

GLOBAL CLEANTECH100

Leading cleantech solutions to solve
the world's biggest challenges



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FOREWORD



WRITTEN BY
RICHARD YOUNGMAN,
CEO, CLEANTECH GROUP

It has been 16 years since we first started the Global Cleantech 100 – in 2009 – to act as an annual barometer on global cleantech innovation.

That was in the middle of a period some labelled, with the benefit of hindsight, as cleantech 1.0 (albeit it was more accurately renewables 1.0, given the dominance of investments in that period of solar, wind, batteries and biofuels, and the lack of investment at that time in 80% of the cleantech problem-set).

There are signals I see in this year's Global Cleantech 100 – in the process (and the expert panellist's comments), and in the outcomes (the companies) and in the analysis and insights contained herein - that we are in, or close to, some kind of change period on the barometer.

Maybe in a few years 2024/2025 will retrospectively be referenced as the end of climatetech 2.0, and the start of a new phase? No doubt Trump 2.0 will be a factor in such, too.

From the comments used (anonymously) by our expert panel on companies in the shortlist, the picture of a more sober and skeptical market emerges.

THERE ARE SIGNALS I SEE IN THIS YEAR'S GLOBAL CLEANTECH 100 THAT WE ARE IN, OR CLOSE TO, SOME KIND OF CHANGE PERIOD ON THE BAROMETER

On the one hand we have the negative-type commentary, the words that indicate what is top of mind for an increasing number of market players:

- Hype is called out in much more obvious prevalence this year, as illustrated in these comments.
 - “**Lots of hype for years** but still haven't scaled to even pilot and doesn't have a commercial design.”
 - “**Years of hype** and raises but haven't seen any scale or relevant deployment that went past announcement.”
 - “Dubious. **A lot of hype**, but it is brute force and very expensive.”
 - “Full of news, but **nothing works and nothing ships**. I no longer believe the story.”
- These kind of comments speak to the underlying concern and a stronger scrutiny of the economics and scalability of anything and everything:
 - “Likely **never cost-effective**.”
 - “Really **dubious** the product pencils economically.”
 - “Scalability of process is now **under question**; cost too high and efficiency gain too low.”





On the other hand, we have clues as to what is required to gain widespread trust and support in today's investment market:

- The importance of demonstrable progress towards commercialization, the ability to get there, and the ability to scale reliably once there, are all highly prized. These comments are illustrative thereof.
- “Their technology is a low cost solution and this is **essential technology for mass penetration** of renewable energy.”
- “Great team, impactful tech, **commercial traction**, need we say more...”
- “**Crazy strong traction and growth**, with no churn - and huge opportunity set in multiple large verticals.”
- And where something is unproven and pre-commercialization, the bar seems to have significantly been raised. The cost trajectory needs to have outstanding potential, and not be over-sold, to gain strong support:
- “Interesting and **unique** approach that would potentially reduce the cost **dramatically**.”
- “This means that the cost, footprint, complexity and speed of solution are all **dramatically improved**.”

– “A credible story lead by a **credible** CEO. They are not claiming cost parity next year, but rather putting forward realistic plans to get within spitting distance in the 2030's. **That is real**.”

– “More CAPEX-intensive model, today, but **big impact on lowering cost**...”

– “**Novel** process. Seems highly scalable and low-cost.”

– “**Unique** value proposition, as the market looks for low cost capabilities. Major OEMs involved.”

In addition to these general sentiment observations, I would point to three trends I see in the identity of the 2025 Global Cleantech 100 companies themselves:

1. There is a clear sense of a flight to traction and execution plays. Think companies such as:
 - **BasiGo, Crux, LevelTen Energy, Omnidian, PVcase, and Raptor Maps**
2. There are more solutions in this year's 100 than ever before that relate to the earth's hardcore (and its geology), on the one hand, and its oceans, on the other:
 - **CorPower Ocean and Ebb Carbon** speak to the latter; **44.01, Fervo Energy, Heirloom, Koloma, and Vaulted Deep** speak to the former

3. Water innovation features more strongly than it has done for many years, as per the following companies – **Aclarity, Aqua Membranes, Indra, Moleaer, Pani, and ZwitterCo**.

Are we finally waking up to the water crisis coming our way in the 2030s?

Exaggerated, unrealistic promises made in the hot markets of 2020-21 have come home to roost.

It is especially felt in sectoral areas like hydrogen and carbon capture. Some of the old favorites and Global Cleantech 100 companies have not made the list, where they have not commanded a strong level of consensus support across the market this year. Some in the market have seen enough in recent years and need to see more from them to believe in their long-term story.

As we look forward to 2025, market sentiments today suggests that we will see two obvious consequences:

1. Less of the shiny new objects – and certainly ones that are fully reliant on U.S. federal policy and taxpayer support will struggle
2. Less of the “me-too’s” – with capital more scarce, the best and the reasonably valued should flourish as there may be fewer, well-funded competitors.

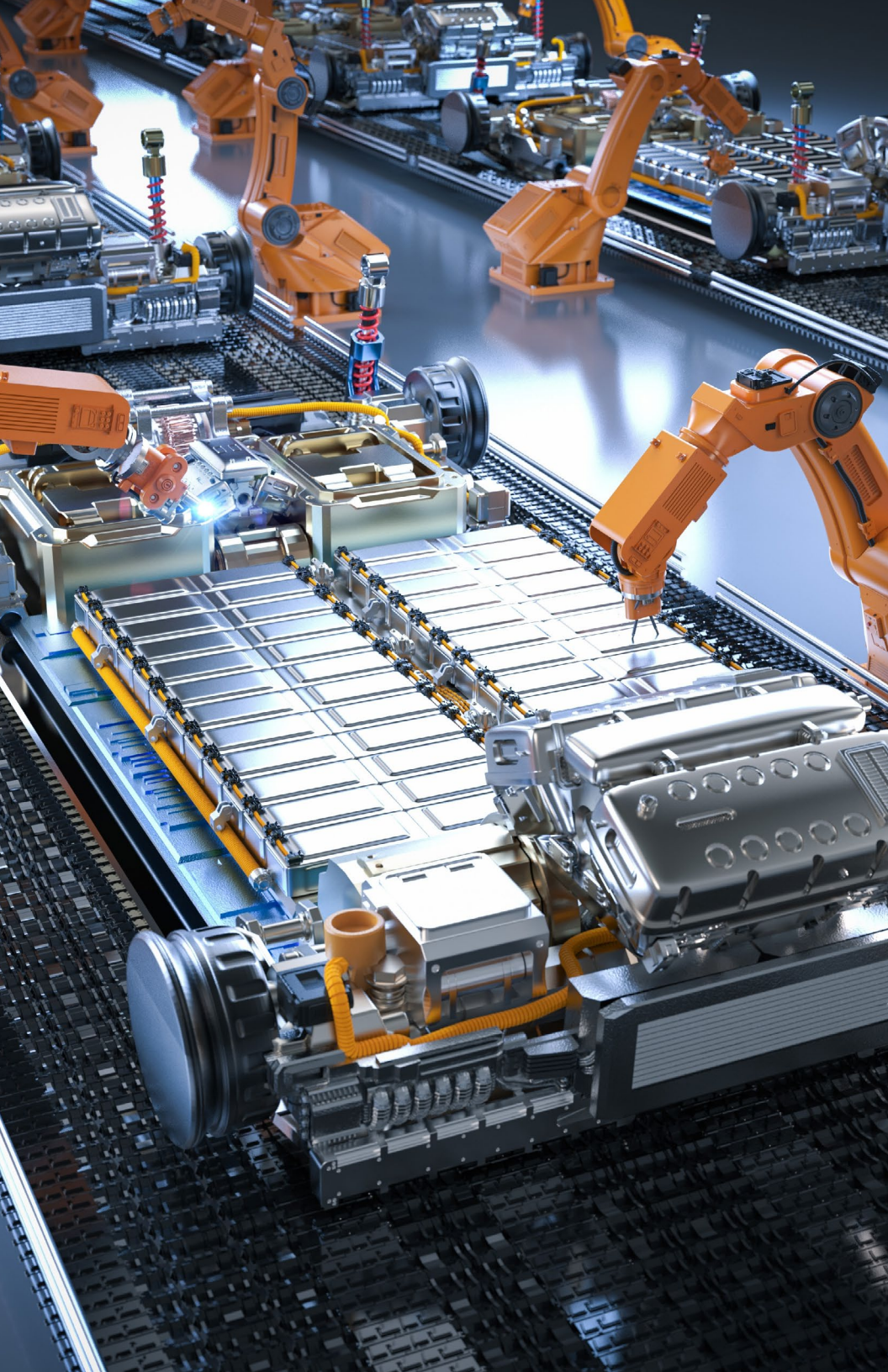
The market is still open to new technologies and approaches. It's not as if some of the forerunners have obviously and fully got the future solution set tied up; the anaemic M&A/IPO environment, as described in the Graduates section, is testament to that.

However, the bar has gone up for what kind of level of potential novelty, uniqueness, and cost improvements might be attractive.

A more sober, skeptical environment and a return to fundamentals is apparent.

RY





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ACKNOWLEDGEMENTS

Cleantech Group is pleased to present the 16th annual Global Cleantech 100. We recognize that this long-standing report would not be able to come together without the support and participation from the innovation ecosystem and would like to thank a few specific groups.

We first want to express our gratitude for the ongoing support of Chubb, the world's largest publicly traded property and casualty insurance company. Chubb has been the headline sponsor of the annual Global Cleantech 100 program for over ten years.

The list would not have been possible without the 80 expert panelists (see pages 66-68) who gave their time to provide their input and opinions. This is in addition to the many hundreds who made company nominations. We also wish to acknowledge the support we receive all year from members of our international Advisory Boards, all of whom are leading players in this innovation ecosystem.

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HOW WE SELECT THE GLOBAL CLEANTECH 100

THE QUESTION WE SEEK TO ANSWER:
 According to the world’s cleantech community, which 100 private companies today are most likely to make significant market impact over the next five to ten years? We answer this question in three phases:

Phase 1: Nominations

Nominations come from five sources:

- The expert panel of 80 investor and multi-national corporation representatives.
- Our i3 platform tracking the investment and partnership history of thousands of relevant companies.
- Over 70 third-party awards where expert assessment has been applied.
- Our sector analysts.
- The global ecosystem* (i3connect.com/gct100/nominate).

Phase 2: Evaluation

Since our aim is to objectively synthesize and represent consensus, nominations are scored in a system rewarding companies that have multiple validations from our nomination sources. From this, a shortlist is created and sent to our panel of industry experts comprised of investor and multi-national corporation representatives. The panel votes positively or negatively based on their knowledge of the company’s innovation, market and ability to execute.

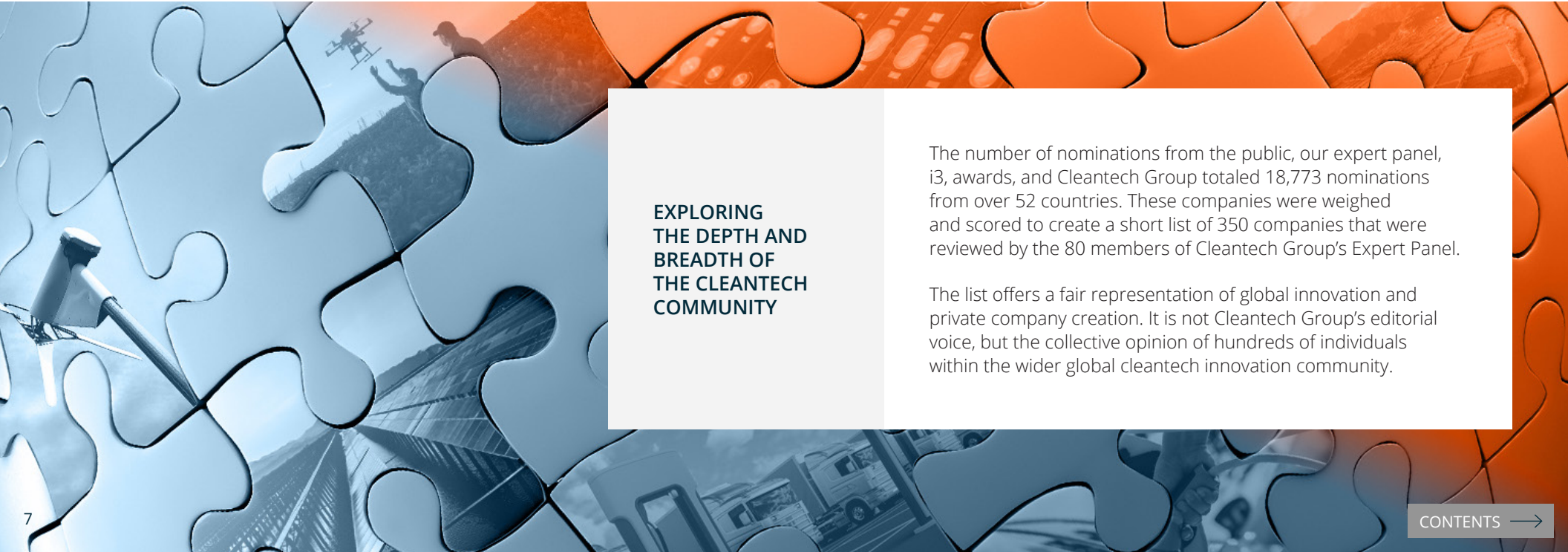
Phase 3: The Final 100

A combination of data from Phase 1 and Phase 2 are pooled and adjusted for geographic or other biases. Companies with the highest points overall make it to the final 100.

* To be valid, nominations of your own company (or one you are part owner of), be they made by the expert panel or the open call to the ecosystem, must be accompanied by nominations of at least two other companies you admire and with which you have no commercial association.

Any independent, private, for-profit cleantech company can qualify for the Global Cleantech 100. These companies must have a knowledge-based offering that embodies doing more with less (provides superior performance at lower costs, greatly reduces or eliminates negative ecological impact and improves the productive and responsible use of natural resources). We exclude those who we know to have reached Unicorn status and/or those who have been in the list seven times before.

The list was struck on 1 October 2024.



EXPLORING THE DEPTH AND BREADTH OF THE CLEANTECH COMMUNITY

The number of nominations from the public, our expert panel, i3, awards, and Cleantech Group totaled 18,773 nominations from over 52 countries. These companies were weighed and scored to create a short list of 350 companies that were reviewed by the 80 members of Cleantech Group’s Expert Panel.

The list offers a fair representation of global innovation and private company creation. It is not Cleantech Group’s editorial voice, but the collective opinion of hundreds of individuals within the wider global cleantech innovation community.



GLOBAL CLEANTECH100

2025

Listed in alphabetical order by Industry Group





AGRICULTURE & FOOD

DATA STATS
 7 COMPANIES ↓
 7 COUNTRIES ↑

INDUSTRY INSIGHT FERMENTATION TECHNOLOGIES TO ADVANCE ALTERNATIVE PROTEINS AND PRECISION TOOLS THAT OPTIMIZE AGRICULTURAL PRODUCTION REFLECT CLIMATE INVESTOR PRIORITIES

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
Agreena	Precision Agriculture	Soil Monitoring	Platform that incentivizes farmers to switch to regenerative agriculture by issuing CO ₂ e-certificates	Denmark	2018
Arkeon	Alternative Proteins	CO ₂ -to-Protein	Fermentation of edible protein from captured carbon emissions	Austria	2021
eAgronom	Precision Agriculture	Decision Support Software	Enables farmers to view operational data and make informed decisions	Estonia	2016
In5 Pro 菌菌普科技 菌菌普科技	Food Waste	Insect Bioconversion	Modular black soldier fly farms used for upcycling food waste into valuable products	China	2021
POW.BIO	Alternative Proteins	Fermented Proteins	Continuous fermentation platform for sustainable biomanufacturing	United States	2019
Rumin8	Animals	Methane Reduction	Feed supplement that reduces methane emissions from livestock	Australia	2021
Tropic	Crop Inputs	Crop Genetics	High-performing varieties of tropical crops developed using gene-editing technologies	United Kingdom	2016

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA

A&F 1/1



ENERGY & POWER

DATA STATS
 39 COMPANIES ↓
 13 COUNTRIES ↓

INDUSTRY INSIGHT CERTAIN SECTORS INCLUDING INDUSTRIAL DECARBONIZATION, THERMAL ENERGY STORAGE, BATTERIES, GRID RESILIENCY AND ENERGY MANAGEMENT SOLUTIONS ARE WELL POSITIONED TO SCALE IN THE COMING YEARS

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
ACCURE Battery Intelligence	Energy Storage	Battery Analytics	Platform that enables APIs to access battery data to manage, analyze, and predict battery health	Germany	2020
AMOGY	Hydrogen	Ammonia Cracking	Carbon-free energy storage system using ammonia as fuel	United States	2020
ANTORA	Energy Storage	Thermal Energy Storage	Low-cost thermal battery for grid-scale energy storage	United States	2017
ATMOSZERO 4°	Buildings	Boilers	On-site heat production process to provide an alternative to fossil fuel systems	United States	2021
CorPower Ocean	Hydro & Marine	Wave Power	Wave energy converter technology	Sweden	2009
CRUX	Energy Networks	Tax Credit Marketplace	Transferable energy tax credits from clean energy projects for clean energy developers, tax credit buyers, and financial institutions to manage and exchange tax credits	United States	2023
deepki	Buildings	Building Management Systems	Software for buildings using statistics and computer science to turn existing customer data into energy efficiency action plans	France	2014
ENERGYDOME Our WORLD can't wait.	Energy Storage	Long-duration Energy Storage (CO ₂ Battery)	Long-duration electricity storage solutions using liquid CO ₂	Italy	2019
enersion	Biomass & Waste-to-energy	HVAC	Cooling technology that uses waste heat instead of electricity	Canada	2016
Enode	Energy Networks	DER Management	Digital infrastructure software that connects to energy hardware applications	Norway	2020

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA

E&P 1/4



ENERGY & POWER

DATA STATS
 39 COMPANIES ↓
 13 COUNTRIES ↓

INDUSTRY INSIGHT CERTAIN SECTORS INCLUDING INDUSTRIAL DECARBONIZATION, THERMAL ENERGY STORAGE, BATTERIES, GRID RESILIENCY AND ENERGY MANAGEMENT SOLUTIONS ARE WELL POSITIONED TO SCALE IN THE COMING YEARS

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
ezinc	Energy Storage	Long-duration Energy Storage (Zinc Battery)	Zinc reactor technology that stores electricity in zinc metal for large-scale energy storage	Canada	2012
FERVO ENERGY	Geothermal	Enhanced Geothermal	Technology for power generation using enhanced geothermal systems	United States	2017
granular energy	Energy Networks	Energy Management & Trading	Clean energy management software that provides solutions for utilities, energy managers, traders, and large energy buyers	France	2021
H2SITE	Hydrogen	Ammonia and Methanol Cracking	Membrane-based liquid reforming systems for ammonia and methanol cracking	Spain	2019
HYDREXIA	Hydrogen	Hydrogen Storage	Developer of hydrogen storage systems	Australia	2006
Hysata	Hydrogen	Hydrogen Electrolysis (Capillary-fed)	Capillary-fed hydrogen electrolyzer, that produces green hydrogen for steel, transport, and chemical sectors	Australia	2021
hystar	Hydrogen	Hydrogen Electrolysis (Proton Exchange Membrane)	PEM electrolyzers for large-scale green hydrogen production	Norway	2021
Infinitum	Buildings	Electric Motors	Electric motor technology	United States	2014
Instagrid	Energy Storage	Portable Li-ion Batteries	Portable power packs for professionals with various applications including construction, small businesses, and event organizers	Germany	2018
Kelvin	Buildings	Residential Energy Management	Room-level temperature control solutions for radiators in homes	United States	2011

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA



ENERGY & POWER

DATA STATS
 39 COMPANIES ↓
 13 COUNTRIES ↓

INDUSTRY INSIGHT CERTAIN SECTORS INCLUDING INDUSTRIAL DECARBONIZATION, THERMAL ENERGY STORAGE, BATTERIES, GRID RESILIENCY AND ENERGY MANAGEMENT SOLUTIONS ARE WELL POSITIONED TO SCALE IN THE COMING YEARS

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
KOLOMA	Hydrogen	Geologic Hydrogen	Natural hydrogen by drilling in the U.S. midwest	United States	2021
KRAFT BLOCK	Energy Storage	Thermal Energy Storage	Thermal energy storage solutions	Germany	2014
LevelTen Energy	Energy Networks	B2B Renewable Procurement	Transaction infrastructure for renewable energy buyers, advisors, sellers, and financiers	United States	2016
OMNIDIAN	Solar	Rooftop PV Asset Monitoring	Protection plans for investments in residential solar energy systems	United States	2015
PVcase	Solar	Solar Soft Cost Reduction	Solar design and energy modeling software for utility-scale solar power plants	Lithuania	2017
QPINCH	Biomass & Waste-to-energy	Waste Heat-to-process Heat	Chemical heat pump that converts waste heat into carbon neutral industrial heat	Belgium	2012
RAPTOR MAPS	Solar	Solar Asset Inspection	Solar performance optimization software and aerial inspection solutions	United States	2014
redoxblox	Energy Storage	Thermochemical Heat Storage	Thermal energy storage technologies for industrial processes to displace natural gas	United States	2020
SENSORFACT	Buildings	Industrial Energy Management	Intelligent Energy Management System (IEMS) to help industrial companies reduce their energy consumption	Netherlands	2016
skyventechnologies	Biomass & Waste-to-energy	Industrial Heat Pumps	Mechanical vapor recompression steam generating heat pump	United States	2013

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA

E&P 3/4



ENERGY & POWER

DATA STATS
 39 COMPANIES ↓
 13 COUNTRIES ↓

INDUSTRY INSIGHT CERTAIN SECTORS INCLUDING INDUSTRIAL DECARBONIZATION, THERMAL ENERGY STORAGE, BATTERIES, GRID RESILIENCY AND ENERGY MANAGEMENT SOLUTIONS ARE WELL POSITIONED TO SCALE IN THE COMING YEARS

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
SPAN	Buildings	Electrical Panels	Smart electrical panels and paired software to provide visibility and control at the edge-of-grid	United States	2018
SUNAN	Solar	Lightweight Solar PV Panels	Light and flexible solar panels and mobile floating solar systems	China	2014
SUNROOF	Solar	Rooftop PV	Rooftop solar manufacturer	Sweden	2013
tibber	Energy Networks	Residential Energy Management	Smart home devices encouraging renewable energy consumption through a digital management platform	Norway	2016
TS CONDUCTOR <small>Electricity delivered better.</small>	Energy Networks	Advanced Conductors (Grid Transmission)	Carbon-core encapsulated aluminum conductors to increase the ampacity of electric transmission and distribution lines	United States	2019
TWAICE <small>Battery Analytics Software</small>	Energy Storage	Battery Analytics	Predictive analytics software for battery management	Germany	2018
VEIR	Energy Networks	Advanced Conductors (Grid Transmission)	Evaporative cryogenic cooling system for high-temperature superconductors in electricity transmission	United States	2019
WeaveGrid	Energy Networks	DER Control, Aggregation & Demand Response	Machine learning software which solves EV-grid integration challenges for utilities	United States	2018
YOTTA ENERGY	Solar	Rooftop PV	Solar modular energy storage solution	United States	2017

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA

E&P 4/4



MATERIALS & CHEMICALS

DATA STATS
 23 COMPANIES [↑]
 9 COUNTRIES [↔]

INDUSTRY INSIGHT IMPROVING EFFICIENCY AND IMPROVING COSTS OF OF EFUELS, ALTERNATIVE FUELS AND CARBON CAPTURE DEPLOYMENT IS AT THE CORE OF THE TOP MATERIALS & CHEMICALS INNOVATION THIS YEAR

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
aeroseal.	Building Materials	Building Insulation	Seals central heating/cooling and ventilation ductwork within residential homes and commercial buildings	United States	1993
Aether Fuels	Fuels & Chemicals	Synthetic Fuels	Sustainable fuels to decarbonize aviation and ocean shipping	United States	2022
again	Carbon Capture Usage & Storage (CCUS)	Point Source Carbon Capture	Technology that captures CO ₂ from industrial emitters at the point of emission using synthetic biology to develop biocatalysts (bacteria)	Denmark	2020
BOSTON METAL	Industrial Materials	Steel (Molten Oxide Electrolysis)	Molten oxide electrolysis technology for steelmaking, and production of other metals and alloys	United States	2012
carbon clean	Carbon Capture Usage & Storage (CCUS)	Point Source Carbon Capture	CO ₂ capture technology and solvents that significantly reduce the costs and environmental impacts of CO ₂ separation	United Kingdom	2009
COOLBROOK	Fuels & Chemicals	Ethylene (Cracking)	RotoDynamic Reactor which electrifies steam cracking and cement production	Finland	2011
Copprint	Advanced Energy Materials	Additive Copper Printing	Conductive nano copper inks for additive copper printing	Israel	2016
Dioxyce	Carbon Capture Usage & Storage (CCUS)	Carbon-to-ethylene	Integrated modular electrolyzer systems to capture and convert industrial carbon dioxide emissions	France	2020

KEY: [↑] Increase on 2024 figures [↓] Decrease on 2024 figures [↔] Same as 2024 figures / NA

M&C 1/3



MATERIALS & CHEMICALS

DATA STATS
 23 COMPANIES [↑]
 9 COUNTRIES [↔]

INDUSTRY INSIGHT IMPROVING EFFICIENCY AND IMPROVING COSTS OF OF EFUELS, ALTERNATIVE FUELS AND CARBON CAPTURE DEPLOYMENT IS AT THE CORE OF THE TOP MATERIALS & CHEMICALS INNOVATION THIS YEAR

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
econic	Fuels & Chemicals	CO ₂ -to-polyols	Catalysts that enable production of polycarbonates, polyols, and polymers from CO ₂	United Kingdom	2011
INERATEC	Fuels & Chemicals	eFuels	Modular chemical plants for power-to-x and gas-to-liquid applications	Germany	2016
INFINIUM™	Fuels & Chemicals	eFuels	CO ₂ utilization technology that produces transportation fuels using renewable power and CO ₂ emissions	United States	2020
INNOVATIONS	Process Technology	Membrane-based Separations	Durable hydrocarbon ion-exchange materials and polymers for fuel cells, hydrogen production, energy storage, metal recovery, and CCU	Canada	2018
LUXWALL SEE BEYOND™	Advanced Materials	Building Insulation (Glass)	Vacuum-insulated glass that improves energy efficiency of commercial buildings	United States	0
MANGROVE LITHIUM Unlocking a battery-powered future	Industrial Materials	Direct Lithium Extraction	Modular platform for the cost-effective production of battery-grade lithium hydroxide	Canada	2017
Mantel	Carbon Capture Usage & Storage (CCUS)	Point Source Carbon Capture	First molten-salt based carbon capture technology	United States	2022
OXCCU	Fuels & Chemicals	eFuels	Sustainable fuels, chemicals, and biodegradable plastic products generated from captured CO ₂	United Kingdom	2021

KEY: [↑] Increase on 2024 figures [↓] Decrease on 2024 figures [↔] Same as 2024 figures / NA

M&C 2/3



MATERIALS & CHEMICALS

DATA STATS
 23 COMPANIES
 9 COUNTRIES

INDUSTRY INSIGHT IMPROVING EFFICIENCY AND IMPROVING COSTS OF OF EFUELS, ALTERNATIVE FUELS AND CARBON CAPTURE DEPLOYMENT IS AT THE CORE OF THE TOP MATERIALS & CHEMICALS INNOVATION THIS YEAR

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
	Industrial Materials	Solvent-based Metallurgy	Processes and new methodologies for extractive metallurgy	Canada	2020
	Industrial Materials	Electrified Cement Production	Electrochemical process to produce cement	United States	2020
	Industrial Materials	Direct Lithium Extraction	Lithium and other valuable metals from brine water using advanced nanomaterials	Canada	2018
	Carbon Capture Usage & Storage (CCUS)	Point Source Carbon Capture	Energy-efficient technology for capturing carbon dioxide from industrial sources	Canada	2007
	Fuels & Chemicals	Photocatalysis	Photocatalyst technology for chemical conversions to produce low-cost, low-emission hydrogen and chemicals	United States	2017
	Fuels & Chemicals	Ammonia Synthesis	Ammonia production technology at lower temperature and pressure for on-site applications	Japan	2017
	Carbon Capture Usage & Storage (CCUS)	Carbon Removals	Slurry sequestration technology that injects organic waste underground for permanent carbon removal	United States	2023

KEY: Increase on 2024 figures Decrease on 2024 figures Same as 2024 figures / NA

M&C 3/3



RESOURCES & ENVIRONMENTAL MANAGEMENT

DATA STATS
 7 COMPANIES ↓
 3 COUNTRIES ↓

INDUSTRY INSIGHT HIGH-QUALITY OFFSETS AND ADAPTATION AND RESILIENCE TECHNOLOGIES REMAIN THE PROTAGONISTS OF RESOURCES & ENVIRONMENTAL MANAGEMENT

