pitch as a startup and found the coaching very effective.
- Participants received interest from across the semiconductor ecosystem including foundries, OEM and Research institutes working on low-GWP alternatives.
- The participants overall enjoyed the experience of presenting live at SEMICON West and felt it was a good platform to expose their technology to the right audience. They were grateful to make solid connections with potential investors and sustainability professionals in the industry, who understood the value of their product. They appreciated the feedback on their corporate pitch as well and found connection for the long-term.
- “Excellent feedback, contacts within the industry. Help in securing a few new points of contact is underway” program participant

3. FINDING THE RIGHT STARTUPS BY CATEGORIZING THE NEEDS

Each year, the S³ call for applications centers on a set of three search categories which have evolved slightly from year to year to reflect the most up-to-date thinking of where and how the semiconductor industry needs to tackle sustainability. The S³ CVC organizers gather feedback from the sustainability and technical teams of their respective corporate parent companies (e.g. Intel, EMD Electronics, Micron, etc.), where conversations reveal the most pressing needs for sustainability innovation for semiconductors. (See the callout sections of this paper for the Sustainability Challenges for Semiconductor.)



This might include broader climate tech topics such as direct air capture, green hydrogen and PFAS destruction technologies, or GenAI and other digital solutions: all areas that have seen bursts of growth and VC attention in recent years. Since many of these technologies are often focused on first customers in other industries that might seem easier to access, one goal of the S³ program is to demystify the semiconductor industry for these entrepreneurs and help break down barriers of entry into the semiconductor industry.

The broad Climate Tech topics such as direct air capture, green hydrogen and PFAS destruction technologies, or GenAI and other digital solutions: all areas that have seen bursts of growth and VC attention in recent years. Since many of these technologies are often focused on first customers in other industries that might seem easier to access, one goal of the S³ program is to demystify the semiconductor industry for these entrepreneurs, help break down barriers of entry into the semiconductor industry.

By pairing the specific sustainability needs of the semiconductor industry with the trends observed in the broader startup ecosystem, the S³ team arrives at a set of categories each year. Some topics may require a solution specifically tailored for the semiconductor industry, while others might be readily solved by delivering an existing Climate Tech or AI solution to semiconductor customers.

Over the past four years, water, energy, and materials – including circularity, emissions, and waste have consistently made the list. Figure 1 shows the evolution of categories year over year. In Year 1, emphasis was on water and energy usage. Year 2 and Year 3, based on feedback and market trends, the S³ team placed added importance on the topic of emissions mitigation, and hence, became its own category

2022 Yr 1	Energy Efficiency Surging energy consumption in semiconductor fabrication plants has created both hurdles for growth and environmental concerns. We are calling for innovations that reduce energy intensity throughout the manufacturing floor including fabrication tools and facility systems such as HVAC, compressed dry air, cooling water, chemical delivery, and abatement systems. Some examples of potential opportunities are: - New designs, materials or processes that improve fabrication throughput & reduce energy consumption per unit of production. - Improved thermal management in fabrication tools and facility systems to minimize energy use - Advanced power supply modules to reduce energy conversion loss - Innovative sensors and management software to identify energy saving opportunities	Water Technologies - Efficient water use is critical for the continued growth of the semiconductor industry. - The semiconductor industry seeks collaboration with new and emerging technologies to assist in its goals of 100% water recapture and reuse from our fabs, with a focus on the following areas: - Digital Water - platforms that enable fast/simple access to water consumption data and associated value creation based on that data and analytics thereof. - In-situ Separation - technologies that enable economic steam segregation and advanced separation inside or adjacent to a specific process tool (i.e. technologies that allow segregation of water before sending to end of line water treatment facilities). - Drop-in efficiency - new membrane, filter, or technology that reduces the energy intensity of water treatment while fitting within existing treatment footprints.	Materials Usage - Alternative Chemistries - new chemistries for wafer processing with less reliance on environmentally negative chemistries: - Relevant processes in wafer processing (front-end-of-line & back-end-of-line): Deposition, Lithography, Patterning, Etching (dry/wet), Planarization, Plating, Cleans, Packaging - Materials and chemicals innovation that increase sustainability, are more eco-friendly: - Lower toxicity and/or reduced emissions - Materials designed for circularity - Sustainable/ethical sourcing - Materials that enable novel sustainable processes or reduced materials consumed - Digital solutions (process efficiency, circular product design, new material discovery) - For reduced e-waste toxicity/better recycling - Materials for high performance, low power chips with fundamentally new architectures - Waste management/recycling - Abatement, waste stream reduction, recycling, circular economy.
	Energy Efficiency Decreased energy intensity for current and future production nodes, including: - New designs, materials or processes for fabrication throughput - Improved thermal management - Advanced power supply module - Innovative sensors and management software	Emissions Technologies - Abatement - Alternative chemistries for wafer processing - Emissions detection/reduction/accounting tools	Circularity – Water & Waste Management - Water - Increased water recycling solutions via: - Digital water solutions - In-situ separation - Drop-in efficiency (new membrane, filter tech, etc.) - Waste Management: - Recycling - Waste stream reduction - Materials and processes designed for circularity
	Energy - New process designs for decreased energy intensity - Improved thermal mgmt, including data center cooling - Alternative energy sources - Energy tracking and management software	Emission Technologies - Direct air capture and treatment - including GHGs - Emissions detection, reduction, and measurement SW & HW tools	Circularity – Water & Materials - Water: waste stream, brine treatments; desalination; metals extraction; water reuse; PFAS removal/collection, destruction; SW (measurement, planning, maintenance) - Materials: SW/AI for sustainable chemicals development; Green H2/H2 recycling; recycling/reuse; sustainable processes/storing/shipping; sourcing/mining/refinement of materials. (e.g., H2, helium, rare earth, copper, ammonia, cobalt, metals, organics/inorganics)
	Sustainable Data Center Sustainability and efficiency solutions for data centers, including thermal management, power management, system and components	GenAI for Sustainable Design GenAI, SW and other AI solutions for alternative materials discovery, device and physics simulation, energy efficient chip design, end-to-end sustainable product design	Sustainable Semiconductor Manufacturing More sustainable solutions for energy (new process designs for lower energy intensity, energy tracking and management software) and materials (sustainable materials, emission control and abatement, water solutions, PFAS destruction, recycling)

Figure 1: S³ Category Evolution since program inception

In Year 4, the needs have been recategorized based on product. Semiconductor manufacturing topics have been joined by GenAI and Datacenter Sustainability, reflecting downstream - or Fab Scope 3 - pressures for reducing emissions and the promise of leveraging AI-powered solutions to unlock new sustainability gains. Key areas of importance continue to include topics such as water usage, toxicity, abatement, manufacturing simulations, and materials discovery.

