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SEIZING GREEN WINDOWS OF OPPORTUNITY: Evidence from Cleantech Startup Value Creation

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TECHNOLOGY, INDUSTRIALISATION
AND DEVELOPMENT (TIDE) CENTRE

WORKING PAPER 95
APRIL 2026

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ABSTRACT

As part of the global transition toward net zero, cleantech startups have emerged as crucial enablers of decarbonisation, resource efficiency, and circular innovation. However, accurately assessing their value remains challenging due to long R&D cycles, capital intensity, technological complexity, and policy dependence. Drawing on comparative valuation data and applying OxValue.AI's valuation framework, grounded in the Utility Theory of Technology Value, this paper provides one of the first systematic assessments on where value is created across cleantech startups, how this varies by region and sector, and what is required to sustain and amplify that value. By analysing value creation across key dimensions, including market factors, technological novelty, lifecycle positioning, and risk and team characteristics, we offer evidence-based insights into the evolving landscape of frontier cleantech innovation and identify the diverse strategies through which cleantech innovations translate value creation into climate impact across different regions and sectors. By understanding where value is generated today and which factors underpin future value growth, policymakers, investors, and innovators can better seize green windows of opportunity and shape the pathways that accelerate the green transition. .

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Preface

OxValue.AI is pleased to present this paper, “Seizing Green Windows of Opportunity: Evidence from Cleantech Startup Value Creation”, produced in collaboration with the Department of International Development at the University of Oxford and Nottingham University Business School. The global transition toward net zero has created green windows of opportunity for governments, investors, and industries, particularly in developing economies, to leapfrog traditional development stages through the adoption and scaling of clean technologies. This paper provides one of the first systematic assessments on where value is created across cleantech startups, how this varies by region and sector, and what is required to sustain and amplify that value. Drawing on comparative valuation data, it offers evidence-based insights into the evolving landscape of frontier cleantech innovation.

Cleantech startups have emerged as crucial enablers of decarbonisation, resource efficiency, and circular innovation. However, accurately assessing their value remains challenging due to long R&D cycles, capital intensity, technological complexity, and policy dependence. In this paper, we apply OxValue.AI’s award-winning valuation framework, grounded in the Utility Theory of Technology Value, to evaluate two cohorts of cleantech startups: early-stage pioneers developing breakthrough climate solutions, and more mature startups that have scaled to unicorn status. The model enables analysis of value creation across key dimensions, including market factors, technological novelty, lifecycle positioning, and risk and team characteristics.

Our findings reveal both the opportunities and underlying drivers shaping cleantech innovation and deployment. The most highly valued pioneering cleantech technologies originate from a diversity of countries, while top cleantech unicorns are concentrated in Europe, China, and the US. Clear sectoral variations are evident, with most high-value firms operating in renewable energy, sustainable materials, and transportation sectors. Regional differences in sectoral distribution reflect local priorities. Across both cohorts, value creation is strongly sensitive to changes in team strength, risk mitigation, technology novelty, and technology lifecycle. Market factors matter, but valuation appears less sensitive to market size than to other drivers in general.

This study sheds light on how cleantech startups are redefining value in the age of sustainability. It highlights the diverse strategies through which cleantech innovations translate value creation into climate impact across different regions and sectors. By understanding where value is generated today and which factors underpin future value growth, policymakers, investors, and innovators can better seize green windows of opportunity and shape the pathways that accelerate the green transition.

OxValue.AI remains committed to advancing its valuation methodology to support industry leaders, investors, and policymakers with deeper insights that foster the sustainable development of the global cleantech sector.

Acknowledgements

We would like to express our sincere gratitude to all those who contributed to the development of this paper. We are especially grateful to the project leads, Professor Xiaolan Fu of the University of Oxford and Dr Jing Zhang of the University of Nottingham, for their guidance and intellectual leadership throughout this study. We also thank Minzheng Liu for the valuable assistance with this research. We further acknowledge the dedicated efforts of the OxValue.AI research and technical teams for their work in applying and refining the valuation platforms used in this study. We are grateful to Professor Xiong Yu, Professor Kun Jiang, and Professor Maggie Fu for their constructive feedback and comments that helped strengthen this paper. Finally, we appreciate the support of the British Academy (grant number TDA23\230187).

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Introduction

The accelerating global response to climate change and the pursuit of the Sustainable Development Goals have created “Green Windows of Opportunity” (United Nations Conference on Trade and Development, 2023), which is a transitional period during which structural shifts in technology, regulation, funding availability, and market demand align to favour the emergence of low-carbon industries. This juncture also presents an opportunity for countries, particularly developing economies, to leapfrog stages of industrial development by adopting the latest clean technologies (cleantech). As governments commit to net-zero pathways and implement industrial policies supporting clean energy, low-emission mobility, sustainable materials, and circular systems, cleantech has evolved from a niche experiment to mainstream implementation, becoming a central pillar of environmental resilience and economic competitiveness.

In recent years, startups have emerged as key drivers of disruptive cleantech research and development (R&D) and commercialisation (Cleantech for UK, 2023). These firms operate at the technological frontier, frequently advancing breakthroughs in renewable energy, energy storage, carbon capture, advanced materials, green agriculture, and resource-efficient manufacturing. Their inherent agility enables them to rapidly develop, test, and deliver new solutions to climate challenges. For policymakers, cleantech startups act as engines of sustainable innovation, job creation, economic growth, and environmental progress. For investors, startups provide access to cutting-edge low-carbon R&D, emerging markets, and the potential for significant returns. For researchers and inventors, they serve as a crucial vehicle to translate ideas and prototypes into commercially viable products with real-world impact.

Despite their growing influence, positive environmental contributions, and potential profitability, cleantech startups frequently operate in highly complex markets characterised by long development timelines, high capital intensity, technological risks, inadequate infrastructure, inconsistent regulatory environment, and imperfect capital markets (Polzin et al., 2016). These barriers make it more difficult for startups than for established firms to attract

the financing needed to push the boundaries of what is technologically and commercially possible. Such financing gaps exist across both developed and developing countries.

Accurate valuation of cleantech startups is, therefore, both challenging and essential. Robust valuation provides startups with a foundation for attracting investment, reducing uncertainty, allocating resources to R&D, and scaling operations. It also enables investors and policymakers to make informed decisions, distinguish genuine innovation from speculative hype, and ensure that resources flow to the solutions with the greatest real-world impact. However, traditional valuation methods – designed for predictable revenue streams and established markets – often struggle to capture the unique value dynamics inherent to cleantech, given its technical complexity, environmental externalities, policy dependencies, and long-time horizons. Developing rigorous and transparent valuation is thus critical, not only for the success of individual companies, but also for scaling the cleantech sector as a whole and advancing global sustainability.

This white paper applies the “Utility Theory of Technology Value”, pioneered by the OxValue.AI R&D team. Using a model derived from this theoretical framework and supported by an AI-driven methodology, we assess the value creation of cleantech startups across four dimensions: market factors, technological novelty, technology lifecycle, and risks and team capabilities. Based on the valuation of a number of cleantech startups worldwide, this paper identifies the top 30 cleantech startups, selected according to their valuation outcomes and their development of groundbreaking climate technologies, expected to generate substantial impact in the coming years. It also highlights the top 15 cleantech unicorns – defined as startups under 10 years old with estimated market valuations surpassing the \$1 billion threshold – representing the most commercially mature and highly valued startups in the cleantech ecosystem. It further reveals the differences in value drivers across groups of startup companies.

Our analysis shows that the most highly valued pioneering cleantech technologies originate from a wide range of countries, whereas the top cleantech unicorns are largely concentrated in Europe, China, and the US. Significant sectoral variations are evident among the most valuable cleantech startups, with the majority operating in the renewable energy, sustainable materials, and transportation & logistics sectors. Regional differences in sectoral distribution

mirror local needs, resource endowments, and policy priorities. Across all four dimensions of value creation, team and risk factors, along with the stage of the technology lifecycle, are the strongest contributors to startup valuation, while market factors also play a critical role, particularly when considering sector characteristics and the size of domestic markets. Overall, the findings reveal where value is generated and which factors drive future value growth. They offer insights for policymakers, investors, and innovators seeking to make informed decisions in a sector central to the global sustainability transition. This paper also identifies a few priorities for stakeholders seizing the green windows of opportunity.

Overview of Cleantech Startups' Development

2.1 Cleantech Startups and Their Characteristics

Cleantech startups are early-stage, privately held companies that develop products or services addressing global climate and environmental challenges. Their core purpose is to deliver innovative, environmentally sustainable solutions that reduce ecological impact and improve the efficiency of resource utilisation (Cleantech Group & UNIDO, 2024).

Although still a relatively small segment, cleantech startups have grown quickly, accounting for about 5% of all new startups founded between 2010 and 2022 across OECD countries, with particularly rapid growth in the last two years (Dechezleprêtre & Kelly, 2025). They are concentrated in several main sectors, including clean energy, energy storage, energy efficiency, low-carbon mobility, sustainable food and agriculture, pollution abatement, and circular economy solutions.

Cleantech startups often display distinctive characteristics that set them apart from other startups:

- **High environmental and social impact:** Their solutions aim to deliver both financial returns and measurable sustainability benefits, contributing to climate change mitigation, human health, local economic resilience, and sustainable regional development (Hegeman & Sørheim, 2021).

- **Strong innovation base:** Many originated from universities or research institutions, building on scientific discoveries to pioneer cutting-edge technologies and adopting agile approaches to respond to emerging needs (Sato, 2024; UNDP, 2025).
- **Diverse market targets:** While certain cleantech solutions are designed to address broad, scalable global needs, such as renewable energy, energy storage, and water efficiency, many others serve niche markets with highly specialised solutions to complex environmental challenges (Cleantech Group, 2024b).
- **High growth potential but high upfront cost:** While cleantech is seen as a transformational industry attracting growing venture capital (VC) interest (Sato, 2024), it demands heavy early investment in R&D, prototyping, and infrastructure before commercial viability is achieved (Gaddy et al., 2017).
- **Need for scalability and cost parity:** Cleantech startups must demonstrate credible pathways to scale and competitive cost structures in order to gain market acceptance and investor confidence (Cleantech Group, 2025b).
- **Local appropriateness:** Successful cleantech startups adapt their innovations to local socio-economic and regulatory contexts, leveraging local resources to address place-specific challenges (UNDP, 2025).
- **Dependence on public-private partnership:** Due to payback periods and capital intensity, public funding and policy support are often critical for reducing risk and crowding in private investment (Sato, 2024).
- **Chronic underinvestment:** Despite high potential, cleantech remains underfunded relative to other sectors, partly because of perceived risk and long development cycles (Gaddy et al., 2017).

2.2 Background of the Emergence of Cleantech Startups

2.1.1 Technology-Driven Growth

A wave of enabling technologies has accelerated cleantech innovation and startup formation. Artificial intelligence (AI) has emerged as a key driver, enabling technologies such as smart grid and energy management, real-time energy optimisation, and material discovery. For

example, AI is used by utilities to detect grid vulnerabilities linked to climate risks, improving infrastructure resilience and investment planning (Cleantech Group, 2024b).

AI combined with Internet of Things (IoT) helps maximise energy efficiency, reduce operating costs, and enable the integration of renewables into distributed energy systems (Anavatti & Prajapati, 2025). It also underpins real-time environmental monitoring and early warning systems, while predictive modelling smooths supply/demand spikes. AI is increasingly applied in validating and derisking first-of-a-kind (FOAK) cleantech solutions, helping investors assess performance and accelerating commercialisation (Cleantech Group, 2024b).

