ROYAL SOCIETY OF CHEMISTRY

Igniting innovation

The case for supporting UK deep tech chemistry

Introducing our new perspectives series

In a world where global challenges and advances in technology bring both uncertainty and new possibilities, the chemical sciences have a critical role to play. But what will that role be? How can we maximise the impact we make across academia, industry, government and education? And what actions should we take to create a stronger, more vibrant culture for research that helps enable new discoveries?

Our perspectives series addresses these questions through four lenses: talent, discovery, sustainability and science culture. Drawing together insights and sharp opinion, our goal is to increase understanding and inform debate – putting the chemical sciences at the heart of the big issues the world is facing.

Discovery

Chemistry is core to advances across every facet of human life. But where do the greatest opportunities lie? How will technology and the digital era shape the science we create? And what steps should we take to ensure that curiosity-driven research continues to unlock new opportunities in unexpected ways?

Science Culture

Scientific research and innovation is becoming increasingly multidisciplinary and collaborative. How do we create the open, inclusive, dynamic environments that will allow scientists to thrive and make their maximum contribution to global prosperity? And how should we recognise and incentivise the breadth of skills and diversity of people, contributions and achievements that enable new discoveries and breakthroughs?

Sustainability

Our planet faces critical challenges – from plastics polluting the oceans, to the urgent need to find more sustainable resources. But where will new solutions come from? How can we achieve global collaboration to address the big issues? And where can the chemical sciences deliver the biggest impacts?

Talent

Talent is the lifeblood of the chemical sciences. But how do we inspire, nurture, promote and protect it? Where will we find the chemical scientists of the future? And what action is required to ensure we give everyone the greatest opportunity to make a positive difference?

Find out more at **www.rsc.org/new-perspectives**

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Foreword

Chemistry-led innovation is contributing to the solutions we need for our future economy, for a healthier, more sustainable world. Clean, affordable energy, tackling disease, sustainable agriculture, recycling and reuse technologies – chemistry underpins them all.

Chemistry-intensive SMEs (small and medium-sized enterprises) and in particular deep tech chemistry SMEs play, an important role in developing these solutions and bringing them to market. They are a vital part of the UK's innovation ecosystem.

However, the journey from start-up through to commercialisation is particularly challenging for chemistry SMEs. The public and private investment landscape is often poorly adapted to the foundational nature of chemistry and the uncertainty of lab-based development. Commercialising and producing new products often requires collaboration and careful attention to intellectual property. And we must not underestimate the mix of technical, managerial and leadership skills required to transform R&D into real-world applications.

The Government has acknowledged, through its Innovation Strategy, that the UK could be doing more to exploit the research and development that's happening within deep tech SMEs.

We must create an environment within which deep tech chemistry SMEs can thrive. Our action plan provides the measurable steps we're taking to influence change, working with others. Policymakers, funders, partners and advocates – we must all work together to help these innovative companies fulfil their scientific and market potential.