The full set of S³ finalists is shown in Figure 2. Within each category, the S³ team announces the top startups each year. This highlights the importance of each category and is why the category selection and definition must reflect the actual sustainability innovation needs in the semiconductor industry. Ultimately, winners are invited to SEMICON West each year for the opportunity to present, hold a booth, and otherwise gain facetime with investors and semiconductor corporate teams, increasing the likelihood of developing a new pilot project or onboarding a new customer.

2022 Yr 1	Energy Efficiency	Water Technologies	Materials Usage
	  	 	 
2023 Yr 2	Energy Efficiency	Emissions Technologies	Circularity - Water & Waste Management
	  	  	  
2024 Yr 3	Energy	Emission Technologies	Circularity - Water & Materials
	  	 	   
2025 Yr 4	Sustainable Data Center	GenAI for Sustainable Design	Sustainable Semiconductor Manufacturing
	Call for applications currently <u>Active</u> . To be announced ahead of SEMICON West 2025!		

Figure 2: Startup Finalists by Category, since S3 Program inception (2022 – today)

SUSTAINABILITY CHALLENGES FOR SEMICONDUCTOR

In an era defined by rapid technological advancement, the growth of the semiconductor industry has also brought to light its substantial environmental impact. Semiconductor chips are vital components used in almost all modern electronics, and their production necessitates the use of water, energy and raw materials before transforming them into devices used across the consumer and industrial spectrum, as depicted in Figure 1. Reducing the environmental impact associated with chip production poses significant challenges and demands new innovations in manufacturing processes, waste treatment, material use and design, among others.^{1,2}

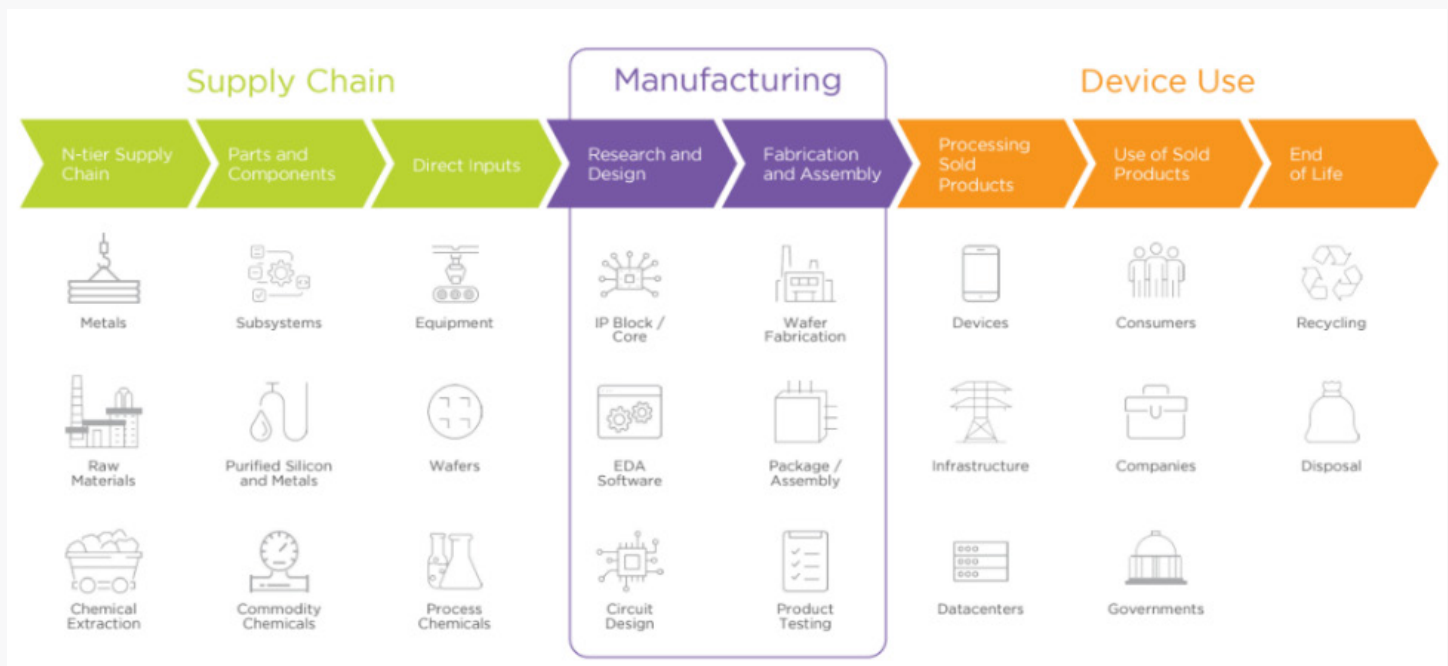


Figure 3. Semiconductor value chain activities. Source: SEMI Semiconductor Climate Consortium's BAR Working Group and BCG. (2023). "A White Paper on Transparency, Ambition, and Collaboration."

The industry's journey towards sustainability is not only a response to these environmental concerns, but also a strategic adaptation to evolving regulatory landscapes and shifting consumer expectations, as well as a proactive effort to adapt the industry onto a more sustainable production path.

Challenging this, however, is that advanced node manufacturing at smaller scales, such as 2 nm, tends to be associated with increased resource use and emissions. To achieve the sustainability aims of the industry, new efficiencies, processes and solutions will need to be developed, and some of these will need to be developed within industry companies, which already spend 15-20% of annual sales on R&D, second only to the pharmaceutical industry in the US, according to corporate SEC filings.

¹ Applied Materials. (2023). "Applied Materials Charts Progress Towards Environmental, Social and Governance Goals in Latest Sustainability Report."

² EE News Europe. (2022). "First Semi sustainability report calls for more investment."

