

March 2021

SCOTLANDIS CLIMATE TECH REPORT

Analysis and Assessment of Climate Tech Opportunity in Scotland



Executive Summary

ScotlandIS, in partnership with Scottish Enterprise, have created this report to analyse the current landscape of Climate Tech in Scotland, the economic value of Climate Tech, and the potential of this sector moving forward. In doing so, we have highlighted several exciting initiatives already taking place, demonstrating Scotland's level of ambition. In addition, we have created a Climate Tech Knowledge Hub, a resource portal showcasing Climate Tech activity in Scotland. You can view the portal on our website [here](#).

This Climate Tech Hub seeks to help position Scotland as one of the world's leading countries for activity related to Climate Tech. The aim is to be recognised internationally as a vehicle for communication, innovation, ideas, motivation, and partnerships. We have broken the hub down into areas of key focus which are case studies, opportunities, news stories, the support ecosystem, and Climate Tech events. This report focuses in on some of the key opportunities that Climate Tech can offer Scotland's future economy and workforce. It also aims to identify those areas of market demand and the potential investment pipeline for future climate technologies.

We have highlighted a range of case studies taking place across Scotland and we are grateful to those who have taken the time to be interviewed and provided insights into their ongoing work on Climate Tech.

Methodology

ScotlandIS conducted a broad range of research activity looking at the landscape of Climate Tech in Scotland currently, and the future potential of it as a lever of sustainable economic growth. This has included attendance at a range of seminars on Climate Tech with experts such as Committee for Climate Change in conversation with Chief Executive Chris Stark, the World Economic Forum, Connect with Climate Tech (University of Glasgow), Microsoft Sustainability Forum, AREG Climate Policy Special, and Scotland's Climate Assembly.

In addition, ScotlandIS conducted a number of one-to-one, focused interviews with leading experts in the Climate Tech domain, including experts in Finance, Forestry, Public Sector, Academia, Digital Technology, Waste Production, Renewables, and Vertical Farming.

Acknowledgements

We are grateful to expert contributions from the following organisations:

- ◇ The University of Edinburgh
- ◇ Topolytics
- ◇ PwC
- ◇ Ecometrica
- ◇ Reath
- ◇ Scottish Power
- ◇ Ongen
- ◇ BT Scotland
- ◇ SAOS
- ◇ Microsoft
- ◇ Wood Group plc
- ◇ Nature Scot
- ◇ Michelin Scotland Innovation Parc
- ◇ Integrated Environmental Solutions
- ◇ Climate Tech Capital Partners
- ◇ 2050 group
- ◇ Scottish National Investment Bank
- ◇ Intelligent Growth Solutions
- ◇ Space Intelligence
- ◇ Scottish Government

And with thanks to our partner, Scottish Enterprise.

Introduction

In the digital and tech ecosystem, one of the fastest growing sectors is known broadly as “Climate Tech”. Climate Tech encompasses many tech solutions as well as demand opportunities, focussed on tackling the challenge of decarbonising the global economy, with the aim of reaching net zero emissions before 2045 here in Scotland. When thinking about Climate Tech, we can draw similarities to the Clean Tech agenda. Climate Tech is a sufficiently broad term to incorporate a wide range of technologies and industries, but it also encapsulates the growing sense of urgency and youth movement around the “climate crisis.”¹ Climate Tech directly links the technological solutions to the urgency of climate crisis, which also creates a “mission” element behind some of the companies; this is perhaps the key differentiator to “Clean Tech”.

Climate Tech includes an array of technologies that operate across key sectors including electricity and energy, transport and mobility, agriculture, food systems, manufacturing and building technology. Underpinning these technologies is the digital technology, the know-how, the ability to optimise digital tech and data science to help deliver solutions that will address the impact of climate change. Stakeholders across all of these sectors and beyond are becoming increasingly aware of patient long term capital investment towards Climate Tech.

Analysis from the Stanford Social Review considers Climate Tech solutions to broadly fit into five main categories, which we also concur with. The table below illustrates these categories and highlights the stages of development each are at:

¹ <https://www.greenbiz.com/article/why-climate-tech-new-cleantech>

Climate Solution by Innovation Stage

SOLUTION CATEGORY	ENERGY SUPPLY	TRANSPORTATION	BUILDINGS	AGRICULTURE, FORESTRY, AND OTHER LAND USE	INDUSTRY
Commercially viable or near commercially viable solutions	<ul style="list-style-type: none"> ■ Silicon-based photovoltaics ■ Onshore wind power ■ Lithium-ion batteries for short duration (< 4 hour) storage ■ Power system optimization software solutions ■ Demand response and consumer engagement solutions ■ Ice-based thermal energy storage ■ Generation 3+ nuclear power 	<ul style="list-style-type: none"> ■ Light- and medium-duty electric vehicles ■ Sugarcane feedstock biofuels ■ Composite materials for vehicle lightweighting 	<ul style="list-style-type: none"> ■ LEDs ■ Residential cold climate heat pumps ■ Building automation and control technologies ■ Efficient window technologies and coatings 	<ul style="list-style-type: none"> ■ Advanced sensing solutions ■ Crop resource optimization technologies ■ Crop waste recycling ■ Forest management and reforestation ■ Anaerobic digestion ■ Biotechnology assisted animal breeding ■ Genetic modification of crops 	<ul style="list-style-type: none"> ■ Low-grade industrial heat production ■ Combined heat and power systems
Nascent solutions	<ul style="list-style-type: none"> ■ Carbon capture and sequestration ■ Generation 4 nuclear energy technologies ■ Fuel cell technologies ■ Long-duration energy storage solutions (> 4 hours) ■ High-efficiency, low-cost transmission ■ Offshore wind power ■ Next-generation photovoltaics 	<ul style="list-style-type: none"> ■ Low carbon hydrogen production and storage ■ Hybrid or electric heavy-duty vehicle drive trains ■ Algal or cellulosic biofuels ■ Fuel cell vehicles ■ Advanced combustion engines 	<ul style="list-style-type: none"> ■ Hyper-efficient building envelope technologies ■ Hyper-efficient refrigeration and freezing ■ Wide bandgap semiconductors ■ Transparent photovoltaic window coatings 	<ul style="list-style-type: none"> ■ Carbon-neutral fertilizer production processes ■ Livestock methane capture ■ Synthetic meat production ■ Vertical farming techniques ■ Genetic engineering for sustainable food production 	<ul style="list-style-type: none"> ■ Industrial process-integrated carbon capture ■ Low-carbon cement production ■ Low-carbon steel and aluminum production ■ High-efficiency industrial motors ■ Thermoelectrics, rectennas, and other waste heat recovery technologies
Unexplored solution spaces	<ul style="list-style-type: none"> ■ Biomass energy with carbon dioxide capture and storage ■ Fusion energy ■ Solar geoengineering 	<ul style="list-style-type: none"> ■ Next-generation transportation solutions (e.g. "hyperloops") ■ Third- and fourth-generation biofuels (solar fuels) 	<ul style="list-style-type: none"> ■ Space-based living and terraforming 	<ul style="list-style-type: none"> ■ Non-fuel-based ammonia production 	<ul style="list-style-type: none"> ■ Non-fossil petrochemical production ■ Carbon-negative cement ■ Space-based mining

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This table illustrates the difference between “commercially viable solutions” and those “unexplored solutions”. In later stages of the paper, we will explore existing Climate Tech models in Scotland and “future” Climate Tech models which require further commercialisation.

