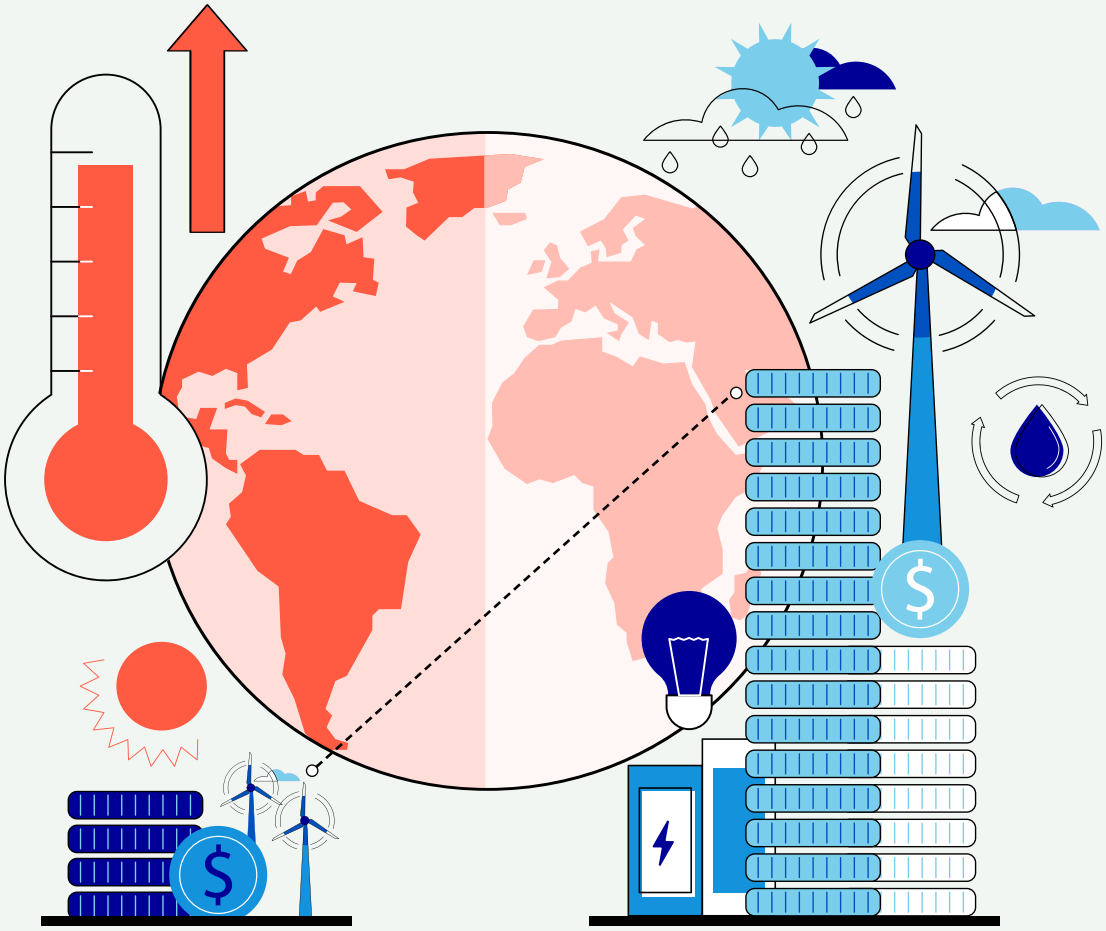


ECONOMIST IMPACT

Climate tech: bridging the gap between innovation and impact

Commissioned by FUTURE IMPROVED 10 YEARS CORPORATE FINANCE

Contents

About this report

Climate tech: bridging the gap between innovation and impact is an Economist Impact report, commissioned and supported by IMPROVED Corporate Finance. The report explores current gaps in innovation and investment in the climate tech sector, paying particular attention to the roles played by entrepreneurs, investors and policymakers in bridging them. Our findings are based on an in-depth literature review, analysis of secondary data sources and a series of expert interviews. We extend our thanks to all the participants in our interview programme (listed here in alphabetical order by surname):

- **Jules Besnainou**
  Executive director, Cleantech for Europe
- **Jackie Firsty**
  Director of Greentown Labs' Investor Program
- **Sammy Fry**
  Head of climate, Tech Nation
- **Juliana Garaizar**
  Chief development and investment officer, Greentown Labs
- **Dr Cameron Halliday**
  Co-founder and chief executive officer, Mantel
- **Dr Carlos Härtel**
  Chief technology officer, Climeworks
- **Dr Aidan O'Sullivan**
  Co-founder and chief technology officer, Carbon Re
- **Herald Ruijters**
  Director of investments, sustainable and innovative transport, European Commission

Foreword

"Whatever we do—or even more impactful—whatever we decide not to do will significantly impact the tasks we leave for future generations."

In a year that has seen global temperatures accelerate to record-setting levels with catastrophic consequences, the notion of coordinated global action and impactful investing has never felt more important.

This is why IMPROVED has commissioned and supported this new report, *Climate tech: bridging the gap between innovation and impact*, to highlight the steps we, as entrepreneurs, innovators and financiers, must take as part of a call to action for the upcoming ten years.

To quote Professor Bruce Usher, "A catastrophe can be avoided only with rapid and sustained investments in companies and projects that reduce greenhouse gas emissions."

But, as this report sets out, achieving net zero will require greater acceptance from investors for higher-risk, higher-reward investments in emerging technologies. It will also require climate tech entrepreneurs and company owners to clearly articulate how their innovations will deliver both attractive financial and non-financial returns.

Well-positioned companies, managed by first-class entrepreneurial teams, will require further support to realise their optimum impact and scale, whether that involves partnering with the best possible investors or transferring to a new owner.

As we mark our 10th anniversary year, we are proud to share with you the results of this research programme by Economist Impact.

Together, we can make the next ten years the most advanced ones. And if we can, we should.

A big thank you on behalf of the entire IMPROVED team for teaming up towards 2033.

Frank Verbeek
Managing Partner, IMPROVED Corporate Finance

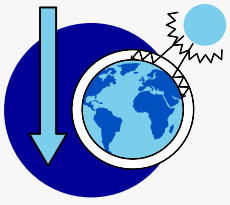
Introduction

Almost five decades after Wallace Broecker first coined the term "global warming", climate change has emerged as the single greatest threat to human wellbeing and planetary health.[1] As we grapple with extreme weather events, mounting food insecurity and irreversible ecosystem damage, swift and unified action is necessary to avert climate disaster. To this end, the 195 signatories of the Paris Agreement committed in 2015 to keep the global average temperature increase below 2°C compared to pre-industrial levels, and preferably below 1.5°C.[2,3] To meet the latter target, global emissions of greenhouse gases must be cut by roughly 50% by 2030, reaching net-zero by 2050.[4]

Achieving the goals of the Paris Agreement will be near-impossible without advances in climate technology, a diverse family of technologies that are explicitly focused on targeting climate change (see box).[5] Research suggests that in order to reach net-zero by 2050, as much as 40% of the reduction in the EU's emissions will rely on the use of currently nascent or undiscovered technologies.[6] Encouragingly, the climate tech sector is expanding rapidly. In fact, the number of emerging technology companies seeking to address climate challenges has quadrupled since 2010, reaching almost 45,000 firms by 2022.[7]

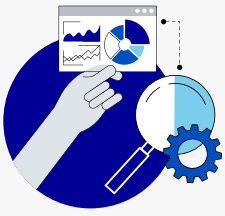
WHAT ARE CLIMATE TECHNOLOGIES?

Climate technologies tend to target one of three broad goals:



1 Reducing emissions of greenhouse gases, or directly removing them from the atmosphere—for example, renewable energy or carbon capture technologies.

2 Bolstering resilience and adaptation to a changing climate—for example, water recycling technologies.



3 Enhancing our understanding of climate change, particularly through improvements in the measurement and accounting of emissions—for example, carbon accounting software.

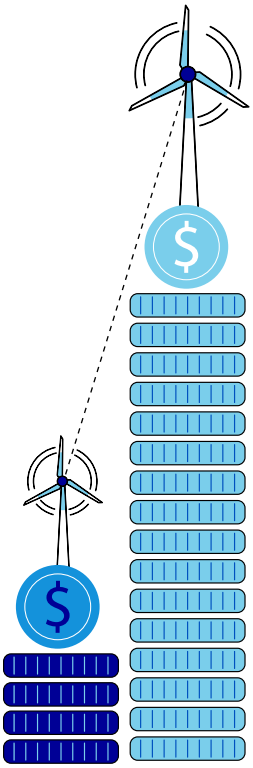
[1] Broecker WS. Climatic change: are we on the brink of a pronounced global warming? Science. 1975 Aug 8;189(4201):460-3. doi: 10.1126/science.189.4201.460.
[2] https://www.un.org/en/climatechange/paris-agreement
[3] https://www.britannica.com/topic/Paris-Agreement-2015
[4] https://www.un.org/en/climatechange/net-zero-coalition
[5] https://www.pwc.com/gx/en/services/sustainability/publications/state-of-climate-tech.html
[6] https://www.mckinsey.com/capabilities/sustainability/our-insights/how-the-european-union-could-achieve-net-zero-emissions-at-net-zero-cost
[7] https://technation.io/climate-tech-report-2022/

45,000

The number of emerging technology companies seeking to address climate challenges

While by no means a panacea, the opportunities afforded by innovation in climate tech—supported by ambitious and globally coordinated policy measures—are enormous. Not only will the adoption of climate tech be necessary to overcome and adapt to a changing climate; the scaling of climate technologies also has the potential to create new jobs, support economic growth and accelerate broader technological advancement.[8,9]