4. KEY PERFORMANCE INDICATORS FOR THE S³ PROGRAM

Leading up to our fourth year of S³, as the sponsoring companies we analyzed ourselves to gauge the efficacy of the program in executing to our core objective: to introduce new sustainability tech to our companies and accelerate adoption in production environments.

“Nothing matters if the dogs don’t eat the dog food” – Marc Randolph, Netflix cofounder

Our success metrics are shared here for the first time showcasing nine examples of how applicants and their products/solutions have been assessed, contracted and invested. The data shows that:

- One in three startups reviewed by internal subject matter experts moves into a proof of concept (POC)
- One in five startups that secure a POC move into a scaled deployment.
- Once in two startups that move into scaled deployment receive direct investment from the CVC arm of the company.
- Approximately one in 30 applicants is successful at a first scaled deployment with a semiconductor customer.

Comapany	Assessments	POCs	Scaled Deployments	Direct Investments
1	0	1	0	0
2	10	3	0	1
3	13	4	1	1
4	23	8	2	0
5	20	9	3	2
6	11	4	1	1
7	2	2	0	0
8	12	2	0	1
9	12	1	0	1
TOTAL	103	34	7	8

Category Definitions:

Assessment	Did the internal subject matter experts perform a deep dive on the technology presented by the startup?
Proof of Concept (POCs)	Did the startup share their product – access to software, a physical prototype, a chemical sample, a simulation – with the internal subject matter experts for direct testing?
Scaled Deployment	After that POC, did the internal subject matter expert recommend and execute on advanced assessment or use in production environment?
Direct Investments	Did the startup receive direct investment from the participant corporate venture capital group?

Example 1 - Excellent Messaging, Failure to Deliver

An applicant from Year 1 had significant venture capital investment and caught the attention of multiple subject matter experts with projected sustainability advantages. After reviews by internal subject matter experts at multiple companies, proofs of concepts were signed.

However, in each proof of concept the startup's product failed to deliver to core metrics – today, no scaled deployments or continued POC activity is known to exist in the semiconductor ecosystem.

Example 2 - Aqua Membranes

Micron spent approximately 12 months assessing the Aqua Membranes technology. Only after 9 months of continuous testing in a first POC, Micron water teams were convinced of the energy savings potential of Aqua Membranes' technology. After another 8 months, the first scaled test deployment occurred in a high-volume setting.

Time to deployment: 2.5 years.

The Aqua Membranes example illustrates the journey of new sustainability technology scaling into legacy industrial equipment. Change to these legacy systems isn't just hard, it is actively discouraged by the requirements of the business where any change to established methods poses a risk to throughput, quality, and yield.

When this patience - demanded by reality - collides with VC-backed startup mantra "fail fast, fail often" it causes mutual frustration. However, once this frustration is identified and expectations are set, a funnel emerges where startups whose combination of value, productization readiness, and team execution prepare them for success with semiconductor customers. The S³ program, particularly the mentoring process, is designed to maximize efficiency and success.

We have found many opportunities to review new sustainability innovations. For example – in 2020, Micron Ventures introduced over 200 sustainability startups to the Micron team members working on point solutions for specific sustainability challenges. This effort brought to light two challenges that, while basic in retrospect, were not considered at the start of the sprint effort:

1. Technology and productization barriers to entry are extremely high for introducing new sustainability technologies into semiconductor manufacturing operations.
2. Productization needs can be unique, and in many cases a technology that can demonstrate and scale at one manufacturing site is not appropriate for adoption in another geography.
3. One semiconductor manufacturer alone is not a large enough customer signal to invest in developing and launching a given, venture-backable product.

Key Learnings and Future Metrics

Venture capital is a business of failure:

- Startups keep prototyping messages and products to discover product-market fit; while
- Investors vote our belief with money, knowing full well most of those beliefs are based on false/unknown assumptions.

168 startup teams have applied to S³. Based on the above data, **the S³ program provides startups with a 4.1% chance of securing a scaled customer.** However, the data is incomplete – due to confidentiality, we do not know which specific startups are represented in the count from each company.

One safe assumption is that member companies have high overlap with the startups selected for internal assessment. Assuming each partner company assessed the same 10 startups, in this case **startups selected for internal assessment have 17% chance of securing a scaled customer.**

This hit rate is significantly higher than the <10% early stage VCs expect when making investments, indicating the structure of S³ is indeed serving to filter quality, timely innovations into the window of sustainability adoption. And for the startups the message is equally clear: have your message, be persistent on connecting with internal subject matter experts, and your probability of a customer win increases by 4x.

We intend to increase our monitoring and transparency of this funnel as a barometer of the value of S³ to the participating companies venture arms. In addition, as the program evolves, we intend to quantify the diffusion rates of scaled solutions across the industry to further prove the thesis that a collaborative, industry-wide approach is valuable for reducing the global environment footprint of our industry as a whole.



Figure 4 Finalist pitching live at SEMICON West 2024 in San Francisco

UNDERSTANDING WATER AND WASTE CHALLENGES

In semiconductor manufacturing, water plays an important role in the production process. In 2019, the global chip industry used approximately 1 trillion liters of water³, much of it had the potential for reuse with the right infrastructure. Indeed, by 2021, a major American chipmaker demonstrated this potential in 2021, where out of the 16 billion gallons of water used in manufacturing that year, more than 80% (13 billion gallons) was captured and reused.⁴

Water serves various functions in the semiconductor industry: 76% is for manufacturing processes, 9% in cooling towers and 11% in scrubbers.⁵ The industry is actively engaging in efforts to reduce water usage. Initial efforts are focused on methods to increase water recycling rates on existing infrastructure and land footprints without increasing energy intensity. One such solution includes switching abatement systems to idle mode when not actively processing, which can cut water usage by 98%. These efforts have seen an overall decrease in water intensity, even as the industry grows.

The industry faces challenges in managing chemical waste and aqueous effluents. Efforts are underway to develop recycling, treatment, and abatement technologies to minimize chemical and greenhouse gas releases. This includes improving wastewater treatment processes and developing more efficient recycling of water and raw materials.