Other enabling technologies are also reshaping cleantech:

- **Digital technologies** (blockchain, big data, 5G, mobile platforms, cloud computing, etc.) enhance transparency, coordination, and responsiveness in industrial systems. Blockchain is now being piloted to improve traceability in low-carbon supply chains (Yang et al., 2024).
- **Advanced materials and chemicals** are critical to improve tech performance and sustainability of batteries, green building materials, lightweight components, and carbon capture systems.
- **Biotechnologies** are advancing bio-based chemicals, industrial enzymes, and engineered biological systems to reduce emissions and improve process efficiency and circularity in agriculture, textiles, and waste management (Cleantech Group, 2025b).
- **Robotics and automation** are cutting costs and scaling operations in areas such as electric vehicle (EV) manufacturing, precision agriculture, grid maintenance, and waste sorting (Cleantech Group, 2024b).

Rather than acting as isolated tools, these technologies increasingly create value through their integration, improving system-level performance, accelerating technology validation, and lowering investor risk. The importance of this integration is evident in low-emission transportation: AI and digital platforms manage energy flows, automation enhances precision manufacturing, advanced materials cut vehicle weight, and biotechnology supports sustainable batteries and recycling. When combined, these technologies amplify one another, producing cleaner, faster, and more cost-effective mobility systems that none of them could

deliver on their own. This demonstrates a broader structural shift in cleantech innovation dynamics, where future competitiveness and scalability depend not just on individual clean technologies but on the depth and sophistication of their integration with AI, digital platforms, advanced materials, biotechnology, and automation.

2.1.2 Policy Support

Global and regional policy frameworks have established powerful market-pull and risk-reduction mechanisms that shape the trajectory of cleantech development. International frameworks such as the Paris Agreement and the International Energy Agency's (IEA) Net-Zero Emissions by 2050 Scenarios (NZE) provide long-term direction, while national policies translate these ambitions into concrete mandates, incentives, and financing tools that generate both demand-side pull and supply-side push for cleantech innovation and development (Table 1).

In the European Union (EU), the European Green Deal and its associated investment programme – over €1 trillion across 10 years – signal long-term policy commitment. More recently, the Green Deal Industrial Plan, the Net-Zero Industry Act, the Critical Raw Materials Act, and the Clean Industrial State Aid Framework aim to scale cleantech manufacturing, streamline granting of permits, and secure capital and other key inputs (European Commission, n.d.). These measures strengthen the investment environment for cleantech firms, though the EU faces risks related to fragmented implementation across member states and intensified competition with US and Chinese subsidies.

China pursues “dual carbon” goals – peaking CO₂ emission before 2030 and achieving carbon neutrality by 2060 – through the 14th Five-Year Plan (2026 - 2030) and extensive sectoral policies. These combine strict regulatory mandates (e.g. coal cap, and energy- and emissions-intensity controls) with large-scale incentives such as subsidies, tax breaks and green credits (IEA, 2024b). These tools have accelerated the development of EVs, batteries and renewable energy; however, concerns remain over industrial overcapacity.

The UK's legally binding 2050 net-zero target is backed by instruments such as the Contracts for Difference Scheme, the 2035 Zero Emission Vehicle Mandate, the Industrial

Decarbonisation Strategy, and the Green Finance Strategy. Complementary support from the UK Infrastructure Bank and British Business Bank improves access to finance for cleantech startups and SMEs, although policy volatility in recent years poses risks to investor confidence. More importantly, the recent Great British Energy Act 2025 lays the foundation for the UK's ambition to become a "clean energy superpower" through upcoming policies and investment programmes supporting domestic clean energy production and supply chains.

In the US, the Inflation Reduction Act (2022) has committed \$369 billion over 10 years to clean energy and climate action, triggering substantial private investment in cleantech manufacturing (Cleantech Group, 2025a). Complementary measures, such as the Infrastructure Investment and Jobs Act and the CHIPS and Science Act, reinforce domestic supply chains and provide funding for early-stage manufacturing in targeted cleantech sectors (Bermel et al., 2024). Nevertheless, political uncertainty and challenges in permit reform remain.

Collectively, these policies anchor cleantech growth by offering regulatory certainty, public funding, and long-term demand signals – factors critical for mobilising capital and accelerating the commercialisation of cleantech startups and SMEs.

Table 1 Policy Frameworks to Support Cleantech Startups in Key Economies

Economy	Net-zero Goal	Policy Area	Key Policy Mechanisms	Support Type	Highlights
European Union	Climate neutrality by 2050	Market signal	EU Emission Trading System (ETS)	Market pull	Provides a carbon-price signal that increases demand for low-carbon tech (indirect support)
		Industrial strategy	Net-Zero Industry Act; Green Deal Industrial Plan; Temporary Crisis & Transition Framework	Permitting; reform; subsidy; funding	Faster permitting and state-aid flexibility improve the deployment environment (indirect), support scaling of manufacturing
		Funding & demonstration	Innovation Fund; InvestEU; Clean Industrial State Aid Framework; EIB Climate Lending	Funding; risk mitigation;	Direct grants + blended finance for pilot/demonstration projects; critical for scale-up
		Supply chain	Critical Raw Materials Act	Regulatory support	Indirect support by improving raw material security for battery, solar, and hydrogen startups
China	Carbon peaking by 2030; neutrality by 2060	Industrial policy	Five-Year Plans; Strategic Emerging Industries' Programs	Market shaping	Strong demand creation for EV, solar, battery startups (indirect); government procurement and demonstration zones
		Market & finance	National ETS; Green bonds; Green credit	Market pull; green finance	Large green-loan ecosystem (indirect); easier access to manufacturing scale credit
		Fiscal incentives	Subsidies; tax incentives; procurement	Fiscal support	Direct cost relief for manufacturing, EV, and solar tech startups; supports early market entry
United Kingdom	Legally binding net zero by 2050	Power market support	Great British Energy Act 2025; Contracts for Difference (CfD) Scheme	Market pull; funding	Indirect support via long-term price guarantees and stable renewable deployment markets; enables startups supplying components/services
		Transport & market creation	2035 Zero-Emission Vehicle Mandate	Market pull	Creates strong future demand for EV supply-chain startups
		Industrial decarbonisation	Industrial Decarbonisation Strategy; Carbon Capture, Usage and Storage (CCUS) Clusters; Green Industries' Growth Accelerator	Funding; risk mitigation	Cluster programmes offer pilot opportunities for hydrogen and CCUS startups (direct); advanced manufacturing support
		Finance	Green Finance Strategy; UK Infrastructure Bank	Blended finance	De-risk capital for cleantech SMEs/startups; support project development

United States	Major emission cuts (no federal legal net-zero target)	Tax incentives	Inflation Reduction Act (IRA)	Funding incentives	Direct tax credits for cleantech manufacturing, hydrogen, CCUS, solar, and storage; drives massive private investment
		Infrastructure & demand	Infrastructure Investment and Jobs Act (IIJA)	Infrastructure; market pull	Indirect support: EV chargers, grid upgrades, and hydrogen hubs; create testbeds and deployment opportunities
		Scale finance	Department of Energy Loan Programs Office (LPO); CHIPS and Science Act; Defense Production Act	Loans, risk mitigation	Direct support: LPO loans for gigafactories and demonstration projects; support certain startups in deep-tech and manufacturing (e.g. energy, climate hardware, batteries, etc.)
		State-level policies	California's Zero-Emission Vehicle Regulation; Renewable Portfolio Standards	Market pull	Strong subnational markets for EV, solar, storage startups

Source: Constructed by the authors.

2.1.3 Market Demand, Capital Support and Investment Gap

Rapid decarbonisation commitments are opening the green windows of opportunity and driving unprecedented demand for cleantech. Global cleantech manufacturing investment grew by 50%, from \$160 billion in 2022 to \$235 billion in 2023 (IEA, 2024b). China represented around 75% of this investment, with the US and the EU also expanding fast.

In 2024, the global market size of clean technology was estimated at \$ 916 billion and is expected to reach \$1,844 billion by 2030, corresponding to a compound annual growth rate (CAGR) of 12.7% (Grand View Research, 2025). The Asia-Pacific region accounted for more than 50% of the global share in 2024. Country-wise, the US generated \$165 billion in revenue in 2024 and is forecast to hit \$305 billion by 2030 (CAGR of 11.1%). China is projected to grow from \$254 billion to \$520 billion (CAGR of 13%), and the EU from \$178 billion to \$355 billion (CAGR of 12.1%). India is expected to have the highest CAGR among major markets, rising from about \$63 billion in 2024 to \$152 billion by 2030, at a roughly 16.1% CAGR (Grand View Research, 2025).

Achieving long-term net-zero goals requires substantial financial resources, and investment in cleantech has surged in recent years. Global clean energy transition investment surpassed \$2 trillion in 2024, with most (90%) flowing into relatively mature sectors like electrified transportation and renewables, while only about 7% reached emerging technologies such as carbon capture and storage (Statista, 2025a).

The private sector, particularly venture capital (VC), plays an outsize role in cleantech financing. In 2021, VCs invested over €74 billion (about \$87.5 billion) in cleantech startups, representing about 15% of global VC funding, and supported about 30% of cleantech startups, compared with 16% for non-cleantech startups (OECD, 2025). Investment is concentrated in North America, Europe and Asia, led by the US (around \$33.5 billion in 2024), followed by Sweden, France, the UK, Germany, India and China (Statista, 2025b). In terms of sectoral distribution, the relative share of investment in energy efficiency and clean energy has declined over time, while funding has expanded in circular economy, sustainable food and agriculture, and low-carbon mobility in recent years. Among clean energy startups, low-

carbon hydrogen energy and battery storage are the rising stars, while the investment in carbon capture and storage is declining.

Beyond VC, cleantech startups also rely on other funding channels, including government grant programmes (e.g. Innovate UK's Net Zero Programme), corporate strategic investors (e.g. OGCI Climate Investments and Amazon Climate Pledge Fund), and dedicated incubators and accelerator programmes (e.g., Breakthrough Energy Fellows and US Elemental Excelsior), as well as mission-driven climate funds like The Africa Decarbonisation Fund I (Cleantech Group, 2025b; and IEA, 2025). Although finance constraints persist, the public sector remains crucial in fostering private investment by reducing borrowers' financial costs and de-risking green investment activities (European Central Bank, 2025).

Despite the substantial capital flowing into the cleantech sector, a large investment gap exists. While China currently leads global energy transition investment, major underinvestment persists in power-grid infrastructure, heavy-industry decarbonization and early-stage cleantech development (García-Herrero & Mu, 2025). To reach the 2030 net-zero target, the EU requires €1.3 trillion in green investment annually, with an estimated gap of €477 billion – equivalent to 3.2% of 2023 GDP (European Commission, 2023). For six key net-zero technologies – solar PV, wind, batteries, heat pumps, electrolyzers, and carbon capture and storage - €92 billion will be needed between 2023 and 2030. Current projections suggest that only €25 billion is likely to come from the private sector and €16-18 billion from public sources, leaving an investment gap of €49-51 billion (Cleantech for Europe, 2024).

Overall, seizing the green windows of opportunity should close the investment gap and meet growing market demand. This will require continued and stable government policy support, combined with innovative financing mechanisms to de-risk early-stage technologies and accelerate the commercialisation of cleantech projects.

2.3 Innovation Landscape of Cleantech Startups

Cleantech startups are generally more patent-intensive than non-cleantech startups. About 10-15% filed for at least one patent and over 5% hold one or more highly valuable patents,

compared with below 5% and 2% respectively for other startups (OECD, 2025). With the proliferation of digital technologies, around 20-30% of cleantech startups embed digital technologies into their green products and services, especially in energy efficiency, low-carbon mobility, and energy storage (OECD, 2025).

While early waves focused on deep technology (hardware, materials, and manufacturing technologies), recent trends show greater investment in fast-return and software-based solutions (Gaddy et al., 2017). New frontiers include grid resilience, sustainable textiles, next-generation plastics, and climate adaptation and resilience (Cleantech Group, 2024b, 2025b, January).