This paper explores the extent to which the climate tech sector is currently able to deliver upon these lofty ambitions, with a focus on Europe and North America. Drawing on a literature review, analysis of secondary data sources and a series of expert interviews, we first explore the sectors and applications of climate tech where innovation is most urgently needed ("the innovation gap"). We then turn to the funding ecosystem for climate tech firms, identifying strategies to negotiate the obstacles that they encounter in securing investment. Finally, we consider how government policy can support the development of climate tech innovations, including through spurring increased investment. In doing so, this paper arrives at three key findings:



1. **Supporting the scaling of existing climate tech is necessary to achieve international decarbonisation targets for 2030.** Government policy can play a role in this by stimulating demand for emerging climate technologies; for example, through public procurement, a supportive regulatory environment, carbon-pricing measures or mandating the phase-out of incumbent, polluting technologies. However, in order to reach net-zero by 2050, higher-risk, higher-reward investments in emerging technologies will be crucial.
2. **Public funding plays a critical role in spurring the development of immature technologies, particularly by supporting early-stage innovations that the private sector may deem too risky.** However, across much of the globe, the manner in which public funding is provided is poorly aligned with the requirements of the climate tech sector. Public grants often lack flexibility, making it difficult for climate tech firms to innovate as they grow, and a reluctance to support technologies with higher-risk profiles stymies the development of the transformative innovations necessary for net-zero.
3. **Venture capital (VC) investment in climate tech has boomed over the past decade.** This is a good thing. However, a more recent slowdown means that such investment still falls far short of what is needed. Although this slowdown is largely a product of broader macroeconomic headwinds, including high interest rates that have dampened VC activity across the board, VC funds' shift away from climate tech in tougher times reveals intrinsic discrepancies between the VC model, which demands substantial returns in short order, and the needs of climate tech firms (that is, patient capital provided over significantly longer timeframes). This underscores the need for fostering greater diversity in sources of funding for climate tech, including actors that can support the sector over the longer term. Such actors include government funding agencies, green investment banks and alternative pools of capital—for example, infrastructure and pension funds.

[8] https://www.weforum.org/agenda/2021/12/jobs-renewable-energy-fossil-fuels/
[9] https://www.reuters.com/article/us-global-climatechange-investment-idUSKBN17Q1U2

Bridging the innovation gap: where is climate tech investment needed?

Supporting the scaling of existing climate tech is necessary to achieve international decarbonisation targets for 2030. However, to reach net-zero by 2050, higher-risk, higher-reward investments in emerging technologies will be crucial.

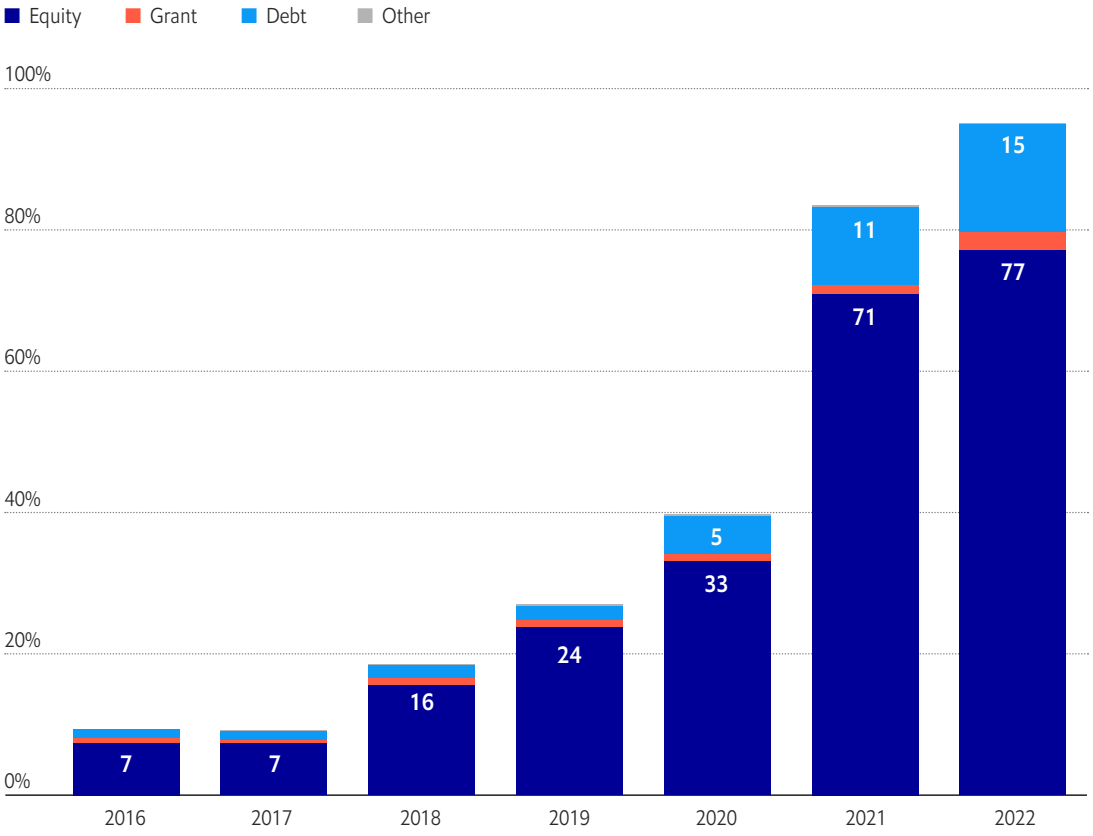
The field of climate technology is astonishingly diverse, encompassing a broad array of technologies with the potential to address climate change and reduce emissions. Such technologies touch on all sectors, including energy, transport, the built environment, industry, waste and agri-food. Climate technologies vary significantly in their maturity, ranging from well-established products that are already manufactured at scale to nascent innovations that still require major technological advances before they can enter the market.[10] "While for instance hydrogen-fuelled buses already exist, we are still quite far away from low-carbon trucks, ships or planes," says Herald Ruijters, director of investments, sustainable and innovative transport at the European Commission. To describe the disparity between the potential that climate tech has to deliver and what it is currently delivering, we use the term "the innovation gap". Bridging the innovation gap—through the discovery and scaling of climate tech innovations across sectors and applications—will require accelerated, targeted investment.

As Figure 1 illustrates, funding for climate tech in Europe and North America has markedly accelerated in recent years. In fact, our analysis indicates that total funding to early-stage climate tech firms and small and medium-sized enterprises in these regions increased more than tenfold between 2016 and 2022. This was principally driven by substantial gains in the volume of equity financing reaching climate tech firms, which increased by US$71.5bn. Escalating investment has facilitated a boom in activity in previously neglected technologies, such as carbon capture and green hydrogen. In fact, the number of emerging technology companies seeking to tackle the climate crisis has quadrupled since 2010, reaching almost 45,000 firms by 2022.[11]

[10] IEA (2021), Net Zero by 2050, IEA, Paris https://www.iea.org/reports/net-zero-by-2050
[11] https://technation.io/climate-tech-report-2022/

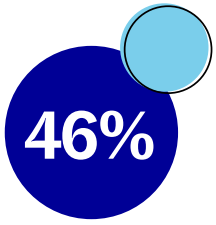
Figure 1: Early-stage climate tech firms funding by type*

Historic trends in funding for early-stage climate tech firms in Europe and North America (broken down by financing instrument: equity, grants, debt and other). $bn



*As defined by Net Zero Insights, early-stage climate tech firms refer to startups and SMEs from the pre-seed to exit stage developing innovative products, services, or technologies addressing at least one of the six objectives of the EU Taxonomy for sustainable activities.

Source: Net Zero Insights, Economist Impact calculations



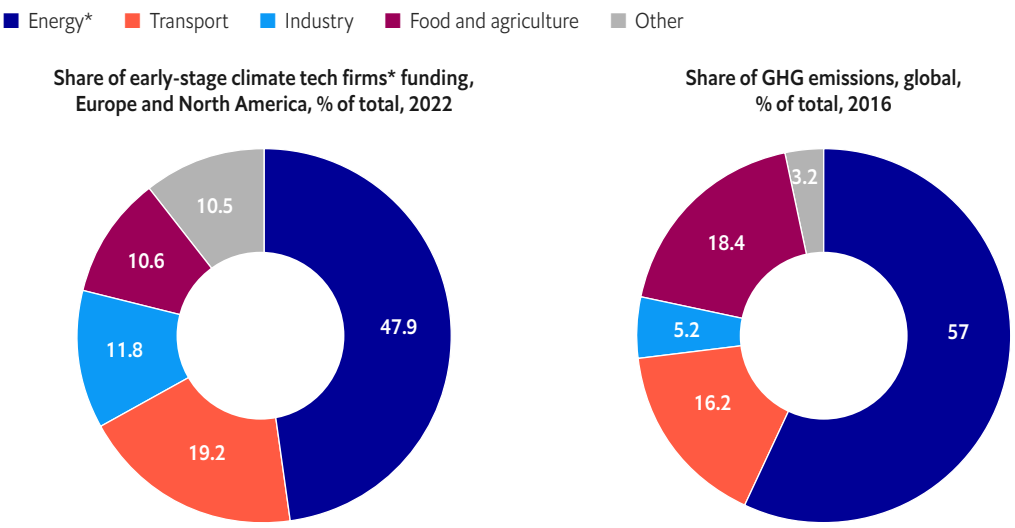
of the emission reductions needed to reach net-zero by 2050 will arise through the adoption of technologies that are still under development

Although these trends are encouraging, significantly more investment is needed to bridge the innovation gap. The International Energy Agency estimates that 46% of the emissions reductions needed to reach net-zero by 2050 will arise through the adoption of technologies that are still under development.[12] Substantially more investment—an estimated US$21trn over the next ten years—will be needed to support the discovery, development, industrialisation and adoption of these new technologies.[13,14] In the case of green hydrogen technologies, for example, a report by the Hydrogen Council, an industry group, and McKinsey, a management consulting firm, calculates that an additional US$540bn of investment is needed to ensure the sector's contribution to reaching net-zero by 2050.[15] Mr Ruijters warns that our traditional funding and financing schemes are not sufficient to drive the rollout of climate tech that is necessary to meet climate targets: "if we want to make this enormous shift, then we need to think outside of the box."