In 2023, authorities from five EU countries proposed restrictions on a particular class of compounds known as perfluoroalkyl and polyfluoroalkyl substances (PFAS), aiming for their gradual phase-out.⁶ Semiconductor manufacturing relies on chemicals, manufacturing equipment and facilities which can incorporate PFAS, such as photolithography formulations. Many organizations, including SEMI, are actively exploring ways to decrease PFAS usage and seeking alternative solutions.

³ Semiconductor Digest. (2022). "Water supply challenges for the semiconductor industry."

⁴ Editorial, "Intel achieves net positive water in three countries," Intel, July 13, 2022.

⁵ Semiconductor Digest. (2022). "Water supply challenges for the semiconductor industry."

⁶ Eurofins Scientific. (2023) "Perfluoroalkyl and polyfluoroalkyl substances (PFAS) restriction proposal: The largest substances ban project ever in Europe"

UNDERSTANDING REGULATORY PRESSURES AND MARKET DYNAMICS

With the growing awareness of climate change and sustainability, regulatory frameworks are imposing stricter standards on emissions, waste management, and resource utilization, and these pressures have reached the semiconductor industry.^{7 8} For instance, the European Union's Restriction of Hazardous Substances Directive (RoHS) and the Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) impact semiconductor manufacturing by mandating hazardous substance reduction and better waste management.

Market dynamics are also at play: the demand for AI, IoT, and 5G has surged, and the global semiconductor market is projected to reach \$726.7 billion by 2027⁹. This demand is fueling the need for more efficient semiconductors. Moreover, supply chain challenges (e.g. COVID-19, geopolitical tensions) have underscored the need for resilient and sustainable supply chains. Consumer awareness and investor pressure have also placed emphasis on environmental, social, and governance (ESG) factors, with major semiconductor companies like Intel and TSMC committed to sustainability goals.^{10 11}

⁷ <https://www.reuters.com/technology/chipmaker-tsmc-aims-net-zero-emissions-by-2050-2021-09-16/>

⁸ <https://www.energy.gov/eere/ammto/articles/what-do-microelectronics-have-do-emissions-reductions>

⁹ Fortune Business Insights. (2020). "Semiconductor Market Size, Share & COVID-19 Impact Analysis."

¹⁰ Intel. (2023). "Corporate Responsibility."

¹¹ TSMC. (2023). "Sustainability."

UNDERSTANDING THE EMISSIONS CHALLENGE

Semiconductor companies have been making commitments to reduce greenhouse gases, but current efforts are insufficient to achieve net-zero carbon emissions by 2050. Emissions from semiconductor chip manufacturers can be categorized into the three scopes: Scope 1) Direct emissions from fabs; Scope 2) Emissions from purchased electricity, steam, heating, cooling equipment; and Scope 3) Indirect emissions in a company's value chain, including those from suppliers and product usage.

To achieve net zero emissions, semiconductor companies must aggressively reduce Scope 1 and 2 emissions through a coherent, industry-wide roadmap. Achieving net zero would mean reducing process gas emissions, reducing heat transfer fluid leakage, and increasing the share of renewable energy - as shown in Figure 2. These measures account for 85% of emissions.

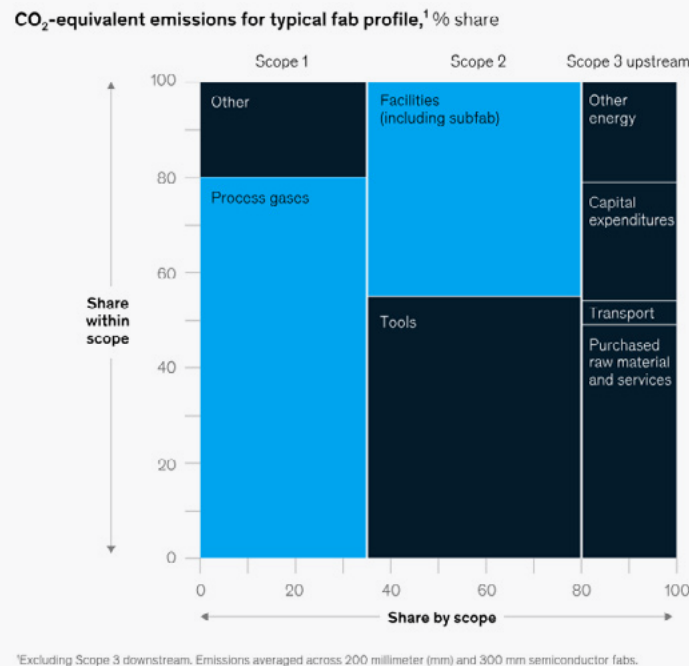


Figure 6. Semiconductor fab emissions primarily come from Scope 1 process gases and Scope 2 electricity consumption. Source: McKinsey and Company. (2022). "Keeping the semiconductor industry on the path to net zero."

The semiconductor industry's use of process gases is a significant environmental concern due to their high GWP and contributed to 80% of all Scope 1 emissions in 2020. These gases, primarily fluorinated gases like perfluorocarbons (PFCs), hydrofluorocarbons, nitrogen trifluoride (NF₃), and sulfur hexafluoride (SF₆), are used in etching and cleaning processes. SF₆, for example, has a GWP 23,500 times higher than CO₂.¹²

A substantial portion of these gases have historically passed through manufacturing tool chambers unreacted and are released into the air without sufficient abatement. To mitigate their impact, the industry is exploring three avenues: process improvements to reduce upfront gas usage,

¹² Semiconductor Digest. (2021). "The time is now: Sustainable semiconductor manufacturing."

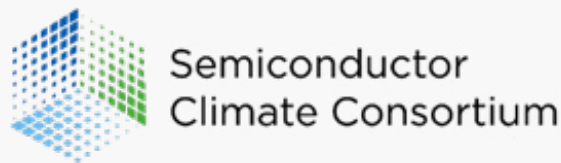
alternative process gas chemicals, and abatement destruction technologies.¹³

Generally, process gases are not reused or recycled due to purity challenges, cost, and difficulties integrating recycling processes into the existing infrastructure¹⁴, and qualifying alternative process gases can be a slow process.

Abatement, however, is a crucial strategy. For example, neutralizing up to 99% of NF₃ is already feasible and effective¹⁵. To reach net-zero emissions goals by 2050, the McKinsey study estimates that gas abatement systems should be installed and cover 90% of tools.¹⁶ A lower fraction of Scope 1 emissions include heat transfer fluid. At least 70% of heat transfer fluid would have to be replaced with low-GWP fluids.¹⁷

Long-term steps involve developing and implementing new technologies for emissions reduction and increasing collaboration across the industry as well as up and down the value chain for joint solutions.