Dr Helen Pain
Chief Executive, Royal Society of Chemistry

About this report

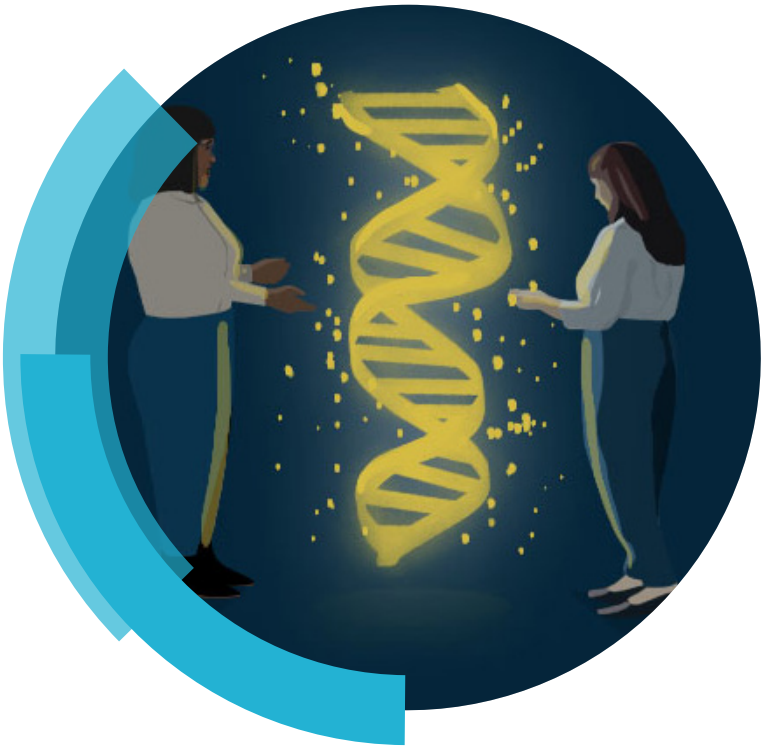
The UK Government's Innovation Strategy sets out a vision to make the UK a global hub for innovation by 2035. It describes the interventions needed: from increasing investment in R&D to establishing 'innovation missions' to tackle societal and environmental challenges. The Plan for Action for Business Innovation 2021–2025 explains how Innovate UK will deliver the strategy.

Small and medium-sized enterprises (SMEs) play a critical role in the UK economy by providing employment and driving innovation. Deep tech chemistry SMEs – the focus of this report – have another important role to play. They are fundamental to achieving potentially transformational breakthroughs in a range of areas, including climate change, developing new treatments for diseases like cancer, and addressing plastic pollution.

But, despite their importance, these companies are not well understood or supported in the UK.

Commissioned in 2021 by the Royal Society of Chemistry and conducted by the Enterprise Research Centre, Warwick Business School, this study highlights the challenges, barriers and unique contributions of deep tech chemistry SMEs.

With this summary, and the full report, we address how a range of organisations can help deep tech chemistry SMEs maximise their contribution to building the future economy and tackle the pressing global challenges we face.



Chemistry SMEs and innovation

Small and medium enterprises (SMEs) are the bedrock of economies and in the UK they account for 99% of all firms. SMEs also provide three fifths of the employment and around half of the turnover of the UK private sector[1].

Chemistry SMEs are a widely diverse group of firms spanning a wide range of industries from agrochemicals to cosmetics, pharmaceuticals to energy. Chemistry SMEs also vary in the roles they play in supply chains and business ecosystems. The types of firms include contract research organisations, analytical services, manufacturers, chemical distributors, consultants and other Research and Development (R&D) active firms, amongst others. Many of these firms are innovative and actively contributing to the development of solutions that enable a better future for people and planet.

The UK Innovation Survey 2019 provides a profile of firms' investments in innovation. When comparing them with the general population of SMEs in the UK, chemistry SMEs are:

- twice as likely to invest in R&D
- more likely to be engaged in new-to-the-market innovation (16% compared to 9% for all SMEs)
- more likely to be involved in new-to-the-market process innovation (8% compared to 4% for all SMEs)
- more likely to invest in other innovation activities (training and acquisition of machinery for example)
- more likely to collaborate, particularly with universities, suggesting a different type of innovation behaviour in these firms.[2]

Table 1: Investing in innovation – SMEs in chemistry-intensive sectors[3] and other SMEs[†] (proportion of firms investing)

Innovation investment (% firms)	SMEs in chemistry-intensive sectors	General SME population
R&D	39	20
Internal R&D	38	20
Acquisition of advanced machinery	27	22
Training for innovative activities	21	13
All forms of design	18	12
Acquisition of R&D (extra-mural R&D)	10	6
Market introduction of innovations	7	4
Acquisition of existing knowledge	6	6

[1]See https://www.gov.uk/government/statistics/business-population-estimates-2020/business-population-estimates-for-the-uk-and-regions-2020-statistical-release-html#composition-of-the-2020-business-population, Figure 2

