Department for Business Energy & Industrial Strategy – A Study to Assess UK Strategic Advantage in Advanced Materials

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Contents

1. Introduction and Background

Perspective Economics was commissioned by the Department for Business, Energy and Industrial Strategy (BEIS) to conduct a study into the United Kingdom's (UK's) Strategic Advantage in Advanced Materials. This report provides a summary of key findings from the study set against each study question. Supporting information, including methodological details and further analysis is provided in the appendices.

1.1. Background to the Study

Advanced materials are critical drivers of innovation across a range of important technologies, which have applications across several strategically important UK industries, from aerospace and aviation, through healthcare, to energy generation, transition and storage. They will become increasingly crucial to transform important industrial sectors to become 'greener', more productive and increasingly competitive, including aerospace, automotive, construction, marine, rail, healthcare and energy, for example through improved battery materials, coatings for corrosion or heat resistance, printed electronics, and embedded sensors. However, while advanced materials have consistently been recognised in UK policy and strategy documentation as an important enabling technology, the market is deemed by some to suffer from a lack of coordination and information failures. Therefore, the Department for Business, Energy and Industrial Strategy (BEIS) wants to assess the current strength of the UK advanced materials ecosystem. Specifically, this study seeks to address the following aims and objectives:

1. To **develop a robust evidence base on the strategic advantage of the UK advanced materials area.** This will involve identifying UK capabilities in advanced materials (key technical and innovation strengths).
2. To **identify the current and forecast levels of UK supply and demand of these materials**, incorporating the differing timeframes of availability/technology maturity.
3. To **identify the key risks for the UK advanced materials area** and factors that would be crucial for **mitigating these risks**.
4. **Define the UK advanced materials scientific research base** across academia and RTOs.
5. To **understand gaps in the availability of data** that would be **needed to inform a national advanced materials strategy**.

1.2. Definition of Advanced Materials

For the purposes of the study, Advanced Materials have been defined as materials designed for targeted properties, including both completely new materials and those that are developments on traditional materials. Such materials show novel or improved structural and/or functional properties including, for example:

- Advanced composites: structural composite materials, with polymer, metallic or ceramic matrices It also includes 3D reinforcing architectures for any matrix (polymer, metal, ceramic).
- Metals and alloys: metallic material compositions, grades or forms with outstanding structural or functional properties, including materials that require special processing or manufacturing to confer those properties.
- Engineering and technical polymers: polymers (and their associated processes and enablers) capable of; operating at high temperature or pressure or containing additional functionality (for example electromagnetic, stimuli-responsive, self-healing, underwater curability etc.).
- Engineering and technical ceramics: ceramic materials and their manufacturing processes owing to either their structural, thermo-structural or functional properties not included in Advanced Composites.
- Technical textiles: textiles (and their processes and enablers) specifically developed for their functional performance for example integrated computing, processing, or data transmission, 3D architectures, protection against blast and ballistic events.
- Metamaterials: captures a composite material in which the constituents are designed and spatially arranged through a rational design-led approach to change how electromagnetic, acoustic or vibrational energy interacts with the material, to achieve a property or performance that is not possible naturally and includes a meta-surface.
- Semiconductors, photonic and optoelectronic materials and devices.
- Graphene and related 2D materials: two-dimensional materials have one dimension at the nanoscale or smaller, with the other two dimensions generally at scales larger than the nanoscale.
- Nanotechnology: materials, technology and structures with any external dimension in the nanoscale or having internal structure or surface structure in the nanoscale and include nano-objects, dispersions or mixtures containing nano-objects, and nanostructured material (including structuring at an interface between materials, including air, and within a material).

1.3. Methodology

The study follows a mixed method quantitative and qualitative approach, including:

1. Review of more than a dozen strategically significant UK strategies and policies spanning economic growth, innovation, research and development, net-zero / climate change, energy, infrastructure, Space and defence (Appendix 1).
2. Identification of key terms deemed to be reflective of the advanced materials of interest to the study, drawing on the policy review and prior definitional work undertaken by BEIS. An initial list of key terms was tested with a panel of experts from BEIS, UKRI and independent industry experts, before being refined and augmented to include a total of 246 key terms deemed to be within the scope of the study (Appendix 2).
3. Application of AI technology (via Glass.ai) that combines language understanding through semantic analysis with resource crawling at scale and the maintenance of a deep topic ontology to identify and categorise approximately 2,300 UK advanced materials companies.
4. Collection of data from other sources (API enabled where possible), including UKRI's gateway to research, Innovate UK data, Crunchbase and Beauhurst.
5. In-depth (c.30 minute) interviews with 27 strategic stakeholders spanning academia, industry and policy representatives with considerable experience and expertise in advanced materials (Appendix 3). In some cases, follow-up interviews were required to fully address the scope of the study.
6. Purposive, evidence-driven identification of case studies and supplementary desk research.

2. Strategic Context

Advanced materials research and commercialisation, and the importance of sustainable and resilient advanced materials supply chains has received increasing interest from governments, researchers and industry stakeholders globally. As a first step towards better understanding advanced materials activity in the UK, the study team undertook a review of strategies and policies to which advanced materials make a substantive contribution. More than a dozen strategically significant strategies and policies were reviewed, under four broad themes, as summarised in Table 2.1 below.

Table 2.1 – Overview of Policy Review Documentation

UK Economic Growth - UK Plan for Growth - Levelling Up the United Kingdom - Inward Investment & Exports - Industry-specific strategies & policies	UK Innovation & R&D - UK Innovation Strategy - UK R&D Roadmap
Infrastructure & Security - National Infrastructure Strategy & Transforming Infrastructure Performance - Defence & Security Industrial Strategy, & the Integrated Review - UK Space Strategy	Climate Change & Sustainability - UK Net Zero Strategy - 10 Point Plan for a Green Industrial Revolution - Energy Innovation Needs Assessment

The full review of policy is provided in Appendix 1, key findings are summarised below for ease of reference.

2.1. Advanced materials for achieving the UK's strategic ambitions

Advanced materials permeate almost every aspect of the UK's strategic ambitions, particularly concerning economic advancement and net-zero.

There is a clear and vital role for advanced materials across the UK's most significant economic, research, innovation, infrastructure and defence strategies. The importance of advanced materials to the UK's strategic economic ambitions is most apparent within the UK Innovation Strategy, which has advanced materials as one element of one part of the UK's seven key technology families.

“This is a truly revolutionary time in advanced materials development. Materials are being manipulated at an atomic level to elicit new properties and vastly improved performance. The UK has a world-leading advanced materials science base.”

UK Innovation Strategy

Yet advanced materials are also, implicitly, crucial for leveraging UK innovation success stories. Throughout the Innovation Strategy, innovation successes highlighted in case studies rely on advanced materials, for example:

- G20 Water Technologies – a company that uses novel materials to produce **precision membrane technology** used for water treatment and resource harvesting (e.g. phosphorous from sewerage, algae for biogas production or salt from desalination).
- Zentraxa Limited – a spinout from the University of Bristol that is manufacturing **biopolymers** for use in highly functional adhesives within medical and industrial settings.
- **3D imaging and printing technology** for the healthcare sector, including generating 3D printed models for surgical planning and imaging artificial intelligence centres of excellence.
- Investment of £28m via the Industrial Strategy Challenge Fund in Orkney that seeks to create an **integrated energy system**, linking local electricity, transport and heat networks into one, controllable overarching system.
- Investment of £42m in the development of **nano-scale optical components** (driven by Seagate Technologies) that will power future digital devices.
- Objectives of **UK Freeports** which include developing advanced manufacturing, low carbon, renewable energy (offshore, tidal and hydrogen) and marine technology clusters.

Advanced materials will also be critical for achieving the UK’s Net Zero strategy, and for delivering new technologies that support future automotive, aerospace, health and life sciences, infrastructure (construction and telecommunications), national defence and space industries in the UK.

For example, advanced materials will play a fundamental role in delivering the policies set out across almost all aspects of the economy highlighted in the Net Zero Strategy, including:

- Power – realising the ‘abundant, cheap British renewables, cutting edge nuclear power … energy storage … carbon capture [and] hydrogen’ will require vast quantities of advanced materials used in the production of wind turbines, solar cells, nuclear energy generation, electricity storage and hydrogen storage and transportation.

- Fuel Supply & Hydrogen – where electrification is not a viable option, advanced materials will be required to improve the efficiency and effectiveness of carbon capture and biofuel technologies, and to support the development, storage and distribution of hydrogen fuels.
- Industrial Decarbonisation – to support the more urgent decarbonisation of existing industries, advanced materials will be central to supporting the transformation to cleaner forms of energy including low carbon hydrogen.
- Heat and Buildings – advanced polymers and other phase change materials are required to meet government targets for heat pump installations, and to improve the efficiency and effectiveness of heat pumps over time.
- Transport – advanced materials are central to decarbonising transport and will be used in huge quantities for lightweighting, batteries, charging infrastructure and hydrogen fuel cells.
- Waste & Natural Resources – novel and advanced materials will be required to support a circular economy, including development of increasingly environmentally friendly bio-based materials, and the development of solvents, materials and processes for improved recycling[1].
- Cross-Cutting Action – advanced materials must also form a central part of cross-cutting actions intended to support Net Zero policies, including support for materials innovation, investment in advanced materials, materials regulations and standards, and materials science skills.

2.2. Unique strategic points of difference for UK advanced materials

While there are, understandably, numerous overlaps between UK and EU advanced materials strategies and policies, there are also some unique points of difference. For example UK strategies, policies and materials roadmaps place greater emphasis on advanced materials for wind power, aerospace, carbon capture and storage, nuclear technologies, and construction. Unique opportunities are also presented by the UK's comparatively liberalised and integrated electricity grid, which could lend itself to energy integration and smart energy.

Beyond the alignment between advanced materials and individual UK strategies and policies, there are also some unique physical attributes of the UK economy that necessitate a long-term and sustained focus on advanced material-enabled technologies. For example, the fact that the UK is an island economy means that it makes strategic sense to have a

[1] https://www.the-ies.org/sites/default/files/journals/ES_March2015_new-materials.pdf

sustained focus on advanced materials for aerospace applications, including alternative fuels, and to continue investing heavily in renewable wind and tidal energy. The UK's population density and demand for infrastructure can drive advanced construction materials and processes e.g. ultra-low carbon concrete, 3D printing, and additive manufacturing. Further, the NHS – one of the UK's greatest assets – also presents opportunities (if appropriately funded) to be a test-bed for the development of advanced biomedical materials.

Lastly, advanced materials have a vital role to play in driving a more sustainable and productive UK economy. While the manufacturing sector has historically led UK productivity improvements, those have stalled since the 2008 financial crisis. Various reasons are cited including automation saturation, low investment and stuttering R&D spend among others[2]. The deployment and use of advanced materials can aid productivity improvements, and while recent investments hint at the role of advanced materials in delivering productivity gains[3], they are not 'front and centre'. Likewise, attention in the design, development and deployment of more sustainable materials can enable a more resource-efficient economy.

"It is imperative to accelerate the development and adoption of advanced materials and processes to drive innovation and productivity within UK industry. Combining greater understanding of performance with improved measurement techniques means that industry can have the confidence to employ advanced materials and reap the benefits that they offer."

Dr JT Janssen, Chief Scientist, NPL

2.3. Conclusion

Ultimately, the review of strategy and policy concludes that advanced materials play a critical role across almost every aspect of the UK's future, from economic prosperity to, environmental sustainability and national security.

For the last two decades successive governments have highlighted the importance of advanced materials. There have been three attempts at developing an Advanced Materials Leadership Council (AMLC), advanced materials have been highlighted as one of the 8 Great Technologies and most recently as part of the Innovation Strategy's first Technology Family.

[2] https://researchbriefings.files.parliament.uk/documents/SN01942/SN01942.pdf
[3] See for example the Advanced Machinery & Productivity Institute funded via Strength in Places.

Yet (as discussed further in Section 3) there is no single plan that articulates how advanced materials activity and investment will be shepherded so that the right support is effectively directed to maximise the economic and environmental opportunities that they enable.

A comprehensive UK advanced materials strategy is required so that all aspects of advanced materials, from economic development and investment, to skills, legislation and standards, are working together to most effectively leverage the UK's unique strengths in advanced materials. Further, any advanced materials strategy should be developed so that it fits coherently with other aspects of the materials supply chain e.g. critical materials, and advanced material technologies e.g. compound semiconductors.