Initially, the economic case for Climate Tech appeared bleak in 2020 due to the coronavirus pandemic but this has not played out as expected. Instead, 2020 has been a ground-breaking year for Climate Tech. Solutions have come from a wide range of different sources such as agriculture, built environment, transport and industrial decarbonisation. Analysis from PwC highlights that Climate Tech investments have grown at five times the venture capital market rate over the

²https://primecoalition.org/wpcontent/uploads/2017/12/Winter_2018_the_investment_gap_that_threatens_the_planet.pdf?x48191

past seven years.³ We can expect this figure to continue growing as activity around Climate Tech accelerates in the lead up to landmark events such as COP26.

The Climate Tech sector has immense potential but there are challenges that still exist for it to truly become a pillar of our economy. The Climate Tech sector still has a relatively small pool of people to draw from. The sector is also complex in that it needs deep technical expertise from different domains, as well as commercial leaders who know how to get to market and commercialise the innovation and products in demand.⁴ Our research has confirmed that demand for Climate Tech is only going to accelerate. With global corporations, investors and governments pledging to transition to net zero, they are all looking to new climate technology breakthroughs to be developed and scalable. Moving forward, it will be crucial that the Climate Tech sub-sector engages with the wider digital and tech ecosystem to ensure a continued pipeline of green skills.

³ <https://moderndiplomacy.eu/2020/09/26/climate-tech-investment-grows-at-five-times-the-venture-capitalmarket-rate-over-seven-years/>

⁴ <https://moderndiplomacy.eu/2020/09/26/climate-tech-investment-grows-at-five-times-the-venture-capitalmarket-rate-over-seven-years/>

Existing Climate Tech Case Studies

Scotland has seen a period of sustained growth in Climate Tech over the last few years. The announcement of COP26 taking place in Glasgow provides Scotland with an opportunity to showcase the innovation and growth of Climate Tech on a global stage.

Below are a range of case studies from ScotlandIS members and key stakeholders who specialise in Climate Tech and have shared insights with us into the sector as it stands. It is important to note that there is a breadth of companies across all of Scotland which ensures Climate Tech is embedded across all regions in Scotland to create sustainable regional economic growth.

Energy

Energy is the dominant contributor to climate change, accounting for around 60–70% of total global greenhouse gas emissions. However, the design and efficacy of renewable energy technologies has evolved over the years. Solar, wind, and battery energy storage technologies have seen measurable success.⁵ In Scotland, we are well placed to facilitate collaboration between the energy sector and climate technologies. Energy has been a key success story for Scotland and we can seek to maximise renewable energy generation and make the necessary strides to build a hydrogen economy to create green jobs and ensure that climate technologies created in Scotland have exporting potential across the globe.

Energy as a whole cuts across most key sectors in the Scottish economy. In doing so, energy from the likes of industry, construction, and transportation, contributes to over 60% of global emissions.⁶

⁵ <https://www.itu.int/en/action/environment-and-climate-change/Documents/frontier-technologies-to-protect-the-environment-and-tackle-climate-change.pdf>

⁶ <https://mittrinsights.s3.amazonaws.com/GFI/Report2021.pdf>

The “Scottish energy statistics hub” regularly reports up-to-date Scottish energy data which tracks progress towards the future of energy production and consumption, according to the goals set out within the Scottish energy strategy. The graph in Figure 1 shows that 89.5% of gross electricity consumption in 2019 derived from renewable sources. The target was to meet 100% of electricity demand in Scotland via renewable sources in 2020. Longannet closed in 2016, and the only remaining coal-fire power station is at Peterhead in Aberdeenshire. Figure 1 illustrates the robust increase in electricity consumption through renewable sources and in terms of resource power that wind is readily available.⁷

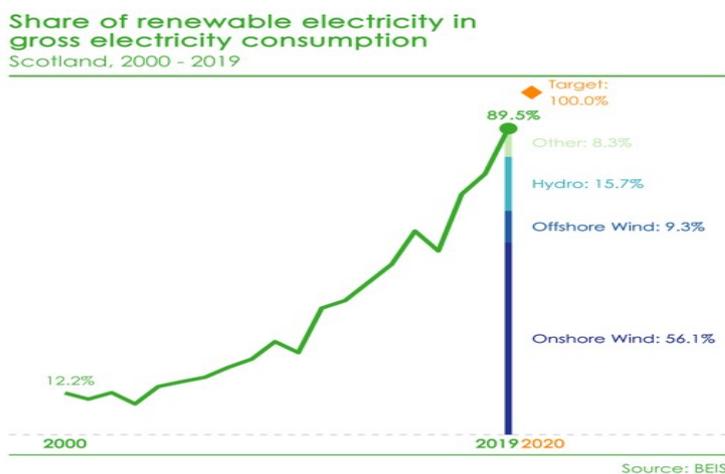


Figure 1.

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Scottish renewables software developer ENIAN is in the midst of developing a new cost-predicting algorithm. The software (according to ENIAN) will help to deliver the best commercially viable innovative or disruptive ideas to accelerate the uptake of green energy. ENIAN will collaborate with the University of Edinburgh’s School of Engineering and The Data Lab over 19 months to develop and test the cost-of-

⁷ <https://scotland.shinyapps.io/sg-energy/>

⁸ <https://scotland.shinyapps.io/sg-energy/>

interconnection prediction algorithm (CIPA), with the aim to digitise, automate and enhance the way that project planners estimate the cost of connecting a new power plant to the nearest available grid. The project began in December and will run until May 2022.⁹

Currently grid connection costs are some of the most difficult to predict but make up a significant share of the total costs for generating new power. As the need for the grid to adopt more renewable energy sources increases, so too does the requirement for rapid, data-driven estimates to give project managers certainty. This type of Climate Tech is vital for increasing productivity and efficiency as we transition towards greener energies.

Aberdeen-headquartered Wood Group plc have created a piece of Climate Tech to assist with the energy transition in Scotland. Wood's ENVision platform provides governance and insight around emissions and carbon releases by streamlining and automating diverse data sets to provide a clear, auditable and accurate view of emissions from any asset, organisation or city. Through providing a clear process for manual data provision, or connected systems data collation, ENVision automates environmental reporting and, with Microsoft Azure, unlocks the value of data for an asset or portfolio of assets.