[12] International Energy Agency (2021), *Net Zero by 2050*, IEA, Paris: Net Zero by 2050 Scenario - Data product - IEA; as modified by Economist Impact.
[13] https://www.bcg.com/publications/2021/private-investment-in-low-carbon-technologies
[14] Giulio Cornelli & Jon Frost & Leonardo Gambacorta & Ouarda Merrouche, 2023. "Climate tech 2.0: social efficiency versus private returns," BIS Working Papers 1072, Bank for International Settlements.
[15] https://www.mckinsey.com/capabilities/sustainability/our-insights/delivering-the-climate-technologies-needed-for-net-zero

Figure 2: Funding for early-stage climate tech firms is not consistent with sectoral contributions to global emissions

Funding for early-stage climate tech firms in Europe and North America, broken down by the economic sector targeted, versus the relative proportion of global greenhouse gas emissions produced by each sector annually.



*As defined by Net Zero Insights, early-stage climate tech firms refer to startups and SMEs from the pre-seed to exit stage developing innovative products, services, or technologies addressing at least one of the six objectives of the EU Taxonomy for sustainable activities.

Source: Climate Watch and the World Resources Institute (2016), Net Zero Insights (2022), Economist Impact calculations

Unequal opportunity?

Although climate tech funding is rising, it is distributed unevenly across sectors. In particular, there are notable mismatches between the sectors contributing most to global emissions and those receiving the most investment (see Figure 2). The agri-food sector contributes almost 20% of total global greenhouse gas emissions (with livestock and manure accounting for as much as 6% of the global total), but early-stage climate tech firms within the agri-food sector received just 10.6% of investment in 2022. These figures do not reflect a lack of investment opportunity; there are many promising climate technologies with potential to curb the emissions of the agri-food sector, including vertical indoor farming, precision agriculture and plant-based proteins.[16] For example, substituting animal-based proteins in food with proteins derived from oats could reduce dietary greenhouse gas emissions by 8-13%.[17] Furthermore, researchers at the University of Oxford report that, should alternative proteins replace all animal-related products, the restoration of newly redundant agricultural land would enable the sequestration of as much as 900 gigatons of atmospheric carbon dioxide over the following century.[18] In fact, investment in plant-based proteins is associated with the highest savings of carbon dioxide emissions per US dollar invested of any sector.[19]

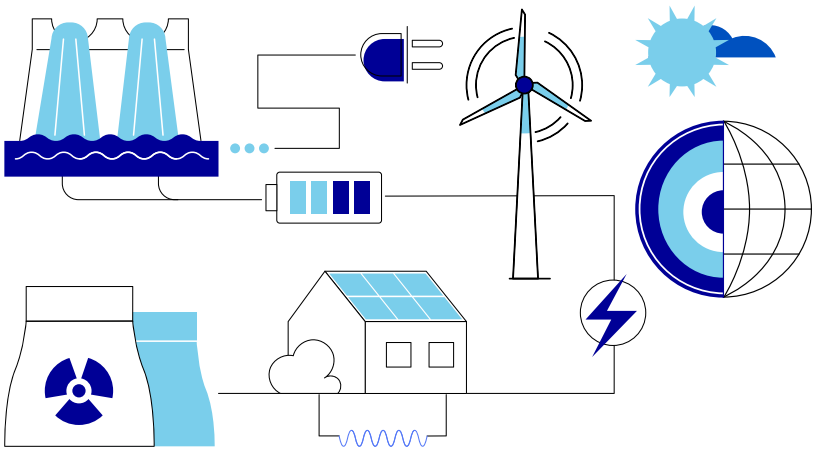
[16] Hood, C. et al. 2019. Technology and climate change: A review of STFC Food Network+ projects and future potential. Santa Monica, CA: RAND Corporation.
[17] Mogensen, L., Heusale, H., Sinkko, T., Poutanen, K., Sözer, N., Hermansen, J.E. and Knudsen, M.T. (2020). Potential to reduce GHG emissions and land use by substituting animal-based proteins by foods containing oat protein concentrate. Journal of Cleaner Production, 274, p.122914.
[18] https://www.smithschool.ox.ac.uk/sites/default/files/2022-03/Climate_Impacts_of_Alternative_Proteins.pdf
[19] https://www.bcg.com/publications/2022/combating-climate-crisis-with-alternative-protein

Bridging the climate tech innovation gap requires prioritising the discovery and scaling of innovations with the greatest potential to counter the challenges posed by the climate crisis. This includes those technologies that are able to facilitate the largest reductions in greenhouse gas emissions in the most polluting sectors of the economy. It also requires accounting for the potential scalability of such technologies; in particular, their technological performance and economic viability.

Ensuring the scalability of climate technologies is particularly important to ensuring that international decarbonisation targets for 2030 are met. "The technologies we need [to meet 2030 targets] already exist," remarks Jules Besnainou, executive director of Cleantech for Europe, a consultancy and advocacy organisation. "The challenge is scaling and industrialising them in time." For example, Carlos Härtel, chief technology officer at Climeworks, a Swiss company developing carbon capture technology, argues for the prioritisation of direct air capture (DAC) technologies that can be smoothly integrated into existing configurations. "Unless you are developing a technology that is a "drop-in" to those DAC solutions, which already have a certain maturity, the time to scale will be too long." As detailed later in this paper, government policy is crucial to scaling existing technologies, in particular through measures to improve their competitiveness and stimulate demand.

"Not enough is being done to identify and invest in the high-risk, high-impact areas that will be necessary for net-zero."

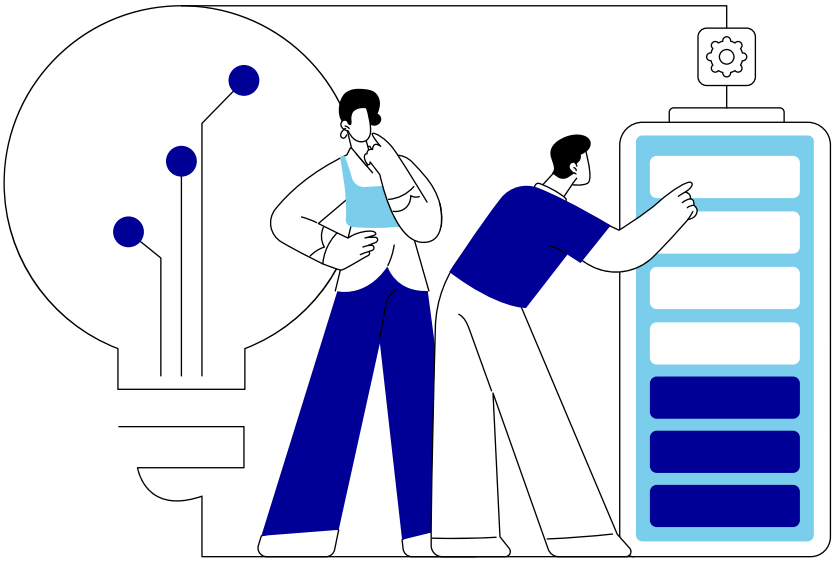
Jules Besnainou, executive director, Cleantech for Europe



However, meeting international decarbonisation targets for 2050 will require a more radical approach. "If you look at 2050, it's much more of an open field, in terms of the technologies that are going to get us to net-zero," says Mr Besnainou. However, he adds, "not enough is being done to identify and invest in the high-risk, high-impact areas that will be necessary for net-zero." In particular, Mr Besnainou laments the fact that available funding is "more easily given to large industrials deploying incremental technologies—rather than newcomers discovering and scaling the kind of revolutions we need".

Mr Besnainou's concerns are borne out in the investment data for climate tech. In fact, just 6% of private investment in the sector went to emerging or early-adoption technologies in 2021, with the remaining 94% invested in more mature tech, such as electric vehicles (EVs), energy storage and solar energy.[20] The EV industry, for instance, attracted over US$400bn in investment over the decade leading up to September 2021, with a quarter of that sum invested since the beginning of 2020.[21]

[20] https://www.bcg.com/publications/2021/private-investment-in-low-carbon-technologies
[21] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/why-the-automotive-future-is-electric



This bias towards funding mature technologies has stymied innovation in multiple areas critical to net-zero. For example, substantial progress is still needed in the development of numerous carbon capture technologies—including carbon capture from steel manufacture and chemical absorption from gas-fired power generation—despite the indispensable role that they must play in balancing unavoidable greenhouse gas emissions.[22] This is in part due to the existence of a large investment gap for such technologies. In fact, it is estimated that catalysing the development and deployment of carbon capture technologies necessary to reach net-zero will require US$160bn of cumulative investment between 2020 and 2030, a tenfold increase on the investment provided in the previous decade.[23] As is discussed later in this paper, mobilising this funding will be contingent on de-risking investment—for example, through intervention by governments to create demand signals for low-carbon technologies.

