

# GLOBAL CLEANTECH **100**

Leading cleantech solutions to solve  
the world's biggest challenges

INNOVATION - MITIGATION - ADAPTATION



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# FOREWORD

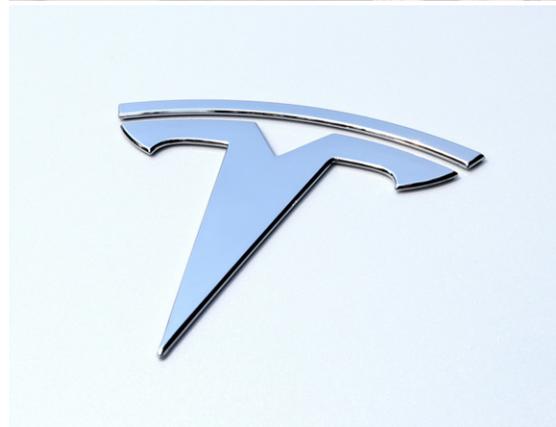
BY RICHARD YOUNGMAN, CEO, CLEANTECH GROUP

It has been 15 years since we first started the Global Cleantech 100, a time when Cleantech Group was still able to exchange emails directly with the CEO of an upcoming private company called Tesla (who was on the inaugural list).

Over those 15 years, the program has lived up to its original purpose of acting as “a barometer on global cleantech innovation,” charting how viewpoints change over time—of what company types, in what industry groups, sectors and sub-sectors, show the strongest signals of common market support and admiration amongst leading and active players in the market, and so show the brightest prospects for future impact.

Our approach deliberately has never required a company to apply or opt in, and all the expert inputs we take are blind to each other to try and avoid “group think” or the loudest opinion in a room drowning out a silent majority. It’s meant as a serious research exercise, not a competition per se.

That first Global Cleantech 100 was dominated by renewables (mostly solar, some wind, even some early wave/tidal energy players), early energy storage solutions, energy efficiency plays, especially around LED lighting (e.g., BridgeLux), but also, and interestingly, more water companies (e.g., NanoH2O) than the Global Cleantech 100 has ever seen again. There were 9 in 2009.





One reflection, when looking at the 2024 cohort, speaks to the incredible costing down that occurred in the 2010's—something we should keep in mind when we wonder about the green premiums on many other clean technology solutions today, represented in the 2024 list, not even on the 2009 radar (e.g., green steel, cement, alternative proteins).

- The first Global Cleantech 100 was dominated by companies developing the beginnings of today's solar industry— most on cells, next-gen panels and PV systems, but also inverters (e.g., Enphase Energy) and the first business model/deployment play (e.g., SolarCity). Today, solar has a sophisticated, industrial value-chain and is an industry well on its multi-decade way to full maturity. The 2024 list carries companies trying to drive down costs and create efficiencies in every part of that value chain (think [Omniadian](#), [Raptor Maps](#)), companies reacting to the huge volumes of solar waste that are coming (e.g., [ROSI](#)); or ones who offer next generational levels of efficiency ([Oxford PV](#), [Sunman Energy](#)).
- Storage and batteries were a significant part of the 2009 list (e.g., A123 Systems, Boston Power), but in 2024 the battery has advanced to the point where the new crop of companies are very much focused on specific ways of improvement — be that in the anode, cathode, via new chemistries, second life, or battery intelligence (e.g., [6K](#), [Accure](#), [Liminal](#), [Relectrify](#)). And the storage category has expanded to thermal (e.g., [Rondo Energy](#)) and to long-duration (e.g., [Energy Dome](#)).
- That we have reached this scaling manufacturing phase explains why there are so many companies in the 2024 cohort representing critical minerals and how to obtain them, whether that appears through Direct Lithium Extraction, battery recycling, recycling of lithium, nickel, rare earth elements, etc. (e.g., [Cyclic Materials](#), [Green Li-ion](#), [Lilac Solutions](#), [Nth Power](#), [Summit Nanotech](#))— or through how to make mining less inefficient and/or less damaging in the original extraction process (e.g., [Minesense Technologies](#), [Plotlogic](#)).

A second reflection in looking at the 2024 list in comparison to 2009 is a feeling of full circle— albeit with some key differences:

- We have a wave company ([CorPower Ocean](#)) back on the list for the first time in more than 10 years; and the presence of geothermal seems to grow year-over-year, after [Fervo Energy](#) debuted in 2022. This speaks to the idea that we will need every form of low carbon energy possible, including nuclear (in the shape of SMRs) and fusion (absent from the list this year, mostly because the leading companies have become too big to qualify).
- The 2009 list saw some of the last vestiges of the fuel cell/hydrogen hype curve of the 2000's (e.g., Bloom Energy). Hydrogen is back in vogue in 2024—with multiple representatives in the electrolysis and production of green hydrogen space.

- The 2009 list had many biofuels companies (e.g., Amyris, Gevo). Today, the fuels companies on the list are far more sustainable in their feedstocks and have very specific solutions in mind—e.g., [Amogy](#) (shipping), [OXCCU](#) (aviation).

In 15 more years, we will be at 2039—by which time, a mere decade out from the “net-zero” target of 2050, I would expect the composition of our annual list to have markedly changed again, and the leading upcoming private companies of that time to reflect such.

Perhaps there will be more Adaption vs. Mitigation companies on the 2039 Global Cleantech 100? We expect to see such companies on future lists, given how we are clearly failing to keep the Paris 1.5C dream alive, despite the best efforts of the 2024 Global Cleantech 100 companies and hundreds more beyond.

*Richard Youngman*





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# ACKNOWLEDGEMENTS

Cleantech Group is pleased to present the 15th 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 57-59) 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](https://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 I and Phase 2 are pooled and adjusted for geographic or other biases. Companies with the highest points overall make it to the final 100.

## 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 25,435 from over 65 countries—a 61% increase from the 2023 nomination process. These companies were weighed and scored to create a short list of 330 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.

\*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 2023.



Listed in alphabetical order by Industry Group

# GLOBALCLEANTECH**100**

INNOVATION - MITIGATION - ADAPTATION

2024



KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# AGRICULTURE & FOOD

DATA STATS  
9 COMPANIES  
6 COUNTRIES

INDUSTRY INSIGHT REDUCING ENVIRONMENTAL IMPACTS OF ANIMAL AGRICULTURE CONTINUES TO BE A KEY DRIVER

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 <b>BeeHero</b>	Beehive management platform including in-hive sensors to monitor colony health and pollination activity	Israel	2017
 <b>loam</b>	Microbial products for soil-based carbon sequestration	Australia	2019
 <b>mori</b>	Silk-derived biomaterial coating that extends shelf life of perishable foods	United States	2016
 <b>Mosa Meat</b>	Cultivated meat grown from animal cells	Netherlands	2013
 <b>paleo</b>	Animal-free heme proteins via precision fermentation, for use as ingredients in alt-protein products	Belgium	2020
 <b>Rumin8</b>	Feed supplement that reduces methane emissions from livestock	United States	2021
 <b>Too Good To Go</b>	App that connects users with unsold food from shops and restaurants to reduce waste	Denmark	2015
 <b>VESTARON</b> THE POWER OF PEPTIDES	Biopesticides using naturally-occurring peptides to replace conventional chemical crop controls	United States	2005
 <b>WILDTYPE</b>	Cultivated salmon saku grown from fish cells	United States	2016

KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# ENERGY & POWER

**DATA STATS**  
42 COMPANIES ↑  
15 COUNTRIES ↔

**INDUSTRY INSIGHT** ENERGY & POWER REMAINS THE LARGEST  
CLEANTECH INDUSTRY GROUP IN TERMS OF RECORDED DEALS  
AND MONEY INVESTED

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 <b>ACCURE</b> Battery Intelligence	Platform that enables APIs to access battery data to manage, analyze and predict battery health	Germany	2020
 <b>AERONES</b>	Robotics for wind turbine inspection, repair, cleaning, commissioning	Latvia	2015
 <b>AKSELOS</b>	Predictive, physics-based digital twins for the management of large energy assets	Switzerland	2012
 <b>AMOGY</b>	On-board ammonia cracking system, enabling retrofits of maritime ships to hydrogen power	United States	2020
 <b>BLOC POWER</b>	Data-enabled, financed heating and cooling retrofit services for multifamily buildings	United States	2014
 <b>CorPower Ocean</b>	Hydraulic wave energy conversion, turning buoys into renewable power generators	Sweden	2009
 <b>C  ZERO</b> Decarbonizing Natural Gas	Methane pyrolysis technology to break down methane into hydrogen and solid carbon	United States	2018
<b>DANDELION ENERGY</b>	Software-enabled residential geothermal systems for heating, cooling and hot water	United States	2017
 <b>deepki</b>	Software for building, using statistics and computer science to turn existing customer data into energy efficiency action plans	France	2014
 <b>Eavor™</b>	Closed-loop, conduction-only geothermal energy solutions	Canada	2017
 <b>ecoligo</b>	Solar utility that provides low-cost solar energy to businesses in emerging markets by financing through a crowd investing platform	Germany	2016

KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# ENERGY & POWER

**DATA STATS**

42 COMPANIES ↑

15 COUNTRIES ↔

**INDUSTRY INSIGHT** ENERGY & POWER REMAINS THE LARGEST  
CLEANTECH INDUSTRY GROUP IN TERMS OF RECORDED DEALS  
AND MONEY INVESTED

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 <small>Affordable green hydrogen</small>	Manufacturer of anode-supported, solid oxide electrolyzer cells, stacks, and fuel cells	Estonia	2001
	Novel electrolysis-based hydrogen production technology for industrial-scale applications	United States	2021
	Power-to-gas energy storage technology that converts excess electricity from wind and solar into renewable gas	Germany	2010
 <small>Our WORLD can't wait.</small>	Long-duration electricity storage solutions using liquid CO <sub>2</sub>	Italy	2019
	Digital infrastructure that connects energy management software to hardware and distributed energy resources	Norway	2020
 <small>Energy Services for Industry</small>	Automated system to monetize the flexibility of industrial and generation energy assets for their clients on the intraday markets through algorithmic trading	Germany	2015
	Zinc battery technology which stores electricity in zinc metal for large-scale energy storage	Canada	2012
	Technology for power generation using enhanced geothermal systems	United States	2017
	Software provider that specializes in clean energy management solutions for utilities, energy managers, traders, and large energy buyers	France	2021
	Hydrogen storage in the form of 'Liquid Organic Hydrogen Carriers' for multi-megawatt energy systems	Germany	2013
	Electric motor technology	United States	2014

KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# ENERGY & POWER

**DATA STATS**

42 COMPANIES ↑

15 COUNTRIES ↔

**INDUSTRY INSIGHT** ENERGY & POWER REMAINS THE LARGEST  
CLEANTECH INDUSTRY GROUP IN TERMS OF RECORDED DEALS  
AND MONEY INVESTED

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 <b>instagrid</b>	Portable power packs for professionals with various applications including construction, small businesses, and event organizers	Germany	2018
 <b>Kairos Power</b>	Fluoride salt-cooled high temperature small nuclear reactor	United States	2016
 <b>KRAFT BLOCK</b>	Thermal energy storage solutions	Germany	2014
 <b>liminal</b>	Ultrasound technology and machine learning to provide insights into battery manufacturing and improve performance and longevity of batteries	United States	2015
 <b>QMNIDIAN</b>	Protection plans for investments in residential solar energy systems	United States	2015
 <b>OXFORD PV™</b> <small>The Perovskite Company</small>	Technology plug and play perovskite-on-silicon tandem solar cells that enable solar energy cost reductions	United Kingdom	2010
 <b>pico®</b>	B2B flexibility auction marketplace that facilitates flexible contracts, and an energy management platform for efficient and reliable energy grids	United Kingdom	2013
 <b>QPINCH</b>	Chemical heat pump that converts waste heat into carbon neutral industrial heat	Belgium	2012
 <b>RAPTOR MAPS</b>	Solar performance optimization software and aerial inspection solutions	United States	2014
 <b>RELECTRIFY</b>	Cell-level battery management system	Australia	2015

KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# ENERGY & POWER

**DATA STATS**  
42 COMPANIES ↑  
15 COUNTRIES ↔

**INDUSTRY INSIGHT** ENERGY & POWER REMAINS THE LARGEST  
CLEANTECH INDUSTRY GROUP IN TERMS OF RECORDED DEALS  
AND MONEY INVESTED

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 <b>RONDO</b>	Thermal battery technology that stores wind and solar power to support industrial decarbonization	United States	2020
 <b>ROSII</b>	Solutions for recycling and revalorization of raw materials in the PV industry	France	2017
 <b>SENSORFACT</b>	Intelligent Energy Management System (IEMS) to help industrial companies reduce their energy consumption	Netherlands	2016
 <b>SPAN</b>	Smart electrical panels and paired software to provide visibility and control at the edge-of-grid	United States	2018
 <b>Starfire Energy</b>	Modular chemical plants including clean ammonia for energy storage and fuel	United States	2007
 <b>SVMAN</b> <small>Lightweight Solar Pioneer</small>	Light and flexible solar panels and mobile floating solar systems	China	2014
 <b>tado°</b>	Smart thermostat and SaaS platform allowing users to control their home heating and cooling systems from their smart phones	Germany	2011
 <b>Terabase</b>	Development and deployment platform that tracks and automates utility-scale solar development	United States	2019
 <b>WeaveGrid</b>	Machine learning software which solves EV-grid integration challenges for utilities	United States	2018
 <b>YOTTA</b> <small>ENERGY</small>	Solar modular energy storage solution	United States	2017

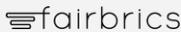
KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# MATERIALS & CHEMICALS

**DATA STATS**  
18 COMPANIES ↓  
9 COUNTRIES ↔

**INDUSTRY INSIGHT** A CONTINUED FOCUS ON HARD-TO-ABATE SECTORS WITH CEMENT IN PARTICULAR GAINING TRACTION COMPARED TO LAST YEAR

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
	Microwave plasma technology for the production of battery materials and additive manufacturing powders	United States	2014
	Process that seals the central heating/cooling and ventilation ductwork within residential homes and commercial buildings	United States	1993
	Renewable natural-fiber composite materials for stiff and lightweight vehicle body panels	Switzerland	2011
	Molten oxide electrolysis technology for steelmaking, and production of other metals and alloys	United States	2012
	Technology to produce carbon-neutral portland cement and supplementary cementitious materials	United States	2019
	Conductive nano copper inks for additive copper printing	Israel	2016
	Catalysts that enable production of polycarbonates, polyols and polymers from CO <sub>2</sub>	United Kingdom	2011
	Virgin synthetic fabrics manufactured with waste CO <sub>2</sub>	France	2019
	Bacterial technology to turn food waste into polyhydroxyalkanoates (PHAs), a high-quality bioplastic	Canada	2016

KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# MATERIALS & CHEMICALS

**DATA STATS**  
18 COMPANIES ↓  
9 COUNTRIES ↔

**INDUSTRY INSIGHT** A CONTINUED FOCUS ON HARD-TO-ABATE SECTORS WITH CEMENT IN PARTICULAR GAINING TRACTION COMPARED TO LAST YEAR

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 INERATEC	Modular chemical plants for Power-to-X and Gas-to-Liquid applications	Germany	2016
 INNOVATIONS	Durable anion-exchange membrane for fuel cells, fuel production and metal recovery	Canada	2015
 MANGROVE LITHIUM <small>Unlocking a battery-powered future</small>	Modular platform for the cost-effective production of battery-grade lithium hydroxide	Canada	2017
 OXCCU	Sustainable fuels, chemicals and biodegradable plastic products generated from captured CO <sub>2</sub>	United Kingdom	2021
 PAPTIC®	New material to replace plastic and paper bags	Finland	2015
 p7	Processes and new methodologies for extractive metallurgy	Canada	2020
 Sublime Systems	Electrochemical process to produce cement	United States	2020
 SUMMIT NANOTECH	Lithium and other valuable metals from brine water using advanced nanomaterials	Canada	2018
 TAU	Solvent-free high performance coatings and wires, enabling more powerful and sustainable motors	Italy	2015

KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# RESOURCES & ENVIRONMENT

**DATA STATS**  
22 COMPANIES ↓  
7 COUNTRIES ↔

**INDUSTRY INSIGHT** A STRONG FOCUS ACROSS CRITICAL MATERIAL SUPPLY CHAINS, SMART WASTE SORTING AND HIGH-QUALITY CARBON REMOVAL

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 AMP ROBOTICS™	Waste sorting AI-guided robotics, computer vision, and deep learning to transform the economics of recycling	United States	2015
 carbon clean <small>TECHNOLOGY TO ACHIEVE NET ZERO</small>	CO <sub>2</sub> capture technology and solvents that significantly reduces the costs and environmental impacts of CO <sub>2</sub> separation	United Kingdom	2009
 carbon upcycling	Technology for sequestering CO <sub>2</sub> gas into a solid form within concretes, plastics and coatings	Canada	2014
 Circular	Traceability software for materials in industrial supply chains, including e-waste, battery materials and plastic	United Kingdom	2017
 Cyclic Materials	Circular supply chain service platform facilitating the recycling of rare earth elements via its proprietary Mag-Xtract and Hydrometallurgy technologies	Canada	2021
 dendra SYSTEMS	Drone-powered aerial seeding and reforestation monitoring services on an industrial scale	United Kingdom	2014
 ebb carbon	Proprietary electrochemical system to remove acid from the ocean and enhance its natural ability to draw down atmospheric CO <sub>2</sub> and store it as oceanic bicarbonate	United States	2021
 green union	Fully re-manufacturing lithium-ion batteries via precipitation, co-precipitation, selective regeneration, and electro separation technologies	Singapore	2020
 greyparrot 	Computer vision solutions to power robotics and smart systems for waste management at each stage of the value chain	United Kingdom	2019
 KAIROS AEROSPACE	Advanced aerial sensors combined with cloud-based analytics to rapidly find methane leaks on a continental scale	United States	2014
 Lilac SOLUTIONS	Lithium extraction technology from brines without the need for evaporation ponds	United States	2015

KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# RESOURCES & ENVIRONMENT

**DATA STATS**  
22 COMPANIES ↓  
7 COUNTRIES ↔

**INDUSTRY INSIGHT** A STRONG FOCUS ACROSS CRITICAL MATERIAL SUPPLY CHAINS, SMART WASTE SORTING AND HIGH-QUALITY CARBON REMOVAL

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 measurabi	On-demand sustainability data and reporting software for real estate owners' performance indicators	United States	2013
 minesense	Shovel sensor technology to capture ore in mining waste and provide real-time analytics during extraction	Canada	2008
 moment energy	Recycler of retired electric vehicle batteries into clean, affordable energy storage	Canada	2019
 NTH CYCLE	Modular system to recycle critical metals from e-waste using a unique electro-extraction process	United States	2017
 NTX <sup>®</sup>	Textile printing dye technology to reduce energy use and wastewater	China	2000
 pani Zero in on water	Predictive optimization and management software to improve the efficiency, uptime, and emissions of water treatment plants	Canada	2017
 PLOTLOGIC	LiDAR, hyperspectral imaging and machine learning algorithm technologies to autonomously characterize materials in mining	Australia	2016
 SORTERA	Scrap metal autonomous sorting technology using AI to optimize recycling	United States	2020
 Svante	Energy-efficient technology for capturing carbon dioxide from industrial sources	Canada	2007
 twelve	Electrochemical process that recycles carbon dioxide into synthesis gas for chemicals and fuels	United States	2015
 XOCEAN <sup>®</sup>	Carbon-neutral ocean mapping and monitoring platform to support sustainable supply chains in the offshore industry	Ireland	2017

KEY: ↑ Increase on 2023 figures ↓ Decrease on 2023 figures ↔ Same as 2023 figures



# TRANSPORTATION & LOGISTICS

DATA STATS  
9 COMPANIES  
3 COUNTRIES

INDUSTRY INSIGHT CLEAR FOCUS ON COMMERCIAL VEHICLE ELECTRIFICATION AND CHARGING INFRASTRUCTURE SOLUTIONS

COMPANY	DESCRIPTION	COUNTRY	YEAR FOUNDED
 BluSmart	Operator of electric ride-hailing fleet and proprietary charging infrastructure network	India	2019
 CHI	On-demand repairs and maintenance support for charging stations	United States	2020
 ELECTRIC ERA	Autonomous software platform for fast-charging EV charging stations to minimize grid strain and optimize charging costs and revenue for operator	United States	2019
 ev.energy	Software platform to integrate electric vehicles into residential energy systems, leveraging predictive forecasting to optimize renewable energy integration, reduce charging costs and grid demand	United Kingdom	2018
 FORUM MOBILITY	Electric heavy-duty trucks and charging-as-a-service	United States	2021
 HARBINGER	Electric medium-duty and specialty vehicles, vehicle components, and autonomous driver assistance software	United States	2021
 Wings	EV tractors with automated operations that provide data analytics	United States	2017
 Recurrent	EV battery data analysis for transparency and battery health monitoring	United States	2020
 ZEROAVIA	Hydrogen-based powertrain to enable zero-emission aviation	United States	2017

# TREND WATCH 2024

WRITTEN BY  
ANTHONY DEORSEY,  
RESEARCH MANAGER



## A SOFT LANDING ON THE RIGHT SIDE OF THE PANDEMIC

Much has been made this year of the venture funding drop-offs across cleantech, and technology at large. As expected, 2021 and H1 2022 remain unmatched in the volume of venture dollars directed at cleantech innovators. Despite this, we come out of 2023 showing that even without the outlier years of 2021 and 2022, the general upward trend continues.

Encouragingly, corporate involvement in venture rounds has stayed closer to 2021 and 2022 than the years prior. Within corporate participation in 2023, Microsoft Climate Innovation Fund alone participated in five investment rounds of 2024 Global Cleantech 100 companies (*Eavor*, *Electric Hydrogen*, *Rondo Energy*, *AMP Robotics*, and *Boston Metal*).

Automotive and aviation corporate venture capital units have become especially important in the mix; take BMW i Ventures who in 2023 invested in GCT100 company *Cyclic Materials* but is also in the cap tables of Global Cleantech 100 companies *Mangrove Lithium*, *bcomp*, *Lilac Solutions*, and *Boston Metal*. Airbus Ventures is an investor in Global Cleantech 100 companies *bcomp* and *Dendra Systems*, and *ZeroAvia* took in a 2023 investment from Airbus.