[2]The UK Innovation Survey 2019, BEIS

[3]Includes 2,141 SMEs in chemistry intensive sectors

[†]Includes 10,722 SMEs across all sectors

Table 2: Undertaking innovation – SMEs in chemistry-intensive sectors and other SMEs (proportion of SMEs)

Innovation behaviour (% firms)	SMEs in chemistry-intensive sectors	General SME population
Innovation active	58	44
Product or service innovation	30	21
New-to-market product or service innovation	16	9
Process innovation	20	15
New-to-industry process innovation	8	4
Abandoned innovation activities	4	2
Scaled-back innovation activities	5	3
Ongoing innovation activities	25	13

Challenges chemistry SMEs face

Chemistry SMEs face much higher barriers compared to the general SME population. Cost, underdeveloped skills and market barriers are all more likely to be reported in SMEs in chemistry-intensive sectors.

The financial barriers to innovation are often suggested to reflect market failures related to the difficulties for firms and their financiers in forecasting the returns from innovation and the associated risks. The barriers to accessing finance are likely to be greater where firms are engaging in new to the market innovation, which has high up-front innovation costs and long project durations.

Deep tech chemistry SMEs

In addition to their contribution to job creation and prosperity, some SMEs such as deep tech chemistry SMEs have another important role to play. Whether it is tackling climate change, helping to create sustainable processes, or improving and saving lives, these companies have a crucial role in developing new technologies that can transform our world.

For this study, we focused on deep tech chemistry firms that are still on their journey to commercialisation, a journey typically lasting 5 to 20 years and therefore heavily reliant on the ecosystem and Government interventions to survive and thrive.

What are deep tech chemistry SMEs?

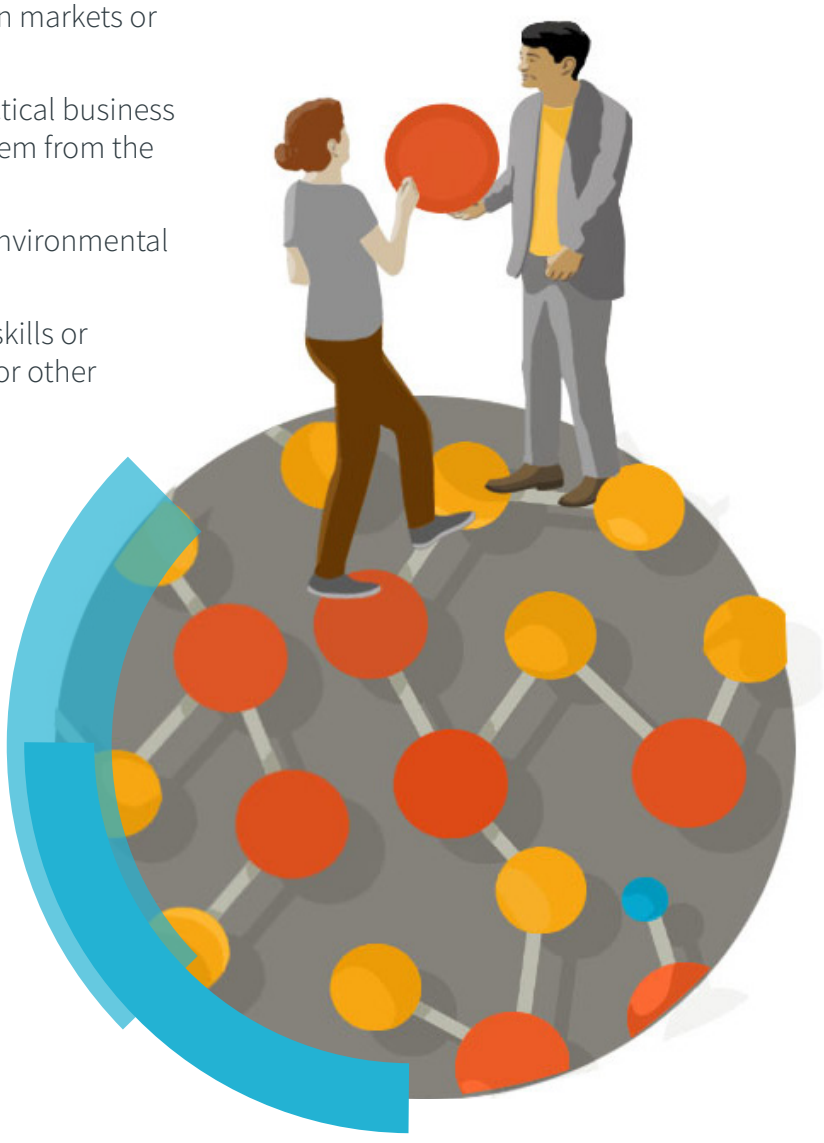
R&D activity lies at the heart of deep tech chemistry SMEs. Their success is dependent on underlying intellectual property (IP) and novel technological advances that require concerted R&D investment to move to market.