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
44.01	Carbon Removal	Carbon Mineralization	Subsurface carbon mineralization solution via enhanced weathering that extracts and stores CO ₂ from the atmosphere	United Kingdom	2020
BURNBOT	Natural Resources	Wildfire Prevention	Integrated system designed for scaling fuel treatment for wildfire mitigation	United States	2022
ebb carbon	Carbon Removal	Blue Carbon	Proprietary electrochemical system to remove acid from the ocean and enhance its natural ability to draw down atmospheric CO ₂ and store it as oceanic bicarbonate	United States	2021
Heirloom	Carbon Removal	Carbon Mineralization	Carbon capture process that leverages natural mineralization by enhancing the carbon absorption capabilities of limestone and permanently stores it as a stable carbonate	United States	2020
meteo matics	Climate Risk & Resilience	Weather Monitoring	Drones and meteorological software that provide climate data for monitoring and renewable energy project power forecasting	Switzerland	2012
NATURE METRICS	Natural Resources	Biodiversity Monitoring	eDNA analysis service for ecosystem, natural capital, and biodiversity assessment and monitoring	United Kingdom	2014
ZWITTERCO™	Water	Wastewater Treatment (Membranes)	Reverse osmosis membranes designed for industrial wastewater treatment and desalination to prevent fouling via nanofiltration	United States	2020

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA

R&EM 1/1



TRANSPORTATION & LOGISTICS

DATA STATS
 8 COMPANIES ↓
 4 COUNTRIES ↑

INDUSTRY INSIGHT VEHICLE AND FLEET MANAGEMENT SOFTWARE, DATA-DRIVEN CHARGING SOLUTIONS, AND HIGH PERFORMANCE COMPONENT INNOVATION ENABLING ELECTRIFICATION OF COMMERCIAL, HEAVY-DUTY, AND OTHER DIFFICULT-TO-ABATE SECTORS

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
BASIS	On-road Vehicles	Electric Buses	Electric buses, charging infrastructure, and pay-as-you-go financing	Kenya	2021
BluSmart	Fleet Management	Fleet Management	Ride-hailing services in electric vehicles and charging infrastructure network	India	2019
ev.energy	Electric Vehicle (EV) Charging	EV Charging Management and Optimization	Managed charging software to reduce grid load and integrate EVs into energy networks	United Kingdom	2018
FORUM MOBILITY	On-road Vehicles	Electric Heavy Duty Commercial Trucks and Charging	Heavy-duty electric trucks and charging depots	United States	2021
HARBINGER	On-road Vehicles	Electric Commercial Vehicles	Vertically-integrated platform for electric medium-duty commercial vehicles including stripped chassis, proprietary drivetrain, and scalable battery pack	United States	2021
LIGHTSHIP	On-road Vehicles	Electric Recreational Vehicles	Electric recreational vehicles (RVs)	United States	2020
MONARCH TRACTOR	Off-road Equipment & Machines	Electric Tractors	Intelligent electric tractors with autonomous capabilities and AI-enabled control and management software	United States	2017
ZEROAVIA	Aviation	Hydrogen Fuel Cell Airplanes	Hydrogen aircraft and components including fuel cells, inverters, and electric motors	United States	2017

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA

T&L 1/1



WASTE & RECYCLING

DATA STATS
16 COMPANIES /
7 COUNTRIES /

INDUSTRY INSIGHT CONTINUED GROWTH FOR INNOVATIVE RECYCLERS AND THEIR SORTATION PARTNERS ALONGSIDE A NEW BURST OF WATER TREATMENT TECHNOLOGIES

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
Aclarity	Wastewater	Wastewater Treatment (Electrochemical)	Electrochemical water purification systems	United States	2016
AMP™	Waste Management	Robotic Waste Sorting	Waste sorting AI-guided material recovery facilities	United States	2015
Aqua Membranes	Wastewater	Wastewater Treatment (Membranes)	Membrane filters for water purification	United States	2011
Circular	Waste Management	Electronic Waste Tracking	Traceability software for materials in industrial supply chains, including e-waste, battery materials, and plastic	United Kingdom	2017
Cyclic Materials™	Waste Management	Rare Earth Elements Recycling & Recovery	Circular supply chain service platform facilitating the recycling of critical metals	Canada	2021
CYLIB	Waste Management	Battery Recycling	Technology for lithium battery recycling	Germany	2022
GREENCORE	Waste Management	CO ₂ -to-industrial Materials	Converts iron and steel slag into calcium carbonate, iron oxide, silica and alumina, while consuming CO ₂ via CCUS	China	2016
greyparrot waste intelligence	Waste Management	AI-enabled Waste Sorting	Computer vision solutions to power robotics and smart systems for waste management at each stage of the value chain	United Kingdom	2019

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA

W&R 1/2

* The former category of “Resources & Environment” is now two new categories: “Resources & Environmental Management” and “Waste & Recycling”.



WASTE & RECYCLING

DATA STATS
16 COMPANIES /
7 COUNTRIES /

INDUSTRY INSIGHT CONTINUED GROWTH FOR INNOVATIVE RECYCLERS AND THEIR SORTATION PARTNERS ALONGSIDE A NEW BURST OF WATER TREATMENT TECHNOLOGIES

COMPANY	SECTOR	TECHNOLOGY	DESCRIPTION	COUNTRY	FOUNDED
 INDRA EVERYTHING WATER.	Wastewater	Wastewater Treatment (Electrochemical)	Modular wastewater treatment system based on patented physio-electrical process to remove pollutants (suspended and dissolved) and pathogens from water	India	2018
 Li Industries	Waste Management	Battery Recycling	Recycling processes capable of recovering battery electrode materials for direct reuse and automated battery sorting technology	United States	2017
 MOLEAER ADVANCING NANOBUBBLE TECHNOLOGY	Wastewater	Wastewater Treatment (Nanobubbles)	Nano-scale aeration technology for transferring gas into liquids	United States	2016
 neustark Removing CO ₂ permanently	Waste Management	CO ₂ -to-concrete	Construction concrete from carbon dioxide and waste concrete	Switzerland	2017
 NTH CYCLE	Waste Management	Critical Materials (Nickel, Cobalt)	Modular system to refine critical metals from e-waste	United States	2017
 pani Zero in on water	Wastewater	AI For Wastewater Treatment	AI-powered water treatment operations and management software	Canada	2017
 SOLARCYCLE	Waste Management	Solar Panel Recycling	Solar technology recycling services and end-of-life solutions that can recover 95% of materials used	United States	2022
 SORTERA ALLOYS	Waste Management	Scrap Metal Circularity	Scrap metal autonomous sorting technology using AI to optimize recycling	United States	2020

KEY: ↑ Increase on 2024 figures ↓ Decrease on 2024 figures ↔ Same as 2024 figures / NA

W&R 2/2

* The former category of “Resources & Environment” is now two new categories: “Resources & Environmental Management” and “Waste & Recycling”.

TREND WATCH 2025



WRITTEN BY
ANTHONY DEORSEY,
RESEARCH MANAGER

Introduction

The only thing certain in this decade is uncertainty—it is only appropriate then, that this mid-point of the decade is already indicating a few critical junctures in cleantech innovation evolution.

In our January 2020 Global Cleantech 100 report, written on the eve of the COVID outbreak, we welcomed readers to the “Roaring 20s” of this century—a decade in which the cleantech growth trend would hit its stride in the consistent expansion that it had, at that point, experienced since 2016.

The very next January, we welcomed readers to the “chaos of the 2020s”, which, while an accurate characterization, was written on the precipice of a historical spike in cleantech investments. At the time of this report’s release, the U.S. will be only days away from re-inaugurating Donald J. Trump as President, marking another significant pivot in the global energy and climate direction just within this half decade.

The only thing certain in this decade is uncertainty—it is only appropriate then, that this mid-point of the decade is already indicating a few critical junctures in cleantech innovation evolution. From where we are sitting today, we can see three over-arching tipping points emerging, that provide the backdrop for 2025’s cleantech innovation unfoldings:

WE STATED THAT IN 2024 WOULD BE WHERE INVESTORS AND CORPORATES STARTED LOOKING BEYOND TECHNOLOGY POTENTIAL AND THAT INNOVATORS WOULD NEED TO COMPETE ON THE MERITS OF THEIR END PRODUCT AND PROJECT ECONOMICS—THIS HAS LARGELY BEEN THE CASE

■ **Tipping point #1:** The supply economics survival game—these past two years have brought an unprecedented wave of first-of-a-kind (FOAK) cleantech project launches. Entrepreneurs have, against all odds, found creative ways to pull together groups of financiers, off-take customers, and workforces to stand up risky projects with a path to scale. The likely melt away of policy support and incentives, at least in the U.S., will accelerate the degree to which these entrepreneurs need to compete on economics alone. As evidenced by this year’s Global Cleantech 100, some have seen around this corner already

■ **Tipping point #2:** The power shortage demand pull—historic increases in demand for power to accelerate data center deployment, improve EV charging availability, and enable electrification of manufacturing and buildings will be a significant pull-through effect on electricity generation sources, energy efficiency, and uptime assurance

■ **Tipping point #3:** The resilience renaissance—climate adaptation and resilience, long a sleepy corner of cleantech innovation, is going to slowly become more mainstream, and not just through the climate lens. Soaring temperatures, once-in-a-generation storms each year, and the expansion of the “uninsurable frontier” are going to drive new tech solutions into public safety, health, and finance conversations. Note the reemergence of water as a prominent theme in this year’s Global Cleantech 100.



TREND WATCH 2025

A lean financing environment demands early indicators of commercial engagement

In last year's Global Cleantech 100 report, we wrote that the cleantech theme had "landed" on the other side of the COVID pandemic and the low-interest rate environment of 2021 and 2022, at higher levels than it had entered it. We had also stated that 2024 would be the year where investors and corporates started looking beyond technology potential and that innovators would need to compete on the merits of their end product and project economics—this has largely been the case.

In 2024, a year in which much of the world still shook off the "COVID hangover" of inflation and supply chain uncertainty, and major national elections loomed for nearly half of the world's population, investors zoomed in on training data of initial commercial results to justify moving capital.

Take, as examples, the role that corporate involvement played in venture investments again this year (at time of writing, nearly 30% of all deals involved a corporation). The focus areas of corporates and corporate VCs backing this year's Global Cleantech 100 offer some directional indication.

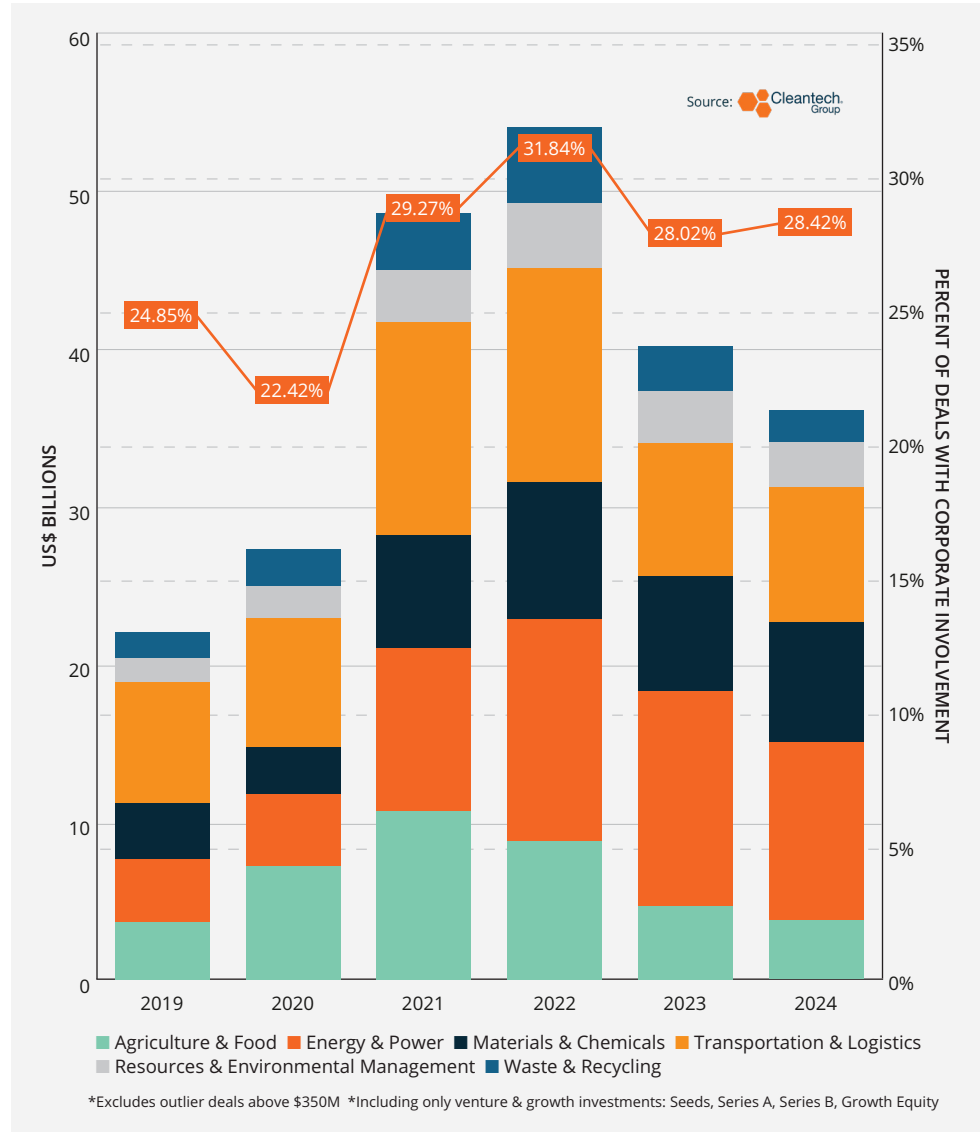
EXPECT TO SEE MORE EXITS IN DATA CENTER SUSTAINABILITY, WITH RIPPLE EFFECTS BACKWARDS THROUGH THE VENTURE INVESTING CONTINUUM

There is a portfolio strategy around clean fuel molecule (hydrogen, ammonia) bets and application-specific clean fuels (e.g., sustainable aviation fuels and shipping fuels) beginning to crystallize in the ecosystem:

- Multiple Saudi Aramco clean fuels portfolio companies landed in this year's list, including Amogy (ammonia cracking, Global Cleantech 100 2023-2025), OXCCU (efuels, Global Cleantech 100 2024-2025), and Syzygy Plasmonics (photocatalysis for hydrogen, ammonia, renewable natural gas, Global Cleantech 100 2022-2023, 2025)
- Mitsubishi Heavy Industries, also an investor in Amogy and Syzygy Plasmonics, has backed an efuels company, Infinium Holdings (Global Cleantech 100 2023, 2025), and this year invested in geologic hydrogen player, Koloma (Global Cleantech 100 2025)
- United Airlines Ventures counts Koloma and OXCCU as portfolio companies as well

Oil & Gas CVCs and climate funds of tech giants are becoming a key source of growth and investments for carbon capture and removals companies, taking a few examples from first-time Global Cleantech 100 award winners this year:

Fig.1: Venture & Growth Investments in Cleantech



TREND WATCH 2025

Fig.2: Exits of Venture-backed Cleantech Companies

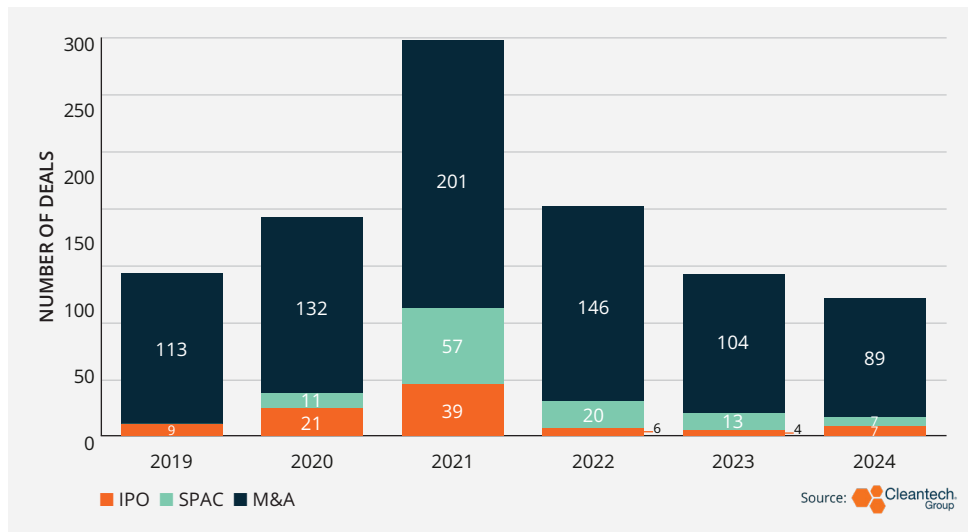
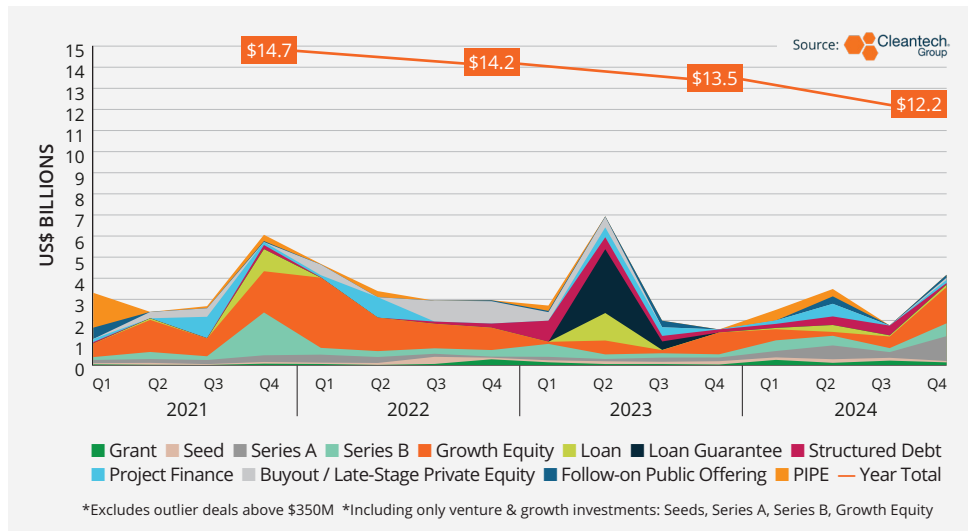


Fig.3: Financing of Venture-backed U.S. Energy & Power Innovators



- Mantel – Developing a molten salt-based point source capture technology – raised a \$30M 2024 round including BP Ventures and Shell Ventures
- Subsurface carbon mineralization company 44.01 raised a \$37M round in 2024 including participants from Equinor Ventures, Climate Investment (OGCI), and Climate Pledge Fund (Amazon)
- Enhanced weathering innovator Heirloom signed a permanent CO₂ removal contract with Microsoft in 2023

Will the FOAK momentum and progress toward tipping point #1 (supply economics) propel more critical materials innovators to exits in 2025? Tipping point #2 (power demand) is already generating some exits along the data centers thread, and we predict will compound in 2025. See Oklo Power, an advanced nuclear fission company that listed on the NYSE through a SPAC in 2024 – days later Oklo and Wyoming Hyperscale entered into a non-binding PPA to power AI data centers. Liquid cooling company JETCOOL was acquired by Flex in November of 2024. Expect to see more like this, and for these exits to generate ripple effects backwards through the venture investing continuum.

Note as well on page 46 the kick-start that corporate ventures in key industrials and insurance companies have given to water tech companies.

A major question for U.S.-based innovators will be what changes will there be under a Trump administration with regard to Department of Energy (DOE) support, namely the Inflation Reduction Act (IRA). As seen in the chart below, even with the IRA still in force, U.S. Energy & Power investments slumped slightly in 2024. Nonetheless, the mechanics around the IRA have become engrained in the innovation ecosystem quickly – note that this year’s Global Cleantech 100 features Crux, a marketplace for transferable tax credits from clean energy projects. Elsewhere, at least 9 of this year’s Global Cleantech 100 list have received some form of DOE support since the beginning of 2019, magnifying the question of what changes to cleantech-supporting mechanisms of the DOE will portend for U.S. competitiveness in these spaces.

With certainty, the still-cold exit environment has created a chilling effect on venture investments in the past 12 months. We see some initial signals of emerging exit demand in the critical materials space, with the 2024 IPO of Stardust Power and acquisitions of Arcadium Lithium (Rio Tinto) and Dimien (Pure Lithium) – we note that these companies have a primary focus on lithium, but that innovators are developing novel extraction and refining for everything from lithium, cobalt, nickel, graphite, and rare earth metals (see “Fight for the Factory Floor” two sections down).



TREND WATCH 2025

The deep tech drive hits a new gear
 In 2024's Global Cleantech 100, we covered the major shift in innovation focus from incremental improvements to deep scientific innovation targeting big picture shifts in sustainability. That trend only strengthened through 2024, and deep tech for cleantech now comprises the largest percentage of investments it ever has. Remarkably, even in a year with lower aggregate cleantech investments, 2024 funding in deep tech for cleantech outpaced their 2023 totals.

Within the deep tech spectrum, we can see bona fide evidence of tipping point #1 (supply economics) crystallizing in real time.

Take, for example, the concept of deep decarbonization in the heavy industries, for years deemed the "hard to abate" sectors of steel, concrete, and chemicals production. This year, we have a bevy of examples in the Global Cleantech 100 of companies that have not only invented ways around the carbon emissions problem but are hitting tipping point #1 in the form of FOAK physical facilities, the critical first step of the cost reduction journey.

■ Six-time Global Cleantech 100 company **Boston Metal** celebrated the opening of their first commercial molten oxide electrolysis facility in Brazil in 2024

■ Three-time Global Cleantech 100 company **Sublime Systems** – who has re-invented the cement production process to manufacture cement at

room temperatures – announced earlier this year their plans to launch a commercial facility in Holyoke Massachusetts, for operation in 2026

■ eFuels for sustainable aviation fuel have taken steps into reality on both sides of the Atlantic with **Infinium Holdings** (Global Cleantech 100 2023, 2025) announcing commencement of operations at a facility in Texas in 2023, with another to also be launched in Texas in 2026. UK-based **OXCCU** (Global Cleantech 100 2024-2025) opened a demonstration plant at Oxford Airport in 2024

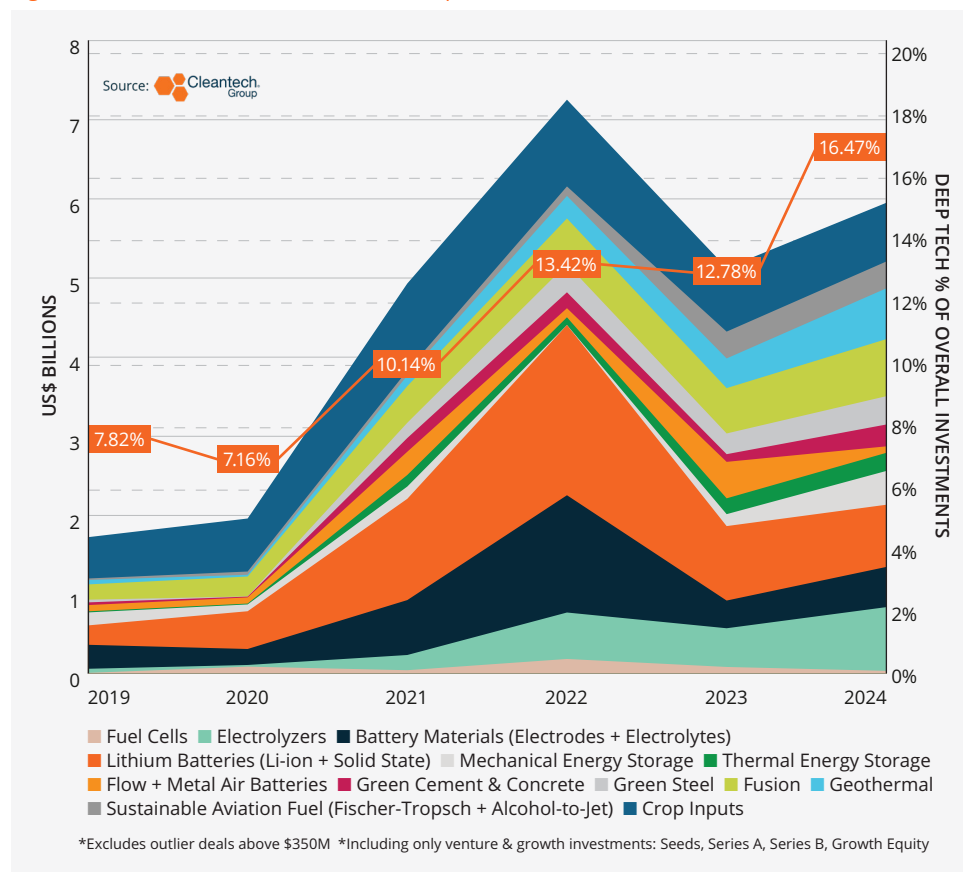
■ Thermal energy storage innovator **Antora Energy** (Global Cleantech 100 2023, Cleantech 50 to Watch 2021) deployed an operational thermal battery with Wellhead Electric Company in California in late 2023, followed quickly by a \$150M Series B to scale its manufacturing operations

We also have seen the effects of tipping point #2 (power demand) accelerate the growth of technologies aiming at tipping point #1 (supply economics) – case in point, four-time Global Cleantech 100 company **Fervo Energy's** late 2023 launch of an enhanced geothermal project to supply Google data centers in Nevada. This project was followed in short order by a \$244M Growth Equity round in February 2024 to drive forward development of a geothermal plant in Utah, scheduled for operations in 2026.

The role of data centers as a demand sink is not to be understated – Goldman Sachs estimates that advanced AI will increase data center power demand by 160% through 2030, the relative demand inelasticity of data centers is likely to pull new technologies into the market sooner than initially planned (clean power generation, grid enhancing technologies, liquid cooling).

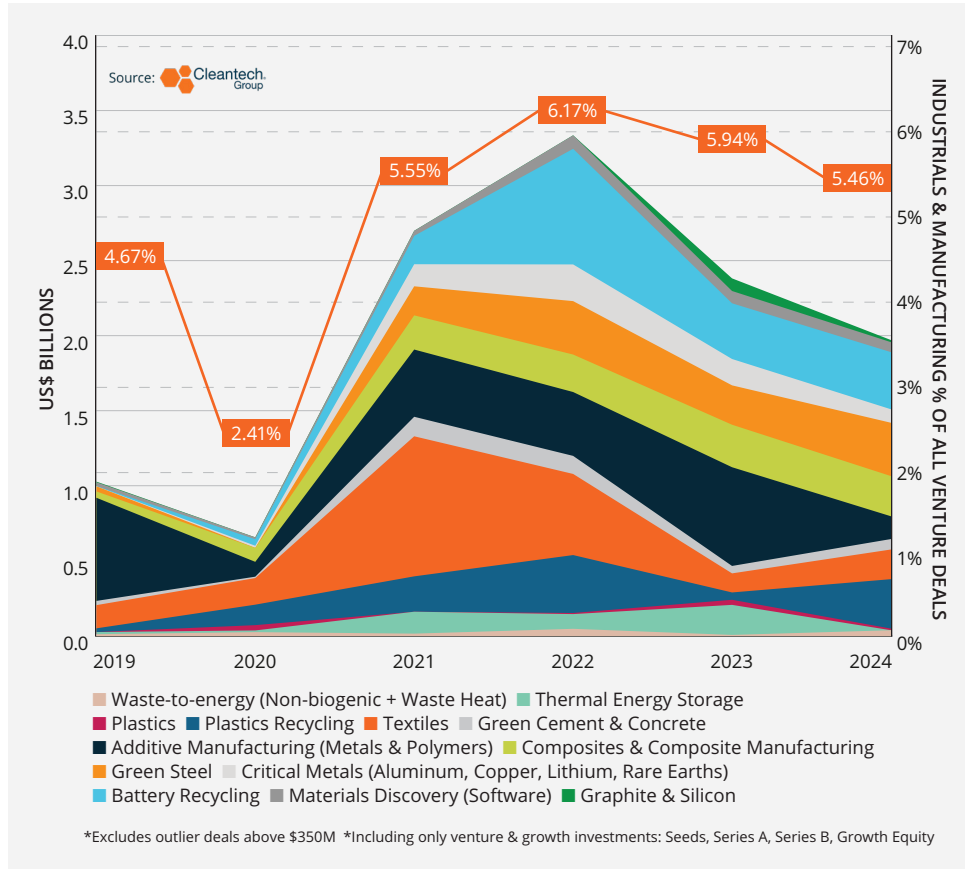
EVEN IN A YEAR WITH LOWER AGGREGATE CLEANTECH INVESTMENTS, 2024 FUNDING IN DEEP TECH FOR CLEANTECH OUTPACED THEIR 2023 TOTALS

Fig.4: Venture & Growth Investments in Deep Tech for Cleantech



TREND WATCH 2025

Fig.5: Venture & Growth Investments in Industrials & Manufacturing for Cleantech



The fight for the factory floor – are winners emerging already?