## WE COME OUT OF 2023 SHOWING THAT EVEN WITHOUT THE OUTLIER YEARS OF 2021 AND 2022, THE GENERAL UPWARD TREND CONTINUES

FIG. 1: VENTURE & GROWTH INVESTMENTS IN CLEANTECH, % OF DEALS WITH CORPORATE INVOLVEMENT

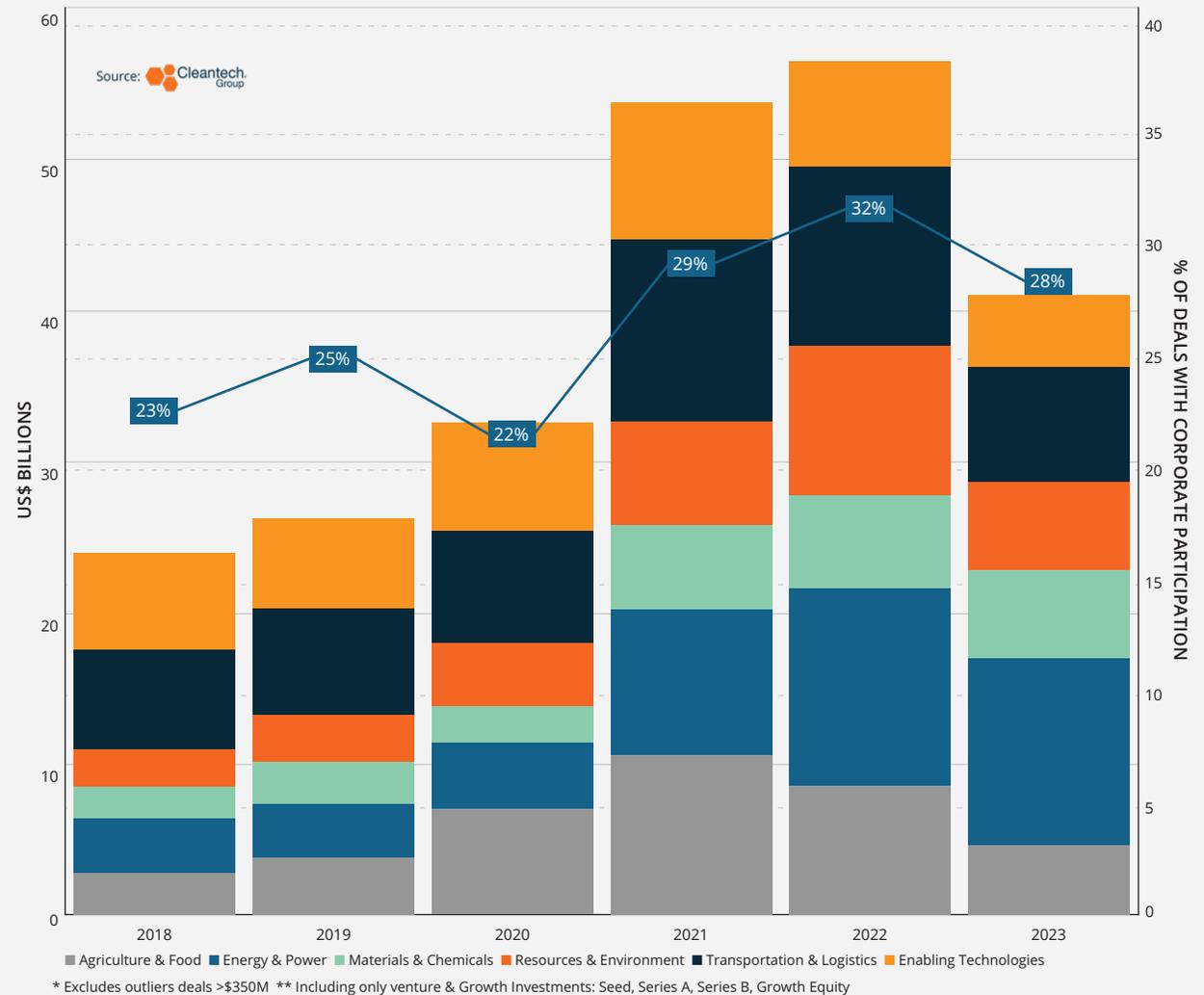


FIG. 2: MERGERS & ACQUISITIONS

Source:  Cleantech Group

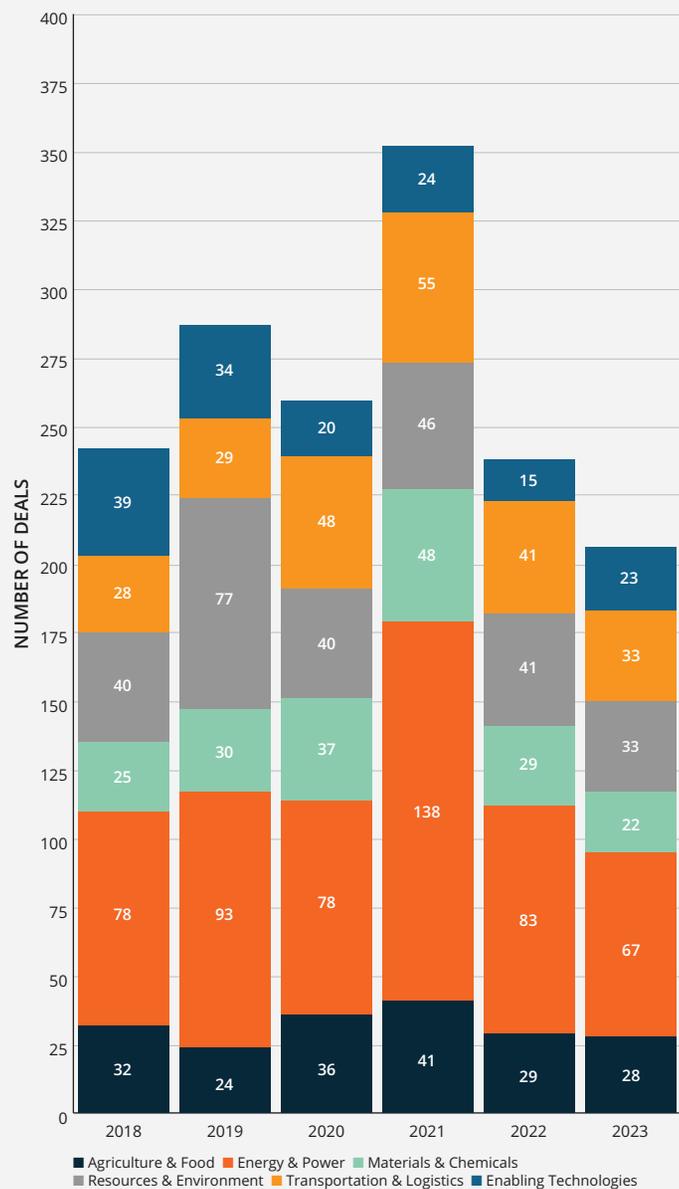
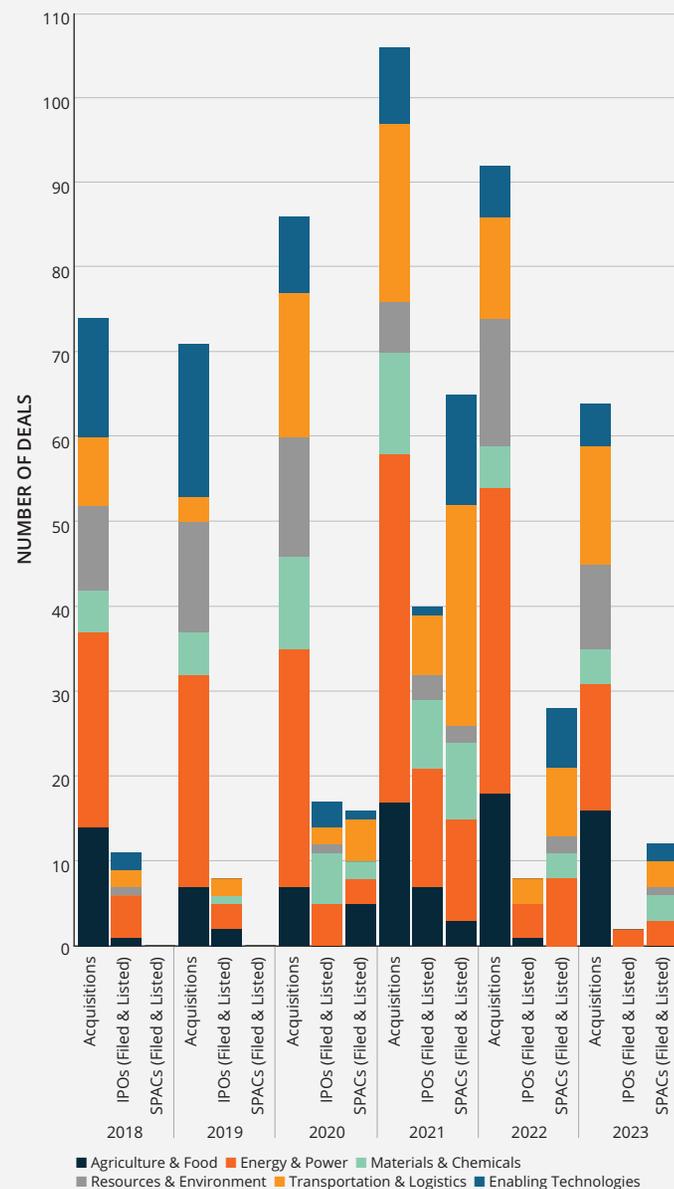


FIG. 3: EXITS OF VENTURE-BACKED INNOVATORS

Source:  Cleantech Group



The mergers and acquisitions environment continued to cool in 2023, after a steep drop-off in 2022. IPOs of venture-backed cleantech companies have slowed considerably since 2021, with venture-backed innovators exiting through acquisitions and IPOs at a level similar to pre-pandemic. The door has all but closed on Special Purpose Acquisition Company (SPAC) listing routes. Reluctance to back companies in SPACs can mostly be attributed to an inability of many SPAC stocks to perform on the public markets - some de-listing through private acquisitions for less than they initially listed for.

Despite a thinner acquisitions market, some companies are still finding daylight. 2023 saw acquisitions of [Carbon Engineering](#) (on the Global Cleantech 100 list 2020, 2021, 2022) for \$1.1B by Occidental Petroleum, [GaN Systems](#) (on the list in 2014, 2015, 2017-2021, 2023), by Infineon and [Deep Sea Technologies](#) (on the last two lists) by Nabtesco.

**THE MERGERS AND ACQUISITIONS ENVIRONMENT CONTINUED TO COOL IN 2023, AFTER A STEEP DROP-OFF IN 2022**

### THE INFLATION REDUCTION ACT A YEAR IN: SOFTENS THE LANDING, FIRMS UP HARD TECH

Perhaps the most significant clean energy catalyst in the U.S. to date, the Inflation Reduction Act (IRA) has already been a critical lever to de-risk private sector investments. Energy & Power innovators in the U.S. are already seeing the effects of the IRA – as can be seen from Figure 4. Venture-backed innovators in the U.S. took in a more diverse array of financing in 2023 than the previous years where equity made up the majority of the mix. This indicates that U.S.-based innovators' business models have become slightly more bankable in the wake of the IRA, softening the blow of high interest rates that otherwise raise the bar of internal rates of return required for equity investments.

If compared to the European Union, U.S.-based energy innovators experienced a better 2022 and a 2023 comparable to 2021. Nevertheless, the effects from the Net Zero Industry Act (NZIA) in the EU have likely already been felt, as the second half of 2023 was significantly brighter for European energy innovators than the first half.

It will come as no surprise that the lion's share of project finance and loan guarantees in the U.S. has gone to solar – the IRA's effects on U.S. solar (Over \$100B in investments and 20,000 manufacturing jobs) have been well-publicized. Elsewhere, energy storage companies are now seeing a path to growth beyond the equity financing continuum, and as a result, are raising more funds in the equity funding stages (see Energy & Power section for analyses on battery and stationary storage technologies).

### ENERGY & POWER INNOVATORS IN THE U.S. ARE ALREADY SEEING EFFECTS OF THE INFLATION REDUCTION ACT (IRA)

FIG. 4: FINANCING OF ENERGY & POWER INNOVATION SINCE THE INFLATION REDUCTION ACT (IRA) & NET ZERO INDUSTRY ACT (NZIA)

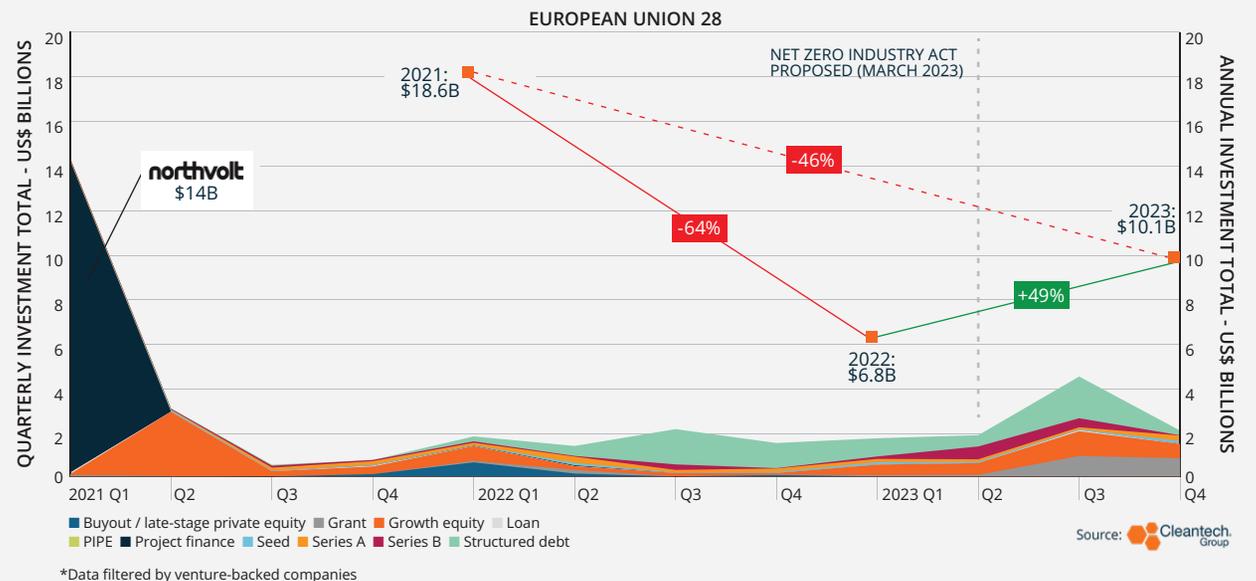
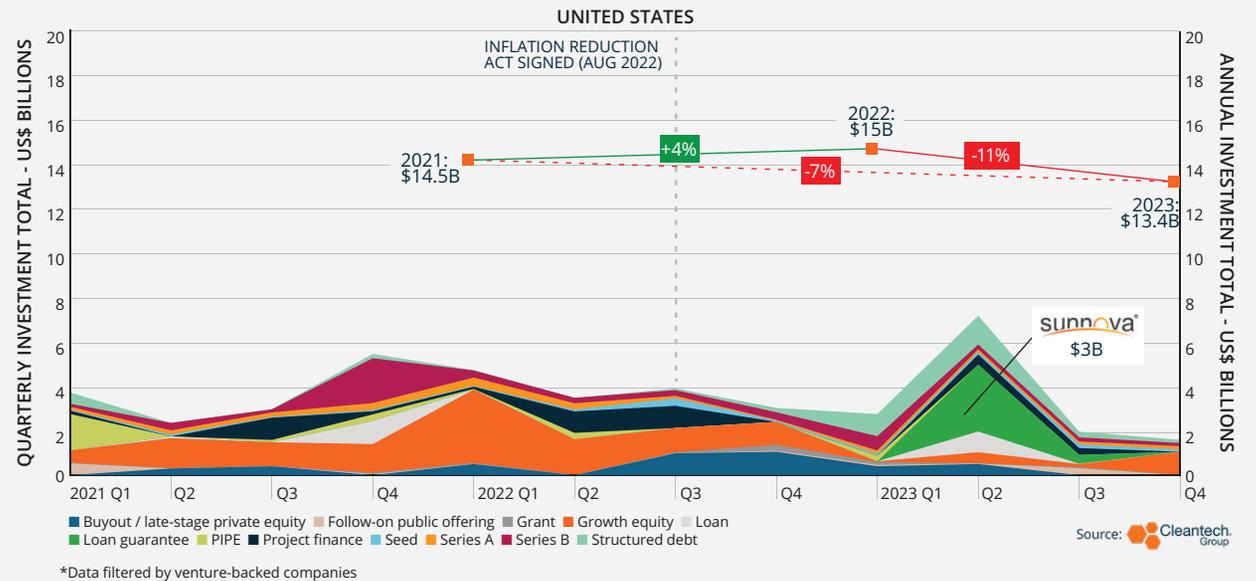
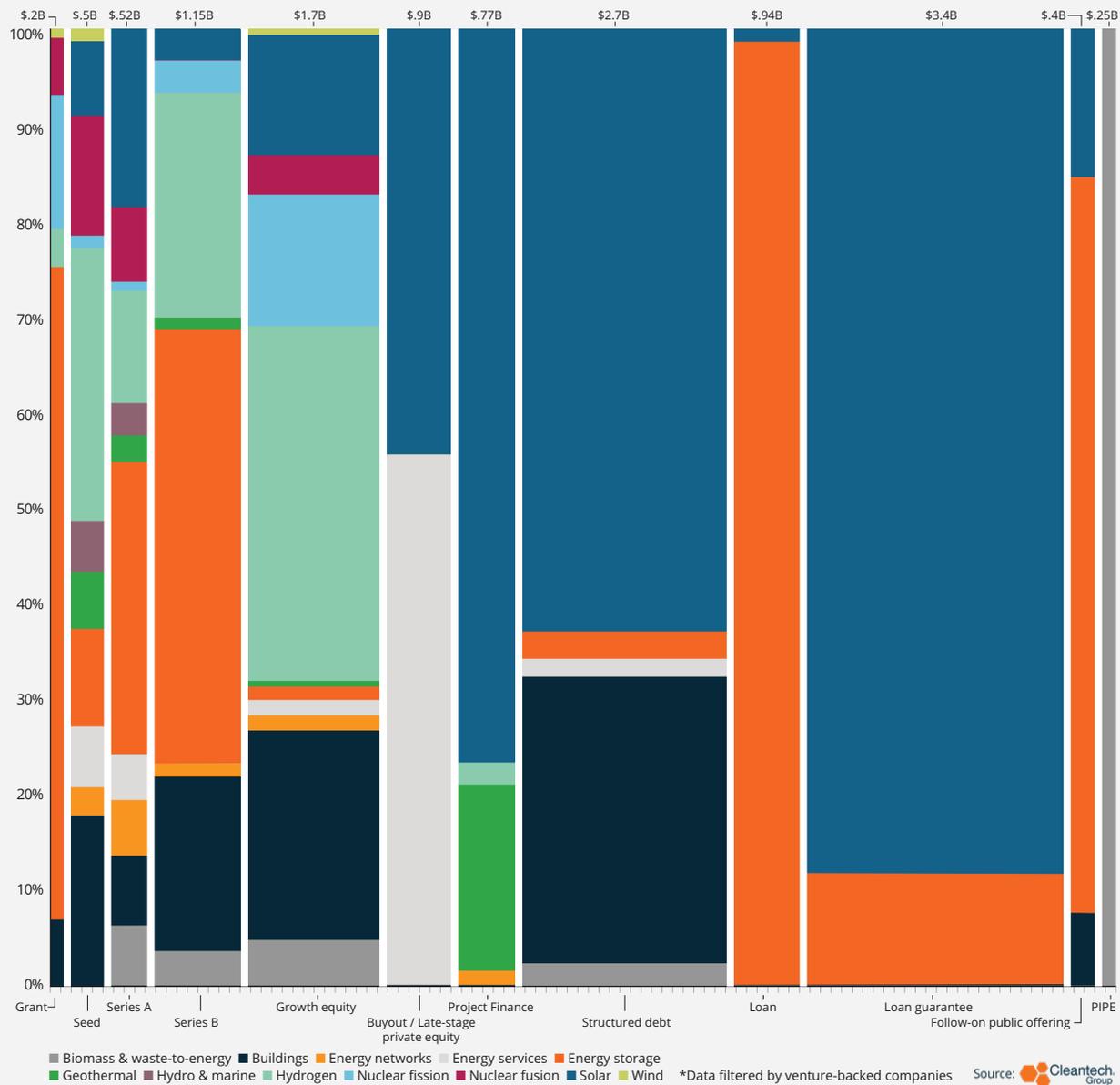


FIG. 5: FINANCING OF ENERGY & POWER INNOVATION IN THE U.S., 2023



Perhaps the most noticeable push can be seen in hydrogen. Low- and no-carbon hydrogen tech has leapfrogged the final mile of the financing continuum to begin hitting manufacturing lines in 2024. Case in point – 2023-2024 Global Cleantech 100 company **Electric Hydrogen** not only raised a \$380M Growth Equity round in 2023, the company also announced plans for a 1.2GW capacity electrolyzer factory in Massachusetts, followed in short order by an announced electrolyzer supply agreement with New Fortress Energy in Texas.

Hydrogen breakthroughs that are accelerated today will have a compounding effect with downstream innovation. New technology for fuel cells (e.g., solid oxide fuel cells, Global Cleantech 100 company **Elcogen**) and power-to-liquids for jet fuels (Global Cleantech 100 companies **OXCCU** and **Interatec**) aim to reduce CAPEX for end users (vs. hydrogen production that reduces OPEX of electricity use).

Outside of batteries and hydrogen, **Blocpower** (Global Cleantech 100 2021–2024) is an example of a company that has taken a giant leap forward through a large equity plus debt round. In 2023, the company raised a \$154M (\$24M equity + \$130M debt round) to accelerate development of its proprietary BlocMaps software that will slash costs and speed up roll-out of the company's building electrification and sealing solutions.

**ENERGY & POWER INNOVATIONS IN THE US ARE ENTERING NEW PHASES OF REAL PROJECTS AND MANUFACTURING**

**THE COMING FIGHT FOR THE FACTORY FLOOR**

One of the most marked shifts in cleantech innovation over the past few years has been a shift in innovator focus toward sustainability in heavy industries and commodities production (see Figure 6). There are two increasingly ubiquitous themes emerging in manufacturing-related cleantech: 1) a fight for ownership over the critical materials supply chain, and 2) competition to own heat decarbonization pathways or to replace heat in industrial processes altogether.

Bills like the IRA and NZIA help to nudge new technologies out the door and keep supply chains onshore – innovators have reacted quickly to improve the extraction, refining, and production of materials for the new energy economy. The race to secure critical materials that support production and recycling of EV batteries is well-reflected in this year’s Global Cleantech 100, with obvious developments in:

- Direct lithium extraction: Adsorption to selectively capture lithium with sorbents and re-inject impurities (2024 Global Cleantech 100 company **Summit Nanotech**) and ion-exchange to remove the need for evaporation ponds (2021-2024 GCT 100 company **Lilac Solutions**).
- Advanced material refining: Electrochemical refining of lithium, post-extraction (2023-2024 Global Cleantech 100 company **Mangrove Lithium**) and non-aqueous solutions to extract copper and platinum group metals from ores and waste materials (2024 Global Cleantech 100 company **Ph7 Technologies**).