Deep tech chemistry SMEs share three main attributes:

- they develop technologies that have the potential to create new markets;
- their R&D takes a long time to reach market-ready maturity;
- they require a substantial amount of capital.

These businesses develop technologies that:

- are novel and significant technological advances;
- may have the power to create their own markets or disrupt existing industries;
- require concerted R&D to develop practical business or consumer applications and bring them from the lab to the market;
- may help to address big societal and environmental challenges;
- are based on underlying chemistry IP, skills or methods, which are a barrier to entry for other businesses.



Why are they important?

For people and the planet

Innovation in chemistry is fundamental to achieving transformational breakthroughs in a range of areas, including: climate change; developing new treatments for diseases, like cancer; addressing plastic pollution; and more.

The innovation happening within deep tech chemistry SMEs has the potential to generate significant social, economic and environmental benefits that far exceed the direct benefits to the businesses concerned.

The UK Government has identified seven technology families that will transform our future economy. Here, we give examples of where chemistry innovation is making real advances that could be transformational for our society and economy.

> **"We have made advances with many invasive human diseases but there are still a lot of people dying from the big ones, cancer, heart disease. But chemistry is really the cornerstone of [addressing] all of that."**

Health and Pharma SME

Innovation Strategy Technology Family	Deep tech chemistry SME case studies
Advanced Materials and Manufacturing	**Mimica** is creating the next generation of food expiry labelling that reduces food waste and improves food safety. In the UK, seven million tonnes of food and drink are thrown away annually, costing the average UK household £470 a year. Mimica Touch is designed to tell if food is still fresh, so more money could be saved, and less waste created.
AI, Digital and Advanced Computing	**Exscientia** is an AI-driven pharma tech company committed to discovering and designing the best possible medicines in the fast-est and most effective manner. Exscientia is the first company to progress AI-designed small molecules into the clinical setting and repeatedly demonstrate the ability of AI to transform how drugs are created. Exscientia's AI platform has now designed two drugs that are in Phase 1 human clinical trials.
Bioinformatics and genomics	**Owlstone Medical** have set out to save 100,000 lives and $1.5B in healthcare costs. They have developed Breath Biopsy® OMNI, an end-to-end optimised service for consistent breath collection and analysis, that aims to enable non-invasive early detection of disease and monitoring of treatment response for diseases such as cancer, liver disease, respiratory diseases and many more.
Energy and Environment Technologies	**Oxford PV** has developed perovskite, a new affordable solar cell material that can convert significantly more energy from sunlight than existing silicon-based solar cells. It delivers more power per square metre which is critical in accelerating the adoption of clean energy in our homes and businesses.
	Echion Technologies develops advanced lithium-ion battery materials. They have developed a product that requires only a six-minute charge, is inherently safe compared to present systems, and has a ten-fold increased lifetime over that of a standard lithium-ion cell. Their products contribute to the ambitions for zero emission vehicles by enabling cell manufacturers to deliver cost-effective, fast-charging, high-energy density, and long-life power cells.
	ViridiCO_2 Ltd developed technology, known as Carbon Capture Utilisation (CCU). It transforms high volume waste carbon dioxide gas emissions from es¬tablished chemical manufacturers and foundation industries – such as steel and cement – into high value carbon-based chemicals and feedstocks which can be found in everyday items such as furniture or batteries.
Electronics, photonics and quantum technologies	**HexagonFab**, a fast-growing biotech company, has developed Bolt, a portable analysis tool containing a graphene composite sensor that will accelerate drug research and manufacturing. This platform technology has potential applications in diagnostics and industrial monitoring. Their technology will lead to new treatments and diagnostics and the successful large-scale manufacture of this nanomaterial will pave the way for an entire generation of new technologies.
Engineering biology	The COVID-19 pandemic has highlighted the importance of viral and bacterial surveillance. **Iceni Glycoscience's** novel technology could be critical in the response to future disease outbreaks. This innovative company is developing diagnostic technologies and treatments for infectious diseases using proprie-tary technology based on carbohydrate chemistry.