We wrote last year about the convergence of two trends—resource reduction in industry and manufacturing of new energy products—to form an undeniable theme in cleantech innovation that an industrial transformation was coming to fruition. In 2024, investments into innovators within these trends outpaced those of 2023, despite the overall dip in 2024 venture and growth investments.

With certainty, investor confidence in the battery recycling and battery materials spaces can be attributed to the rapid progression of FOAK facilities that are serving new demand for onshoring of new energy materials. This year’s Global Cleantech 100 offers a handful of cases of companies hitting tipping point #1 (supply economics) as they launch and scale materials recovery and/or refining facilities:

Back-to-back Global Cleantech 100 company **Nth Cycle** has pioneered a high-selectivity electro-extraction technique that removes target metals without use of fossil fuels. In 2023, Nth Cycle launched the U.S.’s **first nickel and cobalt production facility**

- In September 2024, Global Cleantech 100 first timer **Li Industries** was awarded \$55M from the U.S. DOE’s Office of Manufacturing and Energy Supply Chains to establish a lithium iron phosphate (LFP) recycling and cathode active material manufacturing plant. Li Industries is partnering with General Motors to advance the technology, as the lower-cost LFP formulation becomes more mainstream
- 2025 Global Cleantech 100 **Cylib** (Germany) received a \$2M grant in November 2024 to pilot their water-based lithium and graphite recovery technology at a FOAK facility in Germany, set to open in 2027
- Rare earth element magnets recovery innovator **Cyclic Materials** has moved steadily along the growth curve since launching in 2021, including a pilot plant in 2023 and a commercial demonstration facility in 2024, in addition to locking in off-take contracts with customers like Solvay and SYNETIQ

WITH CERTAINTY, INVESTOR CONFIDENCE IN THE BATTERY RECYCLING AND BATTERY MATERIALS SPACES CAN BE ATTRIBUTED TO THE RAPID PROGRESSION OF FIRST-OF-A-KIND (FOAK) FACILITIES THAT ARE SERVING NEW DEMAND FOR ONSHOREING OF NEW ENERGY MATERIALS



TREND WATCH 2025

The strategic priority of onshoring battery and new energy materials at large is on full display across the value chain in this year's Global Cleantech 100. Innovation in the furthest upstream of direct lithium extraction is represented by **Mangrove Lithium** (on the list for the third year in a row) and **Summit Nanotech** (Global Cleantech 100 2021, 2024-2025). **PH7** (Global Cleantech 100 2024-2025) has developed approaches for sustainable heap leaching of copper and a proprietary "solvommetallurgy" process to extract high-value materials including platinum group metals and copper from e-waste.

Copprint (Global Cleantech 100 2023-2025) has innovated a copper printing process that deposits highly conductive copper onto power electronics faster, and with less waste.

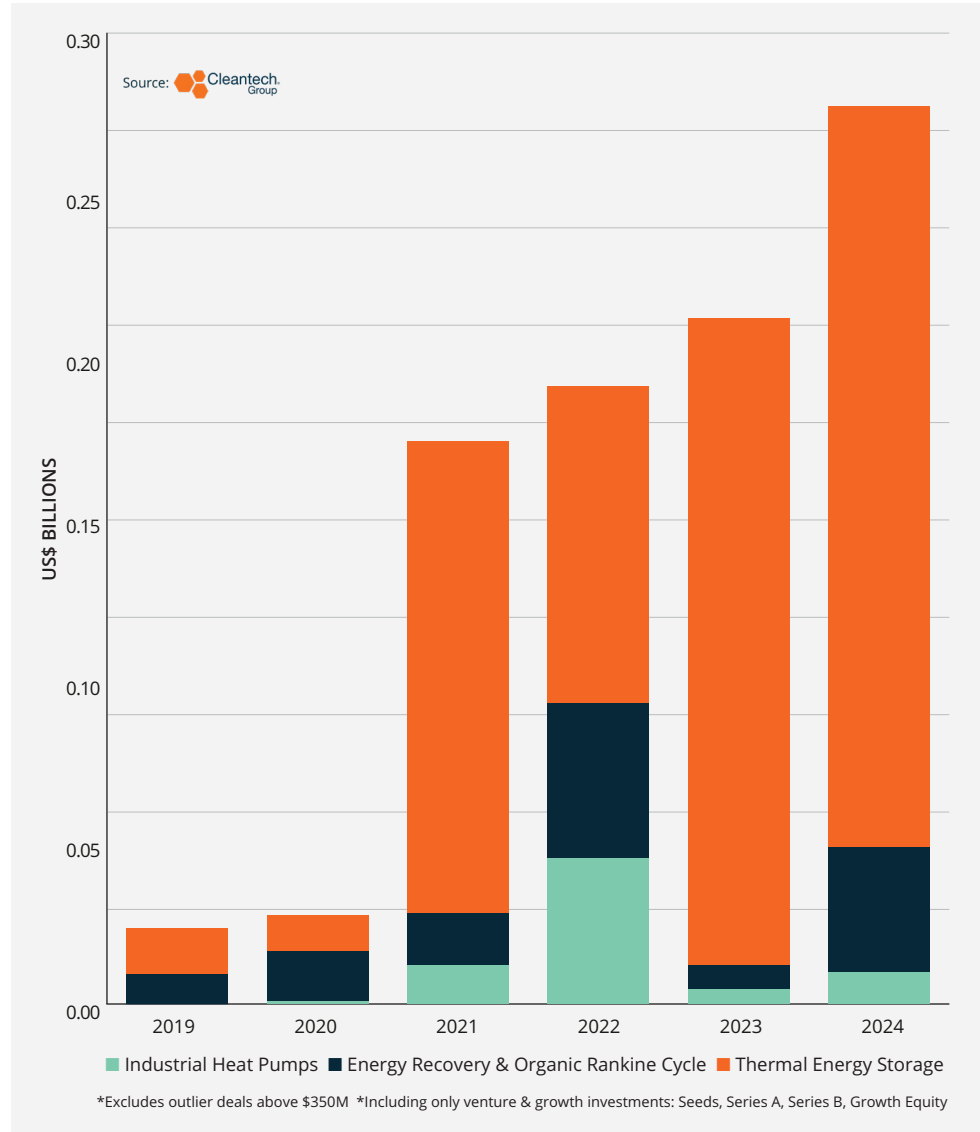
We also wrote in 2024 about the emerging importance of sustainable approaches to manufacturing today's commodities and products. Within the theme of industrial electrification, especially electrification of heat processes, the investment momentum in 2024 outstripped even the most active investing years of 2021 and 2022.

WITHIN THE THEME OF INDUSTRIAL ELECTRIFICATION, ESPECIALLY ELECTRIFICATION OF HEAT PROCESSES, THE INVESTMENT MOMENTUM IN 2024 OUTSTRIPPED EVEN THE MOST ACTIVE INVESTING YEARS OF 2021 AND 2022

This year's Global Cleantech 100 offers some instructive examples of which technologies are starting to be perceived as high-potential industrial electrification vectors:

- Delivering high-temperature process heat to heavy industry processes including steel and cement generally requires temperatures of 1000° C - 1250° C. Thermal energy storage systems operating at these temperatures can also spin a turbine to generate electricity from the stored heat – that's where companies like **Antora Energy** (Global Cleantech 100 2023, Cleantech 50 to Watch 2021), **Kraftblock** (Global Cleantech 100 2024-2025), and first-time Global Cleantech 100 company **RedoxBlox** come in, storing at temperatures of up to 1300° C - 1500°C
- Low-temperature heat (<200° C) is the "bottom of the iceberg" in industrial emissions, found in many large industries such as food and beverage processing, recycling, and in parts of complex chemicals production. This year's Global Cleantech 100 features three first-time award winners in low-temperature heat electrification: **Skyven** (steam-generating heat pumps), **Atmoszero** (electric boilers), **Qpinch** (chemical heat pumps)

Fig.6: Venture & Growth Investments in Industrial Electrification





TREND WATCH 2025

Passing Paris – Can adaptation accelerate in 2025?

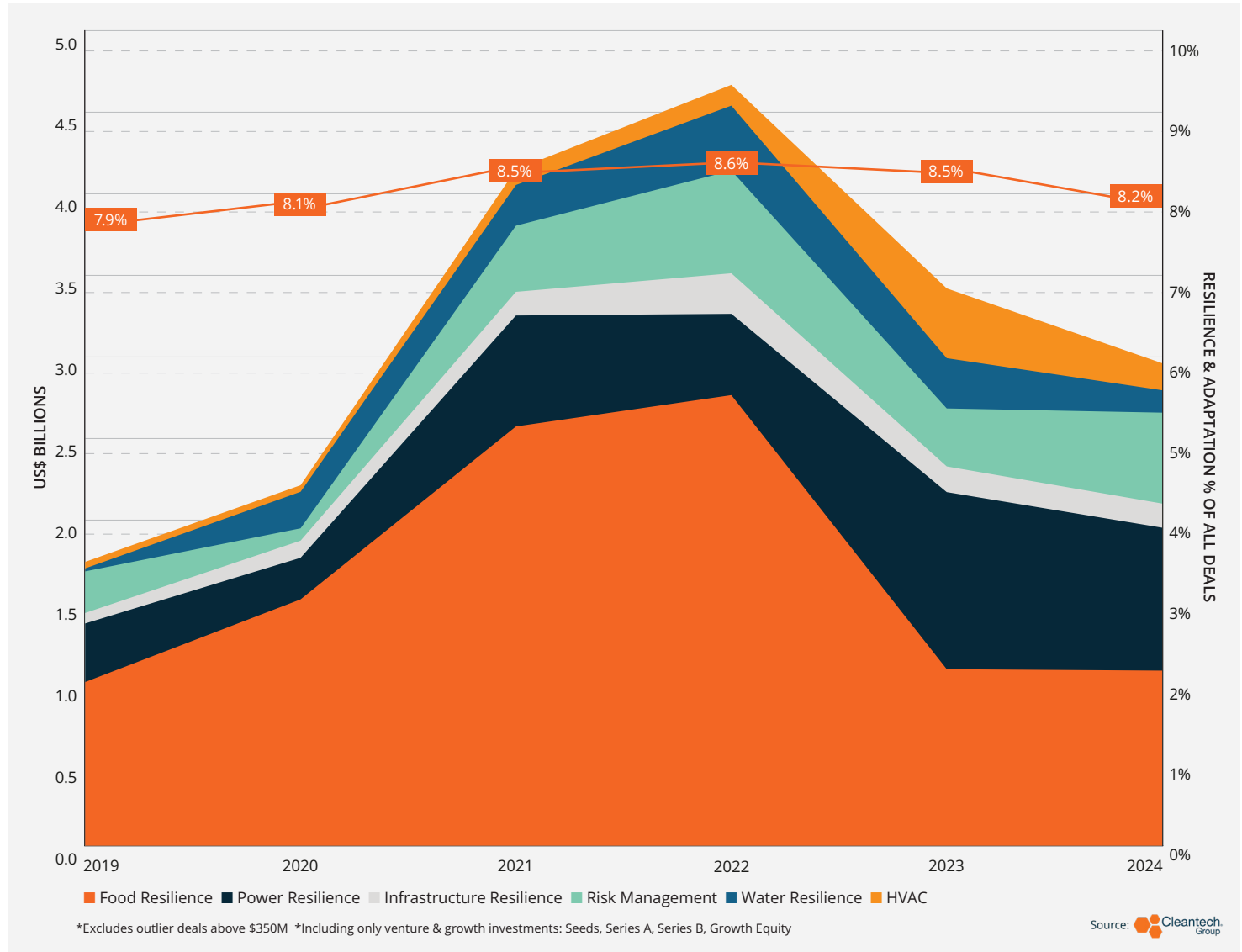
2024 exceeded 2023 as the hottest year on record (World Meteorological Organization), and as the reality begins to set in that the world is likely to surpass the 1.5° C warming limit that the Paris Agreement set out, we continue to wait for the urgency to be reflected in innovation and investment. Venture investments in adaptation and resilience continue to top out between 8-9% of all cleantech investments.

However, this year’s Global Cleantech 100 gives us reason to be optimistic: a handful of adaptation and resilience-focused companies are on the 2025 list, begging the question of whether this will be the year that the trend breaks out.

It is likely that, while adaptation and resilience tech may not see an across-the-board uplift in 2025, some specific focus areas will experience a breakout as the argument for avoiding losses and damages begins to overlap with the need for serving immediate demand pull.

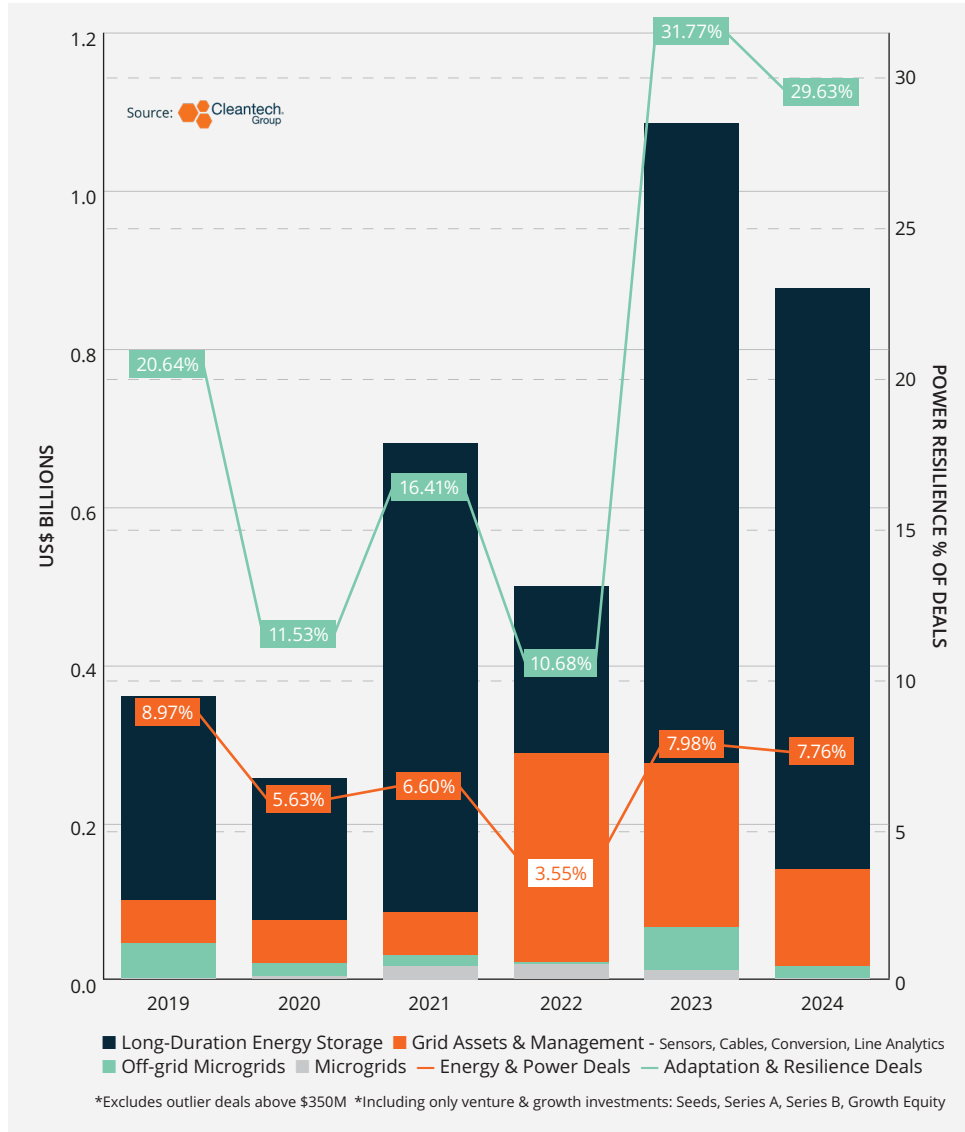
IT IS LIKELY THAT, WHILE ADAPTATION AND RESILIENCE TECH MAY NOT SEE AN ACROSS-THE-BOARD UPLIFT IN 2025, SOME SPECIFIC FOCUS AREAS WILL EXPERIENCE A BREAKOUT

Fig.7: Venture & Growth Investments in Adaptation & Resilience Innovation



TREND WATCH 2025

Fig.8: Venture & Growth Investments in Power Resilience Innovation



The first area to look toward is that of resilience in the power sector— this will be a space where tipping point #2 (power demand) is likely to nudge the needle on tipping point #3 (resilience urgency) faster than the market had initially anticipated. Two grid resilience innovators make a debut on this year’s Global Cleantech 100:

- An estimated 60% of U.S. distribution lines are past their 50-year lifespan, and it’s along these lines that up to 90% of power outages occur. **TS Conductor** has developed carbon-core encapsulated aluminum conductors to increase conductivity and avoid thermal sag in high-temperature zones. **TS Conductor’s** technology can be applied to both transmission and distribution cables, in either newly constructed lines or reconductoring
- **VEIR** is pioneering a nitrogen-based evaporative cooling system for high-temperature superconductors. This approach promises to increase transmission capacity by orders of magnitude but also reduce losses due to extreme temperatures

The power sector is not just vulnerable to infrastructure damages from climate change, it is also vulnerable to its rapidly evolving profile as a risk originator as its own operations become more dangerous in extreme weather conditions. Pacific Gas & Electric’s stunning \$13.5B settlement in 2019 for wildfire-related damages and deaths changed the world’s understanding of the power sector’s relationship to public safety.

New wildfire tech is prepared to close off risk gaps in real time; take 2025 Global Cleantech 100 debutante **Burnbot**, who has developed remote-operated robots to carry out prescribed burns and prevent wildfire outbreaks before they happen. Indeed, the wildfire tech community, while small, is combining forces across parties and is positioning itself to unlock latent demand in 2025. We wrote in last year’s Global Cleantech 100 about the launch of Convective Capital, the first dedicated wildfire tech venture capital fund. In 2024, Convective and a group of partners began formal lobbying efforts and have already engaged with members of the U.S. Congress.

IN ADAPTATION & RESILIENCE, THE FIRST AREA TO LOOK TOWARD IS THAT OF RESILIENCE IN THE POWER SECTOR

TREND WATCH 2025

Fig.9: Venture & Growth Investments in Water

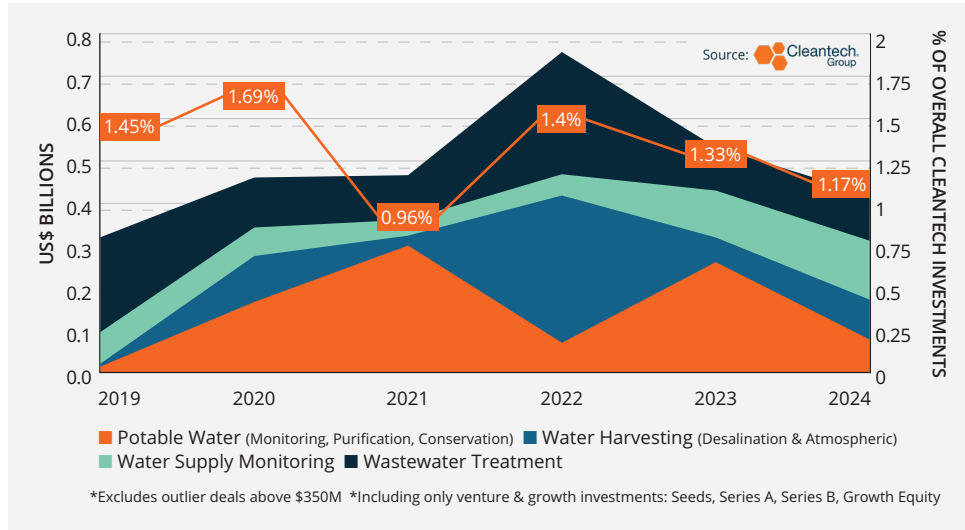
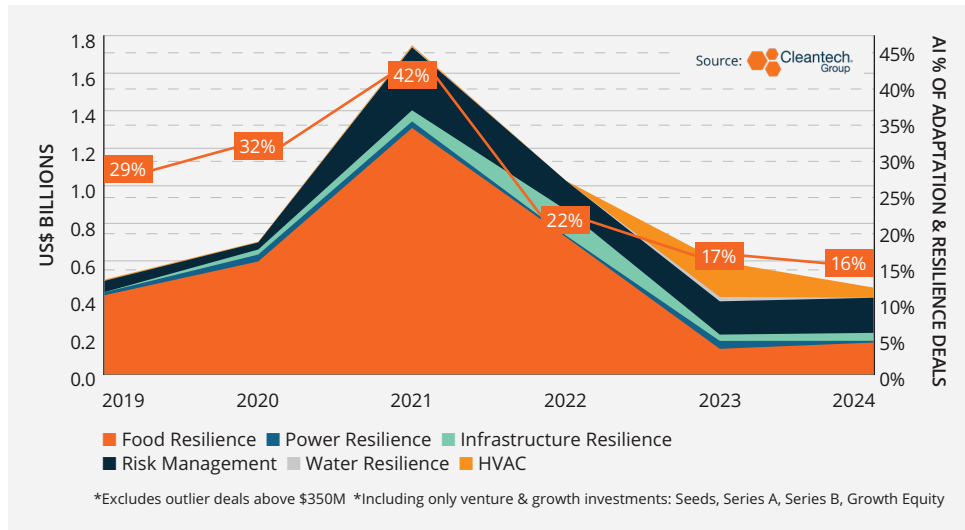


Fig.10: Venture & Growth Investments in AI for Adaptation & Resilience Innovation



Will water finally have its moment in 2025?

In the 2024 Global Cleantech 100, our 15th iteration of the report, Cleantech Group CEO Richard Youngman noted in his foreword that in the first edition of the report, there were nine water-related companies on the list, and that number was never reached again. In 2024, there were two, but the theme shows a glimmer of a return in 2025 with six companies on the list.

Water continues to play a side role in overall cleantech investments (see below), but we see tipping points #1 (supply economics) and #3 (resilience urgency) emerging in a noticeable way in this year's Global Cleantech 100 companies.

Water-intensive industrial operations (food and beverage, mining, chemicals production) are increasingly in the market for technologies that can reduce both exposure to water scarcity challenges and energy use. Moreover, the effort to onshore production of sensitive industries, primarily semiconductors, will require strategic planning around water reliance in new facilities. Two new takes on the reverse osmosis process through unique membrane formulations have landed on this year's Global Cleantech 100 list: [Aqua Membranes](#) and [ZwitterCo](#). Note the corporate urgency here: Micron was an investor in Aqua Membranes and BHP and Munich Re Ventures were investors in ZwitterCo.

Centralized wastewater treatment is viewed as a venue of demand opportunity, as well. This year's Global Cleantech 100 list boasts a mini value chain of wastewater treatment technologies:

- [Moleaer](#) uses nanobubble aeration techniques to flatten energy demand in aeration processes and reduce the need for chemicals to reduce residue
- [Aclarity](#) has developed a novel electrochemical approach to PFAS destruction
- [Indra Water](#) is decentralizing the electrochemical treatment approach and bringing modular treatment units to site-of-use, while also leveraging internally developed automation and analytics for OPEX reduction
- [Pani Energy](#) is bringing AI to wastewater treatment and desalination plants through granular sensing and diagnostics to prescribe surgical chemical inputs and membrane maintenance

Keep an eye on the AI-enabled elements of adaptation and resilience tech – the forward-looking nature of most adaptation tech lends itself to taking value from predictive measures and command-and-control. See below, where despite ebbs and flows in dollar amounts, AI-enabled adaptation tech companies never dip below 20% of the adaptation mix.



TREND WATCH 2025

2025 will be the year we remember the guardrails coming off

From the major themes we have seen this past year – policy uncertainty, leading deep tech innovators clearing the FOAK hurdle, and the unfortunate, but real, growing demand for climate adaptation technologies— we can be confident that the theme of winning on product and project economics will only intensify this coming year.

Companies that are able to catch the wave of organic demand pull where it is online already (think data centers) and start proving technology out in real-life environments without baking in the assumption of favorable policy, will be in the best position to win. Some milestones to keep an eye out for in 2025, as indicators that the tipping points are being hit:

- We expect to see more exits of hardware companies related to data center stand-up and energy efficiency. Think novel cooling solutions, power conversion technologies, grid hardening—for the relatively price insensitive demand owners, snapping up IP and having control over the trajectory of development and deployment of these technologies is very attractive.
- Expect a second mover effect off certain FOAK projects. The astounding success of so many companies in getting the first physical plant off the ground is not to be understated, 2024 was a milestone year. But scale is the prize, and the companies that can deliver economic, nth-of-a-kind facilities will be the winners—the fast followers may develop advantages in being able to learn from FOAK leaders' mistakes
- Expect a few China blindsides. This year's Global Cleantech 100 list presents only two companies from China, begging the question of whether China has truly slowed down that much in cleantech innovation or whether the global ecosystem is just becoming less aware of what's developing within China. The latter feels more likely. As China's astonishing renewables and EV rollout continues, a strong pull-through effect on innovation in long-duration energy storage, grid resilience, and energy storage materials is highly probable. China's ambitious plans for nuclear fission expansion and a heavy R&D emphasis on fusion are likely to yield technological gains, too. With global trade partners retreating, most notably the U.S. and EU, the export prospects of some Chinese cleantech incumbents will dim. However, the flip side of trade
- decoupling is a decoupling of insight—less trade with China will mean more breathing room today for cleantech companies in the U.S. and Europe, but also less visibility into tomorrow's competitive technology being developed there
- Expect a breakout or two in adaptation and resilience sub-themes. It has become commonplace to think of cleantech as being targeted at either mitigation or adaptation. This is a false dichotomy—much adaptation tech has a mitigation benefit, and vice versa. Moreover, climate adaptation is better understood as a spectrum than a category. Different from mitigation technologies, whose impact ultimately can be measured in CO₂e avoided or removed, adaptation technologies have a diverse spectrum of metrics (avoided financial loss, avoided human loss, avoided biodiversity loss, resources saved, etc.). Expect to see markets get comfortable with the metrics of a few tech areas and start to embrace their business models as a result—take note especially of wildfire tech, which now is moving beyond business-to-government models to demand pick up from the private sector, utilities, and in some cases, residential consumers

WE CAN BE CONFIDENT THAT THE THEME OF WINNING ON PRODUCT AND PROJECT ECONOMICS WILL ONLY INTENSIFY THIS COMING YEAR

WE EXTEND OUR CONGRATULATIONS AGAIN TO ALL OF THIS YEAR'S GLOBAL CLEANTECH 100 COMPANIES AND LOOK FORWARD TO CONTINUING TO ACCOMPANY YOU ON THE NEXT LEG OF THE JOURNEY.

AD



INDUSTRY GROUP ANALYSIS

AGRICULTURE & FOOD



WRITTEN BY
JACK ELLIS, SENIOR ASSOCIATE,
AGRICULTURE & FOOD

There's a funding winter in agri-food. But the future looks promising as investors connect the dots between biotech, automation, and climate adaptation

Cleantech start-ups in the Agriculture & Food industry group raised a total of \$3.7B in venture funding in 2024, down from the previous year's \$4.6B and a substantial reduction from \$8.7B in 2022.

Back then, the world was only just emerging from the COVID-19 pandemic; venture markets were flush with capital and in buoyant moods thanks, in part, to pandemic-related government stimulus.

In the intervening years much has changed. Inflation and geopolitics have driven cleantech investors to become more cautious in their approach; and agri-food innovation appears to have felt this effect more than other industry groups.

Nevertheless, deal numbers were down only slightly on 2023, hinting that select investors still see opportunity in backing technologies that can future-proof food production; particularly those at an earlier stage of development, or that fill a specific niche.

New frontiers in alternative proteins

Alternative proteins innovators seek to produce edible protein from non-conventional sources such as plants, fungi, and cell cultures to reduce our reliance on animal agriculture.