ENVision has the ability to focus directly on the IoT and sensor-driven real-time emissions monitoring. It provides a complete view of emissions by integrating with varied systems. ENVision reduces manual tasks associated with data collation and reporting by 80%, with clear auditability, and notifies an operator of an issue over ten times faster than traditional methods and spreadsheets. ENVision enables transparency and confidence to all stakeholders in the journey to achieving emissions and net zero targets.¹⁰

⁹ <https://enian.co/products/energy-search/>

¹⁰ <https://www.woodplc.com/energy-transition>

Recently, COP26 strategic partner, Scottish Power, unveiled its 10-point plan to help deliver clean and sustainable economic growth across some key strategic areas and priorities. 100,000 jobs could be created in the green economy each year until the middle of the decade, at which point the speed will pick up even more, providing we invest correctly in the green economy.

The key areas of focus for Scottish Power are renewable energy, electric vehicles (EVs), low carbon homes, and energy networks.¹¹ Such commitments from a COP26 partner such as Scottish Power are welcome as such strong levels of commitments demonstrate “corporate leadership”, which is a key component of our journey towards net zero here in Scotland.

ScotlandIS member PwC has also committed to reducing its total greenhouse gas emissions by 50% in absolute terms by 2030. This includes a switch to 100% renewable electricity in all territories, as well as energy efficiency improvements in their offices and halving the emissions associated with business travel and accommodation within a decade. PwC will also invest in carbon removal projects, including natural climate solutions. For every remaining tonne (CO₂ equivalent) that it emits, PwC will remove a tonne of carbon dioxide from the atmosphere to achieve net zero climate impact by 2030.¹² PwC have been globally leading in their thought leadership work on Climate Tech and will continue to be a key part of the research and policy landscape leading up to COP26.

On the Island of Orkney, there have been some cutting-edge developments for energy storage utilising AI and Climate Tech. Funded by Innovate UK and the Sustainable Innovation Fund, the HyAI (Hydrogen Artificial Intelligence) project is a pilot demonstration of AI software-controlled hydrogen storage technology. HyAI will

¹¹ https://www.scottishpower.com/news/pages/unlocking_net_zero.aspx

¹² <https://www.pwc.com/gx/en/about/net-zero.html>

show how software integrated with hydrogen hardware can make intelligent, data-driven asset management decisions in real-time, and optimise renewable energy integration into the UK electricity grid.

Trialling the system using energy data supplied by EMEC from its Hydrogen Production Plant in Orkney, the AI platform acts as an energy management system, integrating data about weather, electricity prices and grid management. It then translates this information using AI predictive algorithms to optimise the operation of the storage systems by predicting future power cost and user demands. Initial results have indicated that the AI-enabled approach can produce hydrogen in a more cost-effective way, while also helping to alleviate stresses on the national grid. This has the potential to increase power reliability, allow for higher penetrations of renewable energy, and accelerate the shift to a net zero emission economy. This exciting collaboration will pilot the first energy storage unit that stores renewable energy on demand as an unpressurised solid-state-hydrogen, coupled with the AI software platform.¹³

Scotland's advanced capabilities in hydrogen opens opportunities in the production/supply of hydrogen and its supply chain, including refuelling infrastructure, operation and maintenance, hydrogen safety, and flow rate metering. Aberdeen Hydrogen Hub aims to develop a commercial supply of green hydrogen, while Scotland's flagship blue hydrogen project, ACORN, will produce hydrogen from natural gas at St Fergus Gas Terminal whilst capturing the CO₂ and transporting it for storage in the North Sea.

Reducing energy costs and carbon footprint should assess the potential of generating energy at the very place it is consumed. Volatile energy prices, tight supply margins, grid constraints and environmental legislation have all contributed to a focus on energy consumption. Scotland's energy journey has been accelerated

¹³ <https://www.theengineer.co.uk/h2go-power-and-emec-trial-ai-hydrogen-technology/>

with the utilisation of cutting-edge climate technologies, but there remains work to do.

Built Environment

The Built Environment is perhaps one of the most cross-cutting themes in our society when we think about climate change. Where we live and our housing can have a huge impact on the environment. Construction emissions generated in the UK alone could be cut by 40 percent by 2025 through better design, more intensive building use and by reusing building resources, enabled by digital technology. Smart solutions will accelerate progress to retrofit existing homes and to upgrade vacant buildings, which will benefit areas with high demand for new housing.¹⁴ Emissions from heating all buildings across Scotland need to reach zero by 2045 and demand for heat in buildings must be significantly reduced, with poor energy efficiency removed as a driver of fuel poverty. Currently, heat in buildings accounts for 20% of Scotland's greenhouse gas emissions.¹⁵

Scotland's tech start-up community are becoming more immersed in the Climate Tech domain. One of the leading Climate Tech start-ups is Reath. Edinburgh-based Reath focus on building the digital infrastructure for circular systems. Reath enable businesses to adopt safe, compliant, scalable reuse systems; reusing items that have typically been single-use and sent to landfill. The skills which are vital to the ongoing growth of Reath are data analysis, data modelling, database architecture, technology architecture, software development, service design and understanding of the potential of digital products and technologies in the circular economy. There

¹⁴ https://www.green-alliance.org.uk/smart_building.php

¹⁵ <https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan20182032/pages/8/>

are a lot of barriers getting in the way of companies shifting away from single-use; our society's laws, and our business' systems are built for single use. The Reath software enables safe reuse of items, as well as collecting data that can be used to optimise circular systems, further improving their carbon footprint, and increasing the amount of waste diverted from landfill.

Scottish SME OnGen have a clear mission to reduce an organisation's total cost of energy consumption, provide greater security of supply, and help reduce their carbon footprint. By assessing solar capability using the OnGen Expert software, they have been able to identify 4,000 tonnes of potential carbon savings in the University of Edinburgh's city building stock. OnGen have saved potential energy cost savings of £2.9 million across the lifetime of potential onsite renewable installations and, as a result of this work, the University have secured funding for an initial £4m investment in solar panels on their estate in Edinburgh. The OnGen Expert system was a key piece of climate technology for the University to determine viable renewable energy strategies, on buildings across an incredibly complex estate.¹⁶

The built environment accounts for a significant proportion of current energy use and carbon emissions globally. Improving the performance of, not only new buildings, but also our current building stock, will be key if ambitious decarbonisation targets – such as the Scottish Government's aim to create a net zero society by 2045 – are to be met. It is against this backdrop that Glasgow-based Integrated Environmental Solutions (IES) have been helping to create a Digital Twin of one of Scotland's most iconic buildings. The project ultimately aims to increase understanding of building energy performance and the associated carbon footprint.