What are the barriers to innovation?

There is considerable evidence that deep tech chemistry technologies take a particularly long time to develop. Our research highlights the complexity of their journey and a range of factors that all need to align for success: entrepreneurship capabilities, technology, management skills, technical skills, finance, equipment, access to good advice, networks, collaboration opportunities and effective IP management.

In all these areas, the SMEs we interviewed faced some barriers. And in all these areas, there are at least some characteristics specific to deep tech chemistry SMEs.

The Government recognises that the UK lags behind key competitor countries when it comes to investment in R&D and innovation. And the gap has been growing as other countries have increased their R&D investment levels. In particular, our ability to effectively commercialise new discoveries requires intervention to enable chemistry SMEs to innovate.

The deep tech chemistry firms we interviewed highlighted four main challenges they face in successfully commercialising their ideas:

- access to finance;
- access to bespoke, affordable chemistry facilities;
- innovation leadership and management skills;
- ecosystem and resources/networking.

Whilst there was agreement within the interviewee group that deep tech chemistry SMEs, still on their journey to commercialisation, face significantly different challenges to those in tech, there is an acknowledgement that these firms largely share similar challenges with other science-based deep tech SMEs. These challenges are often interconnected and may require a range of interventions and support.

"No one intervention can overcome every barrier, but many can be overcome if a range of appropriate tools are deployed."

Source: Plan for action for UK Business Innovation, IUK, 2021 p. 61

"...you can have a Fintech which is just a laptop. But when it comes to science, especially chemistry, you need .... top end equipment. So, these are very, interconnected and more cost for you to facilitate the development of technology or the labs, the more [funding] you have to raise." **Net Zero SME**

Access to finance

The Innovation Strategy identifies the challenges in accessing finance in deep tech SMEs. Access to private finance is both a challenge and an enabler for the SMEs we interviewed.

Chemistry innovation is a long and complex journey

They had generally been able to access start-up funding. But, among the SMEs and sector experts, there is a perception that obtaining funding to help them scale up is a bigger challenge. This may relate specifically to 'Series B' funding, which applies when firms have progressed beyond the start-up stage and are preparing to scale.

Some interviewees felt this was due to the unique aspects of chemistry innovation, in particular the length of time needed to develop and test a product before revenue. The long journey to market carries risks, such as the potential change of ownership, the management of investors, or investors withdrawing support.

"Although it takes a long time, you have clear validation points of success along the way. That is not so transparent and clear in the general chemistry space. And so those are a bit of a challenge for the development of chemistry-based businesses because of that period of time, and, therefore, the risk profile and return needs of investors." **Sustainability expert**

It's harder for investors to understand the value proposition

The research suggests that investors are also less likely to invest in innovation that they do not understand or cannot see. This can pose a challenge for the innovator but also represents a potential risk to investors in missing opportunities if they are not able to fully understand and appreciate the market potential of a chemistry innovation. 'Sector savvy' investors are reported to be a positive enabler by some of our interviewees.