Emerging climate tech innovations: a spotlight on artificial intelligence

A number of emerging technologies have the potential to catalyse decarbonisation across multiple sectors of the economy. One notable example, highlighted by Aidan O'Sullivan, co-founder and chief technology officer of Carbon Re, is artificial intelligence (AI). Although AI is hardly a climate tech-specific breakthrough, the pattern-recognition and predictive capabilities of machine learning models are being widely applied to the monitoring, prediction and mitigation of greenhouse gas emissions.

For instance, AI has the potential to improve the efficiency of agri-food systems through precision agriculture, which involves monitoring, analysing and responding to variability in environmental conditions (such as soil moisture) in order to maximise agricultural productivity and sustainability.[24] At scale, this has the potential to reduce emissions from food production through optimised land use and reduced reliance on agricultural inputs with high carbon footprints, such as synthetic nitrogen fertiliser.[25]

In the energy sector, AI has the potential to cut emissions through improvements in the efficiency with which energy grids are managed. AutoGrid, an American climate tech firm, uses AI-driven software to smooth out fluctuations in renewable energy supply and consumer demand by extracting untapped capacity from millions of distributed energy resources (such as home batteries, solar panels and electric vehicles).[26] With over 50 customers in more than ten countries, the promise of Autogrid's technology—both in terms of environmental impact and economic returns—underpinned the company's acquisition by Schneider Electric in 2022.[27]

Although there are AI-based climate tech solutions that have already achieved deployment at considerable scale—as illustrated by Autogrid—most are still at a nascent stage of development.[28] This presents a significant opportunity for entrepreneurs, corporates and investors seeking to accelerate progress towards net-zero. In fact, estimates suggest that the widespread adoption of AI could achieve 5-10% of the emissions reductions necessary to meet targets for 2030.[29]

[22] https://iea.blob.core.windows.net/assets/181b48b4-323f-454d-96fb-0bb1889d96a9/CCUS_in_clean_energy_transitions.pdf
[23] https://www.reuters.com/article/us-iea-carboncapture-idUSKCN26F0IB
[24] Rolnick D et al (2022) Tackling climate change with machine learning. ACM Comput Surv.
[25] Lorenzo Rosa, Paolo Gabrielli. Energy and food security implications of transitioning synthetic nitrogen fertilizers to net-zero emissions. Environmental Research Letters, 2022; 18 (1): 014008
[26] https://www.auto-grid.com/
[27] https://energy.stanford.edu/news/qa-stanford-smart-grid-project-launched-decade-long-journey-recently-acquired-climate-tech
[28] https://www.bcg.com/publications/2022/how-ai-can-help-climate-change
[29] https://www.bcg.com/publications/2021/ai-to-reduce-carbon-emissions

Funding requirements for climate tech development

Public and private sources of funding both play important roles in supporting the development of climate tech firms—from early-stage research through to industrialisation. However, funding from both sources could be better tailored to the specific needs of the climate tech sector.

Bridging the innovation gap requires supporting the development of climate tech firms from research and development (R&D) through to industrialisation. This entails ensuring that climate tech firms are able to acquire sufficient funding. In order to better understand the specific funding requirements of climate tech firms, it is useful to elucidate the generic pattern of development that they follow.

As illustrated in Figure 3, climate tech innovation begins with R&D, which is traditionally funded through grants—from governments or foundations, for example. Public funding is critical at this stage, given the capital-intensive nature of climate tech R&D, which entails higher upfront costs than many other industries.[30] This is particularly true of firms conducting research in nascent sectors and technologies, which are less likely to receive support from private investors owing to factors such as their lack of tangible assets to serve as collateral for large investments.[31] "The early-stage risk is just too high for private investment at the moment—that's where the government has to play a role," says Sammy Fry, head of climate at Tech Nation. This allocation of public resources makes sense: the benefits of government subsidies are maximised when they target early-stage, immature firms in emerging sectors.[32]

Following R&D, climate tech firms must next develop a business plan that outlines their goals, strategy and financial projections. This is contingent on having developed a functional prototype that demonstrates the viability of the technology. As well as grants, this stage of development is mostly reliant on seed funding from long-horizon, "patient" investors, who are more willing to assume the risk of investing in firms with minimal track record and no patented intellectual property.[33]

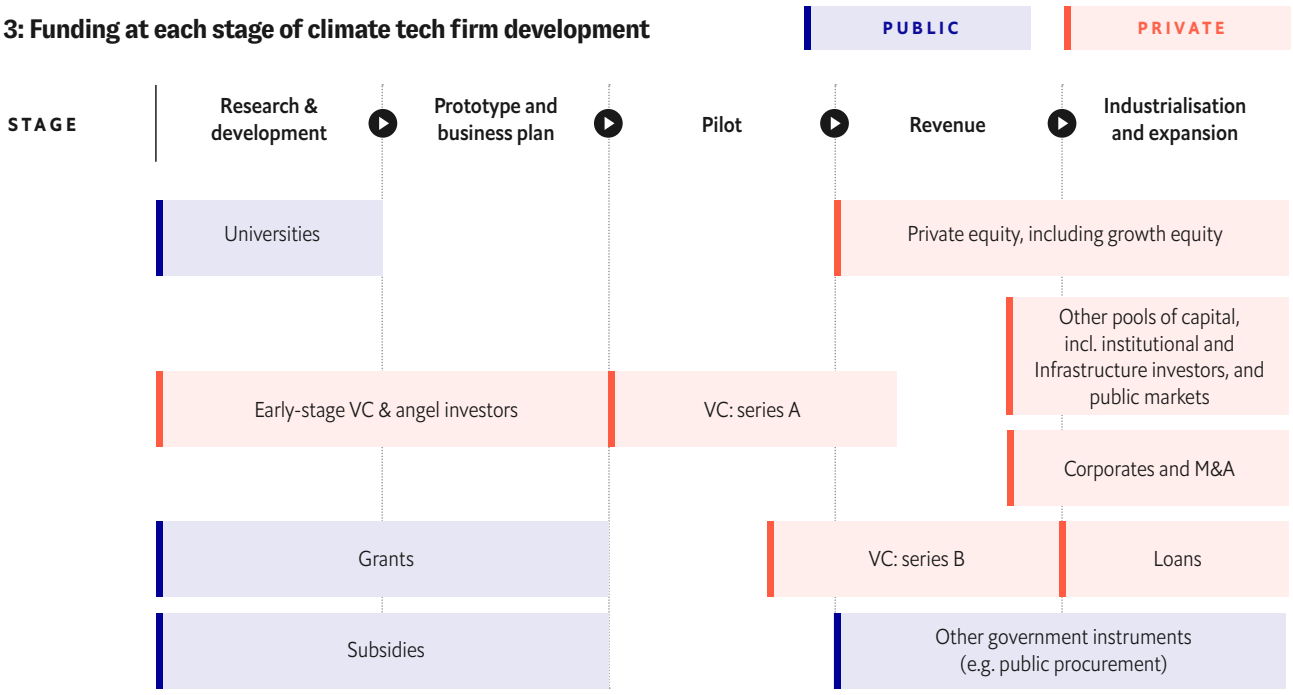
[30] Giulio Cornelli & Jon Frost & Leonardo Gambacorta & Ouarda Merrouche, 2023. "Climate tech 2.0: social efficiency versus private returns," BIS Working Papers 1072, Bank for International Settlements.
[31] ibid.
[32] Howell, S. T. (2017). Financing innovation: Evidence from R&D grants. American Economic Review, 107(4):1136–6
[33] Giulio Cornelli & Jon Frost & Leonardo Gambacorta & Ouarda Merrouche, 2023. "Climate tech 2.0: social efficiency versus private returns," BIS Working Papers 1072, Bank for International Settlements.

These include angel and corporate investors, as well as early-stage VC firms. Patient capital is particularly important, given the high degree of complexity involved in developing novel climate technologies, which often entails much longer timelines to profitability than in other industries. In fact, remarks Mr Härtel, "to scale up an industrial-style technology is a journey of several decades".

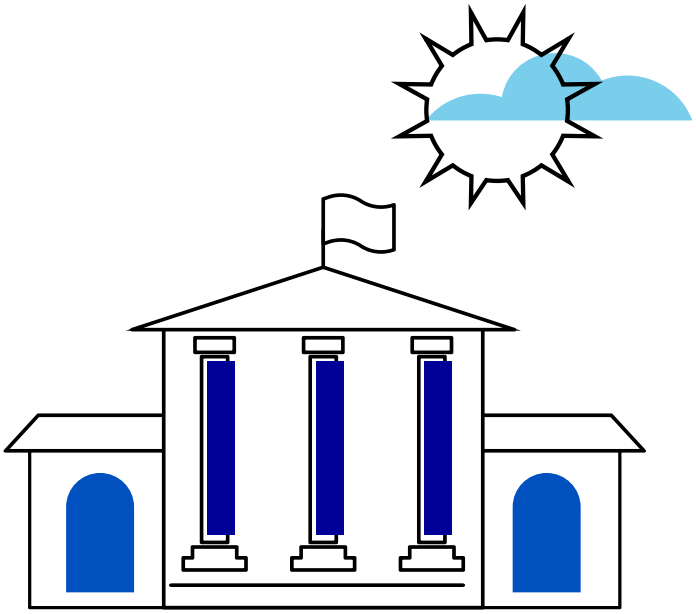
VC funding begins to play a critical role in the next two stages of growth: pilot development and revenue establishment. During these stages, firms test their technologies in real-world conditions and begin to generate revenue through the sale of their products or services. VC investors help to facilitate this process by bridging the funding gap that many firms face when their technology is too advanced to receive public R&D grants but is not yet commercially mature (termed the "valley of death"). "The valley of death is where companies struggle the most to secure funding," says Juliana Garaizar, chief development and investment officer at Greentown Labs. "Once companies have figured out their Series A, it is smoother sailing."