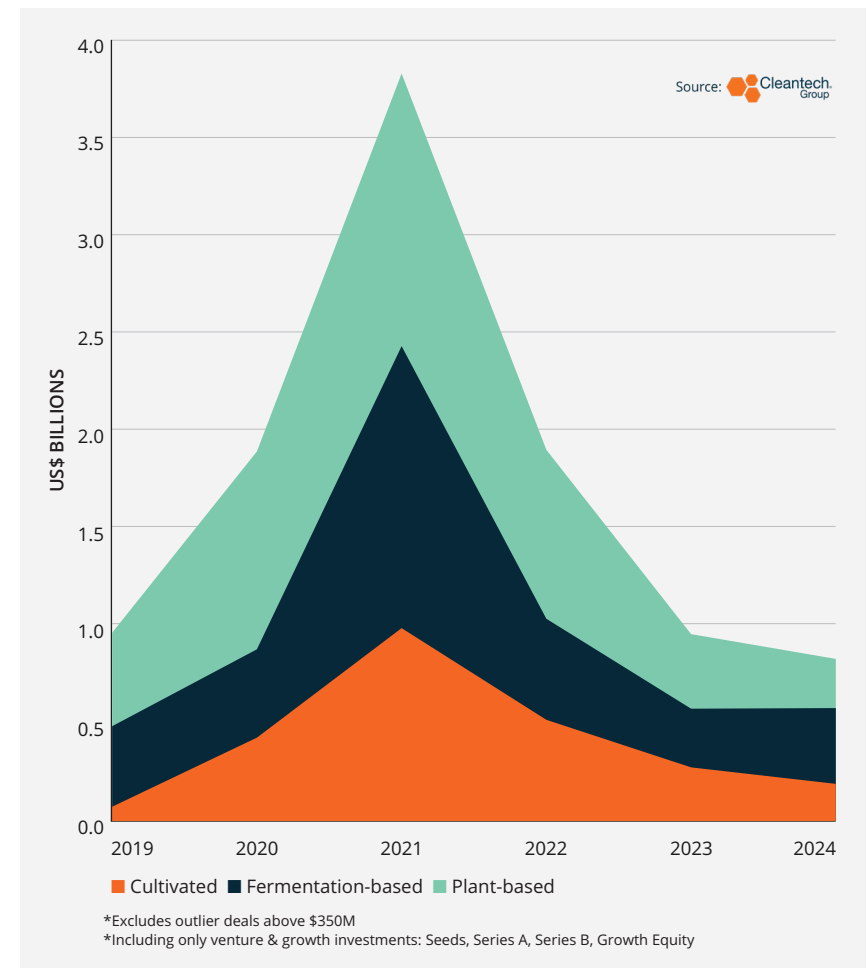
It has been the highest-funded subcategory in Agriculture & Food every year since Cleantech Group began tracking the space, and 2024 was no exception.

While investment dollars (\$1.1B) were flat and deal numbers (101) were down year-over-year in line with venture as a whole, alternative proteins claimed a larger share of overall Agriculture & Food funding (31%) than it did in 2023 (22%).

This marks a return, of sorts, by investors that had sat on the sidelines in 2023 awaiting rationalization in the heavily saturated sector. That rationalization took the form of several company closures; among them **Motif Foodworks** which had raised \$344M since spinning out of **Ginkgo Bioworks** in 2019.

Others to bite the dust in 2024 included **New Wave Foods** and **Nowadays**, producers of plant-based substitutes for shrimp and chicken, respectively.

Fig.1: Alternative Protein Categories Venture Funding 2019-2024





There was also consolidation, with one notable merger seeing **Shiok Meats**, an early darling of the cultivated meat space, being subsumed into fellow alt-seafood innovator **Umami Bioworks**.

Umami itself had undergone a pivot in recent years, refocusing as a B2B provider of cultivated meat production technologies to third parties. This is emblematic of a general trend toward greater specialization in the alt-protein segment, with more players adopting technology and service provider models.

In 2024, many of the headline alternative proteins venture deals centered on novel production technologies aimed at driving down costs and improving taste and texture in an effort to increase consumer adoption.

Prolific Machines, which is developing a photomolecular cell cultivation platform, raised \$55M Series B funding from investors including Breakthrough Energy Ventures and Ki Tua Fund, a corporate venture vehicle of New Zealand dairy giant Fonterra.

Spain's **Novameat** has designed a novel process for texturizing plant-based meat alternatives; it secured \$19.2M in Series A funding from Sofinnova, Unovis, and others.

Fermentation-derived protein, in particular, has piqued investor interest in the past year, overtaking what has historically been seen as the main alt-protein category – plant-based – in dollars invested for the first time.

Two of this year's Global Cleantech 100 companies, **Arkeon Biotechnologies** and **Pow.bio**, are working on advanced fermentation technologies for the agri-food sector.

It is no surprise to learn that fermentation innovators with products on shelves and sales to consumers closed some of the biggest funding deals in 2024. Animal-free dairy alternative producer **Formo** secured \$61M in Series B funding to advance its new range of products made using koji fermentation; it adopted this ancient and proven technique to get to market faster, while it still works to perfect its proprietary precision fermentation technology over the longer term. Likewise, **Meati** raised \$100M Series C funding to expand retail sales of its mycelium-based meat alternatives, which are already sold in U.S. supermarkets operated by Albertsons, Kroger, and Whole Foods.

In the research sector, too, there were positive signals, with both private and public money moving to make alt-proteins more palatable to the public.

Bezos Earth Fund committed \$60M to establish alt-protein research centers across the world; the first three of these

are located at North Carolina State University in the U.S., Imperial College London in the UK, and the National University of Singapore. The UK government also launched its own National Alternative Protein Innovation Hub with just shy of \$20M in funding.

On the regulatory front, Israel granted approval for a cultivated beef product produced by **Aleph Farms** in Q1, making it the third country in the world to allow cultivated meat to be sold to consumers. Hong Kong followed suit in Q4 by greenlighting **Vow's** cultivated quail. The UK approved **Meatly's** cultivated pet food for animal consumption.

While this impetus is welcomed, there are mounting challenges on the horizon for alt-proteins. Sales of plant-based products continue to flatline. Perhaps more worrying is the politicization of the technology in some parts of the world. Italy's government has banned cultivated meat, with its counterparts in France and Austria considering similar measures. In the U.S., state legislatures in Alabama and Florida have done the same.

All of these bans are of token impact given that cultivated meat products are still, for the most part, unavailable to purchase. However, innovators and investors alike should keep a close watch on political developments in 2025 that could create additional obstacles for the alt-protein market.

FERMENTATION INNOVATORS WITH PRODUCTS ON SHELVES AND PROVEN SALES CLOSED SOME OF THE BIGGEST FUNDING DEALS IN 2024



Creating crops for a food-resilient future

2024's second biggest Agriculture & Food subsector was crop inputs, which raised \$742M (20% of the industry group's total) across 61 deals.

As the Paris Agreement's 1.5°C target slips out of reach and demand for food and biofuels grows, investors are increasingly looking at crop inputs as critical climate adaptation technologies. This is because they allow farmers to optimize crop production for local conditions, maximizing yields and minimizing the impact of environmental stresses.

Crop inputs can be broadly divided into three categories: crop nutrition products, which help provide nutrients to the plants as they grow; crop protection products, which are applied to plants to combat pests and diseases; and crop improvement technologies, which involve the engineering of the plants themselves to select for traits like increased yields, better disease resistance, or tolerance to extreme weather conditions.

This latter category saw an upsurge in investment activity in recent years, overtaking crop nutrition and protection in 2024.

Notable crop improvement deals in 2024 included the \$103M round closed by **Inari**, a provider of seed gene-editing tools; **Ohalo**, which emerged from stealth with \$100M in Seed funding for its accelerated crop-breeding technologies; and **Pairwise**, provider of gene-editing solutions for crops, which scored \$40M in Growth Equity funding from Corteva Catalyst, Leaps By Bayer, Aliment Capital, and Deerfield.

Tropic (a Global Cleantech 100 company) is using gene-editing techniques to create climate-resilient varieties of three major commodity crops grown in the tropics: bananas, coffee, and rice.

Among the challenges ahead for crop improvement technologies is the uncertain regulatory environment around this emergent field. One promising sign for innovators and investors in the space is the European Parliament's approval of a draft law that provides a dedicated regulatory framework for gene-editing, which would essentially allow use of the technology for many of its most promising applications in the crop science realm.

Fig.2: Crop Inputs Categories Venture Funding 2019-2024

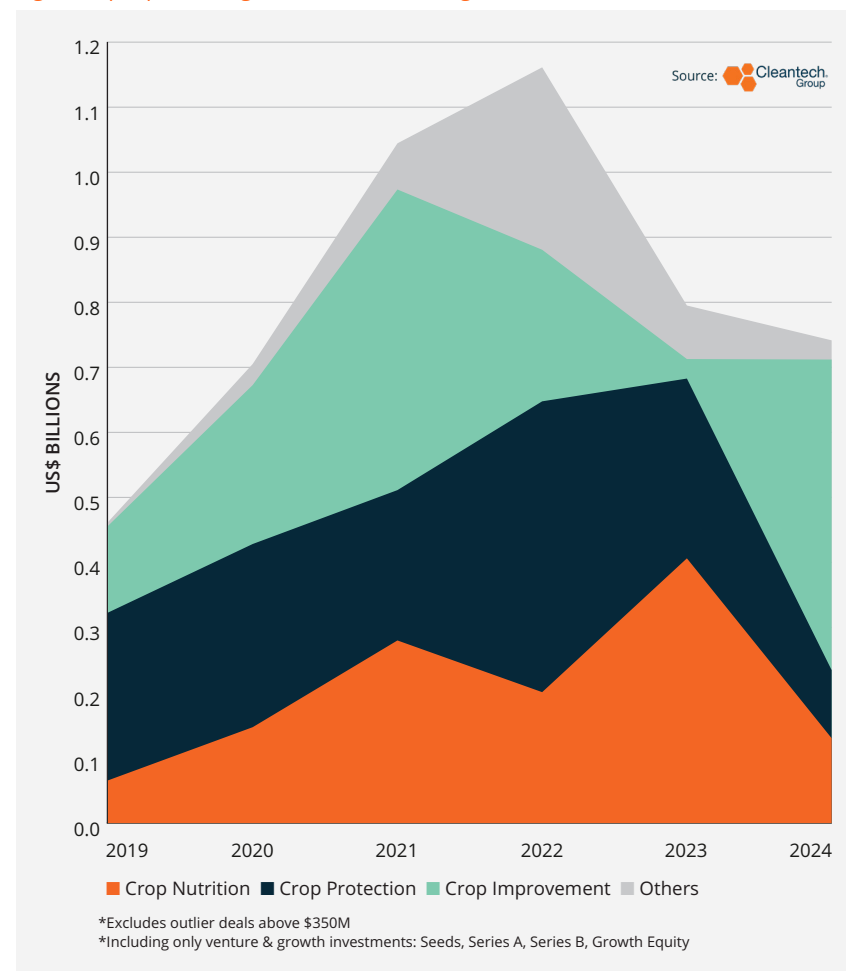
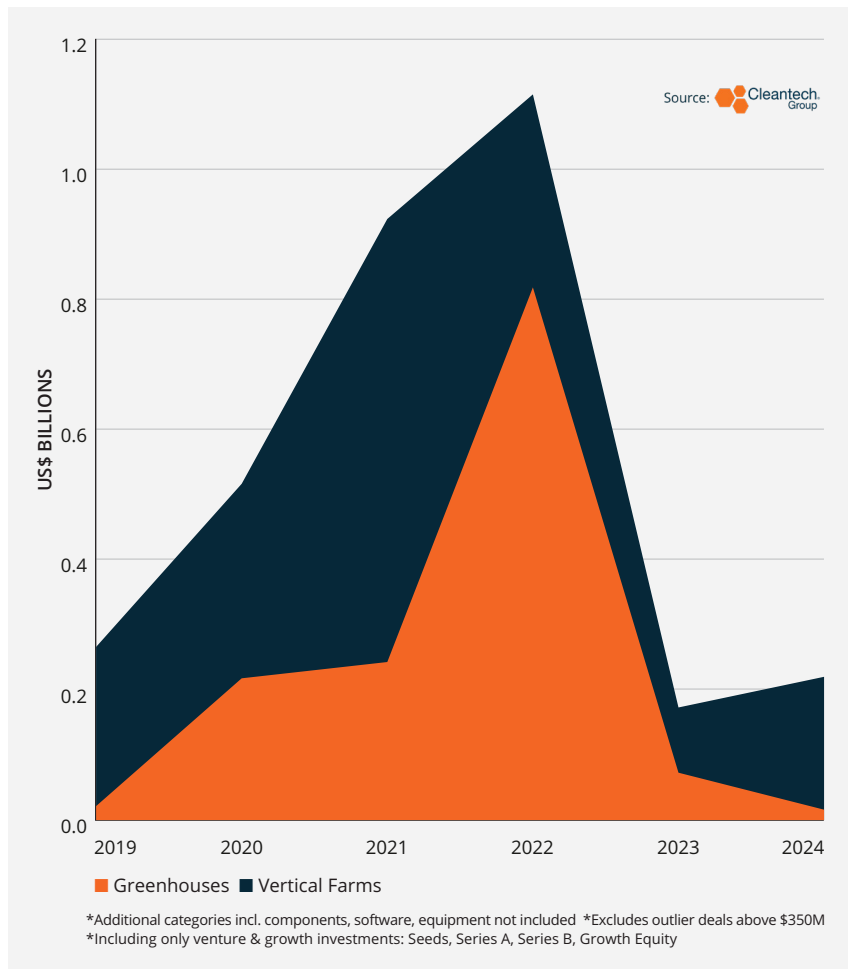




Fig.3: Tech-Enabled Greenhouses & Vertical Farms, Venture Funding 2019-2024



Indoor farming reprise

It would be a mischaracterization to say that indoor farming is back. But 2024 saw a notable bump in funding to a subsector which only a year ago was seen as being at its lowest ebb.

Indoor farming – including high-tech greenhouses, vertical farms, and other controlled-environment formats – raised spectacular amounts of venture capital between 2020 and 2022. Investors were excited at the prospect of technologies which promised the capability to produce food hyperlocally with a fraction of the water, a smidgen of the space, and none of the chemicals required for conventional, open-air agriculture.

More recently, a spate of company shutdowns and shelved SPAC mergers showed that, even with plenty of money in the bank, many indoor farming players simply couldn't make the unit economics work.

The biggest problem was energy costs, particularly for vertical farms designed to be reliant on artificial light.

EVEN WITH PLENTY OF MONEY IN THE BANK, MANY INDOOR FARMING PLAYERS SIMPLY COULDN'T MAKE THE UNIT ECONOMICS WORK

The slight resurgence in indoor farming funding in 2024 was driven by innovators able to address and overcome some of these stumbling blocks.

In a drive to widen margins, U.S.-based **Oishii** has developed a vertical farm with a high level of automation, adjacent solar power supply, and recycled wastewater that grows premium strawberry and tomato varieties which can sell at especially high price points. It raised \$134M Series B funding from Bloom8, McWin Partners, Mizuho Bank, Yaskawa Electric, and others.

Another significant indoor farming deal in 2024 saw **Intelligent Growth Solutions (IGS)** net \$28.6M Series C funding from COFRA, DC Thomson, S2G Ventures, and others. IGS does not operate commercial indoor farms itself but sells its modular vertical farming units to growers. Its Series C raise followed the announcement at COP28 in Dubai that it would be providing its technology for the UAE's 900,000 square-foot GigaFarm project, which is slated to produce 3 million kilograms of produce each year – equivalent to 1% of the UAE's fresh produce imports.



Looking ahead: automation & robotics

The third most funded Agriculture & Food subsector in 2024 was precision agriculture, which raised \$664M across 93 deals (18% of the industry group total).

Three 2024 Global Cleantech 100 companies are relevant to precision agriculture: farm insights and analytics platform eAgronom, drone provider **Meteomatics** (Resources & Environmental Management), and developer of electrified and automated tractors, **Monarch** (Transportation & Logistics).

Precision agriculture is a wide-ranging category that includes software, sensors, and equipment that drive on-farm efficiency. That diversity is reflected in some of the headline deals in 2024, including AI-powered crop spraying provider **Greeneye Technology's** \$20M Growth Equity round; **TerraClear's** \$15M raise for its robotic rock-picking implement; and the \$27M Series B closed by **SunCulture**, a Kenya-based innovator developing solar-powered drip irrigation systems.

Looking ahead into 2025 and beyond, there is one area within precision agriculture which is set to become increasingly important: farm automation.

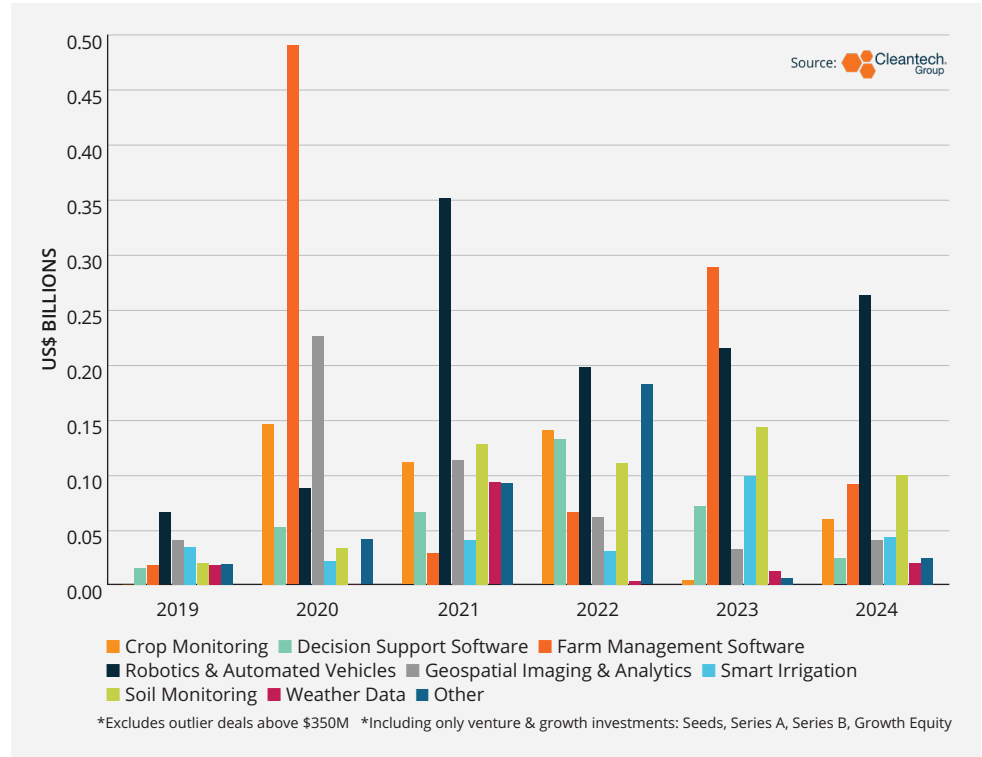
In all but the world's poorest countries, agricultural labor availability has been on a downward trend for several years. That trend only looks set to continue, or even to accelerate, as people seek safer, higher-value jobs and protectionist policy locks out the immigrant labor which has typically been the solution.

Some of the key deals involving ag robotics and automation solutions in 2024 provide a sneak preview of what we are likely to see in the year ahead, as investors bet on the convergence between labor shortages, aging farmer populations, and rising demand for food and fuel.

Carbon Robotics, developer of a laser-powered, AI-driven weeding device, scored \$70M in Series D funding from investors including nVidia's VC unit NVentures. **Agtonomy** raised \$32.8M Series A capital from Toyota Ventures, the Bobcat Company, and Allisson Transmission to grow its self-driving platform for tractors. In a further sign of the segment's maturity, tractor manufacturer Kubota acquired crop monitoring start-up **Bloomfield Robotics**, following similar acquisitions made by its competitors John Deere and CNH Industrial in recent years.

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Fig.4: Precision Agriculture Venture Funding 2019-2024



2025

WHAT TO WATCH



Automation in agriculture is attracting corporate players and investors from sectors as disparate as automotive, industrial equipment, and semiconductors. There will be more of the same in 2025 as agricultural automation moves forward in alignment with advances in AI and robotics.



INDUSTRY GROUP ANALYSIS

ENERGY & POWER



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Macro uncertainty weighs on venture investments, but growing energy demands from data centers have created opportunities for early stage technologies including nuclear solutions which saw significant growth this year

Energy & Power investments have declined markedly compared to 2023, as high interest rates and geopolitical uncertainty have continued to add ambiguity to the global venture investment landscape.

The mood of the cleantech community was further dampened by the U.S. elections and the newly elected President, Donald Trump, a vocal proponent of fossil fuels. The election of President Trump has cast doubt over the future of the U.S. IRA, the wind and solar tax credit, as well as the 45V tax credit that has underpinned hydrogen facilities in the U.S.

While there is a great degree of uncertainty when it comes to the IRA, it is likely that the facilities that are already committed will proceed, even when the legislation itself will be scaled back and early-stage grant support from the government agencies falls away. Late-stage companies in energy storage and hydrogen were able to secure significant rounds this year, such as **Highview Power** \$323M Growth Equity round. However, both segments still carry significant risk, of which the default of **Northvolt** was a stark reminder.

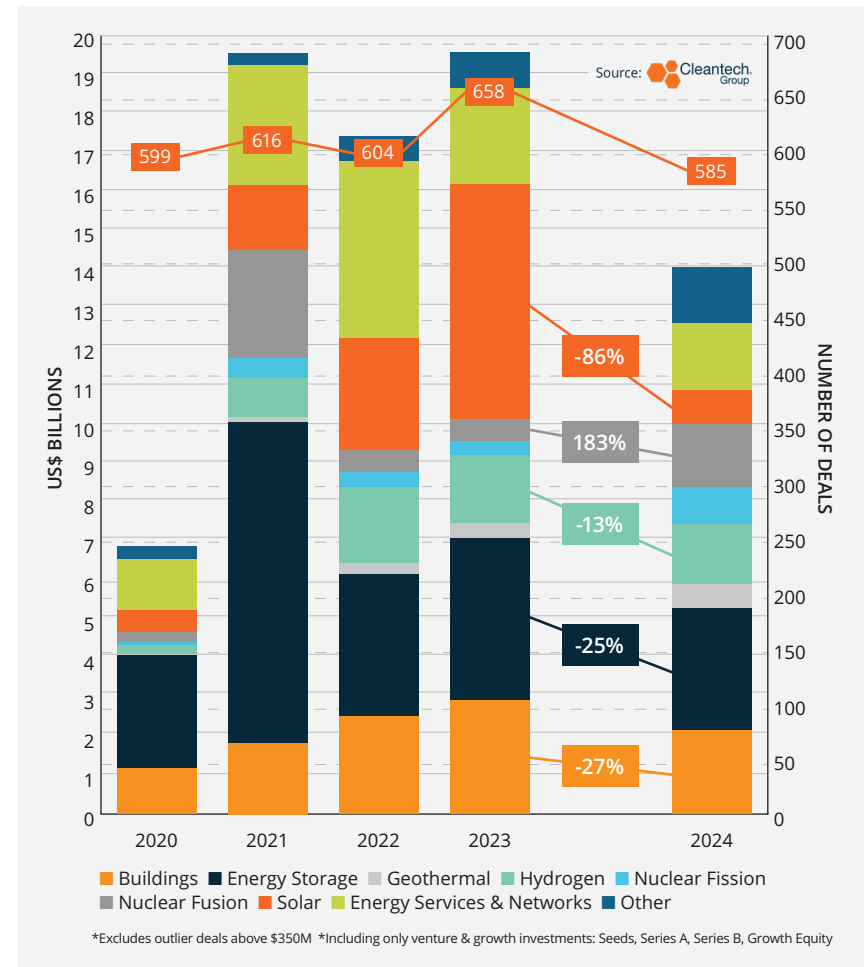
Meanwhile, data centers and associated power solutions, such as small nuclear reactors, geothermal and nuclear fission have emerged as a bright spot.

Early-stage cleantech innovation is likely to pivot away from the U.S. to Europe and APAC, where early-stage funding is bolstered by national and regional grants. The European Central Bank (ECB) has already cut interest rates three times since June 2024 and has signalled further cuts potentially leading to an improved lending environment.

It has been a slow year for exits, with IPOs and SPACs at the lowest level since 2019 and the lowest number of M&As since 2006. On a positive note, forecast interest rate cuts could kickstart the exits market and help appreciate cleantech stocks.

ENERGY AND POWER INVESTMENTS HAVE DECLINED MARKEDLY COMPARED TO 2023

Fig.1: Energy & Power Venture Investments (2020-2024)





Data center power needs provide a demand pull

Data centers currently consume 1–2% of the world's electricity and have the potential to consume up to 3-4% by 2030, according to the International Energy Agency (IEA). Artificial intelligence (AI) demands will play an increasing role driving this sector. As the IT infrastructure evolves to keep pace with the advancements in high-performance computing, energy and data center cooling infrastructure will have to keep up lock step in this rapidly developing industry.

To integrate renewable energy into the equation, data center operators and developers will have to work alongside utilities and renewable developers to source clean energy. Additionally, data center operators will implement new business models and strategies to optimize renewable systems. This can involve utilizing batchable compute and the development of modular data centers and units that can operate in areas with high renewables production. **Cloverleaf Infrastructure** raised \$300M this year and **Crusoe Energy** raised at least \$500M to sustainably scale data center systems and optimize integration of renewables and low carbon sources of energy.

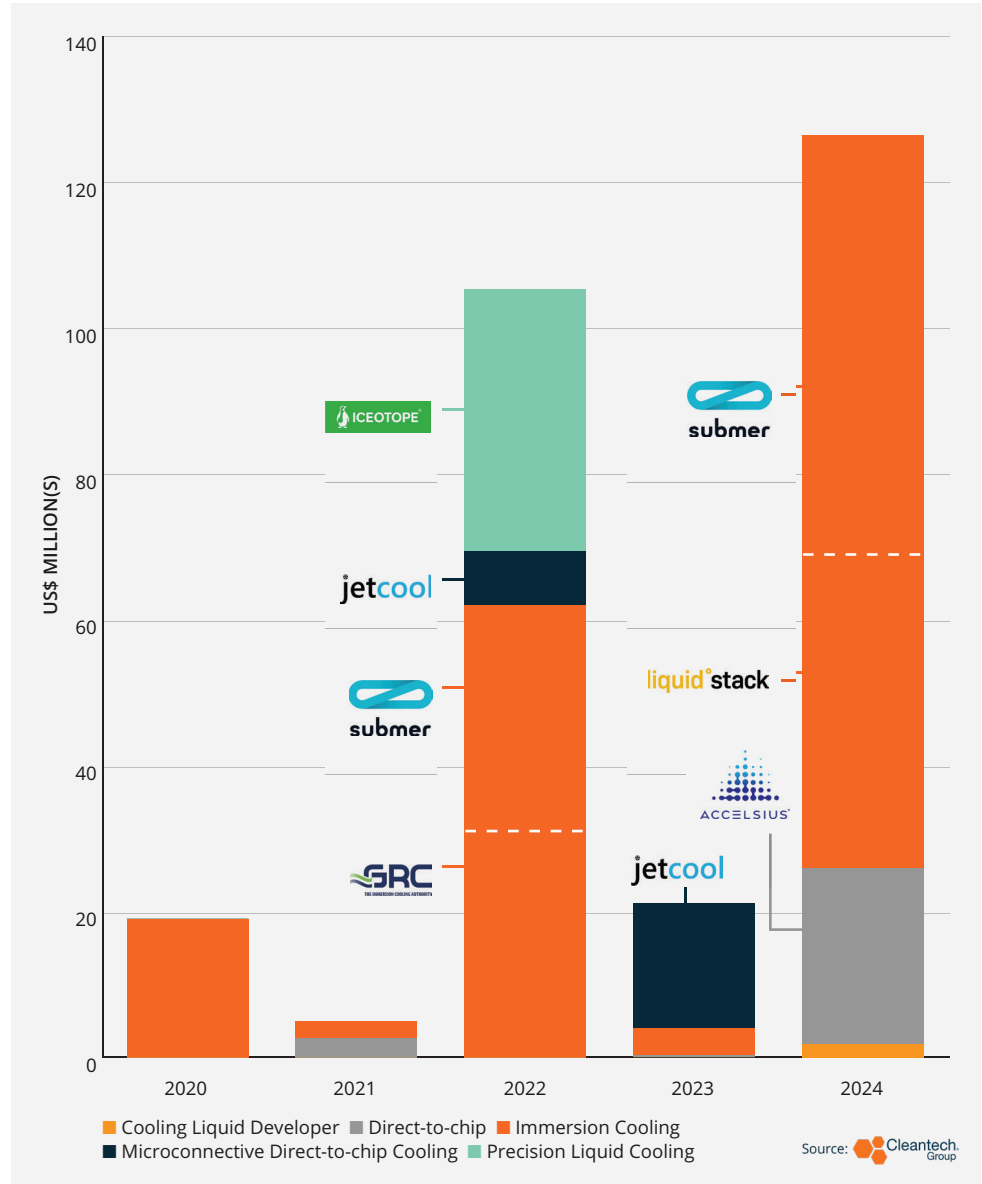
LIQUID COOLING TECHNOLOGIES WILL BE REQUIRED TO MEET THE NEEDS OF AI HARDWARE AND SAVE ENERGY AND WATER

Hardware improvements increasing the density of server stacks to integrate high performance compute and advanced graphics processing units (GPUs) require new cooling technologies. **Crusoe Energy** will construct a purpose-built AI data center using direct-to-chip cooling in one of their sites located in Texas. Liquid cooling technologies will be required to meet the needs of AI and high-performance compute and save energy and water. However, even as data centers become more efficient, the industry will still require Energy & Power infrastructure to grow to reach 1GW data center campuses.