Overall, our interviewees emphasised the importance of public funding to support commercialisation, particularly in the early stages of development. Many of them had benefited from public grant support. However, they have also encountered difficulties in accessing public funding due to the complexity of the process, unclear criteria, timeframes and milestone requirements that do not align with the chemistry innovation process.

"I would say that the use of government grants, and so on is an essential part of the funding mix to help translate technologies to the market. But the problem with this sort of funding is it's only three years. It's an extremely short period of time to be building up capacity. You're just about getting to the point when everything is working when you suddenly pull the plug." **Chemistry industry expert**

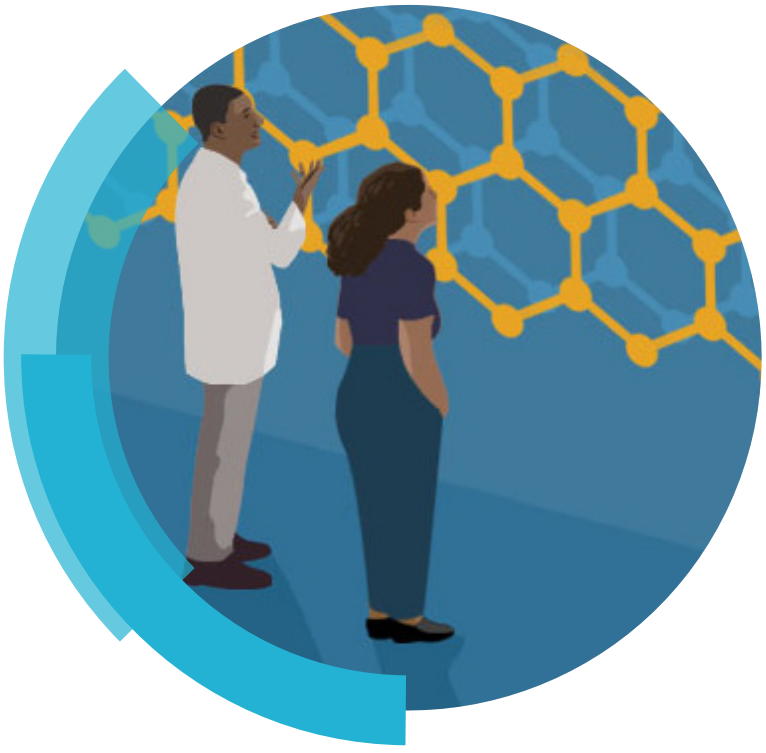
Depending on where you are, location is either a challenge or an enabler

Outside of the 'Golden Triangle', access to venture capital is reported to be a particular problem. There are fewer investors willing to invest in time-consuming, expensive innovation in other parts of the country, fuelling a vicious cycle of less innovation.

One respondent reported that there are traditional areas of chemical strength in the UK that have the potential to be built upon (the North East for example) but, arguably, they do not have the advantages of critical mass, financing or reputation that occur in the South East. This presents a different locational challenge for deep tech chemistry SMEs, even in these days of virtual networking and conferencing.

"I think there are projects in the regional universities but they're just not visible, [and] VCs will not leave the M25 unless they're going to Oxford or Cambridge. But that doesn't mean there aren't great projects outside Oxford, London, and Cambridge."

Health and Pharma SME



Access to bespoke, affordable chemistry facilities

There is a widespread perception of a lack of available, suitably equipped premises. Respondents cited this as a key constraint on business development and scaling up for deep tech chemistry SMEs.

This applies at all stages of development: initial availability of lab space; testing the production process for larger quantities; and scaling to larger manufacture.