3. UK Strategic Advantage in Advanced Materials

The first of five study objectives was to develop a robust evidence base on the strategic advantage and capabilities of the UK's advanced materials area. Doing so required that the study identified and analysed UK capabilities, including but not limited to the scientific research base across Universities and Research Technology Organisations (Objective 4). The study took a data-driven approach, analysing research, innovation and industry data based on the 246 key terms identified as being within the scope of advanced materials. Quantitative and qualitative findings were triangulated, highlighting the following strategic advantages:

- Some unique points of difference between UK and EU advanced materials strategies, policies and technology roadmaps, and more fundamental economic and technological drivers (see Section 2).
- A world-class environment for early-stage advanced materials research (TRLs 1 – 3).
- Research and innovation capability nationwide, including significant experience and expertise in materials measurement, standardisation and regulation.
- A vibrant and diverse advanced materials industry.
- An internationally relevant advanced materials start-up environment.
- Significant levels of advanced materials related Foreign Direct Investment.

The evidence base underpinning each of these strategic advantages is presented in the sub-sections that follow.

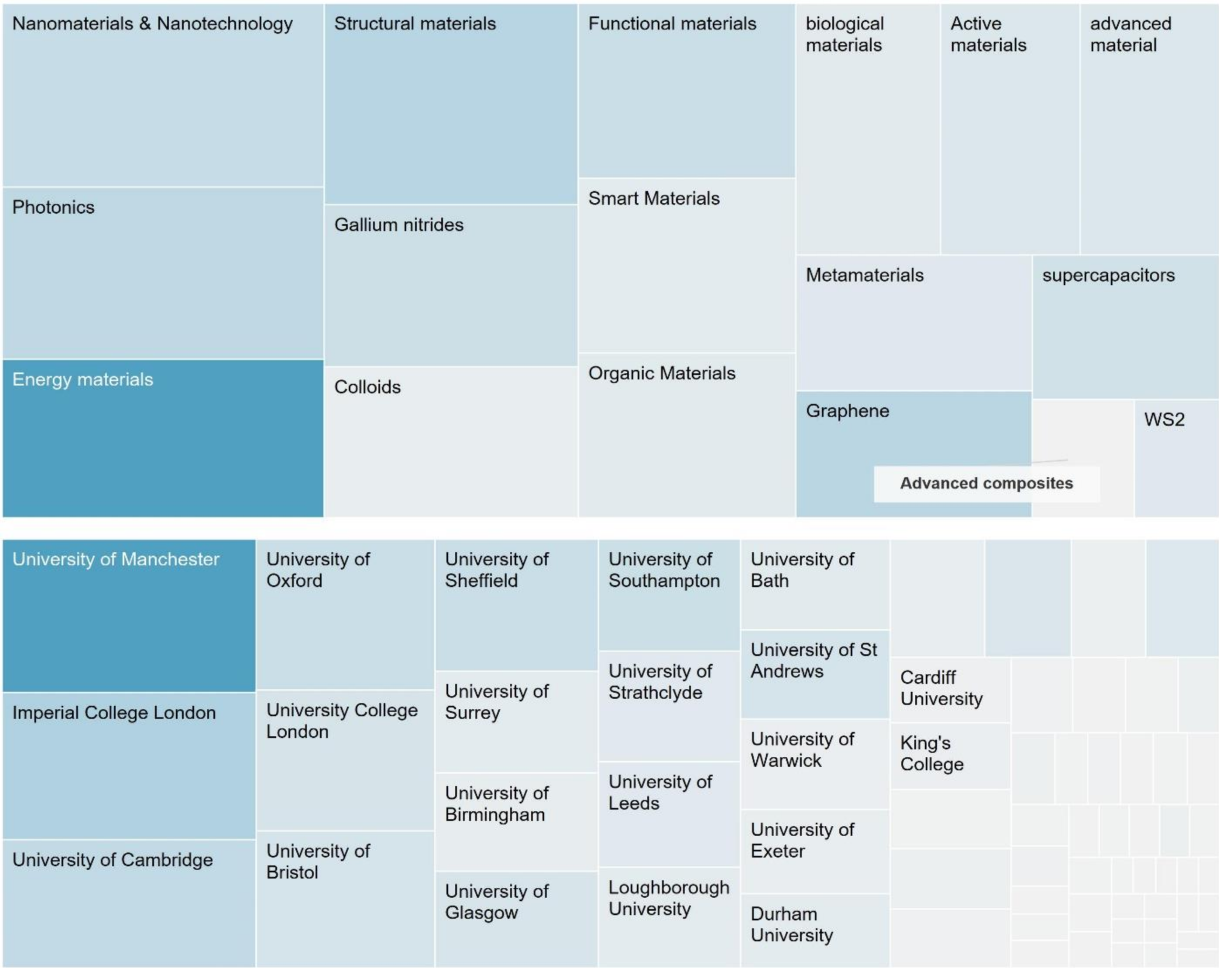
3.1. A world-class environment for early-stage advanced materials research

3.1.1. Breadth and depth of advanced materials research capability

An API-enabled search for the 246 in-scope key terms identified approximately 1,000 funding awards for advanced materials related research in the UK since 2005. Analysis of the resulting data demonstrated the breadth and depth of advanced materials research expertise across UK universities and research organisations spanning energy materials, photonics, supercapacitors, metamaterials, functional materials, advanced composites and nanomaterials (among others). Figure 3.1 illustrates the focus of UKRI investment in advanced materials since 2005 in terms of both key terms and lead research organisations. Segment sizes reflect the number of research project awards, and the density of segment colours reflect the value of advanced materials research awards[4].

[4] Analysis conducted on 658 awards, excluding ‘semiconductor’ awards and Innovate UK awards.

Figure 3.1 – UKRI Funding for Early-Stage Advanced Materials Research



Source: UKRI Gateway to Research

UKRI funding for early-stage research has changed over time yet anecdotally, based on triangulation of quantitative data on early-stage research and in-depth interviews with strategic stakeholders, there appears to be some correlation between those key terms that have received sustained funding over time, and strategic stakeholder perceptions of UK strengths. Figure 3.2 overleaf illustrates the alignment between UK strengths identified by strategic external stakeholders and UKRI funding for advanced materials key terms over time. In particular, the alignment between longer-term funding and independent perceptions of UK strength in photonics, semiconductors, graphene, metamaterials and other 2D materials, and carbon fibre is particularly notable.

Figure 3.2 – Early-stage research funding & perceptions of UK advanced material strengths

"Manmade materials such as **non-graphene 2D and 3D materials / metamaterials / semiconductors design** are a research domain strength of the UK".

"Paragraf is delivering game-changing, commercial-quality, **graphene-based** electronic devices".

"The UK attracts global collaborations to access their capability. Take **unusual forms of glass (glass modifications)**, for example, the UK is ahead when it comes to things like **specialist doped glass**, and we're also globally leading in **hollow optical fibres."**

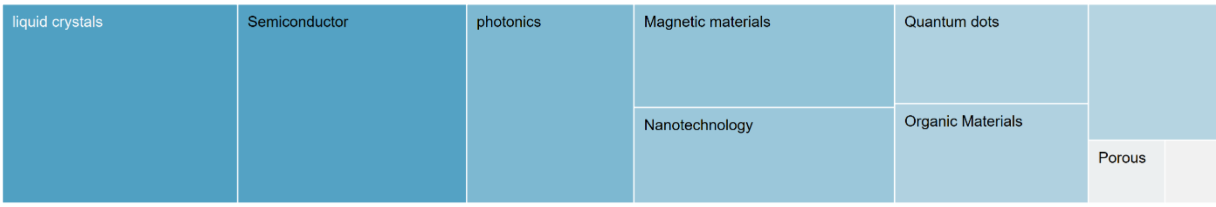
"We have strengths in **pharmaceutically active implants / personalised medicines**, which is a combination of materials science and pharma."

"The manufacturing hub and industry 4.0 is key and plays to **strengths like Turing – AI** etc as well as mechanistic modelling – materials genome in the US has a range of tools that we the UK are attempting to exploit in the pharma domain."

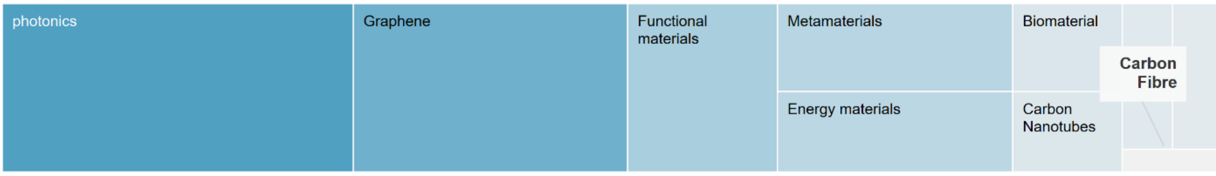
"The UK's strengths in **advanced composites** are in aerospace (carbon fibre composites); in automotive (aluminium and magnesium); in **wind energy in glass and carbon fibre composites**. WMG one of the only groups that focus on high volume manufacturing."

"**Photonic and plasmonic materials** are a UK strength – the materials that go into lenses used by Seagate to make 1/3 of the world's data storage, for example."

Top 10 research areas by award value (2004 - 2008)

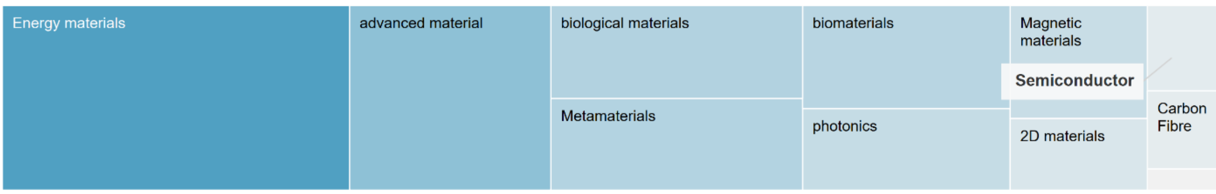


Top 10 research areas by award value (2009 - 2013)



Top 10 research areas by award value (2014 - 2018)

Top 10 research areas by award value (2019 - 2022)

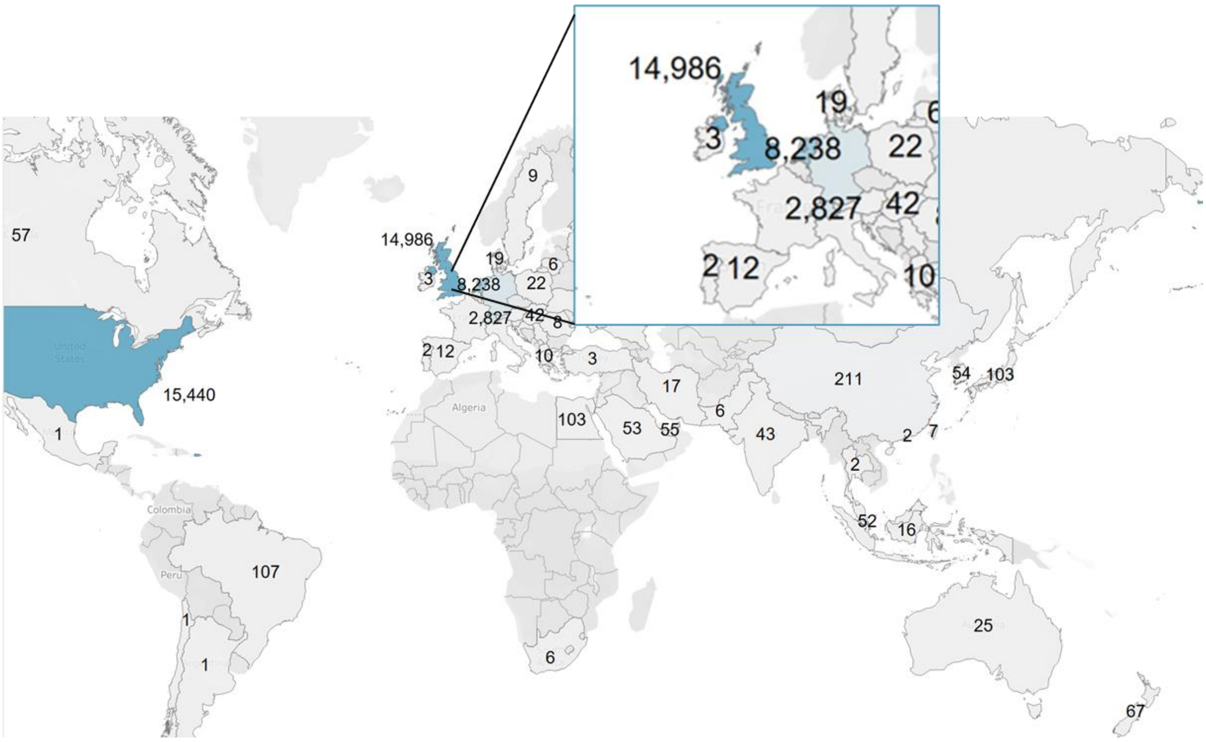


Source: UKRI Gateway to Research, In-Depth Interviews

3.1.2. International prevalence of UK research output

From an academic perspective, one of the most important outputs of research funding is research publications. Based on a search for the same 246 key terms within proprietary research output data platforms, the study identified approximately 45,000 UK authored advanced materials journal articles within the last 5 years published in almost 4,000 academic journals globally. Thirty-four percent of UK authored journal articles were published in US journals (n=15,440), 33% in UK journals, 18% in Dutch journals and 15% in journals across the rest of the world (Figure 3.3).