Innovation hubs in cleantech remain geographically concentrated, but new centres are emerging across additional regions. The US leads in advanced clean energy, electric mobility, and climate-smart agriculture, with Silicon Valley and New York City as the world's top 2 global startup ecosystems (Cleantech Group & UNIDO, 2024). Europe emphasises industrial decarbonisation – such as hydrogen-based steelmaking and energy-efficient technologies – with the UK leading in offshore wind and Germany advancing in renewable energy and climate tech through its Energy Transition Strategy (UNDP, 2025). China contributes nearly one-third of the global clean energy investment and dominates in electric mobility, battery tech and utility-scale renewable energy systems (IEA, 2025).

In recent years, cleantech startups have also begun to emerge in Asia-Pacific, Latin America and Africa, focusing on solving regional-specific challenges. These include, for example, solar energy, EV charging, and battery technologies in India; sustainable agriculture, mining, renewable energy and advanced materials in Australia and New Zealand; mini-grid, biofuels and recycling activities in Africa; and resource management, recycling and agricultural innovation in Latin America. Many of these solutions have strong potential to scale globally as underlying technologies mature and regional investment ecosystems continue to strengthen. Such landscape changes indicate that more developing countries are starting to grab the opportunity of green windows to leapfrog industrial development stages.

2.4 Challenges Facing Cleantech Startups

Despite rapid growth and strong investor and policy interest, cleantech startups continue to face a distinctive set of challenges that hinder their ability to scale and deliver impact. These barriers are multi-dimensional, combining technological, economic, policy, industrial and financial obstacles.

2.4.1 Technological Barriers

Many cleantech innovations remain at a low or intermediate level of technological readiness. Early-stage technologies often require years of costly R&D and piloting before they are market-ready. Even mature solutions, such as solar PV and wind technologies, face bottlenecks in terms of service provision, grid integration, and storage capacity (IEA, 2024c; UNDP, 2025). Disruptive innovations, such as carbon capture, hydrogen, or next-generation materials, also require new infrastructure, supply chains, and customer adoption models, slowing deployment (Shakeel, 2021). This technological immaturity extends the product development lifecycle and increases capital intensity.

2.4.2 Economic and Market Entry Barriers

Cleantech startups typically require large upfront investments in infrastructure, equipment and compliance, making them less attractive compared to software-based ventures. In addition, the profitability track record of many climate technologies is still limited, which increases investor hesitation. These barriers reduce affordability for end-users, limiting mass adoption and slowing down economies of scale (UNDP, 2025).

2.4.3 Policy and Regulatory Uncertainty

The cleantech sector is highly sensitive to regulatory environments. While many jurisdictions have established ambitious long-term frameworks, inconsistent or short-term policies remain a key risk. For example, Climate Action Tracker notes that although the UK's 2021 Net Zero Strategy provides an overarching framework, it fails to quantify the expected emissions reductions of individual policies, which were legally challenged. In 2023, the government weakened several key measures – including delaying the petrol/diesel car phase-out, scaling

back the gas boiler ban, and loosening landlord energy-efficiency requirements – while delays in policy development (e.g., of post-2037 climate planning) have further undermined investment confidence.

In addition, a broader structural challenge is the persistence of fossil fuel subsidies. In several regions, subsidies for fossil fuels still exceed those for renewable energy, distorting markets and undermining the competitiveness of clean technologies (UNDP, 2025). Such policy misalignment slows cleantech deployment and increases risk for startups and investors seeking to bring new solutions to the market.

2.4.4 Industrial Overcapacity Risks

Some cleantech sectors face the opposite challenge of oversupply (IEA, 2024a). In 2024, global solar PV module production capacity was projected to exceed the expected 2035 demand by up to 60%, while existing battery manufacturing capacity was already sufficient to meet global demand through 2030. Such overcapacity, largely driven by China's industrial policies, has triggered price crashes, halted expansion plans and intensified industrial consolidation. Startups are particularly vulnerable in this environment, as falling prices erode valuations and weaken investor confidence (Cleantech Group, 2025b).

2.4.5 Commercialisation and Scaling Barriers

Cleantech startups face the notorious "Valley of Death", the stage between technological validation and commercial deployment where financing needs surge but revenue streams remain limited. The long-cycle and capital-intensive nature of cleantech makes this stage particularly challenging, as traditional VC models are geared toward shorter horizons and faster returns. Many startups may struggle to obtain bank funding as they have limited assets to use as collateral. The equity option is also challenging due to the asymmetry of information about the technology between inventors and investors, as well as the uncertainties related to the technology performance, regulatory changes and market dynamics. As a result, many startups struggle to secure the growth financing required to scale.

Profitability within typical VC investment timelines is difficult to achieve. For example, of the seven companies that went public during the first wave of cleantech investment, only Tesla and Enphase Energy posted a market capitalisation greater than their initial public offering (IPO) valuation by the end of 2023 (Sato, 2024). The broader investment climate has also become more risk averse. Investors increasingly prioritise credible product-market fit and sound project economics over technological potential alone (Cleantech Group, 2025a).

2.4.6 Valuation Challenges

This misalignment between cleantech's structural requirements and conventional financing expectations results in longer investor holding periods, fewer exiting opportunities and persistent valuation challenges. At the startup stage, accurate valuation becomes especially critical, since they must demonstrate both technological readiness and commercial viability to attract the necessary capital.

The unique characteristics and challenges faced by cleantech startups make evaluating their value complex. Traditional valuation models, which often rely on predicted revenue streams and established markets, tend to undervalue climate benefits, technological maturity, commercial risk and long-term externalities (Hegeman & Sørheim, 2021). According to Net Zero Insights (2024), two-thirds of established or scaling stage cleantech firms have experienced valuation disputes, reflecting increased uncertainty among investors. This misvaluation not only discourages investment but also restricts startups' ability to attract strategic partnerships and exit opportunities.

In summary, cleantech startups do not operate in isolation. Their success depends on technological readiness, supply chain resilience, access to capital and critical materials, skilled labour, and stable policies and demand-side incentives. Bottlenecks in any of these areas can delay commercialisation or increase costs. Addressing them, including developing and adopting new valuation methodologies that integrate their unique characteristics, would enable more investment to flow toward cleantech and promote climate transition.

Technology Valuation Methods for Cleantech Startups

The increasing importance of cleantech to the economy and society has made accurate cleantech valuation increasingly essential. Although factors influencing technology value have been discussed in the literature, and different valuation approaches have been applied in practice, there is no systematic and specific framework for cleantech startups, which complicates the valuation considering its unique characteristics and challenges.

3.1 Traditional Valuation Methods

Several methods have been used in previous research and business practice for the valuation of technology, including quantitative methods such as the cost approach, income approach, real-option analysis, and structural models; qualitative approaches such as fuzzy multiple criteria comparison, the specific value points approach and peer benchmarking; and a hybrid approach (see review in Fu et al., 2024). Furthermore, some studies examine factors that affect VC's decision to invest, incorporating factors such as entrepreneurs' quality, patent/product characteristics, market characteristics and financial considerations, which provide valuable perspectives.

While these studies offer interesting insights, they do not provide a systematic framework for the factors deemed important in the evaluation process, nor do they yield comprehensive estimates of the value of cleantech startups. For instance, the cost model quantifies current costs to estimate the economic value of technology, but costs do not necessarily equate to future benefits, particularly for technologies that generate large positive externalities to the environment and human health. The income-based method, real option approach, and hybrid methods rely on predictions of future income, which is inherently uncertain and affected by the long horizon and slower return of cleantech. The benchmarking approach assumes that potential buyers would pay similar prices for comparable technologies (Reilly & Schweih, 1999). However, finding such comparable technologies is often challenging because many clean technologies are disruptive and unique without suitable comparable startups. It is also difficult to find transaction prices due to a lack of transparency (Baek et al., 2007).

In addition, traditional approaches of technology valuation also experience other practical limitations. It is usually time-consuming and inefficient when manually collecting information about the cleantech, startup, market, and associated environment. The evaluation results largely depend on the expertise and experience of evaluators and due diligence personnel, which might be subjective and lack transparency. The requirements of time, human resources and materials make the valuation costly, not favourable for cost-sensitive startups.

In such cases, new valuation methods are needed to accurately capture the value of cleantech startups in a more affordable and efficient manner.

3.2 OxValue Valuation Method

The OxValue valuation model is a leading AI-driven approach to technology valuation, developed from over a decade of research by a team at the University of Oxford. Grounded in the utility theory of value and relevant literature, the theoretical framework captures four key attributes of technology value, namely 1) market size, 2) technology novelty, 3) the position in the technology lifecycle, and 4) team characteristics and risks. To operationalise this framework, the model leverages econometric methods, AI tools and big data analytics, thereby enhancing the efficiency, objectivity, interpretability and scalability of technology valuation.

As a disruptive methodology, OxValue's valuation model has been recognised by leading international organisations, including the WIPO and Innovate UK, and has been strongly endorsed by the UN Technology Innovation Platform. Its theoretical framework has also received both academic and innovation awards, including the 2017 European Academy of Management Best Paper Award and 2021 Falling Walls Science Breakthrough Award. This project won the 2024 Alibaba Cloud Global Best AI Project Practice Award and the 2025 University of Oxford Vice-Chancellor's Award.

3.2.1 Technical Path of the OxValue Valuation Model

The OxValue model rests on a theoretical framework supported by proprietary and external data, AI-driven processes and rigorous compliance mechanisms (as depicted in Figure 1).

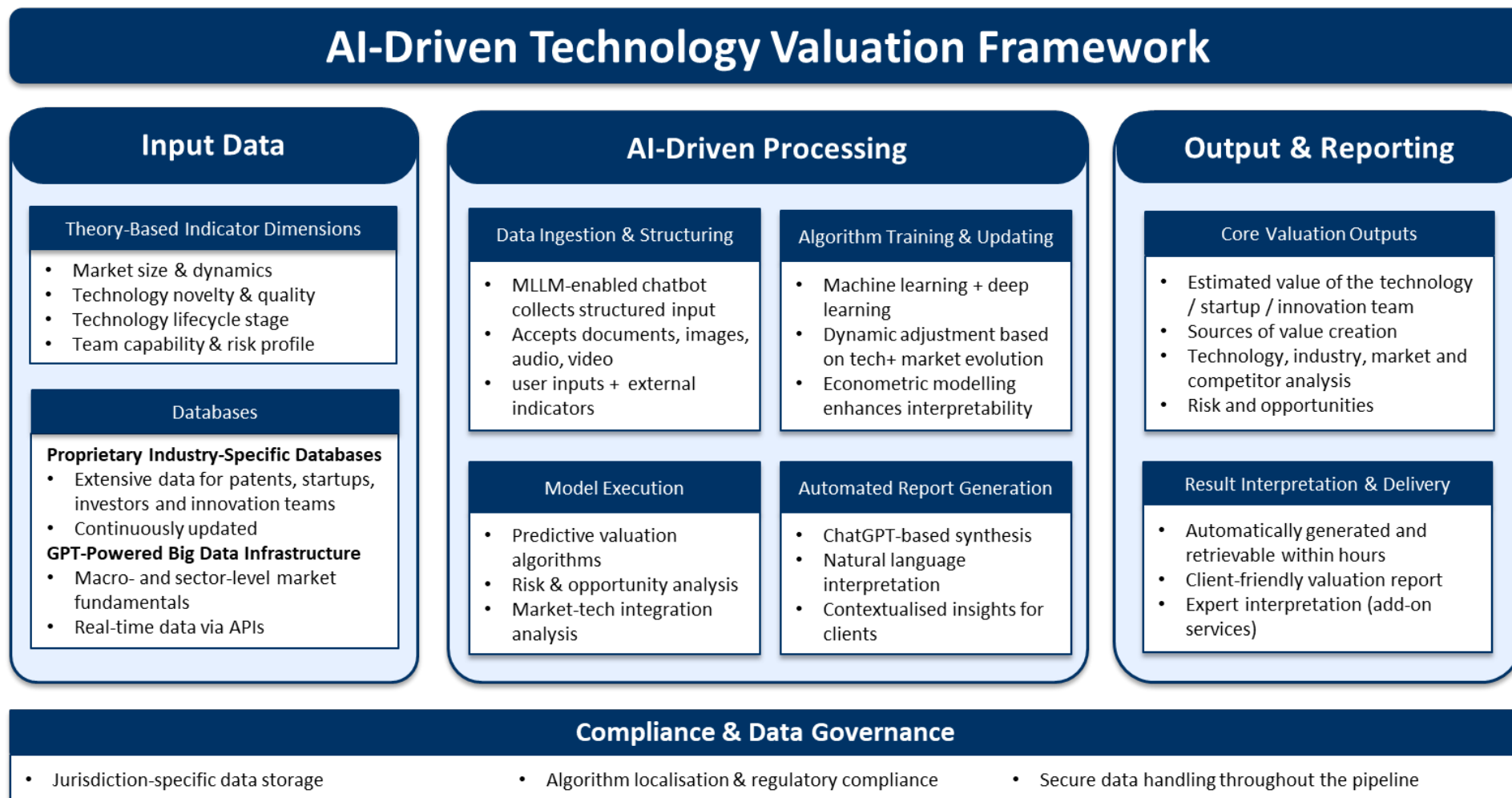
The **theoretical framework** differs from traditional utility theory by shifting from an individual to an industry/society perspective. It focuses on the broader utility that technologies provide to society as they address market demand. Value is understood to derive not only from intrinsic technological characteristics but also from market factors, enabling environments, and lifecycle stages, each of which entails different levels of risk and uncertainty. In practice, factors are classified into 1) the scale and dynamics of the market; 2) novelty and quality of the technology; 3) its position in the technology lifecycle (emerging, growing, mature, and declining); and 4) the risks involved and capabilities of the R&D and commercialisation teams (Fu et al., 2024).