Where technologies with higher-risk profiles fail to attract sufficient interest from private investors, philanthropic funds can also play an important role in bridging the valley of death, given their higher risk tolerance compared with investors motivated by profit.[34] Similarly, philanthropic involvement can help to de-risk ventures, thereby attracting capital from more risk-averse private sources.[35] Importantly, there is substantial scope for philanthropic organisations to play a much larger role in funding climate tech innovation—of the US$64bn of funding disbursed by US-based philanthropies in 2020, just US$320m was targeted at tackling climate change.[36]

Figure 3: Funding at each stage of climate tech firm development



[34] https://www.mckinsey.com/capabilities/sustainability/our-insights/its-time-for-philanthropy-to-step-up-the-fight-against-climate-change
[35] https://www.ft.com/content/8efb6be3-1ab9-4ff4-a687-647b201864a0
[36] https://www.mckinsey.com/capabilities/sustainability/our-insights/its-time-for-philanthropy-to-step-up-the-fight-against-climate-change



"Governments need to step up."

Dr Carlos Härtel,
Chief technology officer, Climeworks

Unlocking this pool of funding—for example, by bringing philanthropists together in fora that can educate them on how to invest in climate tech—could prove instrumental to catalysing high-risk, high-impact innovation in the sector.[37]

Finally, once firms are ready to expand and industrialise, alternative sources of funding become more readily accessible—including growth equity, loans and project finance. This entails the participation of a more diverse set of actors, including private equity firms, banks and alternative pools of capital. For example, institutional investors such as pension funds and insurance companies are able to finance climate tech through multiple routes, including mutual funds, green indices, green bonds, direct investment via private equity, and green infrastructure funds.[38] While such investors' involvement in climate tech is relatively low—pension funds' asset allocation to green investments is currently estimated at less than 1%—there is significant room for growth as more climate technologies reach commercialisation.[39]

Public funding plays a critical role in spurring the development of immature technologies, particularly by supporting early-stage innovations that the private sector may deem too risky. However, across much of the globe, the manner in which public funding is provided is poorly aligned with the requirements of the climate tech sector.

As Jackie Firsty, director of Greentown Labs' Investor Program, notes, "the government plays a really important role in providing initial funding and support to climate tech"—particularly early-stage firms struggling to attract private investment. However, as illustrated in Figure 1, public grants currently constitute a near-negligible portion of the funding provided to early-stage climate tech firms in Europe and North America, making up less than 3% of the total in 2022. Furthermore, while grant funding to early-stage climate tech firms has increased in absolute terms, it has decreased as a percentage of total funding (dropping from 7.3% to 2.8% of total funding between 2016 and 2022). As public funding falls behind the demands and scale of this burgeoning sector, innovation in the higher-risk, higher-impact technologies that are essential to net-zero is put at risk. As Mr Härtel summarises it, "governments need to step up".

[37] https://climatelead.org/approach/
[38] https://www.oecd.org/finance/private-pensions/49016671.pdf
[39] ibid.

"There is a great deal of fluidity between the visions over a one-year timeframe and a ten-year timeframe."

Dr Cameron Halliday, co-founder and chief executive officer, Mantel

The underutilisation of grants in climate tech may in part be due to misalignment between the way public money is awarded and the needs of the sector. Public grants tend to lack flexibility, making it difficult for firms to innovate as they grow. "With grants, if you deviate from what you're doing, lots of questions come up,' says Cameron Halliday, co-founder and chief executive officer of Mantel. "This means that firms aren't able to pivot on the fly, even if that pivot is good for both parties". This poses problems for younger firms that need to adapt their strategy in response to new technological developments and fluctuating market conditions. For such firms, remarks Mr Halliday, "there is a great deal of fluidity between the visions over a one-year timeframe and a ten-year timeframe".

A second issue with the way in which public funding is awarded is a pervasive reluctance to support innovations with higher-risk profiles. "It's a fundamental issue at the heart of all kinds of public funding—the perception that you should only back winners, and that research projects need to constantly be assessed due to a fear factor that some funders have," says Mr O'Sullivan. Although it is critical to ensure that public money is well spent, Mr O'Sullivan notes that this fear of investing in riskier ventures impedes "a disruptive approach to research" that is necessary to foster the innovations required for net-zero. "While there are already plenty of public funding schemes available in Europe, the criteria of these schemes are designed in a way that favour the maturity of large industrial groups, rather than the most innovative solutions," adds Mr Besnainou.

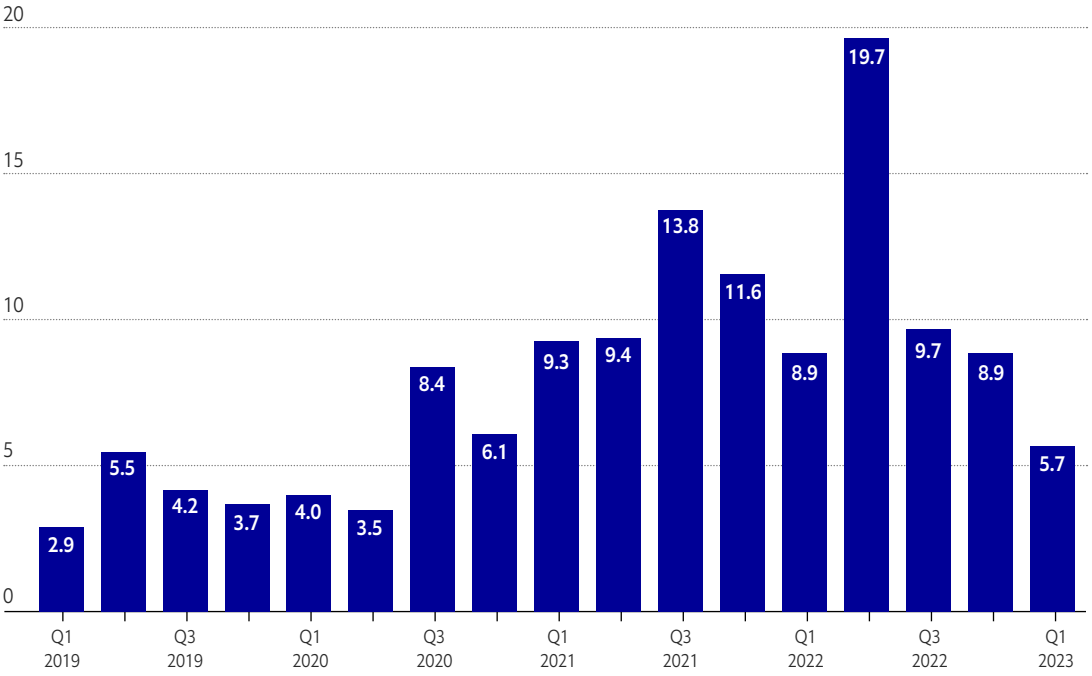
To overcome these issues, Mr Halliday points to alternative approaches to grant design, such as that modelled by Breakthrough Energy's fellowship programme.[40] This programme, which provides non-dilutive, grant-like funding for climate tech firms, allows dynamic adjustment of recipients' milestones, thereby enabling their nimble development and adaptation to changes in the market. Furthermore, Breakthrough Energy's targeting of novel, riskier innovations with high potential to reduce emissions—such as sustainable aviation fuels and carbon capture—is markedly different from the risk-averse investment strategies associated with public grants. As such, one avenue for curbing the conservatism of public funding agencies could involve closer collaboration with less risk-averse funding partners, such as philanthropic funds and private capital. For instance, the EU's recent partnership with Breakthrough Energy, which intends to mobilise up to US$1bn of investment in climate critical technologies, is explicitly focussed on high-risk, early-stage innovations with potential to make Europe what Ursula von der Leyen, the president of the European Commission, has described as "the first climate neutral and climate innovation continent".[41]

More broadly, however—as advocated for by Mariana Mazzucato, a world-renowned economist—governments should consider adopting a mission-oriented innovation policy, selecting recipients of public funding according to their capacity to counter complex societal problems such as climate change.[42] According to Ms Mazzucato, the risk aversion of public funding agencies stems from governments'

[40] https://breakthroughenergy.org/our-work/fellows/
[41] https://cyprus.representation.ec.europa.eu/news/commission-breakthrough-energy-catalyst-and-european-investment-bank-advance-partnership-climate-2021-11-02_en
[42] https://www.project-syndicate.org/commentary/entrepreneurial-state-only-solution-to-climate-change-by-mariana-mazzucato-2022-11

Figure 4: VC investment in climate tech

Quarterly trends in global venture capital investment in climate tech (Q1 2019 to Q1 2023). $bn



Source: Pitchbook

reticence to intervene in markets beyond correcting existing market failures. This incentivises public funders to pick winners, rather than actively shape or create new markets. Instead, a mission-oriented approach would encourage governments to act as "the investor of first resort", assuming a more assertive role in catalysing the innovation necessary to counter the climate crisis.[43] In doing so, governments would utilise the full breadth of financing instruments at their disposal to realise such missions, including public grants, loans, and blended finance.