Figure 3.3 – International Prevalence of UK research output



Source: Lens.org

Once again, quantitative findings regarding UK research outputs aligned with qualitative data. As one strategic stakeholder put it:

"The UK is really strong in materials science, the sheer quality of the academics, students and research output mean that you would want to do your research in the UK."

Consultee, Large Corporate

3.1.3. Quality of UK academics

Volume of research output holds little credibility in the absence of some measure of the quality of UK academics vis-à-vis their international counterparts. One indicator of the comparative quality of UK academics is European Research Council (ERC) grant awards.

'For many in the research community, the most prominent funder of purely excellence based research for the UK at the moment … is the European Research Council, with its mission to "support investigator-driven frontier research across all fields, on the basis of scientific excellence". The ERC delivers this mission through the rigorous peer-review, by acknowledged international experts, of proposals whose quality is driven up by healthy competition from a whole continent's worth of leading scientists.'

Professor Richard Jones, Soft Machines Blog, 21st February 2022

Analysis of ERC grant data demonstrates the comparative quality of UK researchers in research areas that are highly relevant to advanced materials. For example, analysis of 3,083 ERC grant awards across 6 research domains since 2007 shows that UK academics are among the most frequent recipients of European Research Council grants in research areas relevant to advanced materials, having secured 16% of all related ERC grants to date, placing the UK first in per capita terms.

Figure 3.4 – Comparative quality of UK academics

Country	Condensed Matter Physics	Fundamental Constituents of Matter	Physical and Analytical Chemical Sciences	Products and Process Engineering	Synthetic Chemistry and Materials	Systems and Communication Engineering
Germany	2.8%	4.1%	2.9%	2.2%	4.2%	1.5%
United Kingdom	2.3%	2.8%	2.6%	2.5%	4.2%	1.9%
France	3.1%	2.6%	1.3%	1.9%	1.6%	2.0%
Netherlands	1.6%	1.0%	1.4%	1.6%	1.9%	1.2%
Switzerland	1.5%	1.4%	1.3%	1.3%	1.4%	1.2%
Spain	1.2%	0.9%	0.6%	1.9%	1.7%	0.7%
Italy	0.7%	2.0%	0.5%	1.7%	0.6%	0.8%
Israel	0.8%	0.7%	1.0%	0.1%	1.0%	0.8%
Sweden	0.6%	0.6%	0.9%	0.6%	0.6%	0.7%
Belgium	0.1%	0.3%	0.5%	1.0%	0.4%	1.2%
Austria	0.5%	0.9%	0.5%	0.5%	0.3%	0.2%
Denmark	0.3%	0.5%	0.4%	0.3%	0.2%	0.3%
Finland	0.5%	0.2%	0.1%	0.5%	0.2%	0.1%
Ireland	0.1%	0.1%	0.2%	0.7%	0.2%	0.1%
Portugal	0.0%	0.1%	0.0%	0.6%	0.1%	
Norway	0.1%	0.0%	0.1%	0.1%		0.1%
Greece	0.0%	0.0%		0.3%	0.0%	0.1%
Turkey	0.0%	0.0%		0.1%	0.1%	0.2%

Source: European Research Council Grants Database

3.2. UK-wide advanced materials research, development and innovation capability

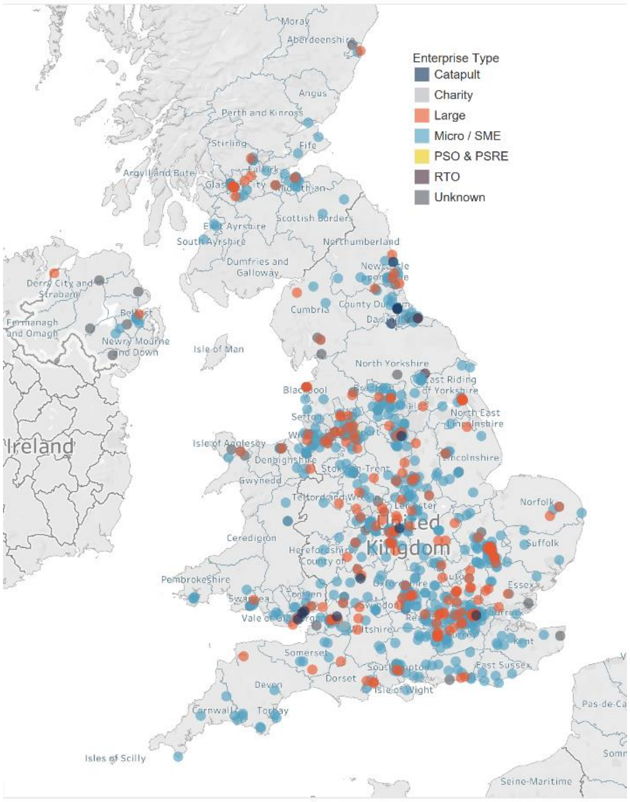
The UK's industrial heritage and the consequent geographic orientation of academic research means that advanced materials present a credible levelling up opportunity. The subsections below demonstrate that a) the UK already has many of the structures and mechanisms required to leverage strengths in advanced materials and that b) there is knowledge, skill and infrastructure available to support growth in advanced materials across the UK, particularly in the North, the West Midlands and the Southwest of England, as well as in Scotland, Wales and Northern Ireland.

3.2.1. Geographic distribution of advanced materials innovation assets

Section 3.1 discussed UK strength in early-stage advanced materials research which, as is the case in so many other sectors, is clearly evident within the Golden Triangle. However, there are also numerous other advanced material innovation assets outside the Golden Triangle.

The study has identified almost 1,400 Innovate UK awards for advanced materials relevant research and innovation since 2005[5], made to almost 600 non-university project leads[6], demonstrating industrial capacity and capability spread throughout the UK (Figure 3.5).

Figure 3.5 – Industrially-led innovation activity



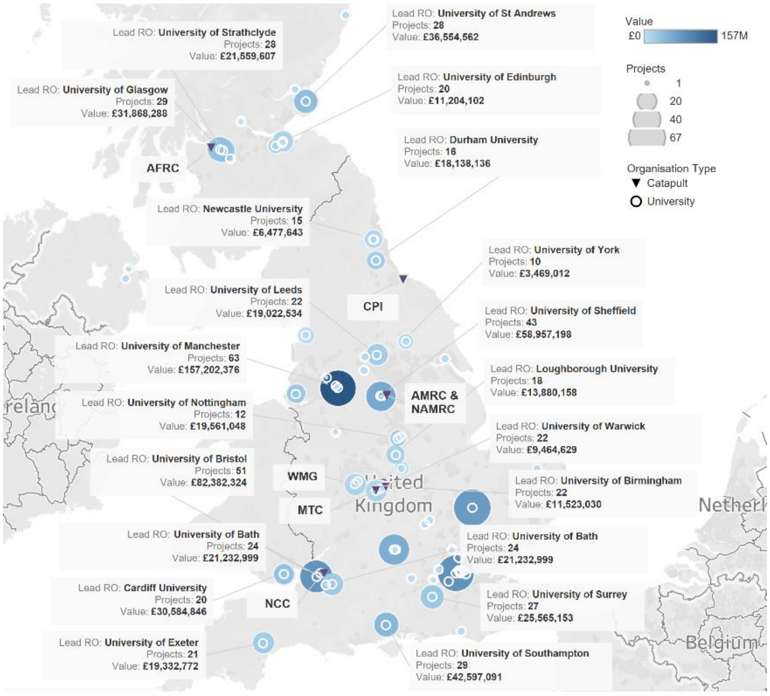
Source: *Innovate UK*

There is, therefore, capacity within industry across the UK to increase the level of advanced materials *innovation* activity. This innovation activity is vital because it can translate strength in early-stage research into productivity gains and economic growth. However, benefits of this potential innovation capacity can only be realised if funding for *translational innovation activity* is substantively increased, and barriers to / incentives for greater SME engagement in innovation are addressed (see Section 4).

[5] Results based on results for the same 246 key terms, excluding awards to academic enterprises.
[6] Excludes academic enterprises and Catapults, note that not all non-university project leads remain as active companies.

The High Value Manufacturing Catapult (HVMC) coordinates the activities of seven centres across the UK:

Figure 3.6 – Advanced materials ecosystem



Source: Gateway to Research

- The Advanced Forming Research Centre (AFRC) has key technical capabilities in near net shape design and make, materials characterisation, component resilience and residual stress, digitalisation, technology planning of process and supply chains, high integrity forging and thermal processing and sheet processing technology. The AFRC is a nationally-recognised centre of excellence in innovative manufacturing technologies, R&D, and metal forming and forging research.
- The Advanced Manufacturing Research Centre (AMRC) has technical capabilities including, design and prototyping, digital manufacturing, lightweighting, machining and near net shape process. The AMRC has a global reputation for helping companies overcome manufacturing problems and has become a model for collaborative research involving universities, academics and industry.
- The Centre for Process Innovation (CPI) has technical capabilities in biotechnology, biotherapeutics, flexible hybrid electronics, photonics, digital and printed electronics. The CPI uses applied knowledge in science and engineering combined with state of the art development facilities to enable their clients to develop, prove, prototype and scale up the next generation of products and processes.
- The Manufacturing Technology Centre's (MTC) key technical capabilities are robotics and automation, additive manufacturing, digital manufacturing, visualisation and virtual reality and metrology. The MTC develops and proves innovative manufacturing processes and technologies in an agile, low-risk environment, in partnership with industry, academia and other institutions.

- The National Composites Centre (NCC) has technical capabilities in advanced composites manufacture, design and simulation, digital manufacturing, automation and tooling, materials and processes and metrology. The NCC is a world-leading authority on composites, bringing together the best minds and the best technologies, to solve the world's most complex engineering challenges.
- The Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC) has technical capabilities in machining, joining metrology, modelling and simulation and advanced assembly. The Nuclear AMRC combines academic innovation with industry expertise to help UK manufacturers improve capabilities and performance along the supply chain. Its facilities and services are open to all.
- Warwick Manufacturing Group (WMG) has technical capabilities in connected and autonomous systems, advanced propulsion systems, batteries and energy storage, lightweight and sustainable materials and digital manufacturing.

3.2.2. Internationally renowned materials innovation assets

Several study consultees also pointed to the positive impact that other elements of Innovate UK funding have had in supporting advanced materials innovation activity. Innovate UK's 2021 'Materials and Manufacturing Review' highlights the relevance of Innovate UK funding vis-à-vis the key issues raised in this study, including advanced materials innovation[7], biotechnology and circularity[8]. Once again, therefore, the UK has the mechanisms (and the technical expertise) it needs to leverage advanced materials strengths, if appropriately resourced and effectively coordinated.

The UK also has renowned experience and expertise in the characterisation, measurement and standardisation of advanced materials, including notably within the National Physical Laboratory (NPL) and the British Standards (BSI) and within data science and Artificial Intelligence at the Alan Turning Institute.