Recent deals include Flex's acquisition of **JetCool**, **Accelsius'** raise of \$24M, **Submer's** raise of \$55M, and multiple other partnerships.

Data center power demands will also drive growth for other sectors including small modular nuclear reactors (SMRs), energy storage and will further drive the need for grid modernization technologies. Transformative partnerships with various technology providers like Google, Microsoft, and Amazon engaging with and developing nuclear and advanced modular technologies will bolster the confidence in this sector.

Fig.2: Venture Investments Into Liquid Cooling Technologies (2020 - 2024)





Data center demand supports nuclear growth

Advancements in fission and fusion technologies have seen significant growth this year. Notable deals include Microsoft supporting the revitalization of a unit located by the Three Mile Island Facility in Pennsylvania in the U.S., with **Constellation Energy**, **X-Energy** receiving \$500M in new investments led by Amazon, and Google announcing their partnership with **Kairos**

Power to support SMR development in the U.S., as well. The new president has once voiced his support for nuclear power while strong demand from data centers could further add positive impetus.

France has also committed to increase their funding in this space. However, permitting and nuclear licensing remains a big hurdle in many countries in developing new nuclear capacity.

Fusion, although in earlier stages of development when compared to SMR systems, still saw significant growth this year. Multiple companies achieved R&D milestones. Funding also increased substantially bordering on 2021 levels of investment with significant growth in China. **Pacific Fusion** raised \$900M, **Xcimer Energy** raised \$100M, **Marvel Fusion** raised \$70M, and **Type One Energy** raised \$83M. Funding into these companies

went into a variety of different reactor technologies. Although tokamaks are the more mature type of reactor system and one favored by countries like China, where most efforts are concentrated around developing tokamaks, the U.S. has seen significant growth in a variety of alternative confinement strategies. These strategies include Z pinch systems, stellarators, and inertial confinement systems.

Fig.3: Venture Investments into Advanced and Small Modular Reactors

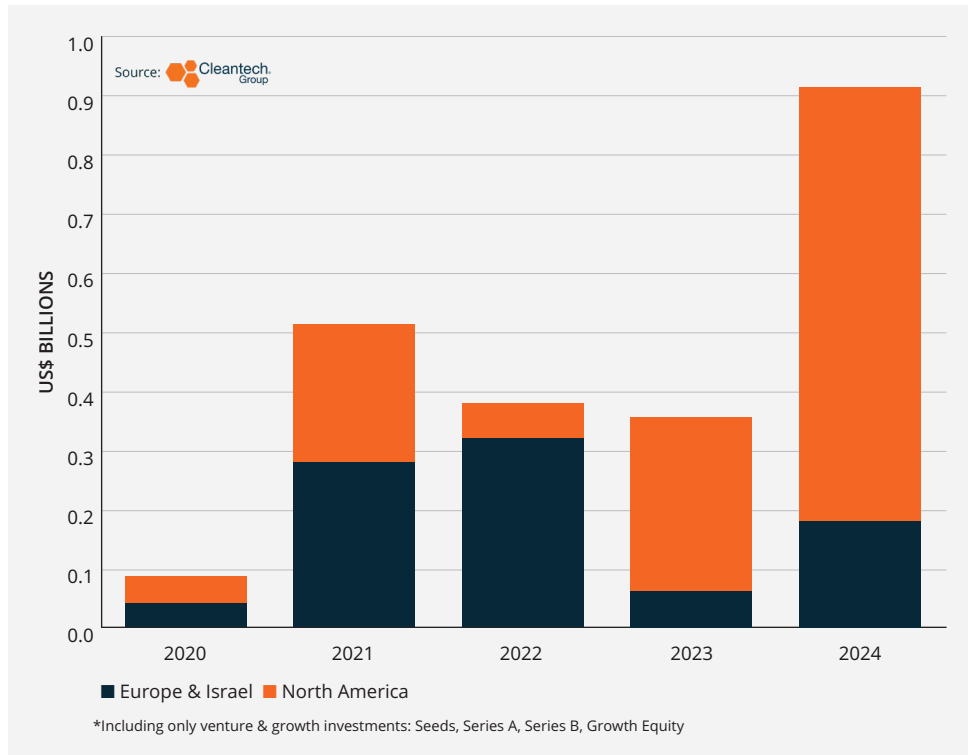
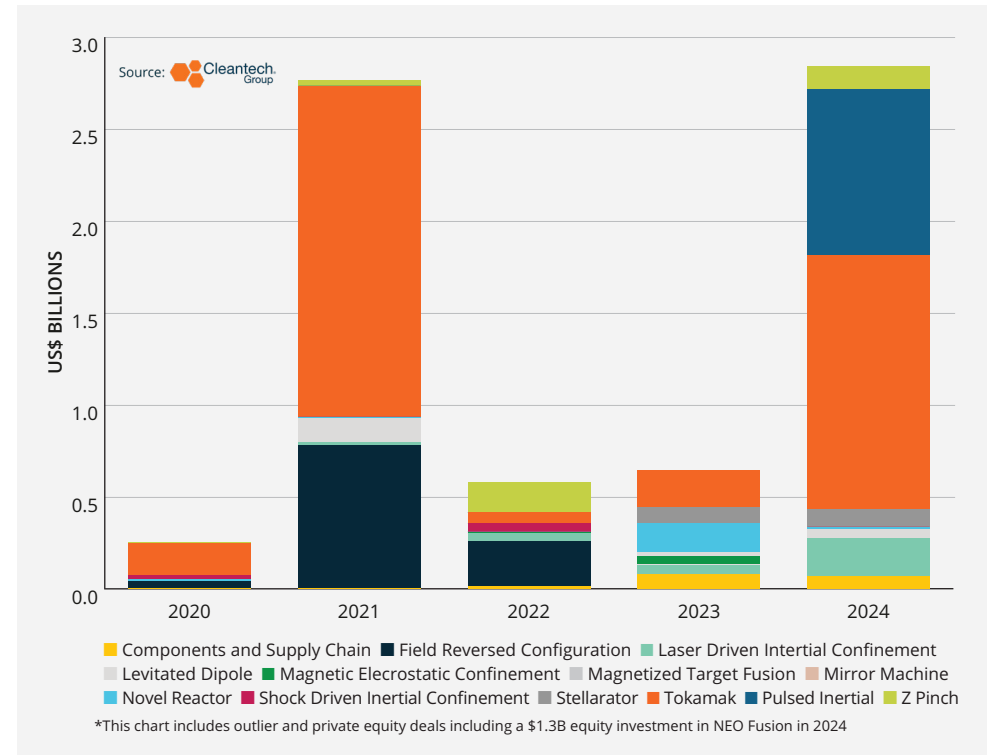


Fig.4: Investments into Fusion Companies by Reactor Type (2020-2024)





Hydrogen focus shifting away from the U.S.

The U.S. hydrogen landscape was already shifting ahead of the election, with projects delayed and cancelled due to the 45V tax credit additionality clause. The clause stipulated that to obtain the 45V tax credit new hydrogen facilities must have an emissions footprint below 4kg/CO₂e and it has to be produced with new renewable power matched on an hourly basis from 2027 onwards.

This additionality clause has made it difficult for new facilities to qualify for the 45V tax credit. The 45V rules were only finalized on 3 January 2025.

European hydrogen scale-ups **John Cockerill** and **Sunfire** both raised significant Growth Equity rounds this year, at \$250M and \$233M, respectively. The electrolyzer OEM's featured in the Global Cleantech 100 list – **Hysata** and **Hystar** – hailed from Australia and Norway, respectively.

The lack of downstream offtake agreements is one of the key problems stifling the industry, as forecast electrolytic hydrogen cost declines have failed to materialize, making green hydrogen uneconomic for many use cases. Securing long-term offtake agreements are crucial for obtaining project financing.

smaller-scale localized hydrogen projects developed for specific localized use cases.

- The focus will shift away from giga projects, which are harder to finance and find offtake agreements for, to

- Companies like **Nitrofix** and **Swan-H** (both on the 2024 Cleantech 50 to Watch) are a testament to the rise of distributed hydrogen use cases. Both companies have developed technologies that enable production of localized ammonia from green hydrogen, cutting out the costly transportation step.

Fig.5: Venture Investments Into Green Hydrogen By Region (2020-2024)

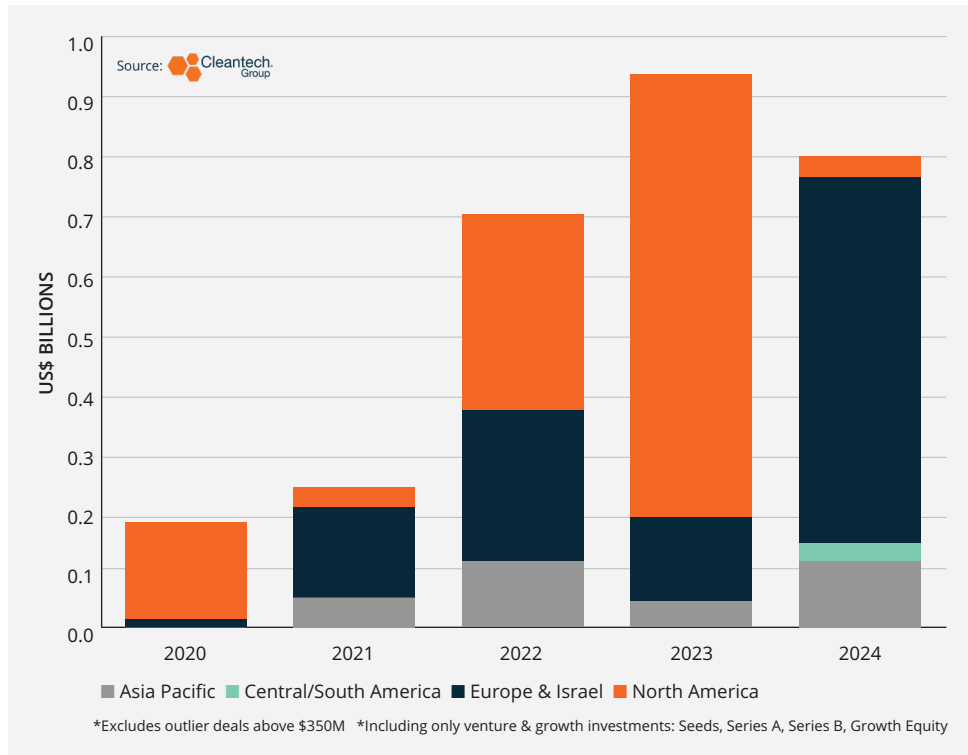


Fig.6: Venture Investments into Hydrogen by Type (2020-2024)

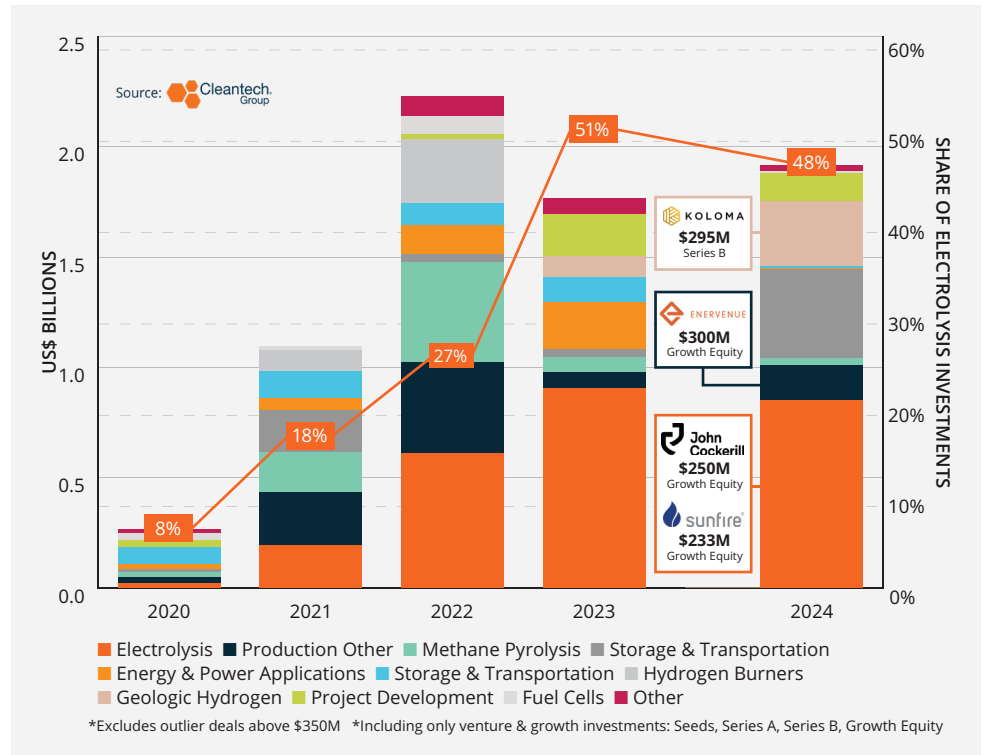




Fig.7: Industrial Electrification Companies Featured in Global Cleantech 100

	HEATING & COOLING	HEATING	HEAT & POWER	ENERGY OPTIMIZATION
INDUSTRIAL HEAT PUMPS	 	 		
THERMAL ENERGY STORAGE (ETS)			 	
OTHER				

■ Technologies that utilize waste heat

Source: Cleantech Group

Industrial electrification

Industrial emissions account for an estimated 24-30% of all global CO₂ emissions. While hydrogen was touted to be one of the key solutions just a few years ago, it has become increasingly clear that a lot of industrial heat and power will be electrified, especially in low-temperature spaces.

Focus on utilizing waste heat allows achieving efficiencies that are over 100%. Low-temperature heat pumps, such as the technology provided by QPinch or Skyven Technologies (both Global Cleantech 100 companies) offer temperatures of over 200°C with efficiencies that exceed 200%. Meanwhile, Kraftblock's (a Global Cleantech 100 company) thermal energy storage technology utilizes waste heat, which can then be stored in waste materials made of slag and furnace waste, that can be rereleased as heat or power.

IT HAS BECOME INCREASINGLY CLEAR THAT A LOT OF INDUSTRIAL HEAT AND POWER WILL BE ELECTRIFIED

This allows facility owners to reduce the energy required to produce heat and cut down on the amount of power required from the grid. In geographies that have high power prices, such as Europe, this could yield significant cost savings.

Key drivers for industrial electrification are the internal net-zero targets many companies have set, but also policy. The European Emissions Trading System (EU ETS) will for the first time include smaller natural gas-fired combined heat and power (CHP) plants as of 2027, adding CO₂ costs to many small manufacturing facilities and encouraging electrification.

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2025

WHAT TO WATCH



Energy Vault commissioned a 25 MW/100 MWh storage facility in Rudong, China in 2024 and Form Energy commissioned its first plant to manufacture iron-air long-duration batteries in Weirton, West Virginia. There has been some movement on the policy side, too, with the United Kingdom announcing a new cap-and-floor support mechanism for long-duration energy storage (LDES) from 2025. LDES is a missing piece of the puzzle in the renewables+batteries+grid flexibility solution that will help decarbonize electricity grids and it is inching closer to reality.

The geothermal segment achieved some key milestones this year, such as Fervo Energy achieving 70% reduction in drilling speeds and the national laboratory UTAH Forge proving the concept of an enhanced geothermal systems (EGS) reservoir in hot dry granite in well stimulation. Meanwhile, Eavor Technologies is progressing in Europe with their closed-loop deep geothermal projects. The reduction in drilling speed, in particular, is likely to encourage the growth of geothermal energy.



INDUSTRY GROUP ANALYSIS

MATERIALS & CHEMICALS



WRITTEN BY
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MATERIALS & CHEMICALS

Investment closely mirrored 2023 activity at over \$5B in venture activity

The overall trend in the Materials & Chemicals industry group reflects positive upward growth, despite some sectors experiencing reduced funding this year, including advanced energy materials and specialty chemicals. Sectors that have experienced the most growth are advanced manufacturing, fuels and CCUS — matching large infrastructure grants and loans by the U.S. and European governments.

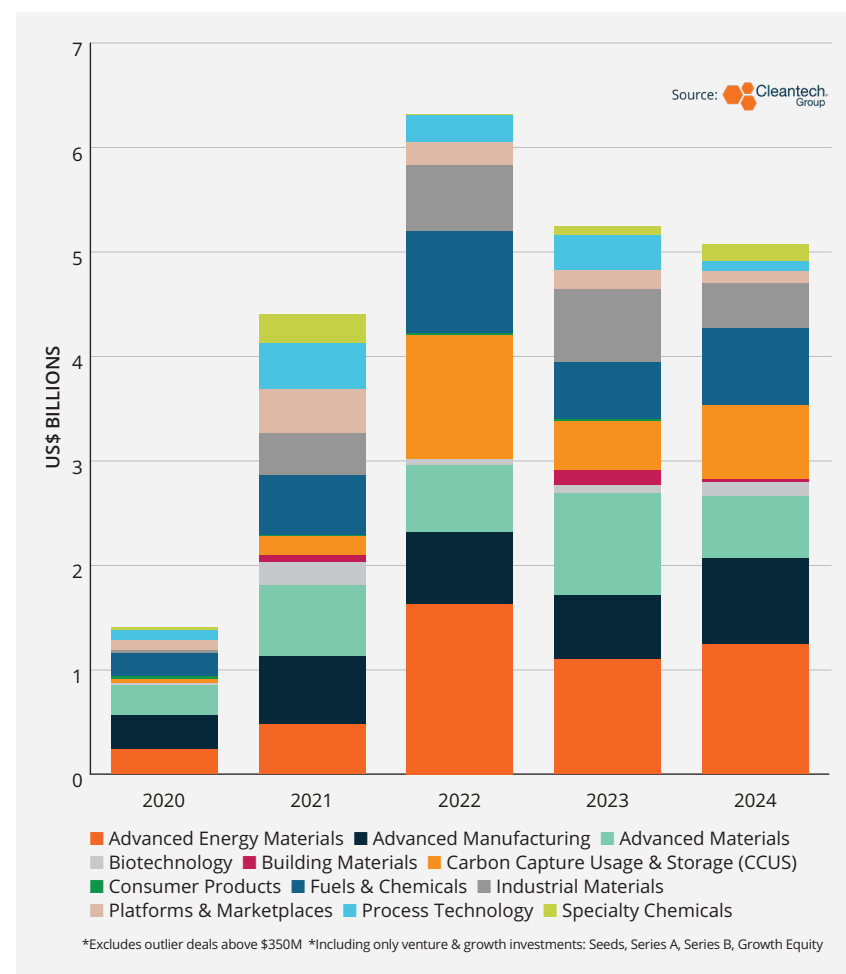
Still, materials innovators are expanding across many sectors with some themes including eFuels sustaining interest from 2023. This year, there are six eFuels innovators on the Global Cleantech 100 including **Aether Fuels**, **Ineratec**, and **Infinium**. Activity is increasing outside of the leading producer countries in North America and Europe. **HIF Global** is developing eFuels projects in Australia and South America. **C2X** is also building a \$3B eMethanol facility in Egypt, targeting maritime customers.

DECARBONIZING HARD-TO-ABATE INDUSTRIES HAS EMERGED AS ONE OF THE MOST LUCRATIVE AREAS OF OPPORTUNITY FOR BOTH INNOVATION AND INVESTMENT THIS YEAR

Without carbon capture deployment, carbon utilization for eFuels and other industries might not be possible. Fortunately, 2024 saw significant growth for carbon capture investment, not surprising considering nearly double the global projects in 2023 are in the project pipeline at various stages of development. Leading the way, **Svante** (a Global Cleantech 100 company) secured \$100M to finance a first-of-a-kind project in Canada using its sorbent-based capture solution.

Several innovators on the list are making significant strides in addressing critical, under-the-radar issues. **Copprint** produces sustainable printed electronics using nano copper inks. **Ionomr Innovations** develops ion-exchange membranes for hydrogen, energy storage, metal recovery, and CCUS, as those industries prepare for scale. **Aeroseal** and **LuxWall** are optimizing building insulation, targeting improved energy efficiency.

Fig.1: Advanced Manufacturing, Fuels & Chemicals, and CCUS take the lead this year, Advanced Energy Materials and Specialty Chemicals take a hit





eFuels

Driven by interest in low-carbon alternatives to fossil-based fuels, eFuels have gained traction as ‘drop-in’ solutions, especially for maritime and aviation sectors where alternative solutions face some technical challenges.

Leading the pack in 2024 is **Infinium** (a Global Cleantech 100 company), who raised \$200M to produce sustainable aviation fuel (SAF) that is high on the list for airlines seeking fuel alternatives. Elsewhere, the maritime industry is focused on eMethanol and eAmmonia.

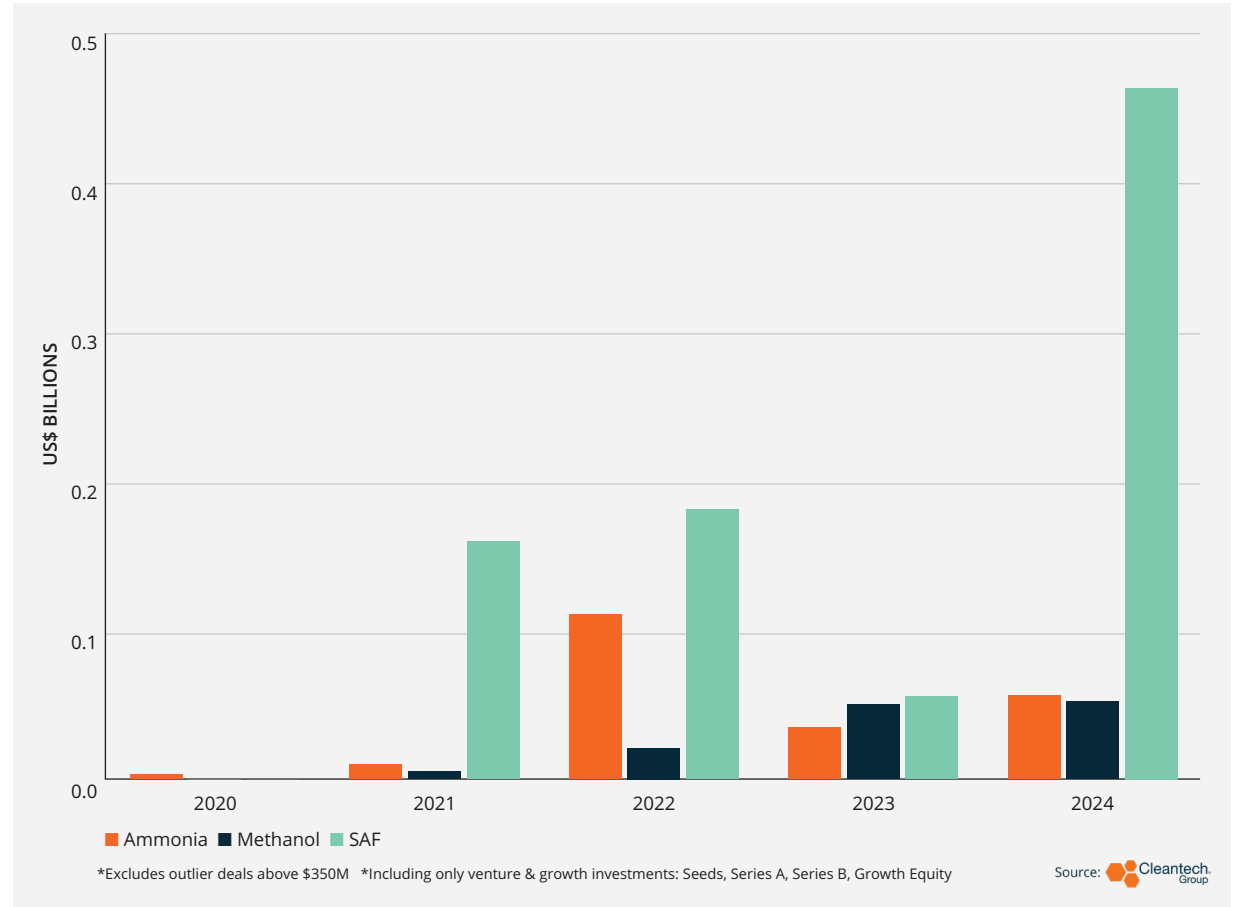
Ineratec (a Global Cleantech 100 company) enables modular production of fuels and chemicals via electrolysis and Fischer-Tropsch catalysis. In January 2024, Ineratec raised a \$129M Series B from Piva Capital, TDK Ventures, Emerald VC, Honda, and eight others to scale production by 2030.

Twelve has developed a CO₂-reducing catalyst for more efficient production of fuels and chemicals. In 2024, Twelve reached unicorn status after raising a total of \$645M through various financing instruments comprised of equity, project finance, and a loan.

Customers, including major airlines and Tier 1 O&G players, are engaged with SAF. However, green premiums are inhibiting widespread adoption with some incentives and standardization waiting to emerge in leading producer countries in North America and Europe.

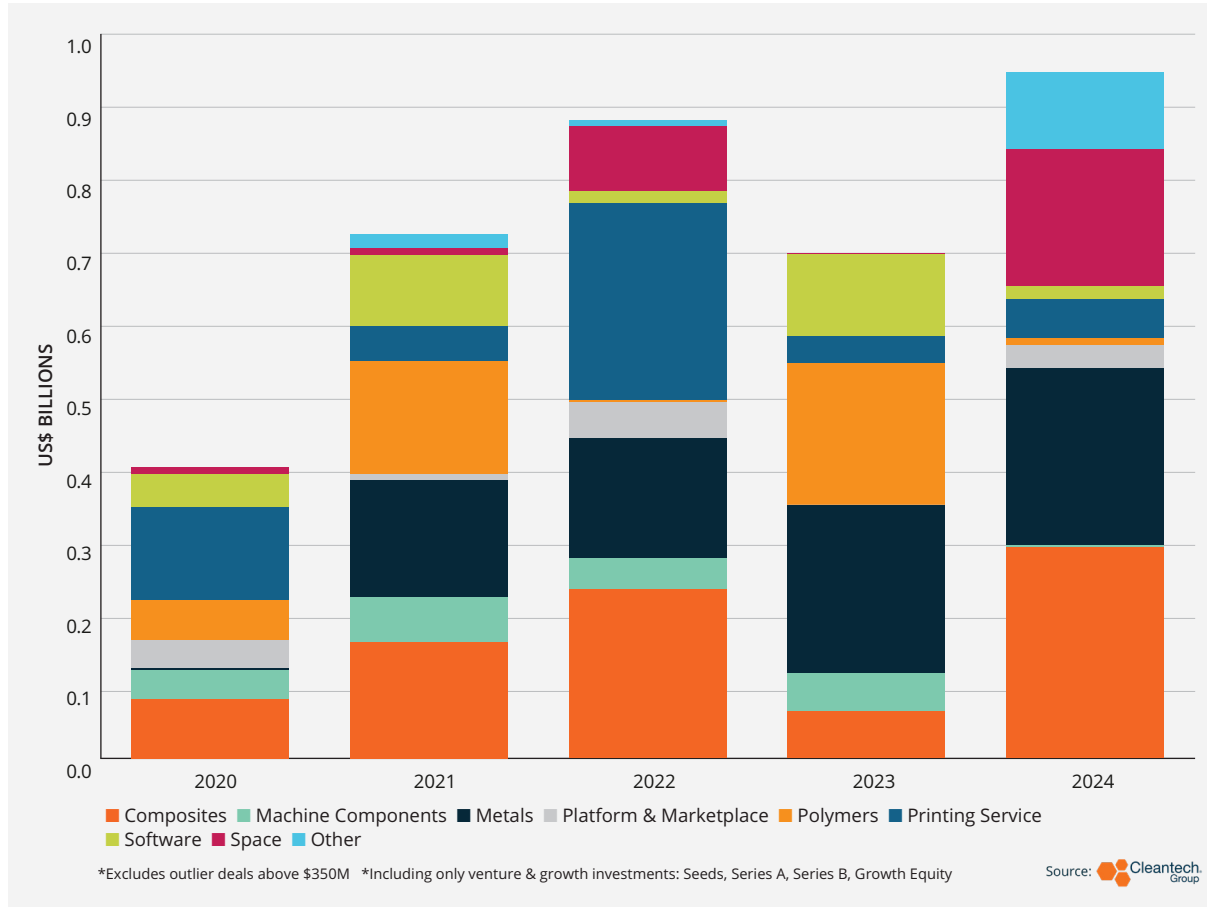
Emerging instruments aim to relieve the strain of high costs. These include incentives for carbon utilization, hydrogen, and fuel production, and well as blending quotas, which can stimulate supply and demand. Continued scale up will be largely dependent on their continued application.