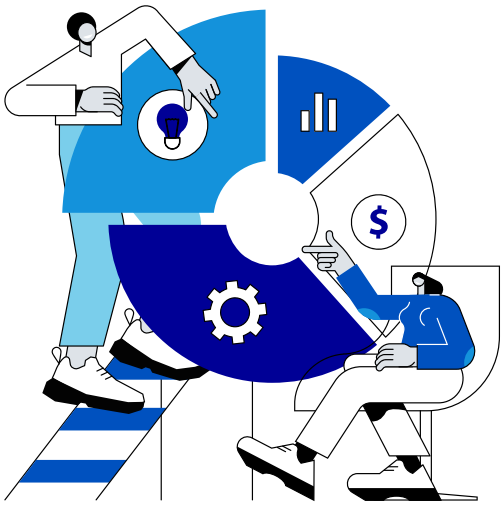
This approach has been trialled in the German government's High-Tech Strategy 2025 (HTS 2025), which is defined around 12 specific missions, including "achieving substantial greenhouse gas neutrality in industry".[44] In order to drive progress on this mission, the German government has employed 12 specific instruments to lower the greenhouse gas emissions of German industry, including investment in transformative research and funding for "reality labs" to demonstrate the viability of new technologies.[45]

VC investment in climate tech has boomed over the past decade. However, a more recent slowdown means that such investment still falls far short of what is needed.

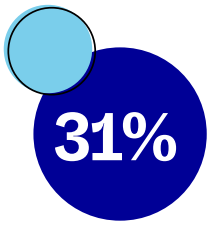
[43] https://www.ucl.ac.uk/bartlett/public-purpose/sites/bartlett_public_purpose/files/mazzucato_perez_2022_redirecting_growth-inclusive_sustainable_and_innovation-led.pdf
[44] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cci/innovation-systems-policy-analysis/2022/discussionpaper_75_2022.pdf
[45] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccp/2021/Hightech_Strategy_2025-second_mission_analysis_report.pdf

"A lot of climate technologies have a heavy hardware or infrastructure component, which doesn't fit the VC model. That's why it's important to diversify sources of funding."

Juliana Garaizar, chief development and investment officer, Greentown Labs



A combination of low interest rates, high liquidity and increased competitiveness of climate-friendly technologies (for example, due to escalating fossil fuel prices) have coalesced to spark a boom in VC investment in climate tech.[46] Total global VC investment in climate tech more than tripled between the first quarters of 2019 and 2021 (see Figure 4). This is a good thing. VC investors lend climate tech firms not just financial support, but also expertise and legitimacy. This can foster success further down the line: firms with VC backing have higher growth rates, are more likely to innovate and are more likely to receive follow-on funding than their counterparts without VC investment.[47]



drop in the number of VC deals recorded in the first quarter of 2023 compared with the previous quarter

However, this surge in VC activity appears to be running out of steam. As illustrated in Figure 4, VC investment in climate tech slowed down over the second half of 2022. In fact, the total value of VC investments in climate tech firms in the first quarter of 2023 was just 64% of what it was in the same quarter of the previous year, meaning that VC investment is now at the lowest level seen since mid-2020. Similarly, the first quarter of 2023 saw a 31% drop in the number of VC deals recorded compared with the previous quarter.[48] It is likely that this trend is a product of broader macroeconomic headwinds—including rising interest rates—that have dampened VC activity across the board.[49] It also reflects the cyclical nature of VC activity, which often slows after a period of rapid growth.[50] However, it may also raise concerns about intrinsic discrepancies between the investment models of VC firms and the requirements of climate tech firms.

In many respects, VC funding is poorly aligned with the requirements of climate tech. The typical VC investor chases returns of 10 to 100 times the figure invested within a short timeframe (less than ten years).[51] "Some VC firms are looking to see these multiples and then—within three years—take their money and get out, which doesn't lend itself to impact of the scale we need", remarks Mr O'Sullivan. This is poorly aligned with the timelines to maturity of climate technologies, which as discussed, require patient capital over the long term. Similarly, the capital-intensive nature of climate tech R&D—which often requires significant investment in heavy industry, even before technology development is complete—does

[46] Giulio Cornelli & Jon Frost & Leonardo Gambacorta & Ouarda Merrouche, 2023. "Climate tech 2.0: social efficiency versus private returns," BIS Working Papers 1072, Bank for International Settlements.
[47] Akcigit, Ufuk & Dinlersoz, Emin & Greenwood, Jeremy & Penciakova, Veronika, 2022. "Synergizing ventures," Journal of Economic Dynamics and Control, Elsevier, vol. 143(C).
[48] https://pitchbook.com/news/articles/VC-climate-tech-drop-2023-startups-founders#:~:text=VC%20funding%20for%20climate%20tech%20startups%20has%20slowed,across%20279%20VC%20deals%2C%20according%20to%20PitchBook%20data.
[49] https://www.bloomberg.com/news/articles/2023-04-06/tech-startup-funding-plunges-by-55-in-quarter-marked-by-crises?leadSource=uverify%20wall
[50] https://www.pwc.com/gx/en/services/sustainability/publications/overcoming-inertia-in-climate-tech-investing.html
[51] Gaddy, B.E., Sivaram, V., Jones, T., & Wayman, L. (2016). Venture Capital and Cleantech: The Wrong Model for Energy Innovation. Econometric Modeling: Corporate Finance & Governance eJournal.

not suit the typical approach of traditional VC investors.[52] "A lot of climate technologies have a heavy hardware or infrastructure component, which doesn't fit the VC model," says Ms Garaizar. "That's why it's important to diversify sources of funding."

Furthermore, many generalist VC firms tend to overstate the importance of 'tangible' indicators—such as intellectual property (IP)—when assessing a firm's suitability for investment. Evidence suggests that VC investors pursue a value-maximising strategy, prioritising firms that already have patented IP and whose innovation strategies are already developed.[53,54] "Typically, VCs like to see patents," notes Mr Halliday. "But the process of acquiring patents is hugely expensive and complex. Furthermore, while the number of patents is a simple metric for VCs to use, their quantity isn't always an accurate signifier of the promise of a firm or technology." This approach impedes investment in emerging climate tech firms, which often lack a significant track record, and thus hinders the development of the next generation of innovations. Concerningly, this is reflected in recent trends in early-stage climate tech funding, where the slowdown in VC activity is reported to have been particularly severe.[55]

The slowdown in VC investment underscores the need for a greater diversity in sources of funding for climate tech, including actors that can support the sector over the longer term. Such actors include government funding agencies, private equity and alternative pools of capital—pension funds, infrastructure funds and insurance companies, for example. To this end, the establishment of green investment banks may help to motivate institutional investors to finance low-carbon technologies by using public money to de-risk investments.[56] Similarly, the establishment of green infrastructure funds may prove a useful vehicle for pooling the resources of institutional investors to finance asset-heavy climate technologies, which VC firms may shy away from.[57]

[52] J. Eilperin, Wired Magazine, February (2012). https://www.wired.com/2012/01/ff_solyndra/
[53] Akcigit, U., Dinlersoz, E., Greenwood, J., and Penciakova, V. (2022). Synergizing ventures. Journal of Economic Dynamics and Control, 143:104
[54] Bottazzi, L. and Da Rin, M. (2002). Venture capital in Europe and the financing of innovative companies. Economic Policy, 17(34):229–270.
[55] https://www.pwc.com/gx/en/services/sustainability/publications/overcoming-inertia-in-climate-tech-investing.html
[56] https://www.oecd.org/environment/cc/Green-Investment-Banks-POLICY-PERSPECTIVES-web.pdf
[57] https://www.eib.org/en/press/all/2022-478-cop27-eif-supports-eur2-5-billion-of-climate-action-investment-with-five-venture-capital-private-equity-and-infrastructure-fund-partners

The role of government policy and regional trends

Governments can play a critical role in stimulating demand for emerging climate technologies, thereby bridging the funding gap that climate tech firms often encounter when industrialising their operations.

Policy action is essential to bridging the climate tech innovation gap. "I don't think there is a way of advancing cleantech innovation without strong policy intervention," says Mr Besnainou. "The market cannot solve it all". Mr Fry agrees, noting that the "government is critical to developing markets and jump-starting investment" in the sector. Governments can provide climate tech firms with financial support through grants, loans, and R&D tax credits and the like, but other policy levers—including innovative approaches to regulation and public procurement, alongside investment in skills and infrastructure—are also vital.

Regulation can be instrumental in facilitating the development of the climate tech sector. "There are some markets which are a lot easier for a climate tech firm to enter and navigate from a regulatory perspective," says Mr Fry. "But then there are others which can be really challenging." On this note, Mr Besnainou highlights the EU's recent proposals to "simplify regulations for permitting, standardisation and certification", which would help "projects in the EU get off the ground faster, thereby creating a significant competitive advantage" over other jurisdictions. Similarly, policy on education and skills development—as well as immigration—is vital to expanding the human capital necessary for climate tech R&D.