Given the rapidly increasing significance of computer-aided materials science for materials development (see for example the US National Institute of Standards and Technology (NIST's) Materials Genome Initiative)[9], it is also vital that the UK expands and accelerates capability and expertise in *data science for materials science*, through the breadth of UK capability in both fields, including via the Materials Innovation Factory at the University of Liverpool (part of the Henry Royce Institute), NPL, BSI, Turing and others as relevant.

[7] https://www.glass-futures.org/, https://csa.catapult.org.uk/, https://csa.catapult.org.uk/blog/case_studies/escape/
[8] https://www.ukri.org/what-we-offer/our-main-funds/industrial-strategy-challenge-fund/clean-growth/smart-sustainable-plastic-packaging-challenge/
[9] https://www.nist.gov/mgi

However, as is the case with both research and innovation funding for advanced materials, UK investment in computer-aided materials science and measurement capability is relatively small by international standards, particularly given the comparative strength of early-stage research in the UK.

Case Study: Measurement & Standards in the UK's Development of Graphene	NPL	bsi.
The global graphene market is expected to reach $1.6bn by 2025 at a high growth rate of 72.8%, driven by applications mainly targeted at the aerospace sector, but with cascaded benefits in other sectors[10]. Yet, as with the development of any novel material, the path to 'at scale', commercially viable applications is fraught with risk. Some of the earliest and therefore most fundamental risks relate to ensuring that the material is consistently measured and defined. In the case of Graphene, the National Physical Laboratory (NPL) has played an important role in helping to maintain the UK's reputation as a primary international location for the production of graphene and development of graphene products. NPL's role in defining and developing standards for Graphene was described during our consultations, and supplemented by independent desk research.		

[10] https://www.bsigroup.com/globalassets/localfiles/en-gb/about-bsi/nsb/innovation/uk-standards-strategy-for-graphene-report.pdf

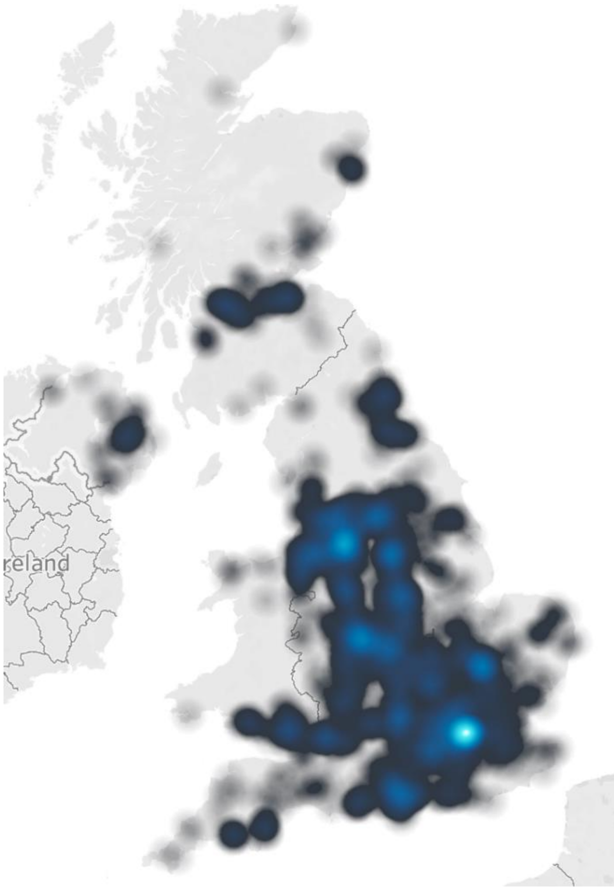
3.3. A vibrant and diverse advanced materials industry

Using AI techniques the study has identified approximately 2,300 companies involved in advanced materials activity in the UK. Of the 2,300 companies identified, approximately 2,100 were SMEs (92%).

As with the geographic distribution of research activity highlighted in the previous section, advanced materials companies are located throughout the UK, with increased density around research and innovation capability in London, the Southwest, the West Midlands, the Northwest and Yorkshire and the Humber (Figure 3.7)[11].

Together, the companies identified employ more than 600,000 people across the UK, of which just under 200,000 are estimated as being within advanced materials related roles[12]. The average salary of advanced materials related roles is c.£6k above the UK average, with salaries ranging from between £23,170 to £52,447 (£21k above the UK average). Together, advanced materials related activity contributes an estimated £14.4bn in GVA to the UK economy, equivalent to around £72k in GVA per employee (25% above the UK average)[13].

Figure 3.7 – Advanced Materials Industry Map



Source: Glass.ai

[11] Location data were available for 1,864 of those companies (82%) and approximately 94% of geocoded companies were SMEs (n=1,753).
[12] Total estimated employment is based on employee mid-points where employment ranges are available within the dataset (77% of companies identified). Employment within advanced materials related roles is based on weightings applied according to each company's position within the advanced materials value chain i.e. RTOs (60%), Materials Producers (25%), Intermediates (60%), Part Producers (20%), OEMs (25%), Consultants (35%), Test Houses (60%), Equipment Producers (45%). Companies identified as being distributers are not included in the analysis.
[13] Calculations use latest available reported revenue data for 1,889 of the 2,300 companies, assuming a blanket 15% profit margin plus estimated salaries for workers in advanced materials related roles using latest available SOC code data. Note that estimating economic contribution was not an explicit objective of the study but an initial estimate has been provided for illustrative purposes. Providing a more robust estimate of the economic contribution of advanced materials activity would require additional analysis.

The c.2,100 SMEs identified in the study employ an estimated 50,000 people (average of approximately 20 employees per company).

Approximately 160 of the SMEs identified have secured fundraising to the value of just under £1bn since 2011 and almost two-fifths of those companies are actively hiring. While there is clearly scope for some optimism when it comes to private investment, further analysis highlights that approximately two-thirds of total investment in advanced materials companies has been concentrated within a small number of sectors (Table 3.1), and is dominated by a small number of very large investments. The median investment in UK advanced materials companies is just £14m.

Table 3.1 – Investment in advanced materials by sector

Sector	Fundraising (%)	Fundraising (£)
R&D and Scientific	23%	£222,740,061
Renewables and Sustainability	13%	£128,749,814
Mechanical and Industrial Engineering	9%	£83,933,513
Biotechnology	7%	£72,004,898
Chemicals	7%	£63,789,163
Medical Devices	7%	£63,550,798
Total	65%	£634,768,247

Source: Beauhurst

Some of the most significant grants and fundraising activity has been by companies such as:

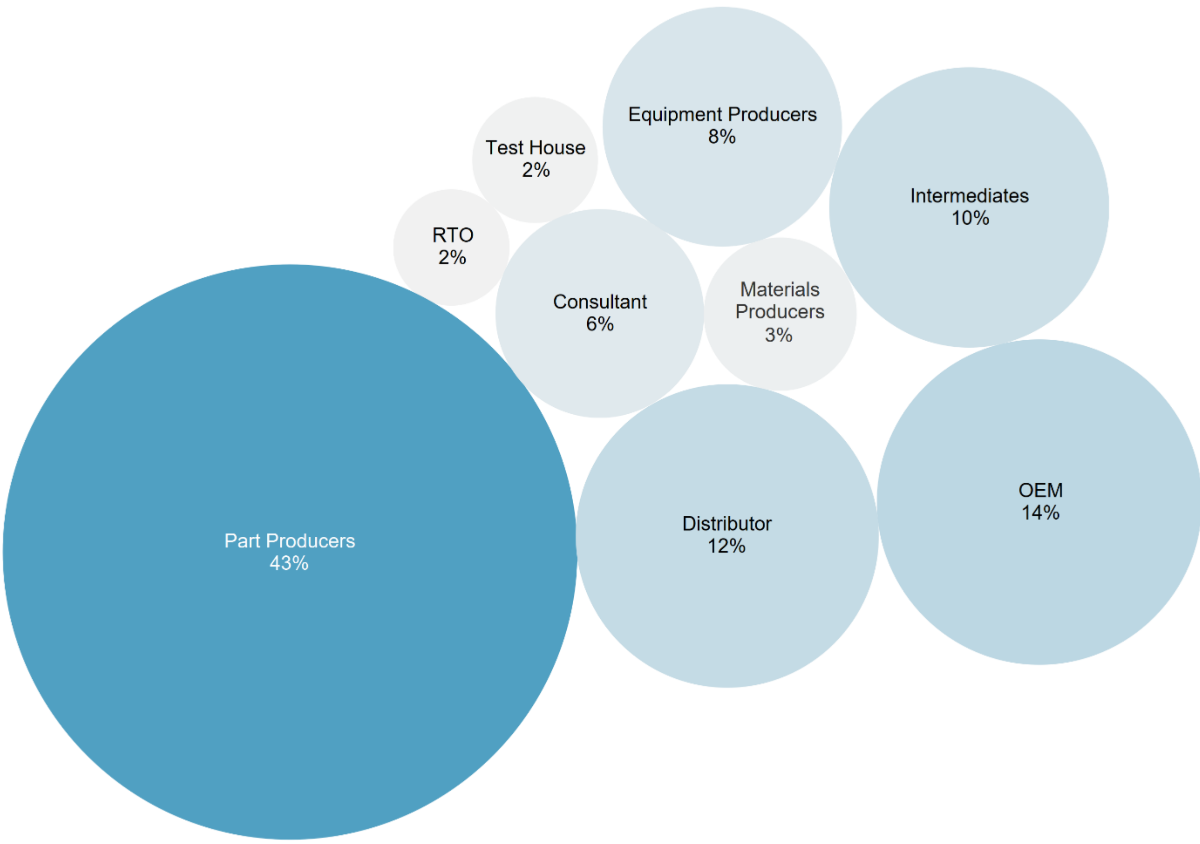
- R&D and Scientific: Paragraf (graphene-based products, £66m), First Light Fusion (nuclear fission, £86m).
- Renewables & Sustainability: Bramble Energy (fuel cells, £41m), NanoSUN (hydrogen fuel and refuelling systems for drones, £14m).
- Mechanical & Industrial Engineering: M Squared Lasers (photonics & quantum technology, £21m), Recycling Technologies (conversion of plastic waste to heat and electricity, £24m).

- Biotechnology: SiSaf (transdermal drug delivery system, £11m), Sixfold Bioscience (£8m).

3.3.1. With capabilities across the advanced materials value chain

Across industry sectors, UK companies have capabilities that span the entire advanced materials value chain. Approximately two-fifths of the companies identified by the study produced parts using advanced materials (43%). Smaller proportions are involved in research, development and testing of advanced materials (just 7% including companies identified as RTOs, Material Producers and Test Houses).

Figure 3.8 – Advanced Materials Value Chain Headlines



Source: Glass.ai

Consultation with advanced materials experts indicated that this headline value chain analysis infers a UK *"trajectory towards becoming no more than integrators of others' technology and that, taken in context of the funding for materials science and loss of key national assets in other parts of the text, we have a real opportunity to reverse this trajectory and build strength in future advanced materials businesses"*.