Fig.2: Ammonia Activity Significantly Dropped Off, SAF and Methanol Activity Increased for Airlines and Maritime Use, Respectively



COMMERCIAL SAF COULD BEGIN AS SOON AS 2025 AT INFINIUM'S FACILITY IN WASHINGTON IN THE U.S. WITH E-METHANOL AND E-AMMONIA FOLLOWING AS SOON AS 2027

Fig.3: The Race to Space Saw Some of this Year's Largest Funding Rounds, Composites and Battery Activity Up



ADDITIVE MANUFACTURING ACTIVITY SLOWED DOWN IN 2024 – GROWING INFLATIONARY PRESSURES AND RISING INTEREST RATES HAVE CAUSED INVESTORS TO TAKE CAUTION

Advanced manufacturing

A number of advanced manufacturing start-ups raised large funding rounds this past year. The growth reflects an increasingly supportive policy landscape, including funding in the U.S. The U.S. IRA currently aims to incentivize onshoring and development of supply chains for key sectors.

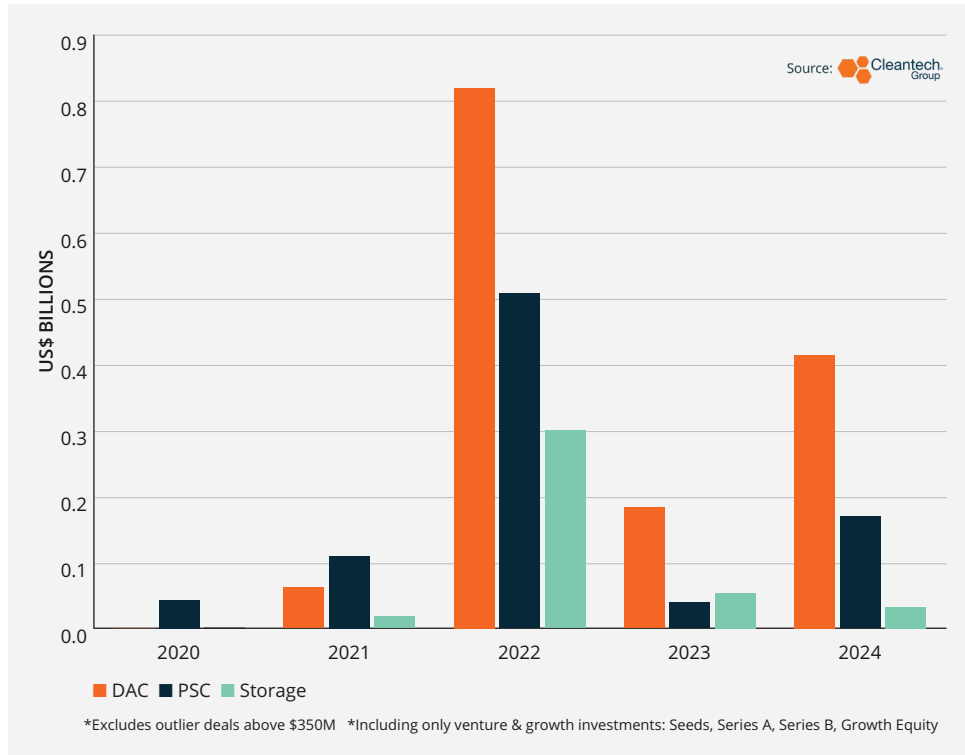
Growth is also supported by attractive technological developments, with advanced manufacturing innovation speeding up manufacturing timelines, reducing costs, increasing energy-efficiency, and reducing environmental impact. Funding poured in for aerospace-related fields, whether for the manufacture of components or to manufacture materials in space.

- **Re:Build** raised funding to manufacture recyclable continuous fiber-reinforced thermoplastic composite tubes and profiles for aerospace, automotives, robotics, and more.
- **Hadrian** builds autonomous, precision component factories for rockets, satellites, jets, and drone manufacturers.
- **Varda** has developed a microgravity formulation platform to manufacture materials in space from its free-flying orbital production satellites with re-entry capability.

Continued interest in this space is expected, as businesses and governments continue to recognize the economic opportunity (and risk) associated with key growth markets in critical technologies including efficient semiconductors and other components across the clean energy landscape.



Fig.4: CCUS Investment is Way Behind; We Absolutely Need More Funding or Risk Doubling or Even Tripling Investment Costs in the Late 2030s



PSC WILL EMERGE AS THE LEADING CAPTURE SOLUTION THROUGH THE MID 2030S, WITH LARGE-SCALE DAC INSTALLATIONS GAINING TRACTION BY THE 2040S

CCUS

The carbon capture value chain has seen significant growth over the last year, particularly for direct air capture (DAC) and point source capture (PSC) technologies. There has also been significant growth in utilization, like for high-value fuels and chemicals, and transport and storage. In 2024, CCUS raised \$615M in VC activity across 28 deals.

DAC has gained significant attention as a pathway to remove and store carbon dioxide from the atmosphere. This technology can also be used for various applications, such as producing sustainable fuels or chemicals. However, DAC faces significant technical and economic challenges, such as high energy consumption, and substantial capital costs and funding has shifted to start-ups which address these challenges.

CarbonCapture raised funds to develop modular DAC units that leverage zeolite-based molecular sieves to capture CO₂. Using zeolites, an abundant mineral, results in significantly reduced costs compared to leading capture technologies.

Meanwhile, storage has continued to present a challenge for industry as carbon leakage comes under focus. Innovators are looking to address this need with both subsurface and surface storage. Fortera, a 2010 Global Cleantech 100 company, raised \$85M Growth Equity to deploy capture of waste carbon dioxide from limestone processing. It is then mineralized with ordinary portland cement in a blend maximum of 15-20% or can be used as a 100% alternative to cement to achieve up to 70% emissions reduction.

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2025

WHAT TO WATCH



Looking forward, effective capture and storage technologies are likely to remain a key theme with access to usable biogenic carbon for mineral storage and fuels/chemicals will likely be a key factor in deployment of sustainable solutions which can benefit from policy incentives.



INDUSTRY GROUP ANALYSIS

RESOURCES & ENVIRONMENTAL MANAGEMENT



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Adaptation, resilience, and ROI: Building tomorrow's climate solutions today

Water innovation – potable, digital, and purification

In 2024, the landscape for water technology for Resources & Environmental Management looked decidedly different from years past as the Cleantech Group taxonomy has since been split and the new focus of Resources and Environmental Management is exclusively on potable water, digital water technologies, and purification solutions. Wastewater treatment technologies are now included in the Waste & Recycling industry group of our taxonomy.

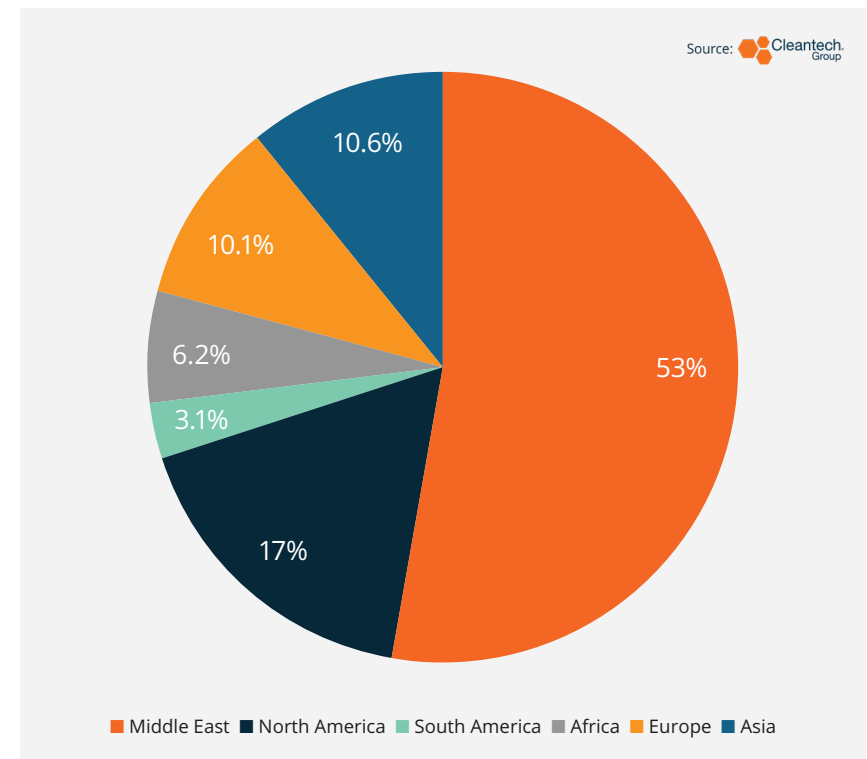
While water demand is projected to rise over 50% by 2050, the absence of wastewater technology, PFAS, and water reuse in the investment numbers presents a more subdued outlook for the sector, reflecting the reality of where demand for innovation is coming from.

DESALINATION ACCOUNTS FOR JUST 1% OF THE GLOBAL POTABLE WATER SUPPLY

Desalination, particularly through renewable energy-powered technologies, is gaining traction. Innovations such as offshore wave-powered systems (*Ocean Oasis*) and hydrostatic pressure-driven subsea plants (*Flocean*, a 2024 Cleantech 50 to Watch company) aim to cut costs and mitigate environmental impact, especially for island or coastal regions. However, high capital expenditures and operational expenses, notably for brine disposal and energy, still limit desalination as a go-to solution for potable water. Currently, desalination accounts for just 1% of the global potable water supply, largely due to the high energy footprint—up to 50% of its total production cost.

Despite advancements, investors in these areas remain hesitant. While pilot projects are underway, achieving cost-effective, scalable desalination solutions that address both environmental and regulatory challenges will require sustained, patient capital—a daunting prospect given the risk aversion seen in the sector. The risk aversion in water technology stems primarily from utilities, government bodies, and the highly regulated nature of the industry.

Fig 1. Installed Desalination Capacity By Region





SCALING SOLUTIONS WILL REQUIRE COORDINATED EFFORTS TO BRIDGE THE GAP BETWEEN TECHNOLOGICAL PROMISE AND ECONOMIC PRACTICALITY

Utilities, often public or semi-public entities, prioritize reliability and long-term stability over adopting unproven or potentially disruptive technologies. Regulatory frameworks in the water sector further reinforce conservative approaches, as stringent standards for water quality and environmental compliance leave little room for experimentation. Additionally, the sector is capital-intensive, with high upfront costs for infrastructure, making stakeholders wary of deploying technologies without clear pathways to scalability and economic viability.

This caution extends to private investors as well, who are often hesitant to fund innovations in a sector where return timelines can span decades, unlike other industries with faster payback periods. The result is a “chicken-and-egg” problem where innovations struggle to gain traction without widespread adoption, and adoption is slow due to a lack of demonstrated success.

Similarly, data centers depend on ultra-efficient cooling systems that utilize recycled or purified water to maintain operational sustainability. The cross-application of these technologies represents a targeted, scalable solution to the growing demand for ultrapure water across industries, driven by stringent process requirements and environmental considerations.

The interplay between water technologies and direct lithium extraction (DLE) processes highlights the vital role of advanced water treatment systems in emerging industries. For instance, DLE processes rely on specialized technologies such as ion exchange membranes, advanced filtration, and zero-liquid discharge (ZLD) systems to recover lithium efficiently while minimizing freshwater consumption and waste. These precise methods not only improve sustainability but also create transferable frameworks for other high-demand sectors.

Looking ahead, the path to addressing these challenges lies in fostering stronger partnerships between public utilities, private investors, and innovators, underpinned by policy frameworks that incentivize risk taking and de-risk adoption. Scaling solutions like renewable energy-powered desalination, advanced water purification, and wastewater reuse technologies will require coordinated efforts to bridge the gap between technological promise and economic practicality.

As industries like hydrogen production, data centers, and electrolyzer manufacturing expand, their need for ultrapure water becomes critical. In green hydrogen production, technologies such as reverse osmosis (RO), electrodeionization (EDI), and advanced deionization systems are essential to produce water of the purity required for electrolysis, ensuring system efficiency and longevity.

Moreover, as semiconductors, data centers, and electric vehicle supply chains ramp up, their increasing reliance on ultrapure and sustainably sourced water will drive investment into water treatment technologies. By aligning these emerging industrial demands with the broader goals of resource efficiency and sustainability, the water technology sector has the potential to play a transformative role in addressing global water challenges while creating new opportunities for growth and resilience.

Fig 2. Major Water Deals

Source: Cleantech Group

COMPANY	FUNDING AMOUNT	FUNDING TYPE	INVESTORS	PURPOSE OF FUNDS
 GLOBAL CLEANTECH 100 COMPANY	\$58.4M	Series B Funding	Evok Innovations, Munich Re Ventures, SiteGround Capital, HG Ventures, Blue Horizon, DCVC Data Collective, BHP	International expansion and rapid advancement of its technology platform
	\$45M	Growth Equity Funding	Convent Capital, Peakbridge Partners, Edmond de Rothschild Capital Partners	Scale technology and expand into new markets, with Abu Dhabi as the next target
	\$43M	Growth Equity Funding	Edison Partners, Allos Ventures	Expand the team, technology investments, and go-to-market efforts



Wildfire risk & resilience

At time of writing, the city of Los Angeles is still in the grips of a tragic spate of wildfires, 2024 was a particularly strong year for wildfire resilience tech investment, showing a notable rise in both investment volume and maturity of the companies involved. Total funding volume for 2024 was dominated by larger, later-stage investments like Series B and Growth Equity, reflecting a market maturing past its early innovation phases. High-value investments, such as the \$93M raised by **Iceye**, highlight the investor confidence in companies focusing on advanced satellite-based monitoring and data analysis for wildfire resilience.

While innovation is global, the U.S. leads in both funding and deployment, with significant contributions from government programs like the U.S. Department of Agriculture’s (USDA) \$500M investment in wildfire prevention and the 2021 Bipartisan Infrastructure Law allocating \$1.5B for fire management activities. Other notable hubs include Europe, with Horizon 2020-funded projects like TREEADS, and Australia, which has pioneered initiatives like CubeSats for bushfire prediction. Partnerships between private innovators, such as **Dryad** and Vodafone, further demonstrate international collaboration.

The demand for wildfire technologies has shifted towards structured, long-term agreements with insurance companies, utilities, and government agencies. Insurers increasingly rely on risk mapping and parametric insurance products, while utilities like PG&E focus on solutions for vegetation management and infrastructure protection. Government budgets are gradually shifting from direct firefighting to prevention and resilience, catalyzing demand for early-warning systems, risk analytics, and real-time monitoring technologies.

Technologies aimed directly at firefighting have matured, with innovations such as jet engines mounted on off-road vehicles (**Team Wildfire**) and advanced fire retardants (**Pyrochill**) reducing environmental harm and reliance on water. AI-powered drones and autonomous systems like **Rain**'s wildfire intelligence system are proving critical for targeted suppression. These solutions often complement pre-combustion tools like fuel thinning machinery and early detection systems, forming a cohesive response chain.

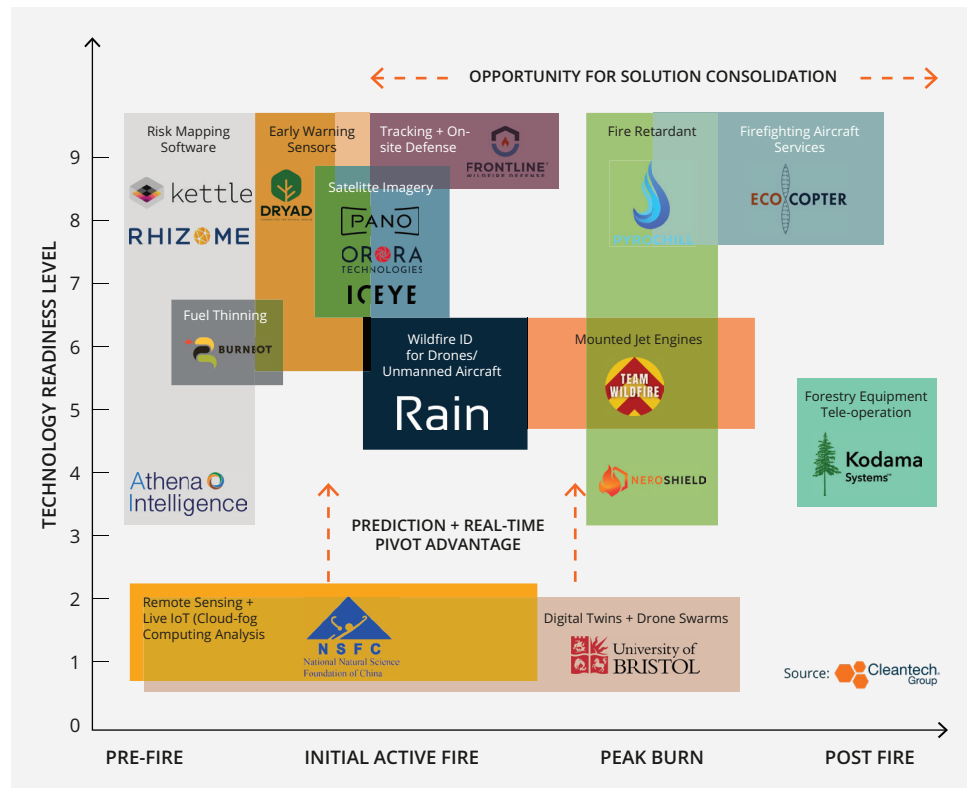
Despite progress, gaps remain in ultra-early detection, real-time fire modeling, and cost-effective suppression. Emerging technologies such as UAV swarms for digital twins, medium-wave infrared detection, and fluorine-free foam replacements are still in pre-commercial

stages. University spinouts and R&D projects, such as University of Bristol’s digital twins program and Australia’s OzFuel mission, are working to fill innovations gaps with AI, IoT networks, and predictive analytics.

The transition from predominantly early-stage funding in 2020-2022 to more substantial Series B and Growth Equity rounds reflects growing confidence in

the technologies designed to combat the escalating risk of wildfires. Investors are increasingly putting their capital behind solutions that integrate satellite data, AI analytics, and remote early detection, recognizing the need that these solutions should be stacked to succeed.

Fig 3. Wildfire Solutions Need to Stack to Succeed





Climate risk & resilience

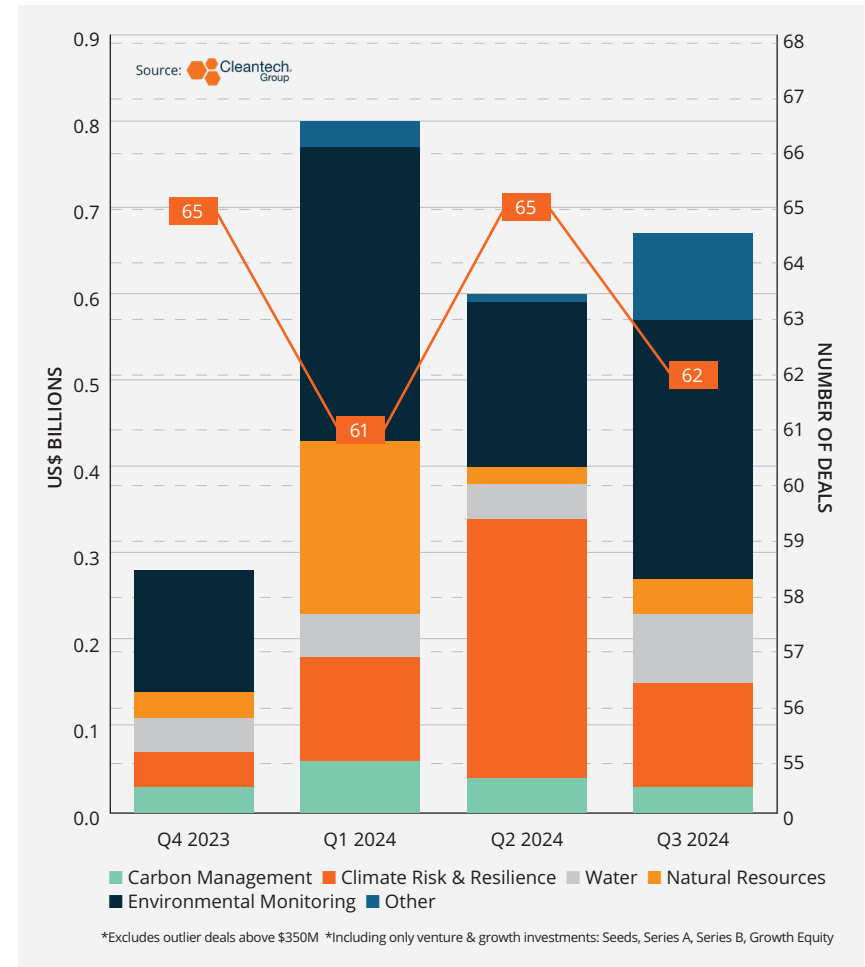
Climate risk & resilience replaced environmental monitoring as the focus area within Resources & Environmental Management during 2024. Funding in this sector doubled from \$117M in Q1 to \$250M in Q2, highlighting the heightened focus on developing proactive and adaptive technologies for managing climate risks. Although investment volumes tapered back to average levels in Q3, the surge in early 2024 underlined a broader trend towards scaling software- and sensor-based solutions for risk analysis, disaster prevention, and resilience-building.

The distinction between understanding and preventing climate risks is increasingly evident in the technologies and investment patterns driving the sector. On one side, companies like **AiDash** and **Blackshark.ai** are advancing the understanding of risks through predictive analytics powered by AI and satellite imagery, enabling utilities and governments to anticipate and mitigate threats such as vegetation-related damage or extreme weather. On the other side, solutions aimed at prevention and adaptation are gaining traction. For instance, wildfire resilience companies like **Burnbot** (Global Cleantech 100 company) and **Frontline Wildfire Defense** focus on proactive measures, such as fuel thinning and automated fire defense systems, to reduce fire intensity and protect assets before disasters strike.

The \$60M raised by **Arbol** for its risk assessment software exemplifies how the financial and insurance sectors are integrating advanced analytics to manage climate uncertainties. This funding reflects an emerging willingness from insurers and corporates to invest in technologies that can quantify and transfer climate risk more effectively. Similarly, Google's \$18M investment in **Climate X** signals corporate interest in leveraging cutting-edge risk management tools, while the Government of Canada's \$420M grant for resilient infrastructure demonstrates the pivotal role of public funding in addressing large-scale climate challenges. These developments indicate that both private and public sectors are increasingly sharing the burden of financing climate resilience, with corporates focusing on high-tech, scalable solutions and governments prioritizing infrastructure and community-level adaptations.

The surge in investments during 2024, particularly from strong funding rounds by **Arbol** and **AiDash**, not only boosted annual figures but also reflects a shift in who is willing to pay for climate resilience solutions. Insurers, corporates, and governments are all recognizing the escalating costs of climate impacts and the necessity of mitigating them proactively. These investments reveal that stakeholders are prioritizing solutions that balance cost-efficiency with scalability, focusing on both immediate impact and long-term adaptability. This balance of understanding and prevention technologies underlines the sector's maturation, moving beyond reactive measures to holistic, integrated approaches to climate risk and resilience.

Fig 4. Climate Risk & Resilience Surpasses Environmental Monitoring in Q2





Environmental monitoring

There has been sustained VC interest in environmental monitoring technologies, particularly in the expansion and integration of advanced data solutions for understanding and mitigating environmental impacts.

Satellite-based monitoring remained a dominant investment focus in 2024, highlighted by major funding rounds for innovators such as **Iceye** and **OroraTech**. Iceye raised approximately \$93M in Growth Equity to advance its high-resolution, radar-based imaging technology, which is critical for applications including deforestation monitoring, pollution tracking, and identifying natural disaster hotspots. OroraTech similarly secured significant funding to expand its nano-satellite network, aimed at providing high-frequency, real-time data for wildfire detection and broader environmental monitoring. Both companies underscore the growing reliance on satellite solutions, driven by declining costs and increasing precision, making these technologies more accessible and impactful for stakeholders across sectors.

AI-POWERED PLATFORMS ARE AT THE HEART OF THE EVOLUTION OF ENVIRONMENTAL MONITORING

While satellite innovators like Iceye and OroraTech focus heavily on applications such as forestry, wildfire monitoring, and disaster response, their technologies are expanding into other markets. Industries such as agriculture, insurance, and marine conservation increasingly rely on satellite data to enhance operational efficiency and risk management. Buyers of these datasets include insurance companies seeking more accurate underwriting, utilities managing vegetation-related risks, and governments focused on urban air quality and marine ecosystem health.

2024 saw a significant diversification in environmental monitoring applications, moving beyond traditional use cases like wildfire and forestry. For example, **LiveEO** expanded its geospatial analytics platform to provide AI-powered, granular, real-time insights for industries ranging from agriculture to utilities. These insights help stakeholders manage vegetation health, optimize resource use, and mitigate risks such as infrastructure damage from environmental factors.

AI-powered platforms are at the heart of this evolution, converting massive amounts of environmental data into actionable insights. AI enhances models by improving the accuracy, speed, and predictive capabilities of environmental monitoring systems.

For instance, machine learning algorithms can analyze satellite imagery to predict deforestation patterns, identify pollution hotspots, and model the impact of environmental changes on ecosystems. This ability to process and contextualize data is crucial for industries like supply chain resilience and insurance underwriting, where real-time environmental intelligence is becoming integral to decision-making.

Fig 5. Major Environmental Monitoring Deals

Source: Cleantech Group

COMPANY	FUNDING AMOUNT	FUNDING TYPE	INVESTORS	PURPOSE OF FUNDS
osapiens	\$120M	Series B Funding	Goldman Sachs	Accelerate product innovation and fuel growth across existing and new markets
Watershed	\$100M	Growth Equity Funding	Greenoaks Capital, Kleiner Perkins, Sequoia Capital, Elad Gil, Emerson Collective, Galvanize Climate Solutions, Neo	Expand operations and business reach
ICEYE	\$93M	Growth Equity Funding	Solidium Oy, Move Capital, Blackwells Capital, Christo Georgiev	Facilitate the next phase of growth by expanding missions' business, developing SAR data products, and solutions for flood/wildfire risk analysis

The environmental monitoring market, which first saw significant investor interest in 2019, is now poised for further consolidation and potential exits. Corporate giants such as Google and S&P Global have increased their involvement through partnerships with monitoring companies, signaling that incumbents see value in integrating these capabilities into their broader business strategies. The question remains whether these partnerships will eventually lead to acquisitions, as incumbents look to gain a competitive edge by internalizing advanced monitoring technologies. As the market matures, further exits through mergers or acquisitions appear likely, particularly as investors and innovators align around scalable solutions with cross-industry applications.

This advancing and diversifying market underscores the growing importance of precision data capture, AI-enhanced analytics, and multi-industry adaptability in understanding complex environmental challenges.

Offsets

In 2024, the carbon offsets and removal sector showed robust growth, driven by advancements in monitoring, reporting, and verification (MRV) technologies, innovative project development, and the emergence of new market mechanisms. These dynamics signal a sector transitioning from niche applications toward scalable, high-impact solutions integrated with global climate strategies. However, many market kinks need to be smoothed before demand owners can invest enthusiastically including overarching regulations, faster development of MRV methodologies, and tools to mitigate risks.

MRV technologies have been pivotal in enhancing the credibility and scalability of offset markets. Key innovations include high-resolution satellite monitoring, AI-powered carbon stock assessments, and blockchain-based carbon credit tracking. Companies like **FLINTpro** are leading the charge in streamlining MRV processes, making them more reliable and cost-effective, which is critical for large-scale projects. Improved MRV methodologies, such as those used in biochar and reforestation projects, have been essential for ensuring the quality and traceability of carbon credits, addressing long-standing transparency issues. This alignment of technology with market needs has unlocked new removal vectors, such as marine-based carbon dioxide removal and enhanced weathering projects.

Fig 6. MRV Hardware & Software

Source: Cleantech Group

INNOVATION		
M Monitoring emissions reduced or avoided		Observation Sensing (Advanced sensing, e.g., LiDAR, remote sensors, e.g. satellite)
		Software (AI modelling, projections & analysis of sensing data)
		Methodology Development (for new project types, e.g. enhanced weathering)
R Reporting of actions		Reporting Software
V Verification of actions and compliance		Sensing for Third-party Verification (e.g. satellite)
		Software (Aggregating assets to assess risks of poor performance, e.g. double-counting and leakage)

KEY INNOVATIONS IN MRV INCLUDE HIGH-RESOLUTION SATELLITE MONITORING, AI-POWERED CARBON STOCK ASSESSMENTS, AND BLOCKCHAIN-BASED CARBON CREDIT TRACKING



The market saw significant investment in pioneering carbon removal projects. For example, 44.01 (a Global Cleantech 100 company) raised \$37M in funding to scale its CO₂ mineralization with seawater or treated wastewater, while Standard Chartered, British Airways, and others supported UNDO's deployment of innovative soil-based carbon removal. These projects reflect the increasing demand for nature-based as well as permanent, tech-based solutions capable of delivering measurable and verifiable results. Investments like these also underline the importance of partnerships between traditional registries like Verra and tech providers to enhance MRV standards and project credibility.