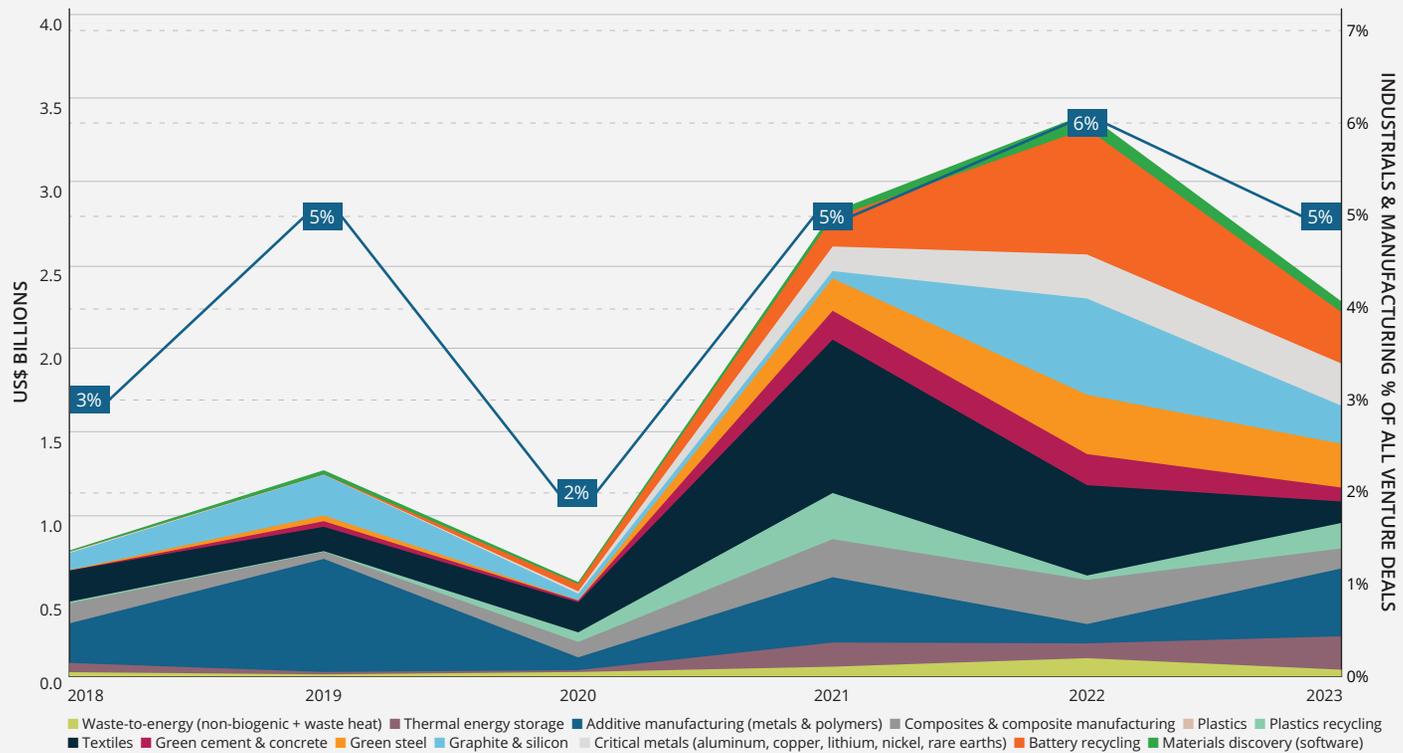
■ Advanced critical materials recovery: Microwave plasma technology (2023-2024 Global Cleantech 100 company **6K**) and electrochemical processing (2024 Global Cleantech 100 company **Nth Cycle**) that aim to advance efficiency of materials recovery beyond today’s hydrometallurgical and pyrometallurgical processes.

Long recognized as the hardest-to-abate sectors, heavy manufacturing (steel, cement, chemicals) and commodities production (glass, paper, metals) have lingered in the background of the sustainability discussion over the past few decades. Core to decarbonization in these industries is reducing either the heat profile of the production process or bringing in non-fossil fuel heat that can slice out the most problematic pieces of industrial manufacturing.

■ Electrochemical processing aims to produce heavy materials with an electrolysis process at low or ambient temperatures – Global Cleantech 100 companies **Boston Metal** (steel through molten oxide electrolysis) and **Sublime Systems** (cement through electrolytic lime production) are pioneering these techniques.

**FIG. 6: VENTURE & GROWTH INVESTMENTS IN CLEANTECH FOR INDUSTRY & MANUFACTURING**

Source: **Cleantech Group**



\* Excludes outliers deals >\$350M \*\* Including only venture & Growth Investments: Seed, Series A, Series B, Growth Equity

■ In cement, there is an additional challenge of removing the point-source CO<sub>2</sub> emissions when converting limestone to lime. Global Cleantech 100 companies **Brimstone** and **Sublime Systems** are leveraging non-carbonate rocks in their process to flatten the direct emissions risk.

■ Novel approaches to thermal energy storage allow for stored temperatures high enough to generate power or directly heat processes using abundant materials – see Global Cleantech 100 companies **Rondo Energy** (perforated bricks) and **Kraft Block** (upcycled steel slag).

■ Global Cleantech 100 company **QPinch** has developed a chemical heat pump to convert industrial waste heat back into process heat, hollowing out OPEX by replacing energy inputs, with applications in Chemicals and Food & Beverage production.

**THE DIGITAL-PHYSICAL INTERSECT INTENSIFIES**

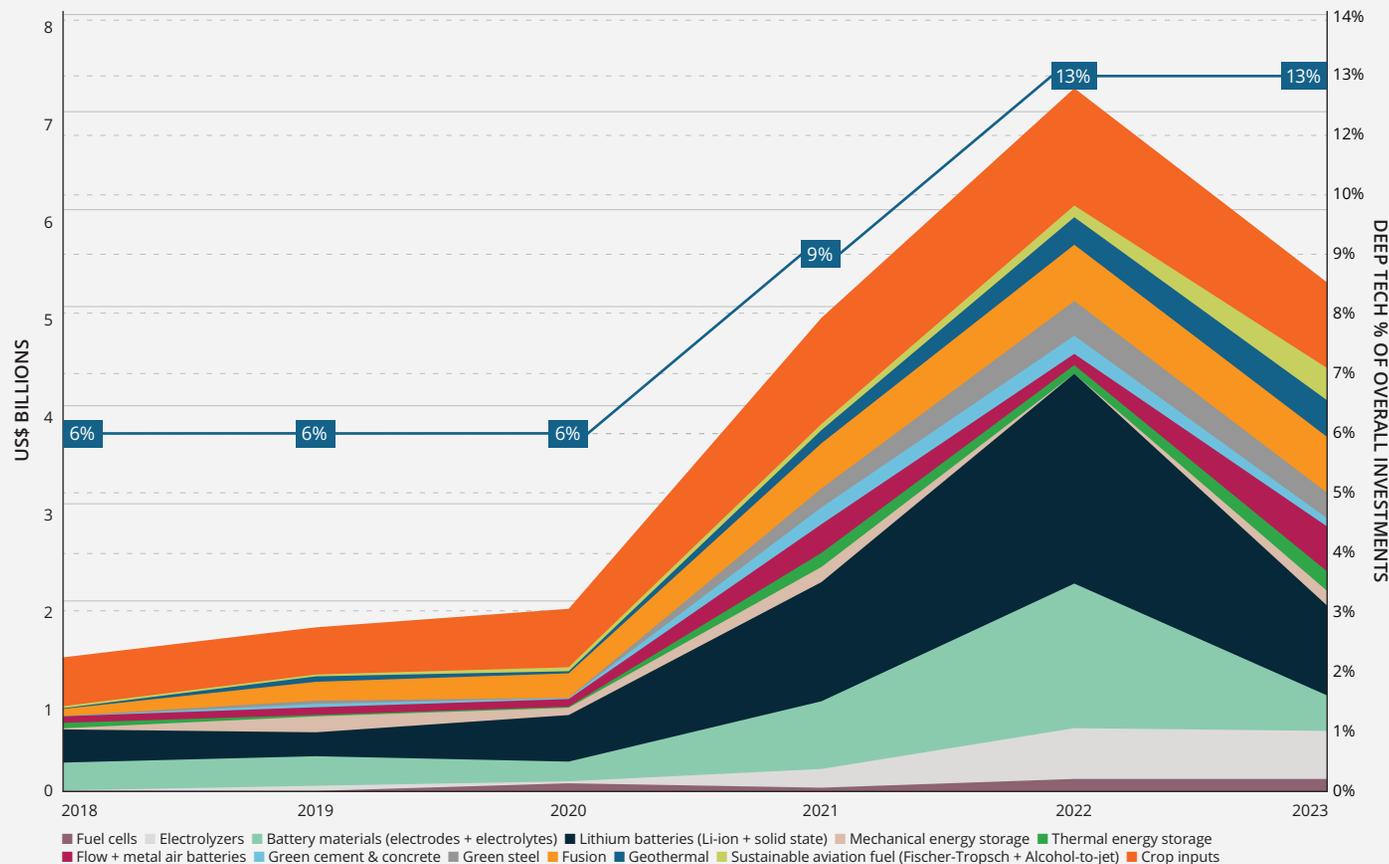
As we have highlighted as recently as our **2023 Cleantech 50 to Watch**, a critical development in the cleantech space has been the growth of innovation and investments in “deep tech”, the core hardware elements of the next sustainability frontier. This trend has only intensified, and deep tech investments in 2023 comprised over 13% of all cleantech investments, the highest percentage they ever have.

Nevertheless, the on-the-ground dynamic is becoming less and less a trade-off of software vs. hardware than it is a race to take hardware to the next level by leveraging AI in the tech development or deployment process. Different from the buzz around generative and general purpose AI, innovators in the cleantech space are taking aim at granular problems, and unsticking hardware limitations to differentiate. If we take the trend of improved attention to manufacturing technology and deep tech as a positive one, this year’s Global Cleantech 100 list demonstrates special promise in the potential of AI to push hardware even further:

■ Battery assessment at all stages: Global Cleantech 100 companies **Liminal Insights** (ultrasound sensing for production quality assessment) and **Accure** (real-time battery performance analytics) are flattening the safety and failure risks of lithium-ion batteries.

■ 2024 Global Cleantech 100 company **Relectrify** has replaced the busbars and battery management system with an on-battery circuit board and software to manage down to the cell, and bypass failing or dangerous cells.

FIG. 7: VENTURE & GROWTH INVESTMENTS IN DEEP TECH CLEANTECH



Source:  Cleantech Group

\* Excludes outliers deals >\$350M \*\* Including only venture & Growth Investments: Seed, Series A, Series B, Growth Equity

Waste identification and sorting: 2024 Global Cleantech 100 company **GreyParrot** is using computer vision and analytics to assess financial value, food value, and brand types in waste streams. 2020-2024 Global Cleantech 100 company **AMP Robotics** is using computer vision to identify classes of waste for automated sorting and de-packaging.

One of the best examples of the deepening physical-digital intersect is within the built environment theme (see Figure 9). While building management systems remain the undergirding technology area in this theme, it is now able to achieve deeper building decarbonization as a result of better HVAC hardware in the mix.

**BlocPower**, mentioned earlier, is leveraging data analytics to compress the “soft costs” of scoping, prospecting, and quoting for building upgrades.

2024 Global Cleantech 100 company **Infinitem** has re-engineered variable frequency drive electric motors for HVAC systems – the Infinitem smart motor system is enhanced by software that allows for granular control and preference-setting.

Solutions like 2024 Global Cleantech 100 company **Deepki** that transform building performance data into ESG insights are likely to stimulate a pull-through effect for better HVAC hardware, as stakeholders gain more visibility into real estate operations.

Still, better hardware innovation is making the challenge of constructing tomorrow’s building stock sustainably more possible than it was just a few years ago. The breakthroughs in steel and cement discussed earlier in this trend watch have unlocked a new world of possibilities in attacking the embodied carbon challenge in new builds – see Figure 9 where in 2018 embodied carbon technologies were only 1% of the built environment space and is now 14%. We expect this trend and recent improvements in construction waste avoidance and recycling to be core in approaching the challenge of building for the two billion more people that will enter the global population by 2050.

FIG. 8: VENTURE & GROWTH INVESTMENTS IN AI FOR CLEANTECH

Source: Cleantech Group

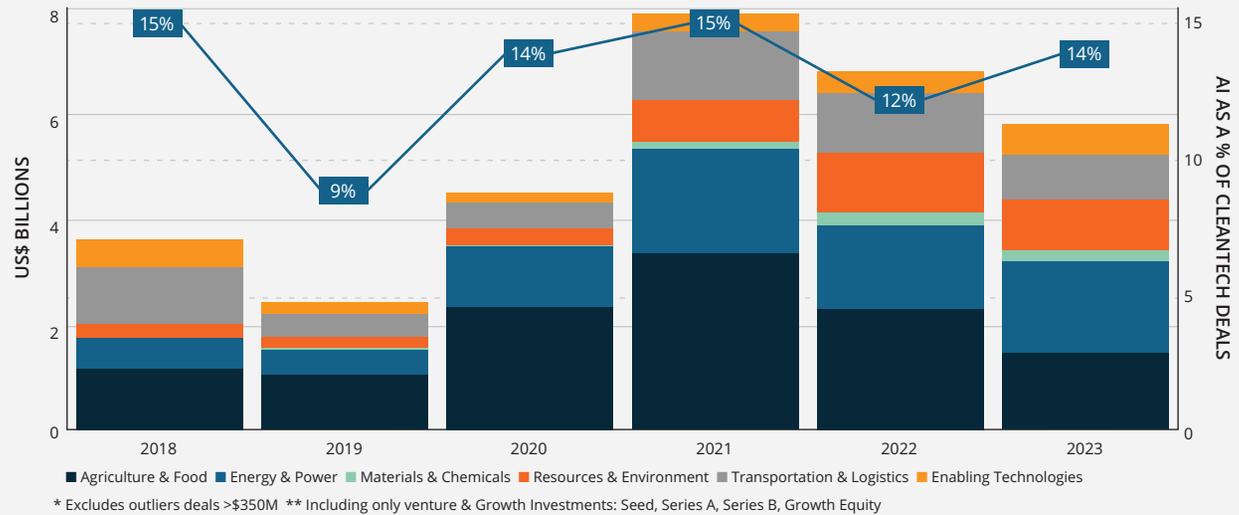


FIG. 9: VENTURE & GROWTH INVESTMENTS IN BUILT ENVIRONMENT

Source: Cleantech Group

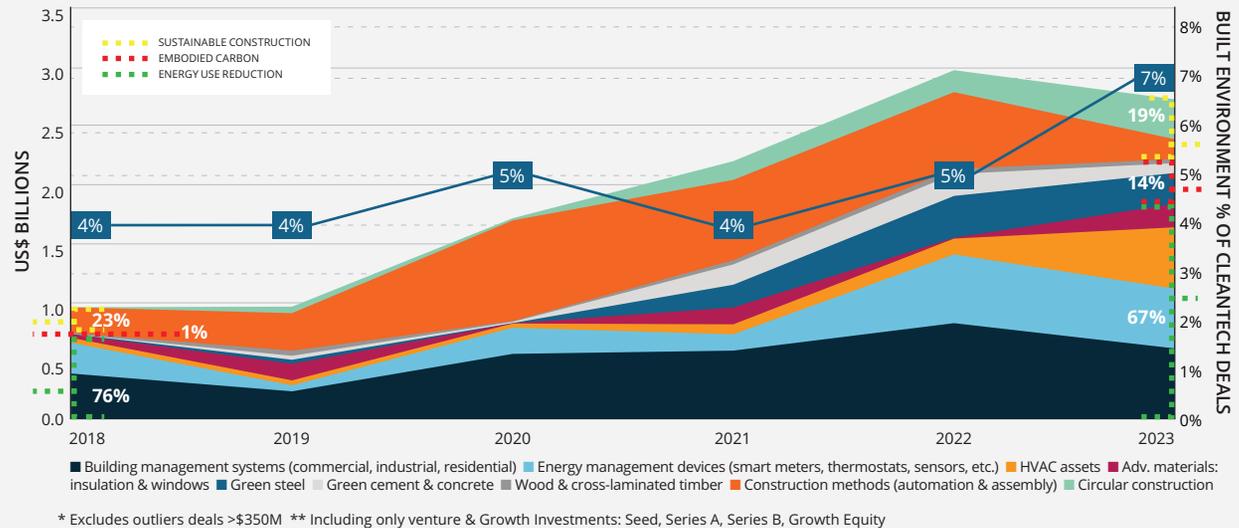
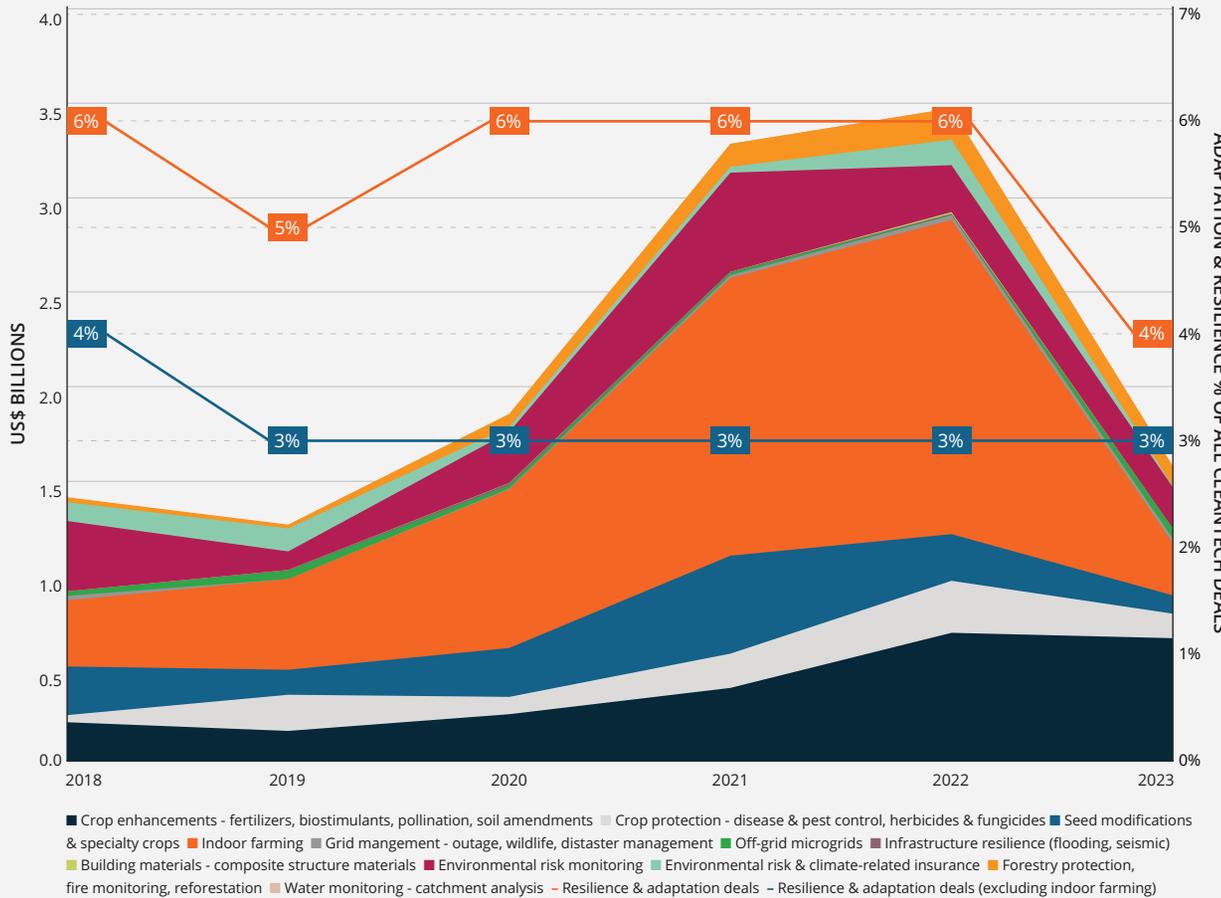


FIG. 10: VENTURE & GROWTH INVESTMENTS IN RESILIENCE & ADAPTATION CLEANTECH

Source:  Cleantech Group



\* Excludes outliers deals >\$350M \*\* Including only venture & Growth Investments: Seed, Series A, Series B, Growth Equity

**RESILIENCE AND ADAPTATION – INVESTMENT TREND NOT MIRRORING URGENCY OF TECH NEED**

Revisiting a trend we acknowledged in last year’s Global Cleantech 100, engagement with technologies supporting climate adaptation and resilience has mostly remained flat as a percentage of investments, begging the question, “How prepared are we truly for the next phase of climate change?”

As can be seen in Figure 10, for years indoor farming was a key underpinning of adaptation and resilience cleantech. In the wake of multiple indoor farming bankruptcies, there is still reason to believe that the Agriculture & Food industry group will be one of the first to draw on innovation, as it seeks to make food systems against changing weather patterns while hitting the moving target of population growth. See Figure 10, where, taken together, crop enhancements, seed modifications and specialty crops, and crop protection have collectively experienced only a minor drop off and remain stronger than in the pre-pandemic days.

Watch the crop inputs space closely. As microbial inputs that sequester carbon (See Global Cleantech 100 company [Loam Bio](#)) expand revenue-stacking for farmers (yielding more crops and selling carbon credits) and the ammonia fertilizer market becomes one of the first demand sources for green hydrogen, we believe the gravitational pull of this currently under-recognized space will grow. Expect to see crop resilience innovation become less of a niche and more of a cross-cutting theme, with supply chains forming around them as business models become more apparent and attractive.

Nevertheless, more innovation is needed to insulate against the effects of climate change that are already written into the coming decades. The regional variance in the effects of climate change makes revenue growth profiles lumpy for innovators. Expect to see innovators going the extra mile to expand the data “base of the pyramid” for demand owners of downstream resilience services – an instructive case is Global Cleantech 100 company [Dendra Systems](#), using machine learning to analyze drone imagery at mining and infrastructure sites, and automating re-seeding by drone for deforestation.

**HOW PREPARED ARE WE TRULY FOR THE NEXT PHASE OF CLIMATE CHANGE?**



## OUT OF THE SHADOW OF THE PANDEMIC, DRIVING TOWARD THE CRUCIAL DECADE

Without question, the Covid-19 pandemic and its continued macroeconomic reverberations have been the background noise to much of the discussion around the potential of cleantech innovation to grow over the past few years. Last year, we wrote that innovators would be entering a “new normal” of a leaner fundraising environment and more prudent corporate spending on new technology experiments. That has largely proven out, but always with some surprises.

We predict that 2024 will be the first year that we get a glimpse into the “next normal” – the coming era of seeing today’s innovation succeed or fail in the mainstream:

- Who can most economically produce electrolyzer units at gigafactory scale?
- Which production pathways will get green steel into infrastructure and auto bodies first?
- In a world where range anxiety calms and EV batteries become more commoditized, who can win the coming cost war?

## IN 2024, COMPETITION WILL MOVE TO END PRODUCT AND PROJECT ECONOMICS

In 2024, some spaces we’ve tracked by venture investments for nearly the past decade will start becoming measurable in manufacturing statistics and product price.

At the earlier stages, expect innovators to start aiming for component substitution to get in pole position for the 2030s.

- Who will improve electrolyzer composition to reduce performance and cost trade-offs?
- Who can keep battery performance constant with maximum abundant materials?
- Who can store the highest temperature in abundant materials and compact units that get dropped into industrial settings?