3.3.2. An internationally relevant start-up environment

Crunchbase is a proprietary data source that tracks global investment data. It provides predefined industry categorisations, one of which is 'Advanced Materials'. Using that predefined characterisation for consistency across jurisdictions, the study team compiled investment and patent data for companies in strategically important international locations including the UK, Europe, the US, Japan, China, and South Korea. Note that the data used here is not consistent with previous industry analyses but is included to provide a comparative analysis of international data. Key findings from the analysis include:

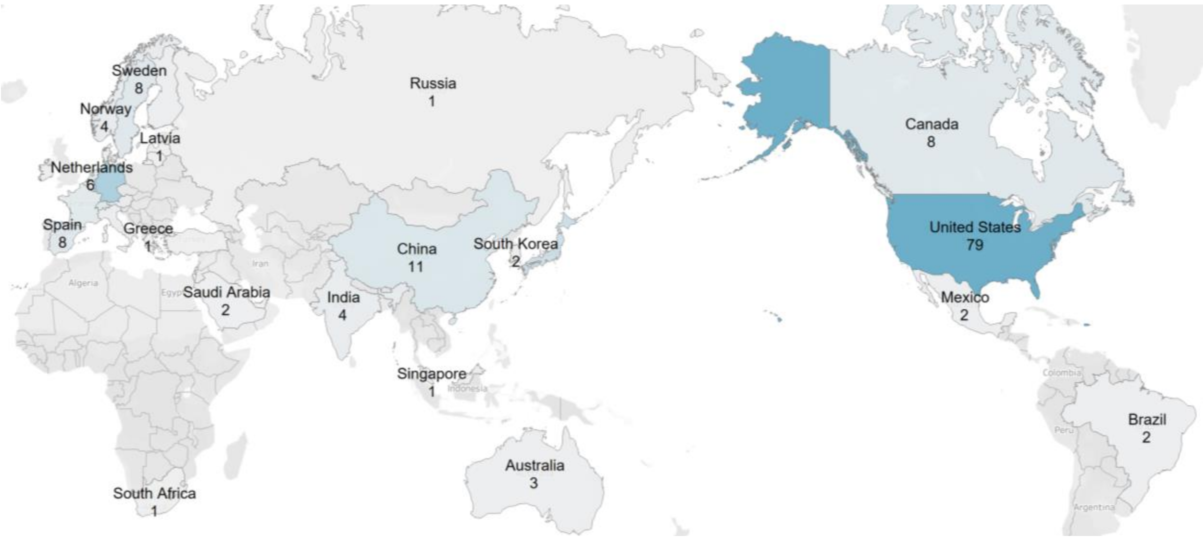
- Outside of the US, the UK is home to the second-highest number of advanced materials companies globally (n=69), behind China but above Germany, Japan and France.
- Over the past twenty years the UK has consistently produced new advanced materials companies and is still among the most prolific start-up locations globally, although since 2015 the advanced materials start-up rate in Germany has surpassed the UK (24 German start-ups compared to 20 UK start-ups).
- Private investment in international advanced materials companies since 2001 totals more than $10bn, with a quadrupling of investment from c.$1bn in 2020 to c.$4.3bn in 2021. This increase is driven predominantly by investments in biotechnology in Japan and electric vehicle companies in the United States (investments of $900m and $800m respectively) Investment in UK companies amounts to 4% of the total.
- Average investment per company is highest in the Netherlands (c.$43m investment per company), followed by Japan and Germany. The UK ranks seventh just below Norway (average investments of $5.5m and $6m respectively).
- The top 5 investors in advanced materials companies internationally include The Carlyle Group, T. Rowe Price, 3i Group, IDG Capital and China Merchants Capital.

3.3.3. Significant levels of advanced materials related FDI

Searches for the same 246 key terms used throughout the study within FDI Markets returns 237 unique advanced materials related FDI projects since 2018. Source countries including the US, China and Europe have invested c.$9.2bn, creating more than 11,000 jobs.

The highest levels of FDI inflows are aligned to UK research strengths, including energy materials ($1.9bn), semiconductors ($1.7bn), photovoltaics ($1.5bn) carbon fibre and polymers ($640m and $400m respectively).

Figure 3.9 – Sources of UK Advanced Materials FDI



Source: FDI Markets

4. Advanced Materials Challenges, Risks and Mitigation

The study's fourth objective was to identify the key risks for advanced materials in the UK, and factors that would be crucial for mitigating these risks. The study used the same quantitative data (described in the methodology) together with qualitative data from in-depth interviews with 30 strategic stakeholders from industry, academia and economic policy to identify challenges, risks and mitigating actions. In addressing Objective 4, it was also necessary to gather views from academia and industry regarding the supply and demand of advanced materials (Objective 2) and to understand the gaps in data that would be required to inform a national advanced materials strategy (Objective 5).

The sub-sections below present evidence that supports key findings regarding the UK's advanced materials challenges and risks, and suggestions about possible mitigating actions. For ease of reference, suggested mitigating actions are referenced together with the challenges and risks to which they relate. Key findings regarding challenges and risks include:

- Underinvestment in advanced materials research, development and innovation (RD&I) – quantitative and qualitative findings both point to a significant risk of underinvestment in advanced materials research, development and innovation. R&D funding for advanced materials has flatlined, and UK academics are trying to do 'more with the same'. Further, and perhaps more importantly, the data also highlights a huge disparity between funding for earlier-stage research and funding for innovation in advanced materials.
- Risk of coordination failure – qualitative data from strategic stakeholder interviews consistently highlighted a pressing need for more effective sector coordination, a more directive approach from the centre of government, and a need to encourage competition for research funding in a different way.
- Scale-up, private investment and patient capital – while the UK has an internationally relevant advanced materials start-up eco-system, qualitative and quantitative data suggest that the UK continues to struggle to effectively scale its innovative advanced materials companies. A lack of truly patient capital and a comparatively weak private investment environment means that it is critically important for policy and public funding support to commit to advanced materials over the long term.
- Gaps in support for activity and funding across TRLs – strategic stakeholder interviews highlighted a key gap in support for activity and funding across TRLs 4 – 6. Various suggestions were made, including the need for research projects to clearly articulate a 'fast-make' vision from the outset. Consultations with industry also identified a need to better reflect the importance of research at lower TRLs for advanced materials while they are in operation and/or at scale.

- Lack of industry pull – consultees offered a strong view that government needs to make it much easier, and more worthwhile for more SMEs to engage in advanced materials RD&I. This is deemed particularly relevant amidst major concerns about access to EU funding, and particularly funding that offered opportunities to engage with SMEs (e.g. European Regional Development Funding).
- Weaknesses in UK materials supply chains – analysis of industry data and consultation with strategic stakeholders suggest important weaknesses in advanced materials, including those that are critical to the UK's economic prosperity and future energy security.
- Not learning from past mistakes – strategic stakeholders highlighted several instances where, in the past, the UK has failed to maximise the benefits of its strengths in early-stage research. From losing a grip on carbon fibre production in the '70s to reduced investment in wind power in the 1990s and 2000s, and the more recent giveaway of perovskite solar cell manufacturing to Germany, the UK must learn from past mistakes if it is to maximise the potential of the green revolution. This will require serious commitment to long-term funding for advanced materials, led by a comprehensive and technically detailed UK materials strategy, and driven by technical expertise at the heart of government.

4.1. Underinvestment in advanced materials RD&I

While data on research funding for advanced materials shows significant levels of investment over time, and the recent announcement regarding the UK's £39.8bn R&D budget for 2022 – 2025 are clearly positives for UK RD&I more generally, underlying trends in the data and strategic stakeholder perceptions raise concerns about the risk of underinvestment in advanced materials RD&I.

At the highest level, even realising the government's ambition to increase total R&D investment to 2.4% of GDP by 2027 would still leave UK R&D spending behind what US and German levels were, in 2019 (3.1% and 3.2% of GDP respectively). It is safe to assert that US and German investment in RD&I has not, and will not stand still in the 8 years between 2019 and 2027.

More specifically, through stakeholder consultations, the study has identified particular concern regarding the appropriate allocation of RD&I funding to advanced materials. As illustrated in the review of policy presented in Section 2, advanced materials are integral to almost every UK strategy guiding economic prosperity, innovation, infrastructure and defence.

The fact that advanced materials underpin so many of the technologies that the UK will rely on to support existing and new markets (aerospace and defence, renewable energy, automotive, electrical mobility, the hydrogen economy) makes targeting investment and support for advanced materials more difficult.

There is a significant risk that this complexity leads to underinvestment in advanced materials. It is not sufficient to assume that investment in, for example, automotive companies via the Advanced Propulsion Centre will effectively deliver pull-through of new materials and technologies without the necessary 'push' to focus on specific advanced materials challenges and opportunities.

4.1.1. Advanced materials research funding

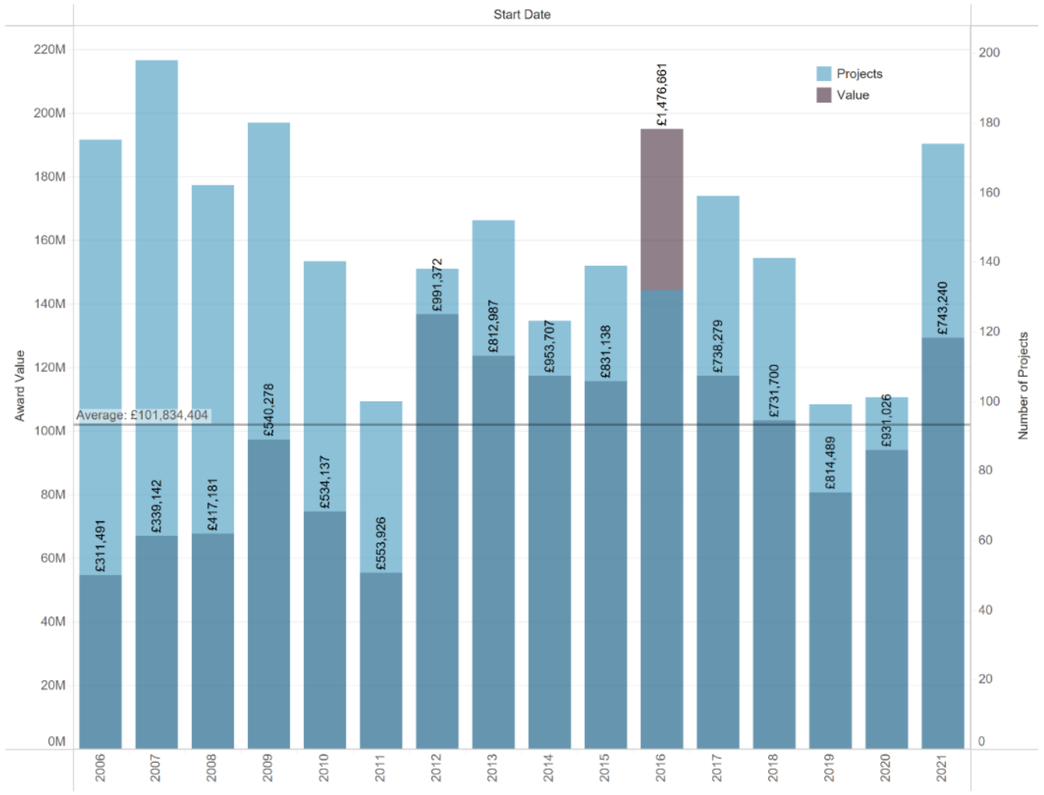
Funding for advanced materials research has declined sharply since a peak in 2016, average award sizes are struggling to keep up with the long-term average, and academics are being asked to do more with the same (Figure 4.1)[14].

Despite an uptick in the level of funding and number of advanced materials projects supported last year, the average value of research funding awards in 2021 was commensurate with average award values in 2017 and 2018. Further, between 2012 and 2019 the average duration of advanced materials research projects increased by approximately 6 months, from 31 months on average for projects that started in 2012, to 37 months on average in 2019.

Average project timescales have shortened in 2020 and 2021, down to an average of 31 months which is positive but should not detract from the overarching concern regarding the risk of underinvestment in advanced materials.

[14] Chart labels present average value of funding per project in each year.