SEMI's Semiconductor Climate Consortium (SCC) was launched in 2023 as a collaborative space to accelerate the development and sharing of best methods to lower emissions across the value chain.



¹³ US EPA, "Semiconductor industry."

¹⁴ Semiconductor Digest. (2023). "Recovery and recycling of process gases: What are the options?"

¹⁵ EE Times. (2020). "The environmental footprint of logic CMOS technologies."

¹⁶ McKinsey and Company. (2022). "Keeping the semiconductor industry on the path to net zero."

¹⁷ McKinsey and Company. (2022). "Keeping the semiconductor industry on the path to net zero."

UNDERSTANDING THE ENERGY CHALLENGE

High-energy demands of chip manufacturing processes – including melting silicon and maintaining vacuum -- make energy usage a key concern. Electricity consumption is responsible for 60% of Scope 1 and 2 emissions, where semiconductor factories can consume up to 100 megawatts-hours per hour.¹⁸

The industry is working towards becoming more energy efficient and increasing the use of renewables. For instance, Intel met 93% of its energy needs through renewables in 2023, though across the three largest players this was only 28%.¹⁹ While growth of the semiconductor industry must ultimately mean increased energy use, the industry is actively reducing its energy intensity (watt-hours per dollar) and was expected to decrease further from an energy intensity of 239 in 2020 to a predicted 206 in 2024 according to an analysis by Deloitte.²⁰

In key regions where low-carbon energy build-out plans are lagging, SEMI has launched the Energy Collaborative to analyze the roadblocks and work with country policymakers to eliminate or lower the roadblocks.

When additionally considering Scope 3 emissions upstream (supply chain) and downstream (device use), electricity generation emerges as the most substantial contributor to overall emissions, linked to 84% of device emissions over its lifecycle (Figure 3). According to a joint study between SEMI and BCG²¹, energy usage emissions are distributed as follows:

- Supply Chain (16%): Energy consumption in the supply chain is substantial, with over half from purchased goods and services used in manufacturing.
- Manufacturing (21%): Energy consumption in design, fabrication, packaging, testing: 65% comes from electricity used to power equipment and buildings.
- Device Use (63%): The majority of lifecycle emissions of a semiconductor chip is attributed to the collective energy consumption of the billions of end products (phones, computers, datacenters).

¹⁸ Christel Galbrun-Noel, “How to improve power reliability for semiconductor fabs,” Schneider Electric blog, November 15, 2021

¹⁹ Based on data reported in publicly available corporate sustainability reports of select semiconductor companies.

²⁰ Deloitte. (2023). “Semiconductor sustainability: Chips take a smaller byte out of resources.”

²¹ SEMI Semiconductor Climate Consortium’s BAR Working Group and BCG. (2023). “A White Paper on Transparency, Ambition, and Collaboration.”

As a result, low-carbon electricity is a major lever. The semiconductor industry can reduce energy usage and its associated emissions through efficiencies in manufacturing processes, adopt low-carbon energy and electricity, design improved end-device efficiency, and even build and design more energy-efficient manufacturing facilities and offices. Above all, collaboration among companies across the value chain is essential to address interdependence within the industry.

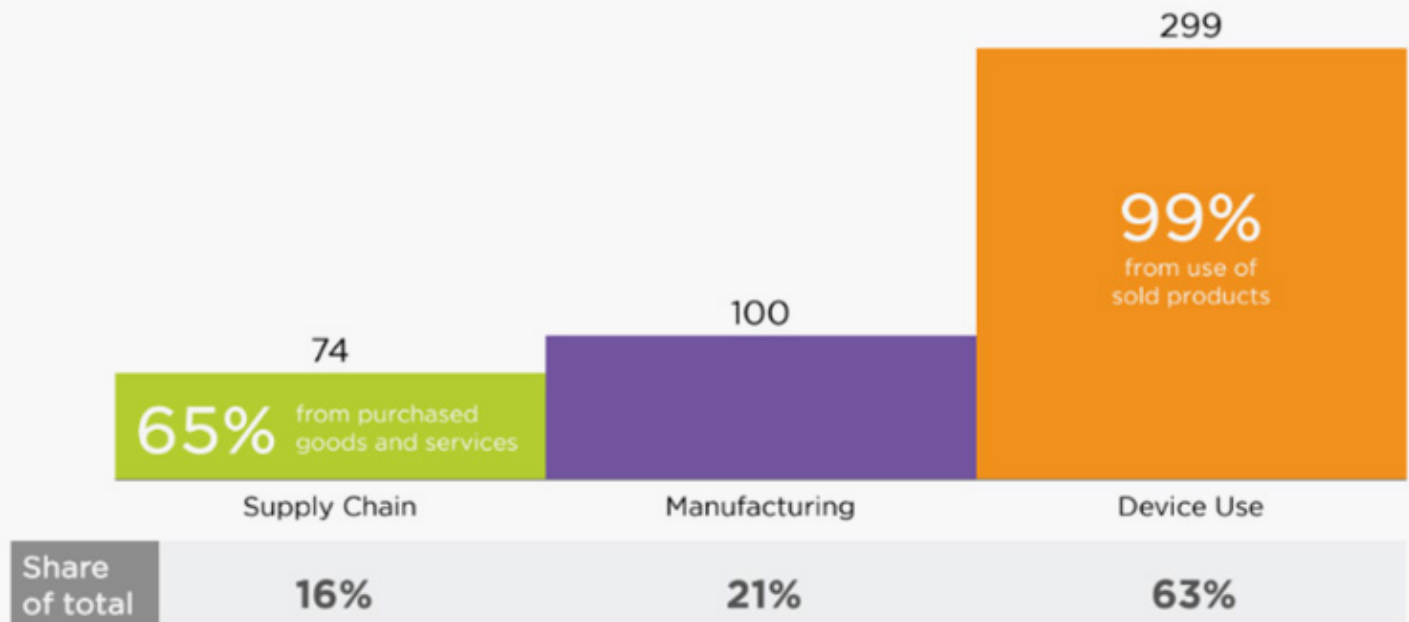


Figure 7 Lifecycle Emissions of a semiconductor device. Source: SEMI Semiconductor Climate Consortium's BAR Working Group and BCG (2023).