The model draws on **two types of databases**. First, OxValue maintains exclusive industry-specific databases that store and analyse valuation data and are continuously refined with new cases to improve accuracy. To date, OxValue has established a dataset covering 180 million patents, 340,000 startups, 1 million inventors, 58 million innovation teams, and extensive industry information. Second, a GPT-powered big data infrastructure supports macroeconomic and market-level analysis and enables dynamic adjustment of valuations.

AI plays a central role throughout the valuation cycle. In the training phase, machine learning and deep learning techniques are used to train the algorithms. AI also analyses industry trends and technological developments, enabling dynamic model adjustments over time. In the data collection phase, a multimodal large language model (MLLM)-enabled chatbot guides users through structured data submission, accepting diverse formats such as documents, images, video and audio. AI organises these inputs, retrieves real-time indicators via APIs (Application Programming Interfaces), executes predictive models, and automates backend processes. Finally, in the reporting phase, valuation outputs are synthesised into detailed reports using ChatGPT APIs, which apply advanced natural language processing to summarise data, interpret model results, contextualise insights, and present findings in a clear, client-focused format.

The OxValue valuation system also maintains **strict data compliance standards**. For example, in China, all data and algorithms related to Chinese firms and technologies are stored within the country, using local cloud service providers to meet regulatory requirements.

Figure 1 OxValue Valuation Flowchart



3.2.2 Effectiveness of OxValue Valuation Model

The OxValue valuation model has demonstrated high predictive power, with accuracy exceeding 92% across 370 UK pharmaceutical startups, over 86% across 583 UK cleantech startups and 87.3% across 1,426 ICT startups in the US – far above the industry average of approximately 12%. To meet diverse client needs, OxValue offers three tailored valuation packages – for individual patents, research teams and startup firms – covering eight industries and suitable for a range of financing purposes. The model has undergone roughly 100 practical tests in China, delivering a 100% accuracy rate for startups aged five years or younger and 86% when older firms are included. By the end of 2025, the company has completed over 10,000 valuation cases. These third-party validations and extensive real-world applications further demonstrate the robustness and practical relevance of the model.

OxValue's end-to-end digital workflow has also transformed the valuation process. While traditional practices typically require several weeks or even months (J.P. Morgan, 2024; Patel, 2024), OxValue's full automated system delivers estimation results within minutes. The process reduces costs to approximately 10% of the market average and minimises human intervention, thereby increasing consistency and reducing subjective bias. Real-time data retrieval guarantees that valuations incorporate the most current market and technology information available. Furthermore, the system's scalability enables high-volume assessments without compromising reliability.

The OxValue model has gained public visibility through demonstrations at major international conferences and events, including the United Nations' Climate Change Conference in 2025 (COP 30), the UN High-level Dialogue, the UK House of Lords Symposium, the 2025 World AI Conference, and the Businessabc AI Global Summit in London. It has also been featured in leading media outlets such as the New York Times, China Daily, and The Tribune India. In addition, the model has received endorsements from prominent organisations and clients, including the International Valuation Standards Council, the UK Intellectual Property Office, SeedLegals, Alibaba, and the British Business Bank.

Overall, the OxValue model provides game-changing solutions in the valuation landscape. By offering quicker, more objective, highly accurate, and affordable valuation services, it not

only accelerates investment decision-making but also enhances the efficiency of technology transfer and commercialisation.

Ranking of Cleantech Startups by Value Creation

Analysing and ranking the value creation of leading cleantech startups provides a valuable lens into broader sectoral development trends, as well as insights into companies' innovation capacity and market potential. Using OxValue valuation model, we evaluate two groups of cleantech startups.

The first group consists of 100 early-stage firms that are delivering pioneering solutions to major environmental and sustainability challenges or have strong potential for regional transformative impact. These companies are selected from the 2024 *Cleantech 50 to Watch* list (Cleantech Group, 2024b), *APAC Cleantech 25* (Cleantech Group, 2025a), and *LATAM Cleantech 25* (Cleantech Group, 2024a). These lists were compiled through global expert nominations and a rigorous evaluation process of Cleantech Group, a leading authority in global cleantech innovation. This group represents the technological frontier, capturing breakthrough innovation that may shape future cleantech markets.

The second group comprises 47 cleantech unicorns, which are startups under ten years old with valuations surpassing \$1 billion, identified by data providers such as CP Insights and the Hurun Research Institute. Compared with the first group, this group represent proven market traction and value creation at scale, reflecting not only technological competitiveness but also commercial adoption, investment mobilisation and market-size potential.

These startups span six major industry groups: agriculture & food, energy & power, materials & chemicals, resources & environmental management, transportation & logistics, and waste & recycling. Notably, around 90% of these firms hold patents and have completed multiple funding rounds, underscoring their technological defensibility and investment readiness.

Together, these two groups provide a comprehensive view of the cleantech innovation landscape among startups: the first highlights emerging, high-impact technological breakthroughs with strong future scaling potential, while the second reflects validated market

demand and large-scale commercialisation. This dual-group approach enables a more nuanced understanding of both frontier innovation and market-validated growth dynamics within the global cleantech sector. Analysing and ranking the value creation of these firms not only sheds light on the international competitiveness of startups in terms of R&D strength, innovation capability, and market influence, but also reveals how drivers of value creation differ across different types of startups, subsectors and regional ecosystems, in order to better seize the green opportunities.

4.1 Top 30 Pioneering Cleantech Startups by Value Creation

After evaluating the first group of startups with pioneering cleantech, we identify the top 30 startups by value creation. Table 2 lists these startups in alphabetical order of their names. Their valuations reflect not only emerging technological novelty but also market positioning, policy support, and the ability to attract strategic capital. Examining valuation, regional distribution, industry focus, and company maturity provides a clear picture of where entrepreneurial activity is taking place and how capital flows to frontier cleantech solutions.

4.1.1 Valuation Levels

These 30 pioneering startups represent a broad cross-section of the cleantech pipeline, from breakthrough energy systems to circular-economy players. Several companies on the list have already achieved notable visibility – for example, CalWave in the US, advancing next-generation wave-energy systems; RIFT in the Netherlands, developing novel clean-heat pathways; Ionate in the UK, building the hardware-software backbone for smart electricity grid; Fleet Space Technologies in Australia, applying satellite-based sensing to support energy and industrial applications; and Lohum and Battery Smart in India, both rapidly scaling solutions in battery materials and electric-mobility infrastructure. Alongside these more established names, the list also includes a wide range of early-stage ventures from China (e.g. Mojia Bio on bio-based chemicals), Latin America (e.g. Kilimo on agricultural water-efficiency platforms) and other regions pursuing breakthroughs in carbon removal, advanced materials, alternative fuels, energy-storage concepts, agriculture efficiency and next-generation industrial processes.

The valuation of the top 30 pioneering cleantech startups ranges from approximately \$111 million at the lower end to over \$476 million for the highest-ranked companies. The average valuation is \$207 million, with approximately 70% of the companies having valuations below \$200 million. This skewed distribution indicates that the majority of pioneering startups are at an early stage of development. They have typically achieved initial technology validation or early market entry but remain in the process of scaling production, securing commercial partners, expanding markets, and proving economic viability.

Table 2 Top 30 Pioneering Cleantech Startups by Value Creation
(In Alphabetical Order)

Name	Year Founded	Headquarters Location	Industry
3DC	2022	Sendai, Miyagi, Japan	Materials & Chemicals
Allegro Energy	2021	Newcastle, New South Wales, Australia	Energy & Power
Ayrton Energy	2021	Calgary, Alberta, Canada	Energy & Power
AZUL Energy	2019	Sendai, Miyagi, Japan	Materials & Chemicals
Battery Smart	2019	Gurgaon, Haryana, India	Transportation & Logistics
CalWave Inc	2014	Berkeley, California, US	Energy & Power
Capture6	2021	Berkeley, California, US	Materials & Chemicals
Carbon Energy Technology	2015	Beijing, China	Energy & Power
Cultivo	2019	Berkeley, California, US/ Mexico City, Mexico	Resources & Environment
CWS	2016	Paris, France	Transportation & Logistics
Element Zero	2023	Perth City, Western Australia, Australia	Materials & Chemicals
Firmus Technologies	2019	Saint Leonards, Tasmania, Australia	Energy & Power
Fleet Space Technologies	2015	Adelaide, South Australia, Australia	Materials & Chemicals
Green Gravity	2020	Wollongong, New South Wales, Australia	Energy & Power
HyperHeat	2023	Offenburg, Baden-Wurttemberg, Germany	Energy & Power
Ionate	2019	Edinburgh, UK	Energy & Power
Kilimo	2014	Cordoba, Argentina	Agriculture & Food

Limelight Steel	2021	Oakland, California, US	Materials & Chemicals
Litus	2019	Calgary, Alberta, Canada	Materials & Chemicals
Lohum	2017	Noida, Uttar Pradesh, India	Waste & Recycling
Luquos Energy	2020	Hong Kong, China	Energy & Power
Marvel-Tech	2015	Shanghai, China	Energy & Power
MojiaBio	2018	Guangan, Sichuan, China	Materials & Chemicals
OpenStar Technologies	2021	Wellington, New Zealand	Energy & Power
Reborn Electric Motors	2016	Rancagua, Chile	Transportation & Logistics
RIFT	2020	Eindhoven, Noord-Brabant, The Netherlands	Energy & Power
Smartville, Inc.	2019	Carlsbad, California, US	Energy & Power
Splight	2021	San Francisco, California, US/ Santiago, Chile	Energy & Power
StarTorus Fusion	2021	Xi'an, Shaanxi, China	Energy & Power
Ungrauemeio	2016	São Paulo, Brazil	Resources & Environment
Average: \$207 million			