Figure 4.1 – UKRI Advanced Materials Funding Over Time



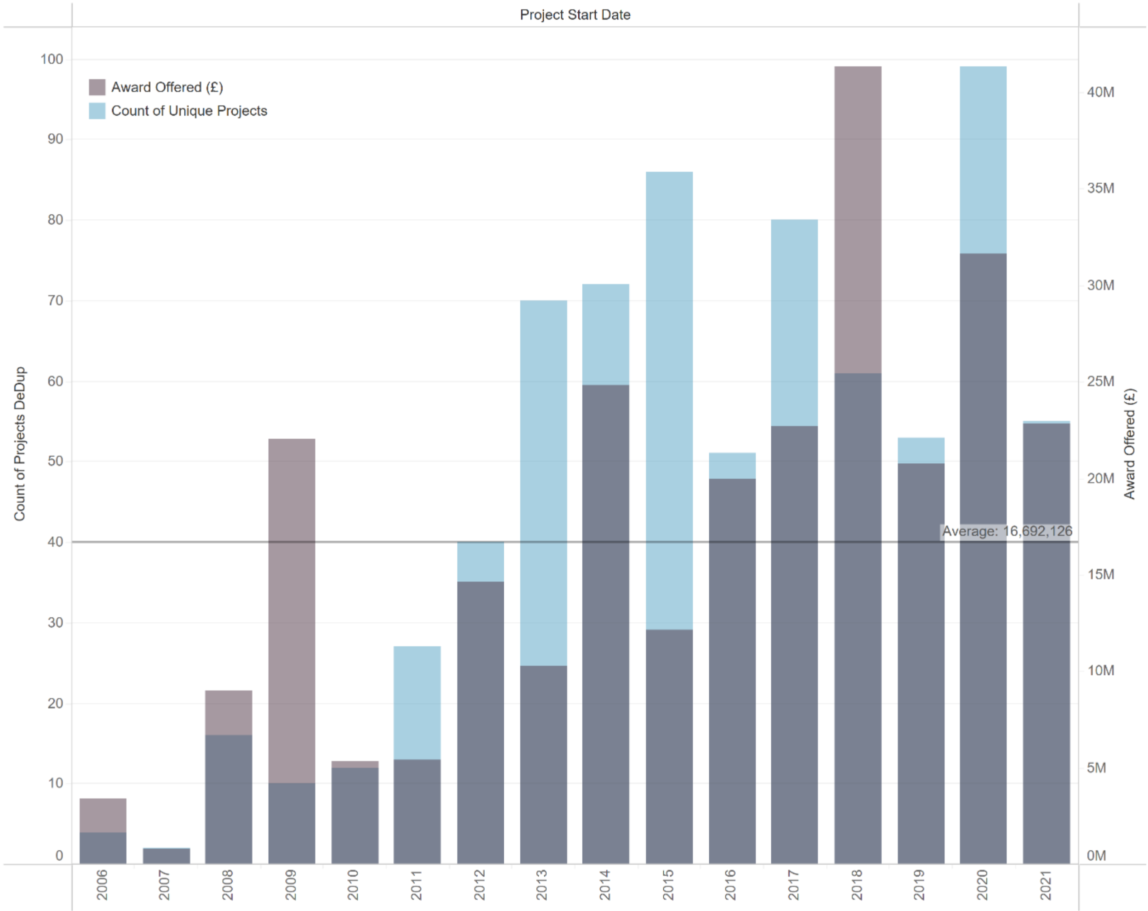
Source: Gateway to Research[15]

4.1.2. Advanced materials innovation funding

Analysis of innovation funding data[16] paints a similar picture, although patterns are more difficult to observe given that annual values of Innovate UK awards fluctuate quite significantly, which in itself poses challenges for strategic support of advanced materials innovation. Since 2016, Innovate UK funding for advanced materials has remained relatively flat, bar spikes in 2018 and 2020. Over the same period, the number of projects supported has been increasing, with spikes in project numbers in 2017 and 2020. Critically, the value of awards for innovation in advanced materials is just a fraction (13%) of the value of research funding[17].

[15] Analysis excludes funding for capital build and semiconductors (the focus of another BEIS strategy).
[16] Innovate UK funding database as at February 2022
[17] £222,651,762 in innovation funding since 2006 compared to £1,629,350,461 in research funding over the 2006 – 2021 period, both excluding funding for semiconductors and large capital investments.

Figure 4.2 – Innovate UK Advanced Materials Funding



Source: Innovate UK

Effective strategic planning and coordination of advanced materials activity are critical to mitigating this risk of underinvestment, and many other risks, as discussed in more detail in the sub-section below.

4.2. Risk of coordination failure

Qualitative data from strategic stakeholder interviews consistently highlighted a pressing need for more effective sector coordination, a more directive approach from the centre of government, and a need to encourage competition for research funding in a different way.

- Advanced materials is one of the UK's critical enabling technologies – perhaps the most important enabling technology for delivering against the Innovation Strategy, Net Zero, and associated elements within national defence, Space and infrastructure strategies.

- As discussed previously, coordination of advanced materials activity is complex because it makes such a vital contribution to almost every facet of the UK's economic and environmental ambitions.
- Previous attempts at coordinating advanced materials activity have met with varying success, but it is imperative – now more than ever – that appropriate coordination mechanisms are put in place, both in terms of sufficient resource within central government, and appropriate reach across the advanced materials area.
- Consultees recognise that there can be no 'one size fits all' approach to coordinating advanced materials activity, but that there is a cohort of leaders spanning the policy, industry and academic spheres with passion and expertise in equal measure, that can form the nucleus of a new effort to effectively coordinate advanced materials activity.

"There are many lessons that the advanced materials industry can learn from the UK's life sciences industry."

"When it comes to advanced materials, it's hard to decide what to invest in because there are so many options. This makes it increasingly difficult to know where to put the money."

"We need to move away from the competition model [of RD&I funding] to getting the right person in to take decisions and make awards."

4.2.1. An international focus on advanced materials policy and funding

A brief review of international materials strategies and policies highlighted the intense focus being placed on advanced materials around the world.

- Europe recognises the significance of advanced materials and has set out a manifesto for advanced materials development and commercialisation to 2030, together with detailed technology roadmaps that assign high priority to emerging issues such as circularity in the design of advanced materials and their applications.
- The United States recognises the significance of having control of its materials supply chain and has invested $1.3bn in its materials strategy 2021 – 2031. The US materials strategy follows 2018 commitments within the 'Strategy for American Leadership in Advanced Manufacturing' which highlighted major increases in investment in advanced manufacturing capability, including a $3bn investment in 14 'Manufacturing USA Institutes'.

- In 2020 Japan's Ministry of Education, Culture, Sports, Science and Technology produced a plan specifically aimed at 'enhancing material innovation power' and has increased investment in advanced materials R&D.
- In China, relevant ministries and commissions have successively launched a series of policy documents, including the Three-Year Action Plan to Enhance the Core Competitiveness of the Manufacturing Industry (2018–2020), the 13th Five-Year Plan for Science and Technology Innovation in the Field of Advanced Manufacturing Technology, the 13th Five-Year Plan for Science and Technology Innovation in the Field of Materials, the Development Guide for New Materials Industry, the Construction Scheme of National Demonstration Platform for New Material Production and Application, the Construction Scheme of National New Material Testing and Evaluation Platform, the Action Plan for New Material Standard Pilot (2018–2020), and the Demonstration and Guidance Catalogue for the First Batch of Applic*ation of Key New Materials (2019 Edition)*.
- Most recently, China's 14th Five Year Plan has dozens of references to advanced materials development, including 'new materials' as a new pillar of China's industrial system.
- The priority that China is assigning to advanced materials is also evident in funding for materials science, which has quadrupled since 2008, and the field receives the second-highest level of funding from the National Natural Science Foundation of China (NSFC), behind only medical sciences (see 'China's funding boost for materials'). The volume of China's materials-science research has grown correspondingly. According to data from the Web of Science, the number of papers on the topic more than tripled between 2006 and 2017, to around 40,000 (see 'Big progress'), and around one in every nine papers published by a Chinese researcher in 2015 was in materials science.
- And it is also evident within current 'at market' technologies that depend on advanced materials, such as offshore wind where in 2021, China connected more offshore wind generation capacity in a single year than the rest of the world managed to install in the last five years. While direct UK-China comparisons are of limited benefit, this example of investment in offshore wind does add some weight to the assertion made by several consultees, that the UK needs to take a more directive approach to investment in advanced materials and their applications.

4.2.2. Harnessing technical expertise and taking a more directive approach

Our consultations also highlighted that there are passionate and technically capable individuals with considerable experience and expertise who can produce an advanced materials strategy and effectively guide actions to ensure that the UK retains and builds on its advanced materials strengths. In response to the common call for a more directive approach to advanced materials within central government, supplementary interviews were conducted, suggesting that a solution could include a full-time technical specialist for advanced materials within the BEIS team.

Advanced Materials Technical Specialists – Critical Success Factors

Consultation with stakeholders who have experience in a BEIS technical specialist role suggested that advanced materials are likely to merit a technical specialist role, but that for the model to be effective it must have long term commitment, a high level of confidence in the individual, commitment to the technical specialist's autonomy, and sufficient funding behind the strategy. A review of funding across the BEIS portfolio including e.g. SICE, UKRI orphan topics etc. would represent a useful first step in supporting a more directive approach to advanced materials activity.

However, it is important to once again highlight the fundamental requirement for better cross-government action on advanced materials, within which a more senior specialist/champion could assist in the coordination effort.

4.3. Scale-up, private investment and patient capital

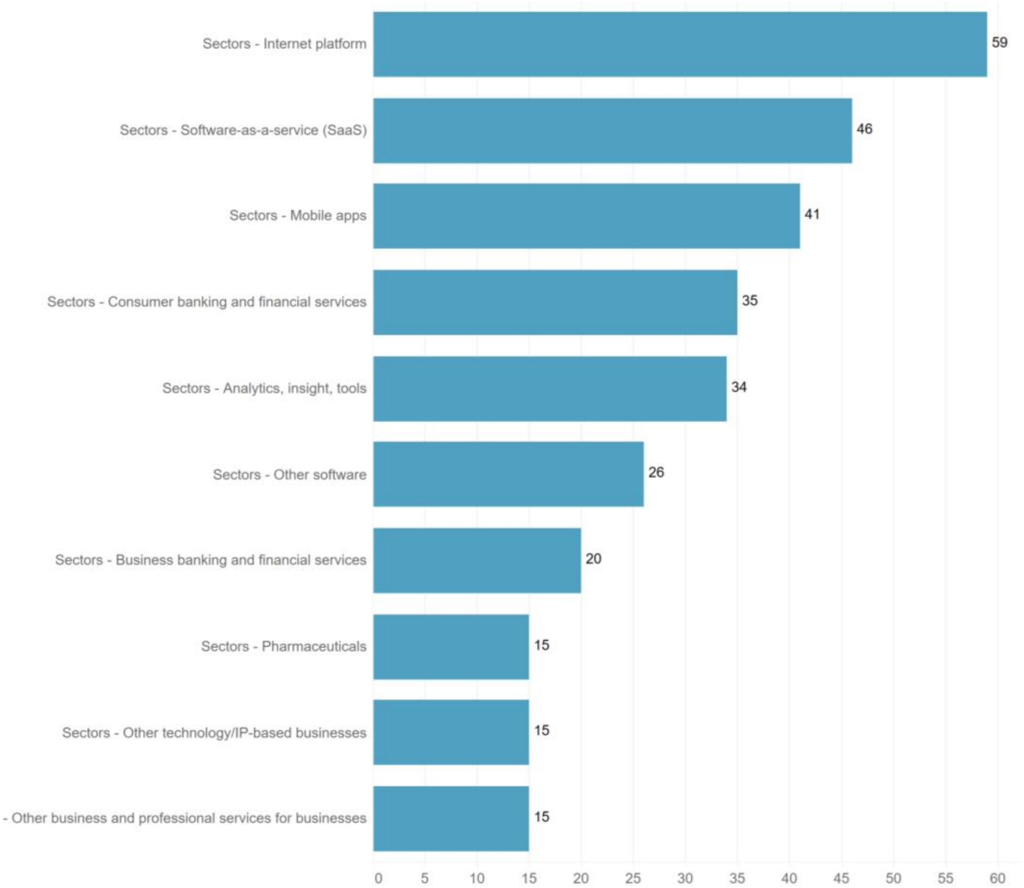
While the UK has an internationally relevant advanced materials start-up eco-system (Section 3.3.2) qualitative and quantitative data suggest that the UK continues to struggle to effectively scale its innovative advanced materials companies.

4.3.1. Lack of patient capital

Lack of truly patient capital has been identified within stakeholder interviews as a major inhibitor of scale-up within the advanced materials area. The issue of patient capital is a long-standing one. In 2017 Government published a review of patient capital which highlighted (5 years ago) that UK scale-up performance is not strong, and that lack of patient capital is "a significant impediment to UK entrepreneurs' success".