The impact and benefits of AI at the R&D stages of new materials and early technologies will not be trivial, and savvy innovators that integrate specialized AI throughout their processes are likely to end up with both proprietary hardware and software products on their hands.

For those innovating against the worst effects of climate change, the remainder of the decade is the fight, and the markets of the 2030s are the prize.

We again congratulate all of this year’s Global Cleantech 100 companies and start 2024 with a sense of excitement.





# INDUSTRY GROUP ANALYSIS AGRICULTURE & FOOD



## Feeding the World with More Sustainable Plant and Protein Production

Cleantech start-ups in the Agriculture & Food industry group raised \$4.8B in venture investment across 392 deals in 2023. This marked a significant drop in dollar terms from 2022's \$8.6B total and 2021's record \$10.6B, as the inflationary environment and other macro headwinds encouraged investors to shift attention from consumer-adjacent models to make more judicious, long-term bets on upstream tech and service providers.

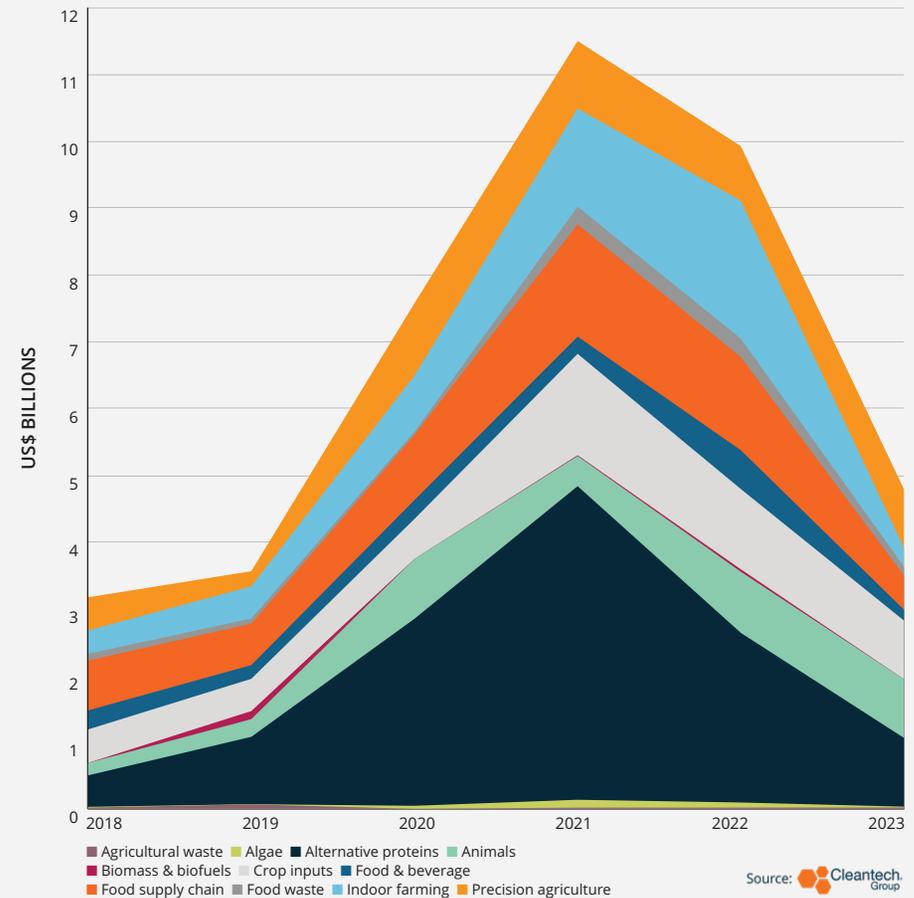
This was reflected in the subsectors that attracted the most funding, with innovations around livestock management and animal feed, non-animal protein sources, crop inputs such as pesticides and fertilizers, and precision agriculture tools leading the way.

Innovations in these fields can have substantial global impact given that the agrifood ecosystem produces as much as a third of total greenhouse gas emissions in addition to being a major cause of land and water degradation, deforestation, and biodiversity loss. At the same time, this ecosystem needs to produce enough to feed the world's growing population, albeit in a more sustainable and resource-efficient manner than it does today.

The Agriculture & Food companies selected for inclusion in the 2024 Global Cleantech 100 similarly underlined these trends.

**START-UPS IN THE AGRICULTURE & FOOD INDUSTRY GROUP RAISED \$4.8B IN VENTURE INVESTMENT ACROSS 392 DEALS IN 2023**

FIG.1: INVESTMENTS INTO AGRICULTURE & FOOD CATEGORIES





SECTOR ANALYSIS AGRICULTURE & FOOD

**ANIMALS**

Total investment into livestock-related technologies in the animals category, comprising livestock-related technologies, hit \$729M, 15.7% of the industry total, shared among 41 deals.

Given that the UN Food & Agriculture Organization (FAO) estimates animal agriculture to be the source of as much as 14% of total greenhouse gas emissions, there is a clear investment rationale behind livestock management and animal feed innovators.

The animals subsector's accession to the top spot was helped in no small part by the \$200M Series D raise by **eFishery**, an Indonesian start-up offering a range of tech-enabled products and services driving efficiencies in the smallholder shrimp and fish farming industry. That deal, led by investors including 500 Global, SoftBank Vision Fund, and Temasek, propelled eFishery into the billion-dollar valuation club, making it the world's first aquaculture unicorn.

More than a quarter of the world's population is reliant on aquatic animals as a key food source, constituting over 20% of their daily protein intake, with demand expected to rise significantly in the coming years. Given that farmed seafood is also a major contributor to agriculture-related emissions (see Figure 2) there is a critical need to simultaneously improve yield while reducing environmental impacts in the aquaculture sector.

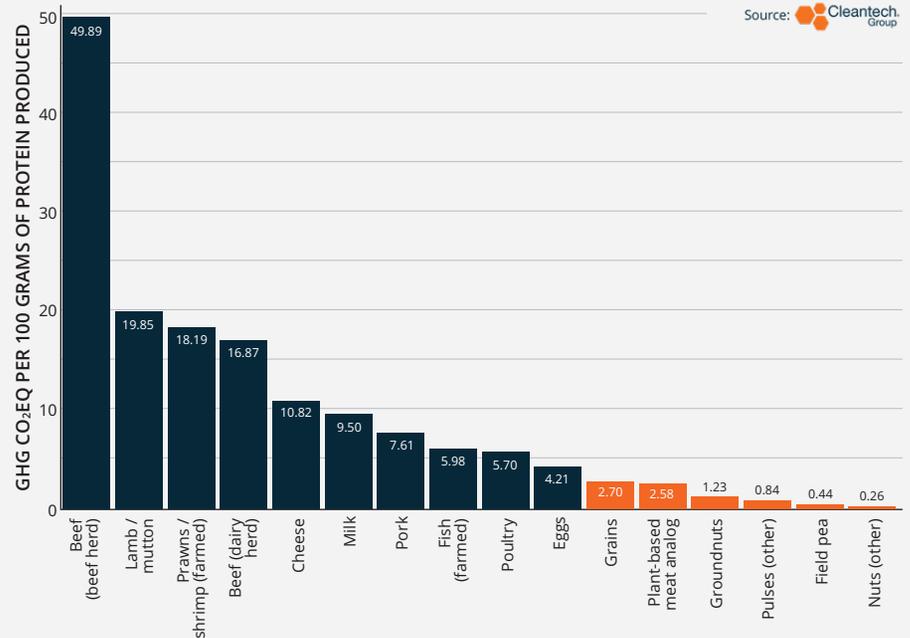
Feed innovations aimed at land-based livestock also secured significant funding in 2023. Among them was first-time Global Cleantech 100 entrant **Rumin8**, which scored \$12M in its Seed round led by Breakthrough Energy Ventures. The Australian start-up is creating supplements that can be added to cattle and sheep feed to inhibit production of methane in the animals' digestive systems. Rumin8 claims its active ingredients can reduce enteric methane from cattle farming, by far the agriculture industry's most emissions-intensive activity, by as much as 85%; or 2 tons of carbon equivalent per cow, per year (see Figure 3).

**Ynsect**, developer of bioconversion solutions using insects to make sustainable animal feed as well as organic fertilizers and food products for human consumption, raised \$175M in Growth funding from undisclosed investors in another of the year's largest Agriculture & Food deals.

The French innovator (and past Global Cleantech 100 honoree) also entered into collaborations with Japan's Marubeni, a key aquaculture feed producer, and South Korean conglomerate Lotte to explore food industry applications; the latter also announced a partnership with past Global Cleantech 100 honoree **CH4 Global** to supply its cattle feedlots with methane-busting supplements. Another insect farmer, **Protix**, received investment from meatpacking giant Tyson as part of a broader partnership.

While the positive investment trend in animal-focused cleantech is an encouraging one, more strategic investments and collaborations of the kind described above will need to come from meat and dairy industry incumbents. Their increased involvement and support will be critical for animal agtech technologies to prove their sustainability and emissions-reduction potential in the field.

FIG. 2: GHG EMISSIONS OF ANIMAL & PLANT PROTEINS COMPARED



SECTOR ANALYSIS AGRICULTURE & FOOD



**ALTERNATIVE PROTEINS**

Alternative protein innovators pioneering cultivated meat, fermentation, and plant-based products received \$1.03B in 2023, with the subsector's 135 transactions leading Agriculture & Food in terms of deal volume.

Like animal agtech innovators, alternative protein start-ups are trying to reduce the negative environmental impact of livestock production. However, they're taking a different route, by aiming to meet more of our protein needs without relying on animals.

2024 Global Cleantech100 honoree **Mosa Meat**, for example, is focusing on cultivated meat: recreating beef

and pork products by isolating animal cells and growing them in a nutrient-rich medium. In 2023, it partnered with Nutreco to develop more efficient media for its cultivated meat. Fellow Global Cleantech 100 member **Wildtype** is working on similar solutions for salmon.

Global Cleantech 100 entrant **Paleo** was one of the recipients, securing \$12.7M for its February Series A round from investors including DSM Firmenich Venturing, Siddhi Capital, and Planet A Ventures. The Belgian start-up is using precision fermentation to produce heme and other ingredients intended for conventional meat products.

FIG. 3: INVESTMENTS IN ALTERNATIVE PROTEINS

Source:  Cleantech Group

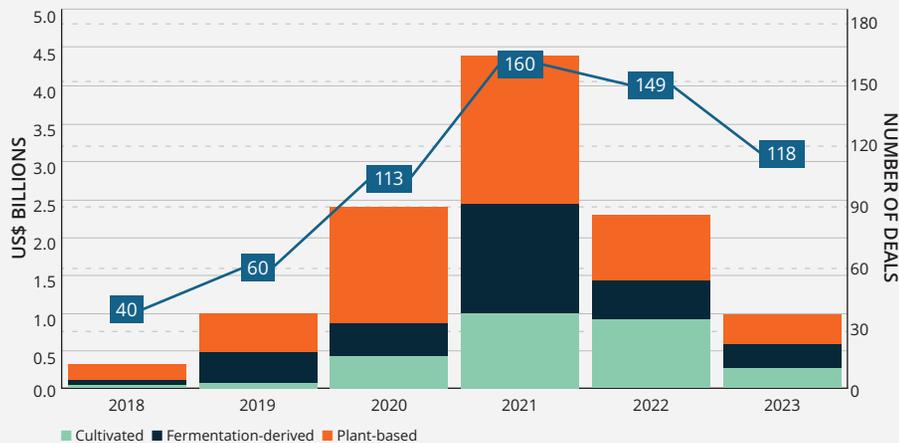
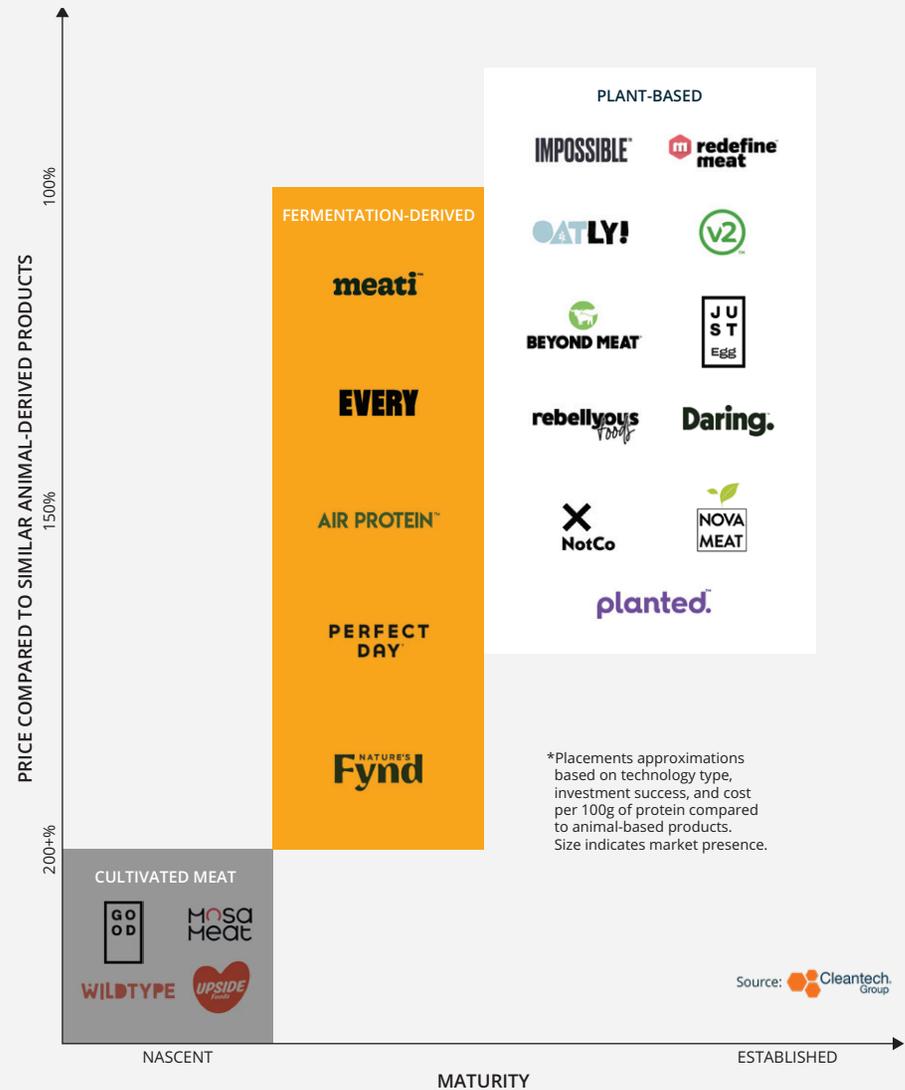


FIG. 4: END PRODUCT PRICE POINT OF ALTERNATIVE PROTEIN SUBCATEGORIES







SECTOR ANALYSIS AGRICULTURE & FOOD

**CROP INPUTS**

Chemical-based crop inputs such as fertilizers and pesticides revolutionized agriculture during the 20th century, vastly improving the productivity of farms across the world as the global population expanded.

But manufacturing and using these products has also brought negative environmental effects in the form of emissions, air and water pollution, and soil degradation.

Innovation in crop inputs is centered on developing alternative technologies that can reduce our reliance on conventional chemicals.

Total 2023 funding for these novel crop input technologies reached \$878M, with geopolitical concerns driving investment into localized fertilizer production solutions and regulatory headwinds doing the same for biological alternatives to chemical crop protection products.

Switzerland's *Atlas Agro*, producer of sustainable nitrate-based fertilizers, claimed the subsector's biggest deal of the year, netting \$375M in Growth funding from Macquarie Asset Management to build industrial-scale plants in the Americas.

Australian Global Cleantech 100 member *Loam Bio* banked \$73M from Lowercarbon Capital, Main Sequence, and others for its fungi-based biostimulant product with a carbon credits platform built on top; while fellow Global Cleantech 100 honoree *Vestaron* announced a collaboration with *Bioinsectis* to develop enhanced bioavailability for its insecticidal peptides.

**CONCLUSION & PREDICTIONS**

Looking forward to 2024, alternative proteins will likely continue to attract a substantial share of Agriculture & Food funding. However, expect more of that capital to go to B2B players making ingredients, consumables, or infrastructure for alternative protein production, rather than consumer-facing brands and end-product manufacturers; underscoring the need to bring down production costs and improve product quality.

Alternative protein companies are also set to experience consolidation as the three conventional divisions – plant-based, cultivated, and fermentation-derived – continue to converge, resulting in more end-products incorporating technologies from all three areas.

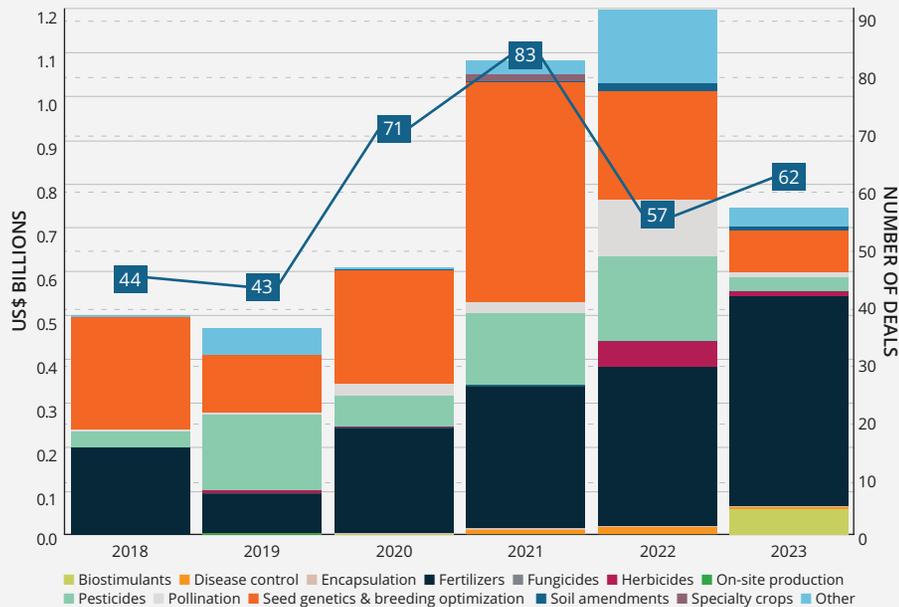
Crop inputs could also see an increase in funding this year if the European Union follows through on a proposal to update its regulatory framework around genetically-modified organisms to allow certain types of gene-editing relevant to plant breeding and biological products. **JE**

Notably, investment levels in crop inputs have held steady since 2022, without experiencing the pronounced downturns seen in some other areas of deep cleantech. This points to the recognition among corporate and, increasingly, venture investors that crop inputs innovations present a significant opportunity to quickly adapt existing agricultural systems to climate realities.

**ALTERNATIVE PROTEIN COMPANIES ARE SET TO EXPERIENCE CONSOLIDATION**

FIG. 6: INVESTMENTS IN CROP INPUTS

Source:  Cleantech Group





# INDUSTRY GROUP ANALYSIS ENERGY & POWER

WRITTEN BY  
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## Energy Buoyant with Plenty of Bright Spots

Despite economic headwinds and geopolitical upheaval, it has been an exceptionally strong year for energy and power cleantech investment. E&P remains the largest cleantech industry group in terms of recorded deals and money invested, with 40 companies out of the Global Cleantech 100 being E&P companies. With \$18.2B of venture capital into E&P technologies, 2023 saw the second highest year in terms of investments since Cleantech Group started recording this data.

For the first time since 2019, the share of US investments has declined, as IRA-qualifying companies take advantage of more robust debt and project financing options. Record growth is predominantly driven by megadeals in China, as the country invests heavily to expand its energy storage and solar manufacturing, and in Europe.

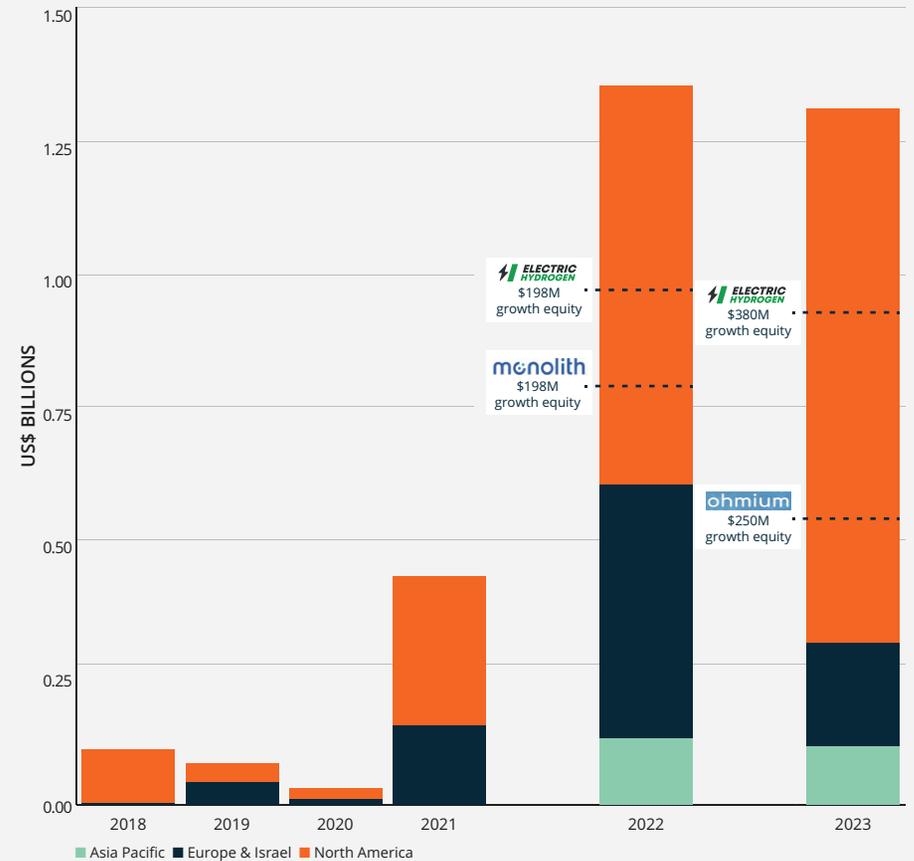
### US TO BECOME A MAJOR HYDROGEN GROWTH HUB

Next year will be crucial for electrolyzer suppliers such as *Electric Hydrogen*, *Nel*, and *EvoIOH*, as they are beginning to scale up their gigafactories in the U.S. Innovation in the electrolyzer space has focused on measures to reduce operating costs to achieve the sub \$1/kg hydrogen production cost target. These include increasing efficiencies, reducing the amount of grid power used and operating with variable renewable power, such as an anion exchange membrane (AEM) electrolyzer developed by *Verdagy*. However, offtake agreements are thin on the ground, which coupled with uncertainty, could lead to project delays and consolidation in a rather saturated market.

IT HAS BEEN AN EXCEPTIONALLY STRONG YEAR FOR E&P INVESTMENT

FIG. 1: LATE-STAGE INVESTMENTS INTO HYDROGEN PRODUCTION

Source:  Cleantech Group





SECTOR ANALYSIS ENERGY & POWER

The IRA has invigorated the U.S. cleantech market amid a precarious capital availability situation. The U.S. is poised to become a major growth market for hydrogen and electrolysis technologies as it backs the creation of hydrogen hubs and hopes to bring the cost of green hydrogen to below \$1/kg with the aid of tax credits.