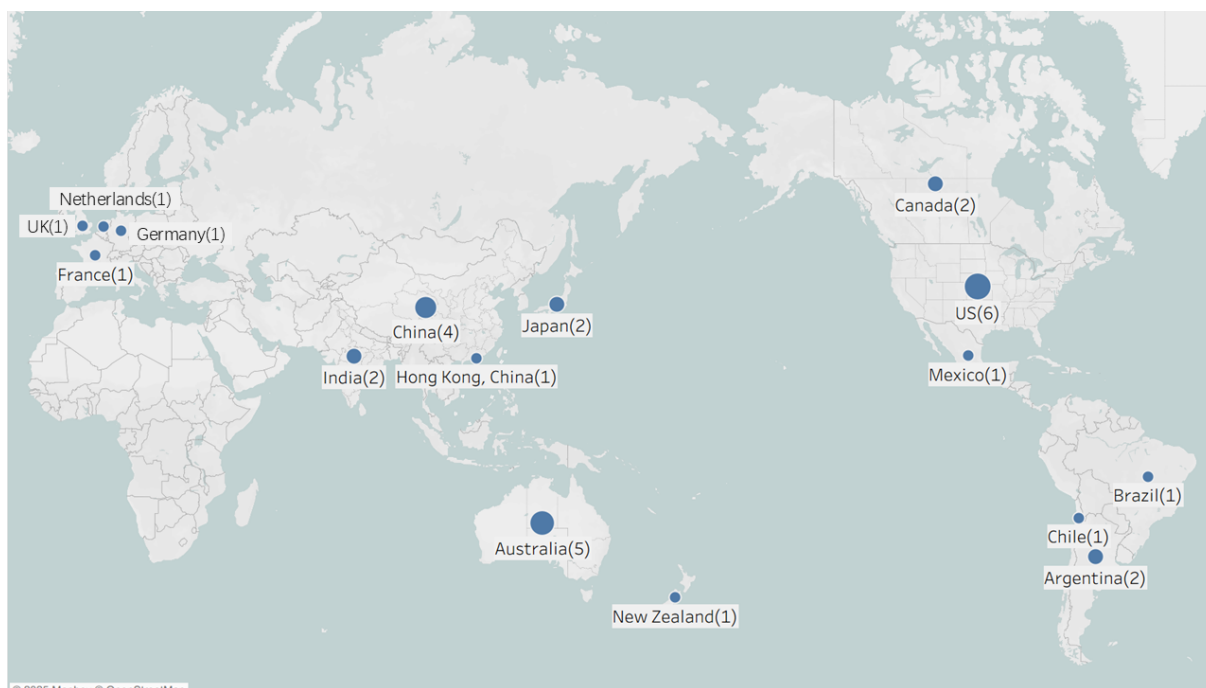
4.1.2 Regional Distribution

Geographically, the top 30 pioneering cleantech startups are distributed across multiple innovation hubs, including North America, Western Europe, the Asia Pacific region, and Latin America (Figure 2). The US leads with 6 startups – 2 of which also maintain operations in Mexico and Chile – primarily concentrated in California. This cluster benefits from world-class research universities, strong early-stage industry adoption, and a rapidly expanding climate-focused VC ecosystem.

Australia contributes 5 startups, spread across its east, south, and west coasts. Unlike the US, Australia's cleantech activity is not confined to a single domain hub; instead, it is emerging across a broader range of local ecosystems. China similarly hosts five pioneering startups located in multiple regions, spanning major metropolitan centres – such as Beijing, Shanghai and Hong Kong – as well as western provinces including Shaanxi and Sichuan. This dispersion reflects China's decentralised yet rapidly scaling innovation landscape.

Several other startups originate from advanced economies with strong R&D capacity, robust innovation infrastructure, and supportive policy environment. These include Japan, the UK, France, Germany, the Netherlands, New Zealand, and Canada. In addition, seven startups come from emerging markets, notably India and several Latin American countries (Mexico, Chile, Argentina and Brazil), highlighting the increasing global diffusion of cleantech innovation beyond traditional technology strongholds.

Figure 2 Regional Distribution of Top 30 Pioneering Cleantech Startups



Note: Two of the six US startups also have operations in Mexico (1) and Chile (1).

4.1.3 Industrial Distribution

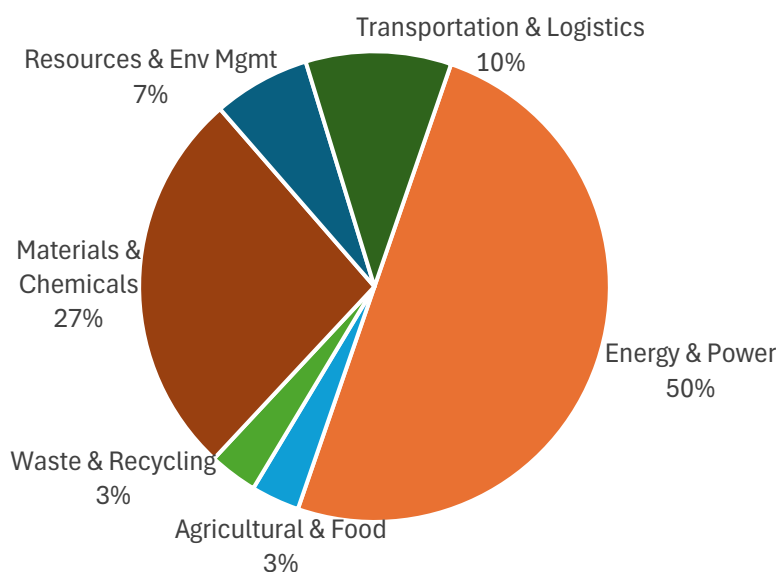
Industrial analysis reveals that while pioneering cleantech innovation spans all six sectors, Energy & Power and Materials & Chemicals remain core focus areas. Fifteen startups (50%) operate in Energy & Power, specialising in renewable generation, grid optimisation, and energy storage – the core enabler of the global net-zero transition. These firms are primarily based in developed economies and China, where multi-trillion-dollar market opportunities, relatively mature technologies, and strong policy incentives drive growth.

Eight startups (27%) focus on Materials & Chemicals that underpin decarbonisation, including low-carbon mineral and material processing, next-generation battery and energy-system components, clean industrial processes, and carbon-removal technologies. These innovations typically involve a long R&D cycle and are concentrated in the US, Japan, Canada, Australia and China.

In Transportation & Logistics, three startups target efficiency and electrification through technologies such as wind-assisted ship engines to reduce fuel consumption, electric buses, and EV battery-swapping networks. These solutions, particularly EV and battery-swapping platforms, offer significant potential for global scale-up.

In contrast, solutions in Resources & Environmental Management, Waste & Recycling, and Agriculture & Food often require shorter R&D cycles and lower capital intensity, making them attractive for early-stage venture funding. These sectors are also well-aligned with regional priorities and natural endowments, especially in Latin America, where abundant natural resources and pressing environmental challenges create strong demand for such technologies. However, these sectors generally offer more limited scalability compared to globally integrated markets, such as renewable energy, advanced materials or EV batteries, even though some solutions can still address cross-regional needs and be adapted for broader deployment.

Figure 3 Industrial Distribution of Top 30 Pioneering Cleantech Startups



4.1.4 Age and Employment Distribution

All 30 pioneering cleantech startups are relatively young, each one is under 11 years old. The average age is 6.2 years, and 43% are five years old or younger. Most operate as micro- or small enterprises: 20% have fewer than 10 employees, and 40% employ between 11 and 50 people. Only two startups qualify as large enterprises with more than 250 employees.

In general, older and larger startups tend to achieve slightly higher valuations, as they typically possess more mature technological capabilities, established pilot projects, and stronger commercial partnerships. However, several younger and smaller firms also command relatively high valuations, particularly those developing disruptive technologies such as AI-enabled resource and energy management.

In summary, across the top 30 pioneering cleantech startups, green innovation opportunities are globally distributed, with strong concentrations in the US, Australia, China, and advanced economies in Western Europe and Asia, alongside emerging activity in India and Latin America. The sectors of Energy & Power and Materials & Chemicals dominate due to large markets, technology maturity, and strong policy support, while transportation, resource management, waste and agriculture attract innovation tailored to regional priorities, particularly in the developing economies. Although these startups are generally young and small in size, their pioneering solutions and strong real-world impact potential position them as important innovation feeders for future scale-up or acquisition.

4.2 Top 15 Cleantech Unicorns by Value Creation

Among the cohort of cleantech unicorns, we identify the top 15 based on their value creation as estimated using the OxValue model (see Table 3). Although these companies are relatively young (≤ 10 years), they are generally more mature and commercially advanced than the pioneering cleantech startups in the first group, and they differ from that group in their valuation levels, regional distribution and industry focus.

4.2.1 Valuation Levels

The valuations of the top 15 cleantech unicorns range from \$ 4.1 to \$ 9.5 billion, with an average valuation of \$ 6.7 billion, which are unmatched by those of pioneering cleantech startups. Such high valuations reflect the significant environmental impact potential of their solutions, the scale and rapid growth of the market they target, and their capacity to achieve global scalability. They also demonstrate strong realised and expected financial returns, enabling them to attract capital from a wide range of investors. However, compared with the most highly valued AI startups (which average \$25.95 billion for the Top 10, OxValue.AI, 2024), the valuations of cleantech unicorns remain relatively low.

Table 3 Top 15 Cleantech Unicorns by Value Creation
(In Alphabetical Order)

Name	Year Founded	Headquarters Location	Industry
1Komma5°	2021	Hamburg, Germany	Energy & Power
DAS Solar	2018	Quzhou, Zhejiang, China	Energy & Power
Aion	2017	Guangzhou, Guangdong, China	Transportation & Logistics
Avatr	2018	Chongqing, Heilongjiang, China	Transportation & Logistics
Commonwealth Fusion Systems	2017	Cambridge, Massachusetts, US	Energy & Power
Crusoe Energy Systems	2018	Denver, Colorado, US	Energy & Power
Enpal	2017	Berlin, Germany	Energy & Power
Hithium Energy Storage	2019	Xiamen, Fujian, China	Energy & Power
Redwood Materials	2017	Carson City, Nevada, US	Materials & Chemicals
ROX Motor	2021	Shanghai, China	Transportation & Logistics
SVOLT	2018	Changzhou, Zhejiang, China	Energy & Power
Verkor	2020	Grenoble, Rhone-Alpes, France	Energy & Power
Voyah	2019	Wuhan, Hubei, China	Transportation & Logistics
Zenobe Energy	2017	London, England, UK	Energy & Power
Zhiji Auto	2020	Shanghai, China	Transportation & Logistics
Average: \$6,732 million			

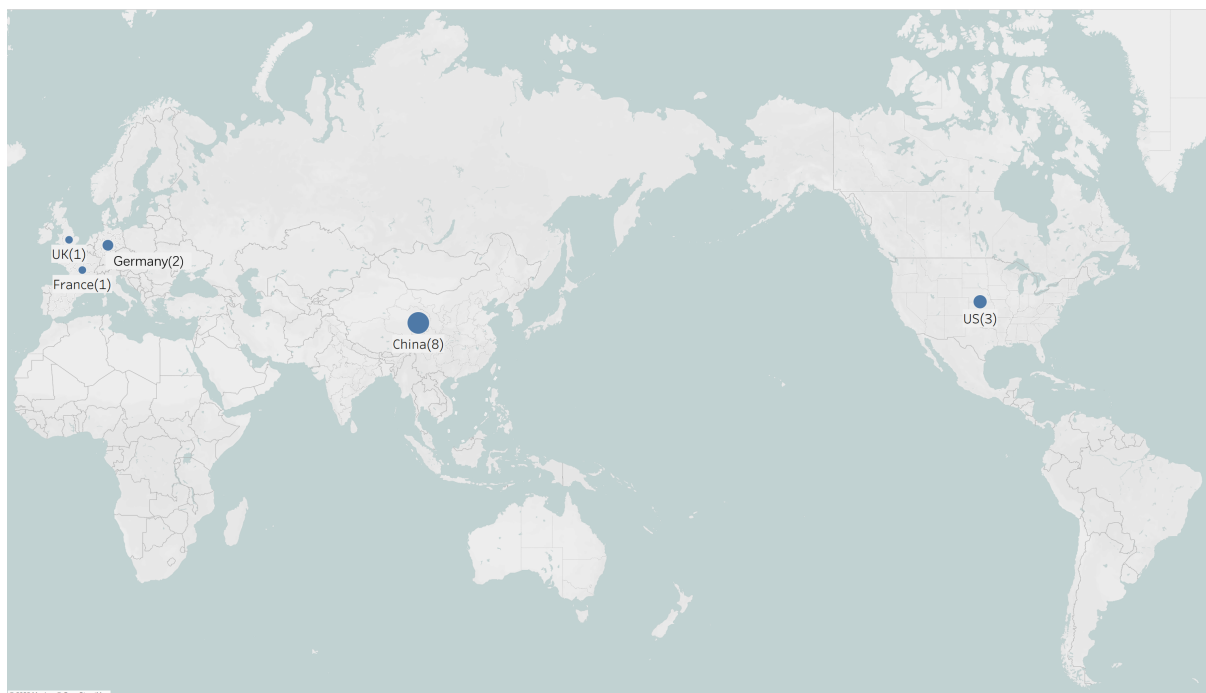
These unicorns include several EV makers with direct-to-consumer sales, such as Aion, Avatr, and Voyah. As the branded EV divisions of major automotive groups, they benefit from strong visibility through consumer marketing, vehicle sales and sustained media coverage in their targeted markets. Some unicorns are especially well known among investors, policymakers and industry leaders. For example, Commonwealth Fusion Systems is one of the most prominent fusion-energy ventures in the US, backed by Bill Gates, Breakthrough Energy, Temasek, and other investors. Redwood Materials, founded by Tesla co-founder JB Straubel, is a leading US producer of anode and cathode materials derived from recycled batteries, playing a central role in domestic battery supply chain development. Verkor, backed by Renault, is a strategic player in the EU's battery strategy and one of the most visible gigfactory projects.