The Patient Capital Review recommended a patient capital investment company backed by the British Business Bank be set up to address the issue. In response, the British Business Bank now operates 'British Patient Capital' which administers the 'Future Fund' – "a £375m co-investment programme for growth-stage R&D intensive technology companies". Analysis of funding administered via the Future Fund suggests that only a very small proportion could be considered to be genuinely 'patient' capital. **Fewer than 20% of awards have gone to industrial sectors, and within that proportion only some are likely to require genuinely patient capital.**

Figure 4.3 – Analysis of Future Fund Data



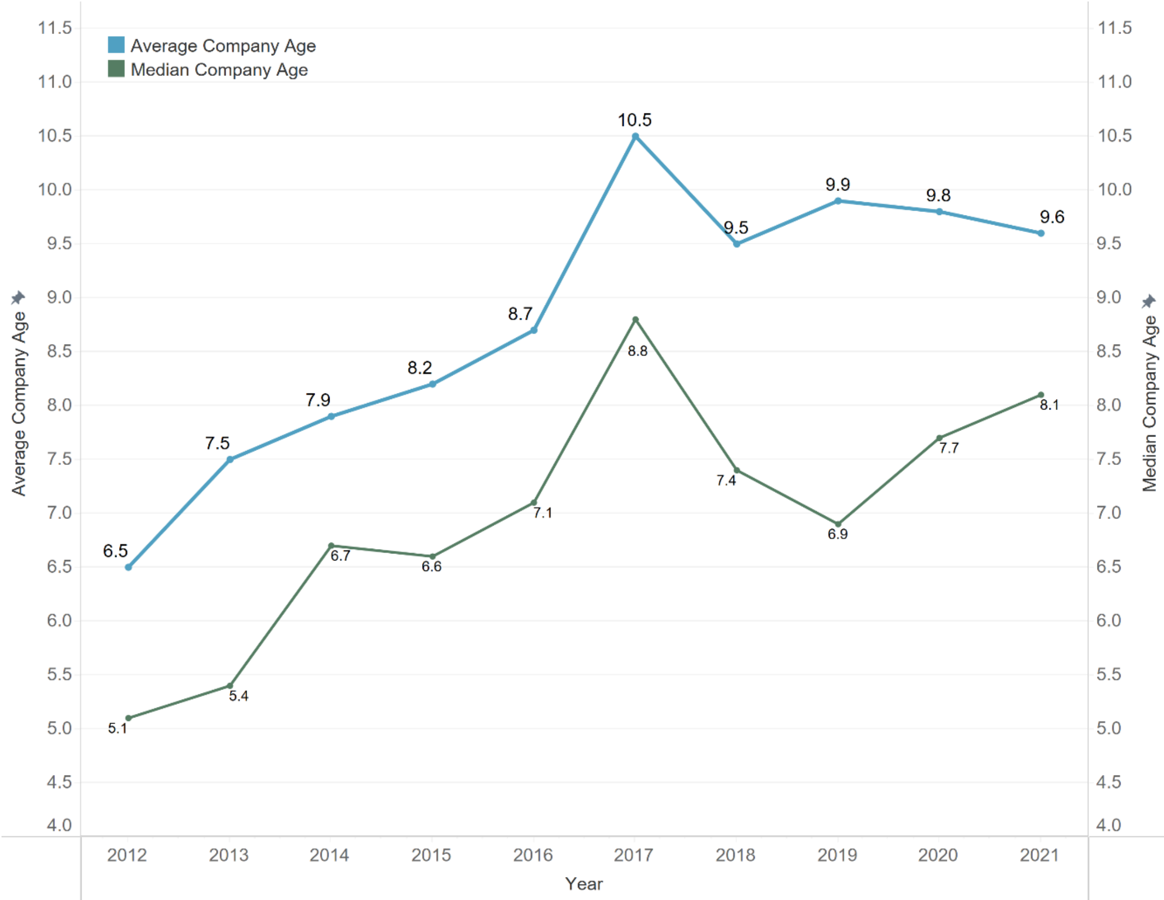
Source: British Business Bank

UK investment data provider, Beauhurst, also highlights the issue in its round-up of investment trends in 2021[18]. Whereas consultees suggest that it takes a minimum of 10 years to get from material discovery to commercialisation (let alone profit), Beauhurst data suggests that the average time between incorporation of an initial UK investment deal, to company exit is just 8 years.

Lead time to company exit is increasing as the UK start-up ecosystem matures, but given the gap between current investor time preferences and the materials development life cycle, much more needs to be done to encourage genuinely patient capital for the UK advanced materials area.

[18] The Deal, 2021 report, Beauhurst

Figure 4.4 – Average Investment Timeframe



Source: Beauhurst

There are examples of where UK venture funding providers are doing things differently, such as Sustainable Ventures. Organisations with commitment to delivering against dual sustainability and return on investment goals should be supported to provide truly patient capital on a much larger scale for advanced materials start-ups and SMEs.

4.3.2. Comparatively weak private investment environment

While comparative data on investment in international advanced materials companies suggests that the UK performs well when it comes to producing advanced materials start-ups, the data also highlights major disparities in the scale of funding provided to UK versus international start-ups.

Using data for almost 1,000 advanced materials companies in receipt of private investment across the UK, the US, Japan and Europe, the UK ranks only 7th in terms of average investment raising per company ($5.6m).

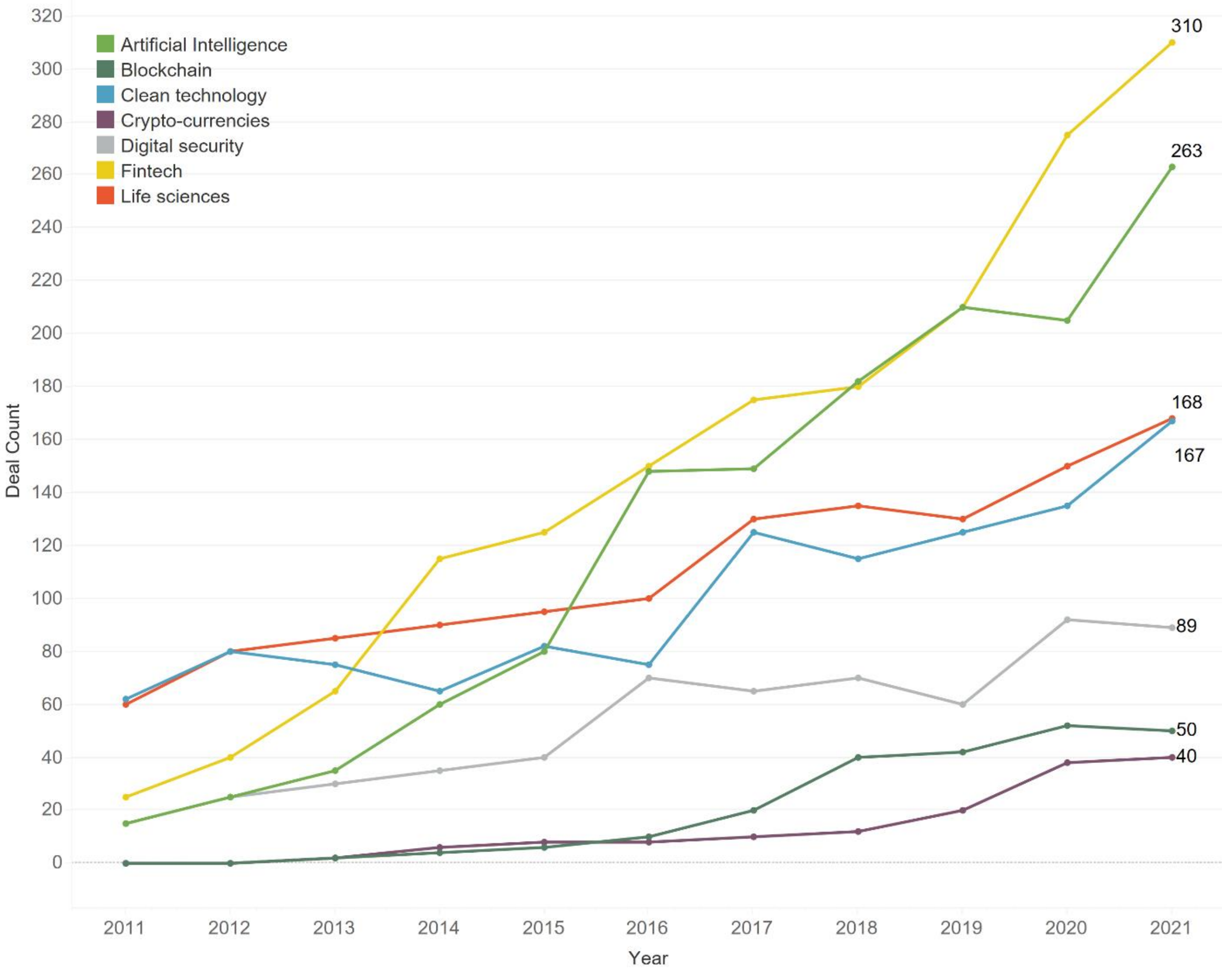
Table 4.1 – International Investment in Advanced Materials

Country	Average Funding Per Company	Total Equity Funding Amount Currency (in USD)
The Netherlands	$43M	$762,316,847
Japan	$27M	$761,472,225
Germany	$21M	$179,332,413
China	$19M	$1,397,896,159
United States	$10M	$5,079,723,439
Norway	$6M	$9,221,730
United Kingdom	$6M	$368,170,040
Finland	$1M	$13,353,570
Ireland	$1M	$2,553,636
Lithuania	$1M	$1,258,286

Source: Crunchbase

UK private investment has been skewed, understandably, towards the fintech sector. However, with lead times to company exit increasing in traditional investment markets, and an unprecedented emphasis on net zero (reflected in increasing cleantech deal counts) there is an opportunity to disrupt UK investment trends in favour of longer-term, environmentally oriented investments into advanced materials.

Figure 4.5 – Focus of UK Investment



Source: Beauhurst

Case Study: The case for advanced materials accelerators

Evidence suggests that incubators and accelerators can have a positive impact on start-ups directly and that they can also bring an increase in venture capitalist funding going to non-accelerated firms as well to those which do not participate.[19] A 2019 BEIS study found that 'accelerators perceive business skills development and access to potential investors to be the most important benefits to start-ups'. However, there is limited evidence of existing 'materials-specific' accelerator or incubator programmes across the UK. While the Henry Royce Institute has offered access to materials science and engineering equipment to

[19] Hochberg, Yael V., and Daniel C. Fehder. 2015. "ENTREPRENEURSHIP. Accelerators and Ecosystems" Science 348 (6420): 1202-3.

support SMEs, spin-outs and start-ups via the Materials Accelerator Token Scheme[20], Beauhurst data on high growth advanced materials companies shows that out of 137 companies attended a minimum of one accelerator, no fewer than 43 different accelerators were involved – none of which was specific to advanced materials[21]. It is therefore worth exploring the extent to which a materials specific accelerator could assist in addressing the UK's advanced materials scale-up challenge.

4.4. Gap in scale-up support and lack of industry pull

We heard repeatedly how the UK fails to effectively support advanced materials companies (and products) through the 'valley of death'. Various reasons were cited, ranging from academic incentives tending to drive research only between TRLs 1 – 3, to lack of 'industry pull' for technologies, lack of commercialisation road-mapping within early-stage research, a lack of 'intermediate institutions' to support technology scale-up, and the lack of patient capital (referred to previously). The quotations below illustrate the unique challenges that face advanced materials companies, and suggestions about how these challenges could be overcome.

"We need intermediate institutions, Vinnova in Sweden and Fraunhofer in Germany are leading by example in this field."

"The Medicines Catapult are very good for this – vaccines institute at Oxford/Cambridge is a good example (capacity to pull through at scale)."

"When making materials, you have to go through a process for making the material, when you want to apply the material, it then has to go back down the TRL levels. In terms of funding this is very difficult, because you come up with the wonder material but not until TRL 6 that Ford or any other industry player will look at it. To get up to TRL9 you have to prove that you can manufacture at scale."

"No funding bodies in the UK will fund materials, they ask who is going to buy it (industry players) and this is a difficult question to answer. General IUK smart call – some calls only have a 7% success rate for materials. Or you go for application specific call but then first question is who the industry sponsor is."

"Discovery is key but has to be linked to development – materials optimisation and at scale through processing. We need a systems view of how we pull materials through centres working in collaboration to look at scale up and advanced manufacturing approaches."