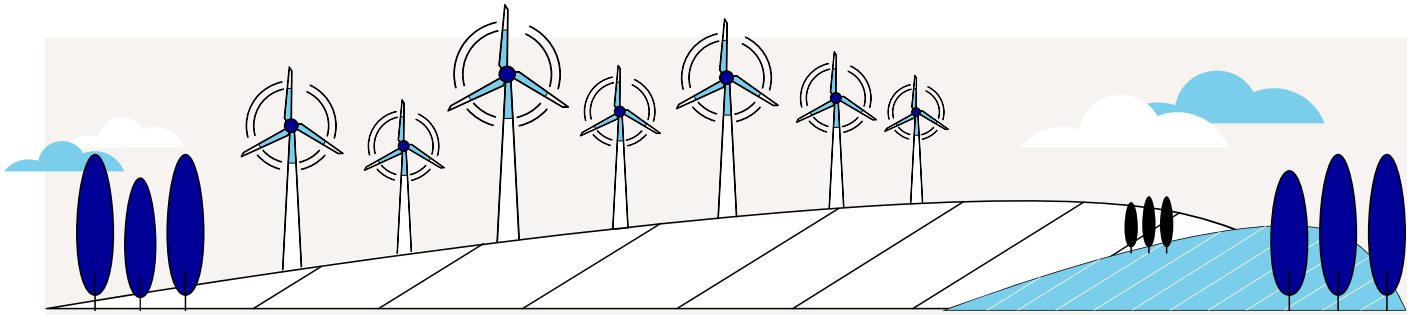
"The market cannot solve it all."

Sammy Fry, head of climate, Tech Nation

Infrastructure plays an important role in facilitating the widespread uptake of climate tech. "If you want to have electric vehicles by 2030, then you need the charging infrastructure that goes with that; if you want a fully decarbonised electricity system, you have to invest in grids," says Mr Besnainou. "There is always an infrastructure angle that must be conducted in parallel with the adoption of new technologies." To this end, Mr Ruijters points to the ambitious work that the EU has pioneered in driving forward the development of alternative fuels infrastructure across Europe, through its Alternative Fuels Infrastructure Facility (AFIF). This programme has brought together public and private money to fund the development of alternative fuels infrastructure, including electric fast-charging points and hydrogen refuelling stations.[58] "This is working very well," says

[58] https://www.eib.org/en/press/all/2021-339-europe-s-alternative-fuels-infrastructure-getting-a-boost-from-new-eib-and-european-commission-support

Mr Ruijters. "We have already had a rollout of hydrogen stations far beyond what is currently needed for the markets." As demonstrated by the AFIF, tapping into alternative sources of capital such as pension funds and development banks can drive forward the development of green infrastructure projects.[59] For instance, the Eiffel Transition Infrastructure Fund, sponsored by the European Investment Fund and managed by Eiffel, a Paris-based asset manager, has secured funding from several large institutional investors, including Allianz, to pioneer the provision of equity bridge financing for green infrastructure in Europe.[60]



The role of government policy in Estonia

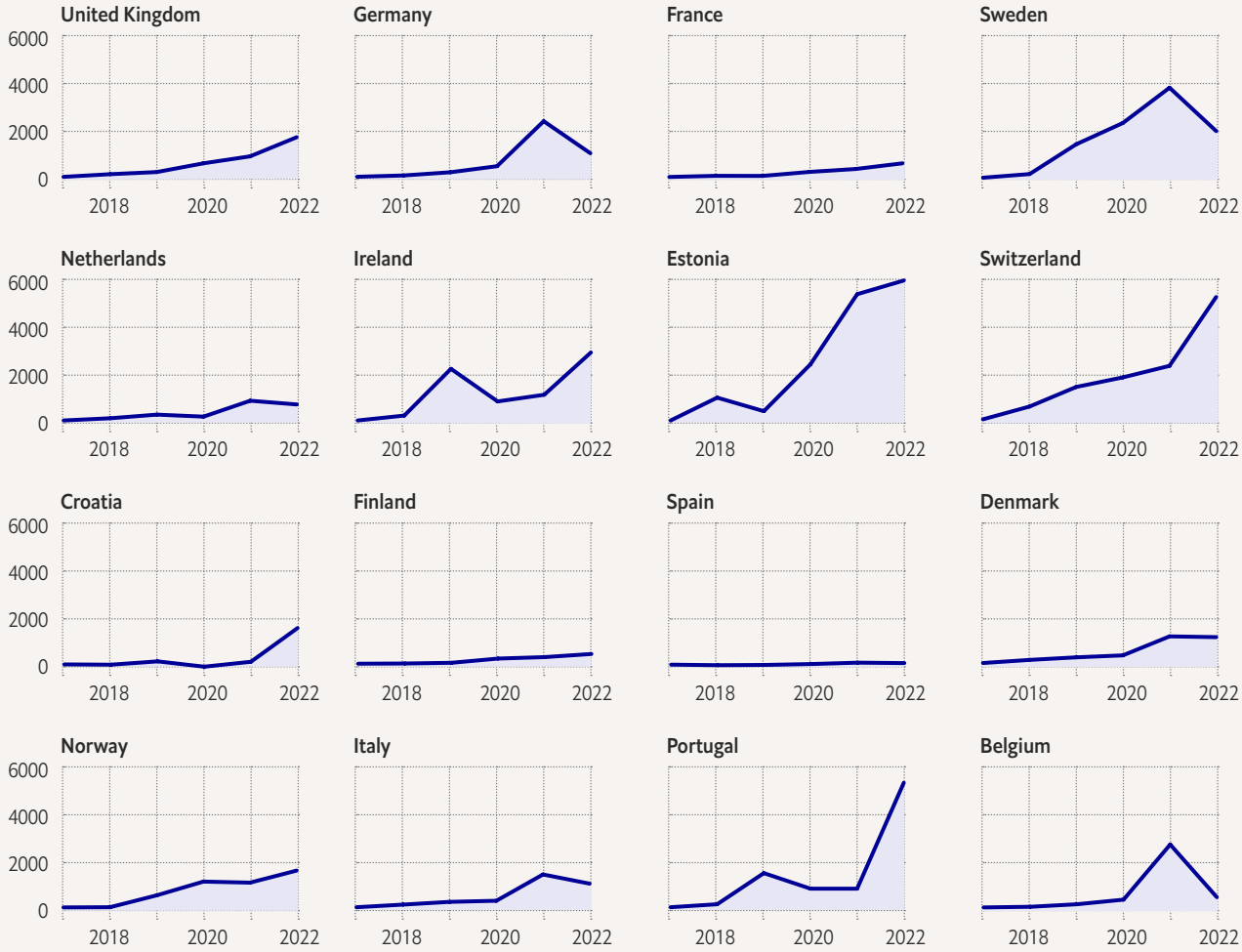
Estonia serves as a useful model to illustrate the impact of these policy levers. As shown in Figure 5, Estonia attracts high levels of investment to its climate tech sector for a country of its size—higher than Italy, Switzerland or Belgium. In fact, for the past four years, over 80% of all tech investment in Estonia has gone to climate tech firms—the highest proportion of any European country.[61] Burgeoning investment has nurtured the development of 224 climate tech firms in Estonia (in 2022), significantly more firms per million population (165) than the UK (78), Germany (44) or the U.S. (43).[62] Estonia's successes in this regard stem from a combination of policy interventions, including:

- Extensive public funding has been made available for climate tech R&D, including through the SmartCap Green Fund, Green ICT Fund, and grants from the Estonian Business and Innovation Agency.[63]
- The government has eased the burden of regulation to streamline and reduce the costs of establishing climate tech firms. For example, Estonia's e-Residency programme—the first of its kind—allows entrepreneurs to start a company in Estonia from anywhere in the world. Furthermore, Estonia's simple, transparent tax regime charges 0% income tax on retained and reinvested profits and covers double taxation treaties with over 60 countries.[64]
- The introduction of a bespoke startup visa has helped Estonia to nurture the human capital necessary for climate tech innovation, in spite of the country's small population.[65] In fact, 25% of startup founders in Estonia are foreign citizens.[66]
- Finally, the Estonian government has prioritised development of necessary infrastructure to enable the scaling and adoption of climate tech. For example, the country succeeded in completing the world's first nationwide electric-vehicle fast-charging network in 2012.[67]

[59] https://www.ey.com/en_gl/government-public-sector/six-ways-that-governments-can-drive-the-green-transition
[60] https://www.eif.org/what_we_do/equity/news/2022/eiffel-investment-group-and-the-european-investment-fund-backed-by-investeu-announce-innovative-equity-bridge-solution-to-support-renewable-energy-in-europe.htm
[61] https://technation.io/climate-tech-report-2022/#investment
[62] Source: Tech Nation, Net Zero Insights, 2022. Economist Impact Calculations
[63] https://estonia.ee/the-booming-estonian-cleantech-ecosystem/
[64] https://investinestonia.com/estonia-leads-europe-in-startups-unicorns-and-investments-per-capita/
[65] https://startupestonia.ee/blog/estonian-startup-visa-in-2022-success-amid-true-challenges
[66] https://investinestonia.com/estonia-leads-europe-in-startups-unicorns-and-investments-per-capita/
[67] https://investinestonia.com/estonia-to-become-a-top-greentech-developer-in-the-world/