Late-stage deals in hydrogen production in the U.S. – Series B and Growth Equity – have increased markedly year-over-year from \$750M to \$1B as producers are keen to lock in the renewable electricity production tax credit (PTC), a per kilowatt-hour (kWh) federal tax credit included under Section 45 of the U.S. tax code for electricity generated by qualified renewable energy resources. Capital from late-stage deals is crucial as it is often used to scale manufacturing up in gigafactories, a very CAPEX-intensive process.

Energy storage innovation is continuing to see daylight in the market, in both the EV battery and long-duration storage spaces. Lithium iron phosphate (LFP) company **Our Next Energy** raised \$300M in a Series B funding round, while Global Cleantech 100 company **Rondo Energy** raised \$60M in a Series B round. Both companies are less than three years old.

**EUROPE LEADS BUILDINGS DEALS DRIVEN BY A HIGH ENERGY PRICE ENVIRONMENT**

- There has been a noticeable geographic shift in investments for building energy optimization, with Europe accounting for a lion’s share of the deals in 2023 compared with last year when the U.S. dominated the buildings landscape.
- Innovation focuses on digital and hardware solutions, such as sensors, that turn “dumb” buildings into smart buildings with control systems that also provide intelligence on usage patterns to utilities and system operators.

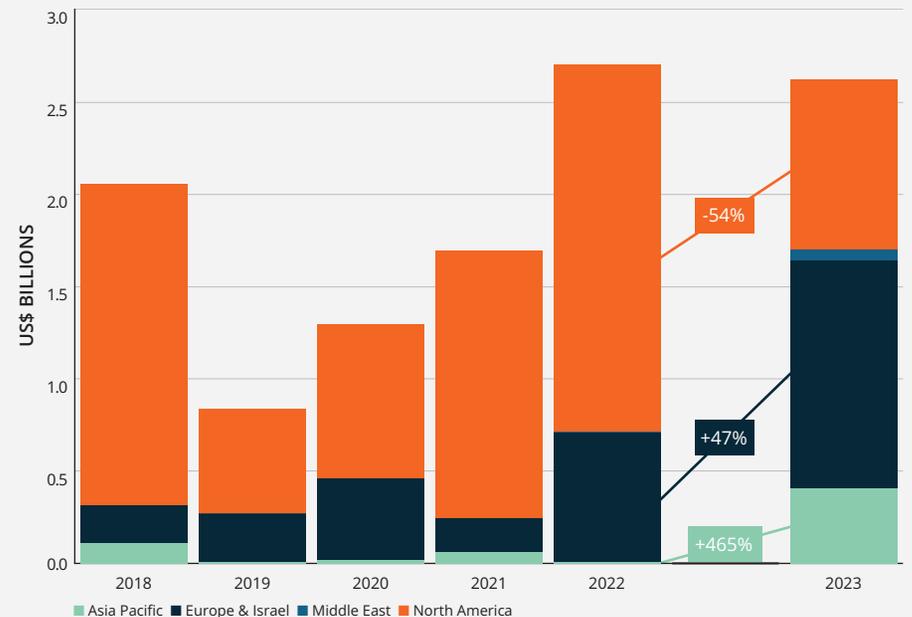
Innovation in the buildings sector clearly focuses on solutions that provide energy efficiency gains. German innovator **1Komma5**, a one-stop shop providing integrated smart home products and control systems to households, has raised nearly \$700M in less than two years. Compatriot innovator and Global Cleantech 100 company, smart thermostat developer **Tado** has raised nearly \$60M in two funding rounds this year alone. Tado’s thermostats allow households to heat and control the temperature of individual radiators.

There is strong interest in technologies that help save energy and provide visibility on usage patterns especially in Europe, amid high and volatile energy prices following the Ukraine conflict. The buildings sector remains attractive for investors as most new technologies are digital, and so easier and cheaper to scale up compared to some of the deep tech solutions. Furthermore, the value chain is simplified by marketing directly to end users, with heat pump manufacturers **Bedrock Energy** and **Gradient** being good examples.

**A NOTICEABLE GEOGRAPHIC SHIFT IN BUILDING ENERGY EFFICIENCY OPTIMIZATION INVESTMENTS, WITH EUROPE ACCOUNTING FOR A LION’S SHARE OF THE DEALS**

FIG. 2: INVESTMENTS INTO BUILDINGS BY REGION

Source:  Cleantech Group



SECTOR ANALYSIS ENERGY & POWER



ENERGY NETWORKS

Constraints in transmission and distribution grid construction have spurred interest in grid optimization technologies, such as **Gridware** and **Origo Energia**. Meanwhile, distributed power solutions coupled with distributed energy resource (DER) management systems enable residential customers to optimize their energy use – consuming power when renewable generation is high and power prices are low, while potentially earning additional revenue by selling power back to the grid. With the emergence of potential vehicle-to-grid solutions, domestic consumers are likely to play a more active role in power system management.

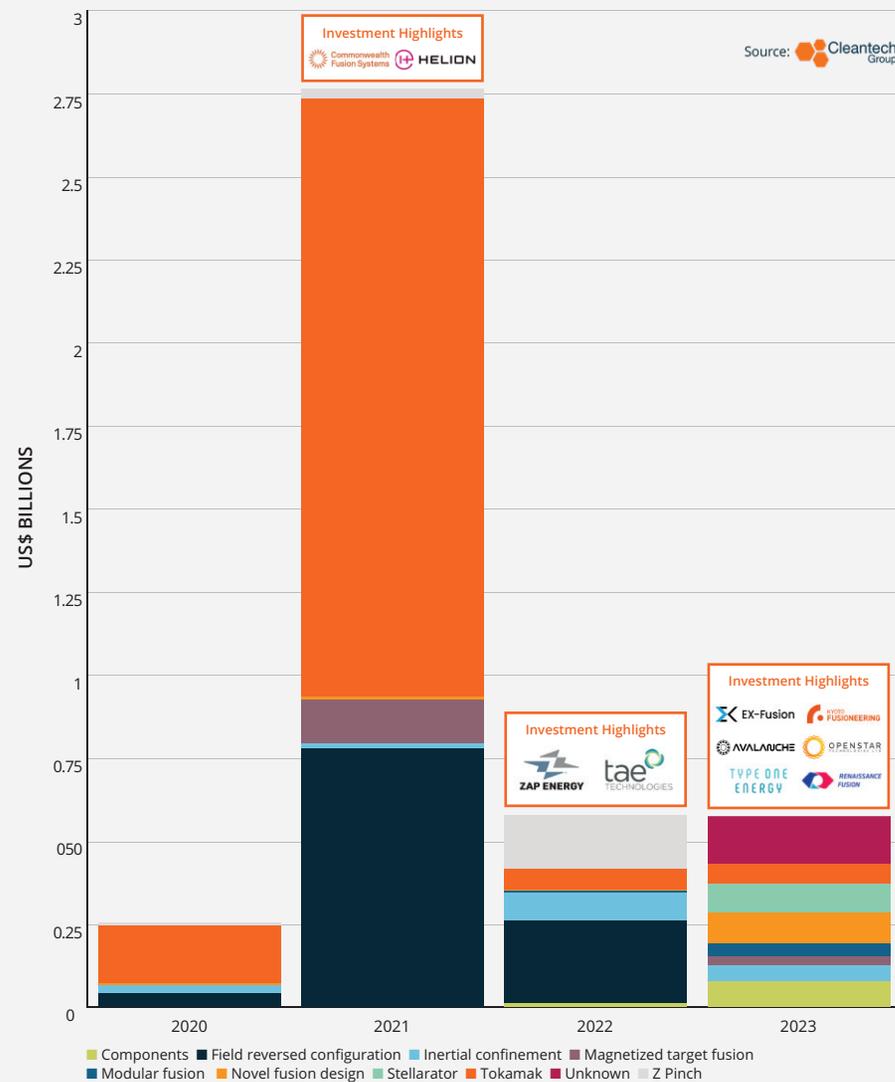
For capital providers, investment in mostly digital asset-light systems that are typically not very CAPEX-intensive, while providing healthy returns, remains attractive. Digital assets are easy to scale, require less investment, and are relatively easy to exit compared to other sectors. DER marketplace **Piclo** raised \$10M in a Series B round this year, while smart electrical panels developer and software provider **span** raised \$96.5M in a Series B. Having said that, there are signs that the DER management and aggregation space on both sides of the Atlantic is getting saturated.

NUCLEAR FUSION

While overall venture deals have declined compared to the previous two years, we have seen a number of novel and early-stage fusion technologies raising smaller rounds. **Avalanche Energy**, **OpenStar Technologies**, **Novatron Fusion** and **Blue Laser Fusion** all raised rounds this year. Also this year, at least 12 publicly reported Seed stage fusion investments were completed compared to 5 from last year. Similarly, stellarator fusion configurations – a subcategory within magnetic confinement fusion reactors – saw at least eight investments this year. This is substantially higher than previous years where there were very few investments in stellarator configurations.

Previous years, specifically 2021 and 2022, saw mega deals such as the \$1.8B in funding for **Commonwealth Fusion Systems** and \$2.2B allocated for **Helion**. These were alongside other large deals for **Zap Energy** and **TAE Technologies** in 2022. While larger players raised significant rounds in previous years, more partnerships were announced from them this year. **General Fusion** partnered with **Kyoto Fusionneering**. **Helion** signed a Power Purchase Agreement (PPA) with Microsoft and an agreement with Nucor for green steel manufacturing and **Tokamak Energy** signed an MOU with Furukawa Electric Group for high temperature superconducting tape.

FIG. 3: VENTURE INVESTMENTS IN FUSION BY REACTOR TYPE (2020-2023)



Source: Cleantech Group

SECTOR ANALYSIS ENERGY & POWER



ENERGY STORAGE

Energy storage solutions are typically very CAPEX-intensive to scale up but a constrained macroeconomic environment has not stemmed the capital flow into this sector.

There is still strong interest in novel lithium chemistries, which benefit from an established value chain, but are more efficient and have improved safety compared to Li-ion batteries. High density cylindrical Li-ion battery

producer **Verkor** (a recipient of Cleantech Group's European Deal of the Year 2023 award) raised \$907M in Growth Equity to expand production in its European gigafactory. Interest in alternative storage technologies, which are moving from pilot to commercial stage and have the potential to capture a lot of the medium-term storage market, also remains strong.

Thermal storage developers **Rondo Energy**, **Kraftblock** (both Global Cleantech 100

companies) and **MGA Thermal** all raised significant Series B rounds. Thermal storage solutions could be used for a multitude of settings, such as industrial load shifting, power generation, as well as heat and steam production.

Interest in energy storage technologies is driven by a combination of increasing proliferation of renewable power, supportive government policies, and volatile wholesale prices, especially in Europe.

**THERE IS STILL STRONG INTEREST IN NOVEL LITHIUM CHEMISTRIES WHICH HAVE IMPROVED SAFETY COMPARED TO LITHIUM-ION BATTERIES**

FIG. 4: STATIONARY STORAGE BATTERY INVESTMENTS

Source: Cleantech Group

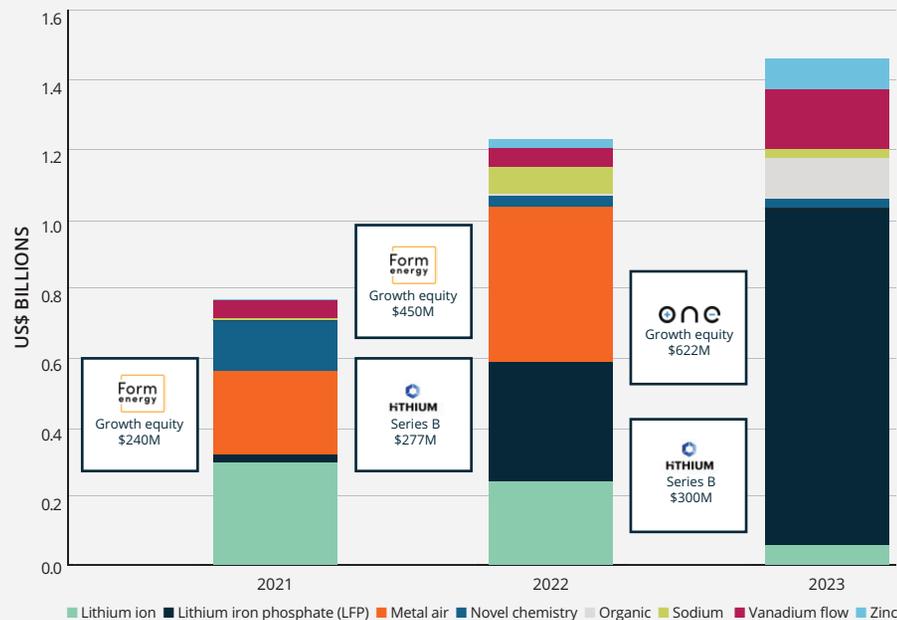
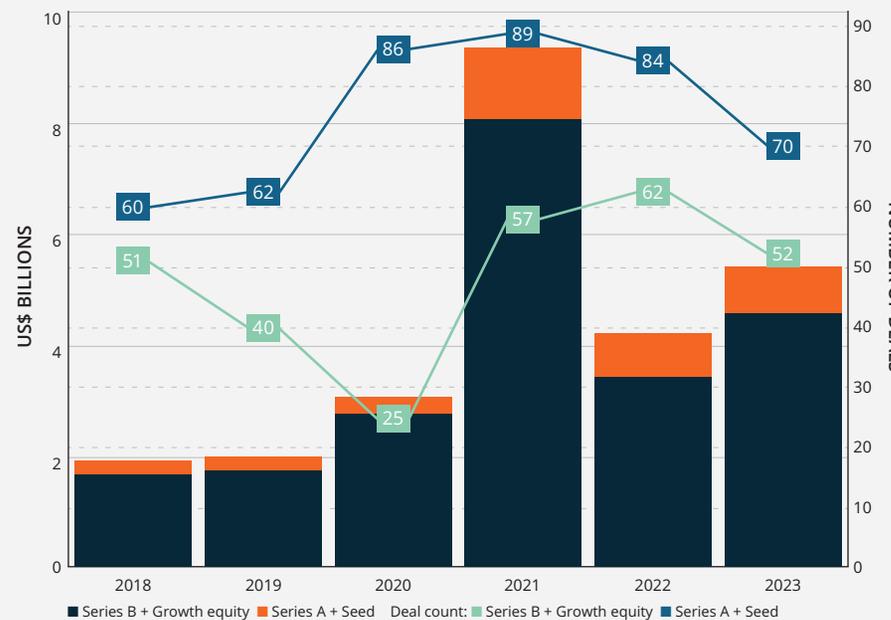


FIG. 5: ENERGY STORAGE LATE-STAGE VS EARLY-STAGE DEALS

Source: Cleantech Group

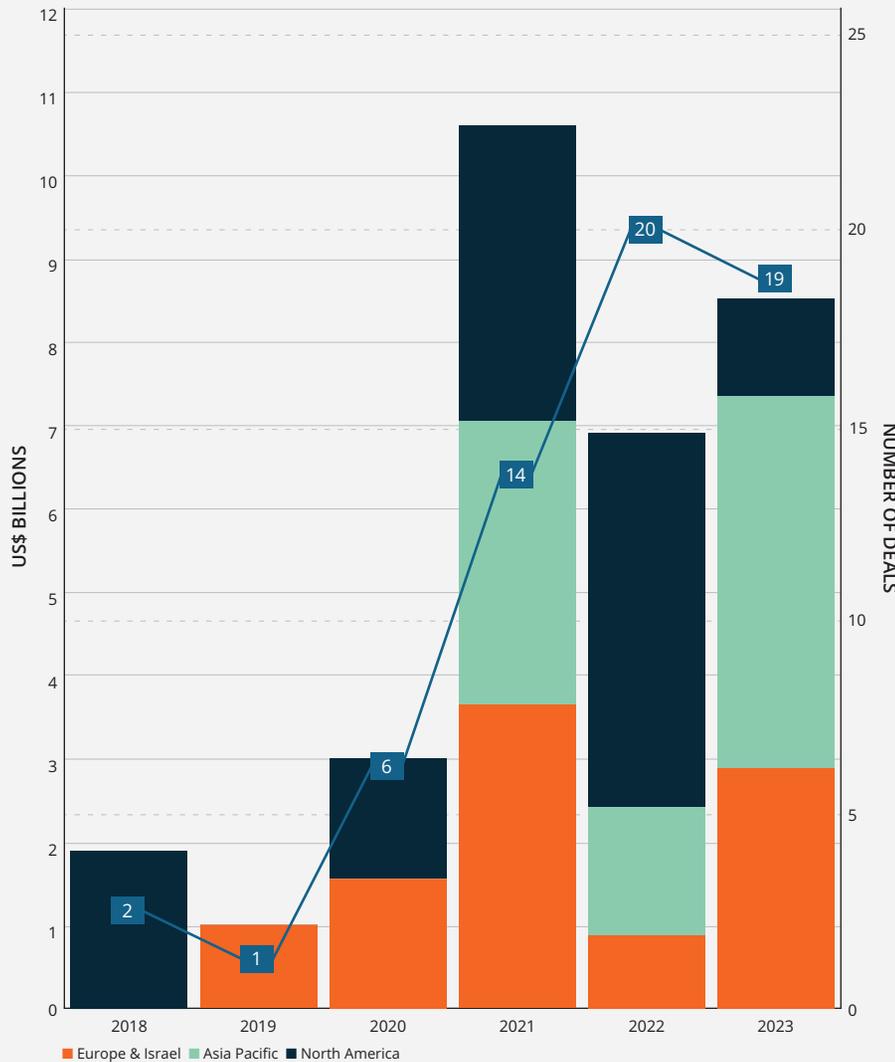




SECTOR ANALYSIS ENERGY & POWER

FIG. 6: ENERGY & POWER VENTURE DEALS >\$200M

Source:  Cleantech Group



APAC DRIVES THE UPTICK IN LATE-STAGE AND MEGADEALS

Much has been said about the funding gap between early- and late-stage rounds in what is called the valley of death of a first-of-a-kind (FOAK) technology – early-stage technology with demonstration that is looking to scale up. This is certainly true for the U.S. venture landscape which saw four megadeals of over \$200M totaling \$1.17B this year compared to China’s 8 deals totaling \$4.47B.

However, Cleantech Group’s data shows that the overall value of late-stage deals in 2023 has exceeded the previous year. In addition, the overall number of megadeals has increased year-over-year. This trend seems to be largely driven by the Asia-Pacific region and China in particular. Three of China’s novel solar PV technology developers, [Qingdian Photovoltaic Technology](#), [Astronergy](#), and [Huasun Energy](#), all raised megarounds this year.

THE OVERALL VALUE OF LATE-STAGE DEALS IN 2023 HAS EXCEEDED THE PREVIOUS YEAR

WHAT TO LOOK OUT FOR:

- Energy storage:** Over the next few years we will see a range of alternative technologies emerging to Li-ion (4-12-hour space), such as flow and thermal batteries that also allow for power and capacity decoupling. Commercial LDES solutions are likely within 2-5 years.
- Heat pumps:** The market size in Europe is increasing quickly and steadily with adoption from many installation companies in the UK and growing regional groups like [Kensa](#) and [WoltAir](#). Innovators will focus on overcoming the limitations of ground and air-source heat pumps to bring the costs down. Easy adoption by end-users encourages investor interest, but bottlenecks around the supply.
- Buildings:** Still plenty of scope for the market to expand – digital solutions coupled with sensors will continue to remain attractive for investors. Regulations for more energy-efficient buildings and high energy prices, which show little signs of letting up, will drive the adoption of building management solutions.
- Energy networks:** Consolidation likely over the next few years, as the market will become saturated in some geographies. More scope to grow in continental Europe and some of the emerging markets with forward-thinking network operators. SL



# INDUSTRY GROUP ANALYSIS

## MATERIALS & CHEMICALS

WRITTEN BY  
IAN HAYTON, GROUP LEAD,  
MATERIALS & CHEMICALS



### Low Emission Industrials Set to Scale, with Material Innovation Needed for More Efficient Energy Systems

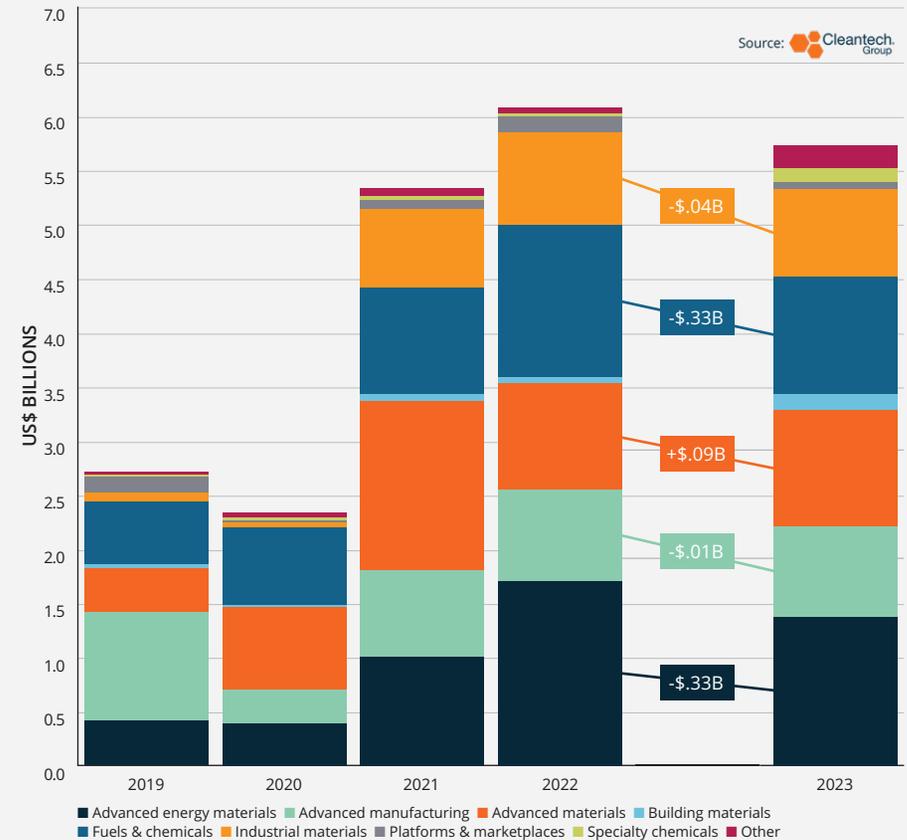
Materials & Chemicals investment dropped year-over-year, but the drop was lower than the drop in venture capital funding across the board. Although experiencing a slight drop in investment, a continued focus on hard-to-abate sectors was reflected in the Global Cleantech 100 list with cement in particular gaining traction compared to last year.

Elsewhere, materials innovation and enabled products are trending. Graphene innovator, **Lyten**, received over \$200M in funding to enable the scale up of lithium-sulfur batteries. In building materials, **Aeroseal** made the Global Cleantech 100.