IES and the client have been utilising the Digital Twin model to assess updates to their lighting design and now, following implementation, are using the model to

¹⁶ <https://ongen.co.uk/>

validate that the savings are as anticipated, with positive results. The Digital Twin therefore provides an invaluable asset for the client on an ongoing basis.

IES intend to continue hosting the model, and through the continuous integration of live data via iSCAN, it will be possible to continually monitor performance and test the impact of further design and operational changes as time goes on. This project is a rare example of the type of modelling that should be undertaken to facilitate truly informed decisions when it comes to our buildings. The project exemplifies tools and modelling processes which can be adopted by any building to help identify and eliminate inefficiencies to significantly reduce energy, carbon and cost impacts.¹⁷

Land Use

One of the most important components of our climate change journey is around our relationship with land use, agriculture, forestry, and food production. Thinking more creatively about food production can decrease our emissions and cut down on our food waste. According to the Food and Agriculture Organization (FAO) of the United Nations, if food waste were a country, it would be the third highest emitter of greenhouse gases after the US and China, and a bigger threat to our environment than plastic waste.¹⁸

Artificial Intelligence has a critical role to play in our land use journey. AI has the potential to monitor crop yields, reduce the need for chemicals and excess water through precision agriculture, and minimise food waste through forecasting demand and identifying spoiled produce. Natural Resource Management can also

¹⁷ <https://www.iesve.com/icl/case-studies/10123/government-building-digital-twin>

¹⁸ <https://www.energyvoice.com/opinion/294475/theres-more-to-cop26-than-co%E2%82%82/>

be improved when local knowledge is combined with geospatial space technologies in conjunction with AI.

Whilst the potential for AI in agriculture and land use is immense, there are challenges that exist for the adoption of it. Constraints within the agricultural sector have prevented wide-scale implementation of technology, ranging from educational/skill gaps, limited intra-industry sharing of best practices, disconnect between innovation strategy and funding, slow deployment of 5G, and the available budget of UK farmers.¹⁹

The Department for Environment, Food and Rural Affairs (Defra), are working with the ISCF Transforming Food Production programme, part of UK Research and Innovation (UKRI), to boost investment in the agricultural sector. They have announced a £12 million competition for feasibility studies and research projects that focus on the development of innovative farm-focused technologies, systems or approaches to help improve food productivity, as well as increasing resilience and sustainability in line with net zero ambitions.²⁰

One of the key growth areas when we look at farming and agriculture has been the emergence of vertical farming. Vertical farms can settle anywhere, independent of climate conditions. Vertical farming has the added benefit of being able to focus on localism of supply chains and consumers. Its local production and harvesting of crops greatly reduce the amount of 'food miles', which positively impacts travel costs and our carbon footprint. In Dundee, Intelligent Growth Solutions takes innovation in food production and Climate Tech a stage further, with platforms that deliver ideal climates for growing food plants indoors. Vertical farming has the potential to not only reduce our emissions in farming and agriculture, but it also has the ability to create sustainable and economically

¹⁹https://www.barclays.co.uk/content/dam/documents/business/businessinsight/Insights_AI_in_Agriculture.pdf

²⁰ <https://apply-for-innovation-funding.service.gov.uk/competition/852/overview>

viable jobs in the farming and agricultural sector. Data collection, analysis and automatic control of the installed devices within the structures are some of the important criteria to prove the worth of vertical farming.²¹

The Scottish Agriculture Organisation Society (SAOS) have created and developed a platform named CarbonPositive. With support and funding from the Scottish Government, the initiative has gathered data on a range of activity areas including soils, woodland, water, and renewable energy, to record and convey the positive contribution of Scottish farms and crofts in capturing carbon and mitigating climate change. Together with the James Hutton Institute and Forest Research, they are gathering data on carbon sequestration to get a picture at a national and individual farm level of the carbon that is stored and being managed on-farm.²² The data will ensure there is the opportunity to evaluate both agricultural emissions and sequestration when it comes to UK greenhouse gas inventories, which inform Scotland and the UK's binding net zero carbon emission targets. Moving forward, this type of work and analysis will help to foster a closer relationship between farming, agriculture and Climate Tech.

ScotlandIS member Topolytics are leading the way in Climate Tech and the relationship with waste. They are aggregating and analysing data at scale to make the world's waste visible, verifiable and valuable. They do this in order to dramatically reduce the material going into waste dumps or leaking into the environment on a global basis. They are starting to scale the business, deploying analytics platforms with organisations across the 'downstream materials' system - waste producers, recyclers and governments.

To manage, process, clean, analyse and visualise a growing volume and velocity of data, Topolytics are building the team across a range of skills and experiences which

²¹ <https://www.intelligentgrowthsolutions.com>

²² <https://saos.coop/what-we-do/carbonpositive>

primarily focus on software development, data science, big data analytics, data modelling, product, waste industry/business, and waste regulation. It is their firm view that digital technologies, tools and experience will underpin humankind's ability to tackle the world's biggest environmental and social challenges, while balancing the potential side effects and negative consequences.²³ Topolytics have seen an increasing demand for their software across the globe and particularly in South East Asia in the last year. The exporting potential and commercialisation of Climate Tech is being showcased admirably by leading players such as Topolytics.

Forestry and earth observation are both critical components of our journey to net zero in Scotland. The Scottish Earth Observation Service (SEOS) is an initiative led by ScotlandIS member Ecometrica to advance applications of Earth Observation (EO) in Scotland; increasing the consistency, continuity, extent and usefulness of geospatial content through the provision of services that address environment and land management challenges faced by a number of Scottish public and private organisations.

SEOS works in partnership with other geospatial service providers to provide a one-stop service for monitoring land assets via the Ecometrica platform. Working with GSi and Carbomap, Ecometrica will collect high resolution LiDAR data and use innovative machine learning techniques to combine with Sentinel 1 and 2 satellite data to generate improved information streams for forestry and vegetation conditions in Scotland. They will be working with commercial forestry companies and land agents to develop due diligence reports with basic forestry metrics to reduce the cost of manual surveys before purchasing new land assets. Ecometrica will also be working with NGOs like the Woodland Trust to develop tools to help monitor native woodland conservation efforts.

²³ www.topolytics.com

Nature-based solutions and sustainable forestry will be a key component to meet Scotland's ambitious net zero targets, with large, well-known brands such as BrewDog leading the way in the private sector. Tools to monitor the impact of these interventions and identify suitable areas for future regeneration will be an important part of the solution going forward.