Figure 5: Climate tech investment

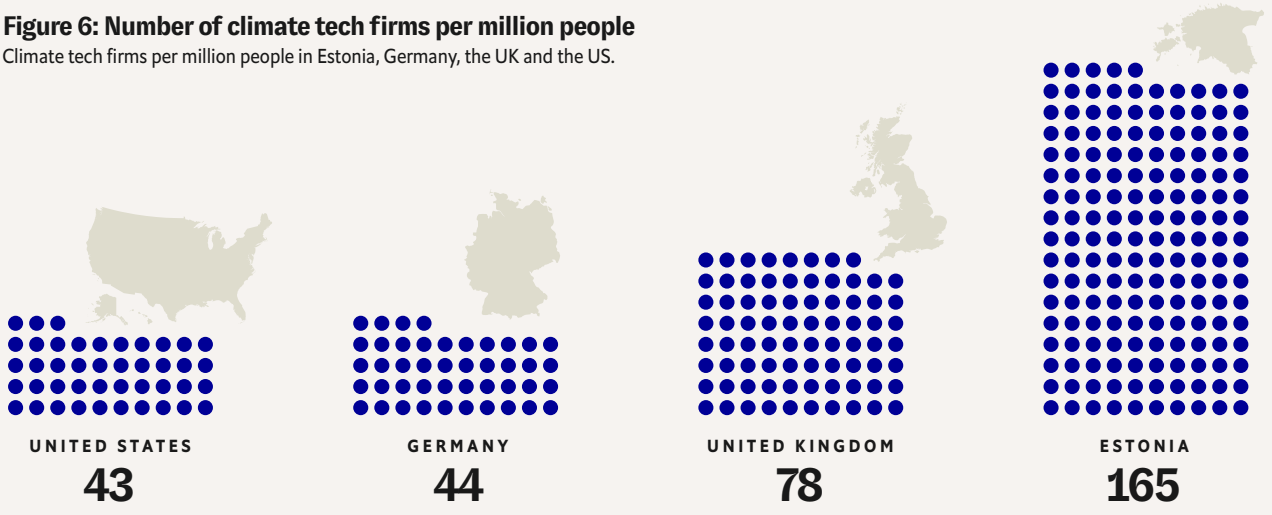
Change in investment in climate tech by country, 2017 to 2022. Investment levels are set at 100 units in 2017, to ensure comparability between countries.



Source: NetZero Insights

Figure 6: Number of climate tech firms per million people

Climate tech firms per million people in Estonia, Germany, the UK and the US.



Source: Tech Nation, NetZero Insights, 2022, Economist Impact Calculations

"Government policy is going to be really important in creating demand for new technologies."

Juliana Garaizar, chief development and investment officer, Greentown Labs

Government policy can stimulate demand for emerging climate technologies through, for example, carbon-pricing measures or mandating the phase-out of incumbent, polluting technologies. This can help climate tech firms to bridge the funding gap that they often encounter when industrialising their operations.

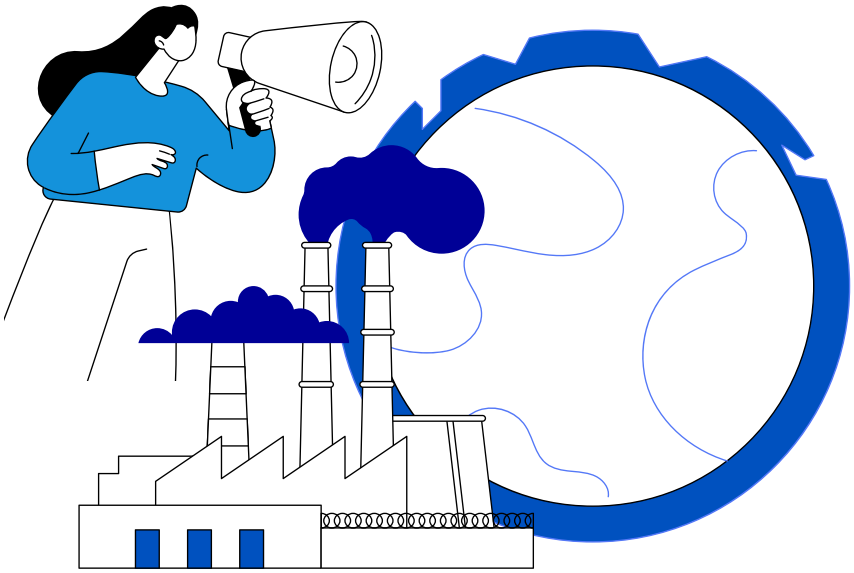
"Perhaps the most significant funding gap that cleantech firms face is after they've validated their technologies at a small scale," warns Mr Besnainou. "It arises when firms need to start building factories and industrialise." This is especially true in the EU where, as Mr Ruijters acknowledges, firms "do not seem to succeed in deployment and scaling up". This may in part be due to a relative paucity of large private investors who are able and willing to provide funds at the scale needed by growing firms. "Europe is great at developing and validating technologies, but we lack the public and private funders to finance the first few large-scale plants for capital-intensive technologies," says Mr Besnainou. It may also stem from a lack of clear financial incentives for investment in firms' industrialisation—meaning that, if a firm succeeds in building a plant, there is little assurance that there will be demand for its products.[68]

"Government policy is going to be really important in creating demand for new technologies," says Ms Garaizar. For example, government policy can stimulate such demand by establishing dates for the phase-out of polluting incumbent technologies. In the UK, for instance, the government has set 2030 as the end date for the sale of petrol and diesel cars.[69] In tandem with investment in charging infrastructure, this is intended to stimulate demand for EVs, catalysing further investment and innovation in EV tech.[70] Similar policy levers include introducing carbon pricing to improve the competitiveness of low-carbon technologies, as well as tailoring public procurement policy to create demand for climate-friendly technologies from government purchasers.[71,72]

[68] https://www.bcg.com/publications/2023/next-generation-climate-mitigation-technologies
[69] https://www.gov.uk/government/news/government-takes-historic-step-towards-net-zero-with-end-of-sale-of-new-petrol-and-diesel-cars-by-2030
[70] http://cied.ac.uk/files/file.php?name=3829-policy-briefing-05-print-phase-out.pdf&site=440#:~:text=By%20focusing%20policy%20attention%20on%20phasing%20out%20carbon-intensive,low-%20and%20zero-carbon%20technologies%2C%20business%20models%20and%20practices.
[71] Bertram, C., Luderer, G., Pietzcker, R. et al. Complementing carbon prices with technology policies to keep climate targets within reach. Nature Clim Change 5, 235–239 (2015).
[72] https://www.iisd.org/articles/deep-dive/advancing-green-public-procurement-and-low-carbon-procurement-europe-insights

A call to action

Not only is climate tech necessary to overcome and adapt to a changing climate; climate technologies also have the potential to create new jobs, support growth and accelerate broader technological advancement. However, as this paper has shown, there is still much progress to be made to realise climate tech's full potential.



Recent developments on either side of the Atlantic should bolster optimism. In the US, federal government spending on climate tech and clean energy is set to triple, driven by new legislation, such as the Inflation Reduction Act (2022) and the CHIPS and Science Act (2022).[73] For example, the Inflation Reduction Act introduces a significant uplift in tax credits for carbon capture and sequestration, which has the potential to transform the economic viability of carbon capture technologies.[74] In the EU, the Green Deal Industry Plan promises to simplify regulations for climate tech and speed up access to funding.[75] As part of the Plan, the European Commission has announced a target to ensure that manufacturing capacity for net-zero technologies within the EU will reach at least 40% of the Union's needs by 2030.[76]

These interventions present an unprecedented opportunity for actors across the climate tech ecosystem to accelerate progress towards bridging the climate tech innovation gap. Unless they are successful in these efforts, the Paris Agreement's critical targets may prove out of reach. In particular:

[73] https://www.weforum.org/agenda/2022/09/us-climate-change-tech-spending/
[74] https://www.jonesday.com/en/insights/2022/08/inflation-reduction-act-expands-carbon-capture-and-sequestration-tax-credit
[75] https://ec.europa.eu/commission/presscorner/detail/en/ip_23_510
[76] https://www.politico.eu/article/commission-releases-net-zero-industry-act/

- **Investors should tailor their climate tech investment strategies to maximise their impact on realising net-zero**. This includes diversifying and balancing their portfolios of climate tech investments in order to account for the complementary roles that different climate technologies will play in a future net-zero ecosystem, as well as variation in the risk profiles of investments and their timescales to maturity. Furthermore, generalist investors should consider participation in specialist VC or infrastructure funds, which are more likely to have the expertise necessary to support earlier stage, high-risk climate tech firms lacking tangible indicators such as IP.
- **Universities and policymakers should do more to ensure that early-stage R&D is translated into scalable technologies with real-world impact.** "There is a lot going on in universities, but no one really knows how to transfer it out of academia," notes Mr Halliday. In the UK and Europe, for example, effective tech transfer may require universities to reduce the high equity stakes that they typically assume in spinouts, which make it harder for firms to raise capital from other sources.[77] This would bring them in line with universities in the US, where equity stakes are typically lower.[78] Policymakers, meanwhile, have a role to play in providing academic institutions with sufficient funding, such that they rely less heavily on extracting money from promising spinouts.[79]
- **Policymakers should consider increasing public support for early-stage innovation in high-risk, high-reward areas—in particular, by adopting a mission-oriented approach to public investment.** Furthermore, in order to stimulate demand for climate technologies seeking to expand, governments could legislate for the phase-out of incumbent polluting technologies, introduce carbon taxes or mandate the public procurement of cleaner alternatives. In doing so, policymakers should be aware that, as climate tech scales—and new markets open up—a plethora of other technologies and inputs along the climate tech value chain will need to scale in tandem. This will require the strengthening of supply chains in sectors ranging from mining to minerals processing. Finally, policymakers should not lose sight of the benefits of maintaining open trade and a level playing field for climate tech across borders. Continued coordination and policy alignment will be crucial to safeguarding these benefits in an era of more muscular industrial policy worldwide.

[77] https://sifted.eu/articles/university-tech-transfer-overhaul
[78] https://www.ft.com/content/a2cb4877-c50e-4353-a697-cd5343eaae2d
[79] https://www.ft.com/content/fd038300-f09a-4afc-9f7d-c0e3d6965243

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