2023 saw strong development in the deployment of green steel production technologies. Leading the way is the production of hydrogen direct reduced iron which will add to demand for renewable energy and green hydrogen technologies. Innovations which lower energy usage and use low grade ores are on the horizon. Electrofuels are also scaling, which will add to demand for hydrogen and renewable energy, and technologies which enable more efficient or flexible production.

**INVESTMENT DROPPED YEAR-OVER-YEAR, BUT THE DROP WAS LOWER THAN THE DROP IN VENTURE CAPITAL FUNDING ACROSS THE BOARD**

FIG. 1: VENTURE INVESTMENT IN MATERIALS & CHEMICALS INNOVATORS



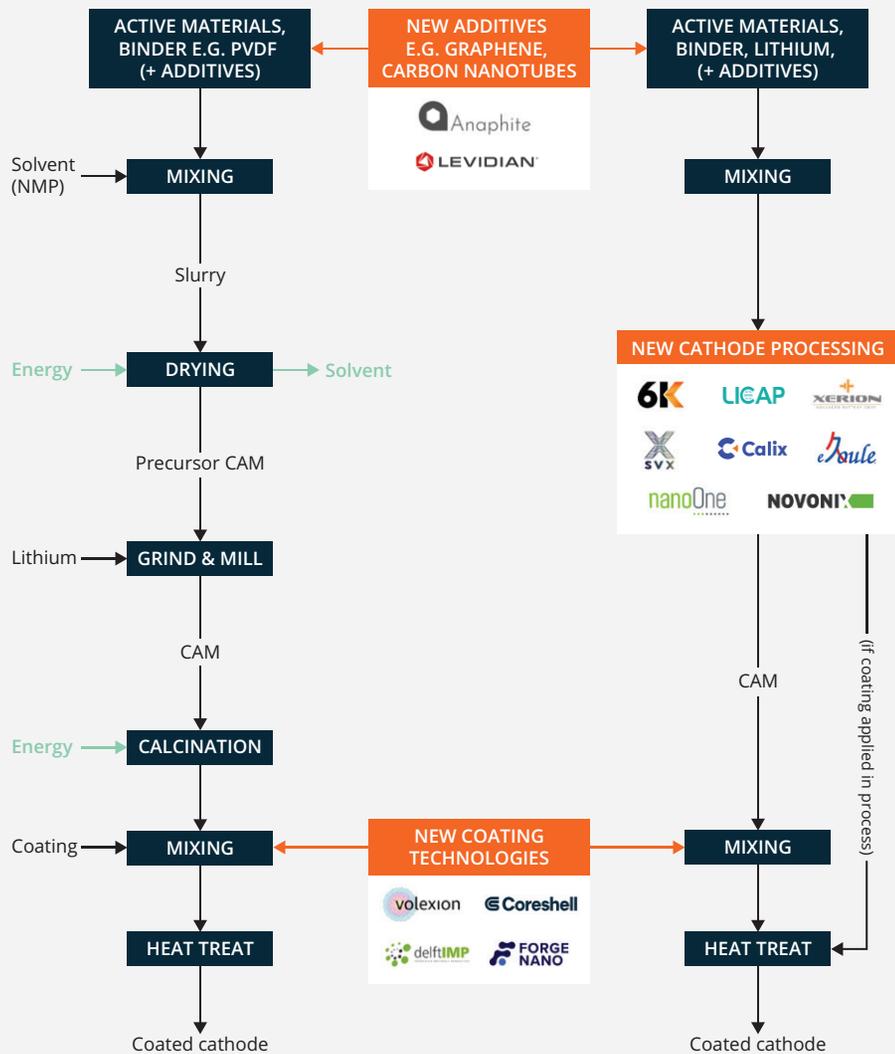
\* Excludes outliers with investment rounds larger than \$350M



SECTOR ANALYSIS MATERIALS & CHEMICALS

FIG. 2: CATHODE MANUFACTURING INNOVATIONS

Source:  Cleantech Group



CATHODES

Cathode active materials (CAM) are the largest part of the EV battery cost (30%+) and the bottleneck to scaling the energy revolution, especially electric vehicle deployment. Yet producing them is complex, inefficient, and wasteful. For instance, producing 5 million additional tons of CAM by 2032 will consume 20 billion gallons of water and produce huge amounts of waste sulphates.

Strong market demand and worries about supply chain vulnerabilities have seen a drive for the onshoring of battery materials. Policymakers are subsidizing projects, and innovators are developing technologies and raising funds to sustainably meet the market demand for high-quality battery materials.

- 6K has developed a high temperature microwave process which produces any cathode materials with chemistry, size, and microstructure tailored for power and energy requirements of application. The Global Cleantech 100 company raised funding from Stellantis Ventures in June 2023 and formed several partnerships targeting battery recycling.
- Forge Nano has developed a nano-coating manufacturing process which enables a 20% performance increase - higher capacity, safety, faster charging, and improved lifetime. Forge Nano raised \$50M in May 2023 to build a second production facility.

A continued focus on domestic supply chains and reducing impact will favor cathode manufacturing innovators. The U.S. is still to distribute funding across the battery value chain, while innovators continue to wait a response to the IRA in other regions, including the EU.

**STRONG MARKET DEMAND AND WORRIES ABOUT SUPPLY CHAIN VULNERABILITIES HAVE SEEN A DRIVE FOR THE ONSHOREING OF BATTERY MATERIALS**



SECTOR ANALYSIS MATERIALS & CHEMICALS

**EFUELS**

With pushback against offsets, demand for alternatives is growing. Airlines are looking for alternatives with sustainable aviation fuel (SAF) high on the list. Meanwhile, the International Maritime Organization (IMO) has set targets on the carbon intensity of shipping activities.

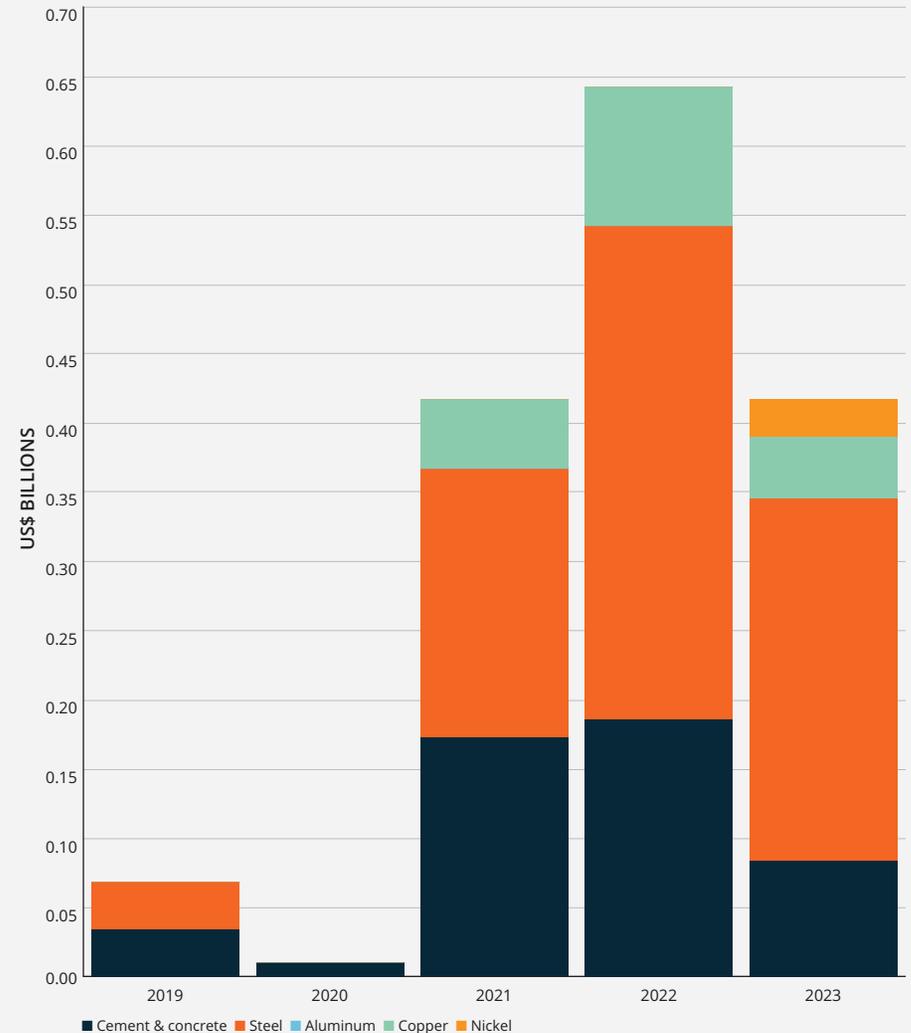
Growing market demand is also met with a green premium, inhibiting production and the use of SAF. Recognizing this, governments are looking to close the gap with production incentives in North America and blending quotas in Europe. Projects are coming online, but there are constraints on the availability of feedstock including biomass or oils.

This is stimulating interest in Electrofuels (e-fuels) made from captured carbon, water, and electricity. However, to reach the volumes of fuels necessary will require huge amounts of renewable energy and ultimately carbon from alternative sources. The Global Cleantech 100 features three companies looking to address some of these challenges:

- **Ineratec** enables modular production of fuels and chemicals, suited to the decentralized nature of carbon sources. Earlier in 2023, Ineratec raised an undisclosed amount and partnered with Honda to advance production, testing and application of renewable e-fuels.
- **OXCCU** has developed an integrated process for production of jet fuel using a single step conversion, reducing CAPEX and enabling smaller commercial plants. OXCCU raised \$23M in 2023 to scale up the technology.
- **Twelve** has developed a CO<sub>2</sub> reducing catalyst which enables a more efficient production of chemicals and fuels. Twelve began construction of a commercial-scale plant for producing SAF from CO<sub>2</sub> earlier in 2023.

Production incentives in the U.S. and a new EU eFuels sub-mandate are set to stimulate demand in the short term, while more efficient technologies for hydrogen production, carbon capture, and fuels conversion will enable more competitive eFuels production – if renewable energy scales to meet needs.

FIG. 3: VENTURE INVESTMENT IN KEY INDUSTRIAL MATERIALS



\* Excludes outliers with investment rounds larger than \$350M

Source:  Cleantech Group

## SECTOR ANALYSIS MATERIALS &amp; CHEMICALS

**INDUSTRY HAS MOVED SLOWLY TO REDUCE EMISSIONS BY INCREASINGLY REPLACING SOME OF THE HIGH EMISSION CLINKER IN CEMENT****CEMENT**

Cement remains an essential material in the modern world – the glue that holds the built environment together. And with urbanization comes increased use of cement with a global production set to continue to increase up to 2050. Unfortunately, cement production accounts for around 7% of global CO<sub>2</sub> emissions – a result of both process and fuel emissions.

Industry has moved slowly to reduce emissions by increasingly replacing some of the high-emission clinker in cement with supplementary cementitious materials (SCM) like fly ash, or granulated blast furnace slag. However, this approach is limited by the availability of SCM. Other approaches typically increase the cost of cement, a premium that many buyers are unwilling to pay. The Global Cleantech 100 features three companies looking to address some of these challenges:

- **Carbon Upcycling** has developed a pressurized milling process which sequesters CO<sub>2</sub> into reactive feeds including crushed glass, fly ash, and steel slag. Carbon Upcycling raised \$26M in July 2023 with CEMEX Ventures among the investors.
- **Sublime Systems** has developed an electrical process for processing limestone into lime (clinker). The process is powered by renewables and not high heat, avoiding the fuels emissions associated with burning of fossil fuels for heat. Sublime Systems raised \$40M in January 2023 to scale up and conduct product testing.
- **Brimstone** produces Ordinary Portland Cement with near-zero emissions. The Brimstone process uses calcium silicate as input material in place of limestone avoiding process emissions, while CO<sub>2</sub> can be mineralized with by-products to make SCM. Brimstone continues to scale the technology and received ASTM certification for its Ordinary Portland Cement.

IRA initiatives will benefit innovators, including \$5.5B for Environmental Product Declaration Assistance and \$5.8B for Advanced Industrial Facilities deployment. Meanwhile, a phase out of free allowances and the implementation of the Carbon Border Adjustment Mechanism (CBAM) starting in 2027 will benefit innovators in the EU. In the long term, we expect technology scale up to reduce costs.

**LOOKING FORWARD**

Addressing the impact of industrial emissions remains imperative and technologies which address bottlenecks in energy and hydrogen usage are likely to be in demand. More sustainable production of fuels is going to remain a key focus, including SAF, methanol, and ammonia. Meanwhile, market demand for sustainable battery materials is likely to see innovators further develop and optimize production technologies. Supply chain vulnerabilities remain a risk for producers in Europe and North America and policymakers will likely continue to support localized production. ■



# INDUSTRY GROUP ANALYSIS RESOURCES & ENVIRONMENT

WRITTEN BY  
HOLLY STOWER, GROUP LEAD,  
RESOURCES & ENVIRONMENT



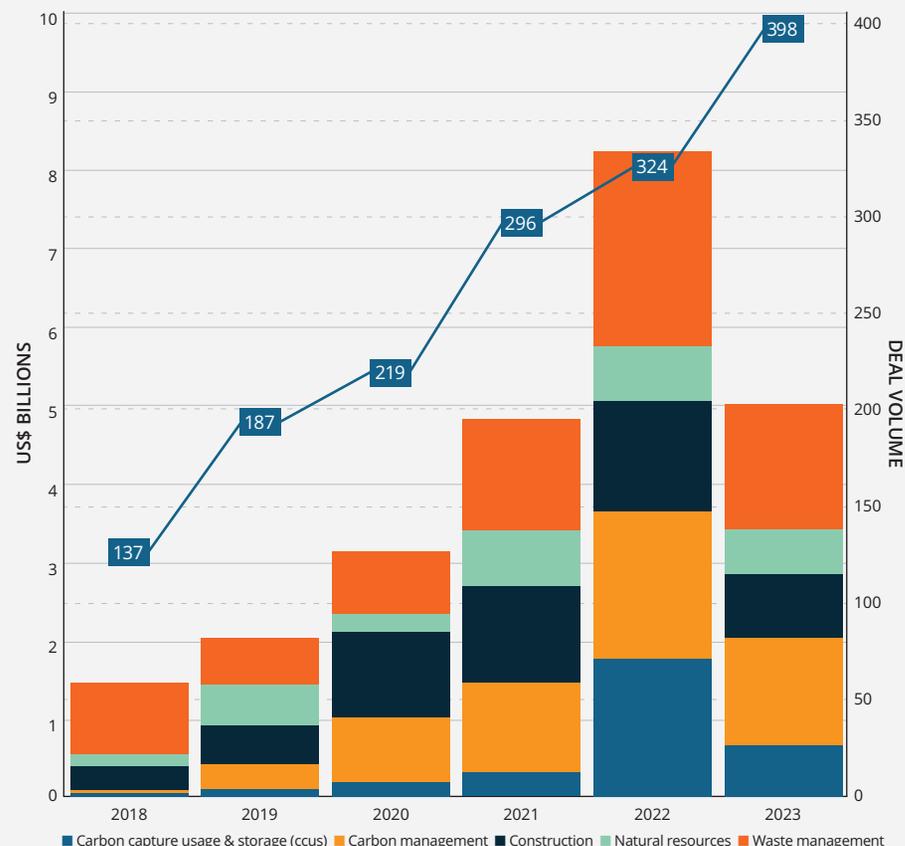
## High Demand for Critical Materials is Catalyzing Investment in Mining and Recycling Innovation, While Carbon Offset Markets Respond to a Transparency Crisis

The Resources & Environment industry group saw a healthy rise in investment from 2017 to 2022, but it saw a drop in investment in 2023. Sectors which experienced a downturn include plastics recycling, and carbon—capture, usage, and storage—with investors diversifying into new forms such as ocean carbon capture.

2023 saw an uptick in investment across the critical materials supply chain, with technologies such as direct lithium extraction (DLE) and battery recycling seeing more market traction, while regulatory pressures and high-water risks drove investment into wastewater management and treatment technologies. Additionally last year, investors in the offset market prioritized high-quality project producers due to increased demands for transparency and quality, while investors are banking on offsets becoming a lucrative asset class and see strategic advantage in investing in market infrastructure.

**2023 SAW AN UPTICK IN INVESTMENT ACROSS THE CRITICAL MATERIALS SUPPLY CHAIN**

FIG. 1: RESOURCES & ENVIRONMENT INVESTMENT



\* Excludes outliers with investment rounds larger than \$350M



SECTOR ANALYSIS RESOURCES & ENVIRONMENT

**CRITICAL MATERIAL SUSTAINABILITY – DLE AND BATTERY RECYCLING**

Critical materials, such as lithium and graphite, are essential to building low-carbon energy and transportation systems. The International Energy Agency (IEA) estimates we need at least 100 new mines to meet the material demands of net-zero targets. The U.S. Department of Energy deemed the supply of materials such as cobalt, graphene, and neodymium as already critical with high supply risk.

Many more materials such as lithium and nickel are expected to join the list of critical materials in 2025 - 2030. Innovation is starting to improve mining and refining efficiency and is creating reverse supply chains with recycling. This should improve existing critical material mining and unlock new, previously uneconomic, sources of critical materials.

**DIRECT LITHIUM EXTRACTION**

Moving to processing and refining, DLE had considerable investment and partnership activity last year. Lithium is lightweight with a high energy density, enabling compact and efficient energy storage. Demand for lithium is expected to increase 40x by 2040, largely driven by the expansion of the electric vehicle and energy storage markets. Due to its unique qualities, high demand, and criticality in these industries, investment in critical materials innovation has largely focused on DLE and lithium.

**DEMAND FOR LITHIUM IS EXPECTED TO INCREASE 40X BY 2040, LARGELY DRIVEN BY THE EXPANSION OF ELECTRIC VEHICLES AND ENERGY STORAGE**

FIG. 2: PROCESS FLOWCHART OF CRITICAL MATERIALS REVERSE SUPPLY CHAINS

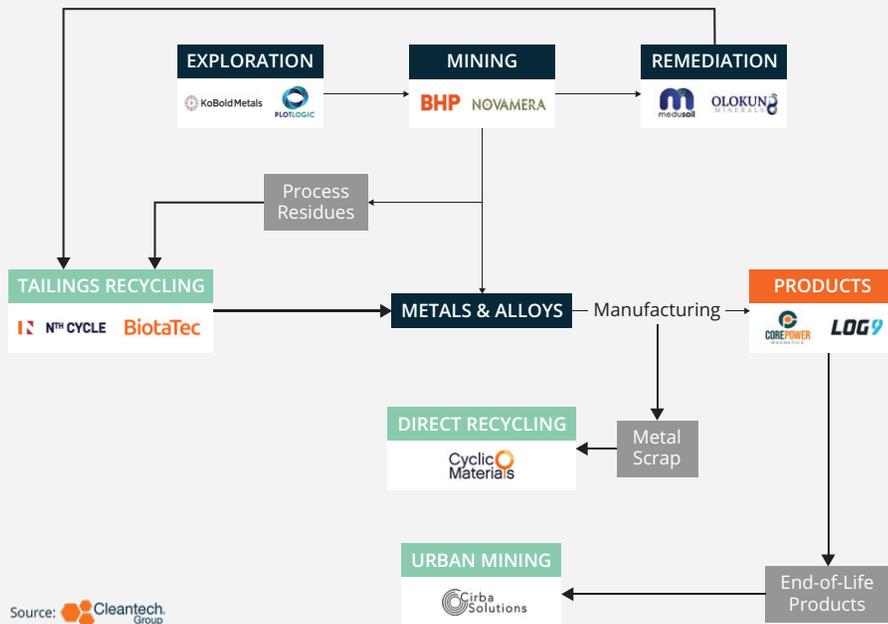
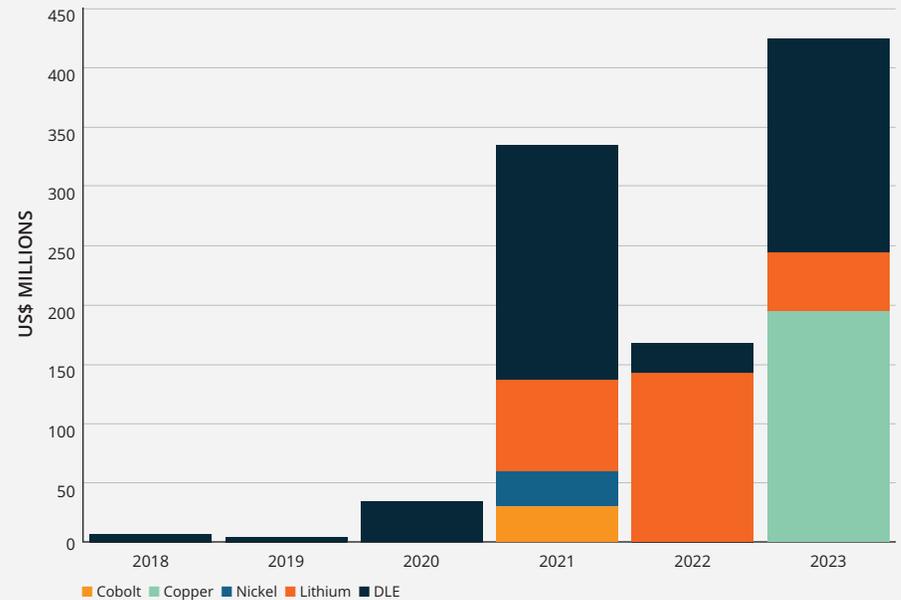


FIG. 3: TOTAL VC INVESTMENT AMOUNT IN MINING EXTRACTION INNOVATORS (BY MATERIAL FOCUS)

Source: Cleantech Group





SECTOR ANALYSIS RESOURCES & ENVIRONMENT

Traditional lithium refining via evaporitic ponds is time-, resource- and land-intensive – while DLE is faster, more efficient, cost competitive when adjusted for higher yields, and can unlock previously uneconomic feedstocks of lithium. For example, DLE can access lithium brine deposits that make up about 66% of global lithium resources but remain largely untapped.

DLE innovators are entering pilot phases with commercial-scale production expected by 2025. Global Cleantech 100 company **Summit Nanotech** is a producer of lithium from brine water using advanced nanomaterials which can extract 90% – 99.9% material. In January 2023, the company raised \$50M in Series A funding to scale its resource base in Canada and began building a technology scale-up center in Santiago, Chile.

With healthy demand signals for EVs, innovators and incumbents are entering off-take agreements with automotive OEMs, as OEMs look to secure a supply of battery materials to scale EV manufacturing:

**April 2023:** GM Ventures led **EnergyX's** \$50M Series B round for technology development, which included an off-take agreement of lithium for EV production.

The DLE market is highly competitive, with limited geographical locations of lithium reserves, strong incumbents, and only a handful of miners or mine owners to sandbox technologies and scale innovations. Strategic mergers are occurring between tech developers to share expertise, maintain value, gain control over a competitive landscape, and compete with major miners.

**May 2023:** Incumbents **Livent** and **Allkem** announced a definitive agreement to merge, with the combined company valued at \$10.6B.