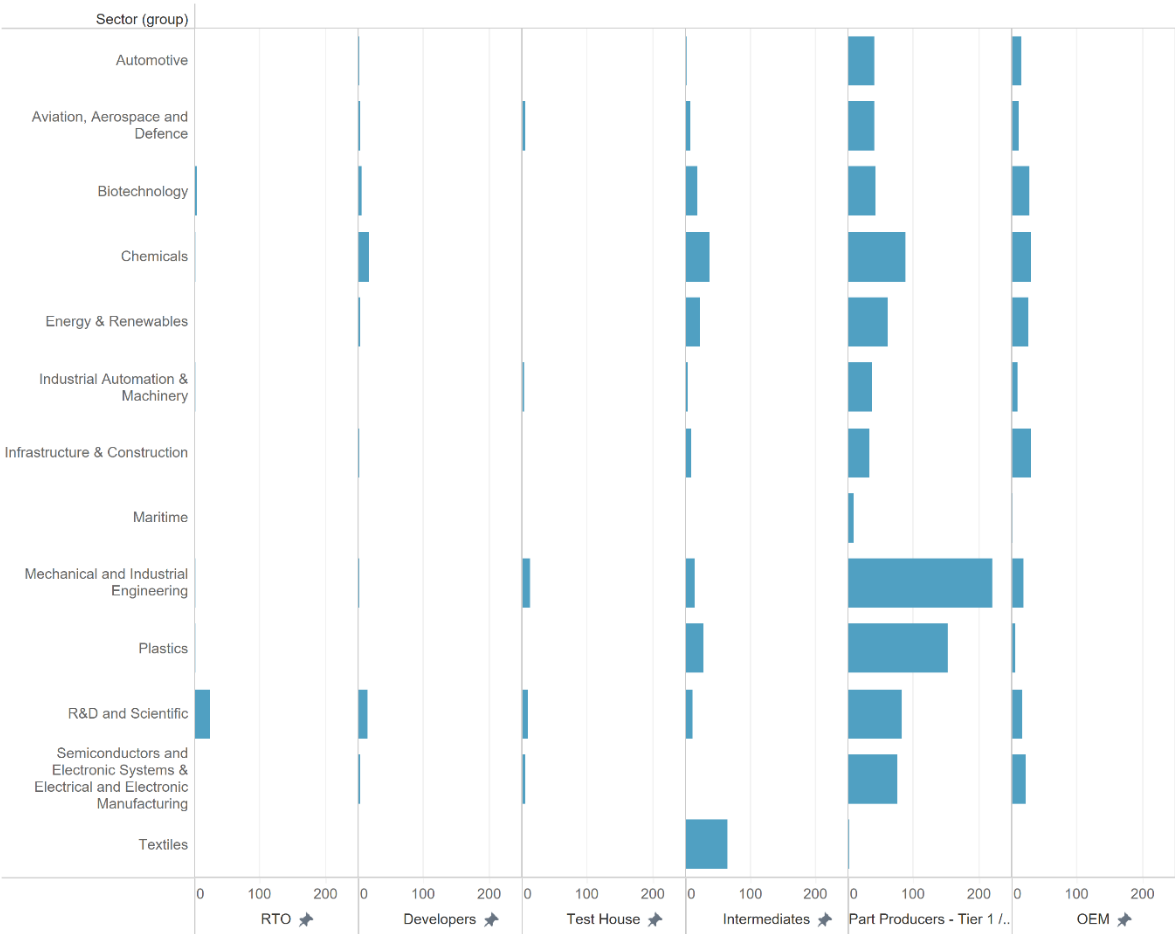
Linked to scale-up challenges, consultees offered a strong view that government needs to make it much easier, and more worthwhile for more SMEs to engage in advanced materials RD&I. This is deemed particularly relevant amidst major concerns about access to EU funding, and particularly funding that offered opportunities to engage with SMEs (e.g. European Regional Development Funding). Particular emphasis should be placed on encouraging scale-up among SMEs in segments of the advanced materials supply chain where capacity and capability are lacking, including for example within RTOs, materials producers and intermediaries.

[20] In 2019, the Royce Materials Accelerator Token Scheme supported over 30 UK-based companies through access to their facilities. Projects ranged from the development of prototypes, characterisation of existing materials and in-situ testing.
[21] The most popular accelerators attended included, the SME Leaders Programme, the Technology Developer Accelerator Programme (TDAP) and Innovation-to-Commercialisation of University Research (ICURe).

4.4.1. Supply chain vulnerabilities

Analysis of advanced materials value chains by industry sector highlights the skew toward parts producers (Tier 1 and Tier 2 suppliers) and suggests a relative dearth of advanced materials RTOs and Producers across key industries (Figure 4.6)[22]. The data supports consultation findings, which suggested that the UK has become and continues down the track of being an advanced materials technology integrator, with limited control of the advanced materials supply chain.

Figure 4.6 – Advanced Materials Value Chain Headlines



Source: Glass.ai

[22] Note that the Figure only presents certain sectors (horizontals) for illustrative purposes, and does not include some value chain segments (verticals) that are considered to be complementary to the core advanced materials area (namely distributors, equipment suppliers and consultants).

The significance of gaps in the UK's advanced materials supply chain capability was highlighted with respect to the current and future demand for carbon fibre and carbon fibre composites – a case study that exemplifies the need for greater clarity and understanding of the UK’s advanced material supply chains.

Carbon Fibre Composites Case Study: Securing supply chains critical for the UK’s future economic prosperity and resilience.

Carbon fibre composites are seen as a vital component of the green revolution and are already used extensively in the manufacture of wind turbine blades and lighter weight, more fuel-efficient cars and aeroplanes (among various other uses). Meeting existing and expected demand for advanced Carbon Fibre materials in the UK requires a sufficient and resilient supply of Carbon Fibre, and the case of Carbon Fibre is, in turn, indicative of the importance of resilient UK advanced materials supply chains generally.

To deliver 40GW of wind power capacity by 2030 (UK Government’s current target) the UK will require an estimated 1,500 tonnes of carbon fibre every year. This requirement now pales into insignificance given that by 2035 the UK is expected to require an additional c.11,000 tonnes of carbon fibre per year to service hydrogen propulsion system supply chains. Consider then this level of demand aggregated to global levels. By 2026 the shortfall in carbon fibre has been estimated as being close to 40% of global capacity.

The scale of future demand for carbon fibre composites to support the green revolution puts its availability, and the resilience of national supply chains, into sharp focus around the world. While the UK is home to some innovative companies operating across the carbon fibre composites supply chain, currently only a very small number of UK companies produce carbon fibres (e.g. SGL Carbon), and at nowhere near the scale required to support UK demand for carbon fibre composites.

In addition to ensuring availability of the materials required to support the UK’s future economic growth, there are also associated environmental benefits to be derived from adequately supporting and securing carbon fibre composite supply chains. The first is an opportunity to position the UK as a leader in reducing the environmental impact of advanced materials. With exponential growth in demand for carbon composite materials comes increased imperative to reduce any associated environmental harm. Securing and supporting UK carbon fibre composites supply chains offers an opportunity to leverage UK academic and industrial capability in the recovery and reuse of carbon fibre composites, within academic centres such as Manchester, Cranfield, and Imperial, and companies such as Gen2Carbon. Further, and relatedly, by securing increased production of carbon fibre at home, the UK will also reduce the level of embodied carbon within the carbon fibre composite products produced here.

4.5. State threats

In addition to supply chain vulnerabilities, within the current geopolitical climate state threats to UK R&D, and by extension to strategic industries and national defence, loom large. Consultations highlighted the risk of excellent UK RD&I being compromised, suggesting that 'state threat actors' are targeting companies of all sizes and using 'whole-of-state' approaches to access ideas, information and techniques – from conducting economic espionage to taking advantage of business collaborations and transactions.

As a result, in the face of the underinvestment in advanced materials highlighted previously, there is a risk that UK advanced materials start-ups and SMEs will seek investment from businesses with foreign state links. In addition, under the National Security and Investment Act 2021, advanced materials is one of the 17 sensitive areas of the economy where businesses and investors are legally required to notify the government of acquisitions that meet certain criteria. The issue of state threats therefore adds a further imperative to bolster indigenous investment in UK advanced materials start-ups and scale-ups.

Meanwhile, the Centre for Protection of National Infrastructure (CPNI) and the National Cyber Security Centre (NCSC) continue to co-create guidance with academia and businesses on how they can identify these risks and embed security early to protect themselves against state threats and help secure their research or competitive advantage and protect their reputations.

5. Conclusions

Advanced materials is one of the UK's critical enabling technologies – perhaps the most important enabling technology for delivering against the Innovation Strategy, Net Zero, and associated elements within national defence, Space and infrastructure strategies. Governments around the world are reviewing their positions concerning advanced materials, and investing heavily so that advanced materials are resiliently available in sufficient quantity to deliver against strategic national priorities.

5.1. Advanced materials strengths, challenges and risks

The UK possesses several important strategic advantages, including; some distinct strengths compared to EU countries, a world-class environment for early-stage advanced materials research, research and innovation capability nationwide and the mechanisms to support advanced materials activity, internationally renowned capability in industrial measurement, materials characterisation and standards, a vibrant and diverse advanced materials industry, an internationally relevant advanced materials start-up environment, and significant levels of advanced materials FDI.

However, the study has also identified several significant challenges and risks facing advanced materials in the UK, including underinvestment in advanced materials research RD&I and a huge disparity between funding for earlier-stage research, and funding for innovation in advanced materials, risk of coordination failure, a weak scale-up and private investment environment and a continued lack of truly patient capital, gaps in support for activity and funding across TRLs 4 – 6, lack of industry pull for research and innovation, and weaknesses in UK advanced materials supply chains.

Two further challenges (or opportunities) include the extent to which the international advanced materials industry is investing in data science for material science to significantly accelerate materials development lead times, and the ever-increasing need to understand and reduce carbon emissions, including embodied carbon. The UK has both materials science and data science capability in abundance and should seek to be a leader of global advancements in this field.

As a significant importer of materials and exporter of recycling, fully understanding and addressing the issue of carbon emissions (including embodied carbon) and the associated benefits of a more circular materials economy should also be high on the government's agenda.

5.2. Mitigating actions

A comprehensive UK advanced materials strategy is required so that all aspects of advanced materials, from investment in research and innovation, economic development and scale-up, to skills, legislation and standards, are working together to effectively leverage the UK's strengths in advanced materials.

A UK advanced materials strategy should target investment in existing UK strengths so that they are bolstered to maximise the UK's competitive advantages, while also addressing risks and addressing supply chain weaknesses. To be effective, a UK advanced materials strategy must be backed by sufficient human and capital resource, and should be developed in alignment with other facets of materials.

There can be no 'one size fits all' approach to coordinating advanced materials activity, but there is a cohort of leaders spanning the policy, industry and academic spheres with passion and expertise in equal measure, that can form the nucleus of a new effort to effectively coordinate advanced materials activity.

There should be a review of research and innovation funding so that increased investment for advanced materials can be secured, and so that the balance between investment in early-stage research, and investment in innovation is better balanced. Reform of R&D tax credits should also recognise the significance of advanced materials R&D and should effectively support industry pull for advanced materials research and innovation.

There are examples of where UK venture funds are doing things differently, such as Sustainable Ventures. Organisations with a commitment to delivering against dual sustainability and return on investment goals, with commitments to longer time preferences should be supported to provide truly patient capital on a much larger scale for advanced materials start-ups and SMEs.

Addressing the TRL 4 – 6 gap and encouraging industry pull are closely linked. Catapults offer one potential mechanism, but the Catapult role must be clearly defined, avoiding risk of confusion (particularly given the number of Catapult centres with apparently similar capability), and sufficient emphasis and resources must be placed on initiatives that can effectively plug the gap. Other potential models are available, such as the NGI and the GEIC in Manchester, and within the UK pharmaceuticals sector, these alternative options should also be considered. There should also be a review of research and innovation funding criteria to ensure that, wherever possible, a feasible 'fast-make' vision is articulated.

Research should be undertaken to understand the impact of the Royce Institute's accelerator token initiative, and the impact of other accelerators that advanced materials companies have attended so that effective scale-up support can be provided to advanced materials companies.

In the past, a lack of long-term commitment and sustained investment in crucial technologies has failed to maximise the UK's strategic advantages. From losing a grip on carbon fibre production in the '70s, to reduced investment in wind power in the 1990s and 2000s, and the more recent giveaway of perovskite solar cell manufacturing to Germany, the UK must learn from past mistakes if it is to maximise the potential of the green revolution. This will require serious commitment to long-term and sustained funding for advanced materials, led by a comprehensive and technically detailed UK materials strategy, and driven by technical expertise at the heart of government, reflective of the cross-cutting criticality of advanced materials to the UK economy.