4.2.2 Regional Distribution

Different from the first group of startups, the top valued cleantech unicorns are concentrated in China, the US and Europe. Such geographical distribution reflects the different technological strengths and policy priorities of major economies.

China hosts the largest number of high-valued unicorns, with eight companies spanning low-emission vehicles, batteries and solar energy. This dominance is closely related to the country's rapidly expanding EV industry, the depth of its manufacturing supply chains, and the scale of its domestic market, which provide both demand and production advantages. Many of China's unicorns are EV brands, while others operate in upstream battery or solar segments that benefit from its industrial policy support and strong export capabilities.

Figure 4 Regional Distribution of Top 15 Cleantech Unicorns



Europe accounts for four unicorns, located in Germany, France and the UK. These companies focus on renewable energy services, smart-energy management, low-carbon battery production, and battery storage. Their emergence reflects Europe's policy-driven commitment to decarbonisation, emission reduction, and grid modernisation.

The US hosts three unicorns, which primarily represent deep-tech and strategic materials' innovation, in areas such as fusion energy, recyclable battery materials, and AI-based energy infrastructure. These companies enjoy high visibility among investors and policymakers, reflecting both the scale of the US capital market and growing interests in securing critical material supply chains and fostering next-generation clean energy solutions.

Overall, the distribution underscores distinct regional profiles among top-valued cleantech unicorns. China leads in scaled manufacturing and consumer EV market; Europe advances energy-transition deployment and infrastructure modernisation; and the US excels in deep-tech innovation and advanced materials. Together, these patterns suggest a degree of regional specialisations and complementarity in global cleantech innovation and deployment at scale.

4.2.3 Industrial Distribution

The top valued cleantech unicorns are concentrated in just three sectors: Energy & Power, Transportation & Logistics, and Materials & Chemicals (Figure 5), indicating an industrial distribution shaped by commercial scalability and large addressable markets.

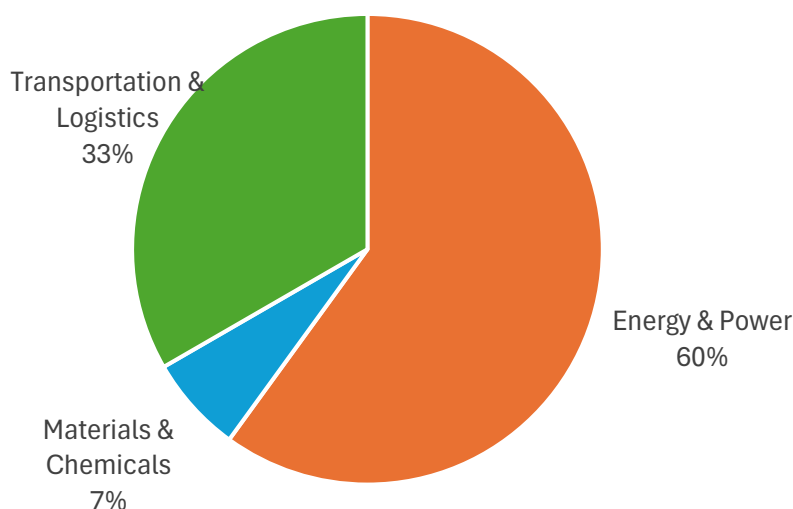
Energy & Power remains the dominant sector, accounting for 60% of the unicorns, a pattern broadly similar to the first group of pioneering startups. This segment includes companies engaged in solar manufacturing, grid-scale storage, advanced batteries, energy-management services, and breakthrough fusion energy technologies. This prominence reflects the capital intensity of large-scale energy solutions and their strong alignment with national decarbonisation and infrastructure modernisation priorities across major economies.

Transportation & Logistics represents 1/3 of the unicorn cohort, driven mainly by EV manufacturers and smart mobility firms. These companies demonstrate strong commercial visibility and rapid sales growth, supported by the technological maturity of EV platforms and the large, policy-driven expansion of electric mobility, especially in China, where all these low-carbon vehicle unicorns originate.

Only one unicorn, Redwood Materials, is classified under Materials & Chemicals (7%). Despite its small share, this segment plays a strategically important role in battery recycling and the production of critical anode and cathode materials. Such capabilities are increasingly central to supply-chain security, resource circularity, and the broader global transition to clean energy.

The industrial distribution of these cleantech unicorns reveals an ecosystem concentrated in energy systems and electric mobility, sectors that offer scale, strong market demand, and alignment with national industrial and climate strategies. These conditions support the successful scaling of early-stage cleantech companies and underpin their high levels of value creation.

Figure 5 Industrial Distribution of Top 15 Cleantech Unicorns



4.2.4 Age and Employment Distribution

The age of these unicorns spans a relatively narrow range, from 4 to 8 years, with an average age of 6.5 years, similar to that of the first group of pioneering startups. More than 70% are older than 5 years, indicating that reaching unicorn-level valuation in cleantech typically requires several years of technological maturation, market entry, and scaling. However, unlike the pioneering startups, only 3 companies (20%) qualify as small or medium-sized enterprises (with fewer than 250 employees). The remaining 12 companies (80%) are large enterprises, including seven with workforces of more than 1000 employees.

There is a clear trend that older and larger unicorns achieve higher valuations. This suggests that, among cleantech unicorns, value creation is closely linked to the team's ability to commercialise the capital-intensive technological solutions and scale operations effectively. Large workforce size may also indicate rapid advancement along the technology lifecycle, accelerated commercial deployment, active market expansion and stronger team capabilities – all factors that contribute to stronger investor confidence and higher valuations.

In summary, the high value levels of the top 15 unicorns illustrate which cleantech firms can climb the value chain as the green window of opportunity widens. As technologies mature and achieve market traction, firms positioned on the frontier of the green transition can

rapidly accumulate value and scale. A large share of the value creation is concentrated in China, Europe and the US, with a strong focus on Energy & Power and low-emission vehicles, mirroring the sectoral distribution of global cleantech investment. Many of these companies have already grown to substantial workforce sizes. Their geographical and sectoral distribution reflects the comparative strengths of these major economies in innovating and delivering different cleantech solutions. It also highlights the segments with strong potential for growth and rapid market expansion, driving value creation and sustaining investor interest.

4.3 Comparative Analysis of Value Creation Sources

The OxValue model allows valuation sources to be decomposed into four dimensions: market factors, technology novelty, technology lifecycle, and team and risk factors. We analyse the sources of value creation across all sampled cleantech startups. This comparative assessment provides insight into how value creation differs across regions, industries, and company stages. These differences reveal how regions and sectors are positioned to seize the emerging green window of opportunity created by the global shift toward decarbonisation.

4.3.1 Overall Patterns of Value Creation Sources

The contributions of individual dimensions vary significantly across the startups studied, ranging from as little as 3% to as much as 84% of total value creation. These differences reflect both the weighting of factors across the four value-creation dimensions and each firm's relative strengths within them.

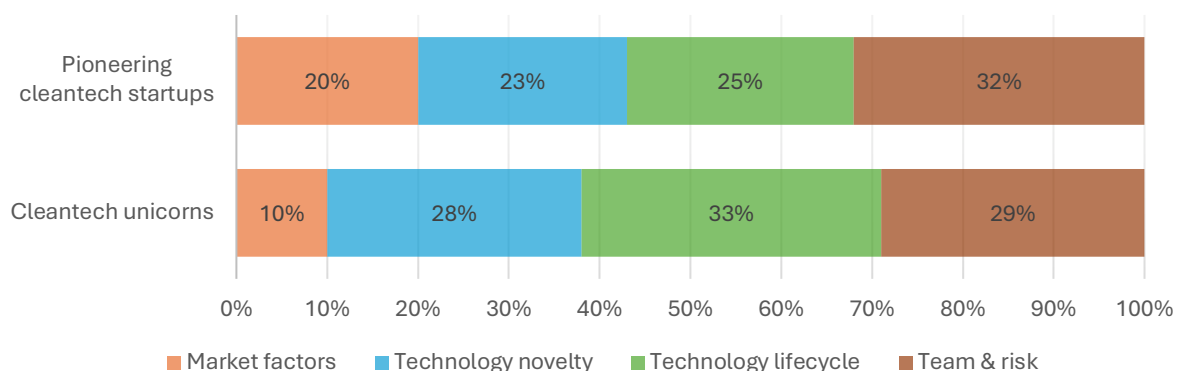
Among pioneering cleantech startups, team capabilities and risk factors contribute the largest share, on average 32%. This underscores the critical role of entrepreneurial expertise, strong R&D teams, and the ability to mitigate technological and commercial risks in shaping value creation (Figure 6). This finding aligns with existing evidence from VC research, which consistently highlights the quality of entrepreneurs and teams as the most crucial factor in early-stage investment decisions (Warnick et al., 2018). It also highlights that cleantech valuations are highly sensitive to changes in risk factors, such as policy and technological uncertainties.

Technology lifecycle – indicating whether a solution is in the emerging, growth, maturity or declining stage – accounts for 25% of value creation. This suggests that the valuation of pioneering startups is very sensitive to shifts in the lifecycle stage. For example, progressing from the introduction phase to growth can generate substantial valuation gains. Meanwhile, technology novelty contributes a similar share at approximately 23%, reflecting that improvements in technology advancement and differentiation significantly increase valuation premiums.

Market factors represent the smallest share, at about 20%. This does not imply that market demand is unimportant; rather, it indicates that valuations are less sensitive to changes in factors related to solution functionality or addressable market size.

Among cleantech unicorns, similar patterns emerge. Technology lifecycle factors contribute 33% of value creation, followed by team and risk at 29%, and technology novelty at 28%. Market factors account for only 10%, indicating even lower elasticity with respect to market size.

Figure 6 Value Creation Dimensions of Cleantech Startups



Note: All startups in the sample are included, i.e. 100 pioneering cleantech startups and 47 unicorns. The patterns for the top 30 pioneering startups and top 15 unicorns are similar.

Compared to digital or AI startups, where market size often contributes between 20-40% of valuation (OxValue.AI, 2024), cleantech startups appear far more sensitive to changes in technology characteristics and team and risk factors. This likely reflects the longer

development timelines and higher upfront capital requirements typical of cleantech solutions, while being less responsive to short-term market size, even though the ultimate addressable market may be very large once technologies reach maturity and real-world deployment.