**July 2023:** Alchemist Mining Inc. (now **Lithos Energy**) acquired **Aqueous**, a developer of an electro-pressure membrane process to recover lithium chloride from aqueous sources.

As the DLE industry commercializes, we expect continued consolidation between innovators, incumbents, and major miners across the lithium supply chain as they compete for supply chain ownership.

FIG. 4: DIRECT LITHIUM EXTRACTION PROCESSES, INNOVATORS AND ADVANTAGES

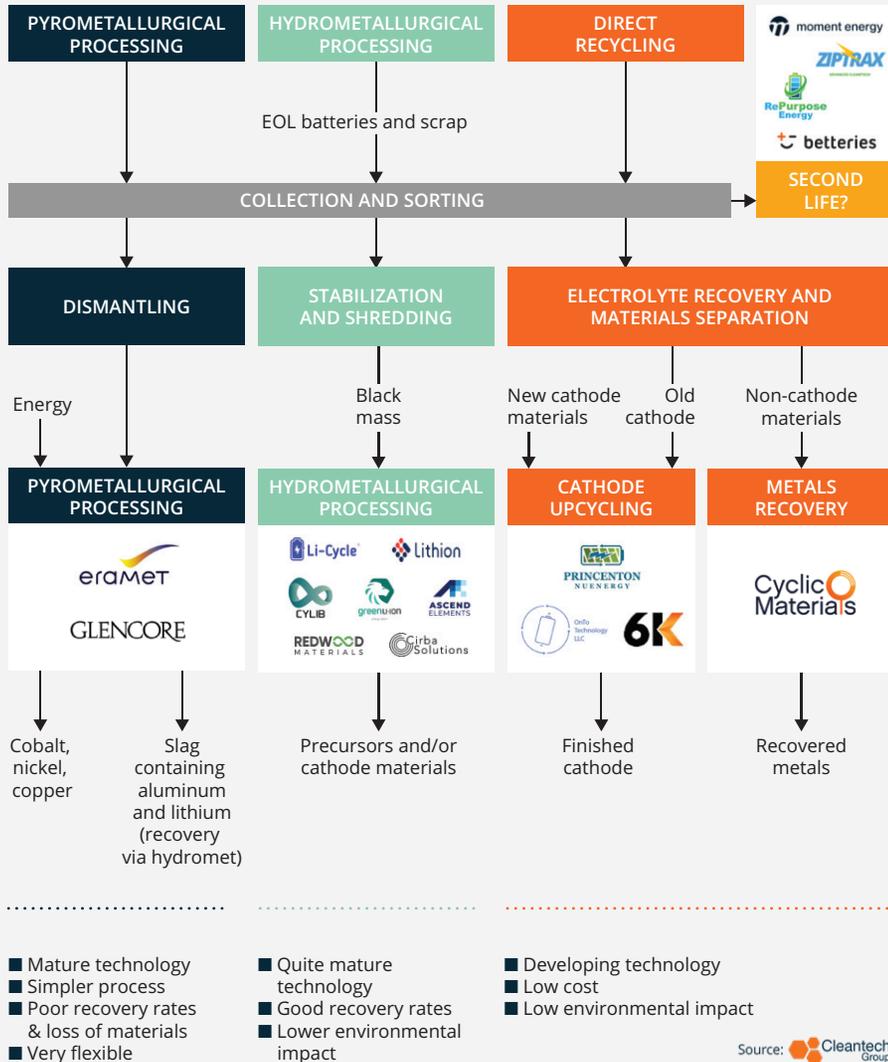
Source: Cleantech Group

METHOD	INCUMBENT APPROACH (PRECIPITATION / EVAPORATION)	SOLVENT EXTRACTION /PRECIPITATION	ION-EXCHANGE	ADSORPTION	MEMBRANE SEPARATION
Innovators					
Process	<p>Brine</p> <p>Evaporation Pond</p> <p>Lithium Salt Recovered</p>	<p>Lithium Salt Recovered</p>	<p>Brine</p> <p>Sorbent</p>	<p>Brine</p> <p>Sorbent</p>	<p>Membrane</p>
Advantages	<ul style="list-style-type: none"> <li>Simple process</li> <li>Low OPEX</li> <li>Time consuming</li> <li>40-60% yields</li> <li>Weather-dependent</li> </ul>	<ul style="list-style-type: none"> <li>Non-weather-dependent</li> <li>High recovery rate</li> </ul>	<ul style="list-style-type: none"> <li>Simple process</li> <li>High capacity</li> <li>Non-weather-dependent</li> <li>Good for low Li concentration</li> <li>High recovery rate / flow rate</li> </ul>	<ul style="list-style-type: none"> <li>No chemical reagents</li> <li>Non-weather-dependent</li> <li>Good for low Li concentration</li> <li>Good for high temp brines</li> </ul>	<ul style="list-style-type: none"> <li>No contact between brine and extracted Li</li> <li>Environmentally-friendly</li> <li>Good for high Li concentration</li> <li>High recovery rate / flow rate</li> </ul>



SECTOR ANALYSIS RESOURCES & ENVIRONMENT

FIG. 5: BATTERY RECYCLING TECHNOLOGIES, INNOVATORS AND BENEFITS



BATTERY RECYCLING

Recycled battery materials have an estimated 4x lower footprint compared to virgin materials. Supply chain risks for critical materials are driving investments which onshore the value of materials, especially in North America and Europe as they scale up automotive OEM manufacturing. Therefore, battery recycling has dominated critical material investment and activity in 2023.

Recycling provides a lower impact, alternative and comparatively stable supply of critical materials, resilient against geopolitical risk. As such, corporates throughout the battery supply chain are partnering and investing in recycling of critical materials from e-waste:

- End-of-life battery and scrap recycler, **Cirba Solutions**, received \$50M in Growth Equity funding from Marubeni.
- **Ascend Elements** and Honda partnered to acquire and recycle materials for Hondas EVs in North America.
- Battery recycler **Cirba Solutions** and Honda partnered to recycle critical battery materials for Honda's future EV products.

There are multiple approaches to battery recycling, each with varying maturity and trade-offs (Figure 5). However, with a range of feedstocks and use cases, we predict no one approach will win out.

For example, the hydrometallurgy process is going to be well suited to end-of-life (EOL), while direct recycling is going to be best suited when producing a similar cathode to the input material or where you are using the same technology for cathode manufacture.

However, you can only recycle materials which are available to be recycled. Most EV batteries are still operational, so the majority of feedstock for battery recycling plants is currently from scrap. In the long term, you will see large volumes of EOL feedstock as batteries degrade over time.

Other challenges include:

- **Complexity and high labor costs** – Sorting and separating batteries means recyclers are not cost competitive with virgin metals.
- **Lack of standardization** – Batteries are manufactured to different specifications and chemistries, making disassembly more difficult.
- **Required specialist skills** – Third-party refurbishers and recyclers do not know what type of battery they are receiving, requiring specialist skills that can cause delays.
- **Uncertainty of battery composition** – Recyclers will need to manage unpredictable inputs of spent materials and scrap, while creating predictable high-quality end products.



## SECTOR ANALYSIS RESOURCES &amp; ENVIRONMENT

In August 2023, the EU Parliament passed the new battery regulation with rules for the design, manufacture, and recycling of batteries sold in the EU. Together with ambitions for a 45% collection rate by the end of 2023 and 73% by end of 2030 for portable batteries, rules also included mandatory waste separation and carbon footprint labelling via a life-cycle assessment, which may drive more sustainable mining upstream.

**WATER**

In 2023, a quarter of Europe experienced drought while water demand is expected to increase by over 50% by 2050. Water is critical in new industrial processes poised to alleviate climate change, including hydrogen production. Increasing water scarcity alongside specific problem pollutants and more stringent regulation are driving substantial investment in water innovations. This marks a shift from previous slower investment trends, largely influenced by the historically low cost of water and tech-averse demand owners.

Water technology investment saw record highs in 2023 with Q2 seeing \$380M of VC investment, while ongoing consolidation via M&A has seen water technology scale-ups emerge:

- Water technology scale-up **Xylem** acquired **Evoqua Water Technologies** for \$7.5B.

- Industrial wastewater and water reuse scale-up **Gradiant** raised \$225M, and became one of the first water technology unicorns. Gradiant has acquired seven water innovators and utility providers since 2020 to expand technological capabilities and geographic market reach.

Growing awareness of harmful pollutants such as Perfluoroalkyl and polyfluoroalkyl substances (PFAS) (forever chemicals) has caused regulators to mandate for PFAS testing and is limiting the use of wastewater biosolids as fertilizers due to concerns of PFAS entering food chains. Solutions to treat PFAS are nascent; technologies use absorbent materials to efficiently bind and eliminate PFAS and other harmful pollutants.

- Biotechnologies developer and PFAS monitoring and remediation solution developer, **Allonnia**, raised \$30M.

- **Aclarity** raised \$12M.

AI and machine learning (ML) software are being stacked with geospatial imagery and direct sensors connected by IoT, which are improving efficiency in water and wastewater management. AI can identify water loss across complex systems, learning from previous leaks and identifying high risk areas where leaks may occur, reducing water loss and protecting against water damage. For wastewater treatment plants, AI and ML can ingest large amounts of data and enable data-to-outcomes decision support for managers.

**CORPORATE SUSTAINABILITY, RISKS & OFFSETS**

The corporate sustainability, risks and offset sector includes sustainability monitoring, climate risk analytics, and technologies in carbon offset project production and markets. The transparency and integrity of corporate sustainability has been challenged in 2023, much to the benefit of emissions and climate risk monitoring providers and for most offsets' innovators. These drivers for more accurate disclosures and effective offsets include:

- The EU published provisional new rules to ban misleading product claims, including claims based on emissions offsetting schemes.
- Following two years of design and consultation, the Taskforce on Nature-related Financial Disclosures (TNFD) launched its final reporting framework.
- Starting in 2024, The European Sustainability Reporting Standards (ESRS) will force large companies in the EU member states to disclose quantitative metrics and targets on emissions and sustainability impact, dependencies, risks, and opportunities.
- Investigations from the Guardian and Corporate Accountability, an NGO corporate watchdog, analyzed the top 50 offset projects categorizing 78% of them as 'junk', having one or more fundamental failings.

**SUSTAINABILITY MONITORING**

As companies across the globe gear up to report their sustainability impact and risks (mostly emissions- and climate-related risks), they are looking for tools and services to accurately report, reduce their reporting burden, and reduce litigation risks of misreporting. As the industry completes half of a decade of development, innovators are specializing via sector, customer-base, or creating integrated platforms for all corporate ESG metrics:

- ESG supply chain tracking, climate risk, and emissions monitoring platform developer **IntegrityNext** raised \$108M in an unknown round.
- Emissions monitoring via spending API developer **Choose**, raised \$15M.

Innovators have also begun to consolidate to acquire a competitive edge in a busy market:

- Behavior change specialist **Dreams Technology** was acquired by **Doconomy** to integrate behavior change science into its environmental impact software.

**THE TRANSPARENCY AND INTEGRITY OF CORPORATE SUSTAINABILITY HAS BEEN CHALLENGED IN 2023, MUCH TO THE BENEFIT OF EMISSIONS AND CLIMATE RISK MONITORING PROVIDERS AND FOR MOST OFFSETS' INNOVATORS**



SECTOR ANALYSIS RESOURCES & ENVIRONMENT

**CLIMATE RISK**

AI and climate scenario modelling enables climate risk to be identified, measured, and priced vs. adaptation actions. This enables data-informed resilience strategies and financial reporting for investors, corporates, and governments, as well as climate data-informed underwriting from insurers. Mandatory climate-risk disclosures are having a similar impact on sustainability monitoring innovators, driving accuracy, and in this case, peril-specific risk analysis, e.g., fire or flood.

Investors are recognizing the business case for better risk analysis:

- **ClimateAI** raised \$22M in a Series B round to expand into India, Japan, and other countries in the global south, worst affected by climate risk.
- Geospatial data and AI-enabled wildfire intelligence provider **Pano** raised \$17M in Growth funding.
- Temasek-backed investment management firm **LeapFrog** is raising \$600-\$700M for a new fund, in part focused on climate adaptation.

**OFFSETS**

The questionable integrity of avoidance credits and non-additional project types such as renewable energy credits have led the market to select for higher quality offset types or innovation to improve existing projects (see Figure 6).

Investors are banking on offsets becoming a lucrative asset class and see strategic advantages in investing in market infrastructure. Market-focused innovators continue to receive strong investment:

- **CarbonPlace**, an offset transaction facilitator, raised \$45M in Seed funding primarily from banking organizations including UBS, Standard Chartered, and Natwest. 

**INVESTORS ARE BANKING ON OFFSETS BECOMING A LUCRATIVE ASSET CLASS AND SEE ADVANTAGES IN INVESTING EARLY**

**FIG. 6: VALUE CHAIN OF HIGH-QUALITY OFFSET INNOVATORS WHICH RECEIVED INVESTMENT IN 2023**





INDUSTRY GROUP ANALYSIS

TRANSPORTATION & LOGISTICS

WRITTEN BY  
NICOLE CERULLI, ASSOCIATE,  
TRANSPORTATION & LOGISTICS



Widespread Transportation Electrification is Under Way, Bringing with it New Energy Challenges

Innovation in on-road vehicles is expanding electrification from passenger cars to niche markets including small four-wheel vehicles optimized for urban mobility, luxury high-end passenger cars, two-wheelers, and difficult-to-abate sectors such as commercial heavy-duty vehicles.

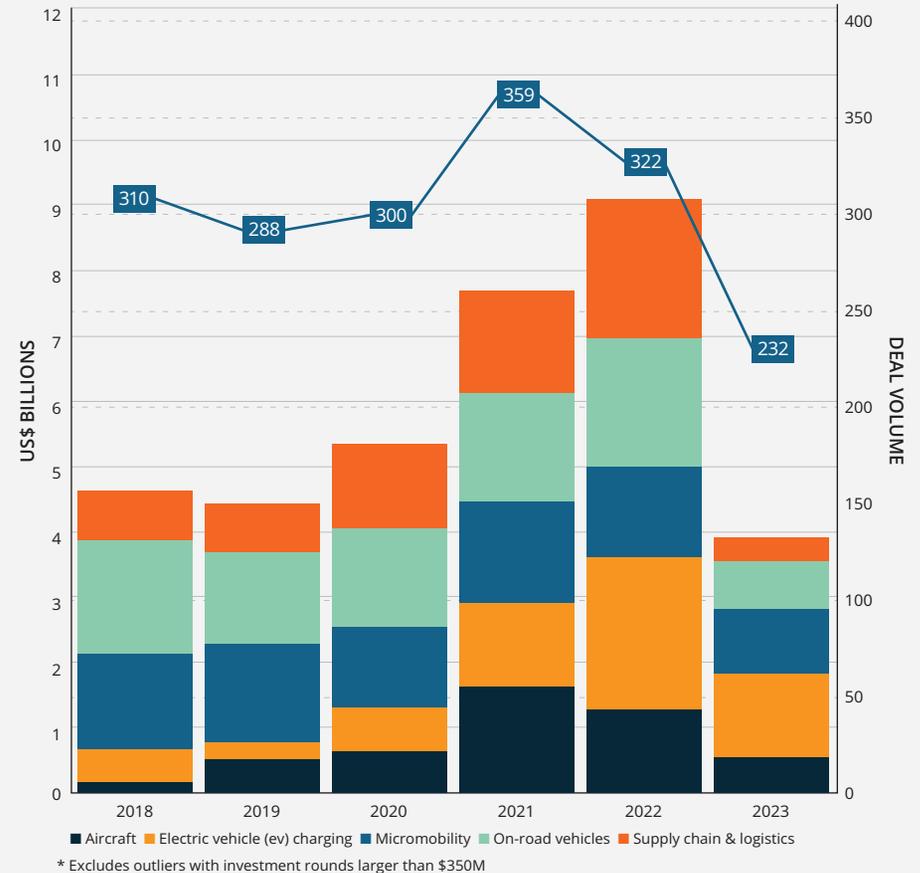
EV charging innovation is facilitating the deployment of widespread EV charging infrastructure including residential, fast-charging, and novel charging solutions such as V2X and bidirectional charging, ultra-fast charging, grid services, and energy storage integration.

Fleet electrification and management: solutions to accelerate fleet electrification from commercial electric vehicle providers to electric fleet charging and logistics management platforms are addressing both the mobility and energy challenges facing newly electrified fleets.

INNOVATION IN ON-ROAD VEHICLES IS EXPANDING ELECTRIFICATION TO NICHE MARKET VEHICLES

FIG. 1: TRANSPORT & LOGISTICS INVESTMENT BY YEAR

Source:  Cleantech Group





SECTOR ANALYSIS TRANSPORTATION & LOGISTICS

**EV CHARGING**

EV charging has been one of the key Transportation & Logistics themes for several years, attracting some of the highest investment numbers across the industry group since 2021.

Over the past several quarters, EV charging activity and investment has centered around the widespread deployment of charging stations and scaling of charging networks, particularly fast chargers. This trend holds across both venture investment and public sector funding—regional, federal, and international governing bodies have rolled out significant funding schemes and supporting policy to deploy large-scale EV charging networks.

Notable examples from the past year include the U.S. Bipartisan Infrastructure Law Charging and Fueling Program, allocating \$2.5B to develop EV charging networks across the country and EU regulation to require fast charging stations (minimum 150 kW) every 60 kilometers on the Trans-European Transport Network by 2025—with future targets of 400 and 600kW chargers along the main network.

More recently, corporate investment and engagement from energy and automobile incumbents as well as oil and gas majors have shifted towards novel technologies to address the roadblocks that stand in the way of increased EV adoption. In addition to the availability and deployment of charging networks, these challenges are energy demand and impact on the grid, access to charging in urban centers as well as areas with poor grid connectivity, and charge time.

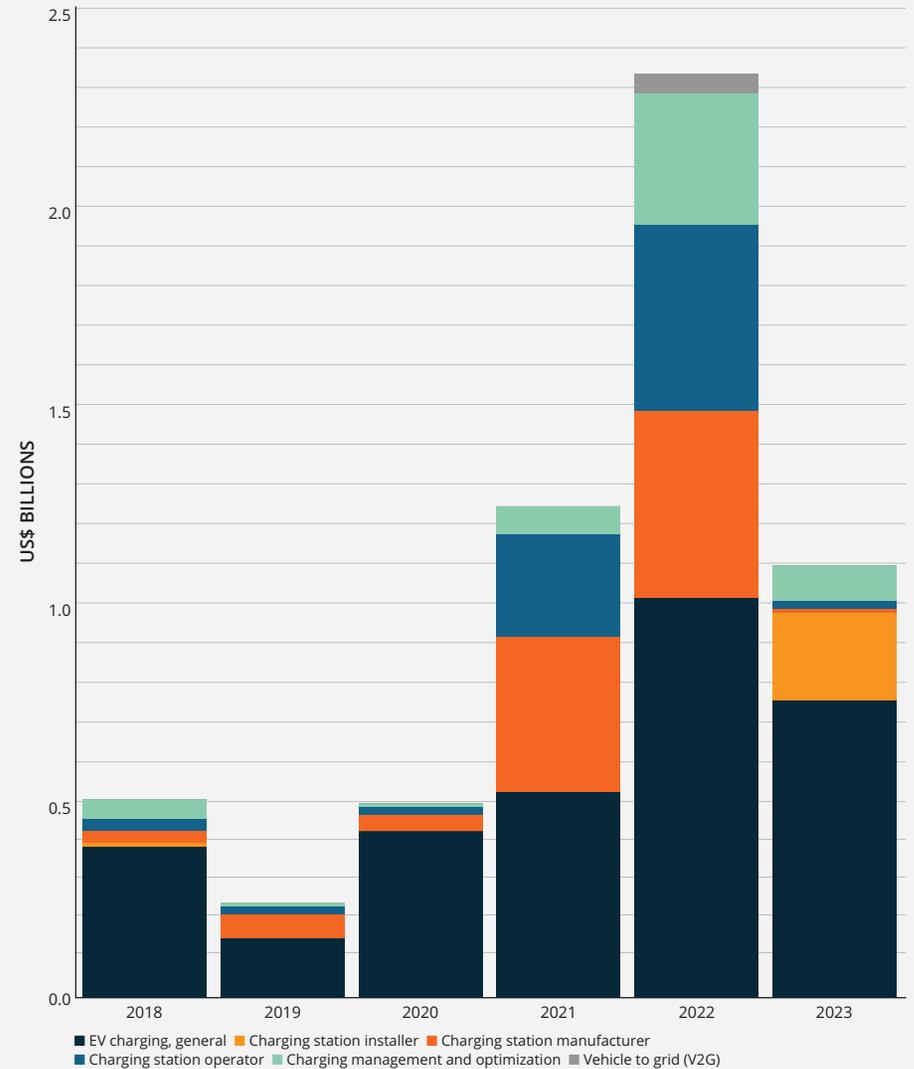
Some of the technologies addressing these challenges include vehicle-to-grid (V2G) and vehicle-to-everything (V2X) solutions (e.g., **Fermata Energy**), charging management software to optimize battery performance and minimize stress on the grid (e.g., Global Cleantech 100 company **ev.energy**), novel urban charging solutions for multi-unit buildings, sidewalk charging, and vehicle-to-building energy management, as well as ultra-fast charging and energy booster technologies (e.g., **Zooz**) to increase charging speed.

**May 2023:** **Jolt Energy**, developer of EV fast-charging solutions for urban areas, raised \$165M in Growth Equity from Infrared Capital Partners to accelerate the implementation of a fast-charging network across Europe and the U.S.

**August 2023:** Tesla acquired **Wiferion**, a provider of wireless fast-charging systems for e-mobility applications.

FIG. 2: EV CHARGING INVESTMENT BY SUBSECTOR

Source:  Cleantech Group





SECTOR ANALYSIS TRANSPORTATION & LOGISTICS

ON-ROAD VEHICLES

PASSENGER VEHICLES

Chinese EV innovators received massive venture investment this past year, with a particular emphasis on smart, passenger EVs. Some notable rounds included a \$960M Growth Equity round from **Hozon Automobile**, from Geely Automotive subsidiary **Zeekr**, and a \$410M Series B from **Avatr Technology**. These innovators are targeting specific markets within the EV passenger vehicle space from smart, compact urban vehicles, to high-end, luxury personal vehicles.

HEAVY-DUTY COMMERCIAL VEHICLES

While both innovators and automotive incumbents continue to optimize passenger EVs and scale manufacturing capacity, this past year has also seen significant innovation and development of zero-emissions heavy-duty commercial vehicles. Though only a small part of the global fleet, heavy-duty vehicles (HDVs) account for over 25% of road transport emissions. HDVs have conventionally been a hard-to-abate sector, emissions intensive, and dependent on diesel.

While battery-electric alternatives to passenger and two-wheel vehicles are proving to be effective zero-emissions solutions, the decarbonization of the HDV sector is more complex.

Though battery technologies continue to improve, the size and high use-rate of HDVs require massive batteries that negatively impact the cargo capacity and range of the vehicle. Additionally, the long charging times of these batteries can be incompatible with fleet operator's scheduling and route requirements.