5.THE CLEANTECH STARTUP LANDSCAPE

The mission of the S³ Program is to identify startups that:

1. Deliver real-world sustainability value to semiconductor use cases;
2. Can scale their innovation in a timeframe in line with the decarbonization goals of our companies; and
3. Provide opportunity for venture-style return on investment.

To set that goal and align our expectation we need to understand the entire pool of startups in the climate tech- and clean tech- space. We turned to Dealroom.co to get perspective on the size and scope of the potential candidates.

Climate tech startups have already been quite successful and have already seen huge outcomes emerge, with **over 240 unicorns – or companies valued at more than a billion US dollars – created**. Figure 8, with data from Dealroom.co, shows more than **11,000 early-stage startups** looking to scale up. More than 600 new startups launched VC-backed journeys in 2024.

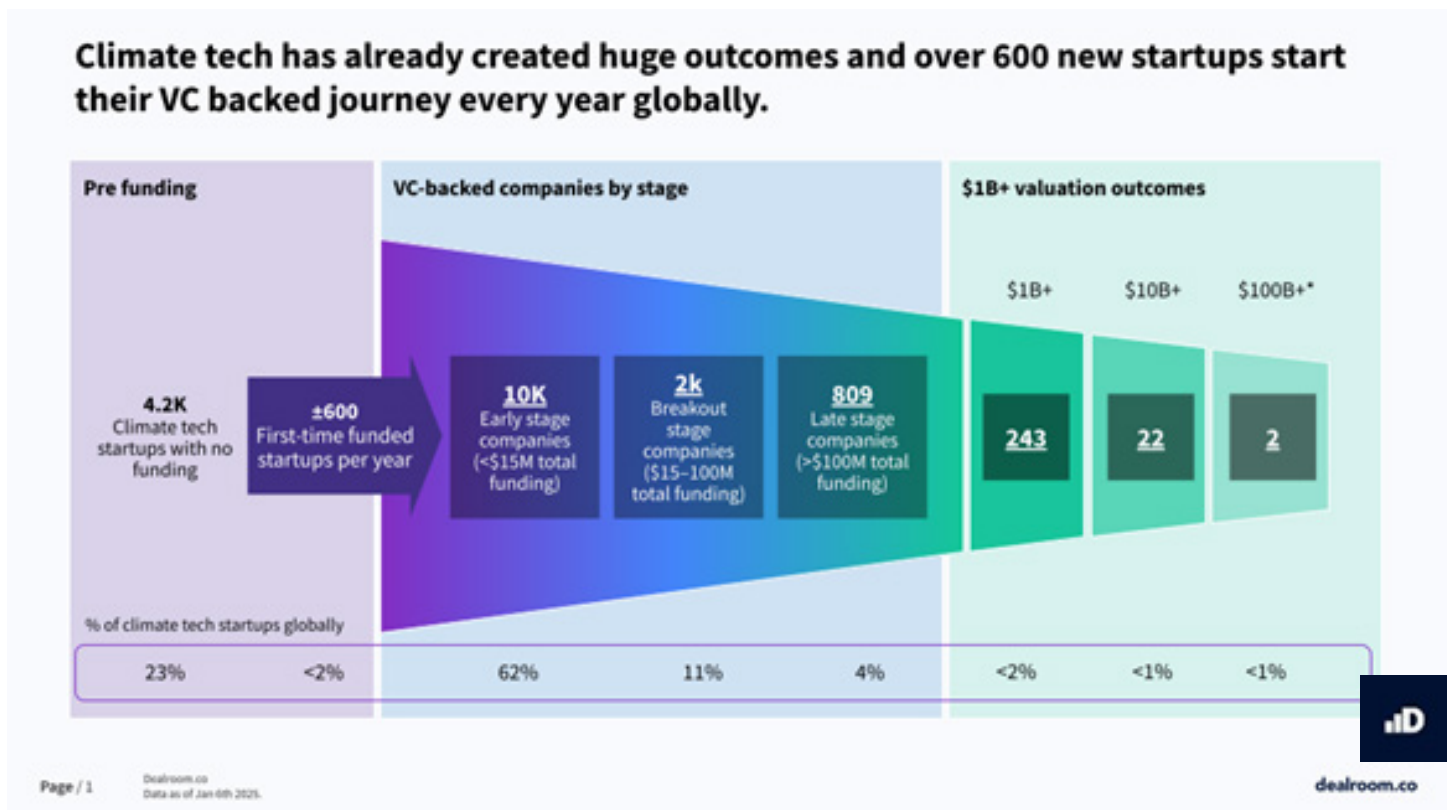
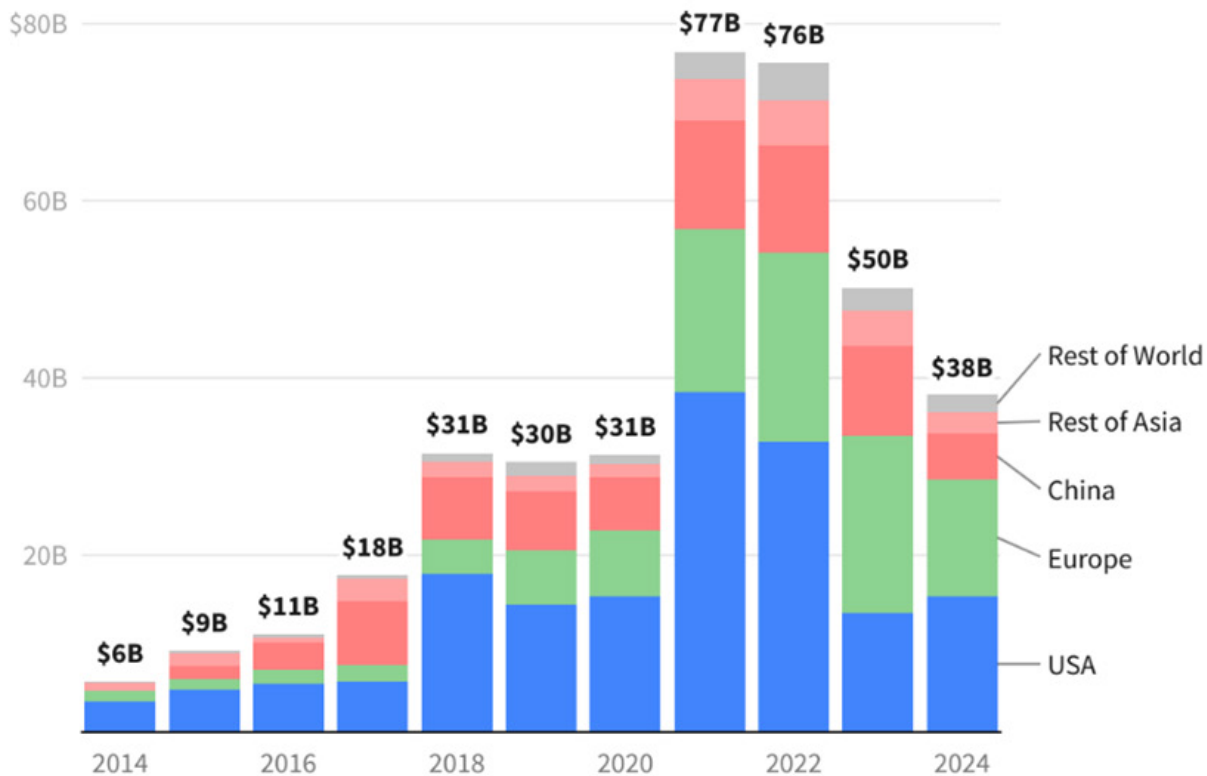