4.3.2 Value Creation Sources by Region

Disaggregating value sources by regions reveals distinct patterns. Among the pioneering cleantech startups, team and risk factors remain the dominant contributors to valuation (each above 30%). Startups in Europe follow this pattern. However, the relative importance of other dimensions varies considerably across regions. In particular, pioneering startups in the Asia Pacific and North America show higher sensitivity to technology novelty (26% and 27%, respectively), suggesting that advancements in technological breakthroughs would significantly enhance valuations in these regions. By contrast, startups in Latin America place greater weight on market factors (28%), indicating that changes in market demand have a stronger influence on valuations than technology novelty or technology lifecycle. This pattern is consistent with earlier findings that Latin American startups tend to focus on addressing regional priorities in agriculture and food, resources and environmental management, and waste and recycling.

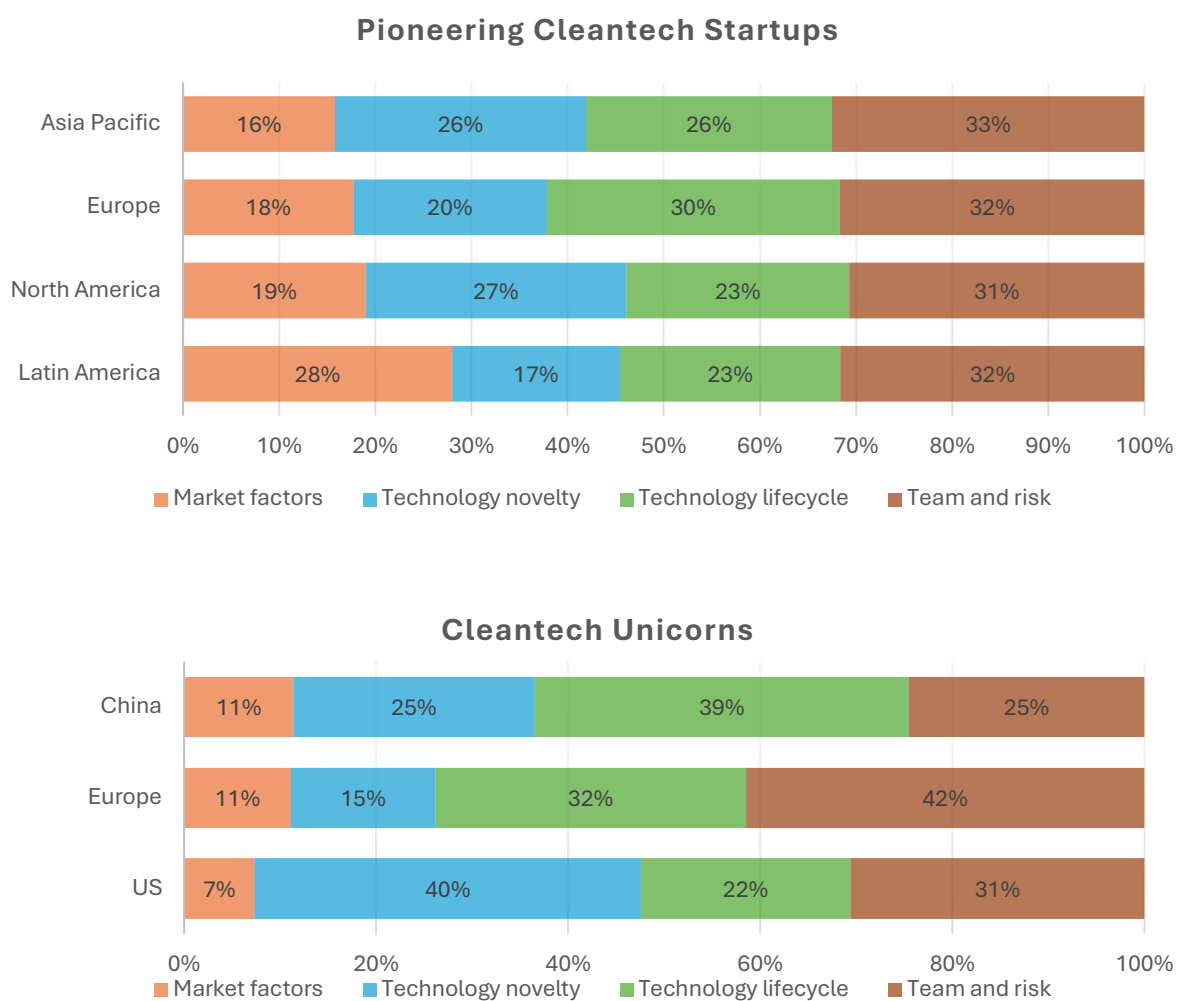
Turning to cleantech unicorns, market factors contribute the least to value creation (11% or less) across 3 economies. This implies that although these unicorns still operate in the global largest markets, their valuations are less sensitive to shifts in demand. The contributions of the remaining three dimensions vary across the major economies. In the US, unicorn valuations rely most heavily on technology novelty (40%) and team capability and risk mitigation (31%). European unicorn valuations are more sensitive to team and risk-related factors (42%) and to the technology lifecycle (32%). In China, the technology lifecycle accounts for the largest share (39%), while technology novelty and team and risk factors contribute equally (25% each).

These differences in valuation drivers reflect the comparative advantages and strategic orientations of leading unicorns in each economy. US unicorns tend to emphasise deep-tech solutions and advanced materials, which require significant novelty and strong research and commercialisation capabilities. European unicorns focus on large-scale energy-related

solutions that depend on mature technologies and well-established teams capable of deploying them at scale. Chinese unicorns include high-volume EV manufacturing and renewable energy companies, where technology novelty, lifecycle progression, and team strength all play crucial roles.

Overall, such regional contrast indicates varied pathways for capturing the global green opportunity. North America and the Asia Pacific may be better placed to do so through frontier innovations, Latin America's opportunity lies more in responding to evolving market demand, while Europe may better capture this opportunity through a combination of strong team capabilities, risk control and technological maturity.

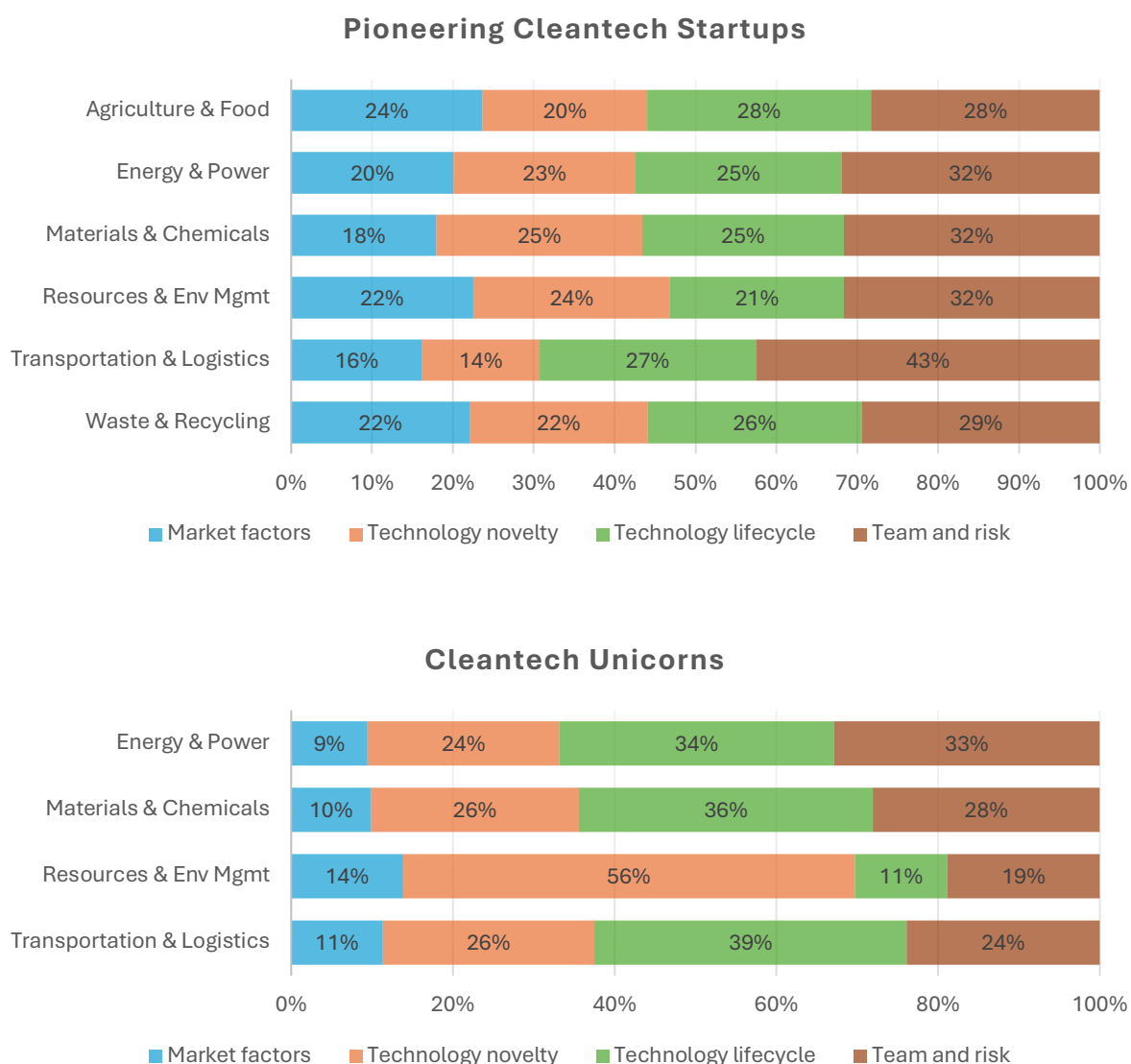
Figure 7 Value Creation Dimensions of Cleantech Startups by Region



4.3.3 Value Creation Sources by Industry

Team and risk factors consistently play the largest role in value creation across all sectors for early-stage pioneering cleantechs. However, the relative importance of the other three value dimensions varies meaningfully across industries.

Figure 8 Value Creation Dimensions of Cleantech Startups by Industry



Note: Among all cleantech unicorns, only 1 firm operates in Agriculture & Food, and none operates in Waste & Recycling. The four unicorns in Resources & Environmental Management do not rank among the top 15 in value creation and therefore are not included in Table 3.

In Energy & Power and Materials & Chemicals, both technology lifecycle and technology novelty are significant contributors to value creation (23-25%), with market factors carrying relatively lower weight (18-20%). This suggests that in these core decarbonisation sectors, all these three dimensions are simultaneously important for shaping startup valuations. In Agriculture & Food, Resources & Environmental Management, and Waste & Recycling, market factors account for a higher proportion of valuation (22-24%), indicating that demand-related dynamics exert a stronger influence than in other sectors. In Transportation & Logistics, valuations rely disproportionately on team and risk factors (43%) and on technology lifecycle (27%), while being less sensitive to technology novelty (14%) and market factors (16%). This pattern suggests that execution capability and technology maturity matter more than innovation breakthroughs or market shifts in this sector.

Among cleantech unicorns, market factors contribute the least to value creation across all sectors (14% or less). In Energy & Power, Materials & Chemicals, and Transportation & Logistics, technology lifecycle emerges as the dominant driver (above 34%), followed by team and risk factors or technology novelty (24-33%). In contrast, unicorns in Resources & Environmental Management show exceptionally high sensitivity to technology novelty (56%), with the other dimensions playing comparatively smaller roles. This indicates that breakthrough innovation is particularly critical for value creation in this sector at the unicorn stage.