> **"Availability of lab space is always a problem. It's not unique to the Northeast ... from the point at which you grow out of an incubator, there's very little growing space... So unfortunately, you end up with a rather expensive laboratory space that you end up having to put more money in to make it workable."**

Health SME

The facilities provided by incubators and accelerators are helpful in supporting deep tech. Practical interventions here would include an audit to establish what premises are available, and creating provision through new public/private partnerships.

Respondents also reflected a lack of awareness of information available to help them access flexible and affordable chemistry facilities. Better signposting to existing information sources would be helpful.

> **"There might be a lot of incubators but as soon as the company gets to 30 staff, there's nowhere it can go or anywhere near."**

Health SME

To manufacture or not – that is the critical question

The chemistry innovation process has multiple stages of testing and scaling, requiring specialised equipment that is expensive and less readily available than in other areas of scientific research. Even if equipment is available, it may not be known about or may be prohibitively expensive for SMEs.

Some deep tech chemistry SMEs we interviewed needed to be able to provide samples on a scale sufficient to convince large manufacturers to adopt the new technology. Firms may consider collaborating with a manufacturer to share the costs and expertise required for testing at a greater scale, but this requires good IP management, alongside a range of other collaborative activities the SMEs we interviewed undertake. Access to larger chemical manufacturers (with a capacity of tons) in the UK was said to be problematic.

"You also need to have a set of equipment that can make the material at scale even during the material development phase to be able to test it and, ideally, sample it to customers. So, it's not a question of making a few milligrams. We need to be able to make hundreds of grams, and then kilos, and then hundreds of kilos. So, the process development and scale-up need to be linked into that as well." **Net zero SME**

The decision to manufacture or not is a critical point in the journey of deep tech chemistry SMEs, and there are a number of choices to be made at different stages of the development process. To some extent the route taken depends on the preferences of the founder/management team, but there are constraints in these choices, such as the availability of facilities at the required scale.

Innovation leadership and management skills

The study revealed that underdeveloped entrepreneurial, innovation management and leadership skills are a significant constraint to business performance.

Innovation requires a unique set of skills

There is good reason to believe that deep tech chemistry SMEs require particular innovation management competencies beyond those needed by most other SMEs. For example, a specific skills set is needed to successfully manage the different aspects of a business, from developing and scaling technologies to regulatory compliance to getting the right people through a protracted period of establishment and commercialisation that will inevitably span a number of years.

We identified many different skills and abilities needed by business leaders and the challenges in combining these skill sets. Leadership teams need skills that go beyond 'management and leadership' or 'entrepreneurial' or other common descriptions of the skills of business leaders. A lack of any one of these skills in the leader or team can, we were told, impact on the success of the enterprise by affecting:

- the ability to identify markets and to commercialise innovation – many SMEs we spoke to had pivoted from their original intended market (sometimes multiple times) as the science developed or market conditions changed.
- the ability to access finance – identification of the right sources and the ability to communicate effectively with potential financiers.
- the ability to access and make use of advice.
- the ability to access, retain and nurture skills and talent.
- general business management skills.
- absorptive capacity – the ability to assimilate and apply new information to their business.

Ecosystem and resources/networking

The spatial clustering of SMEs is important for business success. The agglomeration effects of firms operating in a similar environment enables employment mobility, access to equipment, skills, networks and investors. There is no doubt, for example, that it is easier for deep tech chemistry SMEs to operate successfully in the Golden Triangle of Oxford, Cambridge and London than it is in other areas of the country.

As we've already explored, developing existing regional incubators so that they can better support businesses – from establishment to maturity – would be a practical step forward.

Networking to fill knowledge gaps

The evidence suggests that promoting networking may be among the most effective policy options available to promote growth and innovation in deep tech chemistry SMEs.