Figure 8 Climate tech startups

Globally over **\$38B in VC funding** has been funneled into climate tech startups in 2024, and over \$270B in the last five years. Notwithstanding, funding is **down ~50% from 2021-2022** peak years, following the broader correction in the innovation economy.

The US has historically led in the amount of venture capital raised by companies in the segment, but Europe took the greater share in 2023. In 2024, the US squeaked ahead. Overall, after banner years of funding in 2021 and 2022, the investments appear to be on a downward trend, but with European venture funds sharing the lead with the US for the last 4 years.

Global Climate Tech VC funding by region

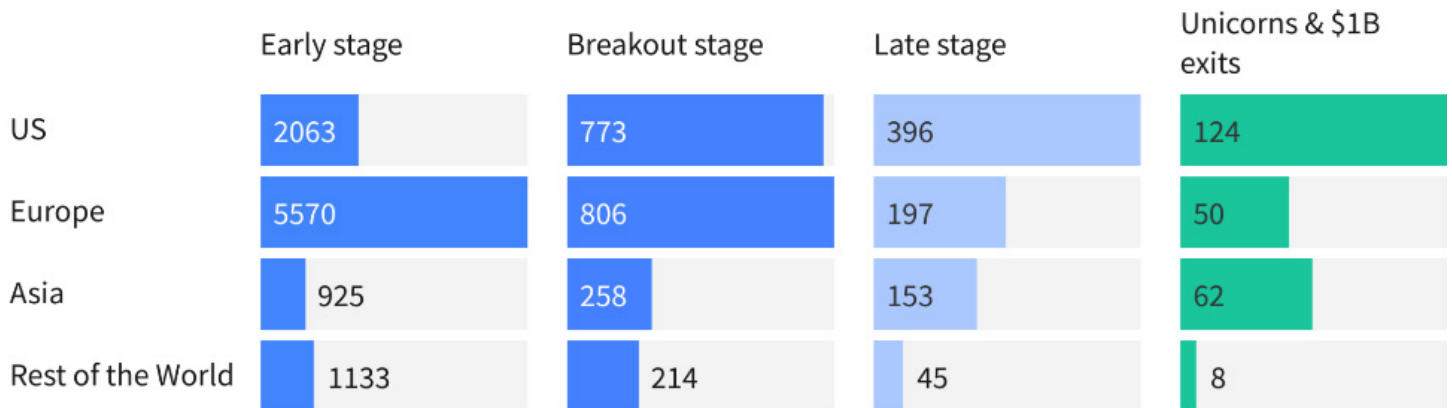


Source: Dealroom.co



Figure 9 Global Climate Tech VC Funding by Region

Figure 10 illustrates the entire world's startups by the stage of and region. Note the strong pipeline of early-stage investments in Europe, boding well for that Region's leadership as those investments mature, and the US lead in large-scale and late-stage VC-backed outcomes for the sector.