The buyer landscape in 2024 has remained static with tech corporates such as Microsoft and Amazon continuing to secure long-term offtake agreements to hedge against price volatility and ensure access to high-quality credits. On the policy front, frameworks such as the Paris Agreement, CBAM, and national carbon pricing mechanisms are creating a fertile environment for compliance-grade offsets. However, the market remains fragmented due to inconsistent global standards and limited transparency, which present barriers to scaling high-quality projects.

Despite the progress, the sector faces challenges such as data fragmentation, technical limitations in MRV, and high project costs that restrict access for smaller developers. The lack of standardized protocols for emerging methods like enhanced weathering further impedes market growth. However, as MRV technologies continue to advance, costs decrease, and regulatory frameworks mature, the carbon offsets market is well-positioned to scale. Future exits are likely to be driven by acquisitions from corporates seeking to internalize MRV and carbon removal capabilities to strengthen their climate strategies.

The evolution of offsets, projects, and markets in 2024 underscores the sector's shift toward credibility, scalability, and innovation. With increasing corporate and governmental commitments, enhanced MRV technologies, and a growing pipeline of high-impact projects, it is on track to become a cornerstone of global decarbonization efforts. While challenges remain, the alignment of technological and market advancements with regulatory demands provides a strong foundation for future growth and integration into broader climate strategies.

AC

AS MRV TECH ADVANCES, COSTS DECREASE, AND REGULATORY FRAMEWORKS MATURE, THE OFFSETS MARKET IS WELL-POSITIONED TO SCALE

2025

WHAT TO WATCH



MRV Tech Maturation: Continued innovation in MRV tools, particularly for emerging carbon removal methods like enhanced weathering and marine-based solutions, will shape the credibility of offset markets.

Industrial Synergies: Watch for advancements in technologies serving high-demand industries such as green hydrogen, EV supply chains, and lithium extraction, which require ultrapure water and precision environmental management.

Policy-Driven Momentum: Legislative developments and public funding initiatives could accelerate innovation, especially in water resilience and climate risk management.

Investment Shifts: Increased capital flow toward resilience technologies, with later-stage investments signaling market readiness for scale.



INDUSTRY GROUP ANALYSIS

TRANSPORTATION & LOGISTICS



WRITTEN BY
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Aviation, autonomy, and APAC innovation take center stage as mature and consolidated EV market shifts gears

Trends

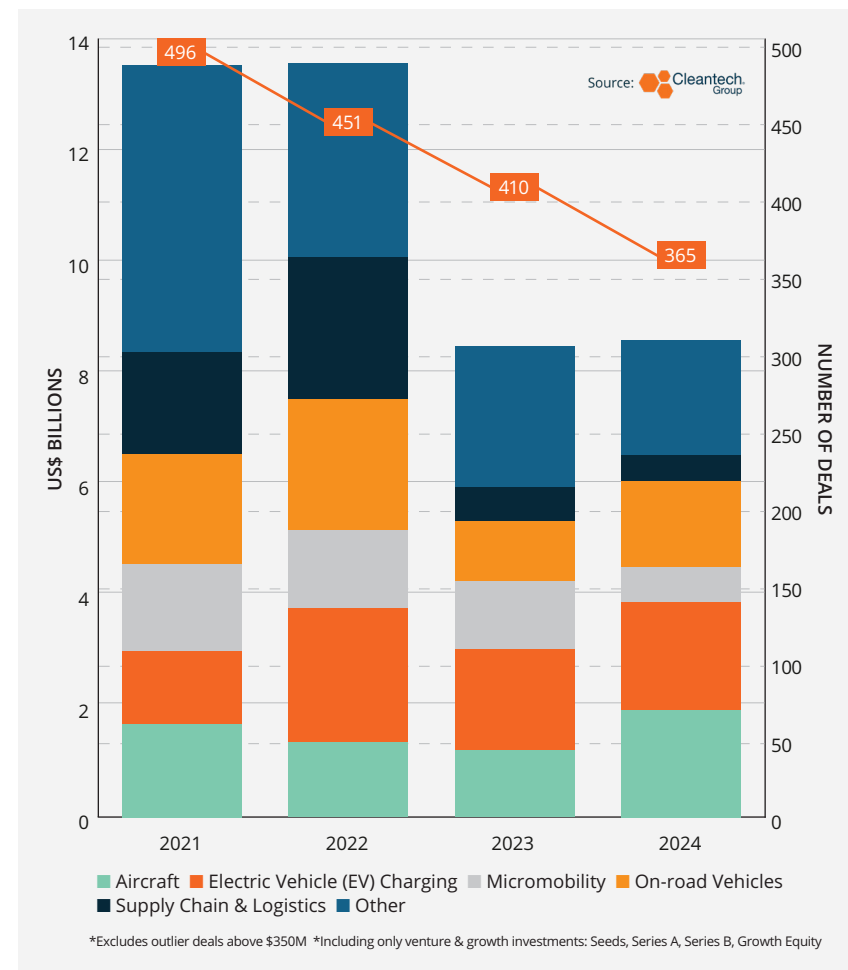
Overall investment in Transportation & Logistics as an industry group remained steady from 2023 despite the slight overall decline in venture investment in cleantech as a whole. The steady investment numbers however, do not reflect underlying volatility in the sector. Q3 of this year saw the lowest investment numbers since 2019 and deal count dropped significantly, reaching an all-time low of 72 in Q4—in fact, overall deal count has fallen steadily since 2021. Despite the lower number of deals, the average investment size has substantially increased from 2023, particularly for late-stage deals. While late-stage deal count dropped to an all-time low in Q4, T&L late-stage deals averaged \$59M, soundly outperforming the cleantech-wide average of \$36M.

The steep drop-off in investment in Q3 2024 was mostly due to a significant decrease in two categories: *EV charging* (\$.16B compared to a two-year average of \$.56B) and *on-road vehicles* (\$.02B compared to a two-year average of \$.46B). While investment numbers recovered slightly in Q4, both remained well below the two-year average (\$0.32B and \$0.29B respectively). 2024 saw a significant yearly investment drop-off in only one sub-sector: micromobility.

The Cleantech Group taxonomy has become more discerning with micromobility innovators, excluding innovators such as ridesharing or leasing companies without clear IP either in vehicle components, design, or fleet management solutions. On a market level, the micromobility space has become increasingly challenging for innovators. Several key factors have coalesced to deter venture investment: unfriendly regulation towards ebikes and e-scooters in European cities, high-profile bankruptcies and losses (e.g., *Bird*, *Voi*), overall market consolidation, and difficulty in differentiating emobility products in a saturated market.

An exception to the challenges facing micromobility innovators are emobility providers focusing on Asia and southern Africa (e.g., *Ola Electric*, *Ather Energy*). High demand for electric mobility solutions for passenger and cargo transport is driving innovation in vehicle design and components, battery-swapping networks, financing, and fleet management.

Fig.1: Transportation & Logistics Venture Investment 2021-2024





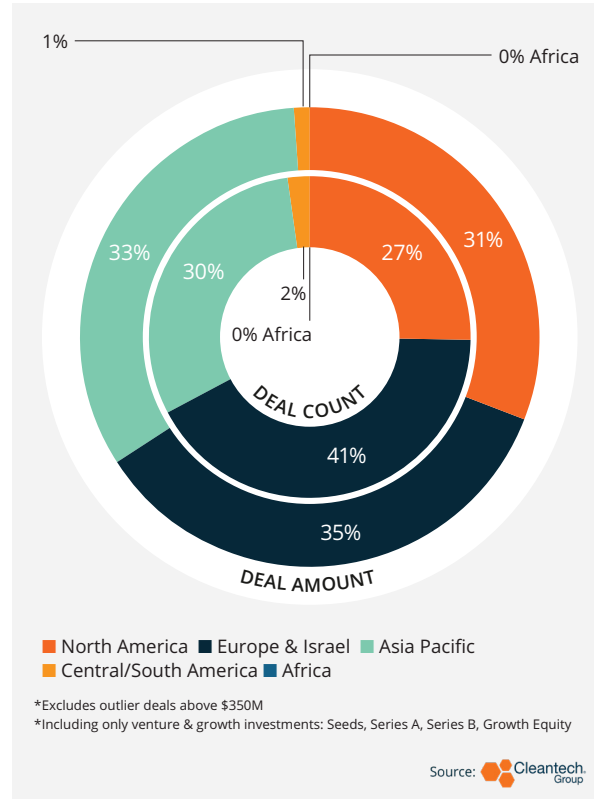
Spotlight: APAC

APAC innovators in Transportation & Logistics have consistently outpaced their peers in other cleantech sectors in securing investments. 2024 solidified this trend, with APAC innovators receiving nearly 33% of all Transportation & Logistics investment compared to 17% of investment across all cleantech sectors.

Indian innovators in particular punched well above their weight this past year. Forty-four distinct Indian T&L innovators closed funding rounds in 2024, more than any other APAC country. In fact, across Asia and Europe, the only categories that outperformed Indian Transportation & Logistics innovators were Materials & Chemicals innovators in China (56) as well as UK-based Chinese M&C innovators (68 deals) and UK-based M&C (60 deals) and E&P innovators (50 deals).

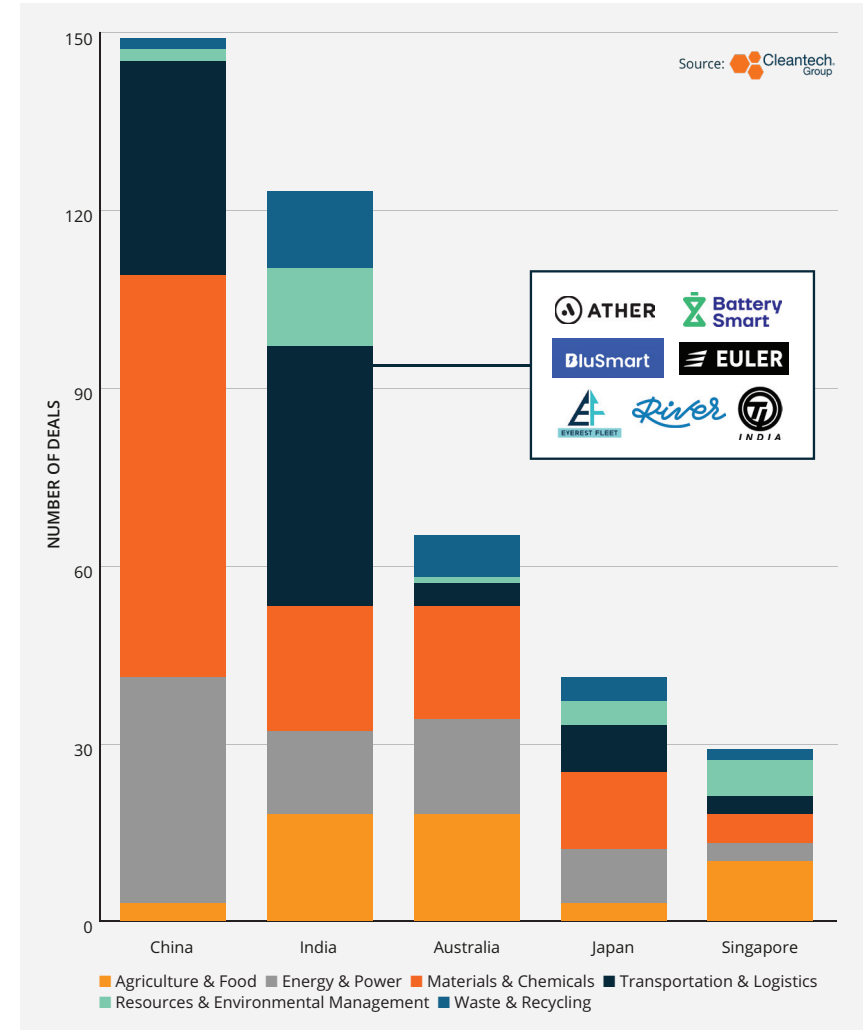
Unsurprisingly, micromobility was a major theme, attracting over 50% of all venture funding in India. As India emerges as a leader in electric mobility, demand has spiked for EV components (e.g., [Chara Technologies](#)), fleet electrification (e.g., [Everest Fleet](#)), and charging and battery swap solutions (e.g., [Ather Energy](#), [Battery Smart](#)) to support the electric transition. Notable rounds in 2024 include \$71M in Growth Equity to [Ather Energy](#), a developer of electric two-wheelers and a charging network, a \$70M Growth Equity round for [TI Clean Mobility](#), provider of electric last mile logistics solutions, and a \$41M Series B round for electric two-and-three-wheeler developer [River](#).

Fig.2: T&L Investment by Geography



44 DISTINCT TRANSPORTATION & LOGISTICS INNOVATORS BASED IN INDIA RAISED FUNDS IN 2024

Fig.3: APAC Innovators Raising Funds in 2024





On-road vehicles

The EV sector has become increasingly challenging for both innovators and incumbents in recent years. Consolidation, commodification, and recent price wars between Chinese and European and North American automotive incumbents has made it increasingly difficult for start-ups to compete in the EV space. 2024 saw several more bankruptcies to the ever-growing list of failed EV start-ups (e.g., [Fisker](#), [HiPhi](#), [Arrival](#)).

Meanwhile, a steady stream of regulatory and public funding has been directed towards supporting auto OEM's transition from ICE to EV production. Under the IRA, \$2B was awarded to over a dozen OEMs to convert ICE production facilities and factories into EV production sites. In this context, the recent drop in venture funding for EVs is not a warning sign—public sector funding is taking over to scale the increasingly mature and commodified market.

In fact, nearly all outlier deals in Transportation & Logistics (deals over \$350M) were closed by EV players across both the passenger and commercial sectors (\$1.1B for [IM Motors](#), \$1B for [Rivian](#), \$688M for [Hozon](#)). The same dynamics that sound the death knell for innovators trying to develop clean-sheet EVs (e.g., high competition, minimal product differentiation, price wars) are pushing European and North American auto OEMs to engage with component and systems innovation.

These OEMs are not only engaging sustainable innovation to meet sustainability mandates and goals but also to reduce final vehicle cost, time to market, and differentiate their products in both sustainability and quality from low-cost imported EVs. The demand for sustainable innovation is reflected by the steady VC and corporate funding for component and systems solutions to these challenges, including automation and vehicle system software, power electronics, and electric motors.

Autonomy

2024 also saw a surge of investment around autonomous capabilities, particularly for commercial and heavy-duty vehicles. Innovators such as [Waabi](#) and [Gatik](#) closed investment rounds to accelerate development and commercialization of autonomous trucks targeting middle-mile logistics. Logistics, freight, and automotive corporates such as Uber Freight and Volvo have partnered with autonomous systems providers and autonomous truck developers to explore supply chain decarbonization strategies. As proven by the robotaxi market, autonomy for Transportation & Logistics is a risky and volatile space. Despite massive funding rounds and high publicity, some autonomous trucking start-ups are struggling to meet targets or pivoting from trucks to other autonomy and AI applications.

While autonomous trucking offers potential sustainability benefits through fuel efficiency and optimized routes, its widespread adoption is hindered by regulatory hurdles, safety concerns, limited data on environmental impact, and concerns about driver displacement.

Key on-road vehicle investments:

- [IM Motors](#), developer of EVs and a joint venture between SAIC Motor, Zhangjiang Hi-Tech Group, and Alibaba Group, raised \$1.1B in a Series B round from the Bank of China, Agricultural Bank of China, and Lingang Group
- [Hozon Group](#) closed a \$688M Growth Equity round to support R&D and product innovation in vehicle intelligence and smart vehicle systems
- [Waabi](#), developer of autonomous driving systems, secured a \$200M Series B investment led by Nvidia, Volvo Venture, Porsche, and others, to launch autonomous trucking services in 2025

2024 SAW A SURGE OF INVESTMENT AROUND AUTONOMOUS CAPABILITIES, PARTICULARLY FOR COMMERCIAL AND HEAVY-DUTY VEHICLES



Electric Vertical Take-Off and Landing (eVTOL)

Aviation investment reached \$2B in 2024 and Q4 saw the highest quarterly investment in aviation in recent years at \$880M, constituting 22% of overall cleantech investment and 44% of T&L investment. Over a third of aviation investment was directed to eVTOL innovators, a significant portion of which was drawn by the eVTOL sector.

Globally, eVTOL developers are on the brink of commercialization, and 2024 saw an influx of high-profile investments intended to push several innovators over the finish line (Toyota committed \$500M to Joby Aviation, Eve Air Mobility received over \$150M in combined loans and equity from Embraer, Citibank, and Brazil National Development Bank).

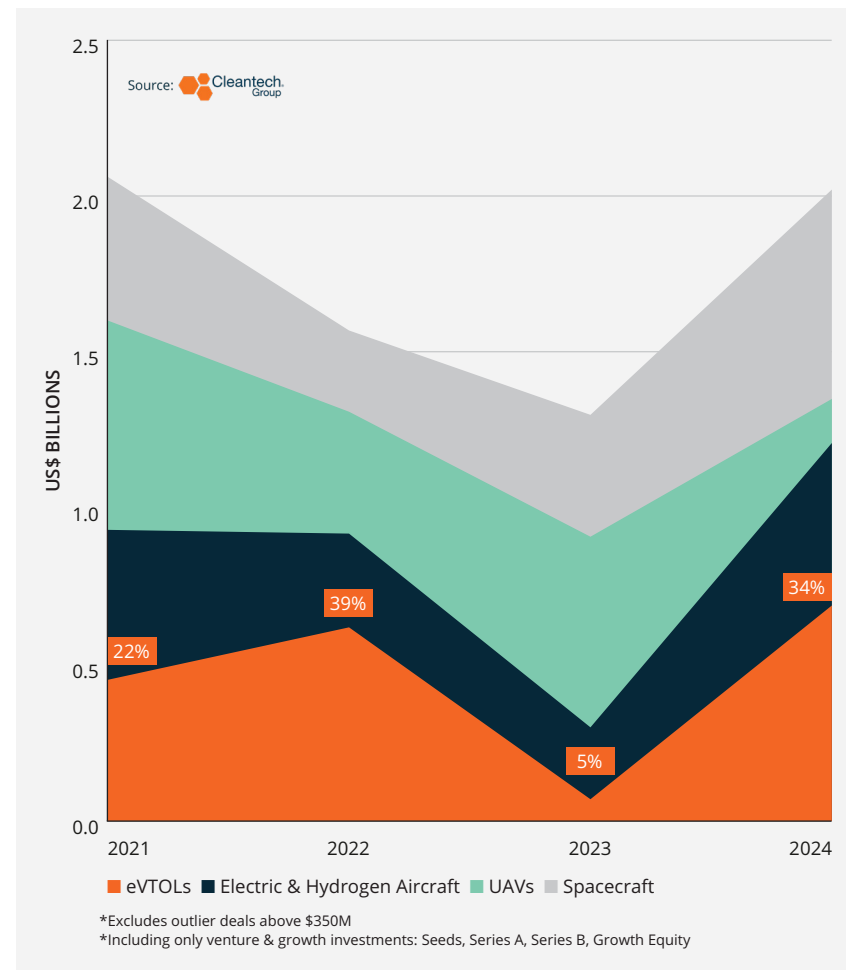
Leading eVTOL producers have partnered with airlines and airports to roll out the first operational eVTOLs as early as 2025. However, key risks and uncertainties around production costs and financial bottlenecks endanger these optimistic targets. The recent high-profile insolvency announcement from Lillium and an additional funding request from Archer suggest that innovators are struggling to meet production targets and bring down costs. The next few months will be critical for a number of innovators struggling to produce prototypes and achieve certifications to retain funding and investors.

Key aviation investments:

- **Beta Technologies**, developer of electric aircraft, eVTOL, and charging infrastructure, raised \$318M in Growth Equity from Fidelity, TPG Rise Climate, QIA, and United Therapeutics, to support production and certification of electric aircraft and charging infrastructure build-out
- **Heart Aerospace** secured \$107M in Series B funding to support certification and production of hybrid-electric aircraft
- Developer of electric aircraft propulsion technologies **H55** closed a \$73M Growth Equity round from Investissement Quebec to support certification and testing of battery-electric propulsion system

THE NEXT FEW MONTHS WILL BE CRITICAL FOR A NUMBER OF eVTOL INNOVATORS STRUGGLING TO PRODUCE PROTOTYPES AND ACHIEVE CERTIFICATIONS TO RETAIN FUNDING AND INVESTORS

Fig.4: Aviation Investment by Subsector (2020-2024)





Aviation

The aviation sector as a whole has experienced a roller-coaster year. SAF has remained a key theme for aviation decarbonization, driving both engagement and investment from aviation stakeholders, chemical and energy producers, and oil and gas majors. Demand is at an all-time high as emissions offset mandates loom and SAF blending minimums come into effect in Europe next year. However, significant challenges in SAF feedstocks and production plant closures and delays are a cause for concern for airlines and operators facing imminent pressure to both offset emissions and increase SAF uptake.

2024 saw an influx of both public and private funding for low-emissions flight solutions such as hybrid, electric (e.g., [Heart Aerospace](#)), and hydrogen aircrafts (e.g., [ZeroAvia](#), a Global Cleantech 100 company), propulsion systems (e.g., [H55](#), [Wright Electric](#)), and alternative aircraft design (e.g., [JetZero](#)). The U.S. Federal Aviation Administration (FAA) provided \$291M in grants from the Inflation Reduction Act for projects to decarbonize the aviation sector by 2050: Fueling Aviation Sustainable Transition (FAST) grants include \$244.5M for SAF production, transport, and supply chains and \$46.5M for zero- or low-emissions aviation technologies.

These technologies enable demand owners to meet emissions targets and lower operational costs, potentially offsetting some of the costs of SAF premiums and fleet upgrades. Critically, compatibility with a range of zero- and low-carbon propulsion solutions enable fleet operators to future-proof their fleets. As technical, logistical, and certification barriers for both electric and hydrogen aircrafts and SAF supply are uncertain, committing to one decarbonization solution remains a significant risk for demand owners. Hybrid systems offer immediate emissions reductions and leave operators free to choose SAF, electric, or hybrid propulsion to achieve full emissions.

Hybrid aircrafts and airships are approaching certification and expect to take flight in the next few years and while hydrogen systems are generally at a lower TRL, high-performance components are on the verge of commercialization. Continued investment in and development of critical components such as high-density batteries, fuel cells, hydrogen storage, and electric motors will improve range, size, and emissions reductions for all low-emission flight solutions.

NG

2025

WHAT TO WATCH



Key mandates and regulations will be coming into play in the EU such as minimum SAF uptake mandates, emissions reporting in the maritime sector under the Emissions Trading System, and a 15% emissions reduction for heavy-duty trucks.

Significant uncertainty remains regarding how the incoming U.S. government will impact U.S. climate policy. Customer incentives to purchase EVs will likely be retracted, along with public funding for EV infrastructure build-out, while programs supporting domestic manufacturing and supply chains for EVs may be spared. Foreign and trade policy, particularly with China, is another major question mark that will determine availability and cost of critical materials and battery supply.

Markets to keep an eye on

Zero-emissions heavy-duty vehicles: China leads the world in electric HDV sales and adoption, partially due to the successful implementation of battery-swapping. Expect eHDV uptake to continue to increase significantly across Europe and the U.S. in 2025. Non-Chinese OEMs and innovators will have to offer clear performance and quality benefits to compete with low-cost Chinese exports.

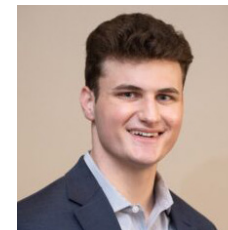
Incoming safety guidelines and best-practices regarding ammonia handling and bunkering, as well as a rising number of bunkering and refueling pilots bode well for uptake of ammonia as a zero-carbon maritime fuel.

The electric two- and three-wheeler market is booming across India, the APAC region, and sub-Saharan Africa. Projections into 2025 suggest a continued upwards trajectory, with a particular opportunity for enabling components and infrastructure innovation that increase efficiency and unlock additional economic opportunities (e.g., battery swapping, high-efficiency low climate impact motors).



INDUSTRY GROUP ANALYSIS

WASTE & RECYCLING



WRITTEN BY
PARKER BOVÉE, ASSOCIATE,
WASTE & RECYCLING

Despite record investment years across recycling technologies, policy remains the missing keystone to solidify circular economies

Plastic recycling

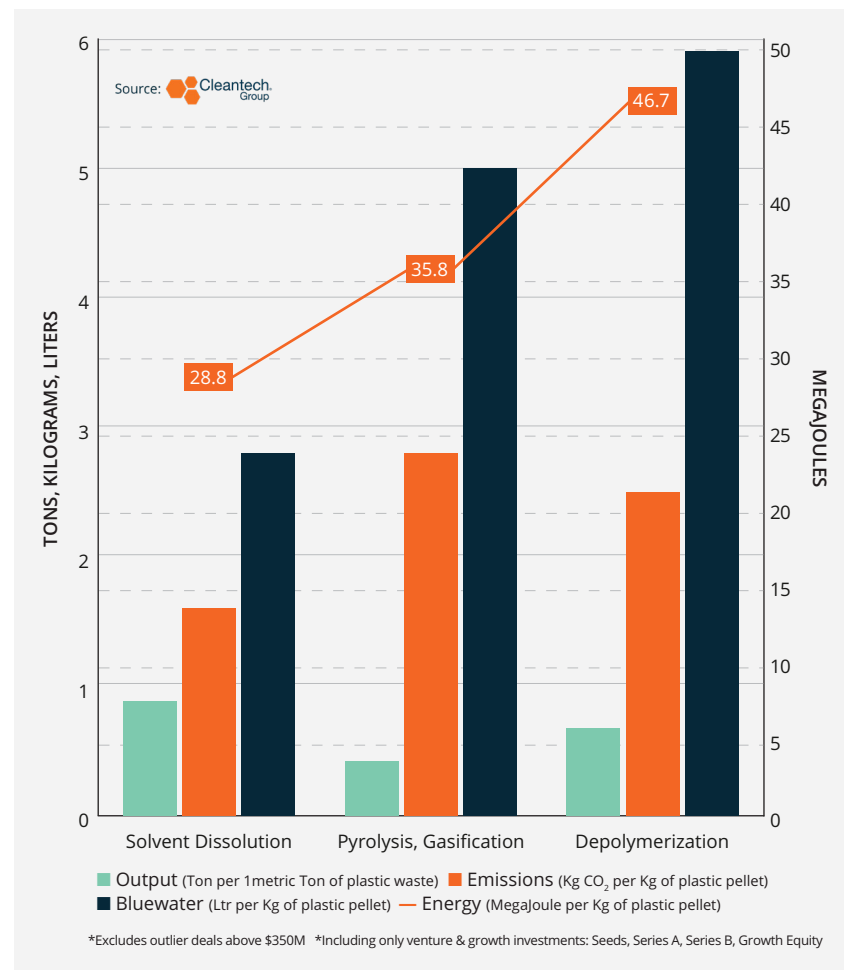
Plastic recycling had a bounce-back year in many ways. After a 75% decline in venture investment from 2022 to 2023, new innovations in advanced recycling technologies (solvent dissolution, depolymerization, and pyrolysis) have improved recycling efficiency and won back investors' interest. In fact, 2024's total for venture investment through the beginning of Q4 2024 is \$737M and anticipated to be the largest year for plastic recycling investment on record.

Advanced recycling received several public hits due to Agilyx's pyrolysis plant closure, Encina cancelling a planned \$1.1B Pennsylvania pyrolysis facility, and several lawsuits against ExxonMobil's pyrolysis facilities. While not abandoned yet, pyrolysis is failing in efficiency and environmental impact compared to innovative recycling processes. Meanwhile, depolymerization and solvent dissolution start-ups continue to advance efficiency and expand their scope of recyclable plastic, stoking investor excitement.

The chill on pyrolysis investment did not hinder depolymerization innovators, who capitalized on high polyethylene terephthalate (PET) demand with innovators like Samsara Eco and Syre planning massive commercial scale-ups. Meanwhile, start-ups Denovia Labs and Macrocycle Technologies (a 2024 Cleantech 50 to Watch company) are innovating, introducing plans for unique depolymerization recycling technologies. Denovia Labs is commercializing hydrolysis, a leading technology in the field of depolymerization while Macrocycle Technologies combines solvent dissolution and depolymerization to maximize chemical purity of offtake products.