> **"Networking with other companies that have been through the same journey it is very important because .... [ ]the tech start-ups, tech work on chemistry, on chemical engineering technologies, they have different challenges than a start-up in education or insurance or finance and so on. They are different. They have different challenges. Some companies fail because they don't have the networks and the relationships. And if you can start to build those early on, that helps them in particular."**
>
> **Health expert**

Good innovators don't necessarily have the skills to:

- identify a market
- develop a value proposition
- develop a business plan that navigates the complexity of chemistry innovation
- know where to go for investors
- pitch effectively
- identify useful networks and collaborators
- deal with IP and regulatory regimes.

At the very least, they need access to the right advice, but that may not always be available or of the right quality. The right locality can be an enabler with access to equipment, skills, networks and investors, but the right locality may not attract experienced managerial and entrepreneurial staff.

Most respondents agreed that networking with peers expands the ambition, skills and confidence of SME owners and managers.

Our action plan

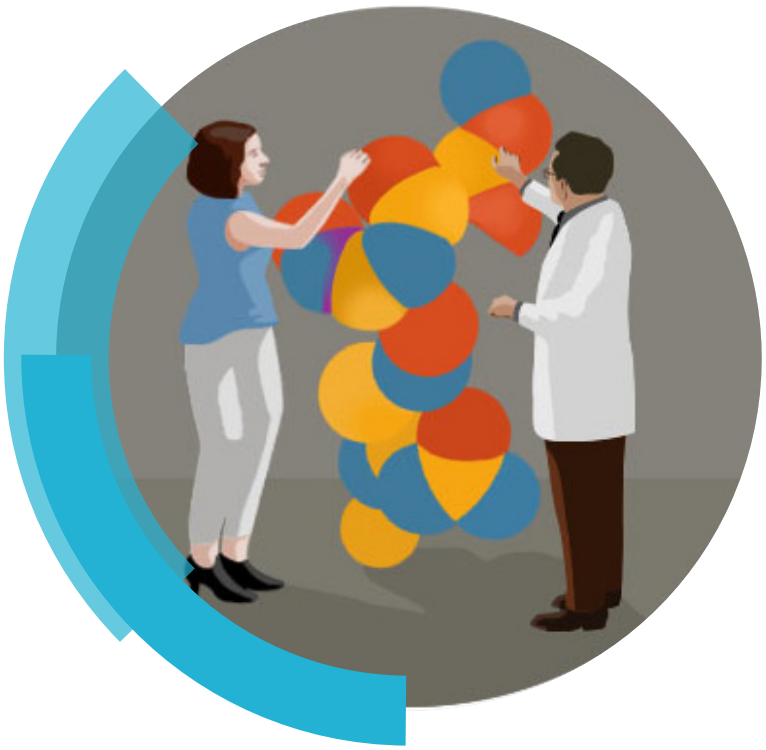
The UK Government's Innovation Strategy highlights the strong case for supporting deep tech companies as part of a mission-oriented innovation policy. This study provides an evidence-based rationale for enabling deep tech chemistry SMEs to realise their contribution to the UK's innovation missions.

Our five-point action plan sets out the practical steps we're taking to support deep tech chemistry SMEs and to influence change.

As a powerful voice for chemistry, we will work with policymakers and other key players in the deep tech ecosystem to:

1. **Champion the role of deep tech chemistry SMEs in tackling some of the most pressing societal and environmental challenges we face.**
2. **Establish and support peer to peer networks to promote leadership skills, growth and innovation.**
3. **Enable connections with investors to improve access to capital.**
4. **Enable funders to provide support and processes that meet the specific needs of deep tech chemistry SMEs.**
5. **Make it easier for deep tech chemistry SMEs to find the premises and equipment they need to grow and thrive.**

Download the full report to explore our research findings and case studies in more depth.



"The case for government to promote innovation in deep and transformative technology is strong. Prospective investors and customers of deep tech may be unwilling to take chances on new and unproven technology or may not fully understand its potential. The journey of tech-based innovation to market can be long, complex, and often non-linear. The UK excels at certain stages of this process but is weaker at others. We should pursue these signals of weakness and address the underlying issues."

UK Government Innovation Strategy

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