Data as of Jan 30th 2025

Source: dealroom.co

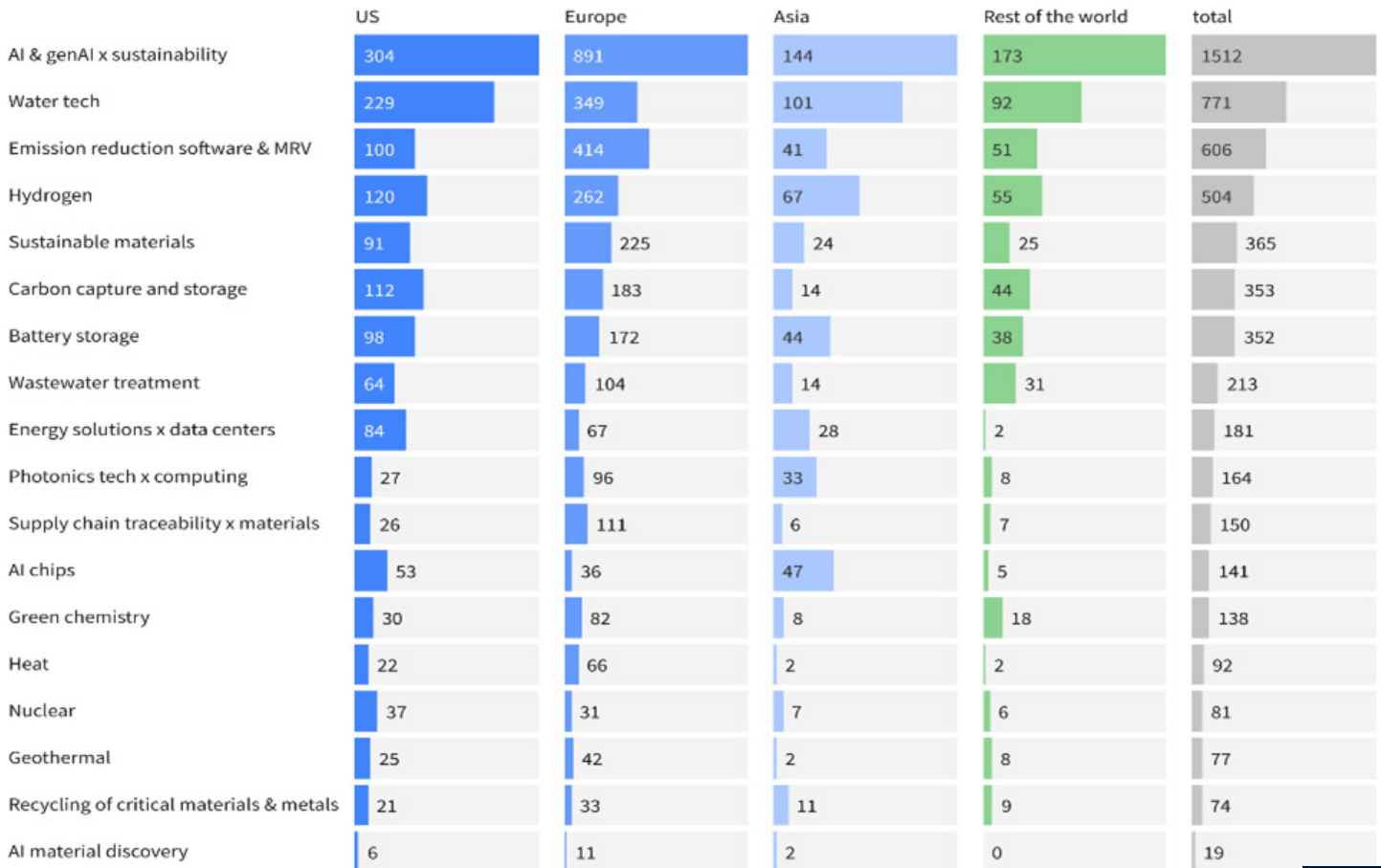


Figure 10 Number of VC-backed climate tech startups by region and stage

An exciting trend is the rise of the Asian climate tech startup ecosystem, as these innovators have closer access to scaled electronics supply chains and high-volume manufacturing across Asia. The S³ program puts special emphasis on attracting Asia-based startups by working with the sponsors from those regions, as well as startup accelerators active in the key regions.

Attracting the startups to solve our sustainability problems (out of the 11,000+ in Figure 10) is our fundamental challenge. Dealroom.co further breaks down the climate tech startups into the following segments and those relevant to the semiconductor sector key sustainability challenges as shown in Figure 11.

Number of startups in selected climate tech segments



Data as of Jan 30th 2025

Source: dealroom.co



Figure 11 Number of startups in selected Climate Tech segments

Analyses like these give the S³ team confidence that our efforts to attract the right startups to our program are not in vain. By providing foothold into the semiconductor ecosystem through mentoring and customer introductions, they can more specifically work to solve more focused and real-world technological challenges. We are pleased to provide exposure to our processes, mentors to answer their questions and potential funds to continue development. Our hope is to move more climate tech startups to breakout, late stage and exit through this partnership.

6. CONCLUSIONS, TAKEAWAYS AND CALLS TO ACTION

The S³ program is an active work in progress and an important part of bringing sustainability to the semiconductor sector. We are encouraged by the momentum and early metrics to date. However, the challenge continues to loom large: bring new technology into legacy semiconductor manufacturing and process methods.

6.1 Lessons learned so far:

We must force new capabilities into scale. Today's industrial leaders were established on yesterday's capabilities, infrastructure, and assumptions, and these leadership positions will not be jeopardized for sustainability efforts.

Experience shows what works to accelerate new concepts into legacy industrial systems:

- **Direct access to subject matter experts** and messaging to those experts in languages they understand – this is the biggest learning from the data, reflected in the 17% conversion rate from expert introduction to scaled deployment.
- Engagement across the value chain – across multiple examples, one key missing ingredient in the program is the **earlier involvement of system integrators**, and we look forward to forging more direct engagements with that community as we evolve;
- Patient, committed capital – decarbonization technology is “venture backable,” but its a different model from software, AI, etc.

We must go faster. Sustainability has a time function – the longer humanity takes to resolve unsustainable practices, the more expensive such resolutions become.

As the number of successful startup engagements grows, we understand the KPIs needed to monitor to assess the scalability of the model:

- Metrics tons of CO₂ equivalent – everything comes back to this value. Determining this value for point replacements in a complex process environment is challenging, but it must be done to assess the efficacy of the startups to decarbonize semiconductors.
- # of semiconductor-related customers – industrial decarbonization only works if the industry adopts a decarbonization technologies. We see this metric as critical for quantifying the scalability of a given solution.

“The S³ competition hits the mark for any start-up engaged with the semiconductor manufacturing industry. Such a focused event was exactly what helped give us the boost of exposure we needed to advance our start-up journey.”

Program Participant

We have taken these new understandings into our fourth year of S³, where together we're discovering:

- system designs for **sustainable datacenter** operations for growing AI workloads.
- entrepreneurs productizing Generative AI to help industrial leaders resolve sustainability challenges; and
- emerging technologies that progressively **decarbonize semiconductor process methods**

6.2 Calls to Action

Finally, we have three Calls to Action - one for each targeted audience of this review:

1. **To startups – we want to hear from you!** Please apply or reach out to any of the member companies to learn more about the program.
2. **To stakeholders across the semiconductor industry – we want to work with you!** S³ is volunteer-based and carries no cost commitment to participating corporates. Reach out to learn more.
3. **To other industries considering similar decarbonization efforts – we want to learn with you!** We believe we are on to something valuable with S³. We're happy to share our thoughts to help establish other similar decarbonization programs outside semiconductors, and we're always looking for ideas, learnings, and lessons to continuously improve.

Onward.



Figure 12: Panel discusses the challenges in making semiconductor manufacturing sustainable. Pictured left to right: Andrew Byrnes, Micron Ventures; Katherine Dei Cas; EMD Electronics; Ted Jeffries, Intel Foundry