NatureScot has been working in partnership with Space Intelligence on a Can Do Innovation Fund Challenge – “AI for Good – How can we use Artificial Intelligence (AI) techniques to tackle the climate emergency?” NatureScot and Space Intelligence are working together to develop a complete and repeatable map of habitats and land use in Scotland to improve how they calculate Scotland's natural capital – one of the indicators in the Scottish Government's National Performance Framework. Natural capital is a term for the habitats and ecosystems that provide social, environmental and economic benefits including the ability of habitats to store and even absorb carbon.

NatureScot did not previously have a national up-to-date map of habitats and land use, and this lack of data affected the accuracy and usefulness of the calculations that we could make. Space Intelligence have used satellite data and AI to create a map for the whole of Scotland that can be repeated, helping us to identify and measure change. This promises to be a game changer in the way that we calculate natural capital and approach land management.

Overall, land use and management are increasingly important in our efforts to reach net zero. From 2022, when wetlands join the national greenhouse gas inventory, around 30% of emissions will be concerned with the use of the land. Having ongoing data intelligence will allow for us to assess changes in natural capital, understand land use in Scotland, and help to take the necessary actions to achieve net zero. Having such data can help to take action on nature-based solutions, like restoring our peatlands, woodlands, hedges and species-rich grasslands. It will also help to

achieve net zero natural resource management on land. This means working with the likes of agriculture, farming, forestry, development, and tourism to reduce emissions. In doing so, Climate Technologies can help to enhance decision-making on how we can best use and manage land to deliver multiple benefits to nature and to people across Scotland.

Transportation

Transport is a leading player in the quest for Scotland to become net zero in greenhouse gas emissions. The greater demand for transport services combined with an increase in population size means that the transportation sector is the only area with an upward trend of CO₂ emissions. While there may be a number of options for reducing carbon emissions in the transportation sector by increasing fuel efficiency, ultimately the sector faces the challenge of shifting away from fossil fuels as a direct energy source. Identifying potential technological pathways for change within the transport sector is therefore pivotal.

Green Alliance's tech task force has produced a "smarter transport report". They believe that although the UK is one of the largest EV manufacturers in Europe, we are lagging behind other countries in switching to EVs and integrated transport. Smart charging is needed to prevent an increased burden on local power networks. Vehicle to grid (V2G) charging, whereby electricity flows both to and from EVs to support the grid, could save the energy system up to £270 million by 2030 in avoided network upgrades and lower peak energy demand.²⁴

In the North-East of Scotland, there are a range of exciting low-carbon transport initiatives taking place. Aberdeen is at the forefront of several exciting hydrogen projects, with the largest fleet of hydrogen buses in Europe. Dundee is home to the

²⁴ https://www.green-alliance.org.uk/smarter_transport.php

UK's largest electric taxi fleet. Dundee is also named the 'Most electric vehicle-friendly city in the UK' by The World Electric Vehicle Association, for its initiatives encouraging the use of electric vehicles (EVs).

Aberdeen-based Trojan Energy recently secured £4m of funding to support an on-street system that is set to make electric vehicle charging more accessible. Trojan says this will make it easier for the estimated 10 million people in the UK who don't have off-street parking to own an EV.²⁵ McGill's buses have recently invested £17.5m into all-electric buses, ordering thirteen from Falkirk bus building company Alexander Dennis. McGill's will also install new electrical charging infrastructure for its depots in Johnstone and Dundee. This latest investment brings the total capital put into the firm since 2014 to more than £50m – around £40m of which has been spent on new vehicles, demonstrating the ongoing shift towards electric and hydrogen powered transport.²⁶

Hydrogen certainly provides new possibilities as a long-term fuel source but will also require significant development, including the increased availability of fuel sources, fuel cells, and related infrastructure. In addition to buses, hydrogen research is being carried out using a number of vehicles (cars and emergency vehicles). In the long-term, hydrogen could provide new possibilities for serving the growing energy needs of the world through a wide diversity of energy sources that do not directly impact the environment.

A new hydrogen accelerator is set to be established at the University of St Andrews. The expertise at the University and partnership with other institutions, centres and initiatives (Michelin Scotland Innovation Parc) across Scotland will drive innovation within hydrogen technology, which will support its application in the transport sector

²⁵ <https://chargedevs.com/newswire/trojan-energy-scores-4-1-million-in-funding-for-on-street-charging-solution/>

²⁶ <http://www.mcgillsbuses.co.uk/>

(phasing out new petrol and diesel cars and vans by 2032) and government's larger net zero target by 2045.²⁷ Scotland could soon see its first hydrogen-powered train created by a consortium of engineering and technology firms in 2021 debut at COP26. The project leaders, Arcola Energy, will be responsible for the hydrogen fuel cell system engineering, design and integration, as well as the project demonstration. The project will form the basis of future opportunities in climate technologies towards transport.²⁸

One of Scotland's leading strengths in our journey towards net zero is our journey towards MaaS. Fundamentally, Mobility as a Service (MaaS) is the integration of various transport modes into a single mobility service. It provides the user with easy, digital access to all available transport options in a particular area, allowing them to make informed decisions as to how they wish to travel.

It is well understood that single occupancy private car use is a significant contributor to overall CO₂ emissions from the transport sector. While electrification of our car fleet is a crucial step towards reducing this impact, it must be acknowledged that no vehicle is truly zero emission. Moreover, a society dependent on the car is an inherently unequal one, with nearly a third of Scots unable to access a car and many more forced into expensive car ownership through lack of choice. It is clear that a simple replacement of the combustion engine for an electric battery or hydrogen fuel cell cannot be the complete solution. We must reduce the number of vehicles on our roads and that means supporting a modal shift from private car use to shared transport. MaaS has a crucial role to play in this, providing a platform that can not only address some of the acknowledged barriers to shared transport use but also incentivise people to reduce private car use and make greener transport choices.

MaaS is a concept based on the integration and presentation of data from multiple different sources and providers. Scotland's recognised strengths in data analytics

²⁷ <https://www.transport.gov.scot/news/new-accelerator-established-to-drive-hydrogen-innovation/>

²⁸ <https://www.theengineer.co.uk/scottish-hydrogen-train-debut-glasgow-cop26/>

and informatics, coupled with its activities in the areas of smart cities and sustainable transport, leave it in a strong position to develop world-leading MaaS solutions. Scotland also boasts strong representation from across the wider MaaS supply chain, including data visualisation and platform development, smart ticketing solutions, and user-centric app development. In addition, the implementation of MaaS in Scotland is being led by a number of public sector bodies, including local authorities, regional transport partnerships, and Transport Scotland. This community, and the delivery of MaaS in Scotland more generally, is supported by MaaS Scotland, a network of over 75 public and private sector organisations who have a shared vision to develop and deploy MaaS solutions in Scotland.