For certain use-cases, innovators and OEMs seem to have overcome these challenges, notably electric buses and school buses. Despite the challenges of heavy-duty electrification today, hydrogen can only fill a specific gap for very long distances where cargo space and refueling time are of critical importance to the route. As a result, innovation that operates at the nexus of charging management, fleet management, and grid flexibility will continue to have an opportunity to break open business cases for fleet operators.

FIG. 3: ZERO EMISSIONS HDV PERFORMANCE AND USE CASES

Source:  Cleantech Group

	PAYLOAD	RANGE	CHARGE TIME	USE CASE
BEV	Medium duty 75%	500 miles	1-8 hours	Urban. Regional
	Heavy duty 80%			
Hydrogen	99%	800 miles	10-20 mins	Heavy-duty, long-haul. Regional fixed-route back to depot
Diesel	Benchmark	1,200 miles	10-15 mins	

**THOUGH ONLY A SMALL PART OF THE GLOBAL FLEET, HEAVY-DUTY VEHICLES (HDVS) ACCOUNT FOR OVER 25% OF ROAD TRANSPORT EMISSIONS**



SECTOR ANALYSIS TRANSPORTATION & LOGISTICS

In that corner of the heavy-duty market that hydrogen can support, innovators and automotive OEMs alike are developing hydrogen combustion and hydrogen fuel cell vehicles, while engaging across the hydrogen supply chain to establish hydrogen refueling networks, and hydrogen storage and management solutions. Hydrogen-powered HDVs have much shorter refueling times, improved range, and eliminate the significant power demand and related grid connectivity challenges of BEV charging stations.

Significant uncertainties remain surrounding hydrogen for HDVs, namely in the availability of hydrogen, the feasibility of establishing refueling stations, as well as storage efficiency, reliability, and safety.

Both BEV and hydrogen HDVs are hitting the roads as manufacturers struggle to increase production capacity to meet demand. HDV incumbents expect to have zero-emissions models commercially available before 2030.

**May 2023:** Daimler, a manufacturer of zero-emissions HDVs, established a joint venture with [NextEra Energy](#) and BlackRock Alternatives to implement public EV charging and hydrogen refueling networks for medium- and heavy-duty vehicles across the U.S.

**July 2023:** [Hydrogen Vehicle Systems](#) (HVS), a developer of hydrogen commercial trucks, closed a \$37M Series A round to establish a network of hydrogen fuel stations.

**MICROMOBILITY**

On the opposite side of the vehicle spectrum, micromobility innovators continue to electrify personal mobility – namely two wheelers including electric scooters, mopeds, and cargo bikes. While electric two-wheelers are no longer novel technologies, a range of new business models and supporting technologies are developing to support the emobility sector. Several examples include battery swapping stations (e.g., [Ample](#)), last-mile logistics electrification (e.g., [Onomotion](#)), electric mobility services, and financing solutions to increase accessibility to emobility solutions.

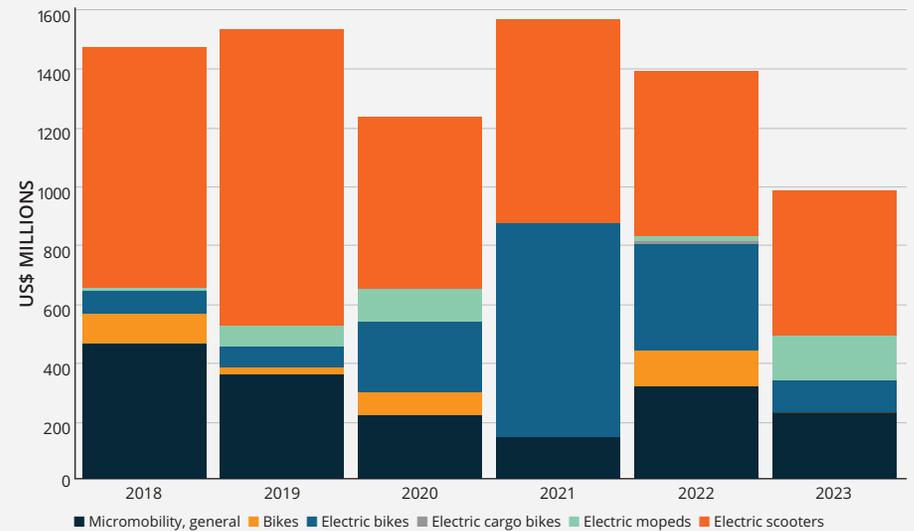
FIG. 4: HYDROGEN STORAGE AND FUELING CHALLENGES AND INNOVATION

	CHALLENGES	BENEFITS	INNOVATORS
<b>Gaseous hydrogen</b>	<ul style="list-style-type: none"> <li>High pressure storage</li> <li>Low-density, high volume requirement</li> </ul>	<ul style="list-style-type: none"> <li>Leverages existing gas pipelines for transport</li> </ul>	
<b>Liquid hydrogen</b>	<ul style="list-style-type: none"> <li>High temperature sensitive</li> <li>Prone to boil-off</li> <li>Requires high efficiency insulated tanks</li> <li>Liquefaction energy and capital-intensive</li> </ul>	<ul style="list-style-type: none"> <li>Higher density, reduces storage space/weight</li> <li>Increases payload and range of vehicle</li> </ul>	

Source: 

FIG. 5: MICROMOBILITY INVESTMENT BY SUBSECTOR

Source: 





## ESTIMATES SUGGEST THAT BY 2024, 35% OF GLOBAL FLEET VEHICLES WILL BE ELECTRIC, REACHING 50% BY 2025

### FLEET MANAGEMENT

#### FLEET ELECTRIFICATION SERVICES

Over the past year, momentum for fleet electrification has been building. Both corporate sustainability goals and global decarbonization targets are increasingly targeting supply chain decarbonization and reducing transport-based emissions. These targets, combined with incentives and impending internal combustion engine (ICE) vehicle bans, are driving up adoption of personal EVs and the electrification of fleets.

**March 2023:** Electric commercial fleet and fleet electrification solutions provider [Revolv Transportation](#) raised \$15M in a Series A round from Greenbacker Capital to expand operations across North America and provide fleets of electric trucks.

**August 2023:** [Dynamon](#), a provider of EV fleet management software for commercial transport and logistics, raised \$5M in a Series A round from bp Ventures. The two companies also announced a partnership to make Dynamon simulation and data analytics tools available to bp Pulse customers for efficient EV fleet management.

On the vehicle supply side, EVs are reaching cost-parity with ICE vehicles in terms of total cost of ownership for fleet vehicles, which are much higher use than personal passenger vehicles, correlating to more cost-savings on operations, maintenance, and refueling. Estimates suggest that by 2024, 35% of global fleet vehicles will be electric, reaching 50% by 2025 (IEA).

#### ENERGY/CHARGING MANAGEMENT

As fleets electrify, fleet operators and drivers face new challenges in adapting operations from ICE to electric vehicles, both in terms of energy management and operations logistics. The optimization of routing and scheduling has become a very crowded field, with innovators offering platforms and services to optimize electric vehicle use, routing, and charging schedules, often leveraging AI, machine learning, and proprietary algorithms that take into account battery management, vehicle charging needs, and overall vehicle distance travelled.

The energy side of the fleet electrification puzzle is perhaps the most complex and challenging, involving a range of stakeholders including utilities, charge point operators, grid management, and fleet operators. Fleet electrification poses a significant challenge to local grids, which are not currently equipped to meet the new demand of electric fleets, particularly those comprised of heavy-duty vehicles.

Innovation in this space includes smart charging and load-shifting software to reduce stress on the grid and minimize charging costs for fleet operators as well as V2G solutions, which leverage bidirectional charging to allow EVs to serve as energy storage and discharge back to the grid to increase grid stability and avoid costly grid upgrades.

An entire ecosystem of services is developing around fleet energy management and fleet-to-grid (F2G), from battery management (e.g., [Fermata Energy](#)), virtual power plants and energy asset management (e.g., [Autogrid](#)), and bidirectional chargers (e.g., [Wallbox](#)). While F2G solutions are currently mainly focused on residential charging and personal vehicles, applying these technologies to electric fleets has the potential to convert EV fleets from grid liabilities to significant assets, enabling increased renewables adoption and contributing significantly to global energy storage capacity.

As the energy demand increases from newly electrified fleets, commercial vehicles such as transit buses and heavy-duty freight vehicles, charging and energy management solutions will be critical to stabilize grids, allow utilities to meet consumer power demands, and avoid extensive grid upgrades. 

# THE 2023 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.

**WE EXPECT THE PACE OF SUCH “UNICORNIZATION” TO SLOW DOWN AND CATCH A BREATH IN 2023- MOST PARTICULARLY IN OTHER INVESTMENT THEMES BEYOND CLEANTECH (WHERE MOST UNICORNS ARE, ANYWAY), BUT ALSO IN CLEANTECH. VALUATIONS WILL SURELY GO THROUGH SOME KIND OF RE-SET IN 2023, ALBEIT, PERHAPS LESS SO, FOR THE VERY BEST AND BRIGHTEST GLOBAL CLEANTECH 100, JANUARY 2023**

Below we record the graduation events since the previous edition of the Global Cleantech 100 up to the cut-off date on September 30, 2023.

It is not surprising to find, given the adjustment period we are in after the hot markets of 2021-22, that there were fewer graduations in this period. There were six M&A's (vs. 14 for the prior period) and two IPO's (vs. 7 the year before), reflective of the cooler market conditions.

## SPACS AND PUBLIC COMPANIES

Companies which announced a definitive agreement to go public via a Special Purpose Acquisition Company (SPAC) before the cut-off date (September 30, 2023) were ineligible for consideration for the 2024 Global Cleantech 100, even though we fully recognize that some might not complete in the end.

An example of this would be [EnOcean](#), an early Global Cleantech 100 company (2009-2012). This German energy efficiency company, a pioneer of energy harvesting IoT devices for buildings, had announced a business combination agreement with the SPAC, Parabellum Acquisition Corp., in November 2022. The SPAC was abandoned in May 2023 and in September 2023, EnOcean cemented its position as a private company with an investment from Innovation Industries, a deep tech venture capital firm in the Netherlands.

Only those which have fully completed and are trading as a public company are included in our roll call of graduates below.

## 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 (e.g., [H2Green Steel](#) raising \$1.5B in equity!) – can no longer qualify for the Global Cleantech 100. With valuations of recent times, this has meant more leading private companies each year who might otherwise have made the Global Cleantech 100, are no longer able to do so.

What we wrote in last year's report (see pull quote opposite), has largely played out, and we do expect more of the same in 2024, as venture capital, along with all forms of finance, go through a bit of a reset.

For the record, the last 12 months of relevance (prior to October 1, 2023) has seen the following cleantech companies become Unicorns:

- 10 of last year's Global Cleantech 100 were among them (compared to 9 the prior year) – [1Komma 5](#), [Ascend Elements](#), [Climeworks](#), [Gradient](#), [Group14 Technologies](#), [H2Green Steel](#), [Kobold Metals](#), [Monolith](#), [Mainspring Energy](#), and [Our Next Energy](#).
- We counted a further 5 cleantech companies over the period – [BeZero](#), [eFishery](#) (a 2020 APAC Cleantech 25 Company), [Jetti Resources](#), [Jiangsu Horizon New Energy Technology](#), and [Lyten](#).

GLOBAL CLEANTECH 100 GRADUATES VIA M&A				
OCTOBER 1, 2022 - SEPTEMBER 30, 2023				
GLOBAL CLEANTECH 100 ALUMNUS COMPANY	ACQUIRER	DATE	NOTES FROM THE ANNOUNCEMENTS	YEARS ON THE GLOBAL CLEANTECH 100
 <b>Blue Pillar</b>	Generac Power Systems	Oct 2022	Generac acquired Blue Pillar to integrate the platform into its power generation products and, in connection with Generac Grid Services' projects, provide distributed energy generation monitoring and control as a built-in feature.	2015, 2017, 2018
 <b>depsys</b>	Kraken, part of Octopus Energy Group	Dec 2022	Kraken acquired Depsys and its 'GridEye' platform to boost its offering to network operators. The 'GridEye' technology platform will become part of Kraken to provide analytics, data, and real time monitoring, including fault management, power quality, and power flow modelling.	2020, 2022
 <b>luxexcel</b> 3D printed lenses	Meta	Dec 2022	This acquisition is intended to boost Meta's positioning in AR (Augmented Reality). Luxexcel uses 3D printing to make prescription lenses for glasses. More recently, the company has focused its efforts on smart lenses, which can be printed with integrated technology like LCD displays and holographic film. By absorbing Luxexcel, Meta is expected to leverage the company's technology to produce prescription AR glasses.	2014
 <b>GaN Systems</b>	Infineon	Mar 2023	Infineon acquired GaN Systems for \$830M to boost its position across all relevant power technologies (silicon, silicon carbide, gallium nitride...). GaN technology can enable more energy-efficient and CO <sub>2</sub> -saving solutions in applications like mobile charging, data-center power supplies, residential solar inverters, and onboard chargers for electric vehicles.	2015, 2017, 2018, 2019, 2020, 2021, 2023 (Hall of Fame)
 <b>deepsea</b>	Nabtesco	Jul 2023	Nabtesco acquired DeepSea to support its move towards the development of autonomous vessels and other AI applications in its business sectors. DeepSea will continue to focus on the development of its established software platforms, which enable shipping companies to decrease fuel consumption and emissions by optimizing vessels and voyages.	2022, 2023
 <b>Carbon Engineering</b>	Occidental Petroleum	Aug 2023	Occidental acquired Carbon Engineering for \$1.1B to help it develop 100 carbon capture plants using direct air capture (DAC) technology.	2020, 2021, 2022

GLOBAL CLEANTECH 100 GRADUATES VIA IPO				
OCTOBER 1, 2022 - SEPTEMBER 30, 2023				
GLOBAL CLEANTECH 100 ALUMNUS COMPANY	IPO TYPE	IPO DATE	DESCRIPTION	YEARS ON THE GLOBAL CLEANTECH 100
 <b>LanzaTech</b>	Via SPAC	Feb 2023	Developer of a carbon capture and reuse technology that transforms abundant waste and low-cost resources into low carbon fuels and chemicals	2010, 2011, 2012, 2013, 2014, 2015, 2017 (Hall of Fame)
 <b>Tigo</b>	Via SPAC	May 2023	Provider of hardware, software and web-based applications to improve PV installation power output	2009, 2010, 2011

While on the subject of M&A, it is worth noting two other dynamics, the likes of which we expect to see more of, in the coming year or two.

One concerns the potential rise of exits and liquidity events with Private Equity (PE) firms. Some PE firms have been raising massive funds with climate/infrastructure called out in the strategy. KKR would be a case in point. We expect to see some exits to such in 2024+.

The other concerns the acquisition of companies from the public markets, especially of companies who went public via SPACs in the hot days of 2020-21 and who have not been able to maintain the confidence of the public markets at their original valuations.

Examples of this from Global Cleantech 100 Alumni over the last 12 months would be:

- **Desktop Metal** (a 2019 alumna) went public via a SPAC in December 2020 at \$2.5B; in May 2023, **Stratasys** acquired it for \$1.8B.
- More dramatically, **otonomo** (an alumna of 2018 and 2019) and **Volta Charging** (an alumna of 2019, 2020 and 2021) both went public in 2021 and were acquired during 2023 – by Urgently and Shell, for \$70M and \$169M, respectively, both for less than 10% of the valuations at the time of the original flotation.

## 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, three companies have reached that milestone and are accordingly inducted into the Global Cleantech 100 Hall of Fame. All speak to resource efficiency being back in vogue, in a range of industrial arenas as varied as growing crops, mining copper, and heating homes.

- **Minesense** is a pioneer in digital mining solutions, supplying real-time, sensor-based ore sorting for mines. In the era of growing concern about future shortages of critical minerals to enable a decarbonized economy, this type of solution's potential to boost output of the mining activity already happening, by say 5-15%, is important.
- **tado** has been pioneering smart thermostats for heating and cooling in Europe since its founding in 2011. Based in Germany, it is now scaling increasingly across Europe, offering millions of homeowners both savings on their rising energy costs and a reduction in their CO<sub>2</sub> emissions.
- **Vestaron** has been proving out the idea that safe and effective pest control can also be biological and sustainable, through its peptide-based insecticide technology. The company first debuted on the list in 2013 but has become a regular returnee under new leadership since 2018.

	HALL OF FAME		
INDUCTED JANUARY 2024			
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, and Events.

We have been the leading authority on global cleantech innovation since 2002.

Contact us anytime, [info@cleantech.com](mailto:info@cleantech.com).



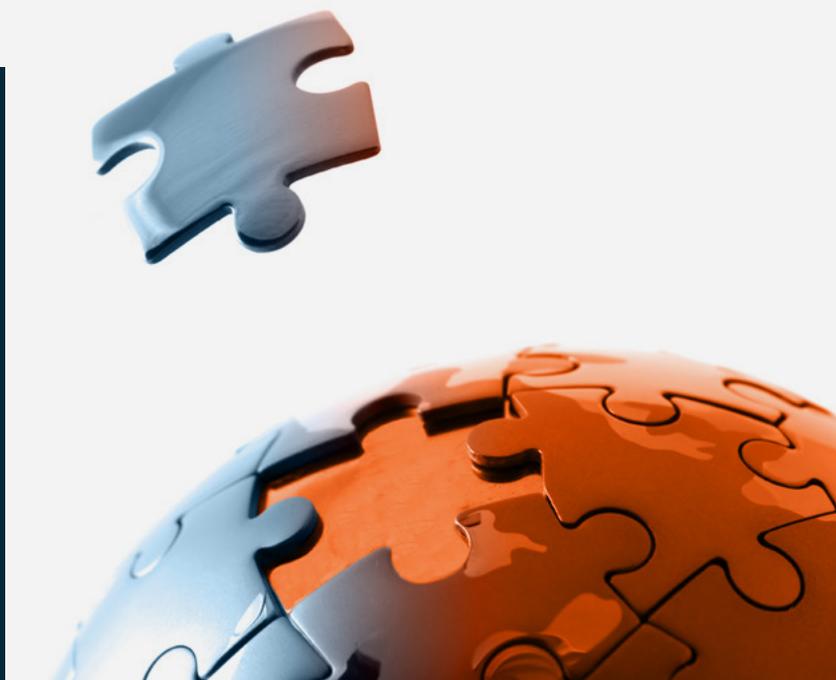
**RESEARCH:** The solution to information overload, our research cuts through the noise to monitor the market and deliver the insight you need on the themes central to your goals on markets, innovators, investments, trends, and the future.



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



**EVENTS:** 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.



# 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.

→ [BIOGRAPHIES](#)

**Christian Hernandez**  
Partner

2150

**Hendrik Van Asbroeck**  
Partner

Astanor Ventures

**Ludwig Goris**  
Partner

Capricorn Partners

**Christina O’Conor**  
Partner

Congruent Ventures

**Lynn Murray**  
Climate Tech Consultant

3M

**Fabio Lancelotti**  
Partner

Aster Capital

**Alfred Lam**  
Partner

Chrysalix Venture Capital

**Shounok Sinha**  
Managing Director

Constellation Technology Ventures

**Nigel Carr**  
Investment Director

Acario Innovation (Tokyo Gas)

**Susan Rohac**  
Managing Partner, Climate Tech Fund

BDC Capital

**Arjune Shukla**  
Senior Investment Associate

Circularity Capital

**Andrée-Lise Methot**  
Founder and Managing Partner

Cycle Capital Management

**Paul Jordan**  
Principal

Activate Capital Partners

**Rhea Hamilton**  
Managing Director

Beyond Net Zero - General Atlantic

**Richard Youngman**  
CEO

Cleantech Group

**Nancy Pfund**  
Founder & Managing Partner

DBL Partners

**Greg Fleming**  
Investment Director

Air Liquide Venture Capital - ALIAD

**Mary Hayes**  
Principal, Ventures

BHP

**Felicity O’Kelly**  
Principal, Investments

Climate Investment

**Scott Himmelberger**  
Director

Decarbonization Partners

**Michelle Robson**  
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**Ernst Sack**  
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Blue Bear Capital

**Aly Bryan**  
Ventures Investor

Closed Loop Partners

**Olivier Bordelanne**  
Partner

Demeter

**Cory Steffek**  
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Ara Partners

**Shaun Healey**  
Investment Director

BP Ventures

**Abhijoy Mitra**  
General Partner

Coatue Management

**Dr. Paul-Josef Patt**  
Managing Partner and CEO

eCAPITAL Entrepreneurial Partners

## MEET THE EXPERTS

[→ BIOGRAPHIES](#)**Sasha Brown**

Partner

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Managing Director

**ENGIE New Ventures****Mani Ghiasi**

Vice President, Venture &amp; Growth

**Galvanize Climate Solutions****Sukhwan Yun**

Senior Investment Manager

**Hyundai Motor Company****Luís Manuel**

Partner and Managing Director

**EDP Ventures****Fabrice Bienfait**

Senior Partner

**ETF Partners****Colin Le Duc**

Founding Partner

**Generation Investment  
Management****Diego Diaz Pilas**Global Head of  
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Managing Partner

**Emerald****Naynika Chaubey**

Partner

**Evok Innovations****Stefon Crawford**

Partner

**GM Ventures****Matias Torellas**

Head of Portfolio Management

**InnoEnergy****Glenn Bijvoets**

Innovation Lead

**Eneco****Lutz Stoeber**

Investment Director

**Evonik Venture Capital****Eric Wang**

Managing Partner

**GRC SinoGreen Fund****Ivo Němejc**

Investment Director

**Inven Capital****Kei Morita**

General Manager

**ENEOS****Dirk De Boever**

Head of Investments

**Finindus****Jamie James**

Managing Partner

**Greensoil Building Innovation Fund****Ali Sharifi**

Managing Director

**Kerogen Capital****Matthias Dill**

CEO &amp; Managing Partner

**Energy Impact Partners****Patrick Elftmann**

Partner

**Future Energy Ventures****Robert Liu**

CEO

**Huaneng Invesco WLR (Beijing)****Ben Murphy**

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**Kiko Ventures****Wally Hunter**

Managing Director

**EnerTech Capital**

## MEET THE EXPERTS

[→ BIOGRAPHIES](#)

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**Ricky Sakai**  
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**Ken MacKinnon**  
CEO & Co-Founding Partner  
MKB Growth Equity

**Martin Kröner**  
Partner  
Munich Venture Partners

**Gert Wrigge**  
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Next47

**Chris Erickson**  
General Partner  
Pangaea Ventures

**Maria Buitron**  
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PIVA

**Jake Simon**  
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Porsche Ventures

**Gabriel Kra**  
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Prelude Ventures

**Eric Kosmowski**  
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**Michael Claes**  
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**Grant Allen**  
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**Peter Kennedy**  
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Silverstrand

**Hee S. Jung**  
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**Arindam Bhattacharya**  
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**Dr. Mark Bonnar**  
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and Climate Solutions VC

**Kurt Faulhaber**  
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**Astorre Modena**  
Managing Partner  
Terra Venture Partners

**Erik Scher**  
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**Qi Lu**  
Partner  
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**Peter Auner**  
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