WHILE NOT ABANDONED YET, PYROLYSIS IS FAILING IN EFFICIENCY AND ENVIRONMENTAL IMPACT COMPARED TO INNOVATIVE RECYCLING PROCESSES

Fig.1: Advanced Plastic Recycling Performance & Environmental Impact





WHILE INVESTOR INTEREST HAS BEEN RESTORED IN ADVANCED RECYCLING, CONTINUED INNOVATION IS REQUIRED TO BRING DOWN OPERATIONAL AND CAPITAL COSTS ACROSS THE ENTIRE PLASTICS RECYCLING VALUE CHAIN

- **Samsara Eco** raised a \$65M Series A round to facilitate the scale up of their enzymatic depolymerization operations in Southeast Asia, alongside investor and retail partner lululemon
- In May, **Syre** became the new name in textile recycling. The H&M-backed start-up raised \$100M to commercialize their glycolysis depolymerization technology converting textile waste into newly spun fabrics
- The depolymerization space is rife with innovation, yet pyrolysis has found new feedstock applications showcased by **Circtec's** \$138M Growth Equity round in May to commercialize end-of-life tire recycling

Perhaps the biggest news in advanced recycling came from emerging solvent dissolution recyclers. Solvent dissolution, an emerging recycling avenue for all plastic types, uses solvents to dissolve adhesives, impurities, dyes, and contaminants from plastic, leaving recyclers with pure polymers. Solvent dissolution differs significantly from pyrolysis and depolymerization as it does not require extensive refining of recycle through cracking or repolymerization. Academic research comparing the three technologies is exceptionally promising, showcasing solvent dissolution's improved recycle output and lower emissions, water, and energy use compared to depolymerization and pyrolysis.

Commercially, solvent dissolution also took several impactful steps forward this year:

- **Purecycle**, a polypropylene (PP) recycler utilizing supercritical butane, raised \$90M through follow-on public offerings before extending a line of capital from Sylebra Capital. The funding will expedite development of Purecycle's second commercial facility in Georgia
- **APK**, a multilayer plastic recycling specialist and Europe's big solvent dissolution name was acquired by LyndonBasell (LYB) as the corporate continues its diverse investment in advanced recycling technologies
- Canadian Polystyrene (PS) recycler, **Polystyvert**, raised a \$16M Series B in July to continue their aggressive solvent patent strategy. The group looks primed to test a licensing model abroad while they recycle PS domestically

While promising, advanced recycling remains a long way from commercial success. Ineffective plastic sortation directly limits advanced recycling's utility. For solvent dissolution, the additional operational cost of solvents, anti-solvents, and solvent cleaning/recycling needs limit its immediate commercial scaling. While investor interest has been restored in advanced recycling, continued innovation is required to bring down operational and capital costs across the entire plastics recycling value chain.

Textile recycling

Textile production, followed closely by end-of-life waste generated, is expected to roughly double by 2035. Considering that textile recycling only supplies 0.5% of global fiber demand (**TOMRA**), there is a good deal of innovation needed to accelerate the industry's circularity.

Thankfully, 2024 brought innovation on several new fronts. Continuing a steady stream of growth since 2020, depolymerization companies received several hundred million dollars in investment to scale up commercial recycling operations in Europe and the U.S. Interestingly, textile recycling has been a thriving home for a diverse range of technologies including hydrolysis, glycolysis, and other depolymerization methods.

These technologies all fall under the category of depolymerization, often using a catalyst to improve reactivity or process economics of depolymerization. The sheer volume of textile waste and diversity of blends creates an interesting niche for recyclers to specialize their innovation based on incoming, or preferred, feedstocks such as polyamide (nylon) for Samsara Eco. Despite this, Polyester/PET remains the primary target across this space.

- **Denovia Labs** emerged from stealth and raised a \$40M Series A to commercialize their hydrolysis depolymerization technology. The company has already signed a range of feedstock agreements with Goodwill, Tymec, and hospitals, and anticipates over \$15M in revenue in their first operational year



- **Syre**, owned by H&M, raised a \$100M round to commercialize their newly acquired glycolysis depolymerization technology. This massive burst in funding will guide development of Syre's first two commercial operations tentatively planned for Vietnam and Spain
- **Syntetica's** \$4.6M Seed round is small compared to the other two but potentially revolutionary in terms of technology. The company depolymerizes using an unnamed solvent at temperatures 50%+ lower than their competitors. Syntetica is commercializing the technology now, hoping to begin facility development in 2025

Depolymerization still struggles with certain fiber blends, contamination, and dyes, limiting its commercial growth without effective sorting. While incorporating solvents catalyzes depolymerization efficiency, solvents are being applied more aggressively in textile recycling elsewhere. Once again following the pathways established in general plastic recycling, solvent dissolution has emerged to specifically target high contamination feedstocks.

Solvent dissolution is uniquely poised for success in textile recycling for the same reason it shows promise in recycling food packaging. Solvent dissolution strips target materials away from contaminants like oils, food, or performance additives in plastic polymers. Tuned for textile waste, solvent dissolution acts in the same way,

separating target textiles from other fibers, dyes, additives, and contaminants. Solvent dissolution companies are now scaling recycling facilities, aiming to deliver renewed interest to textile recycling.

- **Circulose**, formerly ReNewCell, was acquired by Altor Equity Partners with an ambition to retool existing assets for pure cotton extraction from waste textiles. The company had filed for bankruptcy earlier this year after raising more than \$100M through their 2020 IPO. The acquisition is an attempt to secure a foothold in the high-demand European cotton market
- Backed by development partners Sulzer and H&M, **Worn Again** continued work on their 1,000-ton demonstration plant in Zurich to supply a nearby Sulzer Chemtech facility. The facility targets PET and cotton at a higher efficiency and output than depolymerization techniques
- **Ravel** entered the solvent dissolution scene in September, quietly filing a \$3M Seed round. Ravel is unique in their targeting of mixed textile waste, potentially capitalizing on a low-demand feedstock. The company is exploring initial partnerships as they begin plans for their first facilities

As negotiations faltered for a global plastic treaty, textile recyclers of all technology types are growing increasingly worried about a lack of policy supporting domestic recyclers. Usually ahead of the curve on

waste, the European Union has yet to pursue substantive reform in this area leaving several innovators like Worn Again Technologies to lobby for recycled content mandates and further Extended Producer Responsibility regulations.

With historically low margins for recyclers, textiles are not a valuable feedstock for waste valorization. Brands and textile manufacturers have largely avoided substantial regulation and opted for voluntary waste reduction goals, often ignoring their growing virgin fiber use. That said, demand for recycled fiber has remained relatively stable amidst a fast fashion explosion of textile consumption. Surging production of low quality, virgin fibers is compounding the problem, creating unavoidable impacts in waste management chains and landfills. While the core recycling technologies appear promising, serious market reconstruction through regulation appears necessary to keep textile recyclers afloat in the coming years.

California did pass SB 707, the Responsible Textile Recovery Act, which mandates that textile manufacturers must take full responsibility of their product's end-of-life collection, repair, reuse, and recycling. A state committee will be responsible for reviewing, approving, and monitoring the fulfillment of these plans with harsh penalties of up to \$50,000 a day for non-compliant producers.

AS NEGOTIATIONS FALTERED FOR A GLOBAL PLASTIC TREATY, TEXTILE RECYCLERS OF ALL TECHNOLOGY TYPES ARE GROWING INCREASINGLY WORRIED ABOUT A LACK OF POLICY SUPPORTING DOMESTIC RECYCLERS



Battery recycling

Battery and electronic waste recycling pose a nuanced challenge for innovators to solve. E-waste, rich in mercury, arsenic, lead, and cadmium, lacks proper waste management infrastructure whilst only 17.4% of e-waste is properly collected and managed (Natural Resources Defense Council). The remaining 82.6%, regardless of whether it is incinerated or landfilled, pollutes water, air, and soil, causing a cascade of negative health impacts. Yet, the motivation to reclaim electronic waste's valuable minerals – gold, silver, lithium, cobalt, and nickel – has spurred several years of innovation and investment.

By 2040, critical mineral demand is predicted to increase by 870% for lithium, 210% for nickel, 390% for graphite, and 220% for cobalt (IEA). Regardless of what battery chemistry manufacturers choose for low-carbon energy or transportation systems, these materials are critical.

BY 2040, CRITICAL MINERAL DEMAND IS PREDICTED TO INCREASE BY 870% FOR LITHIUM, 210% FOR NICKEL, 390% FOR GRAPHITE, AND 220% FOR COBALT

Adding further complication, China's dominance in refining raw minerals and recycling electronic waste positions them as the world's primary supplier of energy-transition materials creating supply chain risk for other countries. National strategy differs around the world from Australia's aggressive vertical integration of a lithium to battery manufacturing pipeline to the U.S. investing billions of dollars into start-ups recycling or manufacturing batteries. Regardless of approach, battery recycling remains a national security topic.

A battery with recycled cathode materials saves at least 28% in lifetime greenhouse gas emissions, compared to a fully virgin battery (IEA). Unfortunately, battery recycling capacity has outpaced the availability of spent batteries, leading to some of the first investor apprehension for new investments in several years. Total venture investment in battery recycling has declined by over 75% from last year, representing the first decline in annual investment since COVID.

Investors are wary of looming overcapacity in recycling; not enough batteries are coming off the road to supply large battery recycling facilities. Competition between recycling technologies is increasing and differentiation is slimming, direct recycling start-ups [Lohum](#), [Princeton NuEnergy](#), and [Li Industries](#) all attracted large Series A and B rounds while [Ascend Elements'](#) novel hydrometallurgy process garnered the year's only \$60M+ Growth Equity round.

Fig.2: Anticipated Critical Mineral Shortages

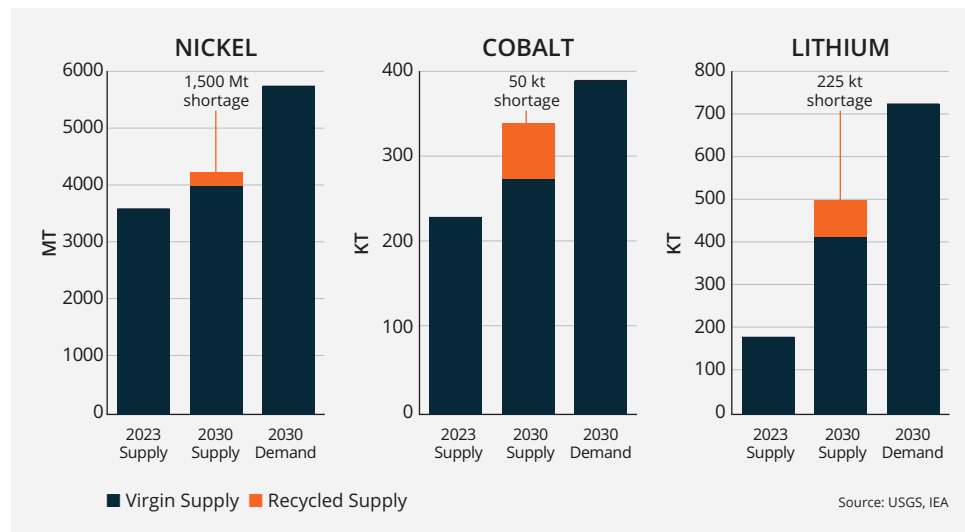
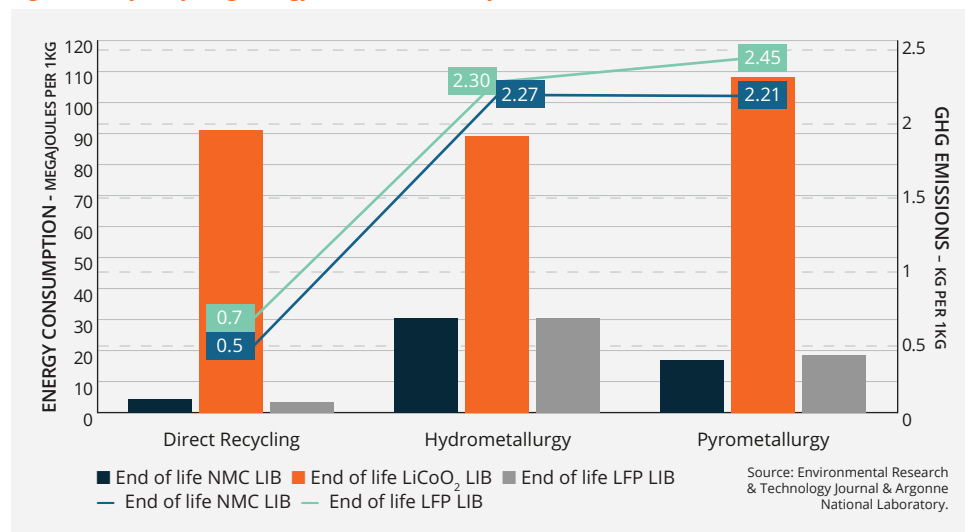


Fig.3: Battery Recycling Energy and GHG Intensity





The three core pathways for battery recycling remain the same. Pyrometallurgy is inefficient but accepts all feedstocks, direct recycling is the most efficient but limited by chemistry and disassembly costs, and hydrometallurgy seems best positioned by proxy of its increasing efficiency and feedstock flexibility to survive a looming valley of death. As an example of vertical reintegration of battery waste streams, Mercedes-Benz opened their hydrometallurgy battery recycling facility in October. The plant was a close collaboration between Mercedes-Benz, Primobius, and the German Federal Ministry for Economic Affairs and Climate Action.

China's dominance over battery supply chains continues to limit rapid battery manufacturing scale-up nearly anywhere else in the world. If states can recover battery minerals domestically, this will change. IEA estimates that recycling consumers' batteries moving forward could reduce virgin mineral demand in battery manufacturing by 30% by 2040. Governments in North America and Europe have replied to this unique market opportunity in spades with \$837M in grants over the last twelve months:

- American Battery Technology Company (ABTC) received over \$210M in project grants and tax credits from the U.S. DOE as they construct a new 100,000 ton/year capacity facility
- The DOE released over \$3B to battery manufacturers in accordance with the Biden Administration's aggressive battery policies; \$738M of this block was reserved for battery recycling scale-ups
- Canadian recycler, Electra Battery Materials, received \$20M from the U.S. Department of Defense and \$5M from the Government of Canada to accelerate their hydrometallurgy recycling operations

As battery recycling enters a clear valley of death for innovators, a few themes are calcifying. Governments are taking varied policy approaches, but the major players (U.S., EU, China) are all now treating battery recycling as a matter of national security. Similarly, direct recycling is receiving favorable government support from India and the U.S. as it finally enters commercial viability.

PB

2025

WHAT TO WATCH



Recycling innovation took center stage in 2024. Innovations like solvent dissolution and direct battery recycling are poised for breakout years in 2025 in which initial commercial facilities come online. Slower moving incumbents initiated investment in both of these spaces in 2024, signaling potential for dramatic changes in two of Waste & Recycling's largest subsectors.

The outlook for textile recycling is far bleaker, unfortunately. While depolymerization technologies still offer tremendous hope, the scale of textile waste appears to be outpacing previous expectations, emphasizing a need for scalable technologies that are not available today. A link between the battery and textile subsectors is policy. Nations are aggressively pursuing critical minerals through battery recycling grants or waste export bans, creating a tense dynamic internationally. Textile recycling made several steps in solidifying policy support, especially in the U.S., where several states passed or implemented new textile recycling bills.

Looking ahead, it is crucial to recognize the importance of policy in waste and recycling. Global import/export markets are emerging to handle waste from high income markets and sell recycled material back at a profit. While this dynamic is helpful for some materials, it forces domestic manufacturing into a precarious reliance on external markets. The region to watch across all three subsectors detailed above is Europe. With recycling niches developing in Latin and North America as well as Asia, Europe's recyclers are currently exporting waste in record numbers and struggling to support their recyclers.


THE 2024 GLOBAL CLEANTECH 100 GRADUATES

Global Cleantech 100 Graduates are companies who have been included in the Global Cleantech 100 at least once, since the first edition in 2009, and then go on to be acquired or become a public company.

Below we record the graduation events since the previous edition of the Global Cleantech 100 up to the cut-off date of September 30, 2024.

- There were a mere three graduation events in the 12-month period, none of which were positive outcomes for the investors involved.
- Last year we recorded eight graduation events, 21 for the year before.

GLOBAL CLEANTECH 100 GRADUATES VIA IPO OCTOBER 1, 2023 - SEPTEMBER 30, 2024				
GLOBAL CLEANTECH 100 ALUMNUS COMPANY	IPO TYPE	IPO DATE	DESCRIPTION	YEARS ON THE GLOBAL CLEANTECH 100
 <small>(now trading as Bolt Projects Holdings Inc)</small>	Via SPAC	Aug 24	Bolt Threads is a biotechnology company that specializes in sustainable biomaterials. Some of their products include b-silk, a material that can replace silicone elastomers, and Mylo, a "leather" made from mycelium	2015, 2016, 2018

GLOBAL CLEANTECH 100 GRADUATES VIA M&A OCTOBER 1, 2023 - SEPTEMBER 30, 2024				
GLOBAL CLEANTECH 100 ALUMNUS COMPANY	ACQUIRER	DATE	NOTES FROM THE ANNOUNCEMENTS	YEARS ON THE GLOBAL CLEANTECH 100
	Wide Open Agriculture	Nov 23	Australian Wide Open Agriculture bought Prolupin out of bankruptcy for \$2.68M. Prolupin specialized in extracting the protein of the sweet lupin and making it usable for food production in the form of the unique lupin protein isolate (LPI). This patented process was based on 25 years of research, and was preserved by the purchase agreement	2022
	Budderfly	Aug 24	Budderfly, a Partners Group-backed commercial energy management company, acquired Sunverge Energy's DERMs platform. The move was motivated to enable the company to easily create virtual power plants across its system. This deal continues the ongoing consolidation, evident in the VPP space	2015, 2017, 2018

Let's hope that this fallow period for exits represents the bottom of the cycle, the last months of a painful adjustment period required after the overly-hyped and hot investment markets of 2020-22 – which included the "SPACmania" period.

We provide a bookend on that period below, in showing how that stands today, to contextualize and illustrate the challenge the global cleantech investment community has on its hands, as we start the second half of the 2020s.



THE 2024 GLOBAL CLEANTECH 100 GRADUATES

SPACs and public companies

The “SPACmania” period has come to an end, even if there are still a few companies going public via this route.

- In Q3 2024, there were three other Special Purpose Acquisition Company (SPAC) listings for clean technology companies, in addition to Bolt Threads, the Global Cleantech 100 graduate mentioned above.
- All four were valued at lower than \$0.5B (an average of \$0.3B), a far cry from the same quarter three years ago when the average valuation of the 34 cleantech listings via SPAC that quarter was 10x that amount, at \$3.5B, as recorded by Cleantech Group’s Quarterly Investment Monitor Q3 2021.

Our analysis, conducted in December 2024, of the relevant listings since 2020 (where the company is still public) highlights a severe destruction of value over that period, a sobering reality which will surely overhang sentiment amongst public market investors for some time to come.

- 85% carry a value less than half their listing value
- 68% carry a value below 25%
- 36% carry a value below 5% (1/20th of the original value)

NuScale Power, the SMR company that listed via a SPAC in May 2022, is one of just three companies with a value today greater than its listing value. It is positioning itself as ready to meet the rapidly growing power needs of data centers and AI, a highly topical subject as we head into 2025.

Unicorns

We have a rule, whereby companies – who have appeared on one of the credible, publicly available unicorn lists (as having a valuation in excess of \$1B), or where such is cited in an article from a credible source, or where it simply stands to reason by the size of a round – can no longer qualify for the Global Cleantech 100.

Valuations in the early 2020’s had meant more leading private cleantech companies each year who might otherwise have made the Global Cleantech 100, were no longer able to do so.

This has slowed markedly.

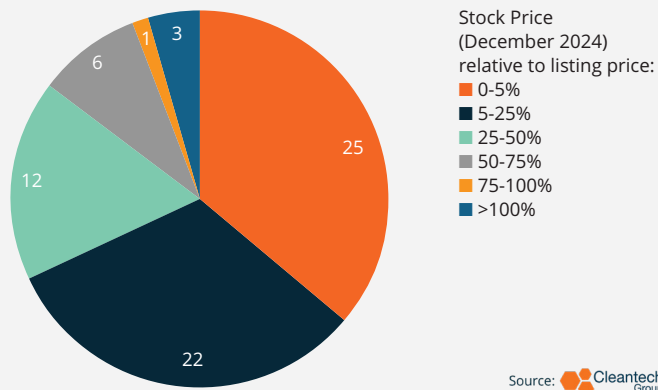
- Market sentiment has shifted elsewhere, predominantly to AI. Of the last 30 companies appearing on Pitchbook’s running list of unicorns, July-November 2024, 16 carried the “Artificial Intelligence & Machine Learning” label.

It was also interesting to note a number of China-based companies of relevance in the unicorn list for 2024 - names such as Guangxi CNGR New Energy, Qiyuan Green Power, Sungrow New Energy, and Zhizi Automobile.

These companies provide a snapshot of China’s continued focus and indeed success in creating dominant positioning in some key energy industries of the future, manufacturing as they do, everything from solar inverters to new energy vehicles (as they are referred to in China), batteries themselves to the materials and asset management services.

- For the record, the last 12 months of relevance (prior to October 1, 2024) has seen the following six cleantech companies become Unicorns, down from 15 in the prior period - 24M Technologies, Ather Energy, Electric Hydrogen, Electra, Zap Energy and Zum. The first three of those have been on past Global Cleantech 100s (as far back as 2011 in the case of 24M).

Fig.1: Climatetech SPAC Listings Since 2020: Value Today vs Listing



Source: Cleantech Group

THE “SPACMANIA” PERIOD HAS COME TO AN END, SHOWING A SEVERE DESTRUCTION OF VALUE

THE 2024 GLOBAL CLEANTECH 100 GRADUATES

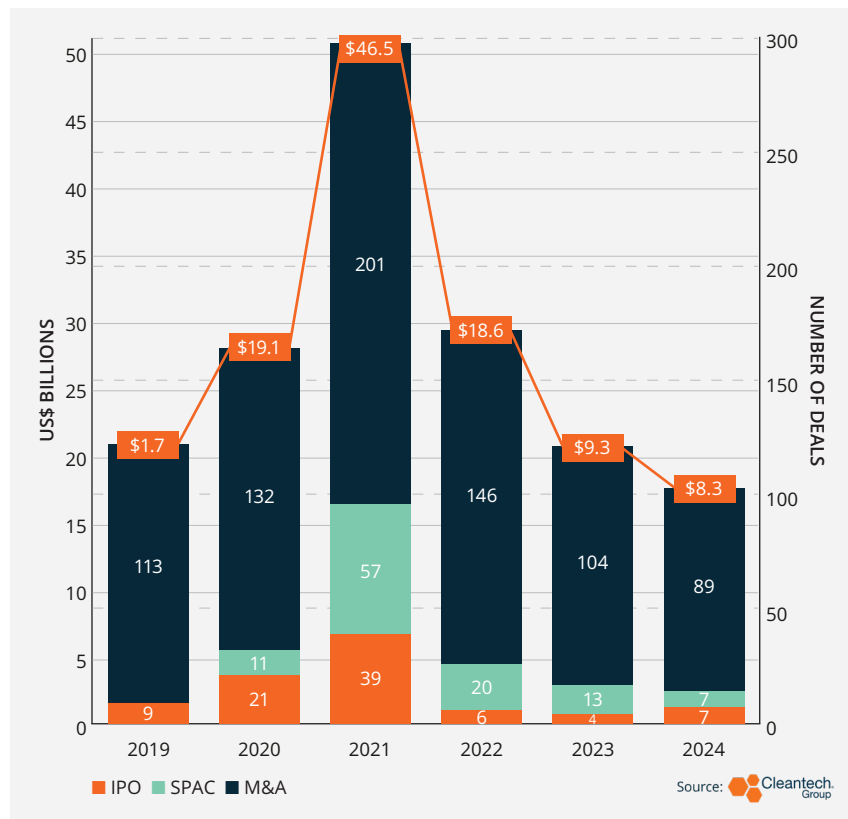
The outlook

There is still considerable dry powder for clean technology companies out there, but for a new wave of funds to be raised, the dire exits picture has to start changing – and soon.

Valuations have clearly been adjusting, as illustrated above by the slowing pace of clean technology companies reaching unicorn status, and by the valuations of the four cleantech companies who listed in Q3 2024 via SPACs.

Have we reached a bottom? Will 2025 see the decline in exits, as illustrated in the chart below, reverse? These will be critical questions to revisit next year.

Fig.2: Cleantech Venture-backed Exits by Deal Volume 2019 - 2024



Global Cleantech 100 Hall of Fame

The Global Cleantech 100 Hall of Fame was created to recognize the achievements of the few companies whose sustained excellence over many years resulted in being on the Global Cleantech 100 list an impressive seven times. To maintain the support of a strong percentage of investors and technology scouts in the market year-over-year (from 2009 onwards) is a great achievement.

Once inducted into the Hall of Fame, companies will not be featured on any future editions of the list. We will, of course, continue to keep a close eye on them, as we do all our alumni.

This year, one more company has reached that milestone and is accordingly inducted into the Global Cleantech 100 Hall of Fame.

Svante, a pioneer in the carbon capture and removal space, first appeared on the Global Cleantech 100 in 2019 and has been a mainstay ever since. It manufactures nanoengineered filters and modular rotary contactor machines that capture and remove CO₂ from industrial emissions.

HALL OF FAME

Svante

PREVIOUSLY INDUCTED

ABOUT CLEANTECH GROUP

Cleantech® Group is a research-driven company that helps corporates, public sector, investors and others, identify, assess, and engage with the innovative solutions and opportunities that are related to the world's massive, and growing, environmental and climate challenges.

Our insights and expertise are delivered to clients all over the world through our Research, Consulting, Events, and Advocacy. We have been the leading authority on global cleantech innovation since 2002.

Contact us anytime, info@cleantech.com.



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To de-risk the future and seize opportunities, leaders need to understand the impact the emerging future might have – only when you clearly see what's coming can you plan for the future.



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Cleantech Forums empower corporate change-makers, investors, entrepreneurs, and innovative stakeholders to forge connections, change the narrative, make deals, and be part of an unforgettable experience.



ADVOCACY

Collective action and hyper-collaboration, moving at record speeds, are needed to bring together all key stakeholders to ensure that innovation can have impact at scale for the transformative changes needed to address the climate crisis.



MEET THE EXPERTS

The expert panel plays an important role in shaping the final list. Their knowledge and insight add weight to the evaluation process.

[VIEW EXPERT BIOGRAPHIES](#) →

Christian Hernandez
Partner & Co-Founder

2150

Lynn Murray
Climate Tech Consultant

3M

Nigel Carr
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Acario Innovation (Tokyo Gas)

Paul Jordan
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Activate Capital Partners

Greg Fleming
Investment Director

Air Liquide Venture Capital - ALIAD

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AP Ventures

Jiten Manglani
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Steve Kloos
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Burnt Island Ventures

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DBL Partners

Earl Jones
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DCVC

Scott Himmelberger
Director

Decarbonization Partners

Olivier Bordelanne
Partner

Demeter

Kathleen Jurman
Technology Scout
Corporate Ventures

Dow

Dr. Paul-Josef Patt
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**eCAPITAL Entrepreneurial
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EDP Ventures

Sasha Brown
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EIF

Gina Domanig
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Emerald

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Victoria Beasley
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Gigascale Capital

Stefon Crawford
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GM Ventures

Eric Wang
Managing Partner

GRC SinoGreen Fund

Jamie James
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Greensoil Proptech Ventures

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Sukhwan Yun
Head of Hyundai CRADLE Berlin

Hyundai Motor Company

Diego Diaz Pilas
Global Head of Ventures & Technology

Iberdrola

Kei Honda
General Manager of
Business Development

Idemitsu Americas Holdings

Matias Torellas
Head of Portfolio Management

InnoEnergy

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Managing Director**Kerogen Capital**Ben Murphy
Investment Director**Kiko Ventures**Bastien Gambini
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SVP of New Business Development**Mitsubishi Heavy
Industries America**Jesse Teichman
Partner**MKB Growth Equity**Gert Wrigge
Partner**Next47**Chris Erickson
Partner**Pangaea Ventures**Jake Simon
Investor**Porsche Ventures**Gabriel Kra
Managing Director**Prelude Ventures**Eric Kosmowski
Managing Partner**Princeville Capital**Michael Claes
Director Technology**SABIC Ventures**Markus Hökfelt
Investment Director**SEB**Wouter Jonk
Managing Partner**SET Ventures**Jermaine Saaltink
Investment Director**Shell Ventures**Dan Baldi
National Head of Climate Tech
& Sustainability**Silicon Valley Bank**Peter Kennedy
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Partner**Stafford Capital Partners**Karthik Chandrasekar
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Managing Partner**Terra Venture Partners**Erik Scher
Operating Partner**True North Venture Partners**Qi Lu
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Partner**VNT Management**Craig Douglas
Partner**World Fund**Sivan Zamir
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