Scotland has positioned itself as one of the global leads for MaaS development. In 2019, the Scottish Government announced the creation of the MaaS Investment Fund to support MaaS projects across the length and breadth of Scotland. This fund, coordinated through Transport Scotland, is supporting 3 initial projects with an additional 2-4 projects expected to be announced in spring 2021. This makes Scotland one of the few countries in the world to have a national, Government-sponsored programme exploring the demonstration and implementation of MaaS.

Value of New Climate Tech

As a rapidly emerging area of opportunity, at this stage Climate Tech should not be viewed as exclusive to the theme areas highlighted earlier in this report. Digital Water, Sustainable Cities, Industrial Decarbonisation, Carbon Removal, Circular Economy and much more present future demand and solution opportunities for the digital community.

The potential growth of Climate Tech is immense, and organisations across the globe are beginning to invest heavily in Climate Tech initiatives and products to ensure they are future-proofing their business moving towards a green economy. 2020 saw ScotlandIS members Microsoft and Amazon drive forward with their investment ambitions around the Climate Tech agenda.

In January 2020, Microsoft announced a bold new environmental sustainability strategy focusing on carbon, water, waste, and ecosystems. As part of that commitment, they are investing \$1 billion over the next four years in new technologies and innovative sustainability solutions focusing on Climate Tech. Some key areas of focus they are particularly interested in are direct carbon removal, digital optimisation, advanced energy systems, industrial materials, circular economy, water technologies, sustainable agriculture, and business strategies for nature-based markets.²⁹

Amazon has also led the way as they shift focus towards new Climate Technology-led investment. Amazon has created a Climate Pledge Fund, kickstarted by their own \$2 billion in funding, which will support the development of sustainable technologies and services that will enable Amazon and other companies to be net zero carbon by 2040. The fund will invest in a range of industries, including transportation and

²⁹ <https://www.microsoft.com/en-us/corporate-responsibility/sustainability/climate-innovation-fund>

logistics, energy generation, storage and utilization, manufacturing and materials, and food and agriculture.³⁰

On the world stage, there is a growing recognition of the role climate technologies have to play in delivering net zero targets and sustainable economic growth. Renowned American actor, Robert Downey Jr, is leading the Footprint Coalition, an investment fund that will try to spot fast-growing green technology businesses. The fund will invest money in sustainably focused companies, create educational content around the environment, and make charitable donations to non-profit organisations. The funds will focus on six key investment areas: sustainable consumer products and services; food and agriculture technology; materials and industrial technology; energy and transportation; education and media; and advanced environmental solutions. Interestingly, some of the venture funds will invest in early-stage technologies while the others will focus on late-stage investments.³¹

One of Scotland's natural assets that is a key player towards clean transport is hydrogen. In January 2021, H2 Green and SGN Commercial Services announced that together they will explore the potential of regenerating sites across Scotland and the south of England to create green hydrogen hubs. These hubs would facilitate green hydrogen generation, storage and retail, providing access to a cleaner and greener alternative to diesel for buses and HGVs. H2 Green's approach has the potential to reduce hydrogen costs by more than 20%.

H2 Green is working with infrastructure and technology companies, vehicle manufacturers and energy providers, to build a reliable hydrogen refuelling network, backed by large-scale storage. Its collaborative approach is centred around a

³⁰ <https://www.aboutamazon.com/news/sustainability/amazon-launches-a-2-billion-climate-pledge-fund>

³¹ <https://www.ecowatch.com/robert-downey-jr-sustainable-funds2650324787.html?rebelltitem=5#rebelltitem5>

simple mission: to provide the customer with low-cost hydrogen and security of supply to enable their Net Zero transition.³²

³² <https://www.h2green.co.uk/post/h2-green-and-sgn-commercial-services-agreement>

Support Ecosystem

The UK and Scotland are both well placed to facilitate emerging Climate Tech into the digital and tech ecosystem. Analysis from Tech Nation demonstrates that Scotland closely follows the desired 50:30:20 ratio for growth and scale-up opportunity with Glasgow (52:28:20) exhibiting the desirable ratio. However, Aberdeen’s Scale Ratio (39:29:23) indicates it has a less developed seed stage pipeline to drive sustained growth. The Scale Ratios of Edinburgh (56:27:23) and Dundee (54:26:20) indicate they have high growth potential, with high proportions of seed stage companies.³³

Whilst the tech ecosystem looks promising for Scotland, it is worthwhile looking at the broader net zero commitments and how the tech ecosystem plays its part in driving towards our climate targets. According to the MIT Green Future Index, the UK is currently ranked 17th in the world for countries making the greatest progress towards a net zero society. Below are the top 20 countries across the globe making the greatest strides towards net zero.

Figure 2: The Green Future Index country rankings

The Green Leaders	The 20 countries making the greatest progress and commitment toward building a low carbon future.								
	1	Iceland	6.45	8	New Zealand	5.71	15	Austria	5.47
	2	Denmark	6.44	9	Belgium	5.63	16	Singapore	5.45
	3	Norway	6.20	10	Netherlands	5.62	17	United Kingdom	5.44
	4	France	5.98	11	Germany	5.55	18	Spain	5.42
	5	Ireland	5.95	12	Sweden	5.54	19	Switzerland	5.40
	6	Finland	5.90	13	Luxembourg	5.50	20	Uruguay	5.38
	7	Costa Rica	5.78	14	Canada	5.48			

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³³ <https://technation.io/scale-ratio/>

³⁴ <https://mittrinsights.s3.amazonaws.com/GFI/Report2021.pdf>

Whilst it is pleasing that the UK is ranked in this top 20, there remains work to accelerate the progress already made, and our Climate Tech community can ensure that we realise our ambitions.

The Climate Tech ecosystem spans across the digital and tech sector as a whole and enjoys close relationships with other emerging tech trends. Perhaps the most obvious parallel can be drawn to Scotland's space sector. It is estimated from a Scottish Enterprise study that Scotland's space sector income could reach over £2 billion by 2030, as well as contributing data solutions to combat climate change.³⁵

The Climate Tech sector will naturally begin to foster an even closer relationship with the data ecosystem. Data Driven Innovation (DDI) is a cornerstone of Scotland's tech ecosystem and is well supported by cutting-edge innovation centres including The Bayes Centre, The Data Lab and CENSIS. Scotland's network of innovation and centres of excellence aim to enhance innovation and entrepreneurship across Scotland's key economic sectors, create jobs, and grow the economy. Innovation Centres have backing from industry and draw on all of Scotland's research expertise in the relevant sector to work on problems and opportunities identified by industry.³⁶

In Scotland we are well placed to support the Climate Tech ecosystem through innovation hubs. Dundee's Michelin Scotland Innovation Parc is a world leading innovation parc focused on sustainable mobility and low carbon energy. The Innovation Parc will be home to a rich variety of activity, alongside companies, academia and skilled people to address key global challenges such as climate change and climate tech innovation. A critical component of MSIP which will help to facilitate the ongoing prosperity of the Climate Tech ecosystem is that there are opportunities to pitch to potential venture investors and potential customers or channels to bring the technologies to commercialisation and market.