In summary, differences in valuation drivers across regions and industries – and between early-stage pioneering startups and unicorns – reflect the technological characteristics of each sector, team strengths, and market environments. Early-stage pioneering cleantech startups are more sensitive to changes in team and risk factors, with technology lifecycle and novelty also playing important roles. Regionally, startups in the Asia Pacific and North America respond more to technological breakthroughs, whereas those in Latin America are more influenced by market demand. Looking at individual sectors, market factors matter more in agriculture, resources and waste, while valuations in transportation rely heavily on team capability, risk reduction and technology lifecycle. Among cleantech unicorns, market factors contribute least across all regions and industries. Instead, valuations hinge on technology novelty in the US, team and risk factors and technology lifecycle in Europe, and

predominantly technology lifecycle in China, where technology novelty and team strengths are also important. Unicorns in Resources & Environmental Management show particularly strong sensitivity to technology novelty. Overall, these patterns highlight how value creation shifts with market factors, technology novelty levels, progression in the lifecycle, team capabilities and risk management. These sensitivities reveal where and how firms can most effectively seize the green opportunity across the global cleantech ecosystem.

4.4 The Role of AI In Cleantech Innovation and Value Creation

Figure 9 shows how AI, as an enabling technology, is being integrated into cleantech innovation across sectors. About 20% of pioneering cleantech startups have adopted AI in their products or production processes. Adoption is especially high in Energy & Power, where 40% of startups apply AI to grid management, energy optimisation, and real-time monitoring – areas central to accelerating decarbonisation. AI is also used extensively in Resource & Environmental Management (about 33%), Waste & Recycling (18%), and Agriculture & Food (18%) to improve project monitoring, detect risks, and enhance operational efficiency.

Among cleantech unicorns, AI adoption is even more widespread, averaging 36% across sectors. The highest uptake occurs in Transportation & Logistics, where more than 60% of unicorns – particularly EV manufacturers – embed intelligence systems in both product design and production operations. This higher adoption rate among unicorns suggests that AI integration becomes increasingly important at the scaling stage of cleantech solutions.

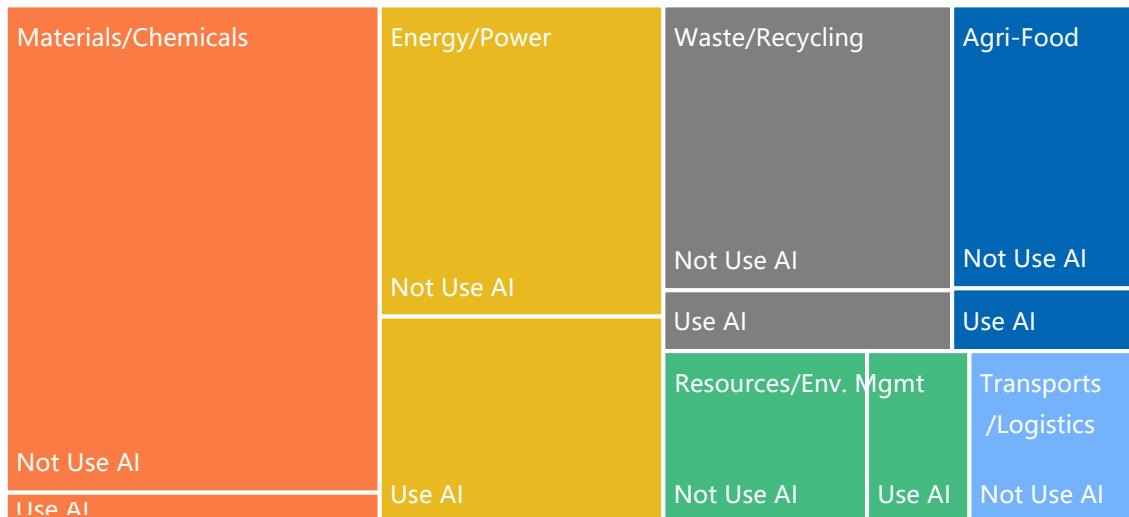
Comparing valuations within sectors, we find that AI adoption is associated with significantly higher value levels of pioneering startups in Agriculture & Food ($p=0.003$) and Resources & Environmental Management ($p=0.017$), as well as for unicorns in Transportation & Logistics ($p=0.023$). These results indicate that AI not only supports operational improvements but also amplifies the value captured by cleantech firms – especially in sectors where efficiency gains, real-time data, and system optimisation are essential.

The pattern of AI adoption suggests that combining digital technologies with climate solutions can open accelerated pathways to value creation. Sectors and regions that integrate AI more deeply are likely to be better positioned to take advantage of the green window of

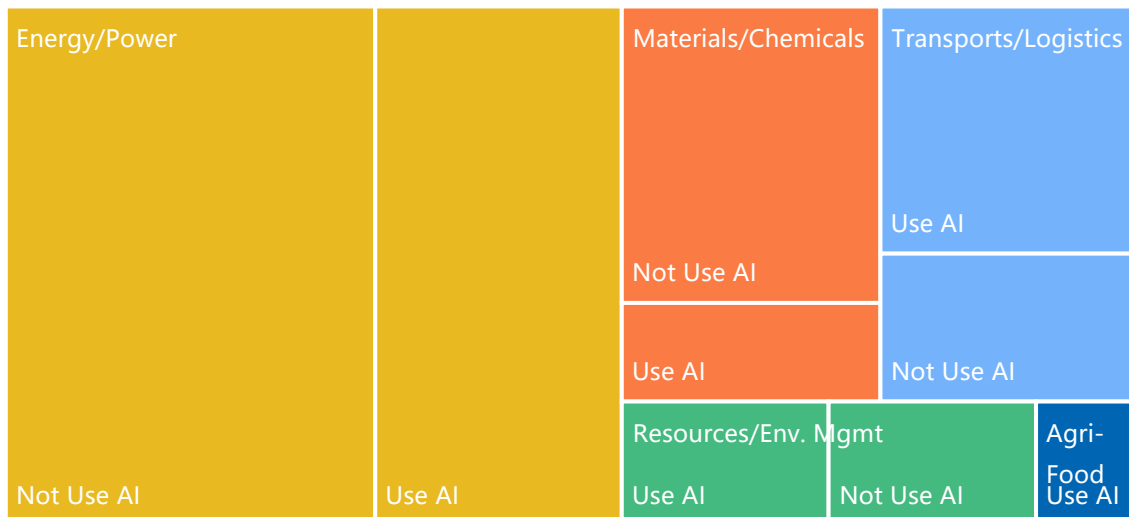
opportunity, using digital intelligence to enhance resource efficiency, strengthen competitiveness, and drive faster deployment of green technologies to scale.

Figure 9 The Use of AI in Cleantech Startups by Industry

The Use of AI in Pioneering Cleantech Startups



The Use of AI in Cleantech Unicorns



Summary and Outlook

5.1 Summary

Across the global cleantech landscape, a clear message emerges: the green window of opportunity is wide open, and countries, investors, and innovators are moving quickly to capture it. Using the OxValue valuation method, this white paper provides a comprehensive assessment of value creation among representative cleantech startups and identifies the key drivers shaping value creation. It offers one of the first systematic comparisons of where startups across the cleantech sector create value and how that value can be sustained through different pathways toward the green transition.

Unlike the AI industry – where value is highly concentrated in a small group of countries – the most valued pioneering technologies emerge across a broad geographic landscape, spanning advanced economies and emerging markets. Breakthroughs in advanced economies are concentrated in energy systems and materials, while developing countries exhibit strong innovation activity in advanced mobility, agriculture, resource management, and waste recycling. These regional and industrial distributions reflect the applied, systems-oriented nature of climate technologies, which respond directly to market demands, local environmental conditions, industrial capabilities and policy priorities.

By contrast, the upper tier of scaled firms – the top cleantech unicorns – is markedly more geographically concentrated. Europe, China and the US dominate this cohort, underscoring their comparative advantages in capital intensity, industrial deployment and the capacity to scale complex technologies. The sectoral distribution of these high-value firms is similarly concentrated in Energy & Power and Transportation & Logistics, sectors that benefit from large global markets, strong policy commitments, huge capital flows, and the ability to drive measurable decarbonization. These conditions support investor confidence and enable rapid scale-up.

Valuation patterns across both early-stage innovators and unicorns highlight the interplay between technology, team and risk factors, and market conditions. Team strength, risk factors, and technology lifecycle progression consistently emerge as the strongest contributors to

value creation across regions and sectors. While market factors appear less sensitive on average, they remain decisive determinants of firm value when interpreted through the lens of sector-specific demand and home-country market size. Regions with robust domestic markets for energy transition technologies enable faster commercial validation and scaling, creating positive feedback loops for both investors and policymakers. These patterns provide insights into how cleantech value creation can be sustained across regions, industries, and stages of scale-up.

At the technological frontier, the integration of AI and other enabling digital technologies is increasingly shaping competitive advantage. These technologies enhance system optimisation, predictive maintenance, materials discovery and capital efficiency, thereby improving the performance and scalability of core climate solutions. The digital-green convergence is likely to accelerate both innovation and valuation across the cleantech ecosystem.

5.2 Seizing the Green Window of Opportunity

Realising the full potential of the green transition requires translating emerging cleantech value creation into scaled commercial deployment, cross-border technology diffusion, and durable industrial advantage. The current moment represents a favourable but time-bound window in which coordinated action by policymakers, investors, and industry leaders can accelerate this process. Several priorities stand out.

- **Strengthen the conditions that enable early-stage innovation to scale.** The progression from pioneering experimentation to commercially viable solutions depends on predictable regulatory pathways, stable sectoral demand, and access to deployment infrastructure. Public policies that reduce risks and uncertainty (e.g., through instruments such as public procurement or dedicated scale-up finance) can greatly accelerate commercial readiness and strengthen value creation.
- **Leverage regional specialisation while enabling global diffusion.** Distinct regional strengths in cleantech innovation, manufacturing and deployment create comparative advantages that can be mutually reinforcing. Governments and investors can support

cross-border collaboration and shared standards to reduce fragmentation and enable technologies deployed in different countries to reach the scale of major global markets.

- **Prioritise sectors with clear pathways to value creation and impact.** Renewable energy, sustainable materials, and low-emission mobility continue to offer strong potential for decarbonization and economic returns. However, some regions may hold comparative advantages in other sectors that currently attract lower levels of investment. Strategic public-private coordination in these sectors, through mission-oriented investment platforms and integrated infrastructure planning, can accelerate deployment and crowd in private capital for future value creation aligned with regional priorities.
- **Invest in organisational capability and technical talent.** Strong team capabilities, technology novelty and effective progression through the technology lifecycle remain essential for cleantech value creation. Talent development programmes, cross-sector mobility schemes, supportive labour market policies, and entrepreneurial support structures can strengthen the national cleantech innovation system and improve the likelihood that early-stage technologies achieve commercial maturity.
- **Align market design with climate and industrial objectives.** Market size and sectoral demand influence which firms can scale and where value concentrates. Clear market signals, such as grid integration roadmaps, fleet-electrification targets, or material-transition standards, can reduce risk, expand demand, and improve the economics of investment. Policymakers can use these levers to accelerate technology adoption and create stable domestic markets for cleantech deployment.
- **Accelerate digital-green integration.** The application of AI and enabling digital technologies enhances cleantech efficiency and lowers risks and uncertainties. Supporting digital innovation, infrastructure and policy frameworks will be essential to unlock the next wave of value creation and improve the competitiveness of cleantech across sectors.
- **Treat valuation as a catalyst for transition.** Valuation of cleantech startups is more than a financial indicator; it is also a critical enabler for the green transition. Accurate, fast and reliable valuations improve firms' ability to raise capital, expand production capacity, and enter new markets. They facilitate technology transfer, accelerate commercialisation, and signal where transformative climate solutions are emerging. Policymakers and investors

can use valuation insights strategically to direct capital toward high-impact technologies, identify bottlenecks in the scale-up pipeline, and ensure that promising firms are not constrained at critical development stages.

By acting on these priorities, stakeholders can convert emerging cleantech momentum into durable economic and climate outcomes. The green window of opportunity may not remain open indefinitely; however, with strategic coordination and the use of robust valuation methods such as OxValue, it can become a gateway to large-scale technology deployment, cross-border diffusion and a cleaner, more resilient global economy.

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