³⁵ <https://digit.fyi/scotlands-space-ambitions-grow-as-glasgow-satellite-firm-signs-skyark-deal/>

³⁶ <https://www.ecosystem.scot/>

Climate Tech organisations will require access to talent in the same manner as the wider digital and tech sector. The plans for the MSIP Skills Academy are most welcome and will have the capability to train, develop and transform individuals into the green workforce of the future.³⁷

The recent Scottish Government announcement of a Green Jobs Workforce Academy will also provide an extra layer of support to the growing Climate Tech sector. The Green Jobs Workforce Academy will focus on new, good, and green jobs. The focus will be predominantly around renewable heat and Scotland's ongoing offshore wind development. Whilst it is important to focus on existing strengths in our climate journey, we must continue to invest in emerging tech and ensure we support start-ups and scale-up opportunities to commercialise, otherwise Scotland runs a risk of losing talent to the rest of the world.³⁸ Focus must be across all components of our climate journey, and Scotland has to be diverse in our outlook and ensure we spread our focus across a range of sectors and technologies which will be pivotal to meeting our emissions and driving sustainable economic growth.

³⁷ <https://www.msipdundee.com/wp-content/uploads/2020/09/MSIP-Marketing-Bro-2.pdf>

³⁸ https://www.scottishrenewables.com/news/777-budget-announcement-of-green-jobs-workforce-academyhailed?utm_source=Twitter&utm_medium=Social%20post

Economic Value/Investment

Investment from private investors and government towards a net zero transition is crucial if we are to harness our potential in Climate Tech. It is important that investment is varied and diverse to ensure a range of funding channels are available to start-ups and SMEs. Climate Tech venture funding is coming from a range of different market investors. These investors range from more traditional VC firms and venture funds specialising in sustainability, to corporate investors including energy majors, global consumer goods companies and big tech, government-backed investment firms, and private equity players getting exposure to deals early.

As an early-stage opportunity, economic value data is qualitative rather than quantitative and looks broadly at the global opportunity rather than being Scotland specific. COVID-19 has demonstrated that government stimulus can take place on a large scale and, moving forward, investment towards the green recovery can be channelled into digital infrastructure, innovation, and programs that will build economic and environmental resilience for the long term, which will future-proof our economy and society.

\$16.3bn was invested into Climate Tech across the world. Back in 2013, that figure was at \$418m. Nearly half of all VC investment into Climate Tech across the past seven years – \$60bn in total – went to the US and Canadian markets (\$29bn), with China receiving \$20bn. Europe, however, received just \$7bn of that total since 2013. That being said, the picture is not completely bleak for Europe, A recent Tech Nation report showed that the amount of funding going into net zero companies in Europe – those which add no incremental greenhouse gases to the atmosphere – increased 129% between 2018 and 2019. Outside of China and the US, the analysis from ScotlandIS member, PwC, shows that Berlin, London and Labège in southwestern France were the places seeing the highest investment into their Climate Tech

companies.³⁹ In the UK, tech start-ups have raised a staggering €1.4bn so far this year, with Clean Tech and Climate Tech firms raising the most capital.⁴⁰ Scotland's thriving start-up community is well placed to increase innovation in the lead up to COP26.

Venture Capital investment has remained resilient in Scotland over the last year and will likely be vital to the success of Climate Tech adoption across the country. Analysis from KPMG highlights that 22 VC deals were completed between April and June, which was an increase of four from the first three months of 2020. These deals equated to a combined value of at least £62 million, up from £32 million. 13 of the 22 deals were completed in Edinburgh, followed by Glasgow with two deals.⁴¹ It is important to note that whilst Venture Capital Investment is likely to be a key mechanism of investment towards Climate Tech, the sector as a whole must seek diverse investment strands considering that Climate Tech investment makes up only 6% of total capital of the VC global market. We can expect this figure to grow in the coming years, provided the wider ecosystem continues on the growth trajectory.

ScotlandIS member BT is leading the way in corporate and start-up investment engagement towards Climate Technology. BT has chosen Glasgow tech start-up, iOpt, to develop new joint products and services aimed at helping its public sector customers reach their net zero emissions targets.

BT will offer the product to local councils across the UK that are looking to adopt environmental monitoring and smart building solutions, which is one of the key challenges in our race towards our net zero targets. The Internet of Things (IoT) platform provides real-time information and alerts on the condition of properties.

³⁹ <https://www.pwc.com/gx/en/news-room/press-releases/2020/climate-tech-investment-report-climateweek.html>

⁴⁰ <https://technation.io/programmes/net-zero/>

⁴¹ <https://home.kpmg/uk/en/home/media/press-releases/2020/05/calm-before-the-storm-as-pre-lockdownventure-capital-funding-in-scotland-remains-resilient-in-q1-2020.html>

Installed sensors allow key information such as damp, mould, and fuel poverty to be collated and address such issues, tracked.

It is anticipated that iOpt solutions can assist councils with social regeneration and deliver improved health and wellbeing outcomes for tenants. They can also lower preventative maintenance costs and cut down unnecessary travel to fix issues, reducing carbon emissions as a whole in the long run. BT will provide the network connectivity and manage the installation of the IoT sensors, while supporting iOpt in growing its customer base.⁴²

Corporate investment and responsibility towards net zero is growing in Scotland. Across a range of different sectors, there is a growing awareness that investment in climate technologies is a key part of the net zero journey. Scottish Widows has become the first major pensions and insurance provider to target halving the carbon footprint of all its £170bn investments by 2030, in its path to net zero by 2050. The company, which has more than six million customers in the UK, will also be investing billions of pounds in climate solutions and energy-efficient technologies by 2025, to underline its commitment to positive change. This move will also ensure that investment is moving in the direction towards our net zero targets.⁴³

Scotland also has historically had a well-supported and vibrant investor market for seed and early-stage SMEs up to the £2m investment level with a combination of Scottish Enterprise and angel-investors providing strong support to this sector. The challenge after this funding was where companies looking to commercialise their ideas and products went for the next stage of significant investment.

The newly-established Scottish National Investment Bank has enormous potential in this space to act as the lever between the public and private sector. The Bank was

⁴² <https://www.scotlandis.com/blog/bt-partners-with-glasgow-start-up-on-net-zero-tech/>

⁴³ <https://www.ftadviser.com/pensions/2021/02/08/scottish-widows-sets-net-zero-target-for-170bn-fund-range/>

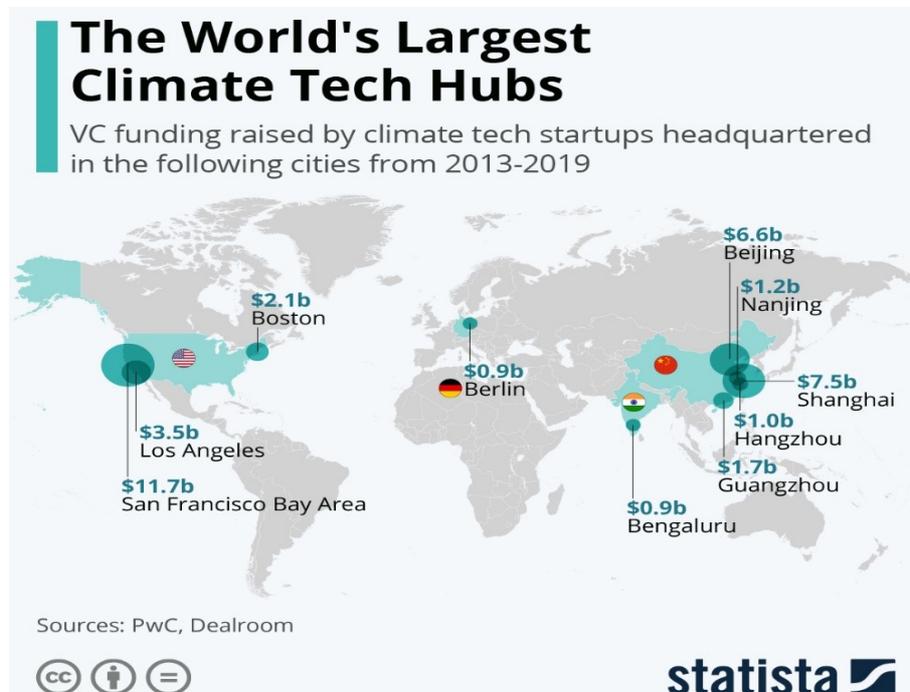
launched in November 2020, announcing its first investment of £12.5 million in M Squared Lasers. It has been established to make mission-led, patient investments in businesses and projects across Scotland.

As the Bank's primary mission is to support the transition to net zero, with another of its missions focussed on harnessing innovation, there is the clear potential for shared interest between the Bank's agenda and the development of Climate Tech. The Bank will seek to invest debt and equity on commercial terms based on the needs of individual projects or businesses and will typically invest in businesses and projects seeking more than £1m in investment support.

The recently launched Climate Tech Capital Partners (CTCP) based in Edinburgh will be a key component of scaling-up venture capital investment in Climate Technologies across Scotland. Anticipating the market requirement and opportunity, CTCP has launched its Climate Tech Venture Fund (the 'Fund'), initially seeking to raise up to £60m, focused on making early stage ("Series A") investments of £2-5m per company in primarily Scottish Climate Technology businesses. The investments will be in companies that have clear market opportunities, are ready for commercial growth to deliver low carbon innovation and efficiencies, and are scalable with the potential for a large addressable international market. CTCP's business model will be to provide the necessary funding and the expertise to support the development of its investee companies. There are five cornerstone sectors that the Fund will invest in: marine energy technologies, offshore wind technologies, integrated energy systems, low carbon transport and smart mobility, and other innovative climate technologies such as energy efficiency and the circular economy.

The global economic case for Climate Tech has grown exponentially in recent years and is projected to continue on the upward trajectory. Research released by The

World Bank estimated the opportunity for smaller Climate Tech firms at \$1.6 trillion.⁴⁴ Across the globe, Climate Tech “hubs” are beginning to emerge in some of the world’s largest cities but Europe currently only has one in the top ten, which is in Berlin as we can see below:



Amongst the top 10 cities for Climate Tech start-up investment – outside of the U.S. and China – are Berlin, London, Labège (France) and Bengaluru (India), attracting \$1.3 billion, mainly across energy, agriculture, and food and land use.⁴⁵ Scotland must have ambitions to put itself on this map alongside other world leaders, focusing more across the Climate Tech spectrum on top of its continuing success in renewable energy generation.

The UK and Scottish Government have both set ambitious net zero targets in 2045 and 2050 respectively. The EU has also set a range of net zero targets and countries within the EU are useful barometers when it comes to looking at how we are

⁴⁴ <https://www.infodev.org/climate>

⁴⁵ <https://techcrunch.com/2020/09/23/new-report-finds-vc-investment-into-climatetech-growing-five-timesfaster-than-overall>

performing. A recent Tech Nation report found that the UK leads Europe for the number of Net Zero companies, at 323 compared to 207 in France (35% less), and 150 in Germany (53% less). Furthermore, 37% of UK Net Zero companies are at an early stage of growth, showing an impressive pipeline for the sector. 26% of UK Net Zero companies are late-stage, highlighting the growth already happening to meet emission targets. In 2019, the UK also led Europe for VC investment into Net Zero companies at £336mn in VC investment, 55% more than France which received £216mn, and 18% more than Germany with £283mn. VC investment in Net Zero in the UK has grown by 28% from 2018 to 2019.⁴⁶ Scotland, with the variety of Climate Tech companies emerging from supported accelerators and university incubators, has a great opportunity to capture a good share of this investment.

⁴⁶ <https://technation.io/net-zero-report/>

Conclusion

To conclude, Scotland is on the cusp of a Climate Tech revolution and in the lead up to COP26, it is vital that we highlight Scotland's Climate Tech capability to the global audience. The case studies highlighted in this report are a demonstration of the innovation taking place across Scotland in a range of different domains but with Climate Tech as the key enabler.

The digital sector is already well on track to reduce its own emissions, which represent 1.4% of the global total, and it has the opportunity to cut global emissions in half by 2030 while driving exponential growth in data performance. The digital sector can also take a strong lead in accelerating demand for 100% renewable energy.⁴⁷

Scotland has an opportunity to demonstrate ambition and become a Climate Tech global leader. By doing so, we will be able to navigate a new and evolving regulatory landscape, and attract investment and top talent globally. The challenge for the Climate Tech sector now is to integrate cutting-edge technologies across all sectors in Scotland to ensure we meet our net zero targets in partnership.

This report has summarised and provided insights into a variety of Climate Tech opportunities that exist (within Scotland, the UK and worldwide) for decarbonising each sector and the various trade-offs among them. Overall, our analysis demonstrates the clear value of reaching net zero targets by transitioning towards Climate Technology solutions. Many of these solutions already exist, as we have highlighted, and they are already improving operating characteristics, productivity and lowering emissions.

Further technological innovation is predicted heading into the next decade as we accelerate our journey to net zero. We need to work in partnership with Government,

⁴⁷ <https://www.weforum.org/agenda/2019/01/why-digitalization-is-the-key-to-exponential-climate-action/>

academia and industry to realise the opportunity that Climate Tech presents and its critical role in meeting